Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī's *al-Mulakhkhaṣ fī al-hayʾa al-basīṭa*: An Edition, Translation, and Study

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ABSTRACT

The *Mulakhkhaṣ fī al-hayʾa al-basīṭa*, composed by Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī in the early-thirteenth century, was an extremely popular astronomical textbook that would play a critical role in the teaching, dissemination, and institutional instruction of Islamic theoretical astronomy. Its study and use as a propaedeutic for more advanced teaching texts is evidenced by thousands of extant copies of the original and its numerous commentaries, super commentaries, and glosses. This dissertation, first and foremost, provides a critical edition and English translation of, and commentary on, this important and influential treatise. Due to ambiguity within the literature regarding exactly when Jaghmīnī flourished (which even led to speculation that there could have been two Jaghmīnīs), the focus of Chapter One is devoted to establishing Jaghmīnī's dates and arguing that he was the sole author of both the *Mulakhkhaṣ* and the equally popular medical treatise *al-Qānūnča*. Among other things, this highlights that one scholar was composing multiple scientific textbooks in the late-twelfth/early-thirteenth century under the auspices of the Khwārizm Shāhs in Central Asia, a period often considered one of scientific stagnation. Chapter Two situates the *Mulakhkhaṣ* within the broader context of the genre of astronomical literature termed *ʿilm al-hayʾa*, a corpus of works that attempted to explain the physical structure of the universe as a whole, and a tradition of which the *Mulakhkhaṣ* was very much a part. Included in this chapter is a survey of summary accounts of theoretical astronomy of Jaghmīnī's predecessors, both Ancient and Islamic, as potential sources for the *Mulakhkhaṣ*. Chapter Three makes the case that the target audience of Jaghmīnī's *Mulakhkhaṣ* was, in the first instance, students studying in madrasas, where his work would have been seen as providing a cosmology glorifying God's creation. The more general issue raised here is whether the standard approach to the pedagogy of Islamic science tends to promote its history as discrete episodes and dependent in the main on courtly patronage or individual initiatives, i.e., outside the core institutional structures of Islamic societies. It is then argued that a serious consequence of this has been the neglect of the vital role religious institutions played in sustaining scientific education in premodern Islam.

RÉSUMÉ

Le *Mulakhkhaṣ fī al-hayʾa al-basīṭa*, composé par Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī au début du XIIIe siècle, était un manuel astronomique extrêmement populaire qui devait jouer un rôle essentiel dans l'enseignement, la diffusion et l'institutionnalisation de l'astronomie théorique islamique. Son étude et son utilisation comme propédeutique pour les textes d'enseignement plus avancés est attestée par des milliers de copies existantes de l'original, ses nombreux commentaires, les commentaires sur les commentaires et des gloses. Cette thèse, d'abord et avant tout, offre une édition critique, une traduction en anglais et un commentaire de ce traité important et influent. En raison de l'ambiguïté existant dans la littérature quant à la période exacte à laquelle Jaghmīnī était en activité (qui a même conduit à la spéculation qu'il pourrait y avoir eu deux Jaghmīnīs), la mise au point du premier chapitre est consacrée à établir les dates de Jaghmīnī et le fait qu'il était le seul auteur à la fois du *Mulakhkhaṣ* et d'un tout aussi populaire traité médical intitulé *al-Qānūnča.* Entre autres choses, cela met en évidence qu'un savant composait plusieurs manuels scientifiques sous les auspices de la Khwārizm Shāhs en Asie centrale à la fin du XIIe/début XIIIe siècle, époque souvent considérée comme période de stagnation scientifique. Le deuxième chapitre situe le *Mulakhkhaṣ* dans le contexte global du genre de la littérature astronomique appelé *ʿilm al-hayʾa*, un corpus d'œuvres qui ont tenté d'expliquer la structure physique de l'univers dans son ensemble et une tradition dont le *Mulakhkhaṣ* faisait absolument partie. Incluse dans ce chapitre est une étude des comptes sommaires de l'astronomie théorique des prédécesseurs de Jaghmīnī, à la fois anciens et islamiques, comme sources potentielles du *Mulakhkhaṣ.* Le troisième chapitre souligne le fait que le public cible du *Mulakhkhaṣ* de Jaghmīnī étaient, avant tout, les élèves étudiant dans des madrasas, où son travail aurait été considérée comme fournissant une cosmologie glorifiant la création de Dieu. La question plus large soulevée ici est celle de l'approche généralement acceptée que la pédagogie de la science islamique tend à favoriser une histoire d'épisodes discrets, une histoire dépendant pour l'essentiel du mécénat de cour ou d'initiatives individuelles, c'est à dire, en dehors des structures institutionnelles fondamentales des sociétés islamiques. Il est ensuite affirmé qu'une conséquence grave de ceci a été la négligence du rôle essentiel que les institutions religieuses ont joué dans le maintien de l'enseignement scientifique dans l'Islam prémoderne.

ACKNOWLEDGEMENTS

I was first introduced to Jaghmīnī over fifteen years ago when I was sifting through the card catalogues at the Süleymaniye Library. I observed an enormous number of works attributed to him in connection with *hayʾa*, and was puzzled as to who he was and why this was not yet sorted out. I was informed that there was simply too much material on the man to attempt such a foolhardy endeavor. Despite the clear warning to look before leaping into the challenge, I leapt.

But in fact I did not jump alone. The edition, translation, and study of Jaghmīnī's *Mulakhkhaṣ* presented here could not have been accomplished without the generosity and support of a great many people whom I am grateful to acknowledge.

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to Jamil

INTRODUCTION

§ 1.0 The Arabic Edition and English Translation of Jaghmīnī's *Mulakhkhaṣ*

The *Mulakhkhaṣ fī al-hayʾa al-basīṭa* was an extremely popular astronomical textbook that played a critical role in the teaching, dissemination, and institutional instruction of Islamic theoretical astronomy. It was composed by Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī in the early-thirteenth century in the region of Khwārizm in Central Asia; and its study and use as a propaedeutic for more advanced teaching texts is evidenced by thousands of extant copies of the original and its numerous commentaries, super commentaries, and glosses contained in research libraries and various other repositories throughout the world. I have identified fifty-seven treatises that were written to elucidate the *Mulakhkhaṣ*, and these span, conservatively speaking, at least seven centuries beyond Jaghmīnī's original composition date. Indeed, the *Mulakhkhaṣ* was also translated from its original Arabic into Persian, Turkish, and Hebrew, and continued to be taught in earnest well into the nineteenth century.[1] The study of the *Mulakhkhaṣ* along with its commentaries was still relevant even after "European science" came on the scene, and it is significant that concerted efforts were made to seek teaching approaches that could accommodate the older Islamic scientific traditions such as that of the *Mulakhkhaṣ* along with new (*jadīd*) scientific developments.[2] So Jaghmīnī's ubiquitous introductory textbook on

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[1] See **Appendix II** for a list of sixty-one commentaries, supercommentaries, glosses, and translations on various aspects of the *Mulakhkhaṣ*. I should add that according to Zalkida Hadzibegovic, the *Mulakhkhaṣ* was still being taught in Bosnia in the twentieth century (see "Compendium of the Science of Astronomy by al-Jaghmīnī Used in Bosnia for Teaching and Learning Planetary Motions," Oral Presentation at the GIREP-EPEC Conference, Opatija, Croatia, 2007: http://www.scribd.com/doc/228710383/Al-Jaghmini-s-Compendium. Accessed on July 25, 2014.

[2] Ḥasan al-Jabartī's (d. 1188/1774-75) circle of scholars provides us an excellent example of the *Mulakhkhaṣ* still being studied in eighteenth-century Cairo, and at the Azhar. According to his famous son, the historian ʿAbd al-Raḥmān al-Jabartī (d. 1241/1825-6), his father Ḥasan was a member of the ʿulamāʾ and attracted students from all parts of the world; and his instruction

theoretical astronomy provides us with a significant example with which to understand a vibrant, ongoing scientific educational tradition within Islam. It is with this in mind that the first and foremost objective of this dissertation has been to present an Arabic edition along with an English translation of the *Mulakhkhaṣ*, neither of which has been previously available. Furthermore, establishing the base (or *matn*) text is a fundamental prerequisite for gaining better insights into the rather daunting commentary tradition that built upon the *Mulakhkhaṣ*.[3]

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included Jaghmīnī's *Mulakhkhaṣ* and Qāḍīzāde's *Sharḥ* along with other *hayʾa* works (for Jabartī, see *History of the Ottoman State, Society & Civilisation,* ed. Ekmeleddin İhsanoğlu, 2 vols. [Istanbul: IRCICA, 2002], vol. 2, pp. 586-87; Jane H. Murphy, "Improving the Mind and Delighting the Spirit: Jabarti and the Sciences in Eighteenth-Century Ottoman Cairo" [Ph.D.diss., Princeton University, 2006], pp. 97-100; Boris A. Rosenfeld and Ekmeleddin İhsanoğlu, *Mathematicians, Astronomers and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)* [Istanbul: IRCICA, 2003], p. 410; *Osmanlı Astronomi Literatürü Tarihi* [History of Astronomy Literature during the Ottoman period], ed. Ramazan Şeşen et al., gen. ed. Ekmeleddin İhsanoğlu. 2 vols. [Istanbul: IRCICA, 1997], vol. 2, p. 479, no. 19; and Cevat İzgi, *Osmanlı Medreselerinde İlim: Riyazī ilimler*, 2 vols. [Istanbul: İz, 1997], vol. 1, p. 386, ç6). Almost a century after Jabartī, the Muslim Ottoman scholar al-Qūnawī (fl. 1857) presents another attempt to reconcile the traditional and *jadīd* science with a quite up-to-date version of the heliocentric system within the context of a traditional astronomical treatise for madrasa scholars (see Robert Morrison, "The Reception of Early Modern European Astronomy by Ottoman Religious Scholars," *Archivum Ottomanicum* 21 [2003]: 187-95).

[3] Having the text of the *Mulakhkhaṣ* should also prove useful for other disciplines, since its influence extends well beyond the discipline of *hayʾa* per se; the treatise's widespread dissemination meant that it crossed multiple borders. For example, there is growing evidence to connect the content of the *Mulakhkhaṣ* with other astronomical disciplines, such as nautical cartography. Jaghmīnī is mentioned in several passages of the atlas of the Tunisian chartmaker al-Sharafī (fl. 1551-79), who attributes his picture of the universe to the "cosmological scheme derived from Jaghmīnī's treatise on the fundaments of theoretical astronomy" (see Mónica Herrera-Casais, The Nautical Atlases of ʿAlī al-Sharafī," *Suhayl* 8 [2008]: 242 and fn. 49).

A high priority was to ensure that the Arabic edition was as close to Jaghmīnī's original version as possible. In other words, I was concerned that my edition not be contaminated with the interjections of later commentators and copyists.[4] For example, there was considerable tampering by later copyists and commentators with the parameters for the climes. Thus given the enormous numbers of extant *Mulakhkhaṣ* witnesses, it certainly would be understandable if my goal of providing the "original" text would be met with skepticism. However, there are several reasons that I believe I have been able to reach a text very close to the author's original.

First of all, the advances in digital technology and information sharing meant that I had access to an enormous pool of extant *Mulakhkhaṣ* witnesses to review and analyze. I also have had, and continue to have, a strong network of support from colleagues worldwide who generously helped me obtain witness copies and shared valuable insights on topics related to my dissertation. As a result of this access and networking, I was able to acquire a vast trove of manuscript witnesses, from which I identified three different versions of the preface of the *Mulakhkhaṣ*: one contained a dedication by Jaghmīnī to a certain Badr al-Dīn al-Qalānisī along with a dedicatory poem Jaghmīnī composed to him; a second version contained only the dedication (i.e., the poem was omitted); and a third version lacked both dedication and poem. As it turned out, it was this last stripped-down version that would become the most ubiquitous one; and in fact it is this preface that is contained in our earliest known *Mulakhkhaṣ* copy, dated 644

[4] This is a major problem of the German translation by G. Rudloff and Dr. Ad. Hochheim ("Die Astronomie des Maḥmûd ibn Muḥammed ibn 'Omar al-Ǵagmînî," *Zeitschrift der Deutschen Morgenländischen Gesellschaft* 47 (1893): 213-75). Rudloff and Hochheim unknowingly added numerous comments from Sayyid al-Sharīf al-Jurjānī's commentary, one of the key witnesses they relied on for their translation. They are certainly not alone in this mistake. (See **§ I.1.2b: A Tale of Two Jaghmīnīs**).

H [1246-7].[5] So apparently within the relatively short period of forty years after the composition date of the *Mulakhkhaṣ* in 603 H [1206], the dedicatory material was removed from the preface.[6]

Although I knew that these earlier prefaces containing the dedication, with or without the poem, would prove quite significant for dating Jaghmīnī (among other things),[7] I also recognized that there was no guarantee that the contents of any given witness, whatever the preface, had not been changed given the tendency of certain copyists and commentators to modify parameters with "updated" ones. I was able to resolve this potentially serious problem based on the fact that certain parameters in the modified versions of the *Mulakhkhaṣ* came from Naṣīr al-Dīn al-Ṭūsī's *Tadhkira fī ʿilm al-hayʾa*, written over fifty years after the *Mulakhkhaṣ* in 659/1261.[8] Thus I was able to ignore these witnesses for the edition. Given the relatively small numbers of remaining witnesses that had the unmodified parameters and the original preface (or, lacking this preface, was an early copy), it became a relatively straightforward task to establish the "original" version. Of course there will always be a few remaining ambiguous readings, and these are noted in the

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[5] This was the discovery by Max Krause in 1936 of a copy of the *Mulakhkhaṣ* dated 644 H [1246-7 CE] ("Stambuler Handschriften islamischer Mathematiker," *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik.* Abteilung B, Studien 3 [1936], no. 403, pp. 509-10).

[6] Note that these three different preface versions and the dating of the *Mulakhkhaṣ* are discussed in more detail in both Chapter One and the Commentary.

[7] In addition, these variant prefaces became a convenient tool for helping decide which witnesses to target and obtain for further examination, since repository catalogues often contain incipits within their witness descriptions.

[8] I discuss this in further detail in my commentary on the second clime (see **II.1 [4]**). The argument for dating the later versions of the *Mulakhkhaṣ* rests on a scribal error that could only have come after the *Tadhkira* was written. F. J. Ragep points out that even as astute a commentator as al-Birjandī (d. 935/1528) was led astray by not realizing that in his dating of Jaghmīnī as post-Ṭūsī he was using values for the climes that had been altered; in Birjandī's defense he was writing some three centuries after the *Mulakhkhaṣ*'s composition ("On Dating Jaghmīnī and His *Mulakhkhaṣ*," in *Essays in Honour of Ekmeleddin İhsanoğlu*, ed. Mustafa Kaçar and Zeynep Durukal [Istanbul: IRCICA, 2006], p. 463).

critical apparatus. A description of the manuscripts used for the edition and the editorial procedures employed can be found in **PART II, § II.1: Editorial Procedures** and **§ II.2: Description of the Manuscripts**.

I should also mention that I made a concerted effort not to make Jaghmīnī appear more "erudite" than he actually was; in other words, my *modus operandi* was to provide the reader with the *Mulakhkhaṣ* as it is in the Arabic, which meant not "correcting" poorly composed sentences, inconsistent use of terminology, and so on. Indeed, it is these colloquial features that bring out the orality of the text; one can often imagine Jaghmīnī lecturing to a classroom of early-thirteenth-century madrasa students. However, here I was confronted with yet another challenge: Jaghmīnī's "simple" (*basīṭa*), introductory work was anything but simple-minded. And this was compounded by the fact that Jaghmīnī, as he put it, went "to great lengths to elucidate and illuminate the content"—some rather complex astronomical material—using "concise and succinct expressions."[9] This meant that I was charged with understanding and then explaining his often pithy formulations that stand in marked contrast to the often overly-elaborated discussions of other *hayʾa* writers. And Jaghmīnī did not limit his subject matter to straight-forward basic definitions, rules, and parameters of the longitudinal motions of the planets and the Earth's inhabited zone: he also dealt with theories of the latitude of the planets, a subject known for its complexity,[10] and such difficult topics as the appearance of the sky in the arctic regions. Fortunately, I was greatly assisted by the following resources: (1) the *Mulakhkhaṣ* commentaries, whose authors often provided detailed explanations, along with clarifying examples, to shed light on Jaghmīnī's more obscure points or overly simplified statements. I relied on several, for each could provide a slightly different perspective on a given subject; my personal favorites were those of ʿAbd al-Wājid (d. 838/1435), Qāḍīzāde (d. ca. 835/1440), and

[9] See *Mulakhkhaṣ*, **Preface [1]** and **II.3 [11]**.

[10] See Noel M. Swerdlow, "Ptolemy's Theories of the Latitude of the Planets in the *Almagest*, *Handy Tables*, and *Planetary Hypotheses*," in *Wrong for the Right Reasons*. Archimedes: New Studies in the History and Philosophy of Science and Technology, vol. 11, ed. Jed Z. Buchwald and Allan Franklin (Dordrecht; New York: Springer, 2005), pp. 41-42.

Yūsuf ibn Mubārak al-Alānī (ca 735/1334);[11] (2) the edition, translation, and study of the *Tadhkira,* Naṣīr al-Dīn al-Ṭūsī's major *hayʾa* work;[12] (3) al-Bīrūnī's *Tafhīm*, another "user-friendly" reference of astronomical terms;[13] and (4) the availability of planetarium software which enabled me to see the movements of the constellations in the sky at various latitudes, and to determine the veracity of Jaghmīnī's statements.[14]

Jaghmīnī claimed that he was delighted in being entrusted with the lofty task of compiling an introductory book on *ʿilm al-hayʾa*.[15] His *Mulakhkhaṣ*, usually classified as "the most elementary" of treatises on the subject of theoretical astronomy, was composed for an

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[11] Jan Just Witkam has reflected on the importance of the "commentary culture" as it developed in an Islamic context and highlighted some reasons they were written ("Poverty or richness? Some ideas about the generation of Islamic texts revisited," pp. 9-10; paper presented at the Commentary Manuscripts [*al-Makhṭūṭāt al-Shāriḥa*] Conference, Bibliotheca Alexandrina, Alexandria, 7-9 March 2006; preprint [15 pp]: http://www.islamicmanuscripts.info/preprints). Accessed on July 25, 2014.

[12] See F. Jamil Ragep, *Naṣīr al-Dīn al-Ṭūsī's* Memoir on Astronomy (*al-Tadhkira fī ʿilm al-hayʾa*), 2 vols. (Springer-Verlag, 1993); a useful glossary of technical terms is included in vol. 2, pp. 581-613. Ṭūsī and Jaghmīnī deal with much of the same astronomical subject matter, so their content overlap proved extremely helpful, especially since Ṭūsī provides far more elaborate explanations than Jaghmīnī.

[13] Abū Rayḥān Muḥammad ibn Aḥmad al-Bīrūnī's *Kitāb al-Tafhīm li-awāʾil ṣināʿat al-tanjīm* (=The Book of Instruction in the Elements of the Art of Astrology), trans. by R. Ramsay Wright (London: Luzac and Co., 1934). I discuss Bīrūnī's text as a reference of astronomical terms, concepts and explanations even though it is ostensibly an "astrological" primer (see **§ I.2.4b: The "Post Modernists"**).

[14] See *Mulakhkhaṣ*, **II. 2:** on various locations having latitude. Quite frankly I marveled at Jaghmīnī's accurate descriptions of what was occurring in the sky at these various latitudes. I used the open source Stellarium software: http://www.stellarium.org/ (accessed on July 12, 2014), but Jaghmīnī obviously had to depend on other means; it would certainly be interesting to explore the tools scholars used to determine this information.

[15] See *Mulakhkhaṣ*, **Preface [1]**.

early-thirteenth-century audience, but it would continue to play a vital role in educating generations of students and individuals interested in learning about the structure of the universe. The Arabic edition and English translation of Jaghmīnī's treatise *al-Mulakhkhaṣ fī al-hayʾa al-basīṭa* presented in this dissertation (eight centuries after the original composition) will, I hope, allow another group of readers to assess its significance.

§ 2.0 A Study of the *Mulakhkhaṣ*

Given the extent of the influence of the *Mulakhkhaṣ* and its impact on the *hayʾa* tradition, it may seem surprising that so little was known about Jaghmīnī the man, the scholar, and even the precise location of Jaghmīn, assuming it is a location. Rather, the focus has always been on the man's work, and not the man. Questions such as what kind of society produced such a scholar, what was motivating Badr al-Dīn al-Qalānisī to demand an introductory astronomical textbook, and who Jaghmīnī's target audience may have been were left unaddressed.

This led to ambiguity in the literature about when Jaghmīnī lived, and even to speculation that there two Jaghmīnīs, a thirteenth-century scholar who composed the popular astronomical work *al-Mulakhkhaṣ*, and a fourteenth-century namesake who authored the equally popular medical treatise *al-Qānūnča.* I devote Chapter One ("The Dating of Jaghmīnī…") to establishing that there was only one Jaghmīnī who composed a corpus of scientific textbooks in the late-twelfth/early-thirteenth century under the auspices of the Khwārizm Shāhs in Central Asia. This includes a review and analysis of the literature on this subject, and I examine the reasons for the ambiguity and why misinformation about the man and his works continues to the present. I also introduce new evidence to shed light on Jaghmīnī's actual dates; and perhaps most significant of all, I discuss why dating Jaghmīnī as flourishing in the early-thirteenth century matters—and it matters a great deal. Among the significant reasons I mention is that it directly challenges the prevalent view that this post-Ghazālī pre-Mongol period was one of scientific stagnation (or demise). Jaghmīnī's example highlights that at least one scholar was composing multiple scientific textbooks and that there was a continuity of scientific learning. It also strongly suggests that the underlying demand for scientific works did not rest with individual initiatives but from the society's need to promote a scientific education.

In Chapter Two I focus on the rich corpus of introductory texts on theoretical astronomy used or potentially used for teaching purposes, which Jaghmīnī inherited and built upon. I include an overview of some formative summary accounts of theoretical astronomy by Jaghmīnī's predecessors, both Ancient and Islamic, that could arguably have been at Jaghmīnī's disposal, either directly or indirectly, to use and modify for the *Mulakhkhaṣ*. In addition, in this chapter I explore the precise meaning of "*hayʾa*," and how the genre of astronomical literature (*ʿilm al-hayʾa*)—which attempted to explain the physical structure of the universe as a whole—came into being in an Islamic context, and how the term evolved. I conclude the chapter with a summary of what Jaghmīnī does—and does not do—in the *Mulakhkhaṣ* in comparison with some of the earlier works on theoretical astronomy; this is an attempt to address how the *Mulakhkhaṣ* fits into this genre, both content-wise and historically. This discussion is also meant to set the stage for addressing the pressing questions of what inspired the commission of the treatise, and who the target audience was.

In Chapter Three I make the case that the readership of Jaghmīnī's *Mulakhkhaṣ* was, in the first instance, students studying in madrasas, where his work would have been seen as providing a cosmology glorifying God's creation. It is my contention that, beginning in the twelfth century, interconnected conceptual and textual transformations began to occur within the discipline of *hayʾa* that transformed the way it was being taught. One very important result is the emergence of a new kind of *hayʾa* textbook that is conducive for a more general audience—hence Jaghmīnī's *Mulakhkhaṣ* enters the picture, both literally and figuratively. No longer is the study of *hayʾa* restricted only to experts, limited to just a handful of individuals; it now can be used by the ʿulamāʾ to educate the burgeoning number of madrasa students who understood that it offered them another approach to serve God. Astronomy in "the service of Islam," becomes valued for more than its practical applications for religious ritual (as it most often is depicted);[16] it is valued for its theoretical applications to achieve a better understanding of the physical world of God's creation. This of course means that major transformations had to have been occurring within the religious institutions; so a more detailed discussion of these transformations and how

[16] This term, coined by David A. King, refers to a notion of science as acting as a kind of handmaiden "in the service of Islam" by addressing only its more utilitarian needs (*Astronomy in the Service of Islam* [Adlershot: Ashgate Variorum Reprints, 1993]).

they interrelate ensues. I include a review of some of the evidence establishing that the mathematical sciences (with a focus on astronomy) were being taught in Islamic institutions, especially the madrasas; and also an exploration of some of the reasons that such teaching has often been denied or deemed irrelevant.

In conclusion, I raise the more general issue as to whether the standard approach to the pedagogy of Islamic science tends to promote its history as episodic and dependent in the main on courtly patronage or individual initiatives, both of which tend to place science outside the core institutional structures of Islamic societies. I argue that a serious consequence of this neglects the vital role religious institutions played in sustaining scientific education in premodern Islam.

PART I

Chapter 1: The Dating of Jaghmīnī to the Late-Twelfth/Early-Thirteenth Centuries and Resolving the Question of Multiple Jaghmīnīs

Chapter 2: An Overview of Summary Accounts of Astronomy before the *Mulakhkhaṣ*

Chapter 3: Situating the Composition and Teaching of the *Mulakhkhaṣ* in a Madrasa Setting

CHAPTER 1

The Dating of Jaghmīnī to the Late-Twelfth/Early-Thirteenth Centuries and Resolving the Question of Multiple Jaghmīnīs

Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī al-Khwārizmī wrote one of the most successful astronomical textbooks of all time. It is not an exaggeration to say that within research libraries throughout the world today there are thousands of extant copies of the original *Mulakhkhaṣ* and its numerous commentaries, super commentaries, and glosses as well as its translations into Persian, Turkish, and Hebrew. Therefore it is surprising that there has been so little agreed-upon information about who Jaghmīnī was, the society that produced him, and the educational context in which his scientific textbooks were written. This has led to conflicting claims in numerous sources, some of which have placed Jaghmīnī in the early-thirteenth century, others in the mid-fourteenth century. Though recently a number of historians have dated the *Mulakhkhaṣ* to the early-thirteenth century, ambiguity about him has continued, leading some to speculate that perhaps there were two Jaghmīnīs, one thirteenth-century Jaghmīnī whose work focused on astronomy, another who lived in the fourteenth century and wrote on medicine. Here we should emphasize what should be an obvious point: determining Jaghmīnī's dates, and whether the same person wrote the textbooks attributed to him, really does matter. If Jaghmīnī lived in the mid-fourteenth century, he would be coming after the Mongol invasions, the building of the Marāgha observatory, and the consolidation of the Islamic scientific, philosophical, and theological traditions in the late-thirteenth/early-fourteenth centuries. On the other hand, if he lived in the late-twelfth/early-thirteenth centuries, this would directly challenge the prevailing narrative that science declined in Iran and Central Asia immediately after Ghazālī (d. 1111) and that there was a strong prejudice against teaching the exact sciences in religious institutions such as the madrasa.[1] Certainly it would be noteworthy that during this alleged scientific Dark Age of the

[1] Please note that my focus here concerns the teaching of the mathematical sciences, especially theoretical astronomy. Historians of other disciplines, such as philosophy, have in recent years been more willing to accept the notion that they were allowed within the madrasa. As Sonja Brentjes points out: "Historical sources such as biographical dictionaries, study programs and

pre-Mongol period we have the example of (at least) one scholar composing in essence a corpus of elementary scientific textbooks. And this raises many questions, such as who was the target audience and where support might have come from within the context of this time and place.[2] Furthermore, if we can establish that there was one Jaghmīnī who flourished under the auspices of the Khwārizm Shāhs of Central Asia (470-628 H [1077-1231 CE]),[3] we could then bridge the supposed chasm that exists between the alleged "golden age" of early Islam and the "reinvention" of the tradition that occurred with the so-called "Marāgha School." Thus this would be a contribution to establishing the continuity of scientific traditions in Islam and countering long-standing views that those traditions were mainly discrete episodes, hanging on the thin threads of individual geniuses and enlightened rulers.

So establishing the identity and date of Jaghmīni is extremely important; and thus reviewing what has been written about the man, and what we now know in light of new evidence, is the focus of this chapter.

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historical chronicles leave no doubt that philosophical treatises by Ibn Sīnā (d. 428/1037), Faḫr ad-Dīn ar-Rāzī (d. 606/1209), Naṣīr al-Dīn aṭ-Ṭūsī (d. 672/1274) or Ğalāl ad-Dīn ad-Dawwānī (d. 907/1501) were studied at *madrasas* in Cairo, Damascus or even in cities of northern Africa" ("The Prison of Categories—'Decline' and its Company," in *Islamic, Philosophy, Science, Culture, and Religion: Studies in Honor of Dimitri Gutas*, ed. Felicitas Opwis and David Reisman [Leiden: E. J. Brill, 2012], p. 131, fn. 2). Science is another matter. As noted by Ahmad S. Dallal: "Scholars of Islamic education mostly agree on the marginality of the sciences," and he goes on to remark that it is exceptional to find studies on the relationship between religious and scientific scholarship (*Islam, Science, and the Challenge of History* [New Haven: Yale University Press, 2010], pp. 19, 184-85, fn. 47).

[2] I deal with addressing these kinds of questions in Chapter Three of this dissertation.

[3] For a nice family-tree charting the reigns of the Khwārizm shahs, see Muḥammad ibn Aḥmad Nasawī, *Sīrat al-Sulṭān Jalāl al-Dīn Mankubirtī li-Muḥammad ibn Aḥmad al-Nasawī*, ed. Ḥāfiẓ Aḥmad Ḥamdī (Cairo: Dār al-fikr al-ʿarabī, 1953), intro., p. 2 [in Arabic].

§ I.1.1 A Man Who Should Need No Introduction

From the final *nisba* in his name, one can deduce that Jaghmīnī hailed from the region of Khwārizm; and indeed Qāḍīzāde al-Rūmī informs us that "Jaghmīn is one of the villages in Khwārizm" in his *Sharḥ al-Mulakhkhaṣ*, the commentary he wrote in 814 H [1412 CE] and dedicated to Ulugh Beg. However, Khwārizm covers quite a bit of territory, so this is not very informative. Thus it would seem that delving more deeply into the precise location of Jaghmīn was not of much concern to Qāḍīzāde, as well as the other commentators I checked, for they provide nothing more specific than this.[4] It is interesting that in the seventeenth century, the well-known Ottoman historian and bibliographer Kātib Čelebī (a.k.a. Ḥājjī Khalīfa) felt no compulsion to remove the cloud of obscurity surrounding Jaghmīnī's life and wrote in his *Kashf al-ẓunūn* that the *Mulakhkhaṣ* was "composed by the eminent [scholar] Maḥmūd ibn Muḥammad al-Jaghmīnī al-Khwārizmī, an author whose fame makes an introduction unnecessary."[5] This sentiment is also attested by the fact that in the late-thirteenth/early-fourteenth century, the prominent scholar Quṭb al-Dīn al-Shīrāzī could mention and even paraphrase from Jaghmīnī's

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[4] See Qāḍīzāde al-Rūmī, *Sharḥ al-Mulakhkhaṣ*, Istanbul, Süleymaniye Library, Ayasofya MS 2662, f. 2b: جغمين قرية من قرى خوارزم A potential opportunity of pinpointing Jaghmīnī's

location was lost in Jaghmīnī's discussion on the *qibla* bearing (see **II.3 [4])**; here he compares the longitude and latitude of Mecca to "our locality" but unfortunately fails to be more specific (understandable since presumably his immediate audience knew where they were). On this point, Qāḍīzāde is once again content to reference Khwārizm (f. 62b); the other commentators I checked followed his example or omitted a location altogether. I have attempted to home in on Jaghmīn's location, but so far without much success. Given the lack of any record of a village, town, or region named Jaghmīn in the geographical sources, one speculative possibility is that Jaghmīnī's name designates a family and not a locale, or perhaps a Turkic tribal affiliation, e.g., he was one of the Jagh [Čagh]-mān.

[5] For this tidbit of information and the English translation, I am thankful to F. Jamil Ragep, "On Dating Jaghmīnī and His *Mulakhkhaṣ*," p. 464:

تاليف الفاضل محمود بن محمد الجغميني الخوارزمى وهو مولف شهرته تغني عن تعريفه

Mulakhkhaṣ without clear reference in the introduction or explicit of his *Nihāyat al-idrāk fī dirāyat al-aflāk*, with the full expectation that the reader would recognize its provenance (assuming that Shīrāzī was not plagiarizing in his paraphrase).[6]

It would certainly be understandable that many scholars such as Quṭb al-Dīn al-Shīrāzī (14th c.), Qāḍīzāde al-Rūmī (15th c.), and Kātib Čelebi (17th c.), as well as the literally dozens of commentators over the centuries, would have been more concerned with the *content* of the *Mulakhkhaṣ* than ascertaining the particulars of where and when Jaghmīni lived. However, since definitively dating Jaghmīni is vital to understanding the nature of his achievement, it is crucial to decipher how the conflicting information contained in the modern sources—which cite him alternatively as flourishing in the early-thirteenth century and the mid-fourteenth century, or speculate that there are two Jaghmīnīs— first took hold and eventually became embedded in the literature. So what follows is an overview of the literature highlighting the main accounts of his life and work and the issues involved. I then provide evidence supporting my claim that there is one Jaghmīnī who wrote multiple works in the exact sciences and medicine, who flourished in the late-twelfth/early-thirteenth century in Khwārizm, most likely in the environs of Merv, and who was a witness to (and most-likely victim of) the onslaught of the Mongol invasions into the region that put an end to the reign of the Khwārizm Shāhs. The additional evidence was collected from the *Mulakhkhaṣ* and some of Jaghmīnī's other works, and bolstered by primary and secondary sources.

[6] For Shīrāzī's direct reference to the *Mulakhkhaṣ* in his explicit, see F. Jamil Ragep, "Shīrāzī's *Nihāyat al-Idrāk*: Introduction and Conclusion," *Tarikh-e Elm* (Tehran, Iran) 11 (2013): 51 [Arabic], 55 [Eng. trans.]. Shīrāzī "borrows" the following from Jaghmīnī (50 [Arabic], 54 [Eng. trans.]) in his introduction:

ليكون اسمه دالّاً على معناه وظاهره مخبراً عن فحواه

"…so that its name will indicate its connotation and its literal sense will be informative about its signification" (see *Mulakhkhaṣ*, **Preface [2],** esp. variant MS L).

§ I.1.2a Review of the Literature

I begin with some general comments. In the late nineteenth/early twentieth centuries, there seems to have been a heavy reliance by several Western scholars on information they gleaned from a rather small pool of available Islamic manuscript catalogues. This limited quantity of reference materials frequently contained errors; moreover, as will be discussed later in this chapter, many scholars seem to have relied on catalogues alone as their only source of information. In other words, they may never have actually examined the manuscripts in question to verify the catalogue information. A serious consequence was that this limited information made it difficult for them to determine the veracity of varying, and sometimes conflicting, claims. Frankly, much of the information I can put forth as new evidence in this chapter is directly due to having had access to a vast number of *Mulakhkhaṣ* witnesses and commentaries on the text (many of which contain valuable dates, dedications, marginal notes, and so forth).

This limited access to Islamic manuscripts contributed to a general lack of sensitivity in the late nineteenth/early twentieth centuries to the important fact that any particular witness to a text might represent one of several versions, could be corrupted or an amalgam of different versions, and/or could intentionally have been modified over time (by the author himself or by others) due to "updating".[7] Indeed, it is not uncommon to find comments, emendations, and

[7] In fact it was not an uncommon practice for many library cataloguers to assume all copies of an Islamic manuscript by a given author were basically the same. Christoph Rauch (current Head of the Oriental Department, Staatsbibliothek, Berlin) told me that Wilhelm Ahlwardt (d. 1909), the meticulous cataloguer of Arabic manuscripts at the Royal Library (Berlin), and who was charged with purchasing additional manuscripts for the collection, believed having one manuscript copy of a title per author was sufficient. And budget restrictions aside, it was standard practice to describe multiple manuscript copies of a single title in catalogues as the "same work" rather than view each as unique, obviously robbing the reader of valuable textual information. Ahlwardt was certainly not alone in this practice; for example, in addition to Ahlwardt (*Die Handschriften-Verzeichnisse der Königlichen Bibliothek zu Berlin. Verzeichniss der Arabischen Handschriften*, 10 vols. [Berlin, 1887-1899]), one finds countless examples contained within Baron William

"corrections" added to texts. Furthermore, it was the habit of some "scholars and writers to leave blank spaces in their works for the later insertion, by themselves or others, of data which were not known to them at the time of writing."[8]

All these factors contribute to making textual analysis a rather complex and daunting endeavor; and it is often quite difficult to disentangle and decipher an original text from a contaminated one. One may thus have sympathy for one's predecessors, but unfortunately errors, whether understandable or not, can become embedded in the literature and over the decades become increasingly difficult to eradicate. This has become the case with Jaghmīnī who has been confidently held to have flourished sometime in the fourteenth century—or even later.[9] Ironically, the basis for this confidence is the following statement, which appeared in the reputable and widely-used *Encyclopaedia of Islam,* First Edition in 1913[10]: "His date is not quite certain but it is very probable that he died in 745 (1344-1345)". Often repeated, this statement is

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MacGuckin de Slane, *Catalogue des manuscrits arabes / par le baron de Slane* (Paris: Imprimerie nationale, 1883-1895).

[8] See Franz Rosenthal, "The Technique and Approach of Muslim Scholarship," *Analecta Orientalia* 24 (1947): 30.

[9] Heinrich Suter informs us that The Cairo Khedieval Library catalogue contains statements that Jaghmīnī died in the ninth-century hijjra, and composed the *Mulakhkhaṣ* in the year "808, 1405/6" (see "Der V. Band des Katalogs der arabischen Bücher der viceköniglichen Bibliothek in Kairo," in *Historisch-literarische Abtheilung der Zeitschrift für Mathematik und Physik*, ed. Dr. O. Schlömilch and Dr. M. Cantor [Leipzig: Verlag von B. G. Teubner, 1893], vol. 38, no. 5, p. 162; and Heinrich Suter, "Zu Rudloff und Hochheim, Die Astronomie des Ǵagmînî," *Zeitschrift der Deutschen Morgenländischen Gesellschaft* 47 [1893], p. 718). Carlo A. Nallino also points out that Cairo catalogues list the ninth-century hijra date for Jaghmīnī in several places ("Zu Ǵaġmînî's Astronomie," *Zeitschrift der Deutschen Morgenländischen Gesellschaft* 48 [1894]: 120). This could be the explanation for how 808 became the year currently listed for the completion of Jaghmīnī's *Mulakhkhaṣ* (without explanation) in Ismāʿīl Bāshā al-Baghdādī's *Hadiyyat al-ʿārifīn* (Istanbul, 1955**)**, vol. 2, col. 410 [in Arabic].

[10] See H. Suter, "al-Djaghmīnī," in *Encyclopaedia of Islam, First Edition (1913-1936)* (Leiden: E. J. Brill, 1913), vol. 1, p. 1038.

still found today in numerous references, many quite reputable,[11] even though mounting evidence challenging this assertion had emerged as early as 1936, with the discovery by Max Krause of a copy of the *Mulakhkhaṣ* dated 644 H [1246-7 CE]).[12] Therefore, two main Islamic reference resources currently list Jaghmīnī as flourishing in the fourteenth century, namely the "al-Djaghmīnī" entry in *Encyclopaedia of Islam,* 2nd ed. (1965) (which simply repeats verbatim what appeared in the 1913 first edition);[13] and the *Encyclopædia Iranica* (2008) article entitled: "Jaǧmini, Maḥmud b. Moḥammad b. ʿOmar (d. 1344), an astronomer from Jaǧmin."[14]

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[11] Let me stress that this error of referencing an eighth-/fourteenth-century Jaghmīnī occurs in non-Western sources as well as Western ones, such as: The Majlis Library catalogue (*Fihrist-i Kitābkhānah-i Majlis-i Shūrā-yi Millī, kutub-i khattī*), ed. ʿAbd al-Ḥusayn Ḥāʾirīʾī (Tehran: Majlis-i Shūrā, 1347 H. Sh. [1968 or 1969]), vol. 10, part 1, p. 512; Abū al-Qāsim al-Qurbānī's *Zindagī-nāmah-i rīyāḍī'dānān dawrah-i Islāmī* (Tehran: Markaz-i Nashr-i Dānishgāhī, 1365 [1986]), pp. 219-220 (no. 69); and Halil Inalcık's *The Ottoman Empire: The Classical Age 1300-1600*, trans. Norman Itzkowitz and Colin Imber (London: Weidenfeld and Nicolson, 1973), p.176fn .

[12] See Krause, "Stambuler Handschriften islamischer Mathematiker," pp. 509-10. The 644 H [1246-7 CE] copy date that Krause mentions, still the oldest one to date, is found in MS L**,** f. 81a of my Arabic edition.

[13] In his defense, Heinrich Suter (d. 1922) had died long before Krause's 1936 discovery, and well before the printing of the entry in *Encyclopaedia of Islam,* 2nd ed. (Leiden: E. J. Brill, 1965), vol. 2, p. 378; it was incumbent upon Juan Vernet, who is listed as co-author, to revise the date. This responsibility also applies to others, such as Fuat Sezgin who lists "Maḥmūd b. Muḥammad b. ʿUmar AL-ǦAĠMĪNĪ" as "probably 745/1345" in the important bio-bibliographical resource *Geschichte des arabischen Schrifttums*, vol. 5: *Mathematik* [= *GAS,* 5] (Leiden: E. J. Brill, 1974), p. 115 (no. 56).

[14] Lutz Richter-Bernburg suggests here that since "Nothing specific is known about his life… it would seem plausible (but no more) to speculate that the author of al-Qānunja was a linear descendent of his earlier namesake…" ("Jaǧmini, Maḥmud," *Encyclopædia Iranica*, vol. 14, Fasc. 4, p. 373; originally published Dec. 15, 2008; online version last updated April 10, 2012: http://www.iranicaonline.org/articles/jagmini-mahmud). Accessed on July 26, 2014.

The fact that many sources cited Jaghmīnī as flourishing circa 618 H [1221 CE][15] did not sway those committed to a 14th-century Jaghmīnī to reevaluate their position. In those cases the 618 H date was either ignored altogether or mitigated by the suggestion of the possibility of there being *two* Jaghmīnīs: an early 13th-century astronomer/mathematician (flourishing circa 618 H), the one who authored the *Mulakhkhaṣ*; and, a fourteenth-century physician who wrote the *Qānūnča* (the "little Qānūn"),[16] an abridged treatise of Ibn Sīnā's medical text *al-Qānūn fī al-ṭibb*. Overwhelmingly, references to the Jaghmīnī who authored the *Qānūnča* state that he flourished in the eighth/fourteenth century.[17] For proof otherwise, see the sections below on new evidence.

[15] For a list of some of the more prominent references that cite the 618 [1221] date, see fn. 37.

[16] Jaghmīnī's choice of *Qānūnča* for the title is interesting since the medical treatise is written in Arabic, but the diminutive suffix "che" is found in Persian. As far as I know Jaghmīnī never wrote scientific texts in Persian, though he does reference the two holidays of Nayrūz and Mihrjān in the *Mulakhkhaṣ* (see **II.2 [2]).** So this title may be an indication of Jaghmīnī's background or perhaps some playful tribute by him acknowledging the wealth of medical literature written in Persian during the twelfth century.

[17] A prominent example is the date "d. 1344/745H" currently listed for Jaghmīnī online at the bio-bibliographies on the *Islamic Medical Manuscripts at the National Library of Medicine* website (with text written by Emilie Savage-Smith, The Oriental Institute, Oxford University): http://www.nlm.nih.gov/hmd/arabic/bioJ.html) Accessed on July 26, 2014. Whereas Savage-Smith points out that there is conflicting evidence about when Jaghmīnī lived and raises the possibility of two Jaghmīnīs in her description, many other sources do not: A. Z. Iskander simply lists "d. A.H. 745/A.D. 1344" in his *A Catalogue of Arabic Manuscripts on Medicine and Science in the Wellcome Historical Medical Library* (London: The Wellcome Historical Medical Library, 1967), p. 57. And a recent edition of Jaghmīnī's *Qānūnča fī al-ṭibb* currently bears both the date 751 H [!] on the book cover, and 745 H on the inside title page (ed. and Persian trans. by Ismāʿīl Nāẓim [Tehran: Tehran University of Medical Sciences, 2012]). I found one exception in which Jaghmīnī (author of the *Qānūnča*) is listed as flourishing circa 618 H in *Fihris al-makhṭūṭāt al-muṣawwara,* ed. Ibrāhīm Shabbūḥ (Cairo, 1959), vol. 3, pt. 2, p. 145 (no. 186).

§ I.1.2b A Tale of Two Jaghmīnīs

How did the two-Jaghmīnī narrative take hold? The short answer is most references that have cited a 618 H [= 1221-2 CE] date[18] for Jaghmīni provided no information as to its source; and this ambiguity led some to question the trustworthiness of the date, but not enough to rule it out completely even after the 14th-century option emerged as a contender. Two different dates, hence two Jaghmīnīs, seemed a logical conclusion to many; however, this was not the conclusion of Henrich Suter (d. 1922) who, as we shall see, insisted on one fourteenth-century Jaghmīni who authored both the *Mulakhkhaṣ* and the *Qānūnča*. The longer answer follows.

Rudloff and Hochheim, in the introduction to their 1893 German translation of Jaghmīnī's *Mulakhkhaṣ*, bemoan the fact that "one searches in vain for any notes from which conclusions can be drawn concerning the date of birth, place of residence, and life circumstances, of the author of the following treatise."[19] Now it is evident that Rudloff and Hochheim are unfamiliar with Islamic history; for example, they openly admit that they are unaware of the identity of al-Shāfiʿī (d. 820) and Abū Ḥanīfa (d. 767), the extremely famous founders of two Sunnī legal schools. Both are cited in the *Mulakhkhaṣ* (see **II.3 [2]**) in the context of Jaghmīnī distinguishing between their opinions regarding the determination of prayer times using shadow gnomons. Furthermore, Jaghmīnī himself was a Shāfiʿī. In addition, Rudloff and Hochheim were unacquainted with the renowned Islamic scholar Sayyid al-Sharīf al-Jurjānī (d. 816 [1413]), except for the fact that he was the author of the *Mulakhkhaṣ* commentary they used for their German translation. But despite these shortcomings, Rudloff and Hochheim discovered an important piece of information in Prof. Josephus Gottwaldt's 1855 Library Catalogue of Kazan, which simply states that Jaghmīnī died in 618 H, and they present this date in their introduction.[20] (Keep in mind that their spade work occurred some five years before the

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[18] Exactly what this date refers to in the literature is ambiguous. At times it is a death date, at others a date for the composition of the *Mulakhkhaṣ*.

[19] See G. Rudloff and Prof. Dr. Ad. Hochheim, "Die Astronomie," p. 213. Note all English translations here of the German are mine.

[20] Rudloff and Hochheim, "Die Astronomie," p. 213. I was able to check the Library Catalogue of Kazan and verify that indeed it states "618 (1221)" without qualification. See Josephus M. E.

initial publication of Carl Brockelmann's seminal *Geschichte der arabischen Litteratur,* vol. 1 in 1898.[21]) Since Prof. Gottwaldt provided no indication as to how he came by this date, it opened the door for speculation that Jaghmīnī may or may not have lived then. Nonetheless, Rudloff and Hochheim upheld this date based on their translation of the *Mulakhkhaṣ*, concluding that Jaghmīnī was a scholar who "delivers through his presentation, a luminous picture of the ideas of those Arabs of the thirteenth century, who dedicated to astronomy a purely scientific interest."[22] I find their assessment of Jaghmīni quite illuminating, despite their German translation being based on an amalgam of manuscripts, all obtained from the Gotha Library,[23] that were often interlaced with commentary notes. Of the four main witnesses that Rudloff and Hochheim used for their final translation: one had a late copy date of 1137 H.; two others were defective; and the last one was a late copy of Jurjānī's 15th-century commentary.[24] Although it is highly

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Gottwaldt, *Opisanie arabskich rukopisej prinadležavšich bibliotekě Imperatorskago kazangskago universiteta* (Kazan, 1855), p. 245 (entry for the *Mulakhkhaṣ* [no. 169] under the category of mathematics) [in Russian].

[21] Carl Brockelmann, *Geschichte der arabischen Litteratur* [= *GAL*], 2 vols. plus 3 supplements (Weimar: Verlag von Emil Felber, [vol. 1] 1898; Berlin: Verlag von Emil Felber [vol. 2] 1902; Leiden: E. J. Brill [suppl. 1] 1937; [suppl. 2] 1938; [suppl. 3] 1942).

[22] See Rudloff and Hochheim, "Die Astronomie," p. 215.

[23] Although Rudloff and Hochheim restricted their translation to witnesses from the Gotha Library Oriental collection, it evidently housed "the largest collection held at German libraries during the nineteenth century." It began with an expedition sent to the Middle East in 1802, specifically charged with acquiring Oriental books and manuscripts; and this apparently "created a need for specialists who were able to read, evaluate, and catalogue the collection" (see Ursula Woköck, *German Orientalism. The Study of the Middle East and Islam from 1800 to 1945*, gen. ed. Ian Richard Netton. Series: Culture and Civilization in the Middle East [London/New York: Routledge, 2009], pp. 92 and 130). Perhaps this may help contextualize why Suter trusted their catalogue information [see below].

[24] For Rudloff and Hochheim's description of these 4 manuscripts, see "Die Astronomie," pp. 216-218. For the catalogue descriptions, see Wilhelm Pertsch, *Die orientalischen Handschriften*

questionable whether Rudloff and Hochheim could distinguish between the words of Jaghmīnī and those of Jūrjānī or other commentators and interpolators, or understand the subtleties of the text they were dealing with, they did correctly place Jaghmīnī in the seventh/thirteenth century. This fact, however, did not go unchallenged by Suter, whose review of their work appeared alongside their translation within the same journal issue in 1893. He contended that their date was "a little too early, although I can find no compelling evidence for a later lifetime."[25]

Suter's opinion was formulated on information gathered from the mathematical and astronomical parts of the published catalogues of the Cairo Khedieval Library.[26] Unlike Rudloff and Hochheim, Suter *was* familiar with Jurjānī and the composition date of his *Mulakhkhaṣ* commentary (813 [1410-11]); and he was also aware of other *Mulakhkhaṣ* commentators such as Qāḍīzāde al-Rūmī and Kamāl al-Dīn al-Turkmānī. He believed that Turkmānī's commentary was especially significant for dating Jaghmīnī since it was written in 755 H. Armed with this date, Suter confidently concluded that any claim that Jaghmīnī was "a scholar of the 9th century H" is highly improbable;[27] but he also states that Jaghmīnī "with near certainty… flourished in the first

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der Herzoglichen Bibliothek zu Gotha (Gotha: Friedrich Andreas Perthes, 1881), vol. 3, part 3, pp. 46-48 (nos. 1385, 1386, 1387, 1388).

[25] See Prof. Dr. Heinrich Suter, "Zu Rudloff und Hochheim, Die Astronomie des Ǵagmînî," p. 718.

[26] See Suter, "Zu Rudloff und Hochheim," p. 718; and ibid, "Der V. Band des Katalogs der arabischen Bücher der viceköniglichen Bibliothek in Kairo," vol. 38, no. 5, pp. 161 and 162.

[27] See Suter, "Zu Rudloff und Hochheim," pp. 718-719. Cf. Nallino, who is also familiar with the ninth-century dating of Jaghmīnī (also based on Cairo catalogues), but is less willing than Suter to reject it; however, Nallino is unaware of Turkmānī's commentary ("Zu Ǵaġmînî's Astronomie," p. 120).

half of the 8th century H."[28] This was an assertion that Suter would tenaciously champion in publications throughout his career.[29]

The crucial piece of "new evidence" that Suter relied on to support his claim that "with near certainty" Jaghmīnī flourished in the "first half of the eighth century H" was a reference he found in the 1881 Gotha Library catalogue; Wilhelm Pertsch informs us here that codex Gotha 1930, folio 1b has a marginal note that states that Maḥmūd ibn ʿUmar al-Jaghmīnī, the author of *al-Qānūnča fī al-ṭibb*, an abridgement of Ibn Sīnā's work, died in the year 745 H.[30] Actually, Pertsch's comment is not found in his description of Gotha 1930, but rather in his summary of codex Gotha 1928 (Section XIX. Medicin, p. 468);[31] nevertheless the marginal note is actually contained in Gotha 1930 (which I checked). However, it is not at all clear from Suter's article whether he actually examined Gotha 1930 or was relying entirely on Pertsch's catalogue for his information. This is unfortunate for had he checked the codex he would have been alerted to the fact that there were several errors in marginal notes pertaining to this particular witness making their reliability suspect;[32] perhaps much of the controversy regarding Jaghmīnī's dates could have thereby been avoided.

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[28] See Henrich Suter, "Zur Frage über die Lebenszeit des Verfassers des Mulaḫḫaṣ fî'l-hei'a, Maḥmûd b. Muḥ. b. 'Omar al-Ǵaġmînî," *Zeitschrift der Deutschen Morgenländischen Gesellschaft* 53 (1899): 540.

[29] See Suter, "Der V. Band des Katalogs der arabischen Bücher der viceköniglichen Bibliothek in Kairo," pp. 161 and 162; Suter, "Zur Frage über die Lebenszeit des Verfassers des Mulaḫḫaṣ fî'l-hei'a," pp. 539-540; Suter, "Die Mathematiker und Astronomen der Araber und ihre Werke," *Abhandlungen zur Geschichte der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen* 10 (1900): 164 (no. 403); and Suter, "al-D̲jag̲h̲mīnī," in *Encyclopaedia of Islam, First Edition (1913-1936)*, p. 1038.

[30] See Suter, "Zur Frage über die Lebenszeit des Verfassers des Mulaḫḫaṣ fî'l-hei'a," pp. 539-40 (no. 2).

[31] See Wilhelm Pertsch, *Die orientalischen Handschriften*, vol. 3, part 3, pp. 468-469 (no. 1928) and pp. 469-71 (no. 1930).

[32] I examined the witness *Sharḥ Qānūnča,* Gotha Ms. orient. A 1930 (which bears a copy date of 949 [1542] (f. 144b)), and the marginal note on f. 1a reads as follows:

According to Suter, the emergence of *Mulakhkhaṣ* commentaries around the fourteenth century strongly supported the 745 H [1344-5] catalogue date, and thus strengthened his dating claim. Suter's heavy reliance on the dates of *Mulakhkhaṣ* commentaries (especially that of Kamāl al-Dīn al-Turkmānī) to bolster his argument may explain why he never considered the two-Jaghmīnī option; indeed, he has just *one* entry for Jaghmīnī, the scholar who authored both the *Mulakhkhaṣ* and the *Qānūnča*, in his seminal work listing 600 Islamic astronomers and mathematicians and their works.[33] Suter never mentions the 618 H date in this entry; and he does

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١أ: اختصره من القانون الكبير لابن سينا توفّى محمود المذكور سنة ٧٤٥

"He abridged it from the great *Qānūn* [Canon] of Ibn Sīnā, the aforementioned Maḥmūd died in 745" [the aforementioned Maḥmūd being Maḥmūd ibn ʿUmar al-Jaghmīnī].

So indeed, according to this statement, Jaghmīnī died in 745; however, A. Z. Iskander, who made a careful examination of Gotha MS 1930, pointed to several unreliable marginal dates and notes in the witness, to wit: the commentary is actually by ʿAlī b. Kamāl al-Dīn Maḥmūd al-Āstarabādhī al-Makkī (as noted on f. 144b), but is misattributed by the annotator (on f. 1a) to Muḥammad b. Muḥammad al-ṭabīb al-Miṣrī, whose name does not appear anywhere in the text (unfortunately, this misattribution is then given by Pertsch [*Die orientalischen Handschriften*, vol. 3, part 3, p. 469]); and the date of al-Miṣrī's death is given by the annotator as the year 801 (f. 1a), which is impossible since the work is dedicated to Sultan Bāyazīd II (f. 2a) who reigned 886-918 [1481-1512]. However, this error is not reported by Pertsch (ibid.). See Iskander, *A Catalogue of Arabic Manuscripts on Medicine and Science*, "Commentaries on K. Qānūnča," pp. 58-59.

[33] See Suter, "Die Mathematiker und Astronomen," pp. 164-165, no. 403. This reference work (written in 1900 on Islamic authors and their works on the exact sciences) was foundational for many subsequent resources: M. Krause used Suter's author numbers for his 1936 "Stambuler Handschriften islamischer Mathematiker" as did G. P. Matvievskaya and B. A. Rosenfeld, *Matematiki i astronomi musulmanskogo srednevekovya i ikh trudi (VIII-XVII vv.)* [Mathematicians and Astronomers of the Muslim Middle Ages and Their Works (VIII-XVII centuries)], 3 vols. (Moscow: Nauka, 1983).

not suggest it as an option in his supplement to this work.[34] Furthermore, he fails to cite other references that list Jaghmīnī twice due to the contrary information, such as we find in Brockelmann, who lists Jaghmīnī twice under the categories of both astronomy and medicine with different dates.[35] Ironically, Pertsch is among those who listed Jaghmīnī twice; so in effect, Suter based his claim on dating Jaghmīnī circa 745 H from information obtained from the Gotha catalogue but ignored the information from the same catalogue which also dated him as flourishing circa 618 H.[36]

Suter aside (and the numerous sources that followed suit perpetuating the 745 date), the vast majority of references to Jaghmīnī the astronomer cite the date 618 H [1221-2] as either the day of Jaghmīnī's death or the date of the composition of the *Mulakhkhaṣ*. In either case, one typically finds that this date is stated without qualification, except it is not uncommon that sources simply reference other sources that provide no evidence for the date.[37]

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[34] See Suter, "Nachträge und Berichtigungen," *Abhandlungen zur Geschichte der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen* 14 (1902): 177.

[35] See Brockelmann, *GAL* 1, p. 473 (no. 5) for Jaghmīnī on astronomy (d. after 618 [1221]); and *GAL*1*,* p. 457 for Jaghmīnī on medicine (745 [1344]). Brockelmann repeats this bifurcation in suppl. 1, pp. 865, 826. After Brockelmann we find other prominent sources following suit; see, for example, Charles A. Storey, *Persian Literature: A Bio-Bibliographical Survey,* 2 vols. (London: Luzac and Co., 1927-1971), vol. 2, pt. 1 (A. Mathematics. B. Weights and Measures. C. Astronomy and Astrology. D. Geography), p. 50 (no. 88) [for astronomy]; and Storey, vol. 2 (E. Medicine), pt. 2, p. 219 (no. 377) [for medicine]. As the basis for dating Jaghmīnī 745/1344-5, Storey refers to the marginal note on folio 1b in Gotha 1930 listed in Pertsch's *Die orientalischen Handschriften*.

[36] Cf. Pertsch, *Die orientalischen Handschriften,* vol. 3, pt. 3, p. 46, no. 1385 (Section XIV: Astronomie und Astrologie) and pp. 468-69, nos. 1928-1930 (Section XIX: Medicin). Suter was obviously aware of the two separate listings for Jaghmīnī since he includes codices listed for Jaghmīnī on astronomy (bearing the 618 H date) in his own list (but without comment); one example is Gotha, no. 1385 (see Suter, "Die Mathematiker und Astronomen," p. 164).

[37] Some of the more prominent references citing the 618 [1221] date are: Brockelmann, *GAL* 1, p. 473 (no. 5), *GAL* suppl. 1, p. 865; İzgi, *Osmanlı Medreselerinde İlim: Riyazī ilimler*, vol. 1, p.

One of the most frequently cited sources for Jaghmīnī is Ḥājjī Khalīfa's *Kashf al-ẓunūn*; and this is particularly noteworthy because the printed editions of his work (at least the two that I have been able to check) omit Jaghmīnī's dates twice, i.e., in the listings for the *Mulakhkhaṣ* and the *Qānūnča*.[38] Nevertheless, Ḥājjī Khalīfa may have been the original source of the 618 H date. A viable explanation for this is that the date was contained in one of the several manuscript versions of the *Kashf al-ẓunūn*.[39] In support of this view, the title page of a manuscript copy of Qāḍīzade's commentary on the *Mulakhkhaṣ* (Cairo, Dār al-kutub, Taymūr Riyāḍa 338, f. 1b) contains a note stating that Jaghmīnī "completed it in the year 618," and that this information

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370, esp. fn.1010; David A. King, *A Survey of the Scientific Manuscripts in the Egyptian National Library* (Winona Lake, Indiana: Eisenbrauns, 1986), p. 150 (G17; 1.2.7); Krause, "Stambuler Handschriften islamischer Mathematiker," p. 509 (no. 403) [Krause does not state a year but refers to Brockelmann, *GAL* 1, p. 473]; Rudloff and Hochheim, "Die Astronomie," p. 213; Matvievskaya and Rosenfeld, *Matematiki i astronomi* , vol. 2, p. 368; Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)*, p. 198 (no. 547); and Khayr al-Dīn al-Ziriklī, *Kitāb al-Aʿlām* (Beirut: Dār al-ʿilm, 1980), vol. 7, p. 181.

[38] See Ḥājjī Khalīfa, *Kashf al-ẓunūn ʿan asāmī al-kutub wa-ʾl-funūn*. 2 vols. (Istanbul, 1941, 1943), vol. 2, cols. 1819-1820 [for astronomy] and vol. 2, col. 1311[for medicine]; and also Gustavus Flügel, *Lexicon Bibliographicum et Encyclopædicum a Mustafa ben Abdallah. Katib Jelebi dicto et nomine Haji Khalfa celebrato compositum*, 7 vols. (Leipzig and London, 1835-58), vol. 6, pp. 113-14 (no. 12886) [for astronomy], vol. 4, pp. 495-96 (no. 9347) [for medicine].

[39] The fact that witness copies vary for a title (each witness unique and potentially containing valuable information) highlights the important and complex issue of establishing the veracity of information, especially if there are conflicting claims. However, Suter seemingly believed that multiple versions of a primary source such as the *Kashf al-ẓunūn* made using it suspect (see "Zu Rudloff und Hochheim," p. 719; and ibid, "Zur Frage über die Lebenszeit des Verfassers des Mulaḫḫaṣ fî'l-hei'a," p. 539); of course, as we have learned, Suter had few qualms about selectively relying on a single secondary source, namely the Gotha catalogue.

was obtained from the *Kashf al-ẓunūn.*[40] This then could have been the basis for Gottwaldt's entry in his 1885 catalogue as well as for other sources that subsequently repeated the date.

§ I.1.3 Evidence Shedding New Light

The origins of the date 618 H [1221-2 CE] for Jaghmīnī's *floruit* would be interesting to resolve;[41] and an historiographical analysis of the literature regarding Jaghmīnī's dates is undeniably interesting for many reasons, among which are the insights one gets from assessing the aftermath of faulty assumptions. Nevertheless, my primary concern here is to remove some of the obscurity surrounding Jaghmīnī's life and works. So the remaining part of this chapter provides additional evidence to support the contention that there was only one Jaghmīnī who wrote multiple scientific works (and in particular the *Mulakhkhaṣ* in 603 H [1206 CE]), and who flourished in the late-twelfth/early-thirteenth century during the extremely tumultuous period that witnessed the end of the Khwārizm Shāhs.[42] As mentioned earlier, my assertions are based on evidence gleaned directly from within the *Mulakhkhaṣ* itself, several of Jaghmīnī's other scientific treatises, and primary and secondary sources that provide valuable supplementary information for developing and (I believe) strengthening my claims. Needless to say, there are

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[40] F. J. Ragep provides the Arabic text of this passage along with an English translation in "On Dating Jaghmīnī and His *Mulakhkhaṣ*," pp. 464-65.

[41] This year may simply have surfaced based on the assumption that Jaghmīnī died with the Mongol invasions.

[42] For historical overviews that provide insights into the complex alliances that were being formed among the peoples of this region during this period, see C. Edmund Bosworth, "The Political and Dynastic History of the Iranian World (A.D. 1000-1217)," in *The Cambridge History of Iran*, vol. 5: *The Saljuq and Mongol Periods,* ed. J. A. Boyle (Cambridge: Cambridge University Press, 1968), pp. 185-95 (section XIII. <u>Kh</u>urāsān in the second half of the $6^{th}/12^{th}$ century, and the expansion of the <u>Kh</u>wārazm-<u>Sh</u>āhs); and W. Barthold, *Turkestan Down to the Mongol Invasion*, 2nd ed., trans. by the author with the assistance of H. A. R. Gibb (London: Luzac and Co., 1958), pp. 323-80 (Ch. III: "The Qarā-Khiṭāys and the Khwārazm-Shāhs").

hundreds (if not thousands) of still-to-be-read manuscripts that need to be examined for future research;[43] and undoubtedly these contain information that will broaden, alter, and enrich our spectrum of knowledge. I hope this comparative drop in the bucket of information contributes to this effort.

To begin with, the original version of Jaghmīnī's *Mulakhkhaṣ* contains a dedication and a poem that Jaghmīnī composed dedicated to the Imām Badr al-Dīn Muḥammad ibn Bahrām al-Qalānisī (**Preface [1]**[44]), who Jaghmīnī informs us proposed that he compile a work on the subject of *ʿilm al-hayʾa* (i.e., an epitome of theoretical astronomy that provides a cosmography [or *hayʾa*] of the Universe).[45] Jaghmīnī also dedicates a short treatise on planetary sizes and distances to Badr al-Dīn al-Qalānisī, a subject he did not include within the *Mulakhkhaṣ*.[46] Since *hayʾa* works often devote a section to this topic, perhaps Jaghmīnī recognized the omission and tried to rectify it by composing this brief astronomical work as a kind of appendage. In any event, Jaghmīnī's presumed oversight is our gain since this work on sizes and distances provides important confirmation of the dedicatee's name, which is stated in the explicit to this work (copied as is from the Cairo witness):

تمت الرسالة التى افادها الامام الجغمينى الخوارزمى حين فرغ من تاليف الملخص فى الهيئة واهداها الى الامام بدر الدن القلانسى والله اعلم

[43] My colleague Sajjad Nikfahm Khubravan has made a listing of over 1,000 extant witnesses of the text of the *Mulakhkhaṣ* and its commentaries. I should emphasize that this is only a preliminary list; just to provide perspective, there are over 300 extant copies of Qāḍīzāde's commentary in Istanbul alone that are not included in this list.

[44] The *Mulakhkhaṣ* has three different preface versions; for more details on this, see Commentary, **[Preface]**.

[45] I discuss the genre of *hayʾa* literature in Chapter Two.

[46] Jaghmīnī's *Mulkhkhaṣ* is not the only elementary *hayʾa* text that lacks a discussion of planetary sizes and distances; *al-Tabṣira fī ʿilm al-hayʾa* of Kharaqī (fl. mid-12th century, Merv) is another example.

“The treatise is completed, which the Imām al-Jaghmīnī al-Khwārizmī presented at the time he completed the work *al-Mulakhkhaṣ fī al-hayʾa*, and he dedicated it to the Imām Badr al-Dīn al-Qalānisī, and God is all-knowing.” (Cairo, Dār al-kutub, ṬJ 429, f. 4b) [47]

So who was Badr al-Dīn al-Qalānisī? Although his life is not well known,[48] there is a substantial number of sources that specifically reference Badr al-Dīn Muḥammad ibn Bahrām ibn Muḥammad al-Qalānisī as the author of a pharmaceutical treatise (in 49 chapters) entitled

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[47] I know of two extant copies of this treatise, both of which I have consulted. The first is listed in David A. King's *Survey,* p. 150 (G17, 1.2.7): Cairo, Dār al-kutub, ṬJ [طلعت مجاميع] 429, 2 ff. 4a-4b). King also provides the explicit in his *A Catalogue of the Scientific Manuscripts in the Egyptian National Library* (Cairo: General Egyptian Book Organization, 1986), vol. 2, p. 21 [2]) [in Arabic]; however King misread al-Qalānisī as “al-Falāsitī (?)”. The witness is described by King as unique, but I was able to identify another witness of it from an online image contained in the Bratislava collection whose catalogue description stated “no title” for a Jaghmīnī text (TG 15; Ordinal Number 291. http://retrobib.ulib.sk/Basagic/EN/291.htm). Accessed on July 26, 2014. Here I am most grateful to Mr. Sajjad Nikfahm Khubravan for bringing the image to my attention. This witness is missing a folio, but fortunately the extant folio (f. 33a) contains the dedication to Badr al-Dīn, since it is written here at the beginning of the text and not in the explicit:

من فوائد الامام الچغمينىّ الخوارزمى حين فرغ من تأليف الملخص واهداه الي الامام بدر الدين القلانسىّ

[48] This paucity of information on the life of “Mohammed ben Bahram ben Mohammed Bedr eddin el Calanisy Essamarcandy” was expressed by Lucien Leclerc in his *Histoire de la médecine arabe par le Dr Lucien Leclerc: exposé complet des traductions du grec; Les sciences en Orient, leur transmission à l'Occident par les traductions latines* (Paris: Leroux, 1876), vol. 2, p. 128. The sentiment was echoed over a century later by Irene Fellmann, who translated into German Qalānisī's pharmaceutical work, and also reviewed the author and his work in her introduction to *Das Aqrābāḏīn al-Qalānisī: Quellenkritische und begriffsanalytische Untersuchungen zur arabisch-pharmazeutischen Literatur* (Beirut: Orient-Institut der Deutschen Morgenländischen Gesellschaft, 1986), p. 1.

Aqrābādhīn al-Qalānisī (composed circa 590 [1194]),[49] and who flourished in the late sixth/twelfth to early seventh/thirteenth centuries.[50] There are also references to Qalānisī found in other early-thirteenth-century medical sources, such as the pharmacological treatise by Najīb al-Samarqandī who is reported to have died in the city of Herat in the wake of the Mongol invasion of 619 [1222],[51] and al-Suwaydī (600-90 [1204-92]), who hailed from Damascus and

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[49] In addition to Leclerc and Fellmann, see Ibn Abī Uṣaybiʿa, *ʿUyūn al-anbāʾ fī ṭabaqāt al-aṭibbāʾ* (2 editions): ed. A. Müller, 2 vols. plus corrections (Cairo: al-Maṭbaʿa al-Wahabiyya, 1299/1882, Königsberg, 1884), vol. 2, p. 31; and ed. Nizār Riḍā (Beirut: Dār maktabat al-ḥayāh, 1965), p. 472. Also see: Brockelman, *GAL* 1, p. 489 (no. 23); suppl. 1, p. 893 (no. 23); A. Z. Iskander, *A Catalogue of Arabic Manuscripts on Medicine and Science,* pp. 79-80; and Iskander, "A Study of Al-Samarqandī's Medical Writings," *Le Muséon Revue d'Études Orientales* 85 (1972): 452 (esp. fn. 7); ʿUmar Riḍā Kaḥḥāla, *Muʿjam al-muʾallifīn: tarājim muṣannifī al-kutub al-ʿArabiyya* (Beirut: Dār iḥyāʾal-turāth al-ʿarabī, 1980), vol. 9, p. 122; Manfred Ullmann, *Die Medizin im Islam*. Handbuch der Orientalistik (Leiden: E. J. Brill, 1970), pp. 307-8; Lutz Richter-Bernburg, "Medical and Veterinary Sciences, Pt. One: Medicine, Pharmacology and Veterinary Science in Islamic Eastern Iran and Central Asia," in *History of Civilizations of Central Asia,* vol. IV: *The Age of achievement: A.D. 750 to the End of the Fifteenth Century. Part Two: The Achievements*, ed. C. Edmund Bosworth and M. S. Asimov (Paris: UNESCO Publ., 2000), p. 310; and *Fihris al-makhṭūṭāt al-muṣawwara*, vol. 3, pt. 2, p. 24 (no. 25).

[50] Only Richter-Bernburg questions this as a "dubious date"; however, he provides neither reason nor alterative ("Medical and Veterinary Sciences," p. 310, fn. 42).

[51] A. Z. Iskander pointed out that the marginal notes to two medical works by Najīb al-Samarqandī contain quotes attributed to Qalānisī (see codex Coll. 1062, MS. Ar. 73 [= UCLA Ar. 73] ("A Study of Al-Samarqandī's Medical Writings," p. 452, esp. fn. 7); and I was able to check this (here I am indebted to E. Savage-Smith for graciously allowing me to consult her copy). However, whether Samarqandī is actually quoting Qalānisī within his treatises, as well as the dating of these marginal notes, needs further careful examination. For more on Najīb al-Samarqandī, see Tarabein Chérif, "Contribution à l'histoire de la pharmacie arabe. Étude particulière du manuscrit intitulé: Al-Nadjibiate Al-Samarkandiate" (Ph.D. diss., Strasbourg University, 1952), intro., p. 6; Storey, *Persian Literature*, vol. 2, pt. 2, p. 215 (no. 368); Ibn Abī

was a contemporary of Ibn Abī Uṣaybiʿa.[52] Some references add the *nisba* al-Samarqandī to Badr al-Dīn al-Qalānisī's name,[53] which is noteworthy since the Banū Qalānisī hailed from a prominent Damascene family. So Badr al-Dīn would seem to have been an émigré to Central Asia from Damascus, which highlights connections between the two regions during this period.[54] Moreover, during this period the Qalānisī family was known to have "gradually evolved into a family of Shāfiʿī scholars and qāḍīs" from a family of government bureaucrats during a period that witnessed attempts to "professionalize" the ʿulamaʾ and codify law.[55] Apparently this

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Uṣaybiʿa, *ʿUyūn al-anbāʾ*, Beirut ed., p. 472, Cairo-Königsberg ed., vol. 2, p. 31; and Ullmann, *Die Medizin im Islam*, pp. 170, 278, 294, 308, and 339.

52 Leclerc states that Badr al-Dīn al-Qalānisī was among the numerous sources cited by Abū Isḥāq Ibrāhīm b. Muḥammad ʿIzz al-Dīn b. Ṭarkhān al-Suwaydī in his medical treatise on remedies entitled *al-Tadhkira al-hādiya* (*Histoire de la médecine arabe,* pp. 128, 199-202 [on "Soueidy"]). For more on Suwaydī, see Brockelman [listed as "ʿIzzaddīn a. Isḥāq Ibr. b. M. b. Tarḫān b. *as-Suwaidī* al-Anṣārī"], *GAL* 1, p. 493 (no. 38), *GAL* suppl. 1, p. 900 (no. 38); Albert Dietrich, "al-Suwaydī," in *Encyclopaedia of Islam*, 2nd ed. (Leiden: E. J. Brill, 1997), vol. 9, pp. 909-10; Ibn Abī Uṣaybiʿa, *ʿUyūn al-anbāʾ*, Beirut ed., pp. 759-61, Cairo-Königsberg ed., pp. 266-67; Ullmann, *Die Medizin im Islam*, pp. 284-85, 291; and *Islamic Medical Bio-Bibliographies at the National Library of Medicine*: http://www.nlm.nih.gov/hmd/arabic/bioS.html Accessed on July 26, 2014.

53 Brockelmann originally listed him as Badraddīn M. b. Bahrām al-Qalānisī (*GAL* 1, p. 489), and then later modified it by changing the name to Badr ad-Dīn M. b. Bahrām al-Qalānisī as-Samarqandī (*GAL* suppl. 1, p. 893).

54 Furthermore, the sources on al-Suwaydī report that he traveled between Damascus and Egypt; so presumably Badr al-Dīn's work would have disseminated both westward and eastward from Damascus.

55 See Joan E. Gilbert, who provides us with valuable information about the Banū Qalānisī residing in Damascus between 468 [1076] and 736 [1335] in "The Ulama of Medieval Damascus and the International World of Islamic Scholarship" (Ph.D. diss., University of California, Berkeley, 1977) ProQuest (7812573). According to Gilbert the family was emblematic of the major political and social changes that were occurring in Damascus during the twelfth and

professionalization of the ʿulamaʾ extended well beyond regulating salaries, and also included attempts to standardize their training and practice. Consequently there was an upsurge in the number of teaching institutions that were constructed, and with them a proliferation of positions, accompanied by a growing demand for standardized textbooks. As I will discuss in Chapter Three, evidence indicates that this demand was not just restricted to the subject of religious law. And I strongly suspect that this phenomenon was not confined to Damascus alone.

So it should not surprise us that Jaghmīnī dedicated works to a scholar-Imām. However, it may seem somewhat odd that Badr al-Dīn al-Qalānisī, whose scholarly pursuits seem to focus on medicine, singled out Jaghmīnī to compose a work on astronomy. A possible explanation, admittedly somewhat speculative, is that Badr al-Dīn may have been a teacher or mentor of a younger Jaghmīnī. Here, if we keep in mind that 12th-century Central Asia was a hub of scholarly activity, "remarkable for the development of a vernacular medical and scientific literature",[56] then it would have consequently become a locus for those seeking a proficient scientific education. In support of this, we have growing indications that Masʿūd ibn Muḥammad al-Shīrāzī (who was Quṭb al-Dīn al-Shīrāzī's father) had pursued studies in Khurāsān during this period, and not just in medicine (for which he is most famous).[57] Badr al-Dīn's *Aqrābādhīn al-*

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thirteenth centuries (pp. 206-8, 222-25). It would seem that the Qalānisī family wore many "hats", figuratively and literally, since the family name *qalānisī* is a *nisba* for small cap/hat makers. Also, see Joan E. Gilbert, "Institutionalization of Muslim Scholarship and Professionalization of the ʿUlamāʾ in Medieval Damascus," *Studia Islamica* 52 (1980): 114-26.

[56] See Edward G. Browne, *Arabian Medicine*, *Being the Fitzpatrick Lectures Delivered at the College of Physicians in November 19 and November 1920* (Cambridge: Cambridge University, 1921), Lecture IV, p. 98.

[57] See Junayd ibn Maḥmūd Junayd Shīrāzī, *Tazkirah-i Hazār mazār: tarjamah-i Shadd al-izār: mazārāt-i Shīrāz* (Shiraz: Kitābkhānah-i Aḥmadī, 1364 H. Sh. [1985 or 1986]), pp. 109-111; and al-Jaghmīnī, *Talkhīṣ kitāb Ūqlīdis*, ed. Ḥusaynī al-Ishkavarī (Qum: Majmaʿ-i dhakhāʾir-i islāmī, 2006), p. 246 (where there is marginal note in this mathematical treatise indicating that Jaghmīnī may have been a teacher of Masʿūd ibn Muḥammad al-Shīrāzī). In his autobiography, Quṭb al-Dīn al-Shīrāzī (d. 710 [1311]) informs us that his father was considered to be the "Hippocrates of his age and the Galen of his day." Quṭb al-Dīn also tells us that he traveled to Khurāsān in search

Qalānisī is a work full of quotations that "attest to his wide reading in the field; besides Ibn Sīnā, a whole range of authors, of whom al-Bīrūnī is the latest datable one, is represented."[58] So it is not inconceivable that Badr al-Dīn's medical knowledge had an influence on Jaghmīnī, directly or indirectly. In any event, Jaghmīnī did compose the *Qānūnča* (which lacks a dedication), and this concise elementary textbook on medicine became extremely popular (comparable to the *Mulakhkhaṣ*). Perhaps in recognition of Jaghmīnī's success in adeptly writing a medical textbook, Badr al-Dīn was hopeful that he could write another primer, this one on the subject of theoretical astronomy.

This scenario is based on the following assumptions: that there is only one Jaghmīnī (who authored both the *Qānūnča* and the *Mulakhkhaṣ*); that he flourished in the late-twelfth/early-thirteenth century; and that Jaghmīnī composed the *Qānūnča* not in the fourteenth century (as Suter et al.) have claimed, but prior to his composing the *Mulakhkhaṣ*. What follows is evidence to support all of these assumptions.

§ I.1.3a Dating the *Qanūnča*

A *Qanūnča* manuscript, recently discovered, states that it was copied on 12 Ramaḍān 601 H [= 3 May 1205 CE], in the city of Konya (*lit.*, ق [= Qūniya قونيه]).[59]

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of further knowledge, perhaps he was following in his father's footsteps (see Kaveh Farzad Niazi, "A Comparative Study of Quṭb al-Dīn Shīrāzī's Texts and Models on the Configuration of the Heavens," [Ph.D. diss., Columbia University, 2011] ProQuest [3479090], pp. 82-85).

[58] See Richter-Bernburg, "Medical and Veterinary Sciences," p. 310.

[59] See Istanbul, Süleymaniye Library, Ayasofya MS 3735, f. 25a. I have Ihsan Fazlıoğlu to thank for his assistance in helping to uncover this information by providing me numerous images of *Qānūnča* witnesses to check. Then together we deciphered that the < ق > in the date meant it was copied in the city of Konya; we did this by comparing another copy date with a non-abbreviated place-name in the same codex (and in the same hand) which stated that that work was completed 20 Ramaḍan [in the same year] in the city of Qūniya (f. 40a).

That this treatise was disseminated to Anatolia in the early seventh/thirteenth century highlights the point that scientific texts were disseminating westward to lands that would later become part of the Ottoman Empire; and it also indicates that this specific treatise was in circulation by 601/1205. As far as I know this *Qanūnča* witness is the oldest one to date, evidently copied during Jaghmīnī's lifetime. This should effectively put to rest the fourteenth-century date for the *Qanūnča* as well as the two-Jaghmīnī hypothesis unless one wishes to maintain that there were two Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī al-Khwārizmī's living in Khwarizm at the same time and that both were writing scientific textbooks.[60]

§ I.1.3b Dating the *Mulakhkhaṣ*

There is strong evidence that the *Mulakhkhaṣ* was composed in 603 H (= 1206 CE); this places its composition as being after the *Qānūnča,* based on the above extant witness dated 601 H. The 603 H date is provided by Jaghmīnī himself in the *Mulakhkhaṣ* **(I.5 [22])** in his chapter on planetary motions, and specifically within the discussion of the parameters for the apogee and nodes. Here Jaghmīnī states: "As for the position of the apogees, they are for the beginning of the year 1517 of Dhū al-Qarnayn [the two-horned, i.e., the era of Alexander the Great]: …" Jaghmīnī did not select this date arbitrarily; rather it was chosen because 1517 was *his* current year and he was providing the students with updated positions. (More speculative is that Jaghmīnī was also using this as an exercise in calendar conversion.) In any event, in support of my update claim, I was able to calculate, using the positions provided by Jaghmīni and Battānī for their apogees and the Alexandrian years between them (1517 minus 1191=326), a constant value for the motion of the apogees, namely 1 degree per 66 years, which is exactly the value given by Jaghmīnī for the precessional motion of the stars and apogees (see commentary for **I.5 [22]**). It would have been very odd indeed for Jaghmīnī to use a date that was not his own, given that he uses it to report the position of the planetary apogees. We can thus conclude that 1517 of

[60] Furthermore, Ayasofya MS 3735 is not the only *Qānūnča* bearing a thirteenth-century copy date; for another example, see Princeton, Garrett 3559Y, which bears a date of the middle of Ṣafar 680 [1281] in the colophon (f. 57a).

the Alexander era, which converts to the year 1206 CE [= 603 H] is the date of composition of the *Mulakhkhaṣ*.[61]

§ I.1.3c Further Evidence for Dating Jaghmīnī

Additional support that Jaghmīnī flourished during this time comes from another of his compositions, this one being a short astrological treatise entitled *Fī quwā al-kawākib wa-ḍaʿafihā* (The Strengths and Weaknesses of the Planets). In this treatise, Jaghmīnī has a discussion similar to the one he put forth in the *Mulakhkhaṣ* on the positions of the apogees for each of the planets; however, here his listing of parameters are based on the planetary positions for the beginning of the year 1516 of Dhū al-Qarnayn.[62] So presumably this work was composed one year earlier than the *Mulakhkhaṣ* in 1205 [= 602 H].[63] This work is also extremely important

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[61] An even more precise calculation of this date is 1517 years from Monday, 1 October –312 = 1 October 1206 [= 25 Ṣafar 603 H]. See Commentary, **I.5 [22]** for more information on this calendar conversion, the term Dhū al-Qarnayn, and variant readings of the year1517. I am not alone in asserting that Jaghmīnī's use of the date 1517 Dhū al-Qarnayn indicates when he lived; see Hanif Ghalandari, "Chagmīnī," *The Great Islamic Enyclopedia* (Tehran, 1390 H. Sh. [2012]), vol 19, pp. 356-57; Farīd Qāsimlu, "Chagmīnī," *Encyclopaedia of the World of Islam* (Tehran, 1387 H. Sh. [2008 or 2009]), vol. 12, p. 61; and Arash Abutorabi Hamedani (ed.) in the introduction to the printed Persian commentary by Muḥammad ibn ʿUmar al-Andiqānī of Jaghmīnī's *al-Mulakhkhaṣ* (*Tarjuma-yi al-Mulaḫḫaṣ fi'l-Haʾa,* in *Nāma-yi Maʿānī, Yādnāma-yi Ustād Aḥmad Gulčīn Maʿānī (Memoirs of Master Aḥmad Gulčīn Maʿānī)* [Tehran, 1383 H. Sh. (2004 or 2005)]), p. 866.

[62] There are two extant copies of this work: Paris, BnF, MS ar. 2589, ff. 174b-176b [Arabic-script numbering: ff. 27b-29b]; and a witness that has been published with the *Talkhīṣ kitāb Ūqlīdis*, pp. 249-53. Jaghmīnī specifically mentions the year 1516 of Dhū al-Qarnayn on p. 250 of the facsimile, and on f. 174b [f. 27b] of BnF, MS ar. 2589,; and in both witnesses the numbers for the year are not alphanumerical but are clearly written out in words.

[63] Jaghmīnī's use of these two successive dates was also noted by Ghalandari, "Chagmīnī," pp. 356-57; and Qāsimlu, "Chagmīnī," p. 61.

for dating Jaghmīnī because one of the two extant witnesses (Paris, BnF, Ms ar. 2589, f. 174b [f. 27b]) states that the work is dedicated to "our teacher Shihāb al-Dīn, may God prolong his life."[64]

Now admittedly identifying who Shihāb al-Dīn was by this abbreviated form of the name would not be an easy task; there were several Shihāb al-Dīns who lived in this region during this period.[65] But fortunately a fuller version of his name—Shihāb al-Dīn Abū Saʿd ibn ʿImrān al-Khwārizmī al-Khīwaqī—is provided by Jaghmīnī himself in another work that he dedicated to him, namely a mathematical treatise entitled *Talkhīṣ kitāb Ūqlīdis* (Epitome of Euclid's *Elements*),[66] in which we learn from the explicit that it was completed on Sunday, 22 Ṣafar 615 H (= Saturday-Sunday, 19-20 May 1218 CE).[67]

In addition to Shihāb al-Dīn al-Khīwaqī's *nisba,* which indicates that his family hailed from Khīwa in the heart of Khwārizm, it turns out that there is much information available about him, from both primary and secondary sources, especially in comparison with the information we have regarding Badr al-Dīn al-Qalānisī. This is due to Shihāb al-Dīn's eminence as a scholar as well as his important role as advisor to the Khwārizm Shāh ʿAlāʾ al-Dīn Muḥammad (596-617 H [1199-1219 CE]). In fact, Muḥammad ibn Aḥmad al-Nasawī (fl. 639/1241), in his *Sīrat al-Sulṭān Jalāl al-Dīn Mankubirtī* (a biography of the Khwārizm Shāh who reigned 617-628 H [1219-31]) devotes an entire chapter to Shihāb al-Dīn in which he describes his departure from

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[64] Obviously being able to connect a specific date 602 H [1205 CE] with the dedicatee Shihāb al-Dīn is extremely valuable information; it is also significant that the statement informs us that Shihāb al-Dīn is still alive. This information however is only contained in the Paris manuscript; the Qum facsimile substitutes the word *fulān* [meaning "unspecified person"] in its place (see *Talkhīṣ kitāb Ūqlīdis*, p. 249).

[65] See Barthold, who lists three other Shihāb al-Dīn's, all flourishing in the late-twelfth/early-thirteenth centuries in this region (*Turkestan*, p. 507). I cannot resist pointing out that Suter was presumably aware of Jaghmīnī's dedicatee (since he lists Paris MS 2589 as a witness for this work [in "Die Mathematiker und Astronomen," pp. 164-165]); however perhaps the task of identifying the specific Shihāb al-Dīn was too daunting.

[66] See *Talkhīṣ kitāb Ūqlīdis*, p. 16.

[67] See *Talkhīṣ kitāb Ūqlīdis*, p. 246.

Khwārizm to Nasā during the crumbling of the Khwārizm dynasty just prior to the arrival of the Mongols circa 618 [1221].[68] Furthermore, there are also other sources that specifically mention Shihāb al-Dīn al-Khīwaqī and that provide insightful information about the period; among these, several were written by contemporary historians.[69]

[68] See Nasawī, *Sīrat al-Sulṭān Jalāl al-Dīn*, esp. Ch. 23: On the Arrival of Shihāb al-Dīn al-Khīwaqī to Nasā from Khwārizm, pp. 109-115 (= *Histoire du sultan Djelal ed-Din Mankobirti, prince du Kharezm par Mohammed en-Nesawi,* French trans. Octave Houdas [Paris: Leroux, 1895], Ch. 22 [=Ch. 23 in Arabic], pp. 82-89). Nasawī entered the service of Jalāl al-Dīn in 1223. The valuable detailed information he provides presumably is due to having the "home court advantage" of writing from the perspective of a native Khurāsānian and living there during this period (see Barthold, *Turkestan*, pp. 38-39).

[69] See ʿAlāʾ al-Dīn al-Juwaynī (d. 681 [1283]), *Taʾrīkh-i jahān-gushā* [in Persian] (= *The History of the World-Conqueror by ʿAla-ad-Din ʿAta-Malik Juvaini. Translated from the text of Mirza Muhammad Qazvini*, trans. J. A. Boyle (Manchester: Manchester University Press, 1958), vol. 1, pp. 322-23); Ibn al-Athīr, *al-Kāmil fī ʾl-taʾrīkh* [in Arabic] (Beirut: Dār ṣādir, 1966), vol. 12, pp. 362-63 (= *The Chronicle of Ibn al-Athīr for the Crusading Period from* al-Kāmil fīʾl-taʾrīkh. Part 3: *The Years 589-629/1193-1231: The Ayyūbids after Saladin and the Mongol Menace*, trans. D. S. Richards (Aldershot, Hants, England; Burlington, Vt.: Ashgate, 2008), p. 206 [within the "Account of the Tatars' irruption into Turkestan and Transoxania and what they did", pp. 204-10]; Minhāj Sirāj Jūzjānī (born 589 H [1193 CE]), wrote his *Ṭabaqāt-i Nāṣirī* [in Persian] in 658 H [1260 CE] (= *A General History of the Muhammadan Dynasties of Asia, including Hindūstān, from A.H. 194 (810 A.D.) to A.H. 658 (1260 A.D.) and the Irruption of the Infidel Mughals into Islām,* 2 vols., trans. Major H. G. Raverty (London, 1881), esp. pp. 252-78); and Yāqūt ibn ʿAbd Allāh al-Ḥamawī (d. 626/1229), who was in Merv just prior to its destruction (616 [1220]), and reports on the extensive endowed libraries and collections of the city (*Muʿjam al-buldān li-l-Shaykh al-imām Shihāb al-Dīn Abī ʿAbd Allāh Yāqūt ibn ʿAbd Allāh al-Ḥamawī al-Rūmī al-Baghdādī* (Beirut: Dār ṣādir, 1955-1957), vol. 5 (1957), p. 114. See also J. A. Boyle, "Dynastic and Political History of the Īl-Khāns," in *The Cambridge History of Iran*, vol.5: *The Saljuq and Mongol Period*, ed. J. A. Boyle, (Cambridge: Cambridge University Press, 1968), p. 306; and S. M. Stern, "Petitions from the Ayyūbid Period," *Bulletin of the School of Oriental and African*

With specific regard to Jaghmīnī's patrons, we have a situation parallel to that of Badr al-Dīn in that Shihāb al-Dīn is another example of a dedicatee who is recognized as a highly esteemed scholar/Shāfiʿī Imām.[70] In addition, both Badr al-Dīn al-Qalānisī and Shihāb al-Dīn had government affiliations. In the case of Shihāb al-Dīn, these are more pronounced; it is reported that he held the status of a trusted advisor (*wakīl*) to the Khwārizm Shāh ʿAlāʾ al-Dīn Muḥammad himself, who "consulted him in all serious circumstances and yielded to his decision in important matters."[71] How these scholars may have used their positions with governmental connections to promote scholarly activities (especially the teaching of the sciences) will be a point I will return to in Chapter Three. However, it is worth noting that the Khwārizm Shāh ʿAlāʾ al-Dīn Muḥammad also had a close relationship with Fakhr al-Dīn al-Rāzī (d. 606 [1210]),[72] so

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Studies, University of London, vol. 27, no. 1 (1964): 15-16. Barthold provides a nice overview of many of these contemporary historians (*Turkestan*, pp. 35-4; on Shihāb al-Dīn, see ibid., pp. 376, 404-5, 429).

[70] Nasawī informs us that "Regarding the science of law, [Shihāb al-Dīn] combined knowledge of lexicography, medicine, and dialectic, and other sciences. Eloquent and versed in various languages, he was also a man of good counsel. Mars had bought happiness from him, Mercury had benefited from his lessons, the finest man was the slave of his wisdom and the greatest thinker was the servant of his ideas" (*Sīrat al-Sulṭān Jalāl al-Dīn*, p. 109 [= Houdas, *Histoire du Sultan,* p. 82]). Cf. Ibn Athīr, *al-Kāmil fī ʾl-taʾrīkh,* vol. 12, pp. 362-63 (= Richards, *The Chronicle of Ibn al-Athīr,* p. 206).

[71] Nasawī, *Sīrat al-Sulṭān Jalāl al-Dīn,* p. 109 (= Houdas, *Histoire du Sultan*, p. 82). The position of *wakīl* meant he "was by no means a subordinate official whose function was literally to carry the decision of the sultan to the chancery … it is obvious that it was an honorary duty attributed to high-ranking courtiers" (S. M. Stern, "Petitions from the Ayyūbid Period," p. 16). Barthold also mentions Shihāb al-Dīn's position of *wakīl* at the Khwārazmian court, and points out that in the twelfth century, Khwārazm Shāh ʿAlāʾ al-Dīn Muḥammad's "bold reform" (p. 379) transferred power from the Imperial wazīr alone to a mandatory unanimous decision by six *wakīl*s (*Turkestan*, pp. 376-80).

[72] ʿAlāʾ al-Dīn Muḥammad was a patron of Fakhr al-Dīn, and also entrusted him with tutoring his children (see See Frank Griffel, "On Fakhr al-Dīn al-Rāzī's Life and the Patronage He

presumably he was highly receptive to supporting scholarly endeavors. Indeed, it is stated that Shihāb al-Dīn was directly responsible for establishing numerous Islamic institutions throughout the region and filling their libraries with extensive collections. Nasawī informs us that Shihāb al-Dīn was charged with teaching in five *madrasa*s and had built a library in a Shāfiʿī mosque in Khwārizm that had no equal "either before or since";[73] and Yāqūt al-Ḥamawī tells us that among the multitude of scholarly books he witnessed (and in fact borrowed) located throughout Merv within various Islamic repositories, he had not seen their like anywhere else in the world in terms of size and excellence.[74] Presumably among these extremely numerous and extensive collections, textbooks in the mathematical sciences would have found welcome homes.

The dating for Jaghmīnī's two dedications to Shihāb al-Dīn (602 [1205] and 615 [1218]) span some thirteen years; these dates not only indicate a rather long-standing relationship between the two, but also fall within the long reign of the Khwārizm Shāh ʿAlāʾ al-Dīn Muḥammad (596-617 [1199-1219]). So the composition dates of several of Jaghmīnī's treatises in conjunction with the flourishing dates of his two dedicatees all support the contention that Jaghmīnī flourished during the reign of the Khwārizim Shāh ʿAlāʾ al-Dīn Muḥammad (r. 596-617 [1200-1220]). Where Jaghmīnī lived throughout this period, though, is not at all clear. The last composition date we have for him is 615 [1218], which as mentioned earlier is given for his *Talkhīs kitāb Ūqlīdis* (p. 246). If he managed to evade the ensuing massacres that occurred in the

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Received," *Journal of Islamic Studies* 13,3 [2007]: pp. 316-17, 331-34). Cf. Fathalla Kholeif, who suggests that this relationship may have started earlier with Fakhr al-Dīn being a tutor to a young Muḥammad during the reign of his father ʿAlāʾ al-Dīn Tekish (568-596 [1172-99]) (*A Study on Fakhr al-Dīn al-Rāzī and His Controversies in Transoxiana* [Beirut: Dar El-Machreq Editeurs, 1984], p. 19).

[73] Nasawī, *Sīrat al-Sulṭān Jalāl al-Dīn,* pp. 109-110 (= Houdas, *Histoire du Sultan*, pp. 83, 84). Also see Barthold, *Turkestan*, p. 429.

[74] The numbers are staggering: according to Yāqūt one library alone held 12,000 volumes; and he also tells us that borrowing was so convenient that he took home around 200 volumes from another library and a deposit wasn't required (see *Muʿjam al-buldān,* vol. 5, p. 114; Svat Soucek provides an English translation of these relevant parts in *A History of Inner Asia* (Cambridge: Cambridge University Press, 2000), pp. 114-15 ["The conquering Mongols"]).

cities of Bukhara (616-17 [1219-21]) and Samarqand (617 [1220-1]),[75] he would have witnessed the ushering in of the reign of Jalāl al-Dīn, which occurred in 617. However, it is reasonable to assume that ultimately he became a victim of one of these many raging battles that ravaged the regions of Khurāsān and Khwārizm and destroyed major centers of learning, such as the cities of Merv and Gurgānj [in 617-18 [1220-21], where most-likely Jaghmīnī was residing; hence we have a viable explanation for the 618 H death date for him that surfaced (unqualified) in the Islamic reference sources.[76]

We know more specifically about the fate of Shihāb al-Dīn; it is reported that his ill-fated advice to the Khwārizm Shāh ʿAlāʾ al-Dīn Muḥammad eventually led to his fleeing to the city of Nasā,[77] along with his son Tāj al-Dīn, where Nasawī writes that they both perished circa 1220.

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[75] Accounts vary whether it was 616 or 617 H [1220] for the capture of Bukhara. However all the sources agree on the ensuing devastation; Jūzjānī describes how Chingiz Khān "martyred the whole of the inhabitants, put the ʿUlamāʾ to the sword, and gave the libraries of books to the flames." He then marched towards Samarqand and captured it on 617 H [1220] (*Ṭabaqāt-i Nāṣirī*, pp. 274-75); cf. Ibn al-Athīr, *al-Kāmil fī ʾl-taʾrīkh,* vol. 12, pp. 361-68 (= Richards, *The Chronicle of Ibn al-Athīr*, pp. 204-10.); and Juwaynī, vol. 1, pp. 75-84 (= Boyle, *History of the World*, vol. 1, pp. 97-109 ["XVI: Of the Capture of Bukhara"]).

[76] See Ibn al-Athīr, *al-Kāmil fī ʾl-taʾrīkh,* vol. 12, 389-95, esp. 394-95 [On the Destruction of Khwārazm] (= Richards, *The Chronicle of Ibn al-Athīr*, pp. 224-28, esp. 227-28); Juwaynī, vol. 1, pp. 97-101 and 119-32 (= Boyle, *History of the World*, vol. 1, pp. 123-28 ["Of the Fate of Khorazm"] and pp. 153-68 ["XXVII: Of Merv and the Fate Thereof"]); and Barthold, *Turkestan*, pp. 436-37.

[77] Nasā, also the hometown of al-Nasawī and where Shihāb al-Dīn is buried, is situated in Khurāsān [near modern-day Ashgabat, Turkmenistan] and was considered a 5-day journey westward from Merv, 2 days from Sarakhs, 1 day from Abīvard, and 6-7 days from Nīsābūr (according to Yāqūt, *Muʿjam al-buldān,* vol. 5, p. 282 [= "Nésâ and Nisa" in Houdas, *Histoire du Sultan*, p. 458]). See also V. Minorsky [C. E. Bosworth], "Nasā, Nisā" in *Encyclopaedia of Islam*, 2nd ed. (Leiden: E. J. Brill, 1993), vol. 7, pp. 966-7.

Nasawī also informs us of Shihāb al-Dīn's valiant attempts to preserve what he considered the most valuable books, but concludes that ultimately they were lost.[78]

Destroyed perhaps, but their contents were not all completely lost; this in light of the extant scientific works that date from this tumultuous period composed by Jaghmīnī among other writers. Conceivably many of these works were able to circulate to safer lands due to having been copied (possibly multiple times) either before the eye of the storm actually hit the region or between waves of attacks. In any event, some twenty-five years after the devastation, specifically in 644 H [1246-47 CE], we find a copy of the *Mulakhkhaṣ* surfacing (= MS L); and shortly thereafter, we find two extant copies of a treatise that Jaghmīnī composed on arithmetic, both bearing colophon dates from the seventh/thirteenth century, and one explicitly stating that it was completed in the Ṣadriyya *madrasa* in Khwārizm in 661 [1263].[79] One is reminded of Mark Twain's 1897 retort upon reading of his demise: "…the report of my death was an exaggeration."; so too were false proclamations concerning the demise of Islamic science during this period.

§ I.1.4 So What's in a Date?

Pinpointing that Jaghmīnī flourished in the late-twelfth/early-thirteenth century, and resolving once and for all the confusion that there was only *one* of him— one scholar who authored both the *Mulakhkhaṣ* and the *Qānūnča*—is not insignificant. More is at stake than just finally putting

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[78] Nasawī, *Sīrat al-Sulṭān Jalāl al-Dīn,* pp. 110-11, 115 (= Houdas, *Histoire du Sultan*, pp. 84, 88-9). Barthold, *Turkestan*, pp. 424, 429-30. One can certainly sympathize with Nasawī's anguish regarding the loss of massive numbers of scholarly works; clearly there was no suitcase large enough to contain them all.

[79] Specifically, Tehran, University of Tehran, Central Library and Documentation Center, MS 6911, p. 12, states it was completed Monday, at noon, the beginning of Rabīʿ II 660 [= probably, 27 February 1262]; and Princeton, Princeton University, Islamic Manuscripts, Garrett no. 502H, f. 51a states it was completed in Khwārizm, at the Ṣadriyya *madrasa* at the end of Shawāl 661 [early Sept. 1263].

to rest repeated errors contained within the reference sources; determining that Jaghmīnī flourished during the period of the reign of the Khwārizm Shāhs in the region of Central Asia *prior* to the Mongol invasions has a major impact on how we view, indeed must now reexamine, the development of scientific inquiry within Islamic society during the premodern period. That he was writing elementary textbooks on a variety of scientific topics such as astronomy, medicine, and mathematics raises many questions such as who their target audience was. This demand for scientific textbooks within Islamic lands is clearly a strong indication that science had not dwindled to a handful of individuals, nor was dependent on these few to keep the scientific torch burning.[80]

So this also means that we should consider that the massive scientific efforts occurring in thirteenth-century Marāgha under the directorship of Naṣīr al-Dīn al-Ṭūsī (597-672 [1201-74]) was a remarkable resuscitation by Ṭūsī (and others) of a well-established mathematical tradition within the fabric of Islamic society that had been interrupted, but not curtailed or terminated, due to the disruptions surrounding the Mongol invasions and politics of the late-twelfth/early-thirteenth century period. Quṭb al-Dīn al-Shīrāzī provides a historical summing up of the *hayʾa* literature up to his time in his major astronomical work *Nihāyat al-idrāk fī dirāyat al-aflāk* (the first version completed in 680/1281); it should not go unnoticed that included in his list are a number of pre-Mongol treatises, Jaghmīnī's *al-Mulakhkhaṣ* included.[81]

The *hayʾa* literature, this rich corpus of works on theoretical astronomy that Jaghmīnī inherited and built upon (and was ultimately disseminated through generations), is the focus of the next chapter.

[80] See F. J. Ragep, "When Did Islamic Science Die (and Who Cares)?" *Newsletter of the British Society for the History of Science* 85 (Feb. 2008): 1-3.

[81] See F. J. Ragep, "Shīrāzī's *Nihāyat al-idrāk*: Introduction and Conclusion," pp. 51 [Arabic], 55 [Eng. trans.]. Shīrāzī specifically cites *al-Mulakhkhaṣ* as one of "the books…set forth and composed in this discipline." Also clear confirmation that Jaghmīnī flourished prior to the Nihāya's composition date (i.e., 680/1281).

CHAPTER 2

An Overview of Summary Accounts of Astronomy before the *Mulakhkhaṣ*

Jaghmīnī's elementary astronomical work *al-Mulakhkhaṣ fī al-hayʾa al-basīṭa* came on the scene in the early-thirteenth century; it would become one of the most popular textbooks on theoretical astronomy ever written in Islamic lands and would play a critical role in its development. As with other *hayʾa* texts, Jaghmīnī's aim as stated was to introduce the reader to the entirety of the cosmos which included both the celestial and sublunar realms (see [**Preface**] and **Introduction**). He makes it clear that the cosmos, or "World," is composed of bodies, these bodies being the subject of his treatise. However, since this does not exactly correspond to "astronomy," either in the modern sense or even in the sense in which the term *astronomia* was used in Hellenistic Greece, this chapter explores the precise meaning of "*hayʾa*," how this genre came into being in an Islamic context, and how Jaghmīnī's text fits into this genre, both in content and historically.[1]

[1] The goal of this chapter is not to provide a general survey of *hayʾa* literature, but rather to highlight *hayʾa* works prior to Jaghmīnī's *Mulakhkhaṣ* that were mainly used as introductory texts for teaching purposes. For overviews of *hayʾa*, see F. Jamil Ragep: "Astronomy," *Encyclopaedia of Islam*, *THREE*, ed. Gudrun Krämer, Denis Matringe, John Nawas, Everett Rowson. Brill Online, 2014. Reference. McGill University. 03 March 2014 http://referenceworks.brillonline.com/entries/encyclopaedia-of-islam-3/astronomy-COM_22652 (especially part 1: "Theoretical astronomy and cosmology"); F. J. Ragep, "*Hayʾa*," in *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures*, ed. Helaine Selin (Dordrecht: Kluwer Academic Publishers, 1997), pp. 395-97; and F. J. Ragep, *Tadhkira*, vol. 1, pp. 33-41 ("The *Tadhkira* as Genre"). See also Y. Tzvi Langermann, *Ibn al-Haytham's "On the Configuration of the World"* (New York: Garland [Harvard Dissertations in the History of Science], 1990), pp. 25-34 ("Predecessors and the *hayʾah* tradition"); and David Pingree, "*ʿIlm al-hayʾa*," in *Encyclopaedia of Islam*, 2nd ed. (Leiden: E. J. Brill, 1971), vol. 3, pp. 1135-38.

§ I.2.1 The Meaning of *Hayʾa*

Jaghmīnī's *al-Mulakhkhaṣ* is part of a genre of astronomical literature termed *ʿilm al-hayʾa,* which developed at least as early as the eleventh century in eastern Islam and replaced *ʿilm al-nujūm* (the science of the stars), or sometimes "astronomia" as transliterated from the Greek, as the general term for the discipline of astronomy.[2] Naṣīr al-Dīn al-Ṭūsī (d. 672 [1274]) provides us with what would become the classical definition of the discipline: "The subject of astronomy is the simple bodies, both superior and inferior, with respect to their quantities, qualities, positions, and intrinsic motions."[3] This new delineation of astronomy focused on topics related to the configuration (*hayʾa*) or structure of the universe as a coherent whole, in other words its subject matter dealt with both the upper bodies of the celestial region ("cosmo-graphy") and the lower bodies of the terrestrial realm ("geo-graphy"). According to Qāḍīzāde, a fifteenth-century commentator on the *Mulakhkhaṣ*, this definition was a way "modern" Islamic astronomers (in which he includes Jaghmīnī) differentiated their science from that of the ancient Greeks in that it brought together the unchanging realm of the celestial aether and the ever-changing realm of the

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[2] E.g., in the tenth century *ʿilm al-nujūm* or *ʿilm al-aḥkām* (the science of judgments) is still being used in Islamic reference books by al-Farābī in his *Enumeration of the Sciences*, Abū ʿAbd Allāh al-Khwārazmī in his *Mafātīḥ al-ʿulūm*, and the Ikhwān al-Ṣafāʾ's Epistle 3 as the general term for astronomy (with the latter two designating *ʿilm al-hayʾa* as a branch). However, *ʿilm al-hayʾa* becomes the general term in Ibn Sīnā (d. 1037)'s *Aqsām al-ʿulūm al-ʿaqliyya* (Classification of the Rational Sciences), and it becomes synonymous with astronomy in most accounts of the discipline after this time (see Ragep, *Tadhkira*, pp. 34-37).

[3] See Ragep, *Tadhkira*, I.Intr. [2] (pp. 90-91), and p. 38 (on "All simple bodies as the subject matter of astronomy"). Some 75 years later, one finds a similar definition of the discipline by the Egyptian encyclopaedist Ibn al-Akfānī (d. 749 [1348]): "the science from which one learns the situations of the lower and upper simple bodies, their forms, their positions, their magnitudes, the distances between them, the motions of the orbs and the planets and their amounts. Its subject is the aforementioned bodies from the point of view of their quantities, positions, and inherent motions" (see Jan J. Witkam, *De Egyptische Arts Ibn al-Akfānī* [Leiden: E. J. Brill, 1989], p. 408).

four elements, the world of generation and corruption, into a single discipline.[4] And although one finds topics dealing with the inhabited world included within Greek astronomical works, indeed a prominent example being Ptolemy's *Almagest*, Book II,[5] it is significant that Islamic astronomers saw themselves as doing something new and considerably expanded.[6]

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[4] See Qāḍīzāde (*Sharḥ al-Mulakhkhaṣ*, Istanbul, Ayasofya MS 2662, f. 2b), who informs us:

ويمكن أنْ يكون المراد بهيئة العالم علم الهيئة الذي يبحث فيه عن أحوال **الأجرام البسيطة العلوية والسفلية من حيث الكمية والكيفية والوضع والحركة اللازمة لها وما يلزم** منها. وإنّما أطلقنا القول في البسائط السفلية لانّ المتأخّرين ومنهم المصنّف تعرّضوا لها مطلقاً وإنْ لم يتعرّض صاحب المجسطي منها إلاّ لكرة الأرض والماء معاً.

"…[Also] it is possible that [Jaghmīnī's] intention by *hayʾa* of the world is the science of *hayʾa* in which one studies the states of the **superior and inferior simple bodies, with respect to their quantity, quality, position, and intrinsic motion** and what pertains to them. Moreover, we have used the term "the lower simples" because the Moderns, among whom is the author [i.e., Jaghmīnī], deal with it without restriction; even though the author of the *Almagest* only presents the sphere of the Earth and water together [i.e. without the other lower simple elements]."

Note that Qāḍīzāde's definition for the subject matter of the discipline of astronomy (which I have bolded here) is strikingly similar to that of Ṭūsī's (*Tadhkira*, I.Intr. [2]) quoted above. Qāḍīzāde suggests this definition could also apply to Jaghmīnī, since Jaghmīnī does not provide one in the *Mulakhkhaṣ* within his explanation of *hayʾa* and discussion of the simple bodies (see *Mulakhkhaṣ*, **Intr.[1]**).

[5] Moreover, Ptolemy is the authority Jaghmīnī relies on for matters pertaining to the terrestrial region (see **II.1 [2]**).

[6] This was pointed out by F. J. Ragep, *Tadhkira*, p. 38; and Ragep, "Astronomy in the Fanārī-Circle: The Critical Background for Qāḍīzāde al-Rūmī and the Samarqand School," in *Uluslararası Molla Fenârî Sempozyumu (4-6 Aralık 2009 Bursa)* (International symposium on

One major consequence of the recategorization of the discipline from *ʿilm al-nujūm* to *ʿilm al-hayʾa* is that *hayʾa* is no longer a subdivision of astronomy but becomes the term for the field in general. *Hayʾa basīṭa* then becomes one branch of the discipline, which provides a general overview of cosmography but devoid of geometrical proofs and complex mathematical derivations;[7] Jaghmīnī's *al-Mulakhkhaṣ fī al-hayʾa al-basīṭa* falls into this category. Thus the genre of *hayʾa* literature is recognized as a strictly mathematical discipline with an emphasis on transforming mathematical models of celestial motion into physical bodies in attempting to explain the universe as a whole; and its focus addresses the external aspects of cosmology, in other words issues related to "how" the celestial or terrestrial realms operates the way it does, and not with dealing with questions of "why." The fact that *hayʾa* works do not discuss subjects related to the "causes" of natural phenomena and matters of Aristotelian metaphysics is quite significant; however, it should be duly noted that this is not because these issues are unimportant, but rather because the internal aspects of cosmology, or matters related to natural philosophy, were dealt with elsewhere.[8]

However, some modern studies of the discipline of *ʿilm al-hayʾa* maintain that Islamic astronomers regarded the universe "purely as a mathematical construct having no necessary physical counterpart," at least until Ibn al-Haytham came on the scene in the eleventh century.[9]

Molla Fanārī, 4-6 December 2009 Bursa), ed. Tevfik Yücedoğru, Orhan Koloğlu, U. Murat Kılavuz, and Kadir Gömbeyaz (Bursa: Bursa Büyükşehir Belediyesi, 2010), pp. 165-76.

[7] Ragep, *Tadhkira*, pp. 35, 36-37.

[8] Jaghmīnī informs us that *why* simple bodies are spherical when left unimpeded and in their natural state is "shown in another science" (*Mulakhkhaṣ*, **Intr.[1]**). Likewise, Ṭūsī explicitly states that there is a demarcation of subject matter between disciplines, and that the science of *hayʾa* relies on principles "proved in another science and are taken for granted in this science" (see *Tadhkira,* Intr.[1], pp. 90-91).

[9] See Pingree, "*ʿIlm al-hayʾa*," pp. 1135-36; Carlo Nallino also takes a similar position: "…Like Ptolemy, the most ancient Arabic astronomers neglect to define the idea of the celestial spheres and limit themselves to considering them in the mathematical aspect of ideal circles representing the movements of the heavenly bodies. The Aristotelian conception of solid spheres was introduced for the first time into a purely astronomical treatise by Ibn al-Haitham" ("Sun, Moon,

This interpretation then categorizes *ʿilm al-hayʾa,* at least before Ibn al-Haytham, as dealing with the universe as a nonrealistic geometric structure, one endorsed by Ptolemy himself, in which the models contained in the *Almagest* were mathematical devices or fictions designed to account accurately for observations (i.e., "to save the phenomena") and for their predictive ability.[10] This

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and Stars (Muhammadan)," in *Encyclopædia of Religion and Ethics*, ed. James Hastings [Edinburgh: T. & T. Clark; New York: Charles Scribner's Sons, 1921], vol. 12, p. 99). In their defense, there were a few Islamic scholars who did focus on imaginary circles rather than solid spheres, a point made by al-Kharaqī (d. 533 [1138-9]) who also claims that Ibn al-Haytham was one of the first to emphasize real spheres; and three centuries later Muḥammad Shāh al-Fanārī (d. 839 [1435-36]), a member of the Fanārī circle of Ottoman scholars who were key players in establishing madrasa curricula, discusses the great circles as mathematical circles rather than physical bodies (see Ragep, *Tadhkira*, p. 33; Ragep, "Astronomy in the Fanārī-Circle," p. 168; Ragep: "Freeing Astronomy From Philosophy: An Aspect of Islamic Influence on Science," *Osiris* 16 (2001): 52; and Ragep, "Hayʾa," p. 395).

[10] Needless to say, an assertion that Ptolemy's geometrical models were only mathematical fictions with no basis in reality ignores or downplays his great cosmological work *The Planetary Hypotheses*; this is discussed further in **§ I.2.3: Ancient Forebears** (on Ptolemy and Proclus). See G. E. R. Lloyd's seminal article, "Saving the Appearances," for an adept analysis of the "instrumentalist" and "realist" debate and its repercussions on the interpretation of ancient Greek science. Lloyd includes a discussion of Pierre Duhem (d. 1916), the foremost proponent of the instrumentalist view, whose insistence that Ptolemy was an instrumentalist (despite opposing evidence) was intertwined with upholding a methodological approach for the development of the history and philosophy of science, one I might add not favorable to Arabs (*Methods and Problems in Greek Science: [Selected Papers].* Cambridge: Cambridge University Press, 1991, pp. 248-50). For more on Duhem and his ramifications, see Ragep, "Duhem, the Arabs, and the History of Cosmology," *Synthese* 83 (1990): 201-14; and Ragep, "Freeing Astronomy," pp. 51-52, esp. fn. 9. And for evidence that this debate still continues, see Peter Barker, who argues that Peurbach's introduction of Ptolemaic geometrical models as physically real corporeal orbs, rather than mathematical fictions, was innovative and a new departure rather than a culmination of the old *theorica* tradition ("The Reality of Peurbach's Orbs: Cosmological Continuity in

definition of *ʿilm al-hayʾa* reduces the debate to an either/or situation (i.e., geometrical constructs versus physical realities) and significantly ignores that Islamic astronomers (as did Ptolemy) believed that the mathematical models needed to be consistent with the physical principles.[11] It also assumes that physical bodies were only first introduced with Ibn al-Haytham's *On the Configuration of the World*, certainly not a clear-cut conclusion.[12]

Unlike works termed *ʿilm al-nujūm*, another significant feature of *hayʾa* works was the exclusion of topics on astrology, especially those espousing predictive capabilities related to future events; and this dissociation of *ʿilm al-hayʾa* from astrology had important ramifications, a prominent one being that it helped to secure *hayʾa* a niche within Islamic religious circles. It should not be surprising that a strictly scientific discipline based on mathematics and observations would be far less objectionable to a religious adherent than one that seemingly limited God's omnipotence, with claims of a parallel ability to make judgments by tapping into the powers of the stars. George Saliba has repeatedly theorized that it was the necessity to demarcate astronomy from astrology that gave birth to the genre of *ʿilm al-hayʾa* itself (as early as the eighth/ninth century[13]). He argues that this was motivated by the need to designate a

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Fifteenth and Sixteenth Century Astronomy," in *Change and Continuity in Early Modern Cosmology,* ed. P. J. Boner, Archimedes 27 [Springer, 2011], Ch. 2, pp. 7-31).

[11] G. E. R. Lloyd articulation of the *compatibility* of the two options is worth repeating here: "It is only if the mathematics is engaged in to the exclusion of any ambition to do physics that we would have prima-facie grounds for describing this as an instrumentalist position. But when mathematics is engaged in as a preliminary to a further, physical investigation, that is fully compatible with a realist position—and the same can be said with even greater conviction when the mathematical inquiry takes as given or presupposes certain physical assumptions" ("Saving the Appearances," p. 250). See also, Ragep, "Duhem, the Arabs, and the History of Cosmology," p. 210.

[12] Langermann argues that this is a misconception, and concludes that "it is quite clear …that Ibn al-Haytham does not regard himself to be the first person to address the problem of the physical description of the heavens" (*Ibn al-Haytham's "On the Configuration of the World,"* p. 25).

[13] Saliba has moved the date demarcating the two disciplines back several centuries from what he states in his "Astrology/Astronomy, Islamic," in *A History of Arabic Astronomy: Planetary*

corpus of literature within a strictly Islamic context distinct from, indeed free of the stigma attached to, the Greek astronomical tradition that had been appropriated into Islamic society with the ninth-century translation movement.[14]

However, one should not conclude that any "Islamic" corpus of scientific and philosophical works totally eliminated Greek or any other "foreign" elements;[15] and it would also be misguided to assume that there was a strict demarcation with no overlap in subject matter between these (or other) disciplines.[16] Undoubtedly, the role of the astrologer was multifaceted within medieval Islamic society, and the practice of astrology was widespread and quite popular in some circles. However, any discipline, perhaps especially a scientific one, that incorporated tenets of Aristotelian natural philosophy and/or relied on Greek, Indian, and Persian sources attracted its share of critics as well as adamant supporters.[17] Few could deny the allure of a

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Theories during the Golden Age of Islam (New York: New York University Press, 1994), pp. 66, 78-79.

[14] See George Saliba: "Islamic Astronomy in Context: Attacks on Astrology and the Rise of the *Hayʾa* Tradition," *Bulletin of the Royal Institute for Inter-Faith Studies* 2, no. 1 (Spring/Summer 2002): 25-7, 42; "The Development of Astronomy in Medieval Islamic Society," in *A History of Arabic Astronomy*, pp. 53-61, 65; and "Arabic versus Greek Astronomy: A Debate over the Foundations of Science," *Perspectives on Science* 8, no. 4 (2000): 328-29, 330.

[15] Saliba specifically states that "the attack on astrology did not entail a rejection of the foreign sciences altogether" ("The Development of Astronomy in Medieval Islamic Society," p. 56; and also see Saliba, "Astrology/Astronomy, Islamic," pp. 66-81).

[16] Since many Islamic scholars composed treatises in multiple subjects, one would suspect some overlap in discussions, especially since it was common practice to include parts of the work you were criticizing within the discourse. We have the prominent example of Bīrūnī: out of 146 works listed for him, 39 are classified as astronomical, 23 are astrological, and 15 mathematical. Furthermore, it is well known that Birūnī wrote both seriously and critically on the subject of astrology (see Edward S. Kennedy, "Birūnī," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie [New York: Charles Scribner's Sons, 1970], vol. 2, pp. 152, 155-56).

[17] Saliba provides an overview of the social status of the astrologer between the ninth and eighteenth centuries that includes a detailed examination of the pros and cons of astrology in his

discipline that dangles “the promise of predictive power over a full scale of phenomena ranging from cosmic events to the outcome of a battle or the length of an individual’s life”[18]; nevertheless, opponents of the practice of astrology and alchemy—and they ranged from Hellenized philosophers to religious adherents—found much fault among the practice itself and its practitioners, not the least of these being claims of special abilities for interpreting God’s divine will.[19] Therefore, astronomical treatises that lacked the taint of astrology, such as *hayʾa* works, were presumably far less objectionable for inclusion within religious institutions.[20] On the other hand, content contained in *hayʾa* works was highly indebted to the scientific works of the

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article, “The Role of the Astrologer in Medieval Islamic Society,” *Bulletin d’Études Orientales* 44 (1992): 45-67. For a discussion of astrology as a scientific discipline and some of the accepted methods of argumentation, see Charles Burnett, “The Certitude of Astrology: The Scientific Methodology of al-Qabīṣī and Abū Maʿshar,” *Early Science and Medicine* 7, no. 3 (2002): 198-213.

[18] See A. I. Sabra, “Configuring the Universe. Aporetic, Problem Solving, and Kinematic Modeling as Themes of Arabic Astronomy,” *Perspectives on Science* 6, no. 3 (1998): 289.

[19] For a scathing critique against both astrology and alchemy, see Ibn Khaldūn, “[31] A refutation of astrology. The weakness of its achievements. The harmfulness of its goal.”, and “[32] A denial of the effectiveness of alchemy. The impossibility of its existence. The Harm that arises from practicing it.” in *The Muqaddimah: An Introduction to History*, trans. Franz Rosenthal (Princeton, N.J.: Princeton University Press, 1967), vol. 3, pp. 258-67 and 267-81 (respectively).

[20] That a *hayʾa* work such as the *Mulakhkhaṣ* was viewed as one “dedicated purely to interests of science” was duly noted by Rudloff and Hochheim. Although they were writing from a nineteenth-century perspective, they assumed that Jaghmīnī’s exclusion of astrological discussions indicated that “he must have looked down on it with contempt” and that “Jaghmīnī’s abstinence is all the more to be admired since astrological ambition of the time held a lot of attraction for the easily aroused imagination of the Oriental, and furthermore under favorable circumstances brought a lot of profit” (“Die Astronomie des Maḥmûd ibn Muḥammed ibn ‘Omar al-Ǵagmînî,” pp. 215-16). Their views probably indicate more about the attitudes of nineteenth-century German scholars than late-twelfth-century Islamic ones.

Greeks and other "foreign" sources, with the result that making them more suitable for a broad Islamic audience presented a challenge. Which foreign sources were selected, and how Islamic scholars adapted or reformulated subject matter into an astronomy that was "distinctly Islamic"[21] is the focus of the remaining sections of this chapter.

§ I.2.2 How *Hayʾa* became Popularized Within an Islamic context

When Badr al-Dīn al-Qalānisī requested that Jaghmīnī compose an elementary *hayʾa basīṭa* textbook sometime in the late-twelfth/early-thirteenth centuries, he clearly felt that there was a pressing need for an abridged version on the subject matter of *ʿilm al-hayʾa*; it was a genre that had been several centuries in the making and so by then had become an established discipline though without necessarily having a textbook accessible to a general audience. Indeed, Jaghmīnī was confronted with a rather daunting task (*al-Mulakhkhaṣ,* **II.3 [11]**), since by that period he had inherited a rather extensive corpus of sources as well as pedagogical styles to choose from. The following sections focus on examining some of this available literature—specifically from late antiquity up until the time that Jaghmīnī composed the *Mulakhkhaṣ*—in an attempt to determine which ones possibly influenced him, taking into account content matter, structure of a work, as well as pedagogical style of writing.[22] Our aim is to situate Jaghmīnī's *Mulakhkhaṣ* within the broader range of teaching texts of theoretical astronomy, with special attention to highlighting those among them that dealt specifically with *hayʾa*.

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[21] Saliba: "The Development of Astronomy in Medieval Islamic Society," p. 65.

[22] Liba Taub points out that too often neglected is that authors writing on scientific, mathematical and medical subjects had numerous options available to them to convey their ideas and information. Her focus is scientific texts, and she explores how mathematical ones display a "variety of forms, or genres, including, but not limited to, poetry, dialogue, lecture, question-and-answer text, letter, biography, recipe, epitome, encyclopedia and commentary" in "On the Variety of 'Genres' of Greek Mathematical Writing: Thinking about Mathematical Texts and Modes of Mathematical Discourse," in *Writing Science: Medical and Mathematical Authorship in Ancient Greece*, ed. Markus Asper (Berlin/Boston: Walter de Gruyter, 2013), pp. 333-34.

I begin with some general comments. During the early ʿAbbāsid period of Islamic history, the unprecedented phenomenon, often referred to as the "translation movement," occurred whereby almost all the scientific and philosophical texts from the Greek-speaking world that was available as well as material from other cultural areas including India, Persia, and China entered eighth-/ninth-century Baghdad. As forcefully argued by A. I. Sabra in his seminal article on the subject, this appropriation of "foreign" materials into Islam was an active endeavor and involved the full participation of a wide range of society;[23] it required enormous financial backing, decision-making (which texts to seek out, where to look), and people proficient in numerous languages and skilled in subjects in order to translate, rework, and also reconstruct works in Syriac[24] or the original Greek (many of which are no longer extant in Greek but only exist today in Arabic translation). Let me emphasize that during this period many works underwent multiple translations (such as Euclid's *Elements* and Ptolemy's *Almagest*), some had to be reworked (such as Apollonius's *Conics*), and this often involved the development of new technical scientific terminology.[25] Subsequently, the process of appropriation was a creative

[23] His argument still has resonance even though it has now been over twenty-five years since Sabra asserted that scientific and philosophical activity in medieval Islam involved the full participation of Islamic society, and was not merely constituted by just "a small group of scholars who had little to do with the spiritual life of the majority of Muslims, who made no important contributions to the main currents of Islamic intellectual life, and whose work and interests were marginal to the central concerns of Islamic society" ("The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement," *History of Science* 25 [1987]: 229).

[24] Dimitri Gutas reminds us that before the ʿAbbāsids relatively few Greek works had been translated into Syriac; this came later in the ninth century (*Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early ʿAbbāsid Society (2nd-4th/8th-10th Centuries)* [London: Routledge, 1998], pp. 21-22).

[25] J. L. Berggren provides several examples of Arabic translations of mathematical works from the Greek, all which highlight the complexities and creative engagement involved in translating and reconstructing scientific texts (*Episodes in the Mathematics of Medieval Islam* [New York; Berlin; Heidelberg: Springer, 2003], pp. 2-5, esp. his chart on p. 5).

engagement, meaning the act of translating was not a purely neutral endeavor, which led to transformations as Islamic scholars also adapted the material they inherited to their own cultural environment.

Some have viewed this "phenomenon" as a totally externally-inspired affair, and denied the possibility that it was a "home-grown" movement with deep Islamic roots.[26] On the contrary, the Egyptian historian Aḥmad Amīn (1886-1954) argued that with time the translations would have eventually occurred under the earlier Umayyads, albeit at a slower pace, since they had already provided the social and intellectual conditions necessary for the translation movement that was brought to fruition under the ʿAbbāsids; in effect, these necessary intellectual conditions were "home-grown" and not the result of "external" forces. .[27] George Saliba also reminds us "that there was a class of people, who were already in place by the time the Abbasids took over from the Umayyad dynasty, who were competent enough to use sophisticated astronomical instruments, to cast horoscopes, to translate difficult astronomical texts, and to transfer their basic calenderical [!] parameters, as well as to compose theoretical astronomical texts…."[28] And

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[26] Ernest Renan prominently asserted that these translations were "entirely the work of Persians, Christians, Jews, Harrānians, Ismāʿīlīs, Muslims internally rebelling against their own religion" (*L'islamisme et la science: conférence faite à la Sorbonne le 29 Mars 1883* [Paris: C. Lévy, 1883], p. 16). And though mounting evidence has challenged Renan's portrayal of the translation movement, one still finds it espoused in prominent journals. For example, Anna Akasoy's harsh review of Karl Wulff's *Bedrohte Wahrheit: Der Islam und die modernen Naturwissenschaften* (*Isis* 103 [2012]: 391-92) led the author to a nine-point response summarizing his "essential points" which included: "The cultural awakening in the early Abbasid time was due not to the religion of Islam but to the Hellenistic heritage. Only a very few of the main players at that time can be described as Muslims," and "Science had never been institutionalized within the premodern Islamic world. Hence, there had never been the opportunity to develop an uninterrupted scientific tradition" ("Letter to the Editor," *Isis* 104 [Dec. 2013]: 818).

[27] See Aḥmad Amīn, *Ḍuḥā al-Islām* (Cairo: Maktabat al-nahḍa al-Miṣriyya, 1961), introduction ("Social Life during the First ʿAbbāsid Age").

[28] See Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), p. 16.

furthermore, the translation movement was not Islam's "first contact" with foreign or outside or non-Islamic sources; concepts of Greek mathematical astronomy had already reached Islam by the eighth century through translations and adaptions of Sanskrit and Pahlavi texts, and the process of modifying these materials in accordance with their needs was well underway.[29]

So what follows is an overview of some formative sources from late antiquity up until the late-twelfth century that were inherited by Muslim scholars or written during the early Islamic period that could arguably have been at Jaghmīnī's disposal, either directly or indirectly, to use and modify so as to comply with Badr al-Dīn's lofty command that he compose an elementary introduction to *ʿilm al-hayʾa*.

§ I.2.3 Ancient Forebears

§ I.2.3a Ptolemy's Predecessors

According to Otto Neugebauer, the eminence of the scientific works of the Alexandrian Claudius Ptolemy in the second century CE would cause "an almost total obliteration of the prehistory of the Ptolemaic astronomy."[30] Indeed, once Ptolemy came on the scene, he undoubtedly had a major impact on theoretical astronomy, including the development of the *hayʾa* tradition that became dependent on his works. Nevertheless, to avoid developing a case of "precursitis" and reading the future into the past, this section sifts through some of the remnants of this prehistory in search of any hidden gems for teaching astronomy amongst the rubble, before moving on and experiencing that "sense of elation" with the arrival of Ptolemy.[31]

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[29] David Pingree is vigilant in reminding us that not all mathematical astronomy within Islam during this period was "Ptolemaic" ("The Greek Influence on Early Islamic Mathematical Astronomy," *Journal of the American Oriental Society* 93, no. 1 [Jan.-Mar., 1973]: 32).

[30] See Otto Neugebauer, *A History of Ancient Mathematical Astronomy* [= *HAMA*] (New York: Springer-Verlag, 1975), p. 5.

[31] I am indebted to A. I. Sabra here for being my conscience regarding avoiding this disease, and encouraging me to check out any preexisting conditions (see "Appropriation," pp. 223-24).

A. I. Sabra pointed out that the term *hayʾa,* in its base meaning of shape, figure or form, could conceivably apply to the Aristotelian form ("configuration") of the universe as a structure of homocentric spheres obeying physically accepted principles of motion. Although his comment was directed at cautioning us all against projecting motivations into the use of a term alone,[32] ironically Book 12, chapter 8 of Aristotle's *Metaphysics* could have potentially been a source of inspiration for using the term *hayʾa*. F. J. Ragep suggests that Aristotle (fourth century BC), who was influenced by the mathematical models of Eudoxus and Callippus, attempted to show how these mathematical models of the astronomers can be fitted in order to provide a coherent and unified account—or cosmology—of the universe;[33] and Aristotle's picture of a system of homocentric spheres, or the arrangement of a geocentric world enclosed by contiguous spheres, was inspirational for any subsequent elementary textbook on *hayʾa* that sought to give a unified account of the world (see *Mulakhkhaṣ*, **Intr. [2]; and Figure 1: Illustration of the Orbs**).

The movement to translate Greek scientific and philosophical sources into Arabic, as well as some Persian and Indian ones, stretched roughly from the eighth into the tenth century; and this included Aristotle's corpus of works, the *Metaphysics* among them.[34] Ibn al-Nadīm lists

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[32] See A. I. Sabra, "Reply to Saliba," *Perspectives on Science* 8, no. 4 (2000): 342-43.

[33] Ragep, *Tadhkira,* pp. 26-29. Also see Otto Neugebauer, who summarizes the Eudoxan model of planetary motion (fourth century BC), in which Eudoxus describes four concentric spheres, and how these were then modified by Callippus who increased the number of spheres. In both cases the spheres remained independent for each planetary system, as also is the case in Ptolemy's *Almagest* (*HAMA*, pp. 677-85, esp. 684).

[34] Amos Bertolacci provides a detailed examination of the various sources of information on the Arabic translations of the *Metaphysics,* which include: *testimonia* on the translations and translators gathered from the Arabic bio-bibliographical literature; "direct" extant translations (as quoted or reported); and "indirect" information gained from references in Arabic philosophical writings from the ninth to the thirteenth centuries (i.e., from al-Kindī, al-Fārābī, Abū Zakariyāʾ Yaḥyā ibn ʿAdī, Ibn Sīnā, al-Shahrastānī, and ʿAbd al-Laṭīf al-Baghdādī) ("On the Arabic Translations of Aristotle's Metaphysics," *Arabic Sciences and Philosophy* 15 [2005]: 241-75). For a more general overview, see Cristina D'Ancona, "Greek Sources in Arabic and Islamic Philosophy," *The Stanford Encyclopedia of Philosophy* (Winter 2013 Edition), ed. Edward N.

some 65 translators working in all fields. Some of the more renowned ones include Ḥunayn ibn Isḥāq (d. 877), his son Isḥāq ibn Ḥunayn (d. 911), Thābit ibn Qurra (d. 901), and Qusṭā ibn Lūqā (d. ca. 900),[35] however there were also numerous lesser known scholars/translators involved in this massive enterprise.[36] It was also not uncommon to have multiple translations of a particular work, and one finds works that were corrected and/or modified by several translators. These works were disseminated; and the high demand for these materials was further bolstered by the introduction of paper by the eighth century.[37] In addition there were individual initiatives, exemplified by that of al-Kindī (fl. ninth century). Known as the "philosopher of the Arabs," al-Kindī undertook an active campaign to promote and disseminate a "Hellenistic outlook" through summaries of both philosophical and specialized scientific subjects.[38] So we can safely assume

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Zalta, URL = http://plato.stanford.edu/archives/win2013/entries/arabic-islamic-greek/. Accessed on July 23, 2014.

[35] See Régis Morelon, "Eastern Arabic Astronomy between the Eighth and the Eleventh centuries," in *Encyclopedia of the History of Arabic Science*, ed. Roshdi Rashed (London: Routledge, 1996), vol. 1: *Astronomy—Theoretical and Applied*, p. 21.

[36] See Ibn al-Nadīm, *Kitāb al-Fihrist*, ed. Riḍā Tajaddud (Beirut: Dār al-Masīra, 1988), trans. as *The Fihrist of al-Nadīm: A Tenth-Century Survey of Muslim Culture* by Bayard Dodge (New York: Columbia University Press, 1970), vol. 2, pp. 586-90. For Fuat Sezgin's listing of Greek sources translated into Arabic, see *Geschichte des arabischen Schrifttums*, vol. 6: *Astronomie bis ca. 430 H.* [= *GAS,* 6] (Leiden: E. J. Brill, 1978), pp. 68-103. In addition, Franz Rosenthal provides an insightful overview of the translators and what was translated in *The Classical Heritage in Islam* (Berkeley: University of California Press, 1975), pp. 5-12.

[37] See Jonathan M. Bloom, *Paper before Print: the History and Impact of Paper in the Islamic World* (New Haven: Yale University Press, 2001).

[38] A. I. Sabra stresses that al-Kindī's philosophical outlook was "all-embracing, encompassing not only metaphysical, and speculative subjects, but also a wide range of specialized scientific and practical problems." Thus al-Kindī made the study of mathematics an imperative for attaining ultimate happiness and salvation ("Some Remarks on Al-kindi as a Founder of Arabic Science and Philosophy," in *Dr. Mohammad Abdulhadi Abu Ridah Festscrift*, ed. Abdullah O. Al-Omar [Kuwait: Kuwait University Press, 1993 [pp. 604-7]). The Philhellene al-Kindī

that by the late-twelfth century Jaghmīnī would have had at his disposal a great number of translated Greek sources, many of which were then supplemented by edifying "secondary" sources and/or commentaries that Jaghmīnī also would have inherited.[39] But given the vast number of these works, which among them would Jaghmīnī have found suitable for emulating for his brand of theoretical astronomy?

Astronomy was often a theme for Ancient Greek poets, and literature was an effective way to educate the public on scientific topics; this is exemplified by the popularity of the didactic poem *Phaenomena* by Aratus of Soli, with its accompanying lavish illustrations. The subject of the poem is the constellations with respect to celestial and meteorological phenomena (basically timekeeping and weather prognostication). Latin versions of the poem along with a tradition of extensive commentaries on them bear witness to its success, this despite numerous scientific errors contained within the work. However, it was the inaccuracies of Aratus's constellations that drew the critical attention of some rather serious scientists, such as Hipparchus (fl. 2nd c. BC), and inspired him to write a commentary (his only extant work) detailing Aratus's reliance on

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virtually became a one-man-propaganda-machine and compiled over 250 treatises on subjects that included logic, philosophy, calculation, arithmetic, music, astronomy, astrology, optics, and medicine (see Ibn al-Nadīm, *The Fihrist of al-Nadīm,* vol. 2, pp. 615-26). For more on the corpus of al-Kindī's scientific works, see Peter Adamson, *Al-Kindī* (New York: Oxford University Press, 2006), esp. Ch. 4 (on "Science: Mathematics and Methodology"); and Peter Adamson and Peter E. Pormann, *The Philosophical Works of Al-Kindī* (Oxford: Oxford University Press, 2012).

[39] The important role of commentaries is brought out by Ibn Sīnā (eleventh century) in his autobiography. He tells us that he rejoiced in finding a commentary by al-Fārābī (tenth century) on Aristotle's *Metaphysics* in the booksellers' quarter of Bukhara that he bought for three dirhams. Dimitri Gutas has translated the autobiography and analyzes this passage, highlighting the importance of commentaries for clarifying issues considered problematic, in this case the purpose of the *Metaphysics* (*Avicenna and the Aristotelian Tradition: Introduction to Reading Avicenna's Philosophical Works* [Leiden: Koninklijke Brill NV, 2014], pp. 16-17 [nos. 8-9], 270-75; cf. William E. Gohlman, *The Life of Ibn Sīnā: A Critical Edition and Annotated Translation* [Albany, NY, 1974], pp. 31-35).

Eudoxus.[40] Islamic astronomers were well acquainted with Hipparchus's astronomical achievements, especially his knowledge of Babylonian observational records; however, the fact that Ptolemy also cites Hipparchus frequently throughout the *Almagest* must certainly have attracted their attention,[41] especially since Aratus's work had been translated into Arabic as early as the first decades of the ninth century.[42] We know in the eleventh century that al-Bīrūnī was quoting Aratus's *Phaenomena*, at least in his *India* (several times), a work he completed in 1030.[43] However, even though the constellations is a topic treated extensively in Ptolemy's *Almagest* (VII and VIII), and he also cites Aratus's *Phaenomena,* as far as I know no *hayʾa* work or subsequent summary or commentary on the *Almagest* cite it. Al-Farghānī (ninth century) would probably have been a likely candidate to mention it (but he doesn't), especially since in his *Jawāmiʿ*, his wide-ranging compilation of the *Almagest*, he devotes entire chapters to detailing with both the constellations (ch. 19) and the lunar mansions (ch. 20). Ṭūsī clearly feels the topic is inappropriate for a *hayʾa* work; he briefly mentions the fixed stars, the Milky Way, and the lunar mansions in his *Tadhkira*, but then quickly directs his readers to seek further

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[40] See Douglas Kidd, *Aratus, Phaenomena: Edited with Introduction, Translation and Commentary* (Cambridge: Cambridge University Press, 1997), pp. 12-20, 43-48; D. Mark Possanza, Review of *Aratus:* Phaenomena, *Translated with an Introduction and Notes* by Aaron Poochigian, *Aestimatio* 9 (2012): 71-2; and Bruce Eastwood, *Ordering the Heavens: Roman Astronomy and Cosmology in the Carolingian Renaissance* (Leiden: E. J. Brill, 2007), pp. 9, 10, 13, 232, 411.

[41] Ptolemy had high expectations to improve on Hipparchus's observations, which ranged from 141 to 127 BC. See G. J. Toomer, Ptolemy's *Almagest* (New York: Springer-Verlag, 1984), p. 687 [for the index listing the extensive references to Hipparchus's commentary throughout the *Almagest*]; and Toomer,"Hipparchus," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie (New York: Charles Scribner's Sons, 1978), vol. 15, p. 208.

[42] See Ernest Honigmann, "The Arabic Translation of Aratus' Phaenomena," *ISIS* 41, no. 1 (Mar., 1950): 30-31; and Sezgin, *GAS*, 6: 75-77. It is not clear whether Hipparchus's commentary was known, but perhaps it would have piqued an interest in the poem.

[43] See *Alberuni's India*, trans. C. Edward Sachau, 2 vols. (London, 1910), vol. 1, pp. 97, 383 and vol. 2 (notes), pp. 292-93, 349.

information on these topics elsewhere (i.e., he specifically states that the "knowledge of the fixed stars and that which concerns them [is] a separate discipline"[44]). Jaghmīnī avoids the constellations altogether in the *Mulakhkhaṣ*, an omission duly noted by Rudloff and Hochheim.[45] Furthermore, the use of literary references were also unsuitable for inclusion in *hayʾa* works. (We will see later that the idiosyncratic Epistle 3 [on Astronomia] of the Ikhwān al-Ṣafāʾ is an exception.) In any event, Jaghmīnī certainly doesn't employ literary detours in the *Mulakhkhaṣ*, unless one counts his verse dedication to Badr al-Dīn ([see **Preface]**); we do know that he composed poetry in another work.[46]

Beginning in the first century BC, "a particular literary *topos*, the introduction," seems to have emerged as a way for writers to present views of celestial science (*astrologia* in Latin; ἀστρολογία in Greek) to their readers.[47] However, the huge discrepancies between these works—

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[44] Ragep, *Tadhkira,* II.4 [9-12] (pp. 37, 128-29). Here too we have another example of notifying the reader that subject matter is demarcated between disciplines (cf. *Tadhkira,* Intr.[1], pp. 90-91). Most-likely the other discipline Ṭūsī is referring to in this case is the *anwāʾ* literature, a corpus of material on folklore that developed from astronomical mapping and weather prognostication that was modified to conform with the 28 lunar mansions (see Ragep, "Astronomy," *Encyclopaedia of Islam*, *THREE*).

[45] Rudloff and Hochheim point out that the *Mulakhkhaṣ* lacks a star catalogue ("Die Astronomie," pp. 214-15); however, they assume this is because Jaghmīnī would have found the catalogue of Ṣūfī to be sufficient. They are referring to ʿAbd al-Raḥmān al-Ṣūfī, the tenth-century author of the lavishly-illustrated *Book of Constellations (Kitāb ṣuwar al-kawākib)*, who describes 48 Ptolemaic constellations based on the *Almagest*, and gives a detailed critique of each of the 1,025 stars in Ptolemy's star catalogue based on his own observations (see Paul Kunitzsch, "Ṣūfī," in *The Biographical Encyclopedia of Astronomers* [New York: Springer-Verlag, 2007], vol. 2, p. 1110). Rudloff and Hochheim are seemingly unaware that Jaghmīnī also had the option of using the *anwāʾ* literature.

[46] See *Talkhīṣ kitāb Ūqlīdis*, pp. 247-49.

[47] See Alan C. Bowen, "Three Introductions to Celestial Science in the First Century BC," in *Writing Science: Medical and Mathematical Authorship in Ancient Greece*, ed. Markus Asper (Berlin/Boston: Walter de Gruyter, 2013), pp. 299-300, 319, 326-27.

with respect to content, structure, and literary style—raise serious questions about what it means to lump together general works dealing with astronomical topics (admittedly with some overlap) and refer to them as a genre of "elementary textbooks" or "introductions," especially when they clearly contain significant differences, and may have been written centuries apart.[48] Moreover, there is no real evidence to support the claim that "these were clearly intended to form part of the curriculum of studies expected of a well-born student."[49] Furthermore, the lack of standardization between the textbooks makes it unclear what exactly was being taught, who the targeted audience was, and what a more advanced study of these topics would have entailed.[50] On the other hand, these multi-faceted works do allow us the opportunity to gain some insights into the range of astronomy topics that were (and were not) of concern during this period, the levels of proficiency, and some of the influences that had taken hold at this time in order to draw some preliminary conclusions. What follows then are some brief examples of available work by which one could nominally have learned about some aspect of theoretical astronomy during what I refer to as "the pre-Ptolemaic period."

Views of celestial science could be contained within works that dealt with both broad and specialized subject matter, in either case written by a "non-specialist"; two examples of this are Diodorus Siculus's 40-volume *Bibliotheca historica*, a work on universal history and the

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[48] See James Evans and J. Lennart Berggren, *Geminos's* Introduction to the Phenomena*: A Translation and Study of a Hellenistic Survey of Astronomy* (Princeton, N.J.: Princeton University Press, 2006), p. 8. Evans and Berggren seemingly find it unproblematic to refer to Germinus's work as an introduction even though they acknowledge that "we cannot be sure that *Introduction to the Phenomena* is the title that Geminos himself gave it," p. 3. Cf. Alan C. Bowen, who is far more skeptical and advocates the need for "a more carefully thought out notion of what an introduction is"; he echoes Sabra's caution about reading motivations into the early use of a word ("Three Introductions to Celestial Science in the First Century BC," p. 303 n.11).

[49] Evans and Berggren, *Geminos's* Introduction to the Phenomena, p. 8. Bowen severely criticizes their claim of evidence to support a curriculum of study in his "Three Introductions to Celestial Science in the First Century BC," pp. 319-20.

[50] Bowen, "Three Introductions to Celestial Science in the First Century BC," pp. 318-19.

engineer Vitruvius's *De architectura,* a treatise dedicated to Augustus offering him—but presumably also architects—advice. Though their readership differs, the works of both authors (written circa 30 BC) emphasize that celestial science should be studied for the utilitarian benefits of astrology. For them this discipline provides important decision-making abilities: for Diodorus it endows humankind with the ability to predict the future and avoid harm; for Vitruvius it provides rulers with the ability to best "judge," which for architects translates into the ability to design and construct sundials.[51]

According to James Evans and J. Lennart Berggren, in "the Hellenistic period, there emerged a demand for popular surveys," and these overviews of celestial science attempted to "produce comprehensive astronomy textbooks written at an elementary level." Both view these works as forming a Greek genre of elementary textbooks on astronomy, even though they also duly point out that they "differ markedly in tone" as well as content and period composed.[52] Some examples of their so-called "corpus" include Geminus's *Introduction to the Phenomena* (also referred to as the *Isagoge*) (first century BC), Theon of Smyrna's *Mathematical Knowledge Useful for Reading Plato* (second century CE), and Cleomedes's *Meteora* (third to fourth century CE). Although the titles alone indicate their diversity,[53] they all seem to provide general

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[51] See Bowen, "Three Introductions to Celestial Science in the First Century BC," pp. 303-5, 309, 310, 313, 317-18.

[52] Evans and Berggren, *Geminos's* Introduction to the Phenomena, pp. 8, 10.

[53] Again, it is not surprising that these works could differ significantly regarding selected topics, reflecting perhaps the personal bent of the author or the time span between their compositions, many written centuries apart. For example, one would assume that Theon of Smyrna's *Mathematical Knowledge Useful for Reading Plato* would address philosophical concerns, since he was known as "a zealous partisan of Plato" (this is Ibn al-Nadīm's description of Theon before he reports that "among his books there was *Sequence of Reading Plato's Books and the Titles of His Compositions*" [*The Fihrist of al-Nadīm*, vol. 2, p. 614]). Although Neugebauer dismissed Theon's work as derivative and elementary (*HAMA,* pp. 949-50 [on *Theon of Smyrna and Adrastus*]), it is significant that a Platonist felt the need to include a section on astronomy; and we have another example of this occurring in the work of the Neo-Platonist Proclus, who will be discussed later in this chapter.

descriptive overviews (some more than others) of astronomy and cover a variety of topics and basic concepts on celestial science for the reader. However, whether they were intended as elementary astronomical textbooks is another matter. In support of this contention, Geminus's *Introduction to the Phenomena* seemingly covers "all important branches of Greek astronomy, *except* planetary theory" [emphasis mine];[54] and he also employs an impersonal rhetorical style suggesting "that of a teacher whose pronouncements are, for the most part, cast impersonally and (presumably) meant to be construed as objective and true by his student-reader."[55] In fact, this is the authoritative style Jaghmīnī deploys in the *Mulakhkhaṣ*, though Geminus (unlike Jaghmīnī) dilutes his objectivity by including subjective literary references.[56] In any event, there is no evidence to support the claim that there was an actual "program of study"; and given the discrepancies in the topics presented between these surveys, and also their lack of accompanying explanations to account for some of the phenomena described, the onus seemingly rests with the reader to wade through the material and decipher key points and essential concepts from the minutia, inaccuracies, and so on.[57] Cleomedes's work may be recognized as the "most detailed

[54] The topics of the treatise (contained within some 25 divisions) include: "the zodiac, solar theory, the constellations, the theory of the celestial sphere, the variation in the length of the day, lunisolar cycles, phases of the Moon, eclipses, heliacal risings and settings of the fixed stars, terrestrial zones, and an introduction to Babylonian lunar theory" (Evans and Berggren, *Geminos's* Introduction to the Phenomena, pp. 2, 8-9, 105-6). For further information on Geminus, see James Evans, *The History and Practice of Ancient Astronomy* (New York: Oxford University), pp. 83-4; Neugebauer, *HAMA*, pp. 578, 581-87; D. R. Dicks, "Geminus," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie (New York: Charles Scribner's Sons, 1972), vol. 5, pp. 344-47; and Ragep, *Tadhkira*, pp. 39-40.

[55] Bowen, "Three Introductions to Celestial Science in the First Century BC," p. 318.

[56] For example, Geminus includes passages from *Aratus' Phaenomena* and Homer's *Odyssey*, so presumably Geminus's "elementary" readership was a rather literary group (see Evans and Berggren, *Geminos's* Introduction to the Phenomena, pp. 26, 163, 177).

[57] For example, in his discussion on "The Inequality of the Seasons," Geminus never keeps his promise to explain the cause of motions of the planets (Evans and Berggren, *Geminos's* Introduction to the Phenomena, p. 118, esp. fn. 17).

source for the famous measurement of the Earth by Eratosthenes,"[58] but an elementary student may be less impressed in finding the work a difficult read.[59]

On the other hand, for our purposes the discrepancies between these works provide insights into the range of topics that were of interest, the level of proficiency, the influences at work, sources used, and so on during this time. It is interesting that within his hodge-podge of topics, Geminus also includes a section on the limitations of weather prognostication (which stands in direct contrast to its importance for Diodorus and Vitruvius); and he also discusses the astrological doctrine of the "aspects" according to which Babylonian astrologers calculated the zodiacal signs' influence on human affairs (in fact four of the seven diagrams in the *Phenomena* are in this section).[60] These certainly indicate that during this period the role and veracity of astrological theory and practice were concerns and varied greatly (though this certainly would apply to other times and places as well). In addition, some of these works include causal explanations to account for various aspects of celestial science;[61] though not necessarily surprising, it does distinguish these works from those works (like *hayʾa* treatises) which sought to weed out philosophical issues in order to confine the subject matter to dealing with only the external aspects of the celestial bodies. Finally, we can note that Babylonian astronomy/astrology made inroads into Greek celestial science during this period, although how deep its penetration

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[58] Evans and Berggren, *Geminos's* Introduction to the Phenomena, p. 10.

[59] For more on Cleomedes, see Neugebauer, *HAMA*, pp. 959-65.

[60] See Evans and Berggren, *Geminos's* Introduction to the Phenomena, pp. 220-2 (Ch. XVII [15-23]: The Stars Indicate But Do Not Cause The Weather) and pp. 125-36 (Ch. II [Aspects of the Zodiacal Signs]; Neugebauer, *HAMA*, pp. 581-88; and D. R. Dicks, "Geminus," vol. 5, pp. 345-6. The other 3 illustrations in *Geminos's* Introduction to the Phenomena are a solar eclipse, a lunar eclipse, and an illustration of the solar theory.

[61] Bowen discusses Geminus's "emphasis" on causation in "Three Introductions to Celestial Science in the First Century BC," pp. 320-6. See also Ragep, who examines the two different approaches (fact/reasoned fact) by the astronomer and the physicist to prove the Earth's sphericity, as told by Simplicius (6^{th} c. CE) quoting Geminus (*Tadhkira*, pp. 39-40); and Evans and Berggren, *Geminos's* Introduction to the Phenomena, pp. 49-51 (on "Reality and Representation in Greek Astronomy").

seems to be a matter of disagreement.[62] In any event, their employment of the Babylonian sexagesimal system (dating back to Eratosthenes around 250 BC) would be the hallmark of a sound astronomical textbook in that it indicates a concern for precision. Indeed, it became *the* notation for Ptolemaic parameters and subsequent *hayʾa* works (including the *Mulakhkhaṣ*), and was a system so widely used by Islamic astronomers that it became known as "the astronomers' arithmetic."[63]

Finally, I should mention the corpus of ancient Greek mathematical and astronomical texts that were translated into Arabic in the ninth century, and sometimes grouped together under the title of the "little or small astronomy collection."[64] Each alone was not a "textbook" per se,

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[62] Neugebauer seems rather impressed with how far Babylonian astronomy had penetrated into Geminus's work: "Of unique value in the Isagoge is the enumeration of numerical parameters of the lunar theory (in chap. VIII) which are of Babylonian origin. The appearance of these data in an introductory treatise indicates how far Babylonian results penetrated early Greek mathematical astronomy" (*HAMA,* p. 579). In contrast, Evans and Berggren conclude (without explanation) that "Geminos writes about Babylonian astronomy and astrology as if they were still new to his Greek readers. This well suits a dating to the first century B.C., when this material was still being absorbed and adapted by the Greeks" (*Geminos's* Introduction to the Phenomena, p. 22; cf. Geminus's references to the Babylonians, pp. 13-5, 125, 192 n4, 228-29). See also, Bowen, "Three Introductions to Celestial Science in the First Century BC," pp. 306-8, 316-18; 322-26.

[63] See Berggren, *Episodes in the Mathematics of Medieval Islam*, p. 41; Neugebauer, *HAMA,* pp. 590-93; and Toomer, Ptolemy's *Almagest*, pp. 6-7.

[64] These works included: "the *Data*, the *Optics*, the *Catoptrica* and the *Phenomena* of Euclid [fl. c. 300 BC]; the *Spherics*, *On Habitations* and *On Days and Nights* of Theodosius [d. ca. 90 BC]; *On the Moving Sphere* and *On Risings and Settings* by Autolycus [d. ca. 290 BC]; *On the Sizes and Distances of the Sun and Moon* by Aristarchus of Samos [d. ca. 230 BC]; *On the Ascensions of Stars* of Hypsicles [d. ca. 120 BC]; and the *Spherica* by Menelaus" (Régis Morelon, "General Survey of Arabic Astronomy," and "Eastern Arabic Astronomy between the Eighth and the Eleventh centuries," in *Encyclopedia of the History of Arabic Science,* vol. 1, pp. 7, 18-19, 21, 55 fn. 6). See also G. J. Toomer, "Ptolemy," in *Dictionary of Scientific Biography*, ed. Charles

but collectively became known as the so-called "Middle Books," and were seen as preparation for Ptolemy because they were to be studied between Euclid's *Elements* and Ptolemy's *Almagest*.

§ I.2.3b Ptolemy[65]

In the second century BC, the Alexandrian Claudius Ptolemy proposed a coherent picture of a universe consisting of contiguous or nested planetary spheres around an immobile spherical Earth; each sphere contained embedded within it additional non-concentric eccentric spheres and epicycles whose various combinations of motions accounted for perceived observations. This so-called "Ptolemaic system" changed the study of ancient mathematical astronomy; the nesting principle for the orbs was the "cornerstone" of *hayʾa*,[66] and thus crucial for its development and consequently the teaching textbook tradition.

Though certainly not a "user-friendly" textbook, Ptolemy's great comprehensive compilation of Greek mathematical astronomy, *Mathematike Syntaxis*, also commonly known as *The Almagest* (*al-Majisṭī*), supplanted most of the work of his scientific predecessors; and it became the standard textbook on astronomy for more "advanced" students in Alexandria (and

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Coulston Gillispie (New York: Charles Scribner's Sons, 1975), vol. 11, pp. 187-88 (for an overview of Greek astronomy as Ptolemy may have found it).

[65] For further selected readings on Ptolemy, see: Bernard R. Goldstein, "The Arabic Version of Ptolemy's Planetary Hypotheses," *Transactions of the American Philosophical Society*, ns, 57, no. 4 (1967): 3-55 at 3-4; Langermann's *Ibn al-Haytham's "On the Configuration of the World,"* pp. 15-25; Neugebauer, *HAMA*, pp. 834-38 ("Biographical and Bibliographical Data" and "The Almagest"), pp. 900-26 ("Planetary Hypotheses" and "Canobic Inscription"), and pp. 926-41 ("Additional Writings of Ptolemy"); Olaf Pedersen, *A Survey of the Almagest* (Odense: Odense University Press, 1974); Alexander Jones, *Ptolemy in Perspective: Use and Criticism of His Work from Antiquity to the Nineteenth Century* (New York: Springer, 2010), pp. 217-29 (bibliography); Liba Taub, *Ptolemy's Universe: The Natural Philosophical and Ethical Foundations of Ptolemy's Astronomy* (Chicago: Open Court, 1993); G. J. Toomer, "Ptolemy," pp. 187-206 (for an excellent overview); and G. J. Toomer, *Ptolemy's Almagest*.

[66] Ragep, *Tadhkira*, p. 517.

presumably Athens and Antioch). (Its influence on the *hayʾa* tradition, which was monumental, is the focus of sections **§ I.2.4 - §I.2.5** of this chapter.) Ptolemy assumes that the student is familiar with elementary geometry as well as some basic terminology and concepts, at least schooled enough to have "already made some progress in the field."[67] The work, in thirteen books, provides geometric models, along with quantitative parameters, to account for the celestial motion of each of the heavenly bodies (the Sun and Moon, each of the upper and lower planets, and the Fixed Stars), each contained within its own sphere. Ptolemy also provides tables to calculate positions of the heavenly bodies and other phenomena.[68]

Ptolemy continued to develop and modify his astronomy throughout his career. For example, in the *Almagest* Ptolemy is still uncertain about the order of the spheres (especially for Venus and Mercury) and their distances (*Almagest*, IX.1), and he provides absolute distances only for the Moon (through parallax) and the Sun (through eclipses) based on Earth radii.[69] However, Ptolemy revisits and rectifies these concerns in his later two-part work, the *Planetary Hypotheses* (*Kitāb al-iqtiṣāṣ* or *Kitāb al-manshūrāt*); and he provides absolute distances of the celestial bodies (in Earth radii and stades, and based on the assumption that the Earth's circumference is 180,000 stades) and sizes so that "these bodies may be fitted together to form a

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[67] See *Almagest*, Book I [Preface]; and Toomer, Ptolemy's *Almagest*, pp. 1-2, 6, 37, and 37, fn. 13. Ptolemy assumes here that the student is familiar with the works of Euclid, and the so-called "Middle Books" mentioned earlier.

[68] See Jones, *Ptolemy in Perspective,* xi-xii. Ptolemy would also later compile his astronomical computations into a separate work entitled the *Handy Tables.* The Ptolemaic parameters for planetary motions (from his works and tables) greatly influenced the *zīj* literature, which Jaghmīnī refers to in the *Mulakhkhaṣ* **(II.3 [7])**. For example, the *zīj* of al-Battānī (who Jaghmīnī mentions (**II.3 [9]))** indicates strong Ptolemaic influence (see E. S. Kennedy, "A Survey of Islamic Astronomical Tables," *Transactions of the American Philosophical Society*, n.s., 46, pt. 2 [1956], pp. 132-33). For the *Handy Tables*, see Anne Tihon and Raymond Mercier, *Ptolemaiou Procheiroi Kanones: Les Tables Faciles de Ptolémée. Volume 1a: Tables A1-A2* (Louvain-la-Neuve: Université catholique de Louvain, Institut Orientaliste, 2011-).

[69] *Almagest*, V.13-16, 19. See Neugebauer, *HAMA*, pp. 917-22; and Toomer, "Ptolemy," pp. 191-94.

coherent, unified structure, or *hayʾa*."[70] Ptolemy's *Almagest* and *Planetary Hypotheses* together provide both the geometrical modeling and the physical structure for a unified celestial and sublunar cosmography, fundamental for any *hayʾa* work.

Although Ptolemy himself states in the introduction to the *Planetary Hypotheses* that he modified (simplified as well as improved) some of the parameters with respect to the *Almagest*, not all *hayʾa* works include the new, improved parameters. Jaghmīnī, for example, opts (for reasons unknown) to use the Ptolemaic values of the *Almagest* in the *Mulakhkhaṣ* rather than those of the *Planetary Hypotheses.*[71] Jaghmīnī also omits any discussion of sizes and distances in the *Mulakhkhaṣ*, which is typically contained in a *hayʾa* work. However, it would be misguided to assume that this is due to his being unaware of the *Planetary Hypotheses*. More likely, this is a

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[70] Ragep, *Tadhkira*, p. 500. For his cosmography, Ptolemy assumes that the order of the planets is the same as that in the *Almagest*, each planet (including the fixed stars) is contained in a physical geocentric sphere, and all these spheres are contiguously fitted exactly together without a void. See Willy Hartner's seminal article, "Mediaeval Views on Cosmic Dimensions and Ptolemy's *Kitāb al-Manshūrāt*," in *Mélanges Alexandre Koyré*, 2 vols. (Paris: Hermann, 1964), vol. 1, pp. 254-82; unfortunately Hartner's work became upstaged by Goldstein's "The Arabic Version of Ptolemy's Planetary Hypotheses," pp. 3-55 (which includes an English translation and commentary of Book I, second part, as well as an Arabic facsimile of this (British Museum MS. arab. 426 [Add. 7473], ff. 81b-102b)). See also Neugebauer, *HAMA*, pp. 919-22 (who includes convenient tables comparing the parameters found in the *Almagest* and the *Planetary Hypotheses* with those of Proclus's *Hypotyposis* and his Commentary to the *Timaeus* along with the values of Thābit b. Qurra); Pedersen, *A Survey of the Almagest,* pp. 393-97; and Toomer, "Ptolemy," p. 197.

[71] We can cite a specific example of this with Jaghmīnī's parameters for the maximum inclination of the inclined orb from the ecliptic orb (see **I.5 [13]**); Jaghmīnī gives for Mars: 1;0 and for Mercury 0;45 [*Almagest*] not 1;50 and 0;10 respectively [*Planetary Hypotheses*]. See also Neugebauer, *HAMA*, pp. 907-9; Pedersen, *A Survey of the Almagest,* pp. 392-93; and Swerdlow, "Ptolemy's Theories of the Latitude of the Planets in the *Almagest*, *Handy Tables*, and *Planetary Hypotheses*," p. 68 (Swerdlow provides here a convenient table of the inclinations for the three Ptolemaic works and the modern values); and Neugebauer, *HAMA*, pp. 907-9

case in which Jaghmīnī considered that pedagogically the subject of sizes and distances was inappropriate for an elementary textbook. In fact, this is Qāḍīzāde's assessment, i.e., that the topic was omitted due to its difficulty.[72]

On the other hand, Jaghmīnī does present the "updated" information from Ptolemy's *Geography*, eight books he wrote after the *Almagest* (actually Ptolemy mentions that its publication will be forthcoming in Book II.13). In the *Geography,* which was translated into Arabic in the ninth century, Ptolemy showcases topics of the terrestrial realm, in comparison to the relatively minor role they played in the *Almagest*;[73] and he provides "for the first time a mathematically clear theory of geographical mapping along with a grid of coordinates, reckoned

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[72] See Qāḍīzāde, *Sharḥ al-Mulakhkhaṣ* (Istanbul, Ayasofya MS 2662, f. 4a) where he states that the difficulty *(ṣuʿūba)* of the subject is the reason for its omission. See also Ragep, *Tadhkira*, p. 500, n 1. Here one should also keep in mind that Jaghmīnī wrote a separate short treatise on sizes and distances (mentioned in Ch. 1). It is interesting though that Jaghmīnī omits all discussion of sizes and distances in the *Mulakhkhaṣ*, but includes in this "elementary" textbook the parameters for planetary latitudes, a subject known for its complexity (according to Swerdlow, "Ptolemy's Theories of the Latitude of the Planets in the *Almagest*, *Handy Tables*, and *Planetary Hypotheses*," pp. 41-42).

[73] Ibn al-Nadīm reports that Ptolemy's "Geography of the Inhabited Lands and a Description of the Earth [Ptolemaei opus geo-graphicum]" was a book in eight sections, that was translated several times in the ninth century; he further comments that: "Al-*Kindī* made a bad translation of it and then Thābit [ibn Qurrah] made an excellent Arabic translation. It is also extant in Syriac." (*The Fihrist of al-Nadīm*, vol. 2, p. 640). See also Berggren and Jones, *Ptolemy's Geography,* pp. 50-52 (on early readers and translators). The line of textual translation of this treatise has not been a straight-forward one. Florian Mittenhuber points out that of the 53 preserved Greek manuscripts, none were written before the late-thirteenth century ("The Tradition of Texts and Maps in Ptolemy's Geography," in *Ptolemy in Perspective: Use and Criticism of His Work from Antiquity to the Nineteenth Century*, ed. Alexander Jones [Dordrecht; New York: Springer, 2010], p. 95).

in degrees.” Included in this is Ptolemy’s latest information on the borders of the *oikoumenê*;[74] and since this is a subject dealt with extensively in *hayʾa* textbooks, i.e., directly related to matters of *hayʾat al-arḍ*, any Ptolemaic modifications made here would have been of great concern. In fact, this is reflected in the *Mulakhkhaṣ*; though Jaghmīnī does not cite the work specifically he states: “Ptolemy, after writing the *Almagest,* claimed that he found habitation below the equator to a distance of 16;25 [degrees]” (see **II.1 [2]** and commentary).[75]

It has been suggested that Ptolemy’s *Almagest* and *Planetary Hypotheses* be “linked” with his great astrological work the *Tetrabiblos* as together providing a better understanding of his cosmology.[76] In the *Tetrabiblos* (*al-maqālāt al-arbaʿ li-Baṭlamyūs*; Latinized as the *Quadripartitum*), a title derived from its four-book structure, Ptolemy deals with the influences of the heavenly bodies on terrestrial events. In viewing astrology as a purely physical science, he argues that the physical attributes and changing positions of the planets can directly impact terrestrial matters. The number of times that this work was translated, corrected and commented

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[74] See Neugebauer, *HAMA*, p. 934. Neugebauer points out that Ptolemy had relied on Hipparchus for many of his basic assumptions in the *Almagest* and so the various geographical data found in his *Geography* indicates different stages of his development (pp. 939-40). See also, J. Lennart Berggren and Alexander Jones, *Ptolemy’s Geography: An Annotated Translation of the Theoretical Chapters* (Princeton: Princeton University Press, 2000), pp. 21-22, 64-77.

[75] Cf. Berggren and Jones, *Ptolemy’s Geography,* p. 110 (Book 7); cf. Toomer, Ptolemy’s *Almagest*, pp. 82-83 (II.6 [1.]).

[76] Both Toomer and Taub seem to be advocating this position: G. Toomer points out that Ptolemy regards “the *Tetrabiblios* as the natural complement to the *Almagest*: as the latter enables one to predict the positions of the heavenly bodies, so the former expounds the theory of their influences on terrestrial things” (“Ptolemy,” p. 198); and L. Taub has asserted that Ptolemy’s “detailed demonstration of the planetary order in the *Planetary Hypotheses* served to fortify the foundation of the physical claims in the *Tetrabiblos*” (*Ptolemy’s Universe*, pp.132-33). However, Neugebauer concluded that “On the whole, the *Tetrabiblios* stands alone” among Ptolemy’s works (*HAMA*, p. 897).

on is certainly not insubstantial, and this also includes a commentary by al-Battānī.[77] It is logical to assume that although the subject of the influences of astrology per se had no place within a *hayʾa* textbook, as a mathematical discipline dealing with the structure of the cosmos, that there would be some valuable "borrowing" of information due to the overlap of topics, basic terminology and concepts, and parameters that would be of interest to both disciplines.[78]

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[77] For his listing of "The Four [Quadripartitum de apotelesmatibus et judiciis astrorum]," Ibn al-Nadīm states that: "*Ibrāhīm* ibn al-Ṣalt [Abū Nūḥ.] translated this book, *Ḥunayn* ibn Isḥāq corrected it, *Eutocius* commented on the first section, which first section Thābit treated as a whole so as to bring out its meaning. ʿUmar ibn al-Farrukhān, Ibrāhim ibn al-Ṣalt, al-*Nayrīzī*, and al-*Battānī* commented on it" (*The Fihrist of al-Nadīm*, vol. 2, p. 640. Eutocius's *Tetrabiblios* commentary is also listed by Johann Georg Wenrich in *De Auctorum Graecorum Versionibus et commentariis Syriacis, Arabicis, Armeniacis Persicisque commentatio* (Lepizig: Vogel, 1842), p. 198:

(كتاب تفسير المقالة الاولى كتاب بطلميوس في القضآء على النجوم) .

Cf. Fuat Sezgin, *Geschichte des arabischen Schrifttums*, vol. 7 [= *GAS,* 7]: *Astrologie* (Leiden: E. J. Brill, 1979), pp. 43-48. This work also became important for prophetic medicine, as exemplified by the eleventh-century Egyptian physician ʿAlī ibn Riḍwān, whose commentary on it was also translated into Latin and printed together with the *Quadripartitum* (see Joseph Schacht, "Ibn Riḍwān," in *Encyclopaedia of Islam*, 2nd. ed. (Leiden: E. J. Brill, 1971), vol. 13, pp. 740-42; and Peter E. Pormann and Emilie Savage-Smith, *Medieval Islamic Medicine* (Washington D. C.: Georgetown University Press, 2007), pp. 154-55).

[78] Astrology may have been deemed an inappropriate topic for a *hayʾa* work; however Jaghmīnī also composed a short astrological treatise entitled *Fī quwā al-kawākib wa-ḍaʿafihā* (The Strengths and Weaknesses of the Planets), which I mentioned in **§ I.1.3c: Further Evidence for Dating Jaghmīnī**.

§ I.2.3c The Ptolemaic Aftermath: Theoretical Astronomy With—and Without—Him

In the fifth century, the neo-Platonist Proclus wrote the *Hypotyposis*, a textbook on Ptolemaic theoretical astronomy which has been described as "the first and last summary of the contents of the Almagest from antiquity."[79] Proclus, a director of the "Academy" in Athens, one of the two major schools in the fifth and sixth century devoted to philosophical issues (the other being the school of Alexandria), demonstrates a remarkable knowledge of astronomy as well as pedagogical acumen. Though written within a philosophical milieu, his *Hypotyposis* is the closest extant Greek writing we have to that of a *hayʾa* work, although there are differences.[80] Far more than an overview of the *Almagest*, this work provides a detailed examination of the celestial realm as well as instructions on the use and construction of astronomical instruments.[81] Proclus presents ten problems by which he criticizes various attempts by astronomers to account for the irregular movements of the heavenly bodies;[82] and he specifically problematizes the

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[79] Neugebauer, *HAMA*, p. 1036.

[80] For example, Proclus's *Hypotyposis* lacks any discussion of the terrestrial realm, which is included in Ptolemy's *Almagest* and a prominent feature of most *hayʾa* works. On the other hand, Ibn al-Haytham, like Proclus, omitted this topic altogether in his *On Configuration of the World*; and furthermore, whereas Ibn al-Haytham does not discuss the sizes and distances of the planets, Proclus does. For comparisons of Ptolemy and Proclus, see Hartner, "Mediaeval Views on Cosmic Dimensions and Ptolemy's Kitāb al-Manshūrāt," pp. 323-40; and Neugebauer (*HAMA*, pp. 920-91), which includes tables of comparative values [pp. 920-22] mentioned in fn. 70.

[81] Proclus discusses the use and construction of Ptolemy's instrument for determining the obliquity of the ecliptic of 23;51,20 (*Almagest*, I.12 [Toomer, pp. 61-63]); and also his "ringed" or spherical astrolabe [armillary sphere], within an entire section devoted its construction and use (*Almages*t, V.1 [Toomer, pp. 217-19]). See *Procli Diacochi Hypotyposis astronomicarum positionum*, ed. Carolus Manitius (Stuttgardt: B. G. Teubner, 1974 [original Leipzig: Teubner, 1909]), pp. 41-55 and pp. 199-213, respectively. Cf. Neugebauer, *HAMA*, p. 1036.

[82] Proclus clearly does not believe the *Almagest* is definitive. For example, in point nine we see that he disagrees with Ptolemy regarding the movement of the fixed stars; Proclus believes there

status of epicycles and eccentrics as either geometrical fictions or physical realities, raising objections to *both* options but without choosing sides.[83] Ultimately, Proclus (the Platonist), and Ptolemy (the Mathematician) both believe in the regularity of celestial motion, but each differs in approach to account for the problem of perceived irregularities: Proclus starts with the principle of simple motions to derive more complex ones (while struggling to be faithful to his Platonic ideals); and Ptolemy seeks simple solutions from apparently complex motions.[84] Given his neo-Platonic bent, Proclus's ability to distinguish himself from Ptolemy and ultimately accept an attitude of agreeing to disagree with him, by raising objections to difficulties contained in the *Almagest* without rejecting Ptolemy outright, strikes me as remarkable and similar to later medieval Islamic astronomers working within the *hayʾa* tradition of "reforming" Ptolemaic astronomy rather than "overthrowing" it.[85]

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is no movement, whereas Ptolemy states they move 1 degree per 100 years (*Almagest,* VII.2 [p. 328]) (see *Procli Diacochi Hypotyposis*, p. 235).

[83] G. E. R. Lloyd provides an excellent overview of Proclus's *Hypotyposis*, highlighting key points regarding his position on astronomy, as well as how he has been misrepresented as being an instrumentalist. Lloyd points out that Proclus attempted to reconcile the complex movements of the heavenly bodies with his desire to uphold Plato's "authority," but charged astronomers with not making clear enough "those things that it is possible to grasp" (p. 263) ("Saving the Appearances," pp. 256-64).

[84] It is worth repeating here Ptolemy's position on the meaning of "simplicity," since he is explicit in articulating it in the *Almagest*, XIII.2: "Let no one, considering the complicated nature of our devices, judge such hypotheses to be over-elaborated. For it is not appropriate to compare human [constructions] with divine, nor to form one's beliefs about such great things on the basis of very dissimilar analogies. For what [could one compare] more dissimilar than the eternal and unchanging with the ever-changing, or that which can be hindered by anything with that which cannot be hindered even by itself? Rather, one should try, as far as possible, to fit the simpler hypotheses to the heavenly motions, but if this does not succeed, [one should apply hypotheses] which do fit" (Toomer, Ptolemy's *Almagest*, p. 600).

[85] I am thinking here of the radical reaction against Ptolemaic astronomy found in twelfth-century Andalusia, whereby Islamic scholars rejected it in search of a purer version of

In addition to Proclus's *Hypotyposis,* mention should be made of several other works sometimes listed as "introductions" to the *Almagest* but which are actually commentaries. One is by Pappus (fl. 320), and another by Theon of Alexandria (fl. Alexandria, second half of fourth century), who tells us in the preface that he composed the work for his students;[86] a third is an anonymous work attributed to Eutocius, who also authored a commentary on Apollonius's *Conics* and was considered to be the head of the Alexandrian school between Ammonius and

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Aristotelian cosmology, one free of eccentrics and epicycles, in which planetary motions of spherical bodies with embedded planets occur in uniform, circular motion within homocentric nested spheres about a stationary Earth. Proclus's approach seems more aligned with those Islamic astronomers who attempted to reconcile inconsistences, the form of argument found in the so-called *Shukūk* [Doubts] literature, in which difficulties or objections were raised against ancient authorities. (The term *shukūk* [doubts]) meant in the sense of the Greek *aporia*, i.e., not simply for an error to be deleted or corrected, but a difficulty, puzzle or problem to be defined before requiring a particular solution.) See A. I. Sabra: "The Andalusian Revolt Against Ptolemaic Astronomy: Averroes and al-Biṭrūjī," in *Transformation and Tradition in the Sciences,* ed. E. Mendelsohn (Cambridge: Cambridge University Press, 1984), pp. 133-35; Sabra, "Configuring the Universe," pp. 290-91, 297-300; and Sabra, "Reply to Saliba," p. 343.

[86] Theon's commentary on the *Almagest*, a work characterized by Gerald Toomer as "never critical, merely exegetic," suggests a redaction of his Alexandrian lectures; of the original thirteen books, Book XI is lost and only a fragment of Book V survives, but these parts are probably extant in other works ("Theon of Alexandria," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie [New York: Charles Scribner's Sons, 1976], vol. 13, pp. 321-22). The work is listed in Ibn al-Nadīm as an "Introduction to 'Almagest' [*Introductio in Almagestum*] with an ancient translation" (*The Fihrist of al-Nadīm*, vol. 2, p. 641), and also as an introduction in Sezgin, *GAS*, 6: 102. The content of Pappus's commentary, in which only books 5 and 6 are extant, indicates that Theon built on his work. Pappus's work is listed by Ibn al-Nadīm as: "A commentary on Ptolemy's book about finding the plane," and it was also translated into Arabic by Thābit ibn Qurra (p. 642). See also Neugebauer, *HAMA*, pp. 965-69.

Olympiodorus.[87] All three of these works contain some overlap, and deal with content concerned with explanations of mathematical computations.[88] In other words, their orientation is quite technical, and so one would presume that the target audience would have been rather limited. However, apparently this topic found resonance with some Islamic scholars, such as al-Kindī who was well known for his attempts to make difficult Greek subject matter more comprehensible for a broader audience.[89] According to Franz Rosenthal, Theon's commentary on the *Almagest* was a major source for al-Kindī's *Kitāb fī al-ṣināʿa al-ʿuẓmā,* a work dealing with the first eight chapters of Book I of the *Almagest*, and from which "Ptolemy's original ideas are often given precedence, but on the whole, Theon's text is followed faithfully."[90]

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[87] Joseph Mogenet attributes Eutocius as being the anonymous author of a work he entitles, "*L'introduction à l'Almageste*" (Mémoires De La Classe Des Lettres, Collection in-8°, 2e Série, vol. 51, fasc. 2 [Bruxelles: Palais des Académies, 1956]); however, Wilbur Knorr skeptically views Eutocius's authorship as only a "possibility" (p. 156), in *Textual Studies in Ancient and Medieval Geometry* (Boston: Birkhäuser, 1989), ch. 7, pp. 155-211 ("On Eutocius: A Thesis of J. Mogenet").

[88] See Neugebauer, *HAMA*, pp. 1042-43. Regarding these three works, G. J. Toomer concluded that "there is no doubt that they are derived from the same work"; he based this in part on the fact that all three works contain content from the mathematician Zenodorus concerning isoperimetric problems (see "The Mathematician Zenodorus," *Greek, Roman and Byzantine Studies* 13 [1972]: 177, and fn. 1; and Toomer, "Theon of Alexandria," p. 321). I might add that Zenodorus's name is not mentioned by Ptolemy in the *Almagest*; however, extensive excerpts of his proofs of propositions are used by Theon in discussing Ptolemy's section on the sphericity of the heavens (*Almages*t, I.3; see Toomer, Ptolemy's *Almagest*, pp. 39-40, and 40, fn. 25).

[89] See Franz Rosenthal, "Al-Kindī and Ptolemy," in *Studi Orientalistici in Onore di Giorgio Levi Della Vida,* Pubblicazioni dell'Istituto per l'Oriente, 52 (Rome, 1956), vol. 2, pp. 440 and 444. I return to al-Kindī's *Almagest* commentary later in this chapter as well as one by Abū Jaʿfar al-Khāzin, whose *Tafsīr al-Majisṭī* also dealt with isoperimetric problems.

[90] Rosenthal is rather explicit in asserting that the "context leaves no doubt that Theon's *Commentary* is al-Kindī's source" and that in parts of the work "al-Kindī follows Theon almost

None of these early Greek works are comparable to Proclus's *Hypotyposis* in providing the reader, in both scope and explanatory detail, a general background of the Ptolemaic system. However, Proclus's work is not listed in the literature as having been translated into Arabic[91] or into Latin (*in toto* or in parts). On the other hand, the library of Cardinal Bessarion, which is said to have housed the largest collection of Greek manuscripts in fifteenth-century Italy, included several Greek *Almagest*s, Proclus's *Hypotyposis*, Theon of Alexandria's commentary on the *Almagest*, Theon of of Smyrna's *Mathematical Knowledge Useful for Reading Plato*, and other hard-to-find Greek works; and Bessarion had an agenda to have as many of these "classical" Greeks works translated into Latin as possible.[92] So it would seem that until the fifteenth century such Greek works would not have been available to a reader in the Latin West, whether that reader knew Greek or not. We do know though that Proclus had students and successors; and so

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literally but expands the discussion in some places" ("Al-Kindī and Ptolemy," vol. 2, pp. 446, 449, fn. 2, and 450).

[91] Ibn al-Nadīm does include "Diadochus *Proclus*, the Platonist"; however, the *Hypotyposis* is not listed among his works translated into Arabic (*The Fihrist of al-Nadīm*, vol. 2, pp. 607-8). The work was printed in Basel in the sixteenth century: *Procli Diadochi Hypotyposis astronomicarum positionum*, ed. Simon Grynaeus (Baseleae: Apud Ioannem Vualder, 1540). However, Rosenthal includes Proclus among "the proud list of names of writers part of whose work has been preserved only in Arabic"; and he points out that "Often, the original text of eminent authors proved hard to understand, and paraphrases and elaborations were easier to master. This happened to the famous Neo-Platonists, Plontinus and Proclus" (*The Classical Heritage in Islam*, pp. 11-12).

[92] Michael H. Shank. "The Classical Scientific Tradition in Fifteenth-Century Vienna," in *Tradition, Transmission, Transformation: Proceedings of Two Conferences on Premodern Science Held at the University of Oklahoma*, ed. F. Jamil Ragep and Sally P. Ragep with Steven Livesey (Leiden: E. J. Brill, 1996), pp. 128-29.; and Michael H. Shank, "Regiomontanus in the Background of Copernicus," an unpublished article scheduled to appear in *Before Copernicus: The Cultures and Contexts of Scientific Learning in the Fifteenth Century*, ed. F. Jamil Ragep and Rivka Feldhay. Shank states that Regiomontanus translated the *Hypotyposis* as the *De sufformationibus* and had plans to print it.

one would presume his astronomical knowledge (with a Ptolemaic bent) would have influenced future generations of scholars.[93]

In ninth-century Western Europe there is "no knowledge of works by Hipparchus, Ptolemy, or Theon of Alexandria";[94] the textbooks used for teaching astronomy were basically Roman, which included Latin translations and commentaries of a few Greek works. The overwhelming consensus by modern historians is that without the knowledge of the principal astronomical works of Greek antiquity, especially *sans* Ptolemy, the teaching of theoretical astronomy and planetary theory was a challenging endeavor; indeed, many portray this period as one of scientific stagnation.[95] Originally, Roman astronomy relied on "odds and ends" of ancient

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[93] It is known that Proclus's student Ammonius had students who included Philoponus, Asclepius, Olympiodorus, Damascius, and Simplicius; and also that Olympiodorus's pupil Stephanus of Alexandria left Athens/Alexandria a century later for Constantinople. For a brief survey of some of the key scholars of the Academy in Athens, and the school of Alexandria, see Neugebauer, *HAMA*, pp. 1031-54; and also Pingree, "The Greek Influence on Islamic Astronomy," pp. 32-34.

[94] See Bruce Eastwood, *Ordering the Heavens: Roman Astronomy and Cosmology in the Carolingian Renaissance* (Leiden: E. J. Brill, 2007), p. 10. Stephen C. McCluskey states that in the Latin West, Ptolemy's name "remained little more than a name, often confused with the Ptolemaic rulers of Egypt" (*Astronomies and Cultures in Early Medieval Europe* [Cambridge: Cambridge University Press, 1998], p. 20).

[95] In his inimitable way, Neugebauer not only proclaimed, "Ptolemy had no successor," but also deemed the extent of extant Greek scientific works at the time of the Roman period as "rather sad" (*HAMA*, p. 5). But even more graphic demonstrations of this overall sentiment of stagnation were employed by Henry Smith Williams, who intentionally left blank pages for his entire chapter entitled "Astronomy in the Medieval Period ("The Christian World—Twelve Centuries of Progress [325-1543, A.D.]" to indicate "astronomical progress" (*The Great Astronomers* [New York: Newton Publishing Co., Schuster, 1932], pp. 99-102); and also by Carl Sagan, whose timeline of the development of Western civilization after the Greeks left a millennium gap (ca. 500-1500) in the middle describing the period as a "poignant lost opportunity for the human species" (*Cosmos* [New York: Random House,1980], p. 335).

Greek astronomy for pedagogical purposes; but this virtually made learning astronomy "along Greek lines impossible."[96] In sum, there was no single astronomical textbook for teaching astronomy; rather, what emerged was a corpus of Roman works, derived from the first to the fifth centuries, that had been piecemealed together, and whose astronomical topics as well as focus varied greatly; it is recognized that foremost among these works were:[97] Pliny the Elder's (first century) detailed encyclopedic *Historia naturalis*, specifically Book II (on celestial phenomena) and Book VI (on terrestrial matters);[98] Macrobius's *Commentarii in somnium Scipionis* (fifth century), a broad cosmological overview connecting the celestial and terrestrial

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[96] See Pedersen, "The *Corpus Astronomicum* and the Traditions of Medieval Latin Astronomy: A Tentative Interpretation," in *Colloquia Copernicana*, iii, ed. Owen Gingerich and Jerzy Dobrzycki (Wroclaw: Ossolineum, 1975), *p. 62.*

[97] See Eastwood, *Ordering the Heavens* (on Pliny the Elder, ch. 3 [pp. 95-178]; on Macrobius, ch. 2 [pp. 31-94]; and on Martianus Capella, ch. 4 [pp. 179-311]). Cf. Neugebauer, *HAMA*, pp. 1028-30; McCluskey, *Astronomies and Cultures in Early Medieval Europe*, pp. 16-17; and, Pedersen, "The *Corpus Astronomicum* and the Traditions of Medieval Latin Astronomy," pp. 60-62.

[98] According to Eastwood, Pliny the Elder's ambitious 37-volume *Natural History*, which claims to cover all human knowledge, is a "gold-mine of information" (*Ordering the Heavens*, p. 178). Book II alone contains 109 chapters, with topics ranging from eclipses to why the sea is salty. Alan C. Bowen and Bernard R. Goldstein highlight Pliny's passage on eclipses (II.12) to assert that he has been an underappreciated source for our knowledge of pre-Ptolemaic Greco-Latin astronomy. Their intention was to counter claims such as Kepler's, who stated that Pliny led "both himself and the reader astray by the obscurity of his words" ("Pliny and Hipparchus's 600-year cycle," *Journal for the History of Astronomy* 26 [1995]: 155-58). I tend to be more aligned with Kepler's view; the scope and magnitude of Pliny's work certainly make it difficult for any reader to distinguish the gold from fool's gold (but of course one could consult XXXIII.43: "Touchstones for Testing Gold").

realms;[99] and Martianus Capella's *De nuptiis Philologiae et Mercurii* (fifth century), Book VIII, which provided some elementary astronomical concepts and data.[100]

Theoretical astronomy was a topic dealt with only peripherally in these Roman sources.[101] As a consequence, one finds a range of competing and often contradictory

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[99] Whereas Pliny presents a wide-range of astronomical topics, Macrobius's commentary on Cicero's dream (written some four centuries later), provides a broad picture of a Platonic cosmos of mathematically-harmonious ordered spheres (with Venus and Mercury above the Sun). Excerpts from both works were used in schools, though apparently not heavily glossed. Striking is Macrobius's theme of relating order of the cosmos with order in the soul; discussions include corresponding zones of the heavens and the Earth, a human soul that migrates between the two realms (one that both ascends and descends) in pursuit of eternal rewards, and what the stars indicate, but do not cause (Eastwood, *Ordering the Heavens,* pp.19, 27, 59-60, 66-67). *See also* McCluskey, *Astronomies and Cultures in Early Medieval Europe*, pp. 117-19.

[100] The title of this 9-volume work is an allegory for the marriage of elegance and wisdom, uniting to combine respectively the *trivium* (grammar, rhetoric, and logic) and the *quadrivium* (arithmetic, geometry, music, and astronomy); Book VIII is devoted to "Lady" astronomy, and in the ninth century, ten astronomical diagrams were appended to it. In addition to providing elementary terminology, Capella seems to be grappling with explaining planetary irregularities, such as the varying lengths of daylight throughout the year and the different length of the four seasons. Unlike both Pliny and Macrobius, he also asserts (without reference) that the paths of Venus and Mercury are around the Sun, not the Earth, whereas the Sun, Moon and three other planets circle around the Earth. See Eastwood, *Ordering the Heavens,* pp.12-14, 20-21, 244-59, 303; Gerd Graßhoff, "Natural Law and Celestial Regularities from Copernicus to Kepler," in *Natural Law and Laws of Nature in Early Modern Europe: Jurisprudence, Theology, Moral and Natural Philosophy* , ed. Lorraine Daston and Michael Stolleis (Farnham: Ashgate, 2008), pp. 144-46; and McCluskey, *Astronomies and Cultures in Early Medieval Europe*, pp. 120-22.

[101] Note that since theoretical astronomy is my primary focus, I do not deal with the teaching of computus. See Eastwood, who seemingly concurs with my assessment in stating that the "separate concerns of astronomy and computus are far more numerous than the overlaps" (*Ordering the Heavens,* pp. 10-12).

astronomical theories; so, for example, we find different scenarios for the sequencing of the planets.[102] Accompanying this is a general lack of technical accuracy and mathematical explanations,[103] i.e., epicycles and eccentrics make only cameo appearances in Roman sources. Far more important it seems was presenting the Roman audience with a general cosmological description, often enhanced with literary references,[104] of a relatively miniscule Earth encompassed by homocentric spheres—in short, a geocentric universe that was ordered and regular. But as Ptolemy wisely forewarned: "It is possible for many people to possess some of the moral virtues even without being taught, whereas it is impossible to achieve theoretical understanding of the universe without instruction."[105]

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[102] A striking example of this is that the three most popular Roman sources for teaching astronomy each presented a different order for the sequence of the planets: Pliny the Elder held that Venus and Mercury circled the Earth below the Sun; Macrobius maintained that these two planets circled the Earth above the Sun; and, Martianus Capella asserted that both did not enclose the Earth, but had circumsolar motions.

[103] Neugebauer provides us with what he refers to as some of the more "absurd parameters" regarding sizes and distances found in Roman sources (*HAMA*, pp. 723-24, 1029-30); and he singles out their oft-repeated postulate that all seven planets move with equal speed in their respective orbits. See also Olaf Pedersen, who bemoans the "non-mathematical character" of astronomical works of popularization ("The *Corpus Astronomicum* and the Traditions of Medieval Latin Astronomy," pp. 61-62, 65).

[104] McCluskey concludes that "literary presentation was more important than rigorous demonstration, philosophical significance more important than mathematical precision" (*Astronomies and Cultures in Early Medieval Europe*, p. 117). Cf. both Eastwood and Pedersen, who intentionally omit those literary sources referencing astronomy and cosmology in their surveys of popular pedagogical astronomical texts (Pedersen, "The *Corpus Astronomicum* and the Traditions of Medieval Latin Astronomy," p. 60; and Eastwood, *Ordering the Heavens*, p. 13). However, as mentioned earlier, it is noteworthy that some of these works, such as Aratus's *Phaenomena* (translated into Latin by Cicero [106-43 BC]), was quoted by al-Bīrūnī, and critiqued by Hipparchus (and Hipparchus's commentary was cited by Ptolemy in the *Almagest*).

[105] *Almagest*, I.1 [Preface] (Toomer, *Ptolemy's Almagest*, p. 35).

Roman astronomy then, in roughly the ninth century, provides us with an alternative account of an astronomical education, one that developed in the main without the benefit of ancient Greek sources for theoretical guidance.[106] This would have been in sharp contrast to Islamic scholars who had amassed a huge corpus of ancient Greek philosophical and scientific texts by this same period. As Franz Rosenthal has aptly stated, it is indisputable that "Islamic civilization as we know it would simply not have existed without the Greek heritage."[107] Thus it is highly unlikely that Islamic astronomers would have relied on Roman sources for astronomical knowledge.[108]

§ I.2.4 Islamic Forebears

Many Islamic scholars writing on theoretical astronomy supported Ptolemy's view, as stated in the *Almagest* preface, that two of Aristotle's three divisions of theoretical philosophy (theology and physics) should "be called guesswork," and that only the third division of "mathematics can provide sure and unshakeable knowledge to its devotees, provided one approaches it rigorously."[109] By the ninth century, Ptolemy's *Almagest* had been translated into Arabic no less than five times,[110] along with the translation of his *Planetary Hypotheses*, other ancient Greek

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[106] Olaf Pedersen attributes "the disappearance of the Greek tongue," and thus the inability to comprehend Greek sources, as "the decisive factor" in stunting the development of early Medieval astronomy in the West; according to him "the West was left with a small number of works written by Latin authors of minor scientific importance and inferior quality compared with Ptolemy or his Greek commentators" ("The *Corpus Astronomicum* and the Traditions of Medieval Latin Astronomy," pp. 59-60).

[107] Rosenthal, *The Classical Heritage in Islam*, p. 14.

[108] Neither Ibn al-Nadīm's *The Fihrist of al-Nadīm* nor Sezgin's *GAS,* 6 include Roman authors in their listings of works translated into Arabic.

[109] See *Almagest* I.1 (Ptolemy's *Almagest*, p. 36, "Relation of astronomy to philosophy").

[110] To summarize, these *Almagest* translations include: a lost Syriac version translated from the Greek; three different versions from Greek into Arabic (two for the caliph Maʾmūn): one by al-

scientific works, and those of other cultures. However, the translation of the *Planetary Hypotheses* into Arabic deserves special mention given its significant role in putting forth the physical component for the picture of the universe, i.e., the so-called "Ptolemaic system" of nested orbs along with absolute distances and sizes of the planets. The *Planetary Hypotheses* complemented the mathematical models of the *Almagest*, and handed Islamic astronomers the roadmap to a complete cosmographical system.[111]

Islamic scholars encountered Ptolemy's notion of the advancement or progress of astronomy through inquiry as a mandate. This great ancient "authority" had made it quite explicit that he was not the final word on the subject, but merely had recounted "everything useful for the theory of the heavens" up until his time in the second century; in other words, Ptolemy had done

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Ḥasan ibn Quraysh (extant traces remain in the work of al-Battānī), and another by al-Ḥajjāj ibn Maṭar; and the third translation from Greek into Arabic being by Isḥāq ibn Ḥunayn (892) for Abū al-Ṣaqar ibn Bulbul, and this version was revised by Thābit ibn Qurra (d. 901) (Morelon, "Eastern Arabic Astronomy," pp. 21-23). See also Ibn al-Nadīm, who reports attempts at translating the *Almagest* into Arabic even earlier (in the eighth century) due to the interest of Yaḥyā ibn Khālid, the Barmakid vizier to the caliph Hārūn al-Rashīd. Ibn al-Nadīm also adds al-Nayrīzī to the list of translators, stating this was corrected by Thābit (*The Fihrist of al-Nadīm*, vol. 2, pp. 639-40); Sezgin, *GAS*, 6: 83-96; and Toomer, Ptolemy's *Almagest*, pp. 2-3. On the other hand, Latin versions of the *Almagest* only became available around the twelfth century, with scholars such as Gerard of Cremona (d. 1187) translating from the Arabic; only later were there translations from the original Greek.

[111] The entire two books of the *Planetary Hypotheses* are extant in Arabic translation (by an unknown translator with corrections by Thābit ibn Qurra); only the first part of Book I is extant in Greek; and there is a fourteenth-century Hebrew translation based on the Arabic version. The work was plagued by a series of various (mis)translations, which eventually led to an English translation, and commentary on just the supposedly "lost" Book I, part 2 by B. Goldstein ("The Arabic Version of Ptolemy's Planetary Hypotheses," pp. 3-4). (The entire text has yet to be critically edited, though there are partial translations into German and French.) Also see Neugebauer, *HAMA*, pp. 900-1, 918-19; Ragep, *Tadhkira*, p. 27, fn. 7; and Sezgin, *GAS*, 6: 94-95.

his part by updating the four elapsed centuries since Hipparchus's observations, and it was now up to Islamic astronomers to continue the struggle for astronomical advancement some seven centuries later, by correcting results and striving for greater accuracy, the advantage that long intervals of time provides to test and improve upon past observations.[112] Needless to say elementary Islamic astronomical textbooks on *hayʾa* were the beneficiaries of this directive.

[112] See *Almagest*, I.1 [Preface], VII.1 and 3, and XIII.11 [Epilogue] (Toomer, Ptolemy's *Almagest*, pp. 37 [esp. 37, fn. 11.], 321, 329, 647 respectively). A. I. Sabra reiterates the point that: "Islamic astronomers must have derived much hope and encouragement from the fact that their observational activities were taking place at a time sufficiently remote from Ptolemy's to allow for obtaining significant results, the intervening period being significantly longer than the one that had separated Ptolemy's own observations from, say, those of Hipparchus" ("Configuring the Universe. Aporetic, Problem Solving, and Kinematic Modeling as Themes of Arabic Astronomy," p. 289). It strikes me that the mandate for scientific advancement so dearly upheld by Islamic astronomers stands in sharp contrast to what was occurring in the Latin Middle Ages; McCluskey bemoans that "our question should not be what contributed to progress in astronomy, for episodes of progress were few. Instead, we will ask what forestalled the decline of astronomy and shaped the continuation and renewal of astronomical practice and knowledge from the fourth to the thirteenth centuries" (*Astronomies and Cultures in Early Medieval Europe,* ix).

§ I.2.4a The "Moderns" [113]

It is not uncommon to find references in *hayʾa* work referring to the opinions of the "Moderns" (see for example, *al-Mulakhkhaṣ,* **I.2 [6]**), which originally came to mean those Islamic scholars who flourished in the ninth century (or later) and provided "updated" information on ancient authorities; in the case of *hayʾa*, this usually meant Ptolemy. This new information was the fruit of concerted efforts by many individual scholars, but it was also due to sponsored scientific endeavors by various patrons that included ʿAbbāsid caliphs like al-Maʾmūn (r. 813-833).[114] So

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[113] The contrast between "ancients" and "moderns" is commonplace but has different connotations depending on the subject. For Islamic astronomers, the dichotomy is generally between the ancient Greeks and themselves. For the contrast as used in literature between the pre- and early Islamic poets versus the later ones, see Jan Geert van Gelder, "Ancients and Moderns," *Encyclopaedia of Islam*, THREE, ed. Gudrun Krämer, Denis Matringe, John Nawas, Everett Rowson. Brill Online, 2014. Reference. McGill University. 24 July 2014 http://referenceworks.brillonline.com/entries/encyclopaedia-of-islam-3/ancients-and-moderns-SIM_0040. For a fuller version of this article, see also Jan Geert van Gelder, "Muḥda<u>th</u>ūn," *Encyclopaedia of Islam*, 2nd ed. (Leiden: E. J. Brill, 2004), vol. 12, pp. 637-40.

[114] Maʾmūn sponsored two sets of observations (one in Baghdad in 828, by astronomers who included Yaḥyā ibn Abī Manṣūr; and another that lasted more than a year [between 831 and 833] near Damascus) with the intent of verifying Ptolemy's parameters of the *Almagest* and *Handy Tables*. One important improvement was determining new values for the obliquity of the ecliptic (see Len Berggren, "Maʾmūn,"and Benno van Dalen, "Yaḥyā ibn Abī Manṣūr," in *The Biographical Encyclopedia of Astronomers*, vol. 2, p. 733 and vol. 2, pp. 1249-50 [respectively]); and Ibn al-Nadīm, *The Fihrist of al-Nadīm,* vol. 2, p. 653. In addition, Maʾmūn sent a group of scientists to survey the Plain of Sinjār in upper Mesopotamia in order to determine a more precise measurement for a meridian degree (see F. J. Ragep, "Islamic Reactions to Ptolemy's Imprecisions," in *Ptolemy in Perspective: Use and Criticism of His Work from Antiquity to the Nineteenth Century*, ed. Alexander Jones [Dordrecht; New York: Springer, 2010], pp. 124-25). See also Y. Tzvi Langermann ("The Book of Bodies and Distances of Ḥabash al-Ḥāsib," *Centaurus* [1985]: 108-28), who presents a portion of Ḥabash's Arabic text

some three centuries later, by the twelfth century, Jaghmīnī would have inherited a rather extensive corpus of *hayʾa* works stemming from this period, many synthesized and transformed, to help him compose his elementary theoretical textbook on astronomy. What follows then is a brief overview of some of the key astronomical textbooks within this tradition that Jaghmīnī might well have had at his disposal even though we cannot in every case prove influence. Such an overview will help us assess how the *Mulakhkhaṣ* fits into the *hayʾa* genre.

It has been suggested that during the earliest stages of this formative period of science, the ʿAbbāsid astronomer Yaʿqūb ibn Ṭāriq (fl. late eighth-century Baghdad) composed one of the first *hayʾa* works, based on the title being *Tarkīb al-aflāk* (On the Arrangement of the Orbs), and also that the work deals with planetary sizes and distances,[115] a common topic associated with most (though not all) *hayʾa* works (i.e., it is omitted in the *Mulakhkhaṣ*). This unique work, extant only in fragments, was composed circa 777/8 (so prior to the translations of most Greek scientific texts) and uses Indian techniques to compute the planetary distances. But as al-Bīrūnī aptly commented, the Hindu approach is markedly different than Ptolemy's "computation of the distances of the planets in the *Kitâb-almanshûrât*, and in which he has been followed both by the ancient and the modern astronomers."[116] Indeed, once Ptolemy's *Almagest* and *Planetary Hypotheses* were translated into Arabic in the ninth century, it is not an exaggeration to state that they become the formative works for the *hayʾa* tradition. So it is not surprising that Bīrūnī, writing two centuries later, would view Yaʿqūb ibn Ṭāriq's cosmology as unfamiliar and "based

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with English translation, clarifying (on p. 109) that despite its title, this work "is a record of the scientific projects carried out by the Caliph al-Maʾmūn."

[115] See Kim Plofker, "Yaʿqūb ibn Ṭāriq," in *The Biographical Encyclopedia of Astronomers*, vol. 2, pp. 1250-51; and David Pingree, "The Fragments of the Works of Yaʿqūb ibn Ṭāriq," *Journal of Near Eastern Studies* 27, no. 2 (Apr., 1968): 98, 105-20 (Pingree includes parts of Bīrūnī's commentary on *Tarkīb al-aflāk* [found in *Alberuni's India*, vol. 2, pp. 67-68, 80] in addition to his own comments). See also Ibn al-Nadīm, *The Fihrist of al-Nadīm,* vol. 2, p. 659; Jamāl al-Dīn Abū al-Ḥasan ʿAlī ibn Yūsuf al-Qifṭī (d. 1248), *Taʾrīkh al-ḥukamāʾ*, ed. J. Lippert (Leipzig: Dietrichische Verlagbuchhandlung, 1903), p. 373; and Sezgin, *GAS*, 6: 124-27.

[116] *Alberuni's India*, vol. 2, p. 69.

on a principle which is unknown to me in the present stage of my knowledge."[117] Bīrūnī was certainly no Hellenophile;[118] he simply was acknowledging the fact that by the eleventh century the impact of Hindu traditions for Islamic astronomers was overshadowed by the Ptolemaic one.

Yet one should not assume that embracing Ptolemaic astronomy sentenced Persian, Syriac, and other Greek sources into forced retirement. In support of this, we have the case of a recently-identified tenth-century *hayʾa* treatise indicating Sanskrit and Syriac influences. This is the discovery of the lost Arabic original of a work that had been incorrectly attributed in its Latin translation to Māshāʾallah (fl. Baghdad, 762-ca. 815), one of the early ʿAbbāsid astrologers associated with the courts of al-Manṣūr and al-Maʾmūn; in fact, it is probably a tenth-century composition.[119] The treatise, translated into Latin as *De scientia motus orbis* or *De elementis et orbibus coelestibus*, in twenty-seven chapters (with a longer version in forty chapters), includes introductory chapters on *hayʾa* dealing with phenomena in both the celestial and sub lunar world, but with a focus on glorifying God and how the celestial orbs influence the sub lunar region.[120]

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[117] See *Alberuni's India*, vol. 2, p. 70. Bīrūnī provides a brief synopsis of Hindu planetary theory and points out that it differs from the Ptolemaic system (p. 69).

[118] See David Pingree, "Hellenophilia versus the History of Science," *Isis* 83, no. 4 (Dec., 1992): 554-55. Cf. Sabra, "Reply to Saliba," pp. 342-43.

[119] This was conveyed to me in a personal conversation from Dr. Taro Mimura (University of Manchester), who examined the treatise preliminarily to determine its authorship and date, and is currently preparing an edition and translation of the text.

[120] Ibn al-Nadīm lists the work as a "book known as The Twenty-Seven" (*The Fihrist of al-Nadīm*, vol. 2, pp. 650-51). So does al-Qifṭī, *Taʾrīkh al-ḥukamāʾ*, p. 327 and Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)*, p. 17 (no. 18, A2). For sources citing the Latin translation, see: Francis J. Carmody, *Arabic Astronomical and Astrological Sciences in Latin Translation: A Critical Bibliography* (Berkeley: University of California Press, 1956), pp. 32-33 (no. 8: De motibus [De orbe]); David Pingree, Mā<u>sh</u>āʾ allāh," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie (New York: Charles Scribner's Sons, 1974), vol. 9, p, 162 [no. 25 in Pingree's list of 28]); Julio Samsó, "Mā<u>sh</u>āʾ Allāh," *Encyclopaedia of Islam*, 2nd ed. (Leiden: E. J. Brill, 1991), vol. 6, pp. 710-12; and Sezgin, *GAS*, 6: 129 (no. 2).

Ptolemy is quoted; however, the treatise uses non Ptolemaic planetary models, seemingly similar to Sanskrit texts and based on Syriac sources.[121]

Nevertheless, Ptolemaic astronomy gained a stronghold, and making Ptolemy's works more comprehensible became a high priority for Islamic astronomers. One of the earliest introductory accounts on various aspects of Ptolemaic spherical astronomy and planetary theory was compiled by Muḥammad ibn Kathīr al-Farghānī, a scholar affiliated with the ninth-century Baghdad ʿAbbāsid court. His thirty-chapter compendium on the science of the stars (*Jawāmiʿ ʿilm al-nujūm*),[122] composed between 833 (after Maʾmūn's death) and 857, has often been

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[121] See David Pingree, "Māshāʾ Allāh: Some Sasanian and Syriac Sources," in *Essays on Islamic Philosophy and Science*, ed. George F. Hourani (Albany: State University of New York, 1975), pp. 10-12.

[122] Farghānī's *Jawāmiʿ* is not really a "summary," but more a compilation of selected parts of Ptolemy's *Almagest* (see Ibn al-Nadīm, *The Fihrist of al-Nadīm,* vol. 2, p. 660); and in fact many titles have been attributed to this work: Ḥājjī Khalīfa just gives *Kitāb al-Fuṣūl al-thalāthīn* (A Book in 30 chapters) in his *Kashf al-ẓunūn* (vol. 4, pp. 438-39); but al-Qifṭī refers to it as *Madkhal ilā ʿilm hayʾat al-aflāk wa-ḥaraqāt al-nujūm* (Introduction to the Science of the Structure (*hayʾat*) of the Orbs and the Movements of the Stars) (*Taʾrīkh al-ḥukamāʾ*, p. 78), although Farghānī refers to his work as *ʿilm al-nujūm*, i.e., not *ʿilm al-hayʾa*, and he restricts the use of the word *hayʾa* to the title of a chapter discussing the "arrangement" of the nested orbs (see *Jawāmiʿ* , Ch. 12 [Paris, BnF, ar. MS 2504, ff. 127b-128b ; Golius, pp. 45-49]). For more on Farghānī, the astronomer-astrologer-engineer, plus an overview of the content of the *Jawāmiʿ*, see A. I. Sabra, "Al-Farghānī," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie (New York: Scribner's Sons, 1972), vol. 4, pp. 541-45 and Bahrom Abdukhalimov, "Aḥmad al-Farghānī and His Compendium of Astronomy," *Journal of Islamic Studies* 10.2 (1999): 142-58. Also see, Fuat Sezgin's reprint of Golius's 1669 Arabic printed edition with Latin translation (Aḥmad ibn Muḥammad ibn Kathīr al-Farghānī [Alfraganus] (about 850 A.D)*, Jawāmiʿ ʿilm al-nujūm wa-uṣūl al-ḥarakāt al-samāwiyya*, ed. Jacob Golius [Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften an der Johann Wolfgang Goethe Universität, 1986]); Sezgin, *GAS*, 6: 149-51; and Gregg DeYoung, "Farghānī, in *The Biographical Encyclopedia of Astronomers*, vol. 1, p. 357.

characterized as a popular elementary textbook—this despite its lack of any illustrations—due to the scope of Farghānī's descriptive selections from Ptolemy's *Almagest*, which are replete with basic astronomical information, definitions, concepts, and parameters, many (but not all) "updated" Maʾmūn values (who Farghānī specifically references).[123] For anyone unacquainted with Ptolemaic astronomy or seeking a quick reference source, this single textbook introduces the reader to a wide range of topics that include *both* the celestial and terrestrial realms, although certain subjects mentioned in the *Almagest*, such as astronomical instruments, are noticeably absent.[124] Aside from providing the names of the Islamic months (ch. 1), Farghānī avoids matters directly applicable to religion and natural philosophy, thus making it more in line with what we have described as the "*hayʾah* tradition."[125] However, a savvier scholar might object to it meriting this categorization, finding fault with its (dis)organization and oversimplifications, and lack of attention to what one might call the "how-to's" of planetary motion, which include his presentation of Ptolemy's nested spheres (e.g., he constantly lumps the upper and lower planets

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[123] Farghānī sometimes provides the old (Ptolemaic) along with the new (Maʾmūnī) parameters, exemplified by his statement that a number of scholars give the Maʾmūn value of 23;35 for the ecliptic obliquity as an update to Ptolemy's 23;51 (*Jawāmiʿ*, Ch. 5 [Paris, BnF, ar. MS 2504, f. 121a; Golius, p. 18); and sometimes he gives only Maʾmūn's new information, such as his measurements for the Earth's circumference (20,400 miles) and the Earth's diameter (approx. 6,500 miles) (*Jawāmiʿ*, Ch. 8 [Paris, BnF, MS ar. 2504, f. 124a; Golius, p. 31]). However, sometimes he retains the old (perhaps unknowingly) rather than presenting the new, as in the case of maintaining Ptolemy's precessional rate of 1°/100 (*Jawāmiʿ*, Ch. 13 [Paris, BnF, MS ar. 2504, f. 128b ; Golius, pp. 49-50]) versus replacing it with the updated 1°/66 value. For more specifics on Farghānī's parameters, and comparisons with other sources, see the **Commentary**, including the charts.

[124] One would have thought Farghānī, being an engineer, would have included some discussion of instruments, especially since Ptolemy deals with instruments and their construction in the *Almagest*. Perhaps, he felt it was unnecessary since he had also composed a separate treatise on the astrolabe.

[125] This is Langermann's assessment in designating Farghānī's work as a *hayʾa* "specimen" (*Ibn al-Haytham's "On the Configuration of the World,"* p. 31).

together, is vague on positions of eccentrics, and so forth).[126] Nevertheless, given the time and place, one must credit Farghānī with providing a description of the *"hayʾa"* of the orbs for each of the planets and their distances from the Earth (Ch. 12), and further acknowledge his overall attempt to make more explicit a lot of information often deeply buried within the thirteen books of the *Almagest*, which includes Ptolemy's numerous parameters. One example is Farghānī's calculation of the distances of the planets from the Earth in miles (in Ch. 21), which seems to be based on an independent calculation using parameters from the *Almagest* rather than the *Planetary Hypotheses.*

It is not at all clear who Farghānī's target audience was (i.e., court officials or the general public); however, the *Jawāmiʿ* inspired a few Arabic commentaries—one by al-Qabīṣī (d. 967),[127] another by Ibn Sīnā's companion and literary secretary al-Jūzjānī (eleventh century),[128] and possibly a third by al-Bīrūnī[129]—which indicates the work was known, and taken seriously by later scientists. But since there are relatively few extant copies and commentaries of the *Jawāmiʿ*, certainly in comparison with other later *hayʾa* works and their commentaries, perhaps it should be considered more of a formative textbook within an Islamic context relative to those

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[126] Langermann suggests that Ibn al-Haytham may have had Farghānī's *Jawāmiʿ* in mind when he criticized his predecessors for producing works that "fall short" in that they lack "an explicit enunciation of the way in which the motions of the stars take place on the various spheres" (*Ibn al-Haytham's "On the Configuration of the World,"* pp. 26-28).

[127] Al-Qabīṣī also wrote a work on sizes and distances. See Sezgin, *GAS*, 6: 209 (nos. 1 and 2); and Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)*, p. 85 (no. 205, A3 and A4).

[128] See F. Jamil Ragep, "The Khilāṣ kayfiyyat tarkīb al-aflāk of al-Jūzjānī: A Preliminary Description of Its Avicennian Themes," in *Avicenna and his Legacy*: *A Golden Age of Science and Philosophy,* ed. Y. Tzvi Langermann (Turnhout: Brepols, 2010), pp. 303-8.

[129] The work is listed as corrections to Farghānī's chapters (*Tahdhīb fuṣūl al-Farghānī*) in D. J. Boilot, "L'oeuvre d'al-Beruni, Essai bibliographique," *Mélanges de l'Institut Dominicain d'Études Orientales* 2 (1955): 181 (no. 14); Sezgin, *GAS*, 6: 274 (no. 13); and Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)*, p. 152 (no. 348, A26).

general astronomical works that came after it. On the other hand, its popularity and influence as an astronomical textbook in medieval Europe is undeniable, given the longevity of its wide circulation there.[130]

Another scholar active in promoting the exact sciences in ninth-century Baghdad was the Ṣābian Thābit ibn Qurra (221-288 H [836-901]), who flourished during the reigns of several post-Maʾmūn ʿAbbāsid caliphs.[131] Renowned for his extensive number of translations and revisions of Greek works (which included the *Almagest* and *Planetary Hypotheses*), he also composed numerous astronomical compositions, several of them on Ptolemaic astronomy, and among these a few that can be classified as introductions.[132] It has been suggested that Thābit

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130 The influence of al-Farghānī [Alfraganus] on medieval European astronomy is indicated by the number and longevity of the Latin translations and printed editions of the *Jawāmiʿ* or *Elements*: two twelfth-century Latin translations, one in Hebrew by Jacob Anatoli (fl. thirteenth century), which served as a basis for a third sixteenth-century Latin translation. It is noteworthy that in the fifteenth century Regiomontanus lectured on Farghānī at the University of Padua (see Noel Swerdlow, "Science and Humanism in the Renaissance: Regiomontanus's Oration on the Dignity and Utility of the Mathematical Sciences," in *World Changes: Thomas Kuhn and the Nature of Science*, ed. Paul Horwich [Cambridge, Mass.: MIT Press, 1993], pp. 131-68; and James Steven Byrne, "A Humanist History of Mathematics? Regiomontanus's Padua Oration in Context," *Journal of the History of Ideas* 67, no. 1 [January 2006]: 41, 43).

131 The number of ʿAbbāsid caliphs that spanned Thābit's lifetime is rather impressive, and include: al-Muʿtaṣim (r. 833-842), his son al-Wāthiq (842-847), his brother al-Mutawakkil (847-861) and his son al-Muntaṣīr (861-862), al-Mustaʿīn (862-866), al-Muʿtazz (866-869) and al-Muʿtamid (870-892) [sons of al-Mutawakkil], and al-Muʿtaḍid (892-902).

132 Régis Morelon attributes to Thābit between 30 to 40 astronomical works, with at least seven of these related to Ptolemaic astronomy (*Thābit ibn Qurra: Œuvres d'astronomie* [Paris: Les Belles Lettres, 1987], pp. XI-XXIII, XXV- XXVI). See also al-Qifṭī, *Taʾrīkh al-ḥukamāʾ*, pp. 115-22 at 117; Ibn Abī Uṣaybiʿa, *ʿUyūn al-anbāʾ*, Beirut ed., pp. 295-300 at 298; and Ibn al-Nadīm, *The Fihrist of al-Nadīm,* vol. 2, pp. 647-48; Sezgin, *GAS*, 6: 163-70; and Morelon, "Ṯābit b. Qurra and Arab Astronomy in the 9th Century," *Arabic Sciences and Philosophy* 4 (1994): 111-12.

may have been familiar with, even influenced by, the work of his predecessor Farghānī;[133] however, Régis Morelon asserts that Farghānī's work was "more superficial" (though not indicating in what sense), and cites their only commonality as being that both had modified Ptolemy's parameters on the ecliptic obliquity (though each gives a slightly different value), and both had agreed on the motion of the solar apogee (taken to be fixed by Ptolemy).[134] In fact there are some significant differences between the two regarding focus, scope, and content, at least as indicated by Thābit's two short extant works on Ptolemaic astronomy, his *Tashīl al-Majisṭī* and *Fī dhikr al-aflāk…*;[135] but they also had some commonalties, and both differences and

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[133] Francis J. Carmody suggests a "possible" relationship between the two, and even that Thābit could have been influenced by Farghānī, based on connections within some minor works by Thābit; however, Carmody's speculation rests heavily on his use of the Latin translations for his analysis, and some of these may have been modified from the Arabic originals (*The Astronomical Works of Thabit b. Qurra* [Berkeley: University of California Press, 1960], pp. 17, 117-18, 120).

[134] See Morelon, *Thābit ibn Qurra*, pp. XLIV-XLV. Thābit gives 23;33 for the ecliptic obliquity (*Tashīl al-Majisṭī* [Morelon, *Thābit ibn Qurra,* Arabic: p. 8, line 7]), and Farghānī gives 23;35 compared with Ptolemy's value of 23;51,20 (*Almagest*, I.12). Each may have been relying on different Maʾmūn observations for their modifications; however, to somewhat muddy the waters, A. I. Sabra points out that Farghānī also gives the inclination of the ecliptic as 23;33 for the year 225 of Yazdegerd (=857-8) in his work on the astrolabe ("Farghānī," p. 543). See also Ragep "Islamic Reactions to Ptolemy's Imprecisions," pp. 129-30 (on "The Obliquity of the Ecliptic").

[135] Morelon refers to these two works by Thābit as introductions and presents an analysis and critical Arabic editions with French translations of both *Tashīl al-Majisṭī* (تسهيل المجسطي) ("L'Almageste simplifié") [Istanbul, Ayasofya MS 4832, ff. 52a-53b] and *Fī dhikr al-aflāk wa-khalaqihā* [correct to *ḥalaqihā*] *wa-ʿadad ḥarakātihā wa-miqdār masīrihā* (في ذكر الأفلاك وخلقها [!] وعدد حركاتها ومقدار مسيرها) ("Présentation des orbes des astres, de leur disposition [should be corrected to "rings"], du nombre de leurs mouvements et de la valeur de leur progression") [Istanbul, Ayasofya MS 4832, ff. 50a-51a (*Thābit ibn Qurra*, pp. XIV, XIX, XX, XXIV- XXV, XXXVII-XLIII). Also see Camody for a brief overview of the content of the

similarities are worth pointing out here for what they indicate about teaching astronomy during this period. Part of their differences lie in the fact that Thābit's introductions deal exclusively with the celestial realm, whereas Farghānī's *Jawāmiʿ* was far more ambitious in the range of subject matter he covered. So given Thābit's focus on the celestial bodies and their movements, he excludes certain terrestrial-related subjects such as determining the sphericity and the centrality of the Earth (found in Farghānī [chs. 3 and 4]), and the discussion of the inhabited world (contained in Farghānī [ch. 8]);[136] and interestingly the word *hayʾa* never enters his picture (it at least makes a cameo appearance in Farghānī [Ch. 23]). Thābit's presentation of material is pedagogically far better organized and structured, certainly when compared to Farghānī's tendency to conflate topics and his piecemeal approach,[137] but then again Thābit confined his subject to the arrangement of the celestial orbs (*tarkīb al-aflāk*), and did not discuss the divisions of the sublunar realm. On the other hand, both have several things in common: they both provide basic astronomical definitions that underscore the fact that a technical terminology was well-established by the ninth century (though in both cases certain terms are in need of refinement[138]); and both felt no compulsion to provide illustrations for their "beginner" students. Both also seem

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Latin translation of Thābit's *Tashīl al-Majisṭī* [= *De Hiis que indigent antequam legatur Almagesti*] (*The Astronomical Works of Thabit b. Qurra*, pp. 21, 117-18).

[136] Generally speaking, absent from Thābit are topics associated with *hayʾat al-arḍ*, such as the seven climes (discussed in Ptolemy's *Almagest* and *Geography* [both works which Thābit translated] and also Farghānī's *Jawāmiʿ*). On the other hand Thābit does include items peripherally associated with terrestrial localities, such as definitions for the meridian and horizon circles, zenith, and so forth.

[137] In fact, Thābit's organization of definitions in the *Tashīl al-Majisṭī* is strikingly similar to Jaghmīnī's, whose definitions are found in his separate chapters on circles and on arcs (*Mulakhkhaṣ,* **I.III** and **I.IV**); the similarity is such that it is worth considering the former as a model for Jaghmīnī, especially since most other *hayʾa* works did not have separate chapters on circles and arcs.

[138] For example, both Farghānī and Thābit seem unconcerned about distinguishing when to use sphere (*kura*) versus orb (*falak*) to mean a constituent part of the general configuration of the world; but this is also an issue that continues well into the thirteenth-century.

content to present parameters as rough approximations, which I find a bit puzzling (e.g., both give the Sun's daily motion simply as 59 minutes of arc even though Ptolemy's value is 0;59,8,17,13,12,31). Now one can obviously attribute this to their being contained in introductory works (but then again Jaghmīnī gives 0;59,8,17), but as mentioned above, this was a period when the Caliph Maʾmūn was sponsoring astronomical observations that produced more precise parameters. In any event, both are certainly keen on incorporating Maʾmūn's new results into their works; though here we find some differences (minor and more significant ones) between the two scholars: whereas Farghānī maintains the Ptolemaic value for precession, Thābit acknowledges modifications have been made, though he provides no specific parameters;[139] and Farghānī presents Maʾmūn's updated values for the Earth's diameter and circumference, and Thābit omits these. On the other hand, Thābit presents the values for the planetary distances, and furthermore he uses the values contained in the *Planetary Hypotheses* (but without citing his source),[140] whereas Farghānī calculates parameters for determining his nearest distances of the planets from the Earth based on the *Almagest*. All of this should remind us that scientists working on the same subject matter, in roughly the same time and location, do not necessarily have access to the same information or are knowledgeable of all available extant sources or are even aware of all new developments. Nor might they have the same views of what the scope and content of their subject entailed.

Furthermore, one should not assume that available new information will be assimilated immediately. Here we have the example of al-Kindī (fl. ninth century),[141] who demonstrates a

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[139] See Morelon, *Thābit ibn Qurra, Tashīl al-Majisṭī* (Arabic: p. 16, lines 10-11).

[140] See Morelon, *Thābit ibn Qurra, Tashīl al-Majisṭī* (Arabic: p. 14, line 5-p. 15, line 3). Since he doesn't reference the values, Carmody is apparently unaware that the values contained within Thābit's *De Hiis* are from the *Planetary Hypotheses*, since he claims that "there is no evidence that Thâbit knew this work" (*The Astronomical Works of Thabit b. Qurra*, p. 19; cf. pp. 130, 137). Neugebauer reiterates the point that Thābit ibn Qurra "fully confirms the numbers from the Planetary Hypotheses" (*HAMA*, p. 920 and fn. 23).

[141] Al-Kindī also flourished during the reigns of several caliphs who included al-Maʾmūn, al-Muʿtaṣim, and al-Mutawakkil. Rosenthal's article is the seminal article on "Al-Kindī and Ptolemy"; but for more on his astronomical writings, also see Ibn al-Nadīm, *The Fihrist of al-*

clear "unreadiness to discard all the vestiges" of the ancient heritage even in light of new developments.[142] It is well known that al-Kindī considered it his "personal task to serve as an Arab transmitter and interpreter" of difficult Greek philosophical and scientific works, and to popularize them for "the curious student or interested layperson."[143] However, if his intention (as he claimed) was to elucidate texts such as the *Almagest* for beginners, his choice to "faithfully follow" Theon's extremely technical *Commentary on the Almagest* as his model for his *Almagest* commentary (*Kitāb fī al-ṣināʿa al-ʿuẓmā*) was odd, as was his decision to discuss the first eight chapters of Book I, which focus on isoperimetric problems related to the Earth's sphericity;[144] one would assume this subject would have had a limited appeal for inclusion in an elementary astronomical textbook, even al-Kindī's simplified rendition of it. However, al-Kindī's decision to use Theon as his source, and also to examine specific issues in great detail (such as determining the Earth's diameter) within a Greek context and completely devoid of any new astronomical developments indicate his strong commitment to ancient sources. It did not go unnoticed that "No mention is made by al-Kindī of the measurement of the meridian under al-Maʾmūn"… "which is inconceivable that he should not have known about it."[145] Rosenthal suggests (halfheartedly) that al-Kindī's rivalry with the Banū Mūsā, who were active in establishing the new measurements during this period, may have been a contributing factor in al-Kindī's decision.

Nadīm, vol. 2, pp. 618-20 (His Astronomical and Cosmological Books); and Sezgin, *GAS*, 6: 151-55 at 153 (no. 1).

[142] See Rosenthal, "Al-Kindī and Ptolemy," p. 455.

[143] Rosenthal, "Al-Kindī and Ptolemy," pp. 440, 444-45, 455. See also A. I. Sabra, "Some Remarks on Al-kindi as a Founder of Arabic Science and Philosophy."

[144] For more on Theon's *Commentary of the Almagest*, see above **§ I.2.3c: The Ptolemaic Aftermath**. For specifics regarding the content of al-Kindī's *Kitāb fī al-ṣināʿa al-ʿuẓmā,* which includes evidence that his source was Theon's *Commentary*, see Rosenthal, "Al-Kindī and Ptolemy," pp. 436-53, esp. 446.

[145] Rosenthal, "Al-Kindī and Ptolemy," p. 454.

An account of the Palmyra-Raqqa scientific expedition in Syria is reported by the Banū Mūsā in a treatise entitled *Ḥarakat al-aflāk* (Motion of the Orbs);[146] and the exact same passage (in fact the entire extant fragment) is contained in another more extensive anonymous treatise attributed to Qusṭā ibn Lūqa (another ninth-century scholar), of Greek Christian origin who composed and translated numerous scientific works. Either attribution makes this theoretical astronomical treatise, which cites Ptolemy and the *Almagest*, an example of an early *hayʾa* work.[147] This commentary strikingly contains some forty-eight two-dimensional mathematical

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146 F. J. Ragep provides a passage of the expedition from the *Ḥarakat al-aflāk* (both the Arabic and an English translation), and situates the expedition within the broader context of the complexity of introducing new parameters, and balancing tradition and innovation in Islamic science (*Tadhkira*, pp. 502-10). See also F. J. Ragep, "Islamic Reactions to Ptolemy's Imprecisions," pp. 122-25. For listings of this work by the Banū Mūsā, see Sezgin, *GAS*, 6: 147 (no. 3); and Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)*, pp. 35-36 (no. 74, A3). The passage is contained in an extant fragment of Damascus, Ẓāhiriyya 4489, f. 12a-b; and the treatise begins "qāla Banū Mūsā" (f. 1b).

147 See Oxford, Bodleian Library, Seld 11, ff. 38b-85b (the passage is on ff. 38b-45a, 47b-48a). This witness describes the celestial world (unlike the Damascus fragment which only deals with the terrestrial realm); and a codex table of contents lists it as *Hayʾat al-aflāk* by Qusṭā ibn Lūqā, but this is clearly in a different hand than the witness itself. Though the text itself is anonymous, George Saliba has consistently attributed this early *hayʾa* work to Qusṭā; see Saliba, "Early Arabic Critique of Ptolemaic Cosmology: A Ninth-Century Text on the Motion of the Celestial Spheres," *Journal for the History of Astronomy* 25 (1994): 119; "Arabic versus Greek Astronomy," pp. 328, 330; *A History of Arabic Astronomy*, p. 17; and *Islamic Science and the Making of the European Renaissance*, pp. 18, 262 (note Saliba cites Sezgin here to support his position [*GAS*, 6: 181-82 (no. 2)], but severely criticizes Sezgin's evidence in "Early Arabic Critique of Ptolemaic Cosmology," p. 119). For more on Qusṭā and his works, see Ibn al-Nadīm, *The Fihrist of al-Nadīm,* vol. 2, pp. 694-95; Elaheh Kheirandish, "Qusṭā ibn Lūqā al-Baʿlabakkī," in *The Biographical Encyclopedia of Astronomers*, vol. 2, pp. 948-49); al-Qifṭī,

illustrations that complement extensive descriptions of various aspects of celestial motions and terrestrial phenomena (such as the lunar and solar eclipses, retrogradation, and so forth). The planets are treated individually, i.e., they are not generically lumped together (a characteristic of other astronomical treatises that led to criticism); however, no attempt has been made to provide a coherent physical picture of the universe. Noticeably absent (from the extensive figures) is an illustration of the configuration of the world; and also the word *hayʾa* (as far as I could tell) does not appear throughout the entire treatise (it is written only in the codex's table of contents, and again not in the copyist's hand). Nevertheless, the word *falak* (not *kura*) is systematically used throughout the treatise, which may be indicative of physical underpinnings at work.[148] Clearly, a more careful analysis of this text and its parameters is needed for the future. For our present purposes , we can say that this treatise, insofar as it was ever meant as a "teaching" textbook, is clearly not well-organized (the subject matter is in one continuous stream distinguished only by subtitles). It does, though, present the reader with many parameters (again as approximations[149]), including the latest values gleaned from the scientific expeditions.

Al-Kindī's unwillingness to abandon Greek traditions in light of new developments is somewhat ironic given his advocacy of upholding Ptolemy's imperative of scientific advancement, which demanded "the necessity of [building on] the consecutive labors of scholars and thinkers."[150] As Rosenthal noted, the novelty of a subject may need assimilation time during its pioneering stages,[151] but al-Battānī (d. 317 H [929 CE]) provides us with a prominent counter-example. In the preface to his great astronomical *Zīj,* Battānī explicitly informs us that his work

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Taʾrīkh al-ḥukamāʾ, pp. 262-63; and Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)*, pp. 59-60 (no. 118).

148 The illustrations in this treatise are more mathematical than physical depictions of the orbs, along the lines one finds in the *Almagest*. But it should be noted that many diagrams in astronomical works, even *hay'a works*, use "mathematical" simplifications rather than the full, spherical versions.

149 E.g., the values given for the climes are rounded Ptolemaic ones (see Oxford, Bodleian Library, Seld 11, f. 44b and Damascus, Ẓāhiriyya 4489, f. 11b).

150 Rosenthal, "Al-Kindī and Ptolemy," pp. 445, 447.

151 See Rosenthal, "Al-Kindī and Ptolemy," p. 455.

is also in accordance with Ptolemy's imperative for scientific advancement;[152] but in contrast to al-Kindī, he presents, within fifty-seven chapters, new and more precise astronomical parameters (many beyond sexagesimal seconds) based on his observational activities that spanned over forty years (264-306 H [877-918]).[153] The focus of Battānī's *al-Zīj al-Ṣābiʾ*,[154] as its title indicates, is

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[152] See Carlo Alfonso Nallino, *Al-Battānī Sive Albatenii Opus Astronomicum,* 3 vols. (Milan: Pubblicazioni Del Reale Osservatorio di Brera, Milano, 1899-1907), vol. 2 (1899), p. 7. As noted by Willy Hartner: "Al-Battānī tells us that errors and discrepancies found in the works of his predecessors had forced him to compose this work in accordance with Ptolemy's admonition to later generations to improve his theories and inferences on the basis of new observations, as he himself had done to those made by Hipparchus and others" ("Al-Battānī," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie [New York: Charles Scribner's Sons, 1970], vol. 1, p. 508).

[153] Much has been written on Abū ʿAbd Allāh Muḥammad ibn Sinān ibn Jābir al-Battānī al-Ḥarrānī al-Ṣābiʾ[also known as Albatenius in the Latin West]. In addition to Hartner, "Al-Battānī," brief summations of his new parameters are contained within Carlo A. Nallino, "Battānī," in *Encyclopaedia of Islam*, 2nd ed. (Leiden: E. J. Brill, 1960), vol. 1, pp. 1104-5; Julio Samsó, "Battani, Al-," in *Medieval Science, Technology, and Medicine: An Encyclopedia*, ed. Thomas F. Glick, Steven J. Livesey, Faith Wallis (New York: Routledge, 2005), pp. 79-80 and Julio Samsó, "Al-Battānī," in *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures*, p. 91. F. J. Ragep also summarizes trepidation in Islam before Battānī, and Battānī's criticism and alternatives in "Al-Battānī, Cosmology, and the Early History of Trepidation in Islam," in *From Baghdad to Barcelona. Essays on the History of the Exact Sciences in Honour of Prof. Juan Vernet*, ed. Josep Casulleras and Julio Samsó (Barcelona, 1996), pp. 283-90. Additional sources include: Ḥājjī Khalīfa, *Kashf al-ẓunūn* [Flügel, *Lexicon,* vol. 3, p. 564 (no. 6946)]; Ibn al-Nadīm, *The Fihrist of al-Nadīm,* vol. 2, pp. 661-62; Qifṭī, *Taʾrīkh al-ḥukamāʾ*, p. 280; E. S. Kennedy, "A Survey of Islamic Astronomical Tables," pp. 132-33, 154-56 (Battānī [no. 55] plus other *zīj*es influenced by al-Battānī); Sezgin, *GAS*, 6: 182-87; and Benno van Dalen, "Battānī," in *The Biographical Encyclopedia of Astronomers*, vol. 1, pp. 101-3. Also see Commentary**, II.3 [9]** and charts included in my commentary that contain his parameters.

concerned predominantly with practical rather than theoretical aspects of astronomy. However, Battānī, like Farghānī, includes a general description of the nested orbs, and also deals with many overlapping topics that make it relevant for *hayʾa* works, though the word itself is rarely used (and then to signify a general structure or configuration of the universe, not a scientific discipline).[155] But Battānī's objective was not to provide a teaching text;[156] rather, his priorities were acquiring and presenting more accurate parameters, so he was less concerned with couching them in a coherent physical cosmology. This is evident by the fact that Battānī often oversimplifies his descriptions of the celestial realm (something he shares with Farghānī and others). He also is not beyond getting the modeling wrong; for example, in the case of Mercury he presents the deferent center as the center of mean motion (whereas it should be the equant point).[157] In short, Battānī's claim to fame was due to his level of competency in providing

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[154] The title *al-Zīj al-Ṣābiʾ* or "The Ṣābian *zīj*" is a reference to Battānī's Ṣabian ancestral roots, and probable links with Ḥarrān in southern Anatolia. This also suggests connections with Battānī's older contemporary, the Ṣābian Thābit ibn Qurra, despite Carmody's statement that Battānī's *zīj* shows "no influence of [Thābit's] work or methods" (given without explanation) (*The Astronomical Works of Thabit b. Qurra,* pp. 18-19).

[155] Langermann, however, wants to situate al-Battānī, along with Farghānī, within the "*hayʾa* literature"; he views Battānī's general description of the nested orbs (Ch. 31) and presentation of parameters for planetary distances and sizes (Ch. 50) as indications of physical concerns associated with *hayʾa* works (*Ibn al-Haytham's "On the Configuration of the World,"* pp. 25-29). Cf. Carlo Nallino, who in stating that the solidity of the spheres was held by almost all Muslim writers, gives Battānī as the one counter example who left the question uncertain ("Sun, Moon, and Stars [Muhammadan]," p. 99, fn. 4).

[156] Battānī's extremely lengthy explanations (throughout the *zīj*) that accompany his parameters can be deadly for pedagogical purposes. On the other hand, E. S. Kennedy viewed his detailed contextualizing of parameters as rewarding gateways into understanding the underlying mathematics behind the numbers ("A Survey of Islamic Astronomical Tables," p. 123).

[157] Hartner points out that anyone familiar with Ptolemy would be struck by Battānī's insufficient and inaccurate explanations, and he provides us with what he refers to as "particularly

various improved parameters for planetary motion; and it is not an exaggeration to state that his *Zīj* became one of the main reference sources for generations of Islamic astronomers, including those scholars working on *hayʾa* textbooks. Battānī is the only "authority" outside of Ptolemy that Jaghmīnī specifically cites in the *Mulakhkhaṣ* (**II.3 [9]**), an indication that Battānī's influence was pervasive some three centuries after he flourished (see Commentary **I.2 [9], "On the sources"** and charts).

§ I.2.4b The "Post Modernists"

Although Jaghmīnī only specifically cites Ptolemy and his *Almagest* and Battānī, he clearly relied on a variety of other unnamed authorities and reference sources.[158] Given that he flourished some three centuries after the so-called "Moderns," and in Khwārizm (a region somewhat distant, but not isolated, from Mesopotamian scientific activities), it is not surprising that over time and space the ensuing work of other scholars would have altered the understanding of theoretical astronomy. For example, we mentioned that Jaghmīnī omits astrological topics in the *Mulakhkhaṣ*; however, this weeding out of astrology from *hayʾa* works only began in earnest beginning in the eleventh century, as we see with Ibn Sīnā's categorization. It was after all a subject sanctioned by Ptolemy (who also includes it in his *Almagest*[159]). And in tenth-century Basra, the Ikhwān al-Ṣafāʾ included both astronomy and astrology in Epistle 3 (entitled "On Astronomia") of their encyclopedic work, but with the astronomy seemingly a handmaiden to astrological applications. Their purpose was not to present a summary account of Ptolemaic astronomy, but rather to provide moral guidance through astronomical knowledge, i.e., orbs being stairways to heaven. The work (an introduction and 31 chapters) gives an overview of the stars, planets, and zodiacal signs employing basic Ptolemaic principles, but without

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bewildering features" contained in the *zīj* ("Al-Battānī," pp. 509-10). See also Samsó, "Battani, Al-," p. 79.

158 E.g., he alludes to Ptolemy's *Geography* (**II.1 [2]**).

159 E.g., see Ptolemy's discussion of the configurations of the fixed stars (*Almagest*, Book VIII.4 [pp. 407-8 and fns 185, 187, 190]).

explanations of planetary models (e.g., the terms epicycles and eccentrics never appear); and Ptolemy's *Almagest* is cited only once [ch. 26] and in the context of its application for salvation.[160]

The moral imperative underlying the astronomical teachings of the Ikhwān al-Ṣafāʾ may be considered anomalistic; however, the introduction of various aspects of theoretical astronomy for application to astrology was not unique. For example, the astrological primer of al-Bīrūnī (born 973), his *Kitāb al-tafhīm* (which he composed in both Arabic and Persian), certainly cannot be overlooked as providing a valuable "user-friendly" reference of astronomical terms, concepts, and explanations even though it is ostensibly an "astrological" text.[161] Bīrūnī's "true" attitude

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[160] The exact date of the fifty-two epistles of the Ikhwān al-al-Ṣafāʾ (the Brethren of Purity) remains as mysterious as the authors themselves. The corpus has four general divisions (Mathematics, Natural Philosophy, Sciences of the Soul and Intellect, and Theology), and Epistle 3 is contained in Mathematics, one of fourteen parts dealing with the mathematical sciences. Their citations range from the Qurʾān and *ḥadith*s to Pythagoras and Aristotle; and some of their potential sources include: Ptolemy's *Tetrabiblos*, Farghānī's *Jawāmiʿ*, Abū Maʿshar's *Introduction to Astrology*, Battānī's *Zij*, and Qabīṣī's *Introduction to Astrology*. For most of the information on the Ikhwān presented here, I am indebted to Jamil Ragep and Taro Mimura (*Epistles of the Brethren of Purity. On Astronomy. An Arabic Critical Edition and English translation of Epistle 3* [The Institute of Ismaili Studies: forthcoming]). Also see: the Foreword by Nader El-Bizri in *On Magic: An Arabic Critical Edition and English Translation of Epistle 52a. Epistles of the Brethren of Purity*, ed. Godefroid de Callataÿ and Bruno Halflants (Oxford; New York: Oxford University Press, 2011), xvii-xxi; Yves Marquet, "Ikhwān al-Ṣafāʾ," in *Encyclopaedia of Islam*, 2nd ed. (Leiden: E. J. Brill, 1971), vol. 3, pp. 1071-76; Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)*, pp. 90-91 (no. 226, E1, A1); Sezgin, *GAS*, 6: 234-39; and Živa Vesel, "Ikhwān al-Ṣafāʾ," commissioned for *The Biographical Encyclopedia of Astronomers*: http://islamsci.mcgill.ca/RASI/BEA/Ikhwan_al-Safa%27_BEA.htm Accessed on June 5, 2014.

[161] Birūnī is explicit in stating that the purpose of the *Kitāb al-tafhīm* is to provide definitions of astronomical terms dealing in the form of questions and answers to help facilitate their further application elsewhere; and he informs us: "I have begun with Geometry and proceeded to

towards astrology has been questioned, and it has been stated that he really believed that the basic tenets of astrology were spurious and that its practitioners were unscrupulous. But given his twenty-three or so compositions on the subject, we must note both the high demand for works on astrology and its complex role within Islamic society and among scholars themselves.[162]

That Bīrūnī was a fellow Khwārizmian of Jaghmīnī, albeit two centuries earlier, also underscores the fact that greater Central Asia was known for being a locus of scientific activity and creativity, and knowledge from this region disseminated throughout Islamic lands.[163] It is undeniable that many prominent scholars hailed from this area; one renowned example being Bīrūnī's contemporary Abū ʿAlī Ibn Sīnā.[164] However, there were many others (some recognizable by their *nisba*s), such as Muḥammad ibn Mūsā al-Khwārazmi (d. ca. 830), Abū Jaʿfar al-Khāzin al-Khurāsānī (d. circa 971), Abū al-Wafāʾ al-Būzjānī (d. 887 or 998), and Abū Saʿīd al-Sijzī (d. ca. 1020). Bīrūnī personally mentioned the observational improvements found in al-Khāzin's *Tafsīr al-Majisṭī*, another Ptolemaic commentary concerned with isoperimetric

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Arithmetic and the Science of Numbers, then to the structure of the Universe, and finally to Judicial Astrology, for no one is worthy of the style and title of Astrologer who is not thoroughly conversant with these four sciences" (*Kitāb al-tafhīm li-awāʾil ṣināʿat al-tanjīm* [=*The Book of Instruction in the Elements of the Art of Astrology*], trans. R. Ramsey Wright [London: Luzac and Co., 1934], p. 1).

[162] See Edward S. Kennedy, "Birūnī," vol. 2, pp. 152, 155-57.

[163] Ihsan Fazlıoğlu refers to the regions of Transoxiana, Khurāsān, and Iran as "philosophical and scientific *granaries* of Islamic civilization" for Ottoman lands ("The Samarqand Mathematical-Astronomical School: A Basis for Ottoman Philosophy and Science," *Journal for the History of Arabic Science* 14 (2008): 8, fn. 13.

[164] For a preliminary overview analyzing Ibn Sīnā's astronomical works (divided into four categories: summaries of Ptolemy's *Almagest* [which includes a rather extensive one of 659 pages]; instruments and observations; philosophical/cosmological works; and miscellaneous), see F. Jamil Ragep and Sally P. Ragep, "The Astronomical and Cosmological Works of Ibn Sīnā: Some Preliminary Remarks," in *Sciences, techniques et instruments dans le monde iranien (Xe-XIXe siècle),* études réunies et présentées par N. Pourjavady et Ž. Vesel (Tehran, 2004), pp. 3-15.

problems of the *Almagest*, Book One;[165] exchanged astronomical data and measurements with Būzjānī (a Baghdad transplant from Khurāsān), who also composed a work entitled *al-Majisṭī*;[166] and befriended (and quoted) the prolific (but not necessarily original) mathematician/astronomer al-Sijzī, who flourished in Khurāsān for some period, and composed a work enticingly entitled

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165 See Bīrūnī, *Qānūn,* vol. 2, p. 653. Recall that the subject of isoperimetrics (contained in the fragment attributed to Abū Jaʿfar al-Khāzin [Paris, BnF, MS ar. 4821, ff. 47-68]) was the focus of Theon of Alexandria's Ptolemaic commentary on the *Almagest*, Book I, and other scholars (see above **§ I.2.3c: The Ptolemaic Aftermath**). In the *Qanūn,* Bīrūnī simply mentions al-Khāzin's improved Baghdad observations (of 212 H) along with the ninth-century Maʾmūn astronomers Khālid al-Marwarrūdhī, ʿAli ibn ʿĪsā, and Sind ibn ʿAlī; but apparently he was critical of al-Khāzin in other works (see Yvonne Dold-Samplonius, "Al-Khāzin, Abū Jaʿfar Muḥammad Ibn Al-Ḥasan Al-Khurāsānī," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie [New York: Charles Scribner's Sons, 1973], vol. 7, pp. 334-35). See also Emilia Calvo, "Khāzin," in *The Biographical Encyclopedia of Astronomers* (vol. 1, pp. 628-29); and Roshdi Rashed, *Founding Figures and Commentators in Arabic Mathematics: A History of Arabic Science and Mathematics Volume 1,* ed. Nader El-Bizri (London: Routledge/Beirut: Center for Arab Unity Studies, 2012), Ch. IV: Abū Jaʿfar al-Khāzin: Isoperimetrics and Isepiphanics); Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)*, p. 82 (no. 194, A3); and Sezgin, *GAS*, 6: 190 (no. 1). For more on the other scholars, see Marvin Bolt, "Marwarrūdhī," (vol. 2, p. 740) and "ʿAlī ibn ʿĪsā al-Asṭurlābī," (vol. 1, p. 34) both in *The Biographical Encyclopedia of Astronomers*; Rosenfeld and İhsanoğlu, p. 26 (no. 42: Marwarrūdhī), p. 28 (no. 47: ʿAli al-Asṭurlābī), pp. 28-9 (no. 48: Sanad ibn ʿAlī); and Sezgin, *GAS*, 6: 159, 143-44, and 138 [respectively]).

166 According to Behnaz Hashemipour, Būzjānī's *al-Majisṭī* presents new observational data and trigonometric applications for astronomy, but he was not known for introducing any "theoretical novelties" ("Būzjānī," in *The Biographical Encyclopedia of Astronomers*, vol. 1, pp. 188-89). See also the Arabic edition by ʿAlī Mūsā, *Majisṭī Abī al-Wafāʾ al-Būzjānī* (Beirut: Markaz Dirāsā al-Waḥda al-ʿArabīya, 2010).

Kitāb al-aflāk.[167] Bīrūnī's various relationships highlight the fact that many scholars known for their compositions on more "practical" aspects of astronomy (such as instruments, observations, compiling *zīj*es, and so forth) were also writing on theoretical issues—though many of these works are either no longer extant or have yet to be carefully examined. Bīrūnī also showcases the vibrant exchange of information between scholars irrespective of time and place during the eleventh century, a phenomenon certainly not confined to this scholar or period alone.

It is also in the eleventh century that Ibn al-Haytham (who flourished in the more westerly regions of Basra and Cairo) composes his *Fī hayʾat al-ʿālam* (On the Configuration of the World),[168] a *hayʾa* work often showcased for being "revolutionary" and as the first attempt to "physicalize" the mathematical constructs of Ptolemaic astronomy. Putting aside the veracity of this claim for the moment, it is certainly undeniable that his fifteen-chapter work influenced generations of scholars throughout Islamic lands and also had a major impact on astronomical planetary theory in the Latin West.[169] Ibn al-Haytham assessed (I believe correctly) that no

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[167] This work is listed with this title in both Rosenfeld and İhsanoğlu (*Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works [7th - 19th c.]*, p. 113 [no. 296, A2]) and Sezgin, *GAS*, 6: 225 [no. 1]). But this title is not mentioned in Glen van Brummelen, "Sizjī: Abū Saʿīd Aḥmad ibn Muḥammad ibn ʿAbd al-Jalīl al-Sijzī," in *The Biographical Encyclopedia of Astronomers,* vol. 2, p. 1059 nor in Yvonne Dold-Samplonius, "Al-Sijzī," in *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Culture*, pp. 159-60. The witness I checked (Tehran, Majlis Shūrā MS 174, which was kindly provided to me by Mr. Sajjad Nikfahm) refers to as a work on judicial astrology. The content seems to deal with detailed parameters for sizes and distances and various celestial motions based on Ptolemy, and it also contains extensive tables. Al-Sizjī was apparently known for his astrological compilations and commentaries, which included at least forty-five geometrical and fourteen astronomical works.

[168] Langermann provides an edition of the text, along with an English translation and notes, in *Ibn al-Haytham's "On the Configuration of the World."* Langermann also includes a brief summary of the work in his article "Ibn al-Haytham," in *The Biographical Encyclopedia of Astronomers*, vol. 1, pp. 556-57.

[169] Ibn al-Haytham [Latinized as Alhacen or Alhazen] became known in Europe in the thirteenth

previous work on theoretical astronomy had actually explained to the reader how the various components of the Ptolemaic models operated and ultimately fit together to form a coherent whole, certainly not with a straightforward and non-technical depiction. Theoretical astronomical textbooks prior to Ibn al-Haytham tended to be general overviews, summaries, and/or (overly) technical selective discussions. In comparison, *On the Configuration of the World* attempts to match the mathematical models of the *Almagest* with physical structures to account for the various motions of the celestial bodies. To accomplish his goal, Ibn al-Haytham did not feel the need to provide parameters, proofs, a discussion of sizes and distances, or even illustrations (though there are indications that Ibn al-Haytham may have wanted to include them[170]).

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century, and his *Configuration* was translated into Spanish, Hebrew, and Latin (see A. I. Sabra, "Ibn al-Haytham," in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie [New York: Charles Scribner's Sons, 1972], vol. 6, pp. 197-98, 210). Its influence on Renaissance scholars, particularly Peurbach's *Theoricae* (a work on planetary theory composed in 1460), was noted by E. J. Aiton who concluded that "Peurbach evidently drew upon Ibn al-Haytham's (Alhazen's) *On the Configuration of the World* or some later work based on this" ("Peurbach's *Theoricae Novae Planetarum*: A Translation with Commentary," *Osiris* 3 [1987]: 7-8). Some thirty years earlier than Aiton, Willy Hartner had also discussed Peurbach's dependency on Islamic astronomers and compared his Mercury model with that of Ibn al-Haytham's. Hartner also recognized Jaghmīnī's interest in the physical reality of the orbs (albeit misplaced to the fourteenth-century [p. 124, fn. 39]), and lumped Jaghmīnī together with Ibn al-Haytham in asserting that "The dependency of early Renaissance astronomers on ALHAZEN and AL-JAGHMĪNĪ is beyond doubt. Yet I am unable to tell at the moment from which of the two (possibly from both), and through which channels, they drew their information" ("The Mercury Horoscope of Marcantonio Michiel of Venice: A Study in the History of Renaissance Astrology and Astronomy," *Vistas in Astronomy*, ed. Arthur Beer [London: Pergamon Press, 1955], vol. 1, pp. 124-35).

[170] See the closing statements at the end of the chapters on the orbs of the Sun, Moon, Mercury, Venus, the Upper Planets, the Fixed Stars, and the Highest Orbs, which seem to indicate that figures should follow (Langermann, *Ibn al-Haytham's "On the Configuration of the World,"* pp.

Furthermore, since his focus is explaining the hows of the celestial components, he keeps terrestrial topics to a minimum and omits philosophical and astrological topics altogether. His work was certainly remarkable, and undoubtedly inspirational for future scholars; however, it is a matter of opinion as to whether this work should also be deemed revolutionary since he was making explicit what was already implicit in previous theoretical works.[171]

It was not Ibn al-Haytham's aim in the *Configuration* to question Ptolemaic theory; this was reserved for criticisms found in his other works such as his *Al-Shukūk ʿalā Baṭlamyūs* (Doubts About Ptolemy), which addressed irregularities and violations by Ptolemy of his own principles in three of his works: the *Almagest, the Planetary Hypotheses,* and the *Optics*. Ibn al-Haytham was truly remarkable in being both prolific and creative.[172] But he was also exceptional in his ability to articulate underlying ideas and sentiment upheld by many Islamic scholars, as exemplified by his *Configuration*, but also conveyed in his statements (contained in his

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131 [209], 150 [272], 177 [321], 196 [337], 206 [359], 215 [374], 223-24 [382] (English); and pp. 37, 46, 54, 57, 60, 63, and 65 (Arabic)).

[171] See F. J. Ragep, who situates Ibn al-Haytham's work within the context of the *hayʾa* tradition, and also reminds us that "it is important to recognize that Ibn al-Haytham is not saying that previous astronomical work has been 'instrumentalist' in some Duhemian sense; in fact, he seems to go out of his way to indicate that previous work has assumed the existence of solid spheres" (*Tadhkira*, pp. 30-33).

[172] A daunting combination, which probably contributed to speculation that one man alone could not have written all the works attributed to him, and that there were two Ibn al-Haythams, one mathematically inclined, one philosophically inclined. However, for evidence supporting the one Ibn al-Haytham position (which I endorse), see A. I. Sabra's two articles: "One Ibn al-Haytham or Two? An Exercise in Reading the Bio-bibliographical Sources," *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 12 (1998): 1-50; and "One Ibn al-Haytham or Two? Conclusion," *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 15 (2002/2003): 95-108.

Introduction to *al-Shukūk*) on scientific advancement and the questioning of scientific authorities (which I believe is worth repeating here):[173]

> "Truth is sought for itself [but] the truths [he warns], are immersed in uncertainties [and the scientific authorities (such as Ptolemy, whom he greatly respected) are] not immune from error…. [Nor, he said, is human nature itself:] Therefore, the seeker after the truth is not one who studies the writing of the ancients and, following his natural disposition, puts his trust in them, but rather the one who suspects his faith in them and questions what he gathers from them, the one who submits to argument and demonstration, and not to the sayings of a human being whose nature is fraught with all kinds of imperfection and deficiency. Thus the duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads, and, applying his mind to the core and margins of its content, attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency."

The fact that Ibn al-Haytham should not be seen "as having single-handedly established physical cosmography in Islam" should not undermine the fact that many of his successors found him inspiring.[174] Naṣīr al-Dīn al-Ṭūsī devotes an entire chapter to the configuration of the epicycles orbs of the planets according to Abū ʿAlī ibn al-Haytham in a Persian appendix to his *Risālah-i Muʿīniyya* (written in 1235);[175] and it is well-known that ʿAbd al-Jabbār al-Kharaqī

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[173] We are indebted to A. I. Sabra for providing us this marvelous translation, whose additional side comments are contained in brackets ("Ibn al-Haytham: Brief life of an Arab mathematician: died circa 1040," *Harvard Magazine*, September-October 2003, p. 54).

[174] See F. J. Ragep, *Tadhkira*, p. 33.

[175] See F. Jamil Ragep, "Ibn al-Haytham and Eudoxus: The Revival of Homocentric Modeling in Islam," in *Studies in the History of the Exact Sciences in Honour of David Pingree*, ed. Charles Burnett, Jan P. Hogendijk, Kim Plofker, and Michio Yano (Leiden: E. J. Brill, 2004), pp. 786-809 (a Persian edition with English translation of chapter 5 of Ṭūsī's *Ḥall-i mushkilāt-i Muʿīniyya* is included in this article).

(477-553 H [1084-1158])—who flourished over a century earlier than Ṭūsī in the vicinity of Merv, during the volatile period of struggle for hegemony between the Seljuk Sultan Sanjar and the Khwārazm Shāh ʿAlāʾ al-Dīn Atsiz[176]—explicitly credits Ibn al-Haytham as being an important influence for motivating him to consider solid spheres as opposed to imaginary circles in astronomy, and inspiring his attempts to reconcile physics with mathematical models.[177] In

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[176] ʿAbd al-Jabbār al-Kharaqī has often been confused with an older contemporary, a Shams al-Dīn Abū Bakr Kharaqī (both sharing the same *nisba*); however, we can confidently date our Kharaqī (i.e., the one who authored *hayʾa* works) based on information he himself provides within his treatises and also from contemporary primary sources. For example, he dedicates his *Tabṣira* to "al-Amīr Shams al-Dīn Abū al-Ḥasan ʿAlī ibn al-ṣāḥib Naṣīr al-Dīn Maḥmūd ibn Muẓaffar" (Istanbul, Ayasofya MS 2581, f. 2a and Ayasofya MS 2579, f. 1b), the son of the vizier who was also known as Ibn Abī Tawba (466-503 H [1074-1110]) and put to death by the great Seljuk Sultan Sanjar (see Max Meyerhof, "ʿAlī al-Bayhaqī's Tatimmat Ṣiwān al-Hikma: A Biographical Work on Learned Men of the Islam," *Osiris* 8 [1948]: 177-78). Ẓahīr al-Dīn al-Bayhaqī (ca. 1097-1169), a contemporary of Kharaqī, also reports that Kharaqī was taken into service of a Khwārazm Shāh; Hanif Ghalandari speculates the ruler was Atsiz (r. 521-551 H [1127-1156]) (Ghalandari, "A Survey of the Works of 'Hayʾa' in the Islamic Period with a Critical Edition, Translation and Commentary of the Treatise *Muntahā al-Idrāk fī Taqāsīm al-Aflāk* written by Bahāʾ al-Dīn al-Kharaqī (d. 553 AH/1158 AD)," Ph.D. diss., The Science and Research Branch of the Islamic Azad University (SRBIAU), Tehran Oct. 2012, pp. 4-5 [in Persian with an Arabic edition]. See also Cemil Akpınar, "Harakī," in *İslam Ansiklopedisi* (Istanbul: Turkiye Diyanet Vakfi [TDV], 1997), vol. 16, pp. 94-96 [Turkish]. For a German translation of the introductions to both the *Muntahā* and *Tabṣira*, see Eilhard Wiedemann and Karl Kohl, "Einleitung zu Werken von al-Charaqi," *Sitzungsberichte der Physikalisch-Medizinischen Sozietät zu Erlangen* 58 and 59 (1926-7): 203-18; reprinted in E. Wiedemann, *Aufsätze zur arabischen Wissenschafts-geschichte* (Hildesheim: Georg Olms, 1970), vol. 2, pp. 628-43.

[177] Actually Kharaqī cites both Ibn al-Haytham and Jaʿfar al-Khāzin in the *Muntahā* (e.g., Berlin, Staatsbibliothek, Landberg MS 33, f. 2a); however, he omits al-Khāzin in the *Tabṣira* (e.g., see Istanbul, Ayasofya MS 2581, f. 2b). See also Ghalandari, "A Survey of the Works of 'Hayʾa' in

turn, Kharaqī writes on theoretical astronomy, especially his *Muntahā al-idrāk fī taqāsīm al-aflāk* , in which he explicitly stated that *ʿilm al-hayʾa* follows theology in standing and nobility in showing God's wisdom, and his shorter, more popular *Tabṣira fī ʿilm al-hayʾa*, both written in Arabic, would play critical roles in the development of *hayʾa*[178] (the *Tabṣira* being the unnamed source extensively used by Jaghmīnī throughout the *Mulakhkhaṣ*).[179] It is Kharaqī's works that

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the Islamic Period with a Critical Edition, Translation and Commentary of the Treatise *Muntahā al-Idrāk fī Taqāsīm al-Aflāk* written by Bahāʾ al-Dīn al-Kharaqī (d. 553 AH/1158 AD)," pp. 149-50.

[178] We know that Kharaqī's *Tabṣira* inspired a thirteenth-century commentary by Muʾayyid al-Dīn al-ʿUrḍī, and at least two others, one by a Yemeni Jew Aluʾel ben Yeshaʿ, and another anonymous one. See Petra G. Schmidl, "ʿUrḍī," and Langermann, "Kharaqī" (both articles in *The Biographical Encyclopedia of Astronomers*, vol. 2, pp. 1161-62, and vol. 1, p. 627 [respectively]). In comparison, I do not currently know of any commentaries written on Kharaqī's *Muntahā*; however Kharaqī's works were often cited by other Islamic scholars, such as al-ʿUrḍī (see George Saliba, "The First Non-Ptolemaic Astronomy at the Maraghah School," in *A History of Arabic Astronomy*, p.114). For more examples of citations, see the following footnote.

[179] See the Commentary for references to Kharaqī, and especially the examples provided in which Jaghmīnī paraphrases sections from Kharaqī's *Tabṣira* (**II.1 [3]:** his description of latitudes from 63 to 66 degrees; and **II.1 [5]**: regarding the astrolabe/gnomon exercise). Rather than charging Jaghmīnī with plagiarism, however, one should keep in mind that Kharaqī's works were probably common knowledge, and so Jaghmīnī may have felt no compunction to cite him. Ṭūsī refers to him simply as "the author of the *Muntahā al-idrāk*" (صاحب منتهى الإدراك) in his *Ḥall-i mushkilāt-i Muʿīniyya,* (Ragep, "Ibn al-Haytham and Eudoxus," pp. 797 [Persian], 805 [Eng. trans.]; see also *Tadhkira*, p. 33 and fn. 25); Quṭb al-Dīn al-Shīrāzī's listing of the *"Muntahā al-idrāk,* and *al-Tabṣira"* when he references titles of well-known *hayʾa* books "composed in this discipline" in the explicit to his *Nihāya* (Ragep, "Shīrāzī's *Nihāyat al-Idrāk*: Introduction and Conclusion," pp. 51 [Arabic], 55 [Eng. trans.]); and Shīrāzī's student ʿUbaydī (d. 1350), who playfully incorporates *tabṣira* into his commentary title to Ṭūsī's *Tadhkira* (*Bayān al-Tadhkira wa-tibyān al-tabṣira*) (Ragep, *Tadhkira*, p. 61).

would codify the basic structure of subsequent *hayʾa* works: an introduction, and (most importantly) the two-part division of regions into the arrangement (*tarkīb*) of the celestial bodies and their motions, and the configuration (*hayʾa*) of the Earth. Other later *hayʾa* works might also devote a chapter or section to the subject of sizes and distances; a discussion of chronology, included as a separate section in the *Muntahā*, tended to be downplayed in these later works.[180] The credit for this new delineation of astronomy associated with *hayʾa* works, i.e., presenting the cosmos as a coherent whole with subject matter divided into two basic arenas—i.e., the upper bodies of the celestial region ("cosmo-graphy") and the lower bodies of the terrestrial realm ("geo-graphy")—has usually been attributed to Kharaqī's two Arabic treatises.[181] However, Kharaqī also wrote another *hayʾa* work, in Persian, entitled *al-ʿUmda li-ūlā al-albāb*. This recently discovered work that exists in a unique copy is dedicated to the above-mentioned Khwārazm Shāh Atsiz and is among the list of "unattributed" *hayʾa* works mentioned by Shīrāzī in his explicit to the *Nihāya.*[182] Kharaqī's Persian treatise, like its two Arabic counterparts, contains his signature two-part division of the cosmos.

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[180] As mentioned earlier, both Kharaqī and Jaghmīnī do not include sizes and distances in the *Tabṣira* and *Mulakhkhaṣ* (respectively), most-likely considering it inappropriate subject matter for a *hayʾa basīṭa* work; however, Kharaqī's *Muntahā* contains a chapter on the subject [*Maqāla* II, *bāb* 17, in 2 parts (*faṣlān*)]. Some later *hayʾa* works would devote an entire section to sizes and distances (e.g., Ṭūsī's *Tadhkira*). Regarding subjects related to chronology (such as year, month, hours), in the *Mulakhkhaṣ*, Jaghmīnī lumps the various topics altogether in his final chapter of Part Two (on an explanation of the Earth and what Pertains to it) under the umbrella title of "Miscellaneous Items" (*Mulakhkhaṣ* **[II. 3 [6-10]**). In comparison, Ṭūsī informs us that subjects related to chronology have no place in a *hayʾa* work and he buries these topics in a section of a chapter in Book III (see Ragep, *Tadhkira*, pp. 36, 36 fn. 12, 300-3 (III.10 [3], lines 10-12)).

[181] See Ragep, *Tadhkira*, p. 36.

[182] See Ragep, "Shīrāzī's *Nihāyat al-idrāk*: Introduction and Conclusion," pp. 51 [Arabic], 55 [Eng. trans.]. Until now we were unaware that the identity of Shīrāzī's unnamed author was Kharaqī, and also that the work was composed in Persian.

Although I have yet to examine Kharaqī's Persian *hayʾa* treatise carefully, its mere existence raises interesting questions that challenge our views regarding the role of Persian compositions of theoretical astronomy, especially their relationship to Arabic treatises during this formative period. The standard narrative has been that "from the fifth/eleventh century onwards [at least]…the language par excellence of science" was "almost exclusively in Arabic."[183] Indeed, the assumption was that any Persian treatises on scientific topics are *later* translations of their Arabic counterparts, perhaps attempts to convey scientific information for court members or a lay audience, people more comfortable with the vernacular Persian and less familiar with Arabic. The possibility that the Persian treatise gave rise to the Arabic is typically downplayed (or dismissed). A good example highlighting this point is the general assumption that Bīrūnī's Arabic version of his *Kitāb al-Tafhīm* preceded the Persian, although it is well acknowledged that there is no evidence to support any priority. Furthermore, it has also been suggested that the Persian rendition was not necessarily done by Bīrūnī himself (who I might add was trilingual in Persian, Arabic, and [his mother tongue] Khwārazmian), again based on unfounded speculation.[184]

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[183] See C. Edmund Bosworth, "The Persian Contribution to Islamic Historiography in the Pre-Mongol Period," in *The Persian Presence in the Islamic World,* ed. Richard G. Hovannisian and Georges Sabagh (Cambridge, Eng; New York: Cambridge University Press, 1998), p. 231.

[184] Although Gilbert Lazard points out that the priority of the two versions has never been explicitly established, he confidently concludes Arabic seniority based on his impression that the Arabic is written in a concise and elegant style, whereas the Persian is written in a more clumsy and belabored way ("Souvent l'arabe est concis, net élégant là où le persan paraphrase plus ou moins et donne l'impression d'une certaine gaucherie et d'une certaine lourdeur." [p. 60]). He also notes that the Persian is highly dependent on Arabic scientific terms, but it is not clear why this is an argument in favor of the priority of the Arabic version. Furthermore, he cites Bīrūnī's objection to composing scientific works in Persian (as expressed in his work on *Pharmacology* [*Kitāb al-Ṣaydala*]); though I should add that Lazard is not alone in referring to this work and referring to Bīrūnī's sentiment that Persian was a language "fit only for the recital of bedtime stories and legends of kings" (E. S. Kennedy, *"Bīrūnī*," p. 155), and also that Persian was a language far "less precise and less lexically rich for scientific purposes" [than Arabic]

So a prevalent narrative is that it would be difficult to point to "scientific texts and say that there was an indigenous Persian scientific production which was independent of the contemporary Arabic production."[185] A preliminary comparison of Kharaqī's three works indicates striking similarities between them, and especially between the Arabic *Muntahā* and the Persian *ʿUmda*;[186] and this clearly supports the notion that the two "productions" are somehow interrelated. However, it would be rash to conclude from this that the Persian is a direct translation or derivative from the "original" Arabic, certainly not without a more careful examination of the content of these treatises. Fortunately, here we have the example of another extant Persian *hayʾa* work dating from this period, one that (as far as I know) has no Arabic counterpart, to assist us in ascertaining the possibility of an independent Persian production of *hayʾa* works. The *Gayhān-shenākht* (Knowledge of the Cosmos) was composed in 498-500 H [1104-1107] by Kharaqī's contemporary Qaṭṭān al-Marwazī (465-548 H [1072-1153]), known for being a physician and also a polymath, who stemmed from a family of scholars among the

(Bosworth, "The Persian Contribution to Islamic Historiography in the Pre-Mongol Period," pp. 231-32). George Saliba also reiterates this in "Persian Scientists in the Islamic World: Astronomy from Maragha to Samarqand," in *The Persian Presence in the Islamic World,* ed. Richard G. Hovannisian and Georges Sabagh (Cambridge, Eng; New York: Cambridge University Press, 1998), pp. 126, 146. Nevertheless, unlike Lazard, Kennedy concluded that Bīrūnī alone prepared both versions of the *Tafhīm* (p. 154). See G. Lazard, *La langue des plus anciens monuments de la prose persane. Études linguistiques* (Paris: C. Klincksieck, 1963), pp. 58-62 (no 10: *Al-Tafhīm*).

185 Saliba, "Persian Scientists in the Islamic World," p. 127.

186 For example, for the *Tabṣira*, Kharaqī has removed the entire section on chronology that is included in both the *Muntahā* and the *ʿUmda* (the following compares the divisions of these three works: ***Muntahā***: Part I: 20 chapters; Part II: 17 chapters; **Part III**: 11 chapters; ***ʿUmda***: Part I: 25 chapters; Part II: 15 chapters; **Part III**: 12 chapters; ***Tabṣira***: Part I: 22 chapters; Part II: 14 chapters). With an admittedly brief skim of the *ʿUmda*, I noted that both the *Muntahā* and *ʿUmda* cite Ibn al-Haytham and Jaʿfar al-Khāzin, whereas the latter is omitted in the *Tabṣira*.

learned circles of Merv.[187] This three-part treatise contains what we have been calling the "classical" two-part division of the cosmos plus a section on chronology, and the early date indicates that this may very well have been the inspiration for Kharaqī's structure (with an alternative possibility being another unknown source that influenced both).[188] In any event, the mere existence of two Perisan *hayʾa* treatises, especially at this formative stage, is a step in debunking the view that Persian astronomy was concerned more with "astrological computations and less with theoretical astronomical issues."[189]

The wide range of subject matter covered in Qaṭṭān al-Marwazī's *Gayhān Shinākht* on theoretical astronomical issues is impressive, and so it would be reasonable to assume Jaghmīnī

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[187] See Behanz Hashemipour, "Qaṭṭān al-Marwazī," in *The Biographical Encyclopedia of Astronomers*, vol. 2, pp. 943-44 and "Gayhānshenākht: A Cosmological Treatise," in *Sciences, techniques et instruments dans le monde iranien (Xe-XIXe siècle),* études réunies et présentées par N. Pourjavady et Ž. Vesel (Tehran, 2004), pp. 77-84 [in Persian]; Storey, *Persian Literature,* pp. 45-46 (no. 82: ʿAin al-Zamān Abū ʿAlī al-Ḥasan b. ʿAlī b. M. al-Qaṭṭān al-Marwazī); and Ghalandari, "A Survey of the Works of 'Hayʾa' in the Islamic Period with a Critical Edition, Translation and Commentary of the Treatise *Muntahā al-Idrāk fī Taqāsīm al-Aflāk* written by Bahāʾ al-Dīn al-Kharaqī (d. 553 AH/1158 AD)," pp. 19-22, 26, 28, 111, 140, and 141. A facsimile of this treatise has recently been published along with an introduction [in Persian]; see al-Ḥasan ibn ʿAlī Qaṭṭān*, Gayhān Shinākht*, Chāp-i 1(Tehran: Kitābkhānah, Mūzih va Markaz-i Asnād-i Majlis-i Shūrā Islāmī, 2012) [with facsimile of Kitābkhānah, *Buzurg-i Ḥaḍarat-i Āyat Allāh al-ʿUẓmā Marʿashī Najafī MS 8494].*

[188] It is certainly possible that contemporary scholars residing in the same locale may not be aware of each other; however the Khwārazm Shāh Atsiz does provide a common link, since Qaṭṭān al-Marwazī is known to have corresponded with Rashīd al-Dīn Waṭwāṭ, who was the Shāh's chief secretary (see Hashemipour, "Qaṭṭān al-Marwazī," pp. 943-4; and "Waṭwāṭ, Rashīd al-Dīn," *Encyclopædia Iranica,* http://www.iranicaonline.org/articles/watwat-rasid-al-din Accessed on May 31, 2014.

[189] Saliba, *"Persian Scientists in the Islamic World," p*. 144.

would have known of this work, especially given the place and date of composition.[190] Nevertheless, it is most likely that Jaghmīnī depended in the main on Kharaqī's *Tabṣira,* which can be shown to be the source for much material he selected and incorporated into the *Mulakhkhaṣ* (several parts directly lifted). On the other hand, his parameters were gleamed from the "authorities" of Ptolemy and Battānī, i.e., not from Kharaqī. And though both Kharaqī's *Tabṣira* and Jaghmīnī's *Mulakhkhaṣ* were both extremely popular elementary astronomical textbooks, there are differences between the two in both subject matter and organization (once we put aside the signature two-part division).[191] Clearly, Kharaqī's *Tabṣira* as the "abridged" version of the *Muntahā* was not abridged enough; and there was a growing demand for another, more accessible elementary textbook.

So now that our trail of dots (or texts) has led us to Jaghmīnī's *Mulakhkhaṣ*, what follows is an overview summarizing what Jaghmīni does—and also does not do—in comparison with some of these earlier works on theoretical astronomy. We can then assess how the *Mulakhkhaṣ* fits into this genre, and how Jaghmīnī complied with the lofty command of his patron.

§ I.2.5 L'Astronomie pour les Nuls

Jaghmīnī's simplified (*basīṭa*) epitome of *hay'a* is in fact anything but simple-minded. Unlike other introductory astronomical textbooks that on the one hand present wide-ranging but non-coherent overviews or on the other hand target specific astronomical problems, Jaghmīnī

[190] The date given in one colophon is Tuesday, 21 Ramaḍān 586 H (= Tuesday, 29 Oct. 1190), which indicates it certainly could have been an available source for Jaghmīnī. Also, the facsimile is not the only witness. The published *Gayhān Shinākht* lists several other witnesses (pp. 67-69), and I was able to check no. 2 on the list (Tehran, Majlis Shūrā MS 202), which contains the exact same colophon; however in this case one was probably copied from the other.

[191] An example of this is that Jaghmīni gives an explanation of *all* the orbs in one chapter (**I.1 [1]-[11]**) and *all* the motions of the orbs in another separate one (**I.2 [1]-[13]**), whereas Kharaqī, similar to Ṭūsī in his *Tadhkira*, combines the descriptions and motions for a planet together (usually in a separate self-contained chapter).

provides fundamental information to comprehend the broad picture of the universe (from top to bottom) that is conceptually packaged. He gives basic definitions and rules along with parameters in easily accessible lists to account for various planetary motions; many of the latter have been updated from Ptolemy for a twelfth-century Khwārizmian audience, the fruits of the work of Battānī and the Maʾmūn observations (the so-called "Moderns") and subsequent scholars. He excludes astronomical topics he deems too difficult or inappropriate for the beginner student and thus omits the topic of sizes and distances. Furthermore, he thinks it inappropriate for a *hayʾa* work to contain an extensive chapter on chronology, though he does incorporate relevant material into appropriate sections. He also eliminates information that the student could (or should) seek elsewhere, such as within practical handbooks with their astronomical tables (*zīj*es) or the *anwāʾ* literature. The general subject of astrology never enters the picture, at least as a science that interprets celestial signs and makes predictions, even though he is undoubtedly aware of its popularity (at least in some circles). However, Jaghmīnī recognizes that the student is familiar with certain components of astrology, such as the signs of the zodiac and the constellations, inasmuch as he never defines the former and omits the latter altogether in the *Mulakhkhaṣ*. He also incorporates the movement of the zodiacal signs and constellations into various discussions, in particular when he discusses their appearances for the various climes. In fact, Jaghmīnī has the clear expectation that the student already has had some previous astronomical training, as evidenced by the following few examples: a student must be familiar with how to use an astrolabe for the "hands-on" exercise in **II.3 [5]** since Jaghmīnī provides no definitions of its parts or operating procedures; technical terms such as *al-shāqūl* (the plumb-line or plummet) in **II.3 [3]** are assumed, again without further explanation; the student should be able to perform computations using sexagesimal notation, often beyond seconds (see **I.5 [30]** for exercises); and the student should be familiar with astronomical dating, in particular the Alexandrian calendar (Dhū al-Qarnayn) as in **I.5 [22]**.

Jaghmīnī's challenge pedagogically was to simplify difficult material (for example by eliminating mathematical proofs), while ensuring that the information presented was both detailed and accurate, unlike the case, as we have seen, with Roman sources. Many of the astronomical textbooks Jaghmīnī inherited camouflaged the information with complex explanations (Proclus's *Hypotyposes*), long-winded discussions (Kharaqī's *Muntahā*), oversimplifications (Farghānī's *Jawāmiʿ*), additional literary references (Geminus's *Introduction* *to the Phenomena*), and/or incorrect statements and depictions (recall Battānī incorrectly depicted the Mercury model in his *Zīj*). Indeed, the success of the *Mulakhkhaṣ* was Jaghmīnī's ability to meet this challenge and make the complex look simple. He presented basic astronomical information with an objective style that exuded authority while also providing expansive asides meant to aid and reassure the student. The reinforcing, pedagogical style is seen throughout the textbook in statements such as "as you will come to know…" and "as you already learned…" (statements he makes at least twenty-one times!). In addition, the *Mulakhkhaṣ* contains several diagrams, which, as we have seen, are not often found in earlier introductions such as Farghānī's *Jawāmiʿ*. These diagrams were not meant to be lavish or elaborate but simply functional with pedagogical value. Perhaps this explains why the original text is not as extensively illustrated as other *hayʾa* works, such as those of Kharaqī or Ṭūsī, or as later commentaries on the *Mulakhkhaṣ*. We should also note that this is not a "passive" treatise but one replete with pedagogical exercises.

Pedagogy here has its limits. Jaghmīnī does not seek to provide moral guidance to the reader by using examples from astronomy, unlike what one finds in Epistle 3 ("On Astronomia") of the "Ikhwān al-Ṣafāʾ. In fact, it bears mentioning that the *Mulakhkhaṣ* only touches on religious needs when it relates to determining the direction of Mecca and determining the prayer times, with distinctions noted between the Ḥanafī and Shāfiʿī schools. God remains a silent partner.

All of this brings us to the pressing questions of what inspired the commissioning of this treatise, and who was the target audience? The new delineation of astronomy as dealing with both the upper and lower bodies connected God's unchanging celestial realm with the ever-changing sublunar one of man (recall Ibn al-Haytham dealt only with half this equation in his *On the Configuration of the World*). And so *hayʾa*'s claim was that it could provide a picture of God's entire creation, both that of the perfect and that of the corruptible. The claim made by Quṭb al-Dīn al-Shīrāzī that the discipline of *ʿilm al-hayʾa* was "the most noble of the sciences" with his support being a citation from the Qurʾan,[192] indicates that within Islamic society there

[192] Quṭb al-Dīn al-Shīrāzī cites Quʾrān III.191 to link the heaven and the Earth in the "Introduction" to his *Nihāya*: "Whoever—standing, sitting or reclining—recall God and reflect on the creation of the heavens and the Earth [will say]: Our Lord! Thou hast not created this in

was an ever-growing segment of the population that had begun to view the study of *hayʾa* as a way to glorify the Creator. Kharaqī clearly believed that the study of *ʿilm al-hayʾa* provided a rational and noble approach to better understand His creation (as stated in his introduction to his *Muntahā*); presumably he still believed this when he composed his *Tabṣira*, but felt there was no need to explicitly state it there, nor did Jaghmīnī in his *Mulakhkhaṣ*. The *Mulakhkhaṣ* then provided the essential keys to unlocking knowledge of His created universe (without attempting to address "why" the celestial or terrestrial realm operates the way it does), which certainly made it an ideal addition to the *madrasa* curriculum.

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vain" (Ragep, "Shīrāzī's *Nihāyat al-Idrāk*: Introduction and Conclusion," pp. 49 [Arabic], 54 [Eng. trans.]).

CHAPTER 3

Situating the Composition and Teaching of the *Mulakhkhaṣ* in a Madrasa Setting

Is locale significant when we consider the teaching of the mathematical sciences in premodern Islam? Many have downplayed its pedagogical role and tell us that it is "almost irrelevant to ask whether these sciences were taught in a teaching institute, a private house, or a garden";[1] the assumption here is that *any* place will do as long as the student-teacher mentoring relationship remains intact. As Jonathan Berkey has asserted, "An education was judged not on *loci* but on *personae*."[2] This personal bond, which gave scholars the option "to choose what to study, with whom, and where, as well as what to teach,"[3] has been depicted as promoting scientific inquiry rather than stifling it; and it is credited with being the backbone of support and stability by establishing flexible and informal networks of individual relationships that ensured the survival of Islamic science itself.[4]

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[1] See Sonja Brentjes, "On the Location of the Ancient or 'Rational' Sciences in Muslim Education Landscapes (AH 500-1100)," *Bulletin of the Royal Institute for Inter-Faith Studies* 4, no. 1 (Spring/Summer 2002): 60. Brentjes addresses the question of place, ultimately concluding that "the locus of teaching simply did not matter nearly as much as the teaching itself."

[2] See Berkey, *The Transmission of Knowledge in Medieval Cairo* (Princeton: Princeton University Press, 1992), p. 23.

[3] Brentjes, "On the Location of the Ancient or 'Rational' Sciences in Muslim Education Landscapes (AH 500-1100)," p. 64.

[4] Berkey and Chamberlain both attribute close ties and networks for shaping the character of instruction and pedagogy in Islam, especially in comparison to institutions, which are depicted by them as creating formal and restrictive barriers to learning. See Berkey, *The Transmission of Knowledge in Medieval Cairo*, pp. 20, 42-44; and Michael Chamberlain, "The Production of Knowledge and the Reproduction of the Aʿyān in Medieval Damascus," in *Madrasa: la transmission du savoir dans le monde musulman*, ed. Nicole Grandin and Marc Gaborieau (Paris: Arguments, 1997), pp. 28-62 (this is essentially Chapter 4 of his *Knowledge and Social Practice*

Such approaches to the pedagogy of Islamic science tend, whether intentionally or not, to promote its history as episodic and dependent in the main on courts or individual initiatives, i.e., outside the core institutional structures, and in particular religious structures, of Islamic societies. A. I. Sabra has referred to this as the marginality thesis, the idea being that science in Islam had nothing to do with Islam (either the religion or the civilization), which in this narrative was hostile to science and, more broadly, rationality.[5] This sentiment was articulated rather explicitly in the works of both Ernest Renan[6] and Gustav von Grunebaum.[7] An underlying motif at play is

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in Medieval Damascus, 1190-1350 [Cambridge: Cambridge University Press, 1994], pp. 108-51). See also Sonja Brentjes, who comments on the positions of Berkey and Chamberlain in her "On the Location of the Ancient or 'Rational' Sciences in Muslim Education Landscapes [AH 500-1100]," pp. 49-50, 61, 64.

[5] A. I. Sabra ("Appropriation," p. 229) raised the poignant question of how Islamic scientists managed to sustain their high levels of scientific achievement some six hundred years after its initial launching in the eighth/ninth centuries with the translation movement. His theory was that this was achieved through a process of acceptance, assimilation, and ultimately "naturalization" of philosophical and scientific materials within mainstream Islam, but at a price that ultimately curbed the scientists' appetite for inquiry and creativity in favor of a more religiously-oriented palate, one geared for utilitarian (instrumentalist) ends in the "service of Islam" (see King, *Astronomy in the Service of Islam*).

[6] According to Renan, this hostility comes from "the inevitable narrow-mindedness of a true believer, of that kind of iron ring around his head, making it absolutely closed to science. …inspires him with a contempt for other religions that has little justification. Convinced that God determines wealth and power to whomever He sees fit, regardless of education or personal merit, the Muslim has the deepest contempt for education, for science…" (*L'islamisme et la science*, pp. 2-3 [Eng. trans. S. Ragep and F. Wallis]).

[7] As Gustav von Grunebaum puts it: "A modicum of astronomy and mathematics is required to determine the direction in which to turn at prayer, as well as to keep the sacred calendar under control; a certain amount of medical knowledge must be available to the community. But anything that goes beyond these manifest (and religiously justifiable) needs can, and in fact ought to, be dispensed with. No matter how important the contribution Muslim scholars were

that one rarely finds the pursuit of scientific knowledge in Islam valued for its own sake, either by the individual or by the society as a whole;[8] and any scientific advances came about due to the mitigating intervention of patrons.[9] Now the importance of patronage for promoting science is not in question; its role is showcased in the stellar achievements of the three "great men" of the eleventh century: Ibn Sīnā, Ibn al-Haytham, and al-Bīrūnī. Furthermore, it seems that some of Jaghmīnī's disciplinary predecessors—al-Farghānī, al-Kindī, Thābit ibn Qurra, Qusṭā ibn Lūqā, Ibn al-Haythām, and al-Kharaqī—were all affiliated at some point in their careers with courts and dedicated their works to highly-placed patrons.[10] I dare say that Jaghmīnī should also be

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able to make to the natural sciences, and no matter how great the interest with which, *at certain periods, the leading classes and the government* itself followed and supported their researches, those sciences (and their technological application) *had no root in the fundamental needs and aspirations of their civilization*" [emphasis added] ("Muslim World View and Muslim Science," in *Islam: Essays in the Nature and Growth of a Cultural Tradition* [London: Routledge, 1964], p.114).

[8] This view flies in the face of Franz Rosenthal's contention that "the religion of Muḥammad stressed from the very beginning the role of knowledge (*ʿilm*) as the driving force in religion, and thereby, in all human life. … *ʿilm* never lost its wide and general significance. Thus the interest in knowledge for its own sake, in systematic learning *per se* and in the sciences as expressions of man's thirst for knowledge, was greatly and effectively stimulated" (*The Classical Heritage in Islam*, p. 5).

[9] Aydın Sayılı, in his seminal work on *The Observatory in Islam*, viewed the rise and fall of observatories in terms of a series of temporal episodes dependent "on the patronage of rulers or rich people even when very large instruments were not constructed"; and he believed the frequent changes of political power handicapped the progress of science (*The Observatory in Islam and Its Place in the General History of the Observatory* [Ankara: Turkish Historical Society, 1960], pp. 311, 427).

[10]Al-Farghānī, al-Kindī, Thābit b. Qurra, and Qusṭā ibn Lūqā were all associated with the court culture of the ninth-century ʿAbbāsid caliphal family; Ibn al-Haytham was patronized by the eleventh-century Fatimid Caliph al-Ḥākim of Cairo (r. 996-1021), who also patronized the astronomer Ibn Yūnus (d. 1009); and Kharaqī (fl. early-/mid-twelfth century) dedicated his

added to this list since Badr al-Dīn al-Qalānisī, and more so Shihāb al-Dīn al-Khīwaqī, were highly-placed individuals.

Nevertheless, courtly patronage and individual initiatives can take us only so far in explaining this long-lived scientific tradition. Something was motivating Badr al-Dīn al-Qalānisī to demand the composition of yet another introductory astronomical textbook dealing specifically with the subject of *ʿilm al-hayʾa*; and Jaghmīnī's corpus of introductory scientific textbooks was definitely not geared for a single individual. It is my contention that something important begins to happen to the mathematical sciences in the twelfth century, especially to astronomy, that transforms not only the way they are taught but also their place within Islamic civilization, that makes them less susceptible to the vagaries of courts and individual circumstance. And this is accompanied by a more general, and broadly based, attempt to codify, systematize and institutionalize Islamic scientific learning. At this time the ʿulamāʾ were consolidating their position in relation to the rulers and the ruling elites, and one way to do this was to democratize learning, to bring a substantial number of the public into contact with the ʿulamāʾ's understanding of Islam, through teaching in the madrasas.

Beginning with the Seljuk rulers, at a time during which it is alleged that al-Ghazālī killed off science, he actually paved a way for logic and the mathematical sciences, including astronomy, to penetrate the madrasa curriculum by accepting their certainty and usefulness.[11]

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popular *Tabṣira* to the son of the minister of the Seljuk Sultan Sanjar (r. 1118-1153). We can add many other scholars to this list.

[11] On how Ghazālī provided a way, admittedly limited, for the mathematical sciences to enter the madrasa, see A. I. Sabra, "Appropriation," pp. 239-40. For a somewhat more positive view of Ghazālī in promoting science, see F. J. Ragep, "Freeing Astronomy from Philosophy: An Aspect of Islamic Influence on Science," *Osiris* 16 (2001): 53-55 and Ragep, "Islamic Culture and the Natural Sciences," in *The Cambridge History of Science*, ed. David C. Lindberg and Michael H. Shank, vol. 2: Medieval Science (Cambridge: Cambridge University Press, 2013), pp. 56-57. Ghazālī has been vilified as instigating scientific decline in Islam due to his fears that the teaching of science and especially philosophy in the madrasas could lead to heresy. Actually Ghazālī insisted on "not being overly overzealous in condemning all ancient science," especially its apodeictic parts such as the mathematical sciences, since this might lead to a mocking of

However, astronomy in the "service of Islam" became valued not just for its practical applications for religious ritual (as it is most often depicted), but also for its theoretical applications to achieve a better understanding of the physical world of God's creation. And here is where the study of *hayʾa*—and Jaghmīnī's *Mulakhkhaṣ*—enters the picture, both literally and figuratively. But in order to better understand how all this fits together, we need first to review some of the evidence establishing that the mathematical sciences (with a focus on theoretical astronomy) were actually being taught in Islamic religious institutions, especially the madrasas; and we also need to review some of the reasons that such teaching has often been denied or deemed irrelevant.

§ I.3.1 Shedding Light on Old Evidence

Although the court, the observatory, the mosque, the *madrasa*, and the hospital are all recognized loci for the promotion or propagation of scientific activity within medieval Islam,[12] most

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Islam, especially by the young (Ragep, "Freeing Asronomy," p. 54). See also Frank Griffel, "The Western Reception of al-Ghazālī's Cosmology from the Middle Ages to the 21st Century," *Dîvân* (2011/1): 33-62 (esp. Renan's views on Ghazālī); F. J. Ragep, "When Did Islamic Science Die (and Who Cares)?" (a rebuttal to the Nobel Laureate Steven Weinberg's claim that after Ghazālī "there was no more science worth mentioning in Islamic countries"); and Aydın Sayılı (quoting E. Sachau) who states that "But for Al Ashʿarî and Al Ghazâlî the Arabs might have been a nation of Galileos, Keplers, and Newtons" (*The Observatory in Islam*, p. 408).

[12] Three of these loci ("The Court, the College and the Mosque") are discussed in Sabra's "Situating Arabic Science" (pp. 661-70). François Charette builds on Sabra's theme to examine the multi-dimensional functions astronomical instruments achieved in various Islamic institutional settings. Charette emphasizes the need to reexamine texts on instruments as being more than utilitarian, and explore their educational and didactic motives. He points out that many introductions to texts on instruments express the author's concerns for "*training the minds of students*" in addition to teaching them how to use the instruments ("The Locales of Islamic Astronomical Instrumentation," *History of Science* 44 (2006): 130-32, 134, fn. 3).

literature tends to attribute scientific achievements to the individuals within them, or the individuals who patronized them,[13] ignoring the role of the institutions themselves. The flourishing of scientific activities that took place in fifteenth-century Samarqand, though occurring several centuries after the time of the Khwārizm Shāhs, provides clear evidence that the teaching of the mathematical sciences in an Islamic religious institution had become well-established. In a personal letter home to his father in Kāshān (a province in Iran near Isfahan), the Islamic astronomer and mathematician Jamshīd Ghiyāth al-Dīn al-Kāshī (d. 832 H [1429]) describes student life at the Samarqand observatory and madrasa under the auspices of the Timurid ruler of Samarqand Ulugh Beg, a patron well-known "for his erudition and great learning."[14] Kāshī informs his father that there are *five hundred* students who have begun studying mathematics (presumably including astronomy) in twelve places scattered throughout Samarqand out of more than *twenty thousand* students, all "engaged in learning and teaching."[15] In his intimate and detailed letter to his father, one of several written home, Kāshī documents the

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[13] Sonja Brentjes traces scientific patronage after 1200 up to the eighteenth century, in lands between Egypt and India, and the shifting personage relationships in "Courtly Patronage of the Ancient Sciences in Post-Classical Islamic Societies," *Al Qanṭara* (2008): 403-36.

[14] See Ghiyāth al-Dīn al-Khwāndamīr, who lists some of these "learned men...who basked in the sun of his favor and patronage" (*Tārīkh-i ḥabīb al-siyar fī akhbār afrād bashar*, English translation of Tome Three, parts one and two, by W. M. Thackston as *The Reign of the Mongol and the Turk* [Cambridge, Department of Near Eastern Languages and Civilizations, Harvard University, 1994], vol. 4, pp. 34-38. [2: 369-71]). Much has been written on al-Kāshī, but for brief overviews, see Aydın Sayılı, *The Observatory in Islam*, pp. 268-88, and Petra G. Schmidl, "Kāshī," in *The Biographical Encyclopedia of Astronomers*, vol. 1, pp. 613-15.

[15] See Mohammad Bagheri, "A Newly Found Letter of Al-Kāshī on Scientific Life in Samarkand," *Historia Mathematica* 24 (1997): 243. This letter supplements another letter written by Kāshī to his father about Ulugh Beg's circle of scholars in Samarqand, a city he depicts as having no parallel in the province of Fārs [in southern Iran], in the teaching and learning of mathematics.

existence of a vibrant scientific community of scholars, scholars who undoubtedly wrote, read, and disseminated scientific materials.[16]

Given the staggering numbers one might assume that Kāshī is just exaggerating;[17] however, his depiction of a Samarqand education is confirmed by a personal account of Fatḥallāh al-Shirwānī (d. 1486), contained in his commentary to Ṭūsī's *al-Tadhkira*. Shirwānī reports that he traveled to Samarqand from his native Azerbaijan in pursuit of scientific studies after reading al-Sayyid al-Sharīf al-Jurjānī's *Tadhkira* commentary with the Shīʿī scholar Sayyid Abū Ṭālib at the Shrine of Imām ʿAlī Riza in Mashhad. He tells us that he spent *five* years at the Samarqand madrasa studying Niẓām al-Dīn al-Nīsābūrī's commentary on *al-Tadhkira* (among other things), before receiving his diploma (*ijāza*) in 844 H [1440] with Qāḍīzāde al-Rūmī, the head-teacher at Samarqand (who was also Ulugh Beg's tutor).[18]

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[16] One should keep in mind that the Samarqand madrasa was just one of several madrasas at the time. "Tīmūr established many civil institutions as well as *madrasa*'s, particularly in his capital Samarqand and in other prominent centers like Herat and Bukhara," with some placing the number at 69 madrasas, and this based only on available sources (Fazlıoğlu, "The Samarqand Mathematical-Astronomical School," p. 10). See also V. V. Barthold, *Four Studies on the History of Central Asia. Vol. 2: Ulugh-Beg*, trans. from the Russian by V. and T. Minorsky (Leiden: E. J. Brill, 1958), pp. 119-29; and Sayılı, *The Observatory in Islam,* p. 268.

[17] Kāshī also boasts that some five hundred scientists witnessed his success in mathematically proving a problem related to leveling the ground and determining the meridian at the site of the Samarqand observatory (see E. S. Kennedy, "A Letter of Jamshīd al-Kāshī to His Father: Scientific Research and Personalities at a Fifteenth Century Court," *Orientalia* 29 [1960]: 198-99). Cf., Aydın Sayılı, *Uluğ Bey ve Semerkanddeki ilim faaliyeti hakkinda Giyasüddin-i Kâşîʾnin mektubu (Ghiyâth al Dîn al Kâshî's Letter on Ulugh Bey and the Scientific Activity in Samarqand)* (Ankara, 1960), p. 36. Sayılı provides an English translation similar to the one by Kennedy; in addition, he provides the Persian text and a Turkish translation along with a commentary in both English and Turkish.

[18] See Fazlıoğlu, "The Samarqand Mathematical-Astronomical School," pp. 36-37, 51, 55 (pp. 41, 46 [Arabic text], 46, 49 [Eng. trans.]). See also F. J. Ragep, "Ḳāḍīzāde Rūmī," in

Shirwānī's detailed account of student life confirms that by the fifteenth century the teaching of the mathematical sciences had become formalized and integrated into Islamic institutions.[19] His personal situation highlights several points: that a student would have sought out a prescribed program of study for a higher education; and also that in order to obtain a diploma, a student had to undergo a rather grueling process demonstrating proficiency through oral testing, listening, and reading. Shirwānī is rather specific in his descriptions of the way lectures were held, and he describes the slow and careful process involved in reading texts by examining the subjects in detail through explanations, discussions, and establishing connections between the texts and their sources.[20] Shirwānī's text, corroborated with historical sources such as Ibn al-Akfānī and Ṭāshkubrīzāde, indicates that students were required to progressively master a body of scientific teaching textbooks categorized as beginner (*mukhtaṣar*), intermediate (*mutawassiṭ*), and advanced (*mabsūṭ*). For the discipline of *hayʾa* the assigned reading consisted of Ṭūsī's *Tadhkira* and Jaghmīnī's *Mulakhkhaṣ* for beginners, works by al-ʿUrḍī for intermediate students, and al-Shīrāzī's *Nihāya* and *Tuḥfa* for the most advanced student.[21]

Encyclopaedia of Islam, 2nd ed. (Leiden: E. J. Brill, 2004), vol. 12, p. 502; and Ragep, "Qāḍīzāde al-Rūmī," in *The Biographical Encyclopedia of Astronomers*, vol. 2, p. 942.

[19] Ekmeleddin İhsanoğlu provides an overview of the "formal" teaching programs of the madrasas, what he calls "the most indigenous institutions of learning in Islam," in "Institutionalisation of Science in the *Medreses* of Pre-Ottoman and Ottoman History," in *Turkish Studies in the History and Philosophy of Science*, ed. Gürol Irzik and Güven Güzeldere, Boston Studies in the Philosophy of Science, vol. 244 (Dordrecht, The Netherlands: Springer, 2005), pp. 265-85. For more sweeping surveys, see "Ottoman Educational and Scholarly Scientific Institutions," pp. 368-90 ("*Medreses*"), esp. 383-87 ("Curricula in Ottoman *Medreses*"); and Cevat İzgi, *Osmanlı Medreselerinde İlim: Riyazī ilimler.*

[20] See Fazlıoğlu, "The Samarqand Mathematical-Astronomical School," pp. 41-46 [the Arabic text], 46-49 [Eng. trans.], and 55.

[21] See Mamluk Ibn al-Akfānī (d. 749 [1348])'s *Kitāb irshād al-qāṣid ilā asnā al-maqāṣid* (Witkam, *De Egyptische Arts Ibn al-Akfānī,* pp. 55-57, [408]-[407] Arabic), and the Ottoman Aḥmad ibn Muṣṭafā Ṭāshkubrīzāde (901-968 [1495-1561])'s *Miftāḥ al-saʿāda wa-miṣbāḥ al-siyāda* (3 vols. [Beirut: Dār al-kutub al-ʿilmiyya, 1985], pp. 348-49). Witkam believes

Qāḍīzāde al-Rūmī hailed from Bursa, and had studied the mathematical sciences there as a member of a renowned circle of scholars in late fourteenth-century Anatolia referred to as the Fanārī school.[22] Qāḍīzāde would become an important link in disseminating the fruits of their scientific activities to Central Asia.[23] But in fact a pipeline had already been established between the two regions. Mullā Fanārī (d. 1431), under the auspices of Bayezid I, had been charged with inviting the best and brightest intellectuals to collect and standardize scientific textbooks for the curricula of the burgeoning Ottoman *madrasa*s; among the scholars he attracted to Bursa was ʿAbd al-Wājid ibn Muḥammad (d. 838 H [1435]), who traveled to Anatolia from his native Khurāsān, where he subsequently became one of Qāḍīzāde's teachers before teaching at the eponymous Wājidiyya Madrasa in Kütahya.[24]

Ṭāshkubrīzāde incorporated Ibn al-Akfānī's material into his own compilation (p. 22). Their only difference is that only Ṭāshkubrīzāde includes the *Mulakhkhaṣ* (under "famous abridgements") and lists four *Mulakkhkhaṣ* commentaries (Faḍl Allāh al-ʿUbaydī, Kamāl al-Dīn al-Turkmānī, Sayyid al-Sharīf, and Qāḍīzāde al-Rūmī), p. 349. See also Fazlıoğlu, "The Samarqand Mathematical-Astronomical School," p. 23.

[22] See F. J. Ragep, "Astronomy in the Fanārī-Circle," pp. 165-76.

[23] However, keep in mind that Qāḍīzāde was not the only link; throughout the Ottoman period scholars traveled extensively, and there were many pipelines between Anatolia and other regions, such as cities located in Egypt and Syria (İhsanoğlu, *History of the Ottoman State, Society & Civilisation*, p. 371).

[24] ʿAbd al-Wājid's *Mulakhkhaṣ* commentary cites Ṭūsī's *Tadhkira*, Quṭb al-Dīn al-Shīrāzī's *Nihāyat al-idrāk* and *al-Tuḥfa*, and Kharaqī's *al-Tabṣira*; presumably he would have incorporated these *hayʾa* textbooks into the material that he taught at the Wājidiyya Madrasa in Kütahya (see F. J. Ragep, "Astronomy in the Fanārī-Circle," pp. 165, 173-5; and Hüseyin Topdemir, "ʿAbd al-Wājid," in *The Biographical Encyclopedia of Astronomers*, vol. 1, pp. 5-6). ʿAbd al-Wājid may have played a role in Qāḍīzāde's decision to compose his *Mulakhkhaṣ* commentary, which subsequently became one of the most popular astronomical textbooks for students in the madrasas (there are at least 300 extant copies of it [see İhsanoğlu, "Institutionalisation of Science in the *Medreses* of Pre-Ottoman and Ottoman History," p. 276]).

The scholarly connections between Anatolia and Central Asia, along with Samarqand's high reputation in the mathematical sciences, were presumably strong factors in Qāḍīzāde's decision to travel eastward; but he undoubtedly remained there due to the high level of proficiency in learning he found.[25] Qāḍīzāde's arrival meant that Samarqand scholars now had access to the collection of the circle of Mullā Fanārī, adding to the already impressive corpus of scientific texts in fifteenth-century Samarqand inherited from their Islamic predecessors. These works were further supplemented with their own original compositions, commentaries, super commentaries, and glosses.[26]

Much of this corpus of scientific treatises—which stemmed from the pre-Mongol, Ilkhanid, and Timurid periods—disseminated widely. This was in large part due to the Ottomans who inherited the Samarqand scientific legacy, and, with a strong centralized administration, standardized these scientific materials and incorporated them into the burgeoning number of educational institutions peppered throughout their vast empire. Mehmet II played a pivotal role in all this. He was able to lure to Istanbul the polymath ʿAlī Qūshjī (circa 1472) who brought the enriched knowledge of the Samarqand tradition of mathematical sciences back to Anatolian soil.[27] In addition, Mehmet II officially demanded that the trust deeds of Ottoman educational

[25] Qāḍīzāde demanded a high level of proficiency from his teachers in the mathematical sciences, one of whom was Sayyid al-Sharīf al-Jurjānī. It has been said that the two "parted ways" because Qāḍīzāde felt he was deficient in these subjects. See Ragep, "Qāḍīzāde," p. 942; and Fazlıoğlu, "The Samarqand Mathematical-Astronomical School," p. 34.

[26] According to the research of Kishimjan Eshenkulova, 63 astronomical works were composed at Samarqand ("Timurlular Devri Medrese Eğitimi ve Ulum el- Evail," Master's thesis, Istanbul University, 2001, pp. 130-42); and al-Kāshī specifically mentions that Qāḍīzāde was working on Jaghmīnī's *Mulakhkhaṣ* then (see Sayılı, *Uluğ Bey*, p. 78). For Kāshī's extensive list of mathematical and astronomical works read in the Samarqand madrasa, see Fazlıoğlu, "The Samarqand Mathematical-Astronomical School," pp. 19-20, p. 20 fn. 78.

[27] ʿAlī Qūshjī's profound impact on the teaching of the mathematical sciences within the Ottoman madrasa system cannot be overstated, nor his influence on future generations of scholars. Many of his compositions (five mathematical treatises [four in Arabic, one in Persian] and nine astronomical ones [seven in Arabic, and two in Persian], were used in Ottoman

institutions require that the employment of professors be dependent on their being knowledgeable in both religious studies and in the rational sciences, which included mathematics, philosophy, and logic.[28] So in effect, the teaching of *hayʾa* treatises was officially sanctioned in Ottoman madrasas, religious institutions that lasted from the fifteenth to the twentieth century, and were dispersed throughout three continents.[29]

The Samarqand mathematical sciences also spread to India during the periods of the Delhi Sultanate and Mughals. In addition to the Arabic and Persian originals, there was also a market for their Sanskrit translations that continued well into the eighteenth century (as indicated by the efforts at Jayasiṃha's court in Jayapura [1687-1743][30]). It is also significant that the emperor Akbar (r. 963-1014 H [1556-1605]) decreed the teaching of the rational sciences as

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madrasas; Fazlıoğlu credits Qūshjī with determining the levels of proficiency for the Ottoman madrasa curricula by designating which treatises were appropriate for teaching at each level (e.g., Qāḍīzāde's *Sharḥ al-Mulakhkhaṣ* and *Sharḥ Ashkāl al-taʾsīs* were designated as intermediate level textbooks for astronomy and geometry, respectively) (see Fazlıoğlu, "Qūshjī," in *The Biographical Encyclopedia of Astronomers*, vol. 2, pp. 946-48). Fazlıoğlu points out that Shirwānī was influential "in shaping the Ottoman scientific outlook" in that he disseminated the accumulated knowledge of Samarqand in the madrasas of various regions throughout Anatolia ("The Samarqand Mathematical-Astronomical School," pp. 24, 26, 38, 60).

[28] See İhsanoğlu,"Institutionalisation of Science in the *Medreses* of Pre-Ottoman and Ottoman History," pp. 274-76; and İhsanoğlu, *History of the Ottoman State, Society & Civilisation*, pp. 375-76.

[29] For more details on the military conquests that established the Ottoman Empire, see Halil Inalcik, *The Ottoman Empire: the Classical Age 1300-1600*, pp. 23-34. A statistical analysis of the development of the number of Ottoman madrasas indicates that by the time of Mehmet II (1451-1481) there were over a hundred Ottoman madrasas, which more than doubled with Süleymān I (1520-1566) due to his extensive construction efforts (see İhsanoğlu, *History of the Ottoman State, Society & Civilisation*, pp. 380-83).

[30] David Pingree provides a list eight works, six authored by al-Ṭūsī, the other two being by al-Zarqāllu and al-Kāshī ("Sanskrit Translations of Arabic and Persian Astronomical Texts at the Court of Jayasiṃha of Jayapura," *Suhayl* 1 [2000]: 101-6).

compulsory in all madrasas. Many of these Arabic and Persian scientific texts, as well as their Sanskrit translations, would have been ideal textbooks for a madrasa curriculum on the one hand, and for more traditional South Asian teaching on the other; however, there has been little scholarship to date that has assessed how widespread their implementation or influence became.[31]

Just as the Ottomans, Mughals, and Safavids[32] were indebted (in various degrees) to the scientific achievements of their fifteenth-century predecessors, our Samarqand scholars were

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[31] Two important works translated into Sanskrit were Qūshjī's Persian *Risāla dar ʿilm al-hayʾa* (*Hayatagrantha* [Book on *Hayʾa*]); and al-Birjandī's commentary on Book II, Chapter 11 of Ṭūsī's al-*Tadhkira* (completed in 913 H [1507-8]), which includes the "Ṭūsī-couple" and mentions prominent astronomers such as Ibn al- Haytham and Quṭb al-Dīn al-Shīrāzī. For additional information, see: S. M. Razaullah Ansari,"On the Transmission of Arabic-Islamic Science to Medieval India," *Archives Internationales d'Histoire des Sciences* 45 (1995): 274-76, 279-80; S. M. Razaullah Ansari,"Transmission of Islamic Exact Science to India and its Neighbours and Repercussions Thereof," *Studies in the History of Natural Sciences* 24 (2005): 31-35; Sonja Brentjes, "The Mathematical Sciences in Safavid Iran: Questions and Perspective," in *Muslim Cultures in the Indo-Iranian World During the Early-Modern and Modern Periods*, ed. Denis Hermann and Fabrizio Speziale (Berlin: Klaus Schwarz Verlag, 2010), pp. 340-45 ("The mathematical sciences in Mughal India"); Fazlıoğlu, "The Samarqand Mathematical-Astronomical School," p. 22; Takanori Kusuba and David E. Pingree (eds. and trans.), *Arabic Astronomy in Sanskrit*: *Al-Birjandī on Tadhkira II, Chapter 11 and its Sanskrit Translation* (Leiden: E. J. Brill, 2002), pp. 1-7; David Pingree, "Indian Reception of Muslim Versions of Ptolemaic Astronomy," in *Tradition, Transmission, Transformation: Proceedings of Two Conferences on Pre-modern Science Held at the University of Oklahoma,* ed. F. Jamil Ragep and Sally P. Ragep with the assistance of Steven Livesey (Leiden: E. J. Brill, 1996), pp. 474-76, 483; and Kim Plofker, who discusses the influence of Islamic texts on Indian mathematics in *Mathematics in India* (Princeton: Princeton University Press, 2009), pp. 255-78 ("Exchanges with the Islamic World").

[32] For an overview of mathematical sciences during the Safavid period, see Sonja Brentjes, "The Mathematical Sciences in Safavid Iran," pp. 345-65. Although Brentjes stresses that her focus is

indebted to the members of the Fanāri-circle, who in turn were indebted to the scientific activities of thirteenth-century scholars, among whom were Naṣīr al-Dīn al-Ṭūsī, Quṭb al-Dīn al-Shīrāzī, Muʾayyad al-Dīn al-ʿUrḍī, and Muḥyī al-Dīn al-Maghribī. This collective group, which included members from regions that spanned China to Spain, has frequently been referred to as "the Marāgha school" in recognition of the important but short-lived Mongol-sponsored observatory that attracted an impressive array of scholars. But to call this a "school" is problematic for a number of reasons. First, it tends to reinforce the notion that Islamic science is episodic and dependent on patronage; however, what this "school" is meant to represent, namely a program of alternatives to Ptolemaic astronomical models, was a tradition that went on for centuries both before and after the Marāgha observatory. In fact, few if any of these alternative models were actually originated during the time the observatory was in operation.[33] Second, it confuses the meaning of "school" within an Islamic context. A group of scholars does not a school make, and of course school normally means "madrasa," which the "Marāgha school" definitely was not. But most importantly, the notion of a "Marāgha school" has tended to mask the great debt thirteenth-century scholars owed to their predecessors in the preceding centuries who established many of the foundations of *hayʾa* that have often been associated with the Marāgha school.[34] However, this dependence has been obscured due to the Mongol onslaught that occurred earlier in the same century, and made it necessary to resurrect the advances that

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not on contextualizing Safavid science with their predecessors, she highlights similarities between the Timurids, Ottoman, and Safavids, which include shared "authorities" such as Ṭūsī, Ulugh Beg, Qāḍīzāde, Kāshī, ʿAlī Qūshjī, Birjāndī, Nīsābūrī, and Shīrāzī, and a strong interest in planetary theory). She also points out some differences, such as little interest in the *zīj* literature, astronomical observations, and timekeeping.

33 See Ragep, *Tadhkira,* pp. 55-56.

34 E. S. Kennedy used this term out of "convenience" ("Late Medieval Planetary Theory," *Isis* 57, no. 3 [Autumn, 1966]: 365); the temptation to call Marāgha a "school" is understandable given that we find an active group of scholars engaged in various scientific activities such as compiling new *zīje*s (the *Īlkhānī Zīj*), discussing and debating theoretical astronomy, producing key texts, and so on.

had been made.[35] Thus the Marāgha scholars should be recognized for their concerted efforts in resuscitating the works of their predecessors. Indeed, by the mid-1240s—just over some thirty years beyond the time Jaghmīnī composed the *Mulakhkhaṣ* in 1206—Naṣīr al-Dīn al-Ṭūsī was embarking on a major project that spanned twenty years (the time of his service with the Ismāʿīlīs and later with the Mongols) to churn out reeditions (often accompanied with original commentary) of many Greek classics and treatises on mathematics and astronomy by early Islamic authors that included: "Euclid's *Elements*, Ptolemy's *Almagest*, and the "Middle Books" of mathematics and astronomy with treatises by Euclid, Theodosius, Hypsicles, Autolycus, Aristarchus, Archimedes, Menelaus, Thābit ibn Qurra, and the Banū Mūsā."[36]

When Quṭb al-Dīn al-Shīrāzī provided his summary list of important *hayʾa* works up until his time in the explicit of his *Nihāya*, he was paying homage to his predecessors; and it is noteworthy that he specifically singles out the titles of al-Jaghmīnī and al-Kharaqī—a strong indication that the Mongol onslaught may have caused the destruction of the *madrasa*s physically,[37] but that it could not eradiate the idea of teaching astronomy. Fortunately not all Islamic scientific treatises composed prior to the Mongol invasions were destroyed, as evidenced by the thousands of extant manuscript witnesses to that period on various astronomical subjects located in repositories throughout the world today.[38] We owe much of this to the vibrant Islamic

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[35] Ṭūsī had first-hand experience of the Mongol devastation of Khurāsān since the destruction included his hometown of Ṭūs in the northeastern part of that region.

[36] See Ragep, "Naṣīr al-Dīn al-Ṭūsī," in *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures,* pp. 757-58.

[37] Before the Mongol invasions, the number of *madrasa*s in Khwārizm and Khurāsān was enormous; there were a reported 400 madrasas in the city of Balkh alone, none of which survived the Mongol onslaught (see Fazlıoğlu, "The Samarqand Mathematical-Astronomical School: A Basis for Ottoman Philosophy and Science," p. 9).

[38] This should give us pause as to what the number of treatises was prior to the invasions; Yaqūt al-Ḥamawī reported one library alone in Merv holding 12,000 volumes (*Muʿjam al-buldān,* vol. 5, p. 114 [see Ch. 1, fn. 70]). See Rosenfeld and İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th - 19th c.)* for a list of some 1,700 scientists, their works, and tens of thousands of manuscript copies; and *The World Survey of*

tradition of copying treatises; this entrenched enterprise assisted in the widespread dissemination of treatises throughout Islamic lands and contributed to their preservation.[39]

Sonja Brentjes comments that various biographical dictionaries may contain entries linking students to specific teachers of particular rational sciences, "but they very seldom indicate where teachers taught, whether by reading texts with their students or by sharing their own thoughts through conversations or lectures. Thus, it is extremely difficult to find an unequivocal statement to the effect that a certain 'rational' discipline was studied or taught at a specific locale." She points out that consequently scholars have mistakenly taken this to mean that they were "banned from madrasas and cognate teaching institutes."[40] Brentjes knows this is

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Islamic Manuscripts, a four-volume guide to the collections of Islamic manuscripts and general information on their holdings throughout the world (Geoffrey Roper, general ed. [London: Al-Furqan Islamic Heritage Foundation, 1993]).

[39] See Franz Rosenthal, who discusses the importance placed in Islamic society on mastering "the technique of the written transmission of learning." According to Rosenthal "Muslim civilization, as much as any higher civilization, was a civilization of the written word"; and he attributes al-Jāḥiẓ (ninth century), "the great lover of books, [with stating] knowledge is that which can be put down black on white" ("The Written Word as the Basis of Knowledge," in "The Technique and Approach of Muslim Scholarship," *Analecta Orientalia* 24 [1947]: 6). This process was aided by the introduction of paper into Islamic lands from Central Asia in the eighth century (see Jonathan M. Bloom, *Paper before Print: The History and Impact of Paper in the Islamic World* [New Haven: Yale University Press, 2001]; and Berkey, *The Transmission of Knowledge in Medieval Cairo*, pp. 24-26).

[40] See Brentjes's "On the Location of the Ancient or 'Rational' Sciences in Muslim Education Landscapes [AH 500-1100]," pp. 58, 60. As the title indicates, Brentjes investigates (using both primary and secondary sources) the "respectability," meaning social sanctioning, of the rational sciences within Islamic society (see esp. pp. 57-60). See also Berkey, *The Transmission of Knowledge in Medieval Cairo*, p. 18; and Jane H. Murphy, who adds the *ijāzas* to the list of entries that rarely specify the location of study ("Aḥmad al-Damanhūrī (1689-1778) and the Utility of Expertise in Early Modern Ottoman Egypt," *Osiris* 25, no. 1 [2010]: 94). Michael Chamberlain finds biographical dictionaries problematic in being more anecdotal than providing

wrong from her own research; she detected several scientific works with connections to religious institutions,[41] as well as evidence indicating that "endowed teaching institutes and particularly important shrines and mosques acquired a steadily growing number of donated manuscripts that became attached to the institute rather than to its professor(s)."[42] So some sources do include

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detailed information (see "The Production of Knowledge and the Reproduction of the Aʿyān in Medieval Damascus," p. 31).

[41] Brentjes provides six examples (which she claims is "by no means exhaustive") of witnesses studied or copied within religious institutions; four give the specific madrasa, the remaining two indicate they were being studied within a religious context: (1) Ibn Sīnā's medical treatise *al-Qānūn* (copied at the Niẓāmiyyya madrasa in 1283); (2) Ṭūsī's *hayʾa* work *al-Tadhkira* (also copied at the Niẓāmiyyya madrasa in 1283 [actually 1284]); (3) a work by al-Kindī on optics (copied at the Kāmiliyya madrasa in Cairo) (4) al-Khafrī's commentary on Ṭūsi's *Tadhkira* (copied by a student of the Ismāʿīliyya madrasa in Shirāz for his teacher); (5) a treatise by a student of ʿAḍud al-Dīn al-Ījī that cites al-Bīrūnī's *Qānūn* and Quṭb al-Dīn al-Shīrāzī's *Nihāya* and *Tuḥfa*); and (6) a work by Ibn alʿAṭṭār, a Shāfiʿī jurist, student of Jamāl al-Dīn al-Māridīnī (who taught Euclid's *Elements* at the Azhar mosque), known for his association with *muwaqqit*s and for composing and teaching astronomy ("Reflections on the Role of the Exact Sciences in Islamic Culture and Education between the Twelfth and the Fifteenth Centuries," in *Études des sciences arabes*, ed. Mohammed Abattouy [Casablanca: Fondation du Roi Abdul-Aziz Al Saoud, 2007]), pp. 17-18. Brentjes's footnotes indicate that this list was compiled based on secondary sources, i.e., not having examined the witnesses.

[42] Brentjes provides many examples to illustrate her point that "various scientific manuscripts exist today that were copied explicitly for a courtly library." She also states "from the last decades of the thirteenth century onwards, princely patronage for madrasas, mosques and Sufī khānqāhs with their prescriptions for teaching posts, stipends and other positions, among them the post of a *muwaqqit,* were features that repeatedly occurred in the cultural politics of Mamluk sultans in Egypt and Syria" (see "Courtly Patronage of the Ancient Sciences in Post-Classical Islamic Societies," pp. 412, 431).

information on pedagogical practice and place of study;[43] and of course many witnesses themselves may contain this information, but the process of detecting it can be a painstaking and time-consuming process.[44] Another important thing to consider is that some of the information we seek may never have been recorded; in other words, we can accumulate evidence of scientific works in endowed institutions, but if a scientific treatise were being studied within a broader classroom environment (i.e., rather than through a personal relationship), there may not have been a need to record this. That said, what follows are four scientific treatises on *hayʾa* treatises connected with religious institutions. I selected these to raise certain points.[45]

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[43] For example, A. Z. Iskander's catalogue lists two witnesses of Jaghmīnī's *Qānūnča* that specifically state the textbook was used in schools of medicine: (1) "…This account was written by … Muḥammad, senior physician to the *Dār-sh-Shifāʾ* [hospital], at the time of the teaching of *K. Qānūnča* on medicine, in order to simplify the chapter on the senses, for students who want to benefit from this book…" [In addition, Iskander informs us that this Cairo hospital was founded by the Mamluk Sultan al-Manṣūr Qalawūn, who ruled 1279 to 1290.]; and (2) [*K. Qānūnča* was] "…currently used in all countries, and indeed, students were as familiar with it as with the midday sun. In view of its very brief accounts of anatomy, and because it embraces so many topics, a commentary is badly needed…" (*A Catalogue of Arabic Manuscripts on Medicine and Science*, pp. 56-57).

[44] My purpose here is not to present a laundry list of skills required for examining a witness (compounded by gaining access to witnesses, and the massive number of them); rather it is to point out difficulties that contribute to our current lack of information.

[45] I have other witnesses, in both the exact sciences and philosophy, documenting the teaching of science in Islamic institutions; this is part of the current ongoing database research projects centered at McGill University (ISMI: Islamic Scientific Manuscripts Initiative; and PIPDI: Post-classical Islamic Philosophy Database Initiative).

MS	SCIENTIFIC TEXT	INSTITUTION	DATE	PERSONS NAMED[46]
Paris, BnF, MS ar. 2499, title page [owners note]	*Muntahā al-idrāk* by Kharaqī (d. 1138/9, Merv)	Ẓāhiriyya Juwāniyya madrasa in Damascus	730 H [1329-30]	Studied by Muḥammad b. Muḥammad b. Aḥmad b. ʿAlī al-Ḥanafī
Berlin, Stabi, Landberg MS 33, f. 1a [owners note]	*Muntahā al-idrāk* by Kharaqī	Shāhzāde Muḥammad Khān madrasa	970 H [1562-63]	Owned by Muḥammad son of our master (*mawlānā*), Abī Sinān, the teacher (*al-mudarris*)
			650 H [1252]?	Copied by the physician Mawdūd b. ʿUthmān b. ʿUmar (*al-mutaṭabbib*) al-Shirwānī [f. 66a]
Vatican City, Vatican ar. MS 319, f. 64a [colophon]	*Tadhkira* by Naṣīr al-Dīn al-Ṭūsī (d. 1274)	Copied in Baghdad (*madīnat al-salām*) at the Niẓāmiyya madrasa	Friday, 5 Muḥarram 683 [24 March 1284]	Copied by Maḥmūd b. Muḥammad b. al-Qāḍī Taqī al-Dīn
Paris, BnF, MS ar. 2330, f. 82b	*Mulakhkhaṣ* by Jaghmīnī	Umayyad Mosque at Aleppo	Friday, 19 Dhū al-Qaʿda 787 [1385]	[Copied]
			Beginning of Rabīʿ II 788 [1386]	[A note in another hand] Read in the presence of the Shaykh ʿAlāʾ al-Dīn, the timekeeper (*al-muwaqqit*)

[46] I have included the occupations in Arabic transliteration (in parentheses) because there can be subtle distinctions between the ordinary and the technical meanings of a term. George Makdisi provides a list of some technical terms with respect to law (institutions, teaching personal, and students) based on the biographical literature [the *ṭabaqāt* works] in "Muslim Institutions of Learning in Eleventh-Century Baghdad," *Bulletin of the School of Oriental and African Studies, University of London* 24, no. 1 (1961): 10-14.

Witness 1: Paris, BnF, MS ar. 2499, title page

Muḥammad b. Muḥammad b. Aḥmad b. ʿAlī al-Ḥanafī **studied** this in 730 H. [1329-30] in Damascus **at the Ẓāhiriyya Juwāniyya madrasa**	**طالع** فيه المفتقر إلى الله تعالى محمّد بن محمّد بن احمّد بن علي الحنفي عفا الله عنه وذلك في شهور سنة ثلثين وسبعمائة بدمشق المحروسة **بمدرسة الظاهرية الجوانية**

Kharaqī's *Muntahā* is in an interesting codex that contains on its title page various marginal notes in Hebrew, Greek, and Latin as well as Arabic. The significance of numerous ownership notes caught the attention of George Saliba who examined them,[47] but he missed an important one that stated it was studied in *al-Ẓāhiriyya al-juwāniyya* Madrasa in fourteenth-century Mamluk Damascus. This is significant in that the student only mentions the institution, and not a particular teacher. This may indicate that the work was being studied within the broader context of the madrasa itself. Michael Chamberlain states that the *al-Ẓāhiriyya al-juwāniyya* at this time was one of a group of madrasas in Damascus known as the "qāḍīs' madrasas," which supported chief judges in the later Mamluk period as well as "clients of powerful people." Chamberlain interpreted this to mean that that the madrasas were being used for purposes that had "little to do with education;"[48] in fact it was the exact opposite, since these were exactly the kind of "clients" that the ʿulumāʾ *were* educating during this time.[49]

[47] Saliba's focus was connecting this codex with the sixteenth-century scholar Guillaume Postel (d. 1581), and highlighting this as a strong indication of "untapped" avenues for the transmission of scientific ideas from the Islamic world to Renaissance Europe (see "Arabic Science in Sixteenth-Century Europe: Guillaume Postel (1510-1581) and Arabic Astronomy," *Suhayl* 7 [2007]: 151-59).

[48] Chamberlain, *Knowledge and Social Practice in Medieval Damascus, 1190-1350*, pp. 57-58, fn. 104.

[49] I will return to this point later in this chapter (**§ I.3.3b: Institutional Transformations**), when I discuss who the ʿulumāʾ were teaching.

Witness 2: Berlin, Staatsbibliothek, Landberg MS 33, f. 1a

The needy Muḥammad, the most deficient of the servants of God the All-giving, known as the son of our master (*mawlānā*) Abī Sinān, the teacher (*al-mudarris*) **at the Shāhzāde Muḥammad Khān madrasa**, may they have forgiveness and charity, is honored to **own** this [book] in the year 97<0> of the Hijra of the most noble of civilization	شرّف **بتمليكه** أضعف عباد الله المنّان محمّد الفقير الشهير بابن مولانا ابي سنان المدرّس **بمدرسة شاه زاده محمّد خان لهم التوبة والإحسان في سنة سبع<ين> وتسعمايه من هجرية أفضلية تمدّنان**

This is an example of Kharaqī's *Muntahā* being owned by someone at a religious institution, namely the Shāhzāde Muḥammad Khān Madrasa. Whether this particular Muḥammad, who apparently is a teacher there, taught it is an open question, but at the least we can say that he is not hesitant in associating this astronomical work, which he is honored to own, with the madrasa, even if indirectly. This information is not contained in Ahlwardt's catalogue description of this witness; he does, however, give the name of the copyist, the physician Mawdūd ibn ʿUthmān ibn ʿUmar al-Shirwānī (f. 66a), and also provides a copy date of 650 H [1252] that I was unable to find in the text.[50]

Witness 3: Vatican City, Vatican ar. MS 319, f. 64a[51]

The writing of this was completed by the sinner in need of the mercy of his forgiving Lord Maḥmūd b. Muḥammad son of the Judge Taqī al-Dīn on Friday, the 5th of Muḥarram of the year 683 at the **College of**	فرغ من تحريره العبد المذنب المفتقر إلى رحمة ربه الغفور محمود بن محمّد بن القاضي تقي الدين يوم الجمعة خامس محرّم سنة ثلاث وثمانين وستمائة **في مدرسة نظام**

[50] I am indebted to Adam Gacek for discovering this particular note. For the catalogue information on Landberg MS 33, see Ahlwardt, *Die Handschriften-Verzeichnisse der Königlichen Bibliothek zu Berlin,* vol. 5, pp. 155-56 (no. 5669).

[51] The English translation is by F. J. Ragep, who also provides the colophon in *al-Tadhkira*, pp. 76-77. Note Brentjes includes this witness in her list (no. 2) and cites Ragep ("Reflections on the Role of the Exact Sciences in Islamic Culture and Education between the Twelfth and the Fifteenth Centuries," p. 18 and fn. 3).

Niẓām al-Mulk in the City of Peace, may God Almighty protect it from the misfortunes and afflictions of time, as a laudation of God Almighty and a prayer for His Prophet; Praise be to God, Lord of the Worlds.	**الملك بمدينة السلام** حماها الله تعالى عن نوائب الدهر وحدثانه حامدا لله تعالى ومصليا على نبيه والحمد لله رب العالمين

This codex connects Naṣīr al-Dīn al-Ṭūsī's *al-Tadhkira* with the famous Niẓāmiyya madrasa in Baghdad, known as the City of Peace (*madīnat al-salām*).[52] It is especially noteworthy that it was being copied in 683 H [1284], some twenty-seven years after the Mongol invasion of Baghdad 656 H [1258], a time that has often been portrayed as a period in which the Mongols destroyed all madrasas and killed off any scientific pursuits.

Witness 4: Paris, BnF, MS ar. 2330, f. 82b: [this witness was used in my edition (=**MS S**)**]**

And God is the One who bestows success and from Whom one seeks assistance, and in Whom is the greatest trust. The completion of its copying occurred during the night of Friday, the nineteenth of the month of Dhū al-qaʿda of the year 787 [Thursday evening-Friday morning, 21-22 December 1385 CE]. Praise be to God alone, and may God bless our master Muḥammad and his family and grant them salvation.	والله الموفّق والمستعان وعليه التكلان اتّفق الفراغ عن كتابته ليلة الجمعة التاسع عشر من شهر ذي القعدة من سنه سبع وثمانين وسبعمائة الحمد لله وحده وصلى الله على سيّدنا محمّد وآله وسلّم
[A note in another hand]: The reading of this under the Shaykh ʿAlāʾ al-Dīn the **Timekeeper** was completed at the beginning of the month of Rabīʿ II of the year 788 [early May 1386 CE] in Aleppo, may God extend its duration.	[ملاحظة بيد أخرى] وفرغ عن قراءته في أوّل شهر ربيع الآخر من سنة ثمان وثمانين وسبعمائة على الشيخ علاء الدين **الموقّت** بحلب فسح الله في مدته

[52] Niẓām al-Mulk founded this Shāfiʿī madrasa in 457 H [1065] (though it was inaugurated two years later), having built nine others (and possibly a tenth) spread throughout Iraq and Khurāsān (eight of them bearing his name) (see Makdisi, "Muslim Institutions of Learning in Eleventh-Century Baghdad," p. 44).

This witness highlights that many *hayʾa* works were being read in mosques as well as madrasas; this is not surprising since the *muwaqqit* (timekeeper) as a profession was often attached to both institutions. The "professionalization" of the *muwaqqit* is often heralded as having provided a stable niche within religious institutions for science to thrive (the caveat being that it was the *only* niche, and furthermore confined to Mamluk regions alone[53]). David King has continually asserted that the science of reckoning time (*ʿilm al-mīqāt*) constituted "the essence of Islamic science" in that *muwaqqit*s often came up with creative, ingenious, and sophisticated solutions to rather complex astronomical problems, albeit "in the service of Islam," which implies for many a focus on matters related to ritualistic needs such as timekeeping and the regulation of prayer times.[54] Hence, the *muwaqqit*s have also been accused of restricting their brand of science to more practical, religiously-oriented concerns.[55] So someone like an Ibn al-Shāṭir, the renowned timekeeper and chief muezzin of the Umayyad Mosque, becomes a rather enigmatic figure

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[53] King believed that there was a similar office in Andalusia at the end of the thirteenth century, but with a different title ("On the Role of the Muezzin and the *Muwaqqit* in Medieval Islamic Society," in *Tradition, Transmission, Transformation*, pp. 299-300). Emilia Calvo confirms that "by the end of that century we find the first mention of an astronomer of this kind at the Jāmiʿ mosque of Granada," and she analyzes two treatises classified under the category of *mīqāt* in "Two Treatises on Mīqāt from the Maghrib (14^{th} and 15^{th} Centuries A.D.)," *Suhayl* 4 (2004): 159-206 at 161.

[54] See David A. King, "Science in the Service of Religion: The Case of Islam," in *Astronomy in the Service of Islam* (Adlershot: Ashgate Variorum Reprints, 1993), p. 245; King, "On the Role of the Muezzin and the *Muwaqqit* in Medieval Islamic Society," pp. 285-346; King, "The Astronomy of the Mamluks," *Isis* 74, no. 4 (Dec., 1983): 534-35; and King, "Mīḳāt," in *Encyclopaedia of Islam*, 2nd ed. (Leiden: E. J. Brill, 1993), vol. 7, pp. 27-32.

[55] Sabra insists that "it would be wrong to consider the *muwaqqit* a 'professional' astronomer" since any of their impressive accomplishments were ultimately geared to guide religious ritual; this Sabra concludes "appears to be the result of the fact that their institutional position did not demand or encourage theoretical ventures for their own sake" ("Situating Arabic Science," pp. 668-69).

displaying stellar achievements in both theoretical and practical aspects of astronomy.[56] Ibn al-Shāṭir was not moonlighting in his theoretical pursuits; we have mounting evidence that there were many other *muwaqqit*s who showed a strong interest in both areas, including ʿAlāʾ al-Dīn as this witness indicates. However, ʿAlāʾ al-Dīn is only listed in the catalogues as having composed works on various instruments,[57] so this witness reminds us that the *muwaqqits* were "versed in many fields," a point Charette has asserted, along with the need to reevaluate many treatises on instruments to explore their didactic component.[58]

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[56] Much has been written on his great feats, especially since Ibn al-Shāṭir's innovations in non-Ptolemaic planetary theory link him with influencing the work of Copernicus; see Jerzy Dobrzycki and Richard L. Kremer, "Peurbach and Marāgha Astronomy? The Ephemerides of Johannes Angelus and their Implications," *Journal for the History of Astronomy* 27 (1996): 189, 207-9; E. S. Kennedy, "Late Medieval Planetary Theory," p. 377; E. S. Kennedy and Victor Roberts, "The Planetary Theory of Ibn al-Shāṭir," *Isis* 50, no. 3 (Sep., 1959): 227-35; David A. King, *Astronomy in the Service of Islam*, Ch. 1, p. 245; D. A. King, "On the Role of the Muezzin and the *Muwaqqit* in Medieval Islamic Society," pp. 285-346; D. A. King, "The Astronomy of the Mamluks," pp. 534-35; D. A. King, "Ibn al-Shāṭir" in *The Biographical Encyclopedia of Astronomers,* vol. 1, pp. 569-70; F. Jamil Ragep, "Copernicus and His Islamic Predecessors: Some Historical Remarks" *History of Science* 45, no 147 (2007): 65-81; Victor Roberts, "The Solar and Lunar Theory of Ibn ash-Shāṭir: A Pre-Copernican Copernican Model," *Isis* 48, no. 4 (Dec.,1957): 428-32; George Saliba, "Theory and Observation in Islamic Astronomy: The Work of Ibn al-Shāṭir of Damascus," *Journal for the History of Astronomy* 28 (1987): 35-43; Saliba, *Islamic Science and the Making of the European Renaissance*, pp. 189-97, 204-13; and Noel M. Swerdlow and Otto Neugebauer, *Mathematical Astronomy in Copernicus's De Revolutionibus*, 2 parts (New York: Springer, 1984), passim.

[57] See David King, *A Survey of the Scientific Manuscripts in the Egyptian National Library*, p. 68 [C54: ʿAlāʾ al-Dīn Abū al-ḤasanʿAli b. Ṭībughā, *muwaqqit* at the Umayyad Mosque in Aleppo]; and his father [C53: ʿAlāʾ al-Dīn Ṭībughā al-Dawārdār al-Baklamīshī]. Like King, François Charette states that ʿAlāʾ al-Dīn was the *muwaqqit* at the Umayyad Mosque in Aleppo (ca. 1400), and that he "wrote on the sine, astrolabic and *shakkāzī* quadrants."

[58] See Charette, "The Locales of Islamic Astronomical Instrumentation," pp. 130, 131.

§ I.3.2 Partial Narratives

Despite the enormous amount of evidence showing that the mathematical sciences were being studied and taught within a religious context for generations, there has been a strong resistance to acknowledging that the institutions themselves played any significant role in this. Even the prominent collective of scientific activities displayed in Samarqand is credited as being the brainchild of "one Timurid prince, i.e., Uluġ Beg,"[59] who happened to have a personal bent for mathematics and the funds to see his vision implemented.[60] Hence the prevailing view has been that Islamic institutions, such as the madrasa, played a limited role in the teaching of the mathematical sciences in favor of the narrative, articulated by A. I. Sabra (over thirty years ago), that in medieval Islam a scientific education was "largely an individual affair in which individual students made special arrangements with individual teachers." And further: "insofar as the madrasas had anything like what we might call a curriculum, the study of the 'ancient sciences' was not part of it."[61]

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[59] See Sonja Brentjes ("The Mathematical Sciences in Safavid Iran," p. 329) who advocates a methodological approach that focuses on "a specific time and locality" rather than one that emphasizes historical predecessors where one runs the risk of placing events in terms of "progress or decline across time," something she clearly wishes to avoid (pp. 325-26, 328).

[60] According to Sayılı, "…the fact that in Ulugh Bey's time there apparently was a large number of scientists representing various mathematical and astronomical fields on the staff of this Samarqand madrasa must have very likely been due to that patron's initiative and encouragement" (*Uluğ Bey*, p. 44).

[61] A. I. Sabra, "Science, Islamic," in *Dictionary of the Middle Ages*, ed. Joseph Strayer (New York: Charles Scribner, 1982), vol. 11, pp. 85, 86. Aydın Sayılı devoted an entire section of his dissertation to discussing the "Exclusion of the Awāil sciences from the Madrasa"; his assertion was that the Greek sciences, "i.e., philosophy, mathematics, astronomy and the physical and natural sciences were not admitted into the curriculum" due to "theologians who had developed the madrasa system, [who] did not believe that the awāil were of any use to a Moslem in this world or in the next. Some theologians were even convinced that the awāil sciences were harmful and undesirable. Thus, the madrasas, which were the only institutions in Islam devoted

Sabra eventually recognized that the rational sciences, or some of them, "were able to penetrate even the *madrasas*,"[62] albeit informally, because occasionally private arrangements might be made between a student and madrasa teacher to teach the mathematical sciences (which, for example, is reported to have occurred between Ṭūsī and Kamāl al-Dīn ibn Yūnus in Mosul[63]). But Sabra was essentially in agreement with George Makdisi's often-cited position (put forth in his seminal work *The Rise of Colleges*) that a *waqf* institution, such as the madrasa, was *legally* bound to follow the stipulations of its endowment, and also that a madrasa's primary focus was the "teaching of the religious sciences with law at its center."[64] This effectively and legally excluded the ancient sciences and philosophy from the madrasa.

Although Makdisi's focus was on one specific madrasa at one particular time in history, he extrapolated that "the Niẓāmīya *Madrasa*, like all *madrasas*, was a traditionalist institution, in the sense that in it were taught only the traditional religious sciences of Islam. The foreign

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to advanced teaching, did not contribute to the transmission and cultivation of the awāil sciences" ("The Institutions of Science and Learning in the Moslem World" [Ph.D. diss., Harvard University, 1941], pp. viii, 40-41, 44-64).

[62] See Sabra, "Appropriation," pp. 234.

[63] Kamāl al-Dīn ibn Yūnus (1156-1242) was a rather renowned Shāfiʿī jurist who directed, taught, and studied at various schools in Mosul and at the Niẓāmiyya madrasa in Baghdad. He was noted for his expertise in astronomy and mathematics as well as his knowledge of logic, physics, medicine, music, and metaphysics. As a result, people came to him from great distances to study both the religious disciplines and the exact sciences. Among his students, who studied the ancient sciences with him, were: Ṭūsī, Athīr al-Dīn al-Abharī, ʿAlam al-Dīn Qayṣir, and ʿAbd al-Laṭīf al-Baghdādī. See Goldziher, "The Attitude of Orthodox Islam Toward the 'Ancient Sciences'", pp. 204-5; Ragep, *Tadhkira,* pp. 7-9; Sabra, "Appropriation," pp 237, 243, fn. 16; and Shawkat Toorawa, "A Portrait of ʿAbd al-Laṭīf al-Baghdādī's Education and Instruction," in *Law and Education in Medieval Islam: Studies in Memory of Professor George Makdisi* (Great Britain: E. J. W. Gibb Memorial Trust, 2004), p. 101.

[64] George Makdisi, *The Rise of Colleges: Institutions of Learning in Islam and the West* (Edinburgh: Edinburgh University Press, 1981), p. 9; and Makdisi, "Muslim Institutions of Learning in Eleventh-Century Baghdad," pp. 16, 46.

sciences, *ʿilm al-awāʾil*, were not allowed here, nor were the rationalist theological sciences."[65] His strict legal interpretation meant that: the terms of the endowment stipulations had to be enforced; all sanctioned subject matter had to be restricted to the study of *fiqh* (Islamic jurisprudence); and any subjects taught outside the purview of the charter had to be done privately. Makdisi later modified his views in recognition of mounting evidence that "the waqf's exclusory rule did not succeed in excluding the foreign sciences [for] there was nothing to stop the subsidized student from studying the foreign sciences unaided, or learning in secret from masters teaching in the privacy of their homes, or in the waqf institutions, outside of the regular curriculum."[66] But the *modus operandi* was that a professor would not, indeed *legally* could not, stray from the subject he was charged to teach,[67] although there was nothing preventing him from straying off course as long as his legal obligations had been fulfilled in accordance with the charter stipulations.

According to Chamberlain:

> "What the lecturer taught, if he taught anything at all, depended on the terms of the waqf, on his own interests, and occasionally on the efforts of rulers to mandate or proscribe subjects. Lecturers taught and wrote in fields other than fiqh. While the lecturer was often expected to lecture in one of the sciences of the sharīʿa, many different forms of knowledge were taught, both in madrasa and in study circles throughout the city. Shaykhs

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[65] See George Makdisi, "The Sunnī Revival," in *Islamic Civilization 950-1150*, ed. D. S. Richards (Oxford: Cassirer, 1973), pp. 158, 160. Makdisi never denied the profound influence of Greek works on the development of Islamic thought and education; he just insisted that "neither the madrasa nor its cognate institutions harboured any but the religious sciences and their ancillary subjects" (*The Rise of Colleges*, p. 77).

[66] See Makdisi, *The Rise of Colleges,* p. 78.

[67] Makdisi insisted professors had to go strictly by the book (or in this case charter): "Ghazzālī could not have taught Ashʿarism in the [Niẓāmīya] madrasa even if it had been possible. He was a professor of Shāfiʿī law, and that is the subject he taught…Outside of that traditional institution of learning, the madrasa, he pursued other subjects…" ("The Sunnī Revival," p. 160).

taught the Hellenistic "rational" sciences in madrasas as elsewhere, in spite of attempts [by the rulers] to forbid them."[68]

So were all these lecturers not playing strictly by the rules?

According to Makdisi, Niẓām al-Mulk, as founder of his eponymous Niẓāmiyya Madrasa, was making all administrative decisions acting in his legal capacity as a private individual, and not in the name of the state, or as the trusted and esteemed vizier in the Seljuq administration.[69] Each madrasa was its own private institution, one among many such institutions, each independent of the other, and each with its own endowment; so what may have been true of one institution may not have been true of another.[70] So this introduced a great deal of flexibility into the madrasa system regarding choice of appointments and subject matter

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[68] See Chamberlain, *Knowledge and Social Practice in Medieval Damascus, 1190-1350*, pp. 83-84.

[69] Makdisi remained steadfast that Niẓām al-Mulk was acting "outside the reach of the Caliph's authority" ("Muslim Institutions of Learning in Eleventh-Century Baghdad," pp. 16, 43, 51-52). Not surprisingly his position—though it applied to Niẓām al-Mulk alone (i.e., not to subsequent founders) —was highly contested since it downplayed the political and social dynamics at play, including key questions such who funded the madrasas, set the curriculum, and so on. See C. Edmund Bosworth, "The Political and Dynastic History of the Iranian World (A.D. 1000-1217)," pp. 71-74; Carla L. Klausner, *The Seljuk Vezirate: A Study of Civil Administration 1055-1194*. Harvard Middle Eastern Monographs (Cambridge: Harvard University Press, 1973), pp. 5, 7, 22-27, 63; Ann K. S. Lambton, "The Internal Structure of The Saljuq Empire," in *The Cambridge History of Iran*, vol. 5: *The Saljuq and Mongol Periods,* ed. J. A. Boyle (Cambridge: Cambridge University Press, 1968), pp. 214-17; Sabra, "Appropriation," p. 233; and Sabra, "Science, Islamic," p. 85; and Tibawi, "Origin and Character of *al-Madrasah*," *Bulletin of the School of Oriental and African Studies* 25 [1962]: 231-36).

[70] See George Makdisi, "Madrasa and University in the Middle Ages," *Studia Islamica* 32 (1970): 258, 263, and 264; and Makdisi, "The Sunnī Revival," p. 158.

taught.[71] There was only one caveat: the terms of the *waqf* could not in any way contravene the tenets of Islam. But what did that mean? Makdisi (and others) interpreted this as "the exclusion of the godless 'sciences of the Ancients' from the curriculum";[72] however the term "ancient sciences" was never clearly defined, nor did it always designate the same thing.[73] Given this ambiguity, many topics might legitimately be understood as "serving" Islam.

Subjects like mathematics and astronomy penetrated the madrasas (as Sabra noted), but not as sideline affairs as usually depicted, but in broad daylight, becoming indispensable tools used for matters related to Islamic law (such as the division of legacies [*farāʾid*]) and the performance of religious ritual).[74] Theoretical astronomical works also seeped in, offering Islam another approach "to reveal the glory of God's creation."[75] And even the oft maligned subject of logic[76] had its share of advocates, and introductory works on the subject were incorporated into

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[71] Tibawi stated that while the "administration of the waqf was governed by the actual deeds in accordance with the sacred law [the *ʿulamāʾ*'s] teaching was on whole free and subject only to mutual checks and balances within the learned community" ("Origin and Character of *al-Madrasah*," p. 232). Berkey also claimed that "the deeds of endowment themselves left a good deal of latitude to the schools' professors. Often they left even the choice of subject matter to the teacher…" (*The Transmission of Knowledge*, pp. 83, 99).

[72] Makdisi, *The Rise of Colleges*, pp. 35-36 and 77-78. Hellenistic philosophy (which Makdisi referred to as the "queen of the 'foreign sciences'") was particularly targeted as being an egregious discipline ("The Sunnī Revival," p. 160).

[73] Sabra points out that though the term "ancient sciences" could apply to everything that was translated into Arabic through the translation movement, "it primarily referred to the occult branches of Hellenistic lore, such as magic, astrology, and witchcraft" ("Appropriation," p. 231).

[74] Sabra, "Appropriation," pp. 231-32, 233; and Brentjes, "On the Location of the Ancient or 'Rational' Sciences in Muslim Education Landscapes (AH 500-1100)," pp. 52-53.

[75] See F. J. Ragep, "Freeing Astronomy from Philosophy," p. 51.

[76] According to Goldziher, the "battle against logic was an opposition of fundamental importance. It (orthodoxy) maintained the recognition of Aristotle's methods of proof was a serious threat to the validity of religious doctrines" ("The Attitude of Orthodox Islam Toward the 'Ancient Sciences'," p. 198). Tibawi also held the position that "orthodoxy, though internally

the curriculum becoming an "indispensable instrument of reasoning."[77] And I should mention that any critics of these topics would have felt the need to deal with them, if only to refute them.[78]

Ironically, this entire argument establishing that the mathematical sciences entered the madrasas with some form of legitimacy becomes totally irrelevant when viewed from the perspectives of Jonathan Berkey and Michael Chamberlain.[79] Berkey, for example, insisted that:

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divided, waged a relentless, if not concerted war" to exclude Hellenistic philosophy from the madrasas ("Origin and Character of *al-Madrasah*," pp. 228, 237).

[77] See Sabra, "Appropriation," p. 232. Franz Rosenthal articulates how important logic became for theologians: "It was indeed the auxiliary science which enabled Muslim scholars to give all their intellectual activities the necessary theoretical foundations. It provided a generally valid method of research and the only approach available in the Middle Ages to dealing with such basic problems of physics as, for example, the problem of the nature of time, space, vacuum and motions. More than that, it constituted the principal point of contact between the 'Greek' and the 'Arabic' sciences, as can be observed in connection with grammar and, at a later date, in connection with the science of the principles of jurisprudence (*uṣūl al-fiqh*)" (see *The Classical Heritage in Islam*, p. 75).

[78] F. Jamil Ragep cites the rise of theological "manuals" of al-Ījī (d. 1355) and al-Taftazānī (d. 1389) and the commentaries these inspired over the next centuries that "included introductory essays on natural philosophy (and even expositions of Ptolemaic astronomy) that adopted much terminology and methodology from the philosophers while seeking to refute them" ("Islamic Culture and the Natural Sciences," p. 57). See also Robert G. Morrison, "What Was the Purpose of Astronomy in Ījī's *Kitāb al-Mawāqif fī ʿilm al-kalām*?" in *Politics, Patronage and the Transmission of Knowledge in 13th–15th Century Tabriz*, ed. Judith Pfeiffer (Leiden: E. J. Brill, 2014), pp. 201-29.

[79] It is even more ironic in that Berkey acknowledges his debt to Makdisi's *The Rise of Colleges*, and refers to it as the "locus classicus for the institutional history of medieval Islamic education" due to its tracing of the rise and "phenomenal spread" of the madrasa (*The Transmission of Knowledge in Medieval Cairo*, pp. 6 and 7, footnotes 12 and 14). We should note, however, the

"institutions themselves seem to have had little or no impact on the character of the processes of the transmission of knowledge. … Indeed, medieval Muslims themselves seem to have been remarkably uninterested in *where* an individual studied. The only thing that mattered was with *whom* one had studied, a qualification certified not by an institutional degree but by a personal license (ijaza*)* issued by a teacher to his pupil. Whether lessons took place in a new madrasa, or in an older mosque, or for that matter in someone's living room, was a matter of supreme indifference." [80]

And as Michael Chamberlain puts it: "there is no evidence that students sought out prescribed programs of study, or enrolled in a madrasa to master a specific body of knowledge. Rather they chose their subjects for themselves, and sought out shaykhs who could 'benefit' them."[81]

Berkey and Chamberlain do not see the individualization of learning to be *necessarily* a bad thing; there were a lot of educational perks to having "no institutional structure, no curriculum, no regular examinations, nothing approaching a formal hierarchy of degrees."[82] It

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importance Makdisi placed on the madrasa for the transmission of knowledge in that it "provided [the student] with all his essential needs for learning" (*The Rise of Colleges*, p. 32).

[80] Jonathan Berkey, "Madrasas Medieval and Modern: Politics, Education and the Problem of Muslim Identity," in *Schooling Islam: The Culture and Politics of Modern Muslim Education*, ed. Robert W. Hefner and Muhammad Qasim Zaman (Princeton: Princeton University Press, 2007), p. 43.

[81] Chamberlain, *Knowledge and Social Practice in Medieval Damascus, 1190-1350,* p. 87. Cf. Makdisi's detailed examination of the "Organization of Learning" ("madrasa curriculum," "class procedure," "teaching days and holidays," "the long years of study") in *The Rise of Colleges*, pp. 80-98; and pp. 9 and 313, fn. 38 (where he provides examples of *madrasa*s in thirteenth-century Damascus designated specifically for the study of medicine); and Fazlıoğlu, "The Samarqand Mathematical-Astronomical School."

[82] See Berkey, "Madrasas Medieval and Modern," p. 43. In *The Transmission of Knowledge* (pp. 44, 217), Berkey adds: "There is little suggestion in the sources that particular schools ever acquired any lasting identity or mission within the academic sphere distinct from that of the

allowed for a higher degree of pedagogical flexibility and creativity: there were fewer restrictions on the range of subject matter one could teach, study, and read; and furthermore, scholars were not governed by specific stipulations regulating pedagogical issues of any given institution. In addition, individualism promoted character development and freed the student to seek out the most reputable and morally upright teacher.[83] Furthermore, it allowed for social

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individuals who taught within them…the whole system remained, as it were, thoroughly nonsystematic." Cf. Makdisi, who maintained that a legal education was a structured and formal affair; and that the introduction of the scholastic method of teaching students and obtaining the license to teach that occurred within the Western university (consisting of the elements of *sic et non*, dialectic, and disputation) had Islamic antecedents (George Makdisi, "Baghdad, Bologna, and Scholasticism," in *Centres of Learning: Learning and Location in Pre-Modern Europe and the Near East*, ed. Jan Willem Drijvers and Alasdair A. MacDonald [Leiden: E. J. Brill, 1995], pp. 146-49, 151). See also Devin Stewart's position regarding a medieval legal education that "the great professors of medieval Islam operated within a structured framework which, like the legal *madhhab*s, showed remarkable stability over space and time. While this framework may have been less formal and rigid than modern educational systems, it did not lack key structural elements, including recognized certificates and degrees" ("The Doctorate of Islamic Law in Mamluk Egypt and Syria," in *Law and Education in Medieval Islam: Studies in Memory of Professor George Makdisi* [Great Britain, 2004], p. 66).

[83] According to Berkey, "the critical factor that a successful student considered was always the character, intellectual quality, and reputation of his instructor…it is important to select the most learned, the most pious and the most advanced in years" (*The Transmission of Knowledge in Medieval Cairo*, pp. 22-23); and Jonathan P. Berkey, "Enseigner et apprendre au temps des madrasas," in *Lumières de la Sagesse: Écoles médiévales d'Orient et d'Occident*, ed. Éric Vallet, Sandra Aube, and Thierry Kouamé (Paris: Publ. de la Sorbonne, 2013), pp. 139-40.

mobility (something familial connections may not have been able to bestow) ,[84] and the prestige of being inducted into the club of scholars known for their "nobility of learning."[85]

But the onus was on the individual, who was not getting institutional or, perhaps more importantly, cultural support. He had to become an advocate, be proactive in seeking out the best teachers, often hopping from teacher to teacher, place to place, accumulating *ijāza*s along the way. More importantly, this individual had to fend for himself financially, unless he was lucky enough to find a patron or came from a family of wealthy scholars.[86] And there was no recourse if the relationship between student and teacher broke down.

But here we reach the following puzzle: could science in Islam, or anywhere else for that matter, have been sustained for almost a millennium—over the course of 50 generations or so—on individual initiatives and networks alone? And even with individual initiative, how does one learn something as complicated and extensive as Ptolemy's *Almagest*, or Euclid's *Elements,* without teachers or *vade mecums*?[87] And who sustained the market for such books, allowing for copyists who had the technical ability to reproduce complicated texts with often arcane terminology as well as diagrams? At this point, we might well call upon that tried and true *deus ex machina*, the patron. But patrons may be able to pay for buildings, instruments and salaries,

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[84] This is pointed out by Jane H. Murphy in "Aḥmad al-Damanhūrī (1689-1778) and the Utility of Expertise in Early Modern Ottoman Egypt," p. 92-95, 102-3.

[85] See Chamberlain, "The Production of Knowledge and the Reproduction of the Aʿyān in Medieval Damascus," pp. 30, 31.

[86] Apparently most common side jobs for young scholars were being guards and night watchmen (see Makdisi, "Muslim Institutions of Learning in Eleventh-Century Baghdad," p. 52).

[87] Toby Huff would have us believe that Muslim scholars used "memorization" and "repetition" to study ancient texts such as Ptolemy's *Almagest* and Euclid's *Elements* (*The Rise of Early Modern Science: Islam, China, and the West* [Cambridge: Cambridge University Press, 1995], p. 164). It would be interesting to see if he could find anyone, Muslim or otherwise, who could memorize Ptolemy's table of chords or his star chart that occupies 60 pages in a modern translation.

but they cannot conjure scientists out of thin air. And patrons collected scholars as trophies,[88] and supported them because they already *were* scholars.[89] These on-the-job training narratives are really inadequate to explain how these scholars got their expertise, especially when we recall the structured hierarchy of *hayʾa* texts given by Akfānī and Ṭāshkubrīzāde needed for mastering the subject and the many years of study in an institutional setting described by Shirwānī.

§ I.3.3 Transformations

I began this chapter with the claim that "something important began to happen to astronomy in the twelfth century that transformed not only the way it was taught but also its place within Islamic civilization." This final section is devoted to addressing this statement and will involve discussing three interconnected transformations that I have identified as having taken place: one being "conceptual," another "textual," and a third "institutional." In the twelfth century the structure of the *hayʾa* text was altered in an attempt to present the material in agreement with the way the discipline itself was being transformed conceptually. One of the results was the emergence of a new kind of *hayʾa* textbook that was conducive for a more general readership. No longer was the study of *hayʾa* restricted only to experts, limited to just a handful of

[88] It is said that Tīmūr collected scholars among the cities he ravaged to quench his inexhaustible delight in debating with them. Among his alleged abductees were Sayyid al-Sharīf al-Jurjānī and Qāḍīzāde (which represents an alternative narrative to how they ended up in Samarqand). Apparently, Ibn Khaldūn, who met Tīmūr in Damascus in 1400-1, was spared by flattering him and promising to include him in his chronology. See V. V. Barthold, *Ulugh-Beg*, p. 39; Beatrice Forbes Manz, *The Rise and Rule of Tamberlane* (Cambridge: Cambridge University Press, 1989), pp. 1, 16-17; and *Tamerlane or Timur The Great Amir*, trans. J. H. Sanders (London: Luzac & Co., 1936), pp. xv, 144-45, 296-99 (Eng. trans. of Aḥmad ibn Muḥammad Ibn ʿArabshāh's *ʿAjā'ib al-maqdūr fī nawāʾib Tīmūr*).

[89] "Scholars engaged in patronage relationships were expected to offer expertise in areas"; and Brentjes presents us with a rather lengthy list in "Courtly Patronage of the Ancient Sciences," p. 407.

individuals; it now could be used by the ʿulumāʾ to educate the burgeoning number of madrasa students who understood that it offered them another approach to better understanding God's creation. This of course also meant that major transformations had to have been occurring within the religious institutions.

§ I.3.3a Conceptual and Textual Transformations of the Discipline of *hayʾa*

In the introduction to his *Muntahā*, Kharaqī explicitly tells us that studying *hayʾa* is a rational and noble approach for attaining a better understanding of God through His creation; and by this he means His creation in its entirety, both the perfect celestial realm and that of the corruptible, sublunar one. Kharaqī was not alone in the view that studying *hayʾa* could provide a gateway to Heaven;[90] as mentioned before, Quṭb al-Dīn al-Shīrāzī also maintained that the discipline of *hayʾa* was "the most noble of the sciences" as stated in his *Nihāya* introduction (with citations from the Qurʾan to support his contention). But the fact that Kharaqī articulates his position gives us an idea of what was motivating him to compose his *hayʾa* works, more so since he eliminates this passage altogether in his abridged *Tabṣira*. This sentiment may have been a contributing factor in Kharaqī's decision to repackage the discipline of *hayʾa* with a new format that reflected his line of thinking; but in any event, the new structuring of his *hayʾa* works were striking departures from those of his predecessors;[91] his would become the model for subsequent *hayʾa* treatises, especially the establishment of a two-part delineation of God's two realms, one dealing

[90] For example, Qāḍīzāde states that the discipline of *hayʾa* is one by which one learns about the Creator, namely from substances and accidents (*Sharḥ al-Mulakhkhaṣ*, Istanbul, Ayasofya MS 2662, f. 2b). See also, F. J. Ragep, "Freeing Astronomy from Philosophy," pp. 51, 64.

[91] I do not here wish to demote the basic two-part division that is also contained in Qaṭṭān al-Marwazī's (465-548 H [1072-1153]) Persian *Gayhān-shenākht* (Knowledge of the Cosmos), which he composed in 498-500 H [1104-1107], i.e., prior to Kharaqī. Its influence and its relationship to Kharaqī's work certainly need to be explored in the future. Nevertheless, Kharaqī's *hayʾa* works are the ones that are most often cited by later scholars. In any case, we see this two-part division appearing in the twelfth century, and in the vicinity of Merv.

with the upper bodies of the celestial region (*hayʾat al-samāʾ*) and the other with the lower bodies of the terrestrial realm (*hayʾat al-arḍ*).

Kharaqī's *Tabṣira* is recognized as having become a very popular elementary textbook on theoretical astronomy, so the question is why did Badr al-Dīn al-Qalānisī feel the need to commission Jaghmīni to write yet another textbook, especially one on exactly the same subject matter?[92] This is even more puzzling given that Jaghmīnī not only relies on the *Tabṣira* as a major source for the content of the *Mulakhkhaṣ*, but even incorporates parts of Kharaqī's work into it. The answer rests with the need for an even more simplified textbook than those of Kharaqī. So let me provide a comparison of the number of chapters in both works before tackling the question of Jaghmīnī's intended audience; this will show us immediately how the *Mulakhkhaṣ* was a far less complex work than Kharaqī's "introductory" alternative:

	Jaghmīnī's *Mulakhkhaṣ*	**Kharaqī's *Tabṣira***
Introduction	Introduction	Introduction (includes an extensive discussion of mathematical terms)
Part One (*hayʾat al-samāʾ*)	**5** chapters	**22** chapters (**5** chapters have extensive subdivisions)
Part Two (*hayat al-arḍ*)	**3** chapters	**14** chapters

Before moving on to the target audience for the *Mulakhkhaṣ*, we should note some additional features and differences between the contents of the two works: (1) in discussing the equinox points Jaghmīnī references the two holidays of Nayrūz and Mihrjān (see **II.2. [2]**), and this may be an indication of Persian influence; (2) Jaghmīnī cites al-Shāfiʿī and Abū Ḥanīfa (see **II.3 [2])**[93]; and, most significantly, (3) Jaghmīnī has considerably condensed the *Tabṣira*'s

[92] I am assuming that I have convinced you that Jaghmīnī flourished in the late-twelfth/early-thirteenth century, and not the fourteenth (in Chapter One).

[93] As mentioned in the commentary, al-Shāfiʿī has been added in the margins of several of the witnesses I used. I interpreted this as meaning that Jaghmīnī originally felt no need to refer to

introductory sections, essentially eliminating Kharaqī's section dealing with mathematical definitions (such as point, line, straight line, and so forth) and giving only the briefest account of the general properties of bodies. In fact, Jaghmīnī has drastically abbreviated Kharaqī's section (contained in Chapter One of the *Tabṣira*) that deals with bodies from the perspective of natural philosophy. The explanation that Jaghmīnī provides in the introduction to the *Mulakhkhaṣ* (**Intro. [1]**) regarding the simple and composite bodies barely hints at its connection with Aristotelian natural philosophy, thus making it far more appropriate than the *Tabṣira* for inclusion in the madrasa.

§ I.3.3b Institutional Transformations: A New Clientele

Let us review what has been established so far: (1) We know that some of the mathematical sciences "penetrated" into the madrasas, and from our evidence we determined that *hayʾa* was among the subjects being taught; (2) some scholars viewed the discipline of *hayʾa* as a noble science and asserted that it was an alternative approach to understanding God's creation; thus the study of *hayʾa* could be seen as compatible with someone with a religious orientation; (3) Jaghmīnī's *Mulakhkhaṣ* was commissioned because there was a demand for a simplified "user-friendly" textbook on theoretical astronomy; (4) an analysis of the *Mulakhkhaṣ* content in conjunction with its pedagogical style indicates that it is a teaching textbook geared for a broad audience.

So why can't we assume that the *Mulakhkhaṣ* was geared for a circle of religiously-oriented students, studying, say, at a private home or somewhere in the marketplace? Why insist on a madrasa audience? The answer rests with our final transformation, that of the religious institutions themselves. According to Joan Gilbert, the period of the twelfth and thirteenth centuries experienced major political, social and religious changes due to "the professionalization of the ulama"; and among the changes was a concerted effort to regulate their salaries and standardize their training and practice. Consequently, there was an upsurge in the

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him explicitly inasmuch as students in a Shāfiʿī madrasa would have known al-Shāfiʿī's position on prayer times.

number of teaching institutions constructed, and a growing demand for standardization of many things, including textbooks;[94] but textbooks for whom?

The reference sources on the Seljuks during this period all seem to point out that there were close links between the central government and the ʿulumāʾ;[95] and they state explicitly that the Seljuk system of civil administration looked to the Shāfiʿī madrasas as training grounds for "judges, lawyers, and administrators, secretaries, ministers, ambassadors, political advisers, in short, the personnel for all public and private functions."[96] Carla Klausner adds: "The Seljuks

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[94] Joan E. Gilbert, "The Ulama of Medieval Damascus and the International World of Islamic Scholarship," pp. 58-59, 71. Gilbert also notes transformations occurring in twelfth- and thirteenth-century Damascus: "By degrees specialized buildings replaced common teaching sites such as mosques, private homes, shops, libraries and gardens, and served not only as places of instruction and devotion but also as residents for professors and students."

[95] Carla L. Klausner reiterates the important point that "A major innovation of the Seljuks was their attempt to link central government with the religious institution through state support for the *madrasa* system of education. There is no doubt that the early organizers of the empire hoped in this way to further the cause of the Sunni revival, to secure the support of the religious classes by giving them a stake in the proper functioning of the state, and to bolster civil administration against the expected encroachments of the military establishment" in the *The Seljuk Vezirate,* pp. 22. See also Dominique Sourdel, "Réflexions sur la diffusion de la madrasa en Orient du XI^e^ au XIII^e^ siècle," *Revue des études islamiques* 44 (1976): 182-83; and Tibawi, "Origin and Character of *al-Madrasah*," p. 234.

[96] Sayılı, "The Institutions of Science and Learning in the Moslem World," p. 23. Ann K. S. Lambton gives an overview of some of the positions held by local administrators of towns and cities who were appointed by the central government (Ph.D. diss., University of London, 1939, pp. 275-92), including the role of the "raʾīs of the town," a local notable who was an important link between the government financial administration, religious affairs, and the people (pp. 290-92). For more on the raʾīs, see Lambton, "The Administration of Sanjar's Empire as Illustrated in the *ʿAtabat al kataba*," *Bulletin of the School of Oriental and African Studies* 20, no. 1 (February 1957): 384-88; and Lambton, "The Internal Structure of The Saljuq Empire," pp. 279-80. Recall

hoped not only to win the support of the religious classes by sponsoring this system, but also to diffuse Sunni Islamic values more widely throughout the society, especially at the political level."[97] Furthermore the histories of the Seljuks and the Khwārizm Shāhs were tightly interconnected;[98] recall that Kharaqī dedicated his *Tabṣira* to the son of a vizier of the Seljuk Sultan Sanjar. So it is reasonable to assume that the Seljuk madrasa system would have had a great influence on the ones throughout Central Asia and Khwārizm.[99] We also know from Jaghmīnī's own personal experience that the dedicatee of at least two of his works was the highly esteemed scholar and Shāfiʿī Imām Shihāb al-Dīn al-Khīwaqī. Shihāb al-Dīn taught at five Shāfiʿī madrasas (and presumably included the *Mulakhkhaṣ* in his list of required reading). Furthermore, Shihāb al-Dīn was the trusted advisor (*wakīl*) to the Khwārizm Shāh ʿAlāʾ al-Dīn who "consulted him in all serious circumstances and yielded to his decision in important matters."[100] It is certainly conceivable that he used his position to promote the teaching of the sciences, especially since he was directly responsible for establishing numerous Islamic institutions throughout the region and filling their libraries with extensive collections.

I will stop here because I feel that we have more than enough evidence to present a plausible case that Jaghmīnī composed his *Mulakhkhaṣ* for the Shāfiʿī madrasas (especially given the weaknesses of the alternative options). Moreover, the popularity of the *Mulakhkhaṣ* as a teaching textbook continued for five centuries beyond its composition; in fact it was still being

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that some members of the Qalānisī family held this position (Gilbert, "The Ulama of Medieval Damascus and the International World of Islamic Scholarship" pp. 206-211).

[97] Klausner, *The Seljuk Vezirate*, p. 5.

[98] See Lambton, "Contributions to the Study of Seljūq Institutions," pp. 13-14. Many of the Khwārizm Shāhs were originally governors for the Seljuks before becoming independent rulers (C. Edmund Bosworth, *The Islamic Dynasties: A Chronology and Genealogical Handbook* [Edinburgh: Edinburgh University Press, 1967], p.107).

[99] "In the thirteenth century the madrasa system had established itself all over Islam from Central Asia to Sudan" (see Sayılı, "The Institutions of Science and Learning in the Moslem World," p. 29).

[100] Nasawī, *Sīrat al-Sulṭān Jalāl al-Dīn,* p. 109 (= Houdas, *Histoire du Sultan*, p. 82).

used as a teaching textbook "in the Azhar in Cairo about 1800."[101] This may explain why there are thousands of extant witnesses (and commentaries on it) spread throughout the world.

So given this wealth of evidence showing that *hayʾa* was taught in religious institutions, why are personal initiatives, informal structure, and patrons promoted and the role of the religious institutions consequently demoted? The answer lies in the value one gives to "promoting" science versus "sustaining" science. Sabra charged the historian of Islamic science with "the important task" of answering the question: "How did a significant scientific tradition *maintain itself* [emphasis mine] for such a long time largely outside the only stable institution of higher learning in medieval Islam?"[102] For him this meant that institutions "did not demand or encourage theoretical ventures for their own sake";[103] thus they were an impediment to scientific advancement. Any accomplishments made by Muslim scholars had no relation to place.[104] He saw the religious institutions only as obstructions in the way of scientific inquiry, and blind to their role in "maintaining" learning.[105] And he was far from being alone in this position. David

[101] See David A. King, "The Astronomy of the Mamluks," p. 552. King comments that "the manuscript libraries of Cairo and Damascus, which contain many manuscripts copied during the Ottoman period, and even the older collections in Europe whose shelves are somewhat less cluttered with late manuscripts, bear witness to the popularity of the works of al-Jaghmīnī." And there are so many *Mulakhkhaṣ* witnesses contained in the Cairo collection that King doesn't attempt to mention them all in his catalogue description of the scientific manuscripts in the Egyptian National Library; he just writes "*etc*." under its listing (see *Survey*, p. 150). As detailed in **Appendix II**, the *Mulakhkhaṣ* tradition was still going strong in the nineteenth and even early twentieth centuries; indeed as reported by a student of Muḥammad ʿAbduh (d. 1905), Sayyid Jamāl al-Dīn al-Afghānī read the *Mulakhkhaṣ* in Cairo with his students (Thomas Hildebrandt, "Waren Ǧamāl ad-Dīn al-Afġānī und Muḥammad ʿAbduh Neo-Muʿtaziliten?" *Die Welt des Islams* 42, 2 [2002]: 215 and fn. 22; I owe this reference to R. Wisnovsky).

[102] Sabra, "Appropriation," p. 234.

[103] Sabra, "Situating Arabic Science," p. 669.

[104] See Sabra, who states all accomplishments "must be regarded as accomplishments in astronomy proper, regardless of their institutional setting" ("Situating Arabic Science," p. 668).

[105] Sabra, "Situating Arabic Science," p. 660; and "Appropriation," p. 241.

King judged Jaghmīnī's textbooks insignificant since they were "a nontechnical digest of Ptolemaic astronomy."[106] But "the promotion of science" and "the sustaining of science" should not be an either/or choice. Ignoring the importance of the latter not only leads to reductionist statements such as place doesn't matter; it blinds us to the role the religious institutions played in providing some stability for an education in the mathematical sciences in order for these great feats of scientific achievement to occur over almost a millennium. Denying the role the madrasas played leads us to episodic history at best, great man narratives at worst—a historiography based on chance and accident rather than a more plausible story of individual effort sustained within an enduring social context.

When Badr al-Dīn al-Qalānisī and Shihāb al-Dīn al-Khīwaqī commissioned Jaghmīnī to write textbooks, neither they nor the author could have guessed how wildly successful his works would become. Had they known, they would have been well-pleased. They would also have been pleased to have known that his works would play such a vital role in educating countless individuals in a madrasa setting.

[106] See King, "The Astronomy of the Mamluks," p. 552.

PART II

§ II.1 Editorial Procedures

§ II.1a Establishing the Text

Although there are a large number of extant manuscripts of the *Mulakhkhaṣ*, either standing as independent texts or incorporated into a commentary or supercommentary, it was possible to establish an edition that, I claim, is close to the author's original. Fortunately, there was a relatively simply way to eliminate the vast majority of extant manuscripts as candidates for the author's original. These witnesses contain modifications that, as I explain in Commentary, **II.1[4]** ("the second clime"), could have only occurred after the publication of the *Tadhkira* by Naṣīr al-Dīn al-Ṭūsī in 659/1261, i.e., well after Jaghmīnī's lifetime.[1] Next, I identified a dedication and poem to Badr al-Dīn al-Qalānīsī that occurs in only a very few manuscripts.[2] I thus chose these manuscripts (MSS B, F, S), which also contain the pre-*Tadhkira* parameters, for the edition. There were two additional manuscripts containing the original parameters that I used: one, MS K, has the dedication but not the poem; and MS L, which lacks both but has the earliest copy date (644/1246-7). One could then distinguish these five manuscripts based on their prefaces: three have the poem and dedication (MSS B, F, and S); one has only the dedication (MS K); and one has neither (MS L). I therefore edited each of the three prefaces separately. After these divergent prefaces, the manuscripts come together in the introduction and continue to the end with relatively minor variants. These are listed in the critical apparatus.

There is no autograph copy, and no single manuscript establishes the "original" version. Each has some deficiency. For example, the oldest one (MS L) lacks the original preface; MS F has one folio missing; MS S has many grammatical mistakes; and MSS B and K contain various mistakes and are further contaminated by one or more commentaries. Nevertheless, using MSS F, L and S, I claim that the edited text is very close to the author's original, given the remarkably few variants between these three unaffiliated manuscripts and the plausible explanations for divergences in MSS B and K (usually due to misreadings or misunderstandings by the copyists, or additional material from one or more commentaries). My occasional use of the commentaries usually confirmed my readings. The earliest commentary by

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[1] See also Ragep, "On Dating Jaghmīnī and His *Mulakhkhaṣ*," pp. 462-64.

[2] The manuscripts used for the edition are described in detail in the next section **§ II.2**.

Yūsuf ibn Mubārak al-Alānī (ca 735/1334) [Istanbul, Topkapı Sarayı Müzesi, Ahmet III MS 3308] had the original values for the climes, while ʿAbd al-Wājid (d. 838/1435) [Istanbul, Süleymaniye Library, Laleli MS 2127] clearly struggled (as I did) with the range of numbers and gave both the original and the post-Ṭūsī parameters for the climes. Other commentators gave the post-Ṭūsī values.

§ II.1b Establishing the Figures

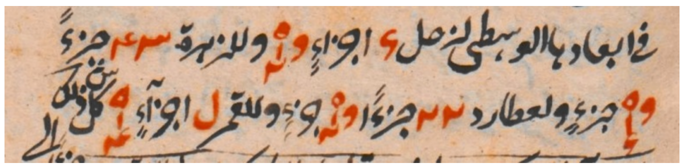
The figures in the manuscripts displayed different degrees of meticulousness; but generally speaking, MS L had the best diagrams. There was also a range of labeling the figures: some copyists being quite detailed, others sparse. Specific figures are occasionally missing; these are noted in the Figure Apparatus. My procedure was to follow the basic structure of the figures (which was usually similar in all manuscripts) and then use the text and context to decide on which labels to include. In a number of cases, I checked commentaries to confirm or clarify, but never used them to supplement or modify my five core manuscripts. Variants to my edited figures are noted in the Figure Apparatus, which follows the edited text.

§ II.1c Variants and Orthography

Since I used only five manuscripts to establish the text, I noted all variants in the critical apparatus with the exception of minor orthographic differences. As noted below in **§ II.3: Explanation of Signs and Conventions**, I have generally modernized the orthography for writing *hamza*s, numbers, and numerals; divergences are not noted except where there could be alternative readings (such as between *thulth* and *thalāth*). When giving variants, I have written these as they occur in the text, providing or leaving out the dots, vowels, and *hamza*s as given.

§ II.1d Parameters

Four out of five of my main manuscripts used the alphanumeric system for numbering parameters. The exception was Berlin; here parameters were often omitted altogether, but it is noteworthy that when included in the text, the copyist wrote them in unit fractional form, an indication of a late Ottoman style:



Since the alphanumeric system lends itself to ambiguity, and inattentive copyists could often introduce mistakes—for example by omitting a dot which would lead one to read a ج [3] as a ح [8] or by forgetting to add a stroke to ك (20) causing it to be read as a ل (30)—I relied on the context to confirm a value, either in the main text or as a variant. In general, values given by Ptolemy and Battānī allowed me to control the text. When this was not possible, or when further confirmation was needed, commentaries in which the parameters were written out in words proved valuable; however, cautious judgment had to be applied in recognition that parameters were often "updated" by commentators (for example, by changing Jaghmīnī's Ptolemaic ones to those found in Naṣīr al-Dīn al-Ṭūsī's *Tadhkira*). Alānī's commentary (the oldest one to date) alone seemed to contain non-contaminated values, so it was particularly valuable for establishing/confirming some of the parameters. A significant example of this occurs in fixing the date that Jaghmīnī gives for the position of the planetary apogees; misreading a single letter ش [300] instead of ث [500] can make a 200-year difference, but fortunately both context and Alānī's commentary provide us with the correct Alexandrian date of 1517, which also gives added confirmation of Jaghmīnī's dates (see **I. 5 [22]**, and **§ I.1.3b: Dating the *Mulakhkhaṣ***).

§ II.2 Description of the Manuscripts

The following list contains the five principal manuscripts that have been used to establish the edition.

	SIGLA	DESCRIPTION OF MANUSCRIPT
1.	ب [= B]	**Berlin, Staatsbibliothek, MS or. oct. 1511, pp. 6-64**. The codex contains several treatises, with a total of 667 pages, all in the same hand. On p. 667, a date of 1275 H / 1858-9 is given. A more expansive colophon is on p. 623, where we learn that the copyist is a certain ʿAbd al-Karīm Bulghārī (عبد الكريم بلغاري) who finished copying that particular work on Wednesday, 24 Jumādā I 1275 H [28-9 Dec. 1858 CE] at Mīr Sayyid al-Sharīf (Mosque, Madrasa?) in Tashkent (al-Tāshkand) in the Kallah Khānah quarter. MS B is contaminated with commentary comments; but, despite the late date, it includes Jaghmīnī's dedicatory poem. Its use of unit fractions is discussed above.
		Colophon: p. 64 والله أعلم بالصواب وإليه المرجع والمآب And God is most knowing of truth, and to Him are the refuge and the final return.
2.	ف [= F]	**Philadelphia, University of Pennsylvania, Rare Book & Manuscript Library, LJS, MS 388, ff. 2b-19b**. The codex of 19 folios contains only this one witness. It is written in a *nastaʿlīq* script. Formerly owned by Muḥammad ibn al-Dawla, 1246 [1830-31], it bears a Qajar seal imprint on ff. 1a and 19b. It was sold by Sam Fogg Ltd., cat. 22 (July 2000), no. 60 to Lawrence J. Schoenberg in 2011**.** **(**See *Transformation of Knowledge: Early Manuscripts from the Collection of Lawrence J. Schoenberg* (London: Paul Holberton, 2006), p. 55 (LJS 388); and

		http://dla.library.upenn.edu/dla/medren/record.html?id=MEDREN_5068122 Accessed July 27, 2014.) The witness was completed day 2 [i.e., Monday] 29 Rabīʿ I 786 H [probably, Sunday-Monday, 22-23 May 1384 CE]. MS F and MS S are closely aligned. The folios in this MS F (2-19) are bound in the wrong order; the correct order should be 2-7, 10, 13, 11, 12, 8, 9, 14-19. In addition a folio is missing between 17v and 18r. This corresponds in my edition to II.3 [1], line 6 to II.3 [4] line 6.
		Colophon: f. 19b والله الموفّق والمستعان وعليه الاعتماد والتكلان اتّفق الفراغ من كتابته يوم٢ ٢٩ شهر المبارك ربيع الأوّل سنة ٧٨٦ هجرية And God is the One who bestows success and from Whom one seeks assistance, and in Whom is the greatest support and trust. The completion of its copying occurred on day 2 [i.e., Monday], the 29th of the blessed month of Rabīʿ I in the year 786 hijra [probably, Sunday-Monday, 22-23 May 1384 CE].
3.	**ك [= K]**	**Cambridge UK, Cambridge University Library, MS Or. 593 (7), ff. 1b-38b** [= Trinity, R. 13.21]; the codex contains 109 folios written in a Persian *naskh* script. According to Edward G. Browne, it is dated 764 [1362-3] and the codex was bought from Élias Géjou on October 30, 1905 (*A Supplementary Hand-List of the Muḥammadan Manuscripts, in the Libraries of the University and Colleges of Cambridge* [Cambridge, 1922], p. 205). E. H. Palmer gives the date incorrectly as 1582-83 (*A Descriptive Catalogue of the Arabic, Persian and Turkish Manuscripts in the Library of Trinity College* [Cambridge; Cambridge: Deighton Bell and Co., 1870], pp. 50-52.) For an online description, see http://www.fihrist.org.uk/profile/manuscript/abef3293-10e8-4e05-8142-f15e28786ae9 ; accessed July 27, 2014. The title page states it was owned by a Muṣṭafā ibn Ḥasan al-Farḍī in the year 1180 [1766-7].

		Colophon: f. 38b والله الموفّق للصواب والحمد لله وحده وصلى الله على سيّدنا محمّد وآله وصحبه وسلّم في تاريخ سنة ٧٦٤ أحسن الله عاقبتها بمنّه وكرمه And God is the One who bestows truth. Praise be to God alone, and may God bless our master Muḥammad and his family and companions and grant them salvation. On the date of the year 764 [1362-3 CE], may God make its outcome favorable by His grace and munificence.
4.	ل **[= L]**	**Istanbul, Süleymaniye Library, Laleli MS 2141/3, ff. 61b-81a**; the codex contains 94 folios. This witness was copied in 644 H [1246-7 CE], making it the oldest *Mulakhkhaṣ* to date. The title page and f. 94a both contain an endowment stamp: Sulṭān Salīm Khān [i.e., Selīm III] ibn Sulṭan Muṣṭafā Khān 1217 [1802-3] (see Günay Kut and Nimet Bayraktar, *Yazma Eserlerde Vakif Mühürleri Waqif* [Ankara, 1984], p. 41 [no. 15]).
		Colophon: f. 81a وبالله التوفيق تمّ الكتاب في شهور خمد («٦٤٤» في الهامش) هجرية With God is success. The book was completed in the months of 644 hijra [1246-7 CE].
5.	س **[= S]**	**Paris, Bibliothèque nationale, MS arabe 2330, ff. 48b-82b**; the codex contains a total of 116 folios. Written in a *naskh* script, the codex contains at least 14 witnesses. (See Baron William de Slane, MacGuckin, *Catalogue des manuscrits arabes / par le baron de Slane* [Paris: Imprimerie nationale, 1883-1895], pp. 408-9). This witness was completed the night of Friday, 19 Dhū al-qaʿda 787 [Thursday evening-Friday morning, 21-22 Dec. 1385 CE]. For more on this witness, see **SECTION ONE, Chapter Three, § I.0, “Shedding Light on Old Evidence” (no. 1)**.

		Colophon: f. 82b والله الموفّق والمستعان وعليه التكلان اتّفق الفراغ عن كتابته ليلة الجمعة التاسع عشر من شهر ذي القعدة من سنه سبع وثمانين وسبعمائة الحمد لله وحده، وصلى الله على سيّدنا محمّد وآله وسلّم And God is the One who bestows success and from Whom one seeks assistance, and in Whom is the greatest trust. The completion of its copying occurred during the night of Friday, the nineteenth of the month of Dhū al-qaʿda of the year 787 [Thursday evening-Friday morning, 21-22 December 1385 CE]. Praise be to God alone, and may God bless our master Muḥammad and his family and grant them salvation.

§ II.3 Explanation of Signs and Conventions Used in Arabic Critical Edition and Apparatus

For the Arabic edition, the following conventions have been used:

1) The orthography and rules for *hamza* follow modern conventions.
2) The dotting of ي follows the rules used by printers in Syria and Lebanon.
3) *Tanwīn* is generally added (but not on feminine *tāʾ* endings).
4) *Shadda*s have been supplied (except for sun letters and *nisba*s).
5) Short vowels have been provided sparingly as aids to the reader and/or to avoid ambiguity

CRITICAL APPARATUS

[	Separates reading in edition from any variant
:	Separates variant and manuscript *sigla*
+	Added in
_	Missing from
=	Indicates another variant
(…)	Editor's comments
ب (B)	Berlin, Staatsbibliothek, MS or. oct. 1511, pp. 6-64
س (S)	Paris, Bibliothèque nationale MS ar. 2330, ff. 48b-82b
ف (F)	Philadelphia, University of Pennsylvania, LJS 388, ff. 2b-19b
ك (K)	Cambridge UK, Cambridge University Library Or. 593, ff. 1b-38b
ل (L)	Istanbul, Laleli MS 2141, ff. 61b-81a
با	بياض (blank)
تا	تحت السطر في (under the line in)
شا	مشطوب في (crossed out in)
طا	مطموس، غير مقروء، إلخ (smudged, unreadable, etc.)
فا	فوق السطر في (above the line in)
ها	في الهامش في (margin)

§ II.4 Arabic Edition of *al-Mulakhkhaṣ fī al-hayʾa al-basīṭa*

/[1] بسم الله الرحمٰن الرحيم[2]

[١] الحمد لله كِفاء[3] إفضاله والصلوة على نبيّه[4] محمّد وآله[5]. قال الإمام البارع الأجلّ العلّامة أستاذ الورى شرف الأفاضل عديم الأماثل ملك الفضلاء خاتم الحكماء محمود بن محمّد بن عمر الفقيهي الجغميني الخوارزمي رحمه الله[6]: إنّه نَقَلَ إليّ[7] أعزّة الأحباب وخالصة الأصحاب أنّ مولانا[8] الإمام الأجلّ البارع المنعم بدر الملّة والدين فخر الإسلام والمسلمين[9] عزيز الملوك والسلاطين شفاء الأرواح خاتمة الحكماء محمّد بن بهرام القلانسي رحمه الله[10]

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[1] ص٦: ب؛ ٤٨ب: س؛ ٢ب: ف؛ ١ب: ك؛ ٦١ب: ل.

[2] الرحيم] +رب الهم بالصواب: س = +وبه نستعين : ف.

[3] كِفاء] ب، ف = كفأ: س.

[4] نبيّه] س، ف = رسوله: ب.

[5] وآله] وعلى اله: س(«على» مشطوبة) = +محمد: شاف.

[6] قال الإمام...رحمه الله] س، ف = يقول الشيخُ الامام الهمام الفاضل الكامل المتبحّر شرف الدّين محمود بن محمّد بن عُمر الجغمنيّ رحمه الله: ب.

[7] نَقَلَ إليّ] س، ف = نُقل الى: ب.

[8] مولانا] س = مولاى: ب، ف.

[9] فخر الإسلام والمسلمين] س، ف = —ب.

[10] رحمه الله] س، ف = —ب.

أشار إليّ أن أجمع في علم الهيئة كتاباً يقرن[١١] بين الاختصار والبيان ويجمع إيجاز اللفظ إلى بسط المعاني[١٢] فعَدَدتُ ذلك من نعمة المتوالية وبادرت إلى امتثال[١٣] إشارته العالية وقلت شعراً[١٤] :

يا لها من إشارة صدرت لي / رفعتْ رتبتي وأعلتْ محلّ[١٥] /[١٦]

صدرت لي[١٧] من الكريم المرجّي[١٨] / بدرِ دين الهدى الإمام الأجلّ

قد رآني أهلاً لأمر خطير[١٩] / ليس مثلي لمثل[٢٠] ذاك بأهل

غير أنّي بذلت في ذاك جهدي / امتثالاً[٢١] لأمره أيّ بذل

قد دعاني لذاك لطفاً وبرّاً / لا افتقاراً إلى[٢٢] بضاعة مثلي

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[١١] يقرن] س، ف = تقرُبُ: ب.

[١٢] المعاني] ب، ف = المعان(؟): س.

[١٣] امتثال] س، ف = امثال: ب.

[١٤] شعراً] س = —ب، —ف.

[١٥] محلّ] س، ف = محلّى: ب.

[١٦] ٤٩آ: س.

[١٧] لي] فاس.

[١٨] المرجّي] س، ف = المروحىّ: ب.

[١٩] خطير] +عظم: تاس.

[٢٠] لمثل] س، ف = بمثل: ب.

[٢١] امتثالاً] س، ف = امثالاً: ب.

[٢] وألّفتُ هذا الكتاب على حسب الإمكان قاصداً للتلخيص فيه مع[٢٣] البيان وسمّيته الملخّص في الهيئة ليكون اسمه مخبراً[٢٤] عن معناه وظاهره دالّاً على فحواه وجعلته يشتمل[٢٥] على مقدّمة ومقالتيْن.[٢٦] [٢٧]

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[٢٢] إلى] س، ف = لى: ب.

[٢٣] مع] هاف(مع رمز «ح») = من: ف.

[٢٤] مخبراً] س، ف = دالا: تاس(مع رمز «ح»).

[٢٥] يشتمل] تشتمل: س = مشتملاً: ف.

[٢٦] وألّفتُ هذا الكتاب... على مقدّمة ومقالتيْن] فالفت هذا الكتاب فى هيئة [ص٧: ب] العالم تدكرةً منّى بَعْدى لكلّ عالمٍ مُتَحرّيا فيه التّلحيْص مع البيان وايجازَ الالفاظ الى بسط المعانى على حَسب الامكان وسميته الملخِّصَ فى الهيئة ليكون اِسمُه دالّاً على معناهُ وظاهرهُ مُحبراً عن معنا فحواه وجعلتَه شتمل على مقدّمة ومقالتىن: ب .

[٢٧] بسم الله... على مقدّمة ومقالتين] بِسمِ ٱللّه ٱلرَّحمَنِ ٱلرَّحِيمِ الحمد لله كفاء(غير مقروء) افضاله والصلاة علي رسوله محمد وآلهِ قال قال(؟) الشيخ الامام الاجل البارع العلامه استاد الوري شرف الاماثل ملك الفضلا خاتمة الحكماءِ محمود بن محمد بن عمر الحعميني الخوارزمي تغمدهُ الله تعالي برحمته ان اعزة الاحباب وخالصة الاصحاب بدر الملة والدين فخر الاسلام والمسلمين عريز الملوك والسلاطين راحة الاشياخ وشفا الارواح محمد بن بهرام القلانسِي احمد الله عواقبه اشار ان اجمع في علم الهيية كتابا يقرن بين الاختصار والبيان ويجمع ايجاز اللفظ الي سط المعاني فعددت ذلك من نعمه المتواليه وبادرت الي امتثال اشارته العاليه والفت هذا الكتاب علي حسب الامكان قاصداً للتلخيص فيه مع البيان وسميتُه الملخص في(غير مقروء) الهيئة اسمه مخبرا عن معناه وظاهره دالا علي فحواه وجعلته يشتمل علي مقدمة ومقالتين: ك = بسم الله الرّحمن الرّحيم الحمدُ لله كِفَآ اِفضاله والصلوة على نبيه محمد وآله نقول عبد الله الفقر الى رحمته محمودُ بن محمدِ ىن عمر الجغمينى رحمه الله انى الفتُ

المقدّمة[٢٨] في[٢٩] بيان أقسام الأجسام على الإجمال. المقالة الأولى[٣٠] في بيان الأفلاك وما يتعلّق بها وهي خمسة أبواب: آ[٣١] في هيئات الأفلاك؛ ب[٣٢] في بيان[٣٣] حركات الأفلاك؛ حـ[٣٤] في بيان الدوائر؛ د[٣٥] في بيان القسي؛ هـ[٣٦] فيما يعرض للكواكب في حركاتها وما يتّصل بذلك. [٣٧]المقالة الثانية في بيان هيئات[٣٨] الأرض وما يتعلّق بها

هذا الكتابَ فى هيئه العالم تدكرةً منّى تعدِى لكل عالم مُتحرياً فه الىلخيصَ مع البياں واىجازَ الالفاط الى ىَسط المعانى على حسب الامكان وسميتُه الملخّص في الهيئه لكون اسمه دالا على معناه وظاهره مُخْبِراً عن فحواهُ وحعلتُه يَشتمل على مقدمة ومقالتين: ل.

[٢٨] ٢آ: ك.

[٢٩] المقدّمة في] اما المقدّمة ففي: ب.

[٣٠] المقالة الأولى] طاك.

[٣١] آ] ف، ل = الاوّل: ب = ١: س = = البَابُ الاول: ك.

[٣٢] ب] ف، ل = والثانى: ب = ٢: س = البَابُ الثاني: ك.

[٣٣] بيان] –ل.

[٣٤] حـ] ف، ل = والثالث: ب = ٣: س = البَابُ الثالث: ك.

[٣٥] د] ف، ل = والرابع: ب = ٤: س = البَابُ الرابع: ك.

[٣٦] هـ] ف، ل = والخامس: ب = ٥: س = البَابُ الخامس: ك.

[٣٧] ٣آ: ف.

[٣٨] هيئات] –ل.

وهي ثلثة أبواب: [٣٩] آ[٤٠] في المعمور من الأرض[٤١] وعرضه وطوله وقسمته إلى الأقاليم؛ ب[٤٢] في خواصّ خطّ الاستواء والمواضع التي لها عرض؛ حـ[٤٣] في أشياء منفردة.[٤٤]

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[٣٩] ٤٩ب: س.

[٤٠] آ] ف، ل = الاوّل: ب =١: س = البَابُ الاول: ك.

[٤١] من الأرض] ـك.

[٤٢] ب] ف، ل = والثانى: ب = ٢: س = الباب الثاني: ك.

[٤٣] حـ] ف، ل = والثالث: ب = ٣: س = الباب الثالث: ك.

[٤٤] منفردة] منفرد: س.

المقدّمة

في بيان أقسام الأجسام على الإجمال

[١] الأجسام قسمان: بسائط وهي التي لا تنقسم إلى أجسام مختلفة الطبائع؛ ومركّبات وهي التي تنقسم إلى أجسام مختلفة الطبائع[٤٥] [٤٦] كالمعدنيات والنبات والحيوان. فالبسائط قسمان: عناصر وهي الأرض[٤٧] والماء والهواء والنار وأجرام أثيرية وهي الأفلاك بما فيها. وكلّ جسم بسيط[٤٨] إذا خُلِّي وطبعه[٤٩] فهو على ما بيّن في غير هذا العلم كري الشكل. فالعناصر بجملتها والأجرام الأثيرية كريّة الأشكال. إلّا أنّ الأرض لقبولها التشكيلات[٥٠] وقعت في سطحها تضاريس لأسباب[٥١] خارجة عنها كما نشاهد[٥٢] من الوهاد والتلال[٥٣] [٥٤] ونحوهما. لكنّ هذه[٥٥]

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[٤٥] ومركّبات وهي التي تنقسم إلى أجسامٍ مختلفة الطبائع] –ب، –ك.

[٤٦] ٢ب: ك.

[٤٧] ص٨: ب.

[٤٨] بسيط] تاس(مع رمز «صح»).

[٤٩] وطبعه] وطبعيته: ك.

[٥٠] التشكيلات] الشكلات: ب.

[٥١] لأسباب] –ف.

[٥٢] نشاهد] نشاهدها: ب، ل.

[٥٣] من الوهاد والتلال] س، ف، ك = من الجبال والوهاد: ب، ل = +والجبال: هاس(مع رمز «خ»).

[٥٤] ٦٢آ: ل.

التضاريس لا تقدح[٥٦] في كونها كرية الشكل[٥٧] بجملتها كالبيضة لو[٥٨] أُلزِقت بها حبّاتُ[٥٩] [٦٠]شعير[٦١] لم يقدح[٦٢] ذلك في شكل[٦٣] جملتها. وكذا الماء كريّ[٦٤] إلّا أنّه ليس بتامّ الاستدارة لأنّه خرج عن سطحه[٦٥] ما ارتفع من

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[٥٥] هذه] هذا: ف.

[٥٦] لا تقدح] ك، ل = لا نقدح: ب = لا يقدح: س، ف.

[٥٧] الشكل] الاسكال: ف.

[٥٨] لو] اذا: ب.

[٥٩] أُلزِقت بها حبّاتُ = أُلْزِقت بها حبّات : ب = أُزلِقت بها حبّاتُ: ف = الْزِقت بها حبات: ل = (بدون حركات في س، ك).

[٦٠] ٥٠آ: س.

[٦١] شعير] شعيرة: ك.

[٦٢] يقدح] +فى كونها لو: شاف.

[٦٣] شكل] هال.

[٦٤] كريّ] +الشكل: ب.

[٦٥] عن سطحه] هاف(مع رمز «صح»).

الأرض. وكذا الهواء كريّ إلّا أنّ سطحه المقعّر[٦٦] مضرّس أيضاً[٦٧] بحسب تضاريس ما فيه من الماء والأرض. والنار كريّة الشكل صحيحة الاستدارة تحديباً وتقعيراً بالرأي الأصحّ.[٦٨]

[٢] والأفلاك كلّها كرية الأشكال وهذه الكرات يحيط[٦٩] بعضها ببعض. والأرض[٧٠] في الوسط ثمّ الماء فهو[٧١] محيط [٧٢]بها[٧٣] ثمّ الهواء ثمّ النار ثمّ فلك القمر ثمّ فلك عطارد[٧٤] ثمّ فلك الزهرة ثمّ فلك الشمس ثمّ فلك المرّيخ ثمّ فلك المشتري ثمّ فلك زحل ثمّ فلك الثوابت ثمّ فلك الأفلاك ويسمّى[٧٥] الفلك الأعظم[٧٦] وهو الفلك

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[٦٦] المقعّر] المقـ المقعّر: ب.

[٦٧] أيضاً] –س، –ك.

[٦٨] الأصحّ] هاف(مع رمز «صح»).

[٦٩] يحيط] س، ك، ل = تحيط: ب = بحط: ف.

[٧٠] والأرض] ب، ك، ل = فالارض: س، ف.

[٧١] فهو] وهو: ف.

[٧٢] ٣آ: ك.

[٧٣] فهو محيط بها]–س.

[٧٤] فلك عطارد] فلك العطارد: ب.

[٧٥] ص٩: ب.

[٧٦] الفلك الأعظم] فلك الأعظم: ف.

المحيط بجميع الأجسام ليس ورائه شيء لا خلاء ولا[٧٧] ملاء.[٧٨] وكلّ محيط يماسّ المحاط به الذي يليه في الترتيب المذكور.[٧٩] وبجملة[٨٠] هذه الأجرام[٨١] من العناصر والأفلاك وما فيها يُطْلق عليها[٨٢] اسم العالم. وصورتها هذه:[٨٣]

[٧٧] لا خلاء ولا] («لا» مرتان قوق السطر في مخطوطة ل).

[٧٨] ليس ورائه شيء لا خلاء ولا ملاء] ليس وراء خلائه وملاء: ب.

[٧٩] وكلّ محيط يماسّ المحاط به الذي يليه في الترتيب المذكور] –ل.

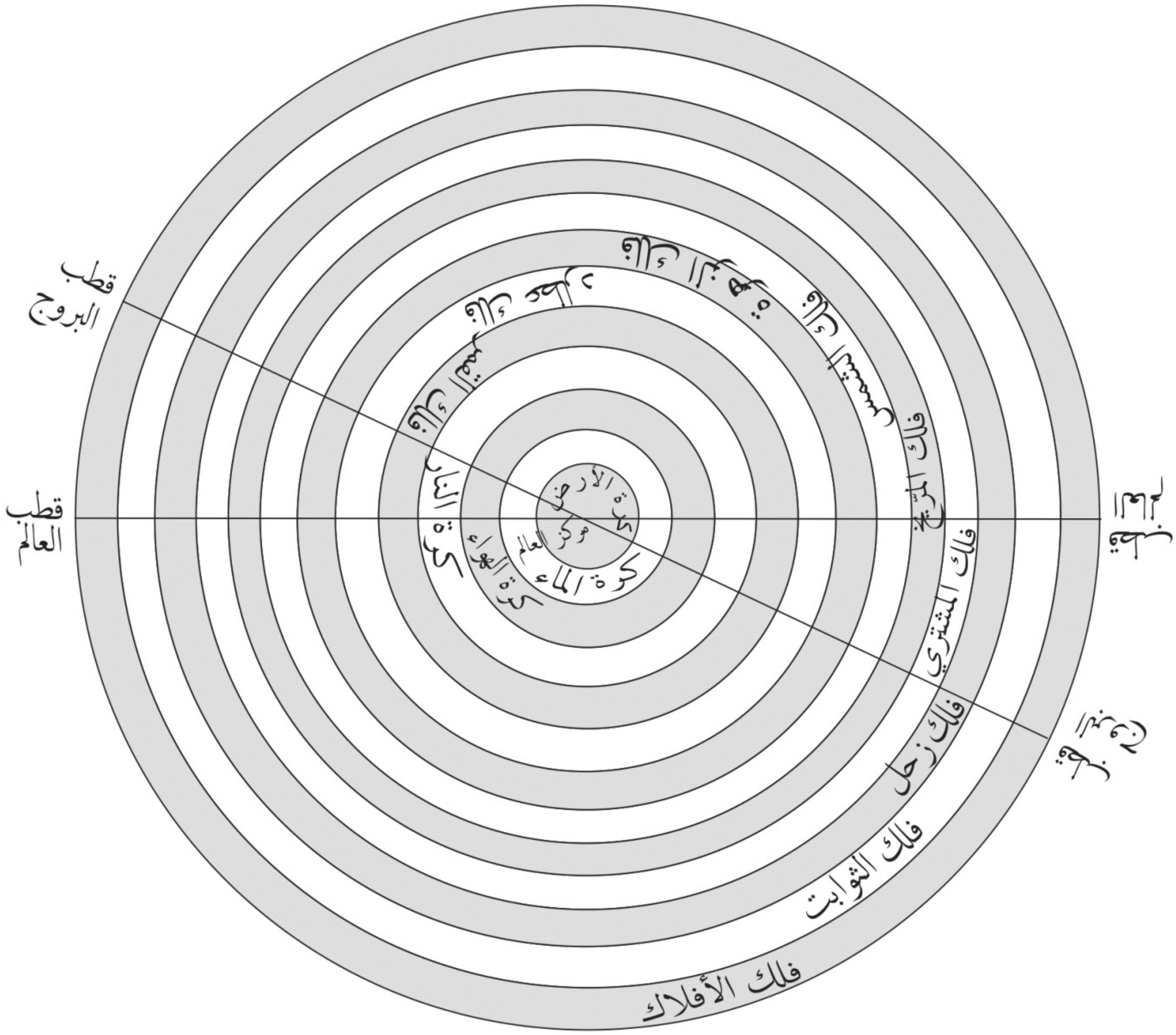
[٨٠] وبجملة] س، ف = وجملة: ب، ك، ل(هناك إشارة إلى الهامش حيث نجد «وعلى» مع رمز «صح» في مخطوطة ل).

[٨١] الأجرام: ب، ك، ل = الأجسام: س، ف.

[٨٢] عليها] ب، فاس، ك = –ف، –ل.

[٨٣] وصورتها هذه] س، ف = وهذه صورة: ب = وهذه وصورتها: ك = صورة كرة العَالَم: ل.

صورة الأفلاك



[شكل ١]

المقالة الأولى[1]

في بيان الأفلاك وما يتعلّق بها[2]

الباب الأوّل

من المقالة[3] الأولى

في هيئات[4] الأفلاك

[١] **فلك الشمس** جرم كري [5]يحيط به سطحان متوازيان مركزهما مركز العالم. وكلّ كرة متوازية السطحيْن فمركز سطحيْها[6] هو مركزها[7]. وكلّ فلك مجسّم [8]شامل للأرض فهو متوازي السطحيْن. وأعني

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[1] ٣ب: ك؛ ٦٢ب: ل.

[2] وما يتعلّق بها] +وهي خمسة ابواب: ك، هال.

[3] المقالة] فاك.

[4] في هيئات] في بيان هيئات: ك.

[5] ص١٠: ب.

[6] فمركز سطحيْها] س، ف = فمركزهما: ب، ك، ل.

[7] هو مركزها] +الكرة: تال.

[8] ٦٣ آ: ل.

بالمتوازييْن هنا[٩] أنّ البعد بينهما واحد من جميع الجهات[١٠] لا يختلف حتّى[١١] يكون للكرة جزء[١٢] أرقّ وجزء أغلظ بل هي متشابهة الثخن.

[٢] وفي داخل ثخن هذا الفلك، [١٣]أيْ فيما بين سطحيْه المتوازييْن لا في جوفه، فلك ثانٍ هو جرم[١٤] كري شامل للأرض يحيط به سطحان متوازيان مركزهما[١٥] خارج عن مركز العالم، محدّب سطحيْه مماسّ لمحدّب سطحيْ الأوّل على نقطة مشتركة بينهما تسمّى[١٦] **الأوج** ومقعّر سطحيْه مماسّ لمقعّر سطحيْ الأوّل على نقطة مشتركة بينهما وتسمّى[١٧] **الحضيض**[١٨] [١٩]أيْ يكون هذا الثاني في داخل ثخن الأوّل لا في جوفه مائلاً إلى جانب منه بحيث[٢٠] تصل[٢١] نقطة من[٢٢] محدّبه إلى محدّب الأوّل ونقطة من مقعّره[٢٣] [٢٤]إلى مقعّر الأوّل.

---

[٩] هنا] ههنا: ب، ك = هاهنا: ل.

[١٠] الجهات] +بحيث: ب.

[١١] حتّى] +لا: س.

[١٢] جزء] جزأً: ك.

[١٣] ١٥آ: س.

[١٤] جرم] جرمى: ب.

[١٥] مركزهما] +هما: شاف.

[١٦] تسمّى] +تلك النقطة: س.

[١٧] وتسمّى] وسمى: ف، ك = ويسمي: ك.

[١٨] الحضيض] شاف = +الاوح ومقعر سطحه يماس لمقعر الاول على نعطة مشتركه سها وسمى الحصضَ: هاف(مع رمز «صح»).

[٣] فبالضرورة[٢٥] يصير[٢٦] به الأوّل كرتيْن غير متوازيتيْ[٢٧] السطوح بل[٢٨] مختلفتيْ الثخن، إحداهما[٢٩] حاوية له، والأخرى محوية[٣٠] فيه[٣١]. ورقّة الحاوية[٣٢] ممّا يلي الأوج؛ وغلظها ممّا يلي الحضيض. ورقّة المحوية

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[١٩] ٤آ: ك.

[٢٠] بحيث] ب، ك، ل = حيث: س، ف.

[٢١] تصل] يَصِلُ: ل.

[٢٢] من] –ب.

[٢٣] من مقعّره] هاف.

[٢٤] ٤آ: ف.

[٢٥] فبالضرورة] فالضروة: ل.

[٢٦] يصير] تصير: ب = تَصر: ل.

[٢٧] متوازيتيْ] موازيتي: س.

[٢٨] غير متوازيتيْ السطوح بل] هال = +محا: شاك.

[٢٩] إحداهما] احدهما: س، ف.

[٣٠] محوية] محبوبه: ك.

[٣١] فيه] له: ب.

[٣٢] الحاوية] الحاوى: ب، ل.

وغلظها بالخلاف[٣٣]. وتسمّى[٣٤] كلّ واحدة[٣٥] منهما **متمّماً**. وهذا الفلك الثاني يسمّى[٣٦] **الخارج المركز** والأول يسمّى[٣٧] [٣٨]**الفلك الممثّل** لأنَّ على محيطه[٣٩] الدائرة المسمّاة أيضاً بالفلك الممثّل[٤٠] وستعرفها في باب الدوائر.

[٤] **والشمس** جرم كري مُصْمَت مركوز[٤١] في جرم الفلك الخارج المركز مغرق فيه بحيث يساوي قطرها ثخن الفلك ويماسّ[٤٢] سطحها سطحيْه.

[٥] **وأمّا أفلاك الكواكب العلويّة والزهرة**، فهي بِعينها كفلك الشمس، لا فرق بينها[٤٣] وبينه البتّة إلّا أنّ لها أفلاكاً صغاراً غير شاملة للأرض[٤٤] بل هي مركوزة مغرقة في أجرام أفلاكها الخارجة[٤٥] المراكز[٤٦] بحيث يماسّ[٤٧]

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[٣٣] بالخلاف] بخلافها: ب.

[٣٤] وتسمّى] ب، س = سمى: ف = ويسمى: ك = سمّى: ل.

[٣٥] واحدة] واحد: ب = –ك.

[٣٦] يسمّى] ك، ل = سمّى: ب = تسمى: س = سمى: ف.

[٣٧] يسمّى] ك = سمّى: ب، ل = تسمى: س = سمى: ف.

[٣٨] ص١١: ب.

[٣٩] محيطه] محيطها: ب.

[٤٠] ٥١ب: س.

[٤١] مركوز] مركوزة: ب.

[٤٢] ويماسّ] ب، ك = وتماس: س = مماسّ: ف، ل.

[٤٣] بينها] بينهما: ب.

[٤٤] ٤ب: ك.

[48] سطح كلّ واحد منها سطحيْ حامله[49]، بمنزلة جرم الشمس في فلكها الخارج المركز. وتسمّى هذه الأفلاك الصغار[50] **أفلاك التداوير**.

[٦] **والكوكب** فيها[51] جرم كري مصمت مركوز[52] في[53] جرم فلك التدوير مغرق فيه بحيث يماسّ سطحه سطح التدوير على نقطة مشتركة بينهما. والأفلاك الخارجة المراكز، لغير الشمس، تسمّى **حوامل** لحملها مراكز التداوير[54] لأنّها أعني المراكز كأجزاء منها.[55]

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[45] الخارجة] الخارجية: س.

[46] المراكز] المركز: ك.

[47] يماسّ] ك = بماس: ب، ف، ل = تماسّ: س.

[48] يماسّ] +سطحه: شاس(مع رمز «ح» فوق السطر).

[49] حامله] حاملة: ب.

[50] هذه الأفلاك الصغار] س، ف = –ب، –ك، –ل.

[51] فيها] –ك.

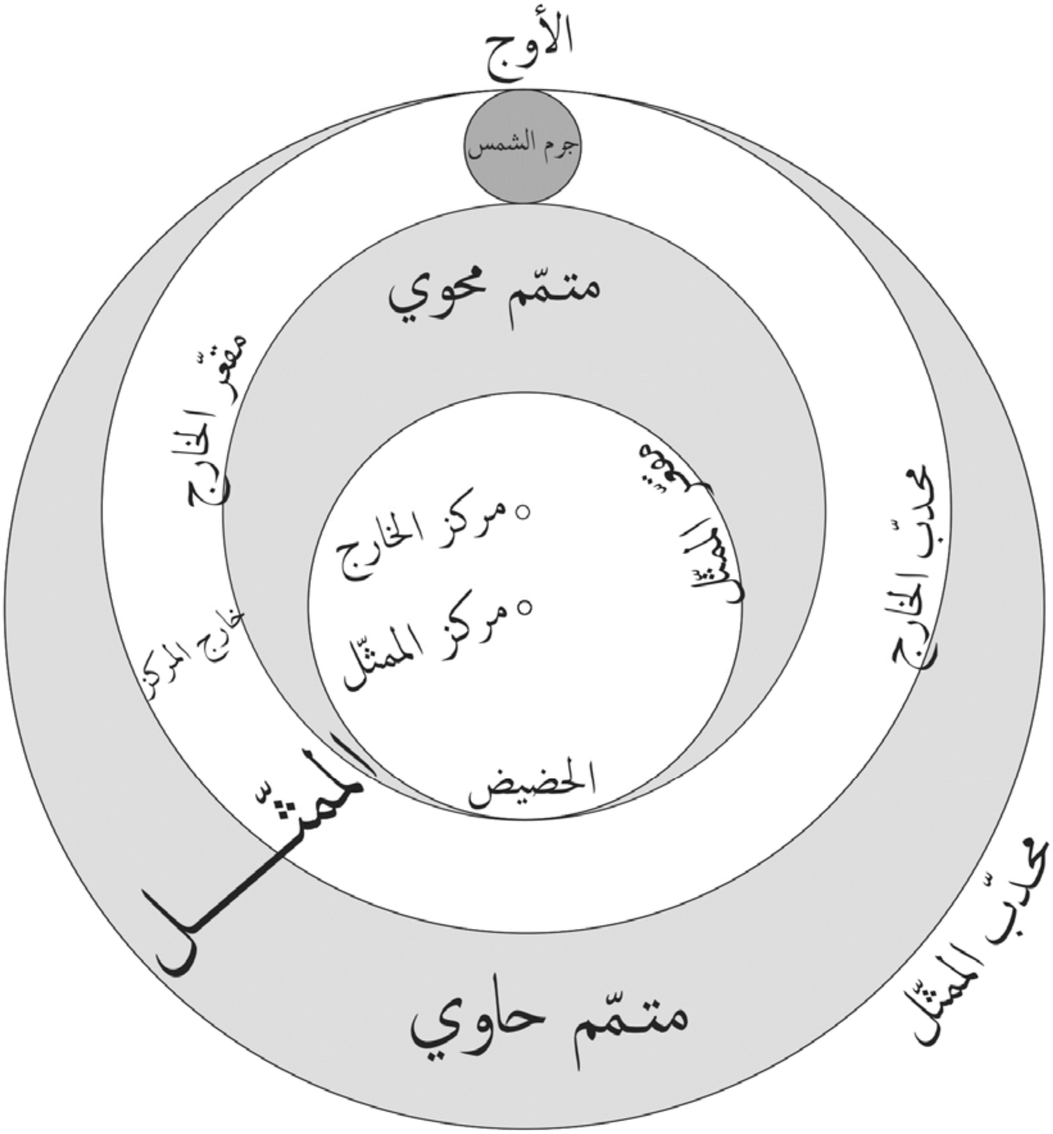
[52] مصمت مركوز] ب، ك، ل = مركوز مصمت: س، ف.

[53] ٦٣ ب: ل.

[54] التداوير] التدوير: ك.

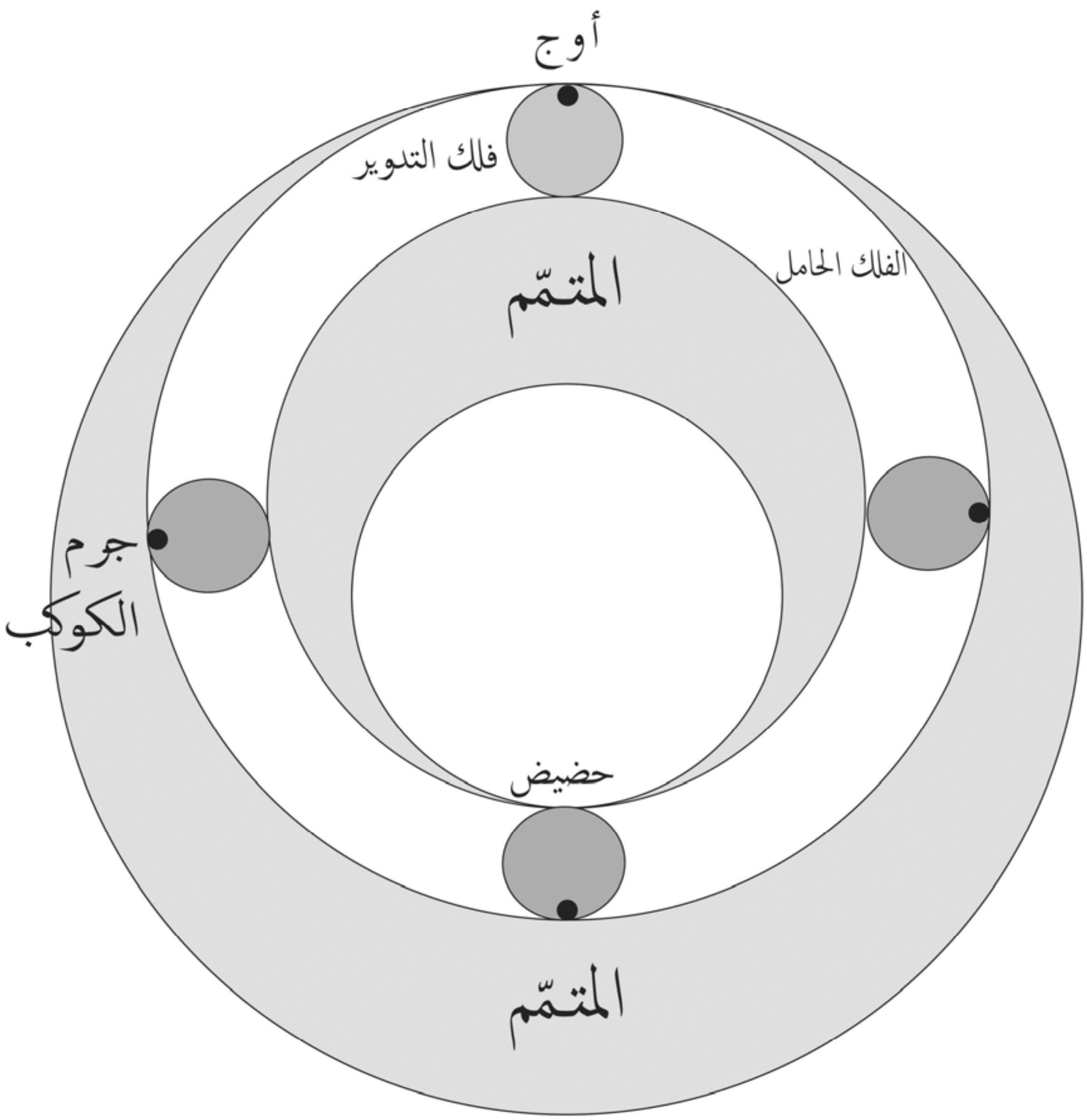
[55] منها] +وهذه صورة فلك الشمس: س، ف.

صورة فلك الشمس



[شكل ٢]

صورة أفلاك الكواكب العلوية والزهرة



[شكل ٣]

[٧] [٥٦] **وأمّا فلكا عطارد والقمر** فكلاهما مشتمل[٥٧] على ثلاثة أفلاك شاملة للأرض وعلى فلك تدوير إلّا أنّ فلك عطارد مشتمل على فلك هو الممثّل مركزه مركز العالم، وعلى فلكيْن خارجيْ المركز[٥٨]، أحدهما، وهو الحاوي للأخر ويسمّى **المدير**، في داخل ثخن الممثّل، على الرسم، أيْ[٥٩] كسائر الأفلاك الخارجة المراكز في ممثّلاتها [٦٠] بحيث يماسّ محدّبه[٦١] محدّب الممثّل[٦٢] على نقطة مشتركة بينهما، وهي[٦٣] الأوج، ومقعّرها[٦٤] مقعّره [٦٥] على نقطة[٦٦]، وهي الحضيض. والثاني من الخارجي المركز[٦٧] وهو المحوي[٦٨] وهو **الحامل** لمركز التدوير[٦٩] في

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[٥٦] ٥٢آ: س؛ ٤ب: ف.

[٥٧] مشتمل] مشتملان: ك.

[٥٨] المركز] المراكز: ك.

[٥٩] أيْ] –ب.

[٦٠] ص١٢: ب.

[٦١] محدّبه] ب، ك، ل = محدّبها: س، ف = +المـ : شاك.

[٦٢] الممثّل] فاب.

[٦٣] وهي] س = وهو: ب.

[٦٤] ومقعّرها] ب، س، ف = ومقعّره: ك، ل.

[٦٥] ٥آ: ك.

[٦٦] نقطة] +كذلك: ك.

[٦٧] الخارجي المركز] ب، س، ل = الخارج المركز: ف، ك.

[٦٨] وهو المحوي] والمحوي: ك.

داخل ثخن جرم[٧٠] المدير على الرسم[٧١]. وفلك التدوير في جرم الحامل والكوكب[٧٢] في التدوير على ما ذكرنا في سائر التداوير[٧٣]. ويلزم أنْ يكون لعطارد أوجان، أحدهما كالجزء من ممثّله، والثاني كالجزء من مديره.

[٨] **وفلك القمر** مشتمل على فلكيْن، [٧٤]مركزهما[٧٥] مركز العالم، وفلك حامل. أحد الأوّليْن وهو المحيط بالثاني يسمّى **الجَوْزَهريْ** والممثّل. والثاني يسمّى[٧٦] **المائل**[٧٧] في جوف الجوزهريْ لا في ثخنه. والحامل في ثخن المائل على الرسم. والتدوير في الحامل والقمر في التدوير على نحو ما ذكرنا[٧٨].

[٩] ومن هذه[٧٩] الدوائر يتصوّر كيفية ما ذكرنا من هيأت الأفلاك.

---

[٦٩] لمركز التدوير] –ك، –ل.

[٧٠] جرم] هاس، –ف.

[٧١] على الرسم] كذلك: ب، ك، ل =+اى بحيث يماس محدّب الحامل محدّب المدير على نقطةٍ مشتركةٍ بينهما وهى الاوج ومقعره مقعره على نقطه وهى الحضيض: ب.

[٧٢] والكوكب] ب، ف، ك، ل = الكواكب: س.

[٧٣] على ما ذكرنا في سائر التداوير] س، ف = على الرسم: ب، ك، ل.

[٧٤] **٥٢**ب: س.

[٧٥] مركزهما] مركزها: ك.

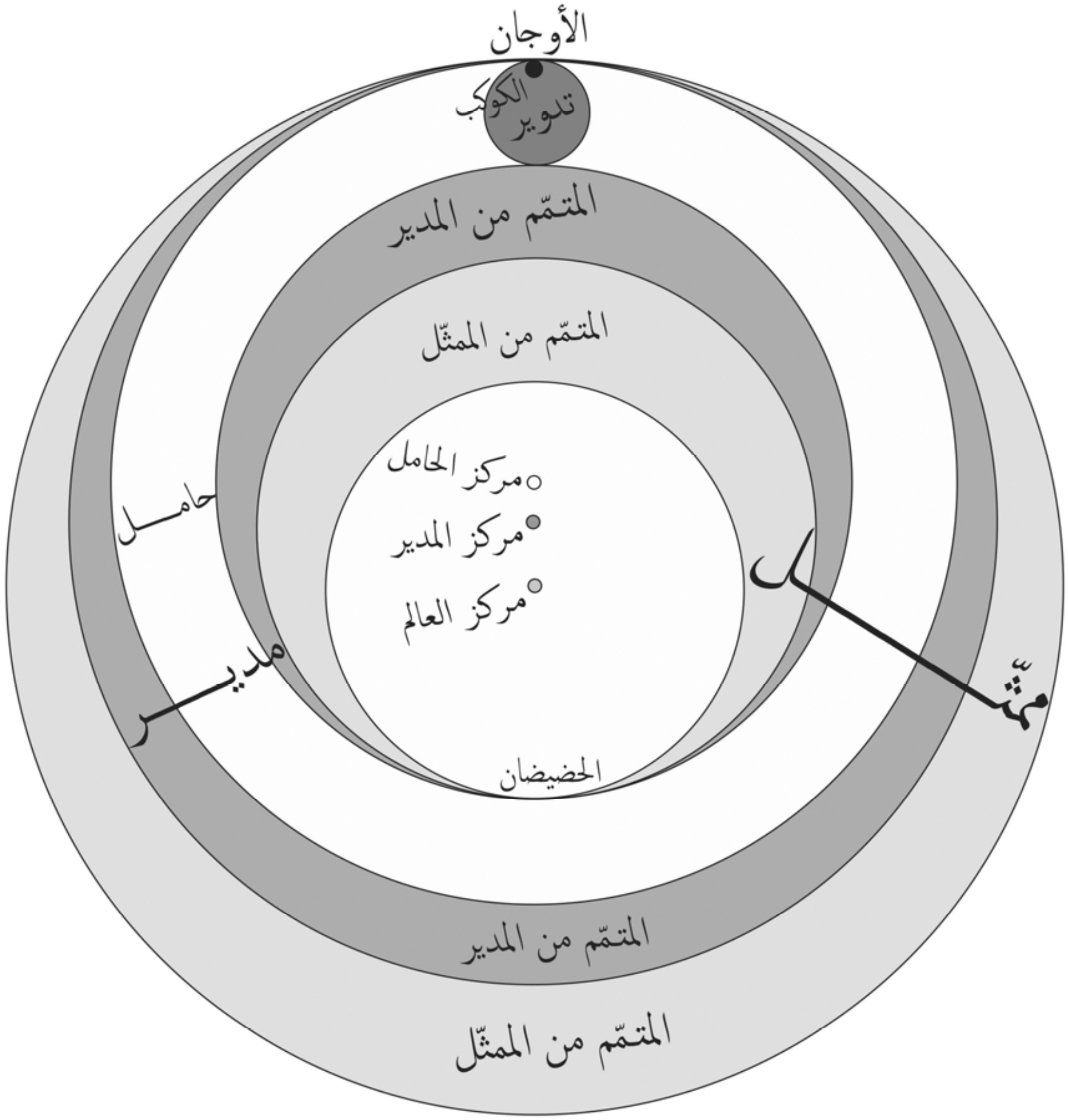
[٧٦] يسمّى] ف، ك = سمّى: ب = وتسمى: س(الـ«و» مشطوب) = ويسمى: ل.

[٧٧] المائل] المائل وهو: هاف.

[٧٨] على نحو ما ذكرنا] س، ف = على الرسم : ب، ك، ل.

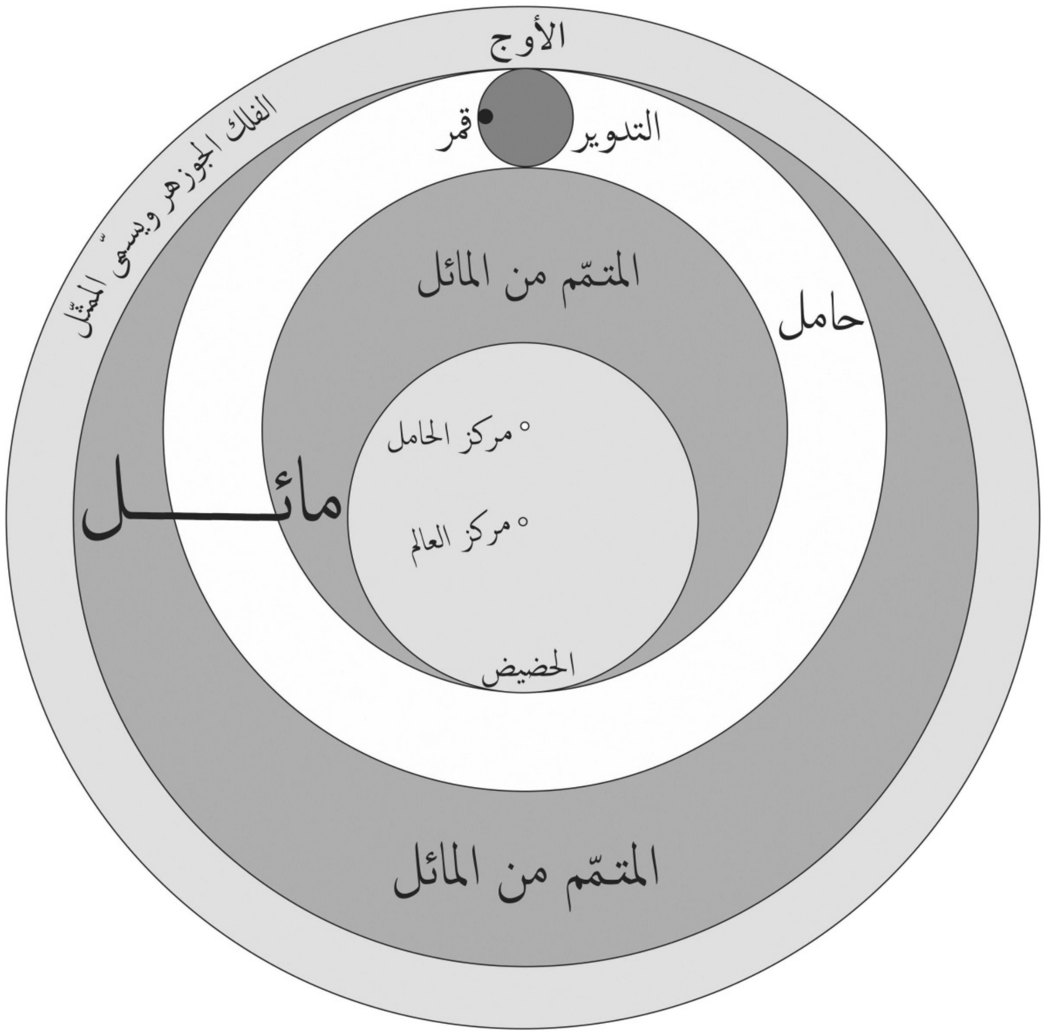
[٧٩] هذه] +الدور: شاك.

صورة فلك عطارد



[شكل ٤]

صورة فلك القمر



[شكل ٥]

[١٠] [٨٠]**وأمّا فلك الثوابت**[٨١] وهو الفلك الثامن ويسمّى[٨٢] **فلك البروج** وستعرف معنى[٨٣] هذا في باب الدوائر فجرم[٨٤] كري مركزه[٨٥] مركز العالم. وهو[٨٦] كرة واحدة على الرأي الأصحّ؛ مقعّر سطحيْه[٨٧] يماسّ محدّب[٨٨] كرة زحل، ومحدّبها[٨٩] يماسّ مقعّر الفلك الأعظم. والكواكب الثابتة بأجمعها مركوزة مغرقة فيه.

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[٨٠] ص١٤: ب ؛ ٦٦آ: ل.

[١١] **والفلك الأعظم**[٩٠] ويسمّى **فلك الأفلاك** جرم كري مركزه[٩١] مركز العالم. مقعّر سطحيْه يماسّ[٩٢] محدّب فلك الثوابت ومحدّبها[٩٣] لا يماسّ شيئاً إذ ليس ورائه [٩٤]شيء لا خلاء ولا ملاء[٩٥].

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[٨١] الثوابت] س، ف = الكواكب الثابتة: ب، ك، ل.

[٨٢] ويسمّى] ك = وسمّى: ب، ف، ل = وتسمى: س.

[٨٣] معنى] هاس(مع رمز «صح»).

[٨٤] فجرم] س، ك = وهو جرم: ب = جرم: ف، ل.

[٨٥] مركزه] هاب(مع رمز «صح»).

[٨٦] وهو] س = وهو جرم: ب = هو: ف، ك، ل.

[٨٧] سطحيْه] سطحه: ك.

[٨٨] ٥٣آ: س.

[٨٩] ومحدّبها] ك، ل = ومحدّبها: ب، س، ف.

[٩٠] والفلك الأعظم] واما الفلك الاعظم: ك.

[٩١] مركزه] ف = +مركزة: شاف.

[٩٢] يماسّ] مماس: ب.

[٩٣] ومحدّبها] ف، ك، ل = ومحدّبه: ب = ومحدّبها: س.

[٩٤] ٦آ: ك.

[٩٥] ملاء] +والله اعلم: ك.

الباب الثاني[١]

من المقالة الأولى

في حركات الأفلاك

[١] حركات الأفلاك[٢] على كثرتها قسمان: حركة من المشرق إلى المغرب وحركة من المغرب إلى المشرق[٣]. فأمّا[٤] الحركة التي هي[٥] من المشرق إلى المغرب فمنها:

[٢] حركة الفلك الأعظم حول مركز العالم وهي الحركة السريعة التي بها تتمّ[٦] دَوْرته في قريب من يوم وليلة[٧]. ويلزمها حركة سائر الأفلاك وما فيها إذ هي في ضمن الفلك [٨]الأعظم لزوم حركة المظروف لحركة الظرف. وبها طلوع الشمس وسائر الكواكب وغروبها. وتسمّى[٩] هذه الحركة **حركة الكلّ والحركة الأولى** لأنّها أوّل ما[١٠]

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[١] الباب الثاني] قال الباب الثاني: ب.

[٢] حركات الأفلاك] –ب.

[٣] المشرق] +الى: شاس.

[٤] فأمّا] واما: ك.

[٥] التي هي] –س = التى: هاس(مع رمز «صح»).

[٦] تتمّ] ف = نتمّ: ب = يتم: س، ك، ل.

[٧] وليلة] ولَيْلته: ك.

[٨] ٥ب: ف.

[٩] وتسمّى] وتُسمّى: ب = وسمى: ف = ويسمى: س، ك، ل.

[١٠] أوّل ما] هال(مع رمز «صح»).

يُعرف من حركات الأجرام السماوية وبها [١١] يتحرّك الكلّ؛ ويسمّى قطباها **قطبي**[١٢] **العالم**[١٣] ومنطقتها[١٤] **معدّل النهار**؛

[٣] ومنها حركة مدير[١٥] عطارد حول مركزه الخارج. وتسمّى[١٦] **حركة الأوج** إذ فيه الأوج الثاني لعطارد[١٧] كما سلف[١٨]. [١٩] وهي على قطبين ومنطقة غير معدّل النهار وقطبي العالم وغير منطقة البروج وقطبيها وستعرفها[٢٠]. وهي[٢١] في[٢٢] كل يوم بليلته ٠ نط ح ك[٢٣] وهو[٢٤] مثل وسط الشمس[٢٥] وستعرفه[٢٦]؛

---

[١١] ٥٣ب: س.

[١٢] قطبي] قطب: ك.

[١٣] ص١٥:ب.

[١٤] ومنطقتها] ومِنْطَقُها: ب.

[١٥] مدير] فاس(مع رمز «صح»).

[١٦] وتسمّى] ف، ك = وسمّى: ب = ويسمى: س.

[١٧] لعطارد] –ف.

[١٨] سلف] +وهي: ك.

[١٩] ٦ب: ك.

[٢٠] وستعرفها] ب ،هاس، ل = وستعرفها: ف، ك.

[٢١] وهي] وحركة: ب.

[٢٢] في] –ك.

[٢٣] ٠ نط ح ك] س، ف، ك، ل = ٥٩ دقيقةً ٨ ثوان ٢٠ ثالثةً: ب.

[٢٤] وهو] وهي: ب.

[٤] ومنها حركة جوزهر القمر حول مركز العالم[٢٧] على منطقة البروج وقطبيها في اليوم بليلته ٠ ج ي لز[٢٨] وهي **حركة الرأس والذنب**؛

[٥] ومنها حركة [٢٩]الفلك المائل للقمر حول مركز العالم على منطقة وقطبين غير معدّل النهار ومنطقة البروج[٣٠] وغير أقطابها في اليوم بليلته يا ط ز مج[٣١] وهي **حركة أوج القمر**.

[٦] وأمّا الحركة التي[٣٢] من المغرب إلى المشرق فمنها[٣٣]: حركة فلك الثوابت وهي حركة بطيئة حول مركز العالم، تقطع[٣٤] على رأي أكثر المتأخّرين جزءاً واحداً[٣٥] في ست وستين سنة شمسية أو ثمان وستين[٣٦]

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[٢٥] وسعرفها وهى فى كل يوم بلىلته ٠نط ح ك وهو مثل وسط الشمس] هاس(مع رمز «صح»).

[٢٦] وستعرفه] وستعرفها: ب.

[٢٧] العالم] +وهي: ف.

[٢٨] ٠ ج ي لز] س، ف، ك، ل = ٣ دقائق ١٠ ثوان ٣٧ ثالثه: ب.

[٢٩] ٦٦ب: ل.

[٣٠] ومنطقة البروج] وغير منطقة البروج: ف = البروج: ك.

[٣١] يا ط ز مج] س، ف، ل = ١١ درجة ٩ دقائق ٧ ثوان ٤٣ ثالثه: ب = يا ط ح مح : ك = يا درجة (فوق السطر) ط دقايق(تحت السطر) ز ثوان (تحت السطر) مج ثالثه (فوق السطر): ل.

[٣٢] التي] +هي: ب، ك، ل.

[٣٣] فمنها] منها: ف.

[٣٤] تقطع] ف = نقطع: ب، ل = يقطع: س، ك.

[٣٥] واحداً] هال.

قمرية وستعرفهما[٣٧]، على[٣٨] منطقة تسمّى أيضاً [٣٩]**فلك البروج ومنطقة البروج**[٤٠] وعلى قطبين غير قطبي العالم يسمّيان[٤١] [٤٢]**قطبي البروج**. ويلزم أن تقاطع[٤٣] منطقتها معدّل النهار وسيتمّ [٤٤]هذا[٤٥] الكلام في باب الدوائر[٤٦]؛

[٧] ومنها حركات الأفلاك الممثلة حول مركز العالم مثل حركة فلك الثوابت وعلى منطقتها وقطبيها كأنّها تتحرك[٤٧] بها؛ وهي حركات الأوجات والجوزهرات سوى أحد أوجي عطارد أي الذي هو في المدير وسوى أوج القمر وممثله وجوزهره؛

[٨] ومنها حركة الفلك الخارج المركز[٤٨] للشمس على منطقة[٤٩] مسامتة[٥٠] لمنطقة البروج وقطبين[٥١] غير قطبيها ومحور مواز لمحور فلك[٥٢] البروج[٥٣] [٥٤] وهي في اليوم بليلته ٠ نط ح ك[٥٥]؛

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[٣٦] وستين] +سنة: س.

[٣٧] وستعرفهما] وستعرفها: س.

[٣٨] على] –ك.

[٣٩] ٥٤آ: س.

[٤٠] ومنطقة البروج] فاس(مع رمز «صح»).

[٤١] يسمّيان] وسُمّيان: ب.

[٤٢] ٧آ: ك.

[٤٣] تقاطع] ف = نقاطع: ب، ل = يقاطع: س، ك.

[٤٤] ص١٦: ب.

[٤٥] هذا] –ف = +في باب: شاك.

[٤٦] الدوائر] +ان شا الله تعالي: ك.

[٤٧] تتحرك] ك، ل = نتحرك: ب، ف = يتحرك: س.

[٩] ومنها حركات[٥٦] الأفلاك[٥٧] [٥٨]الحاملة حول مراكزها الخارجة على مناطق[٥٩] وأقطاب غير منطقتي الفلك الأعظم وفلك البروج وأقطابهما[٦٠]. وهي في كل يوم بليلته:

لزحل ٠ ب ٠ له[٦١]

للمشتري[٦٢] ٠ د نط يو[٦٣]

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[٤٨] المركز] فال(مع رمز «صح»).

[٤٩] منطقة] +البروج وقطبيها: مشطوب في ل.

[٥٠] مسامتة] متشابهة: س.

[٥١] وقطبين] +على: فاب(بين الـ«و» والـ«ق»).

[٥٢] فلك] –ف.

[٥٣] مسامته لمنطقة ... البروج] هال(مع رمز «صح»).

[٥٤] البروج] +وقطبيها: شاس(مع رمز «خ» فوق السطر).

[٥٥] ٠ نط ح ك] س، ف، ل = ٥٩ دمقه ٨ ثوان ٢٠ ثالثه: ب = ح نط ح ك : ك.

[٥٦] حركات] حركة: ك.

[٥٧] الأفلاك] –ف = هال(مع رمز «صح»).

[٥٨] آ٦: ف.

[٥٩] مناطق] منطق: ك.

[٦٠] وأقطابهما] وأقطابها: ك.

[٦١] ٠ ب ٠ له] س، ف، ك = دقيقتان: ب = ٠ ب ه («٠» من تحت «ه»؟) له: ل.

[٦٢] للمشتري] ف، ل = وللمشتري: ب، س، ك.

للمرّيخ[٦٤] ٠ لا كو م[٦٥]

[٦٦]للزهرة[٦٧] ٠ نط ح ك[٦٨]

لعطارد[٦٩] ا نخ يو م[٧٠]

للقمر[٧١] [٧٢]كد كب نج كب[٧٣] .

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[٦٣] ٠ د نط يو] ف، س، ل = ٥ دقائق: ب = مد ه (؟) نط بو : ك.

[٦٤] للمرّيخ] ف، ل = وللمريخ: ب، س، ك.

[٦٥] ٠ لا كو م] س، ف، ك، ل = ٣١ دقيقةً: ب.

[٦٦] ٧ب: ك.

[٦٧] للزهرة] ف، س، ل = وللزهرة: ب، ك.

[٦٨] ٠ نط ح ك] س، ف، ك، ل = ٥٩ (مع رمز «٢» من تحت) دقيقه ٨ ثوان ٢٠ ثالثه: ب.

[٦٩] لعطارد] ف، س، ل = للعطارد: ب، ك.

[٧٠] ا نخ يو م] س، ف، ك، ل = وضعف ذلك (مع رمز «٢» تحت «ذلك»، وهو إشارة إلى الـ«٢» السابق المرافق للزهرة): ب.

[٧١] للقمر] ف، ل = وللقمر: ب، س، ك.

[٧٢] ٥٤ب: س.

[٧٣] كد كب نج كب] ك، ل = ٢٤ درجة ٢٣ دقيقه: ب =كد كج نج كب: س = كد (+«كب» و « نحه» في الهامش) كب: ف.

وتسمّى[٧٤] هذه الحركة وسط الكوكب[٧٥]، تسمّى[٧٦] أيضاً حركة العرض، وهي بعينها[٧٧] حركة الطول إذا أضيفت إلى فلك البروج. وسنزيد[٧٨] وضوح بيان هذا في باب الدوائر؛ وتسمّى[٧٩] أيضاً[٨٠] حركة المركز؛

[١٠] أمّا[٨١] حركات أفلاك[٨٢] التداوير على مراكزها فهي خارجة عمّا ذكرنا من قسمي الحركات لأنّ حركات أعاليها لا محالة مخالفة[٨٣] [٨٤]في الجهة لحركات أسافلها لكونها غير شاملة للأرض، أعني إن كانت حركة الأعلى [٨٥]من المغرب إلى المشرق فحركة الأسفل من المشرق إلى المغرب[٨٦] وذلك لتداوير[٨٧] الخمسة المتحيّرة،

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[٧٤] وتسّمى] ك = وسمّى: ب، ل = ويسمى: س، ف.

[٧٥] الكوكب] الكواكب: ك.

[٧٦] تسمّى] ب = ويسمّى: س = سمى: ف، ل = نسمي: ك.

[٧٧] بعينها] ب، ك = تعينها: س = بعىها: ف = بعنها: ل.

[٧٨] وسنزيد] ل = وسيزيد: ب = وسيرد: س = وسىرىد :ف = سَينزيد: ك.

[٧٩] تسمّى] = سمّى: ب، ف = ويسمى: س، ل = يسمي: ك.

[٨٠] أيضاً] –ب = هال(مع رمز «صح»).

[٨١] أمّا] س، ف = وأما: ب، ك، ل.

[٨٢] أفلاك] هاس(مع رمز «صح»).

[٨٣] مخالفة] +في: ب.

[٨٤] ص١٧: ب.

[٨٥] ٦٧آ: ل.

[٨٦] المغرب] +فحركة الاسفل: شاس.

[٨٧] لتداوير] ب، ف، ل =كتداوير: س = التداوير: ك.

وإن كانت حركة الأعلى[88] من المشرق إلى المغرب فحركة الأسفل بالخلاف وذلك لتدوير[89] القمر. لكن المذكور[90] المعتبر[91] من[92] مسير التداوير بالنسبة إلى البروج، وهو[93] المثبت في الزيجات، هو ما كان على توالي البروج [94]سواء كان حركة الأعلى كما في المتحيّرة أو حركة الأسفل كما في القمر. وحركات التداوير في كل يوم بليلته:

[95]لزحل[96] ٠ نز ز مد[97]

للمشتري[98] ٠ ند ط جـ [99]

للمرّيخ[100] ٠ كز ما م[101]

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[88] حركة الأعلى] –ك.

[89] لتدوير] ب، ف، ل = كتدوير: س = التداوير: ك.

[90] المذكور] المسير: ف.

[91] المعتبر] –ب.

[92] من] منه: ك.

[93] وهو] وهي: ب.

[94] ٨آ: ك.

[95] ٥٥ آ: س.

[96] لزحل] +النخس: شاك.

[97] ٠ نز ز مد] س، ف، ك، ل = ٥٧ دقيقةً: ب.

[98] للمشتري] وللمشتري: ب.

[99] ٠ ند ط جـ] س، ف، ك، ل = ٥٤ دقيقةً: ب.

للزهرة[١٠٢] ٠ لو نط كط[١٠٣]

لعطارد[١٠٤] جـ و كد ز[١٠٥]

للقمر يج جـ نج نو[١٠٦].

وهذه الحركة تسمّى حركة الاختلاف[١٠٧] والحركة[١٠٨] الخاصة للكوكب[١٠٩] والله اعلم[١١٠].

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[١٠٠] للمرّيخ] وللمريخ: ب.

[١٠١] ٠ كز ما م] س، ف، ك، ل = ٢٨ دقيقةً: ب.

[١٠٢] للزهرة] وللزهرة: ب.

[١٠٣] ٠ لو نط كط] س، ف، ل(يتغير الـ«لو» إلى «لز» والـ«نط» إلى «يط» في الثلاث نسخ) = ٣٧ دقيقةً: ب = مد لو نط كط : ك.

[١٠٤] لعطارد] ولعطارد: ب.

[١٠٥] جـ و كد ز] ف، ك، ل = ٣ اجزاء ٦ دقائق: ب = ج و كد كب: س(+«و» و«كد» و«ز» من تحت «و» و«كد» و«كب»).

[١٠٦] يج جـ نج نو] س، ف، ل = ١٣ درجة ٤ دقائق: ب = يح ح نو : ك.

[١٠٧] الاختلاف] الاخلاف: س.

[١٠٨] والحركة] حركة: ب.

[١٠٩] للكوكب] س، ف = للكواكب: ب، ك.

[١١٠] والله اعلم] –ب، –ك.

الباب الثالث

من المقالة الأولى

في الدوائر

[١] **الدائرة** إمّا **عظيمة**، وهي التي تنصّف[١] العالم ومركزها لا محالة مركز العالم، وإمّا غير عظيمة وهي التي لا[٢] تنصّفه[٣] ولتسمَّ[٤] **الصغيرة**.

[٢] **معدّل النهار**[٥]، وتسمّى[٦] **الفلك المستقيم**[٧] وقد عرفتها. وإنمّا سمّيت معدّل النهار لأنّ الشمس إذا سامتتها اعتدل[٨] الليل والنهار في جميع النواحي أي استوياً. والدائرة التي في سطحها على [٩]وجه الأرض تسمّى **خطّ الاستواء**، أعني الدائرة التي تحدث على سطح [١٠]الأرض[١١] [١٢]عند توهّمنا[١٣] معدّل النهار قاطعاً للعالم[١٤].

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[١] تنصّف] ينصف: ف.

[٢] لا] –ب.

[٣] تنصّفه] ينصّفه: ف.

[٤] ولتسمَّ] س، ف = وتسمى: ب، ك = وسمى: ل.

[٥] معدّل النهار] اما الدواير العظام فمنها معدل النهار: ك.

[٦] وتسمّى] ب، ف، س = ويسمي: ك = وسمى: ل.

[٧] الفلك المستقيم] فلك المستقيم: ك.

[٨] اعتدل] اعتدال: ب.

[٩] ص١٨: ب.

[١٠] ٨ب: ك.

والدوائر الموازية[١٥] لها تسمّى **المدارات اليوميّة**[١٦]، وهي صغار موهومة ترتسم بدور الفلك الأعظم من كلّ نقطة تفرض[١٧] عليه.

[٣] **دائرة البروج**[١٨]، وتسمّى[١٩] فلك البروج ومنطقة البروج، وقد عرفتها. [٢٠]والدوائر[٢١] التي في سطحها، أعني الدوائر التي تحدث على سطوح الأفلاك الممثّلة عند توهّمنا دائرة البروج قاطعة للعالم تسمّى[٢٢] أيضاً بالأفلاك الممثّلة. وبالنسبة إلى هذه الدائرة[٢٣] تقدّر[٢٤]كمّية **طول**[٢٥] حركات الكواكب والشمس[٢٦]، لأنّا إذا

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[١١] الأرض] الا:ب(+«رض» فوق).

[١٢] ٦ب: ف.

[١٣] توهّمنا] توهينا: ك.

[١٤] للعالم] لعالم: ب(+«للعالم» في الهامش).

[١٥] الموازية] المتوازيه: ك.

[١٦] اليومّية] +ل المعدل ايضا يسمى مدار يوميا: هال(مع رمز «صح»).

[١٧] تفرض] ب، ل = يفرض: س، ك = نفرض: ف.

[١٨] دائرة البروج] ومنها دايرة البروج: ك.

[١٩] وتسمّى] +هذة: شاك.

[٢٠] ٥٥ب: س.

[٢١] والدوائر] فالدّوائر: ب.

[٢٢] تسمّى] ب، ك، ل = يسمى: س= سمى: ف.

[٢٣] الدائرة] الدواير: ك.

[٢٤] تقدّر] يقدر: س.

[٢٥] طول] –ف.

توهّمنا خطّاً يخرج [٢٧]من مركز العالم إلى سطح فلك البروج مارّاً بمراكز الكواكب[٢٨]، فإن أتّفق أن وقع طرف ذلك الخطّ في منطقة البروج، فموقعه هو مكان الكوكب من فلك البروج، وحينئذ[٢٩] لا يكون للكوكب[٣٠] عرض. وإن وقع خارجاً عن منطقة البروج، توهّمنا دائرة مارّة بقطبي البروج[٣١] وطرف[٣٢] ذلك الخط مقاطعة[٣٣] [٣٤]لمنطقة البروج، فيكون نقطة التقاطع بين تلك الدائرة وبين منطقة البروج مكان الكوكب من فلك البروج، ويكون للكوكب عرض حينئذ[٣٥] فمكان الكوكب إحدى هاتين النقطتين المذكورتين. [٣٦]فكلّما تحرّك الكوكب تحرّكت النقطة[٣٧] على فلك البروج، وهذا هو[٣٨] المعنى بحركة الكوكب في الطول.

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[٢٦] والشمس] –ك.

[٢٧] ٦٧ب: ل.

[٢٨] بمراكز الكواكب] بمركز الكوكب: ب.

[٢٩] وحينئذ] و ح̅ : ف = و ح: ك.

[٣٠] للكوكب] له: فاس.

[٣١] البروج] فلك البروج: ك.

[٣٢] وطرف] وتطرف: ك.

[٣٣] مقاطعة] قاطعة: ب.

[٣٤] ٩آ: ك.

[٣٥] عرض حينئذ] س، ل = حسئذ عرض: ب = عرض ح̅ : ف، ك.

[٣٦] ص١٩: ب.

[٣٧] النقطة] تلك النقطه: ب.

[٣٨] وهذا هو] س، ف = وهو: ب، ك، ل.

[٤] والدوائر[٣٩] الموازية لها تسمّى[٤٠] [٤١] **مدارات العرض**. وهي صغار موهومة ترسّم بدور الفلك الثامن من[٤٢] كلّ نقطة تفرض عليه.

[٥] ولمّا كان قطبا البروج غير قطبي العالم لزم أن[٤٣] تقاطع دائرة البروج معدّل النهار عند نقطتين متقابلتين. إحداهما وهي التي يأخذ[٤٤] منها فلك البروج على التوالي إلى الشمال تسمّى **بنقطة الاعتدال الربيعيّ**، والأخرى **بنقطة الاعتدال الخريفيّ**. ويكون غاية بُعدها عنه[٤٥]، أعني بُعد دائرة البروج عن معدّل النهار، عند نقطتين إحداهما ممّا يلي الشمال وتسمّى[٤٦] **نقطة**[٤٧] **الانقلاب الصيفيّ**، والأخرى ممّا يلي الجنوب وتسمّى **نقطة**[٤٨] **الانقلاب الشتويّ**. فتتعيّن[٤٩] بذلك لدائرة البروج أربع نقط[٥٠] تصير بها أرباعاً. ومدّة[٥١] قطع الشمس[٥٢] كلّ ربع

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[٣٩] ٥٦آ: س.

[٤٠] تسمّى] ب، ك، ل = يسمى: س = سمى: ف.

[٤١] والدوائر الموازية لها تسمّى] وتسمي الدواير الموازية لها : ك.

[٤٢] من] هال(مع رمز «صح»).

[٤٣] أن] طاب = هاب.

[٤٤] يأخذ] ب، ك، ل = تأخذ: س، ف.

[٤٥] عنه] ب، س = –ف، –ك، –ل.

[٤٦] ٩ب: ك.

[٤٧] نقطة] بنقطة: ب.

[٤٨] نقطة] بنقطة: ب.

[٤٩] فتتعيّن] فيتعين: ب، ك، ل = فتعين: س = فتعن: ف.

[٥٠] نقط] نقطة: ب.

منها هي مدّة فصل من أربعة[٥٣] فصول السنة. ثمّ نتوهّم[٥٤] على ربعين متلاصقين منها على كلّ[٥٥] واحد منهما نقطتين بُعد كل واحدة[٥٦] منهما عن الأخرى مثل بُعد الأخرى عن[٥٧] أقرب طرفي الربع اليها. [٥٨]ثمّ نتوهّم[٥٩] ست دوائر عظام تتقاطع[٦٠] بأجمعها على نقطتين متقابلتين هما قطبا البروج[٦١]: [٦٢]إحداهما تمرّ[٦٣] بقطبي العالم وبقطبي [٦٤]البروج[٦٥] وبنقطتي[٦٦] الانقلابين وهذه تسمّى **بالدائرة المارّة بالأقطاب الاربعة**، وقطباها نقطتا[٦٧] الاعتدالين.

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[٥١] ومدّة] وقد: شاف = مده: تاف(مع رمز «صح»).

[٥٢] ٦٧آ : ف.

[٥٣] أربعة] اربع: ب.

[٥٤] نتوهّم] ب، ك، ل = يتوهّم: س، ف.

[٥٥] كلّ] فاف.

[٥٦] واحدة] س، ف، ك = واحدٍ: ب، ل.

[٥٧] عن] من: ب.

[٥٨] ٥٦ب: س.

[٥٩] ثمّ نتوهّم] ك، ل = فيتوهم: ب = ثمّ يتوهم: س، ف.

[٦٠] تتقاطع] س، ك، ل = يتقاطع: ب = سماطع: ف.

[٦١] البروج] +احديهما: ل.

[٦٢] ٦٨آ: ل.

[٦٣] تمرّ] ثم: ك.

[٦٤] ص٢٠: ب.

[٦٥] العالم وبقطبي البروج] البروج وقطبى العالم: ب.

[٦٦] وبنقطتي] ونقطى: ب.

والأخرى تمرّ[٦٨] بنقطتي[٦٩] الاعتدالين وقطباها نقطتا[٧٠] الانقلابين[٧١]. والأربع الباقية تمرّ بالنقط[٧٢] الأربع المتوهّمة على الربعين[٧٣] المفروضين، وبأربع نقط[٧٤] أخر[٧٥] مقابلة للمفروضة هي على[٧٦] [٧٧]الربعين الباقيين المقابلين[٧٨] للمفروضين. فينقسم الفلك الثامن بهذه الدوائر الست اثنى عشر قسماً، كلّ قسم منها يسمّى[٧٩] **بُرْجاً**. والقوس التي بين كلّ دائرتين منها[٨٠] من منطقة البروج تسمّى[٨١] ايضاً برجاً، ولهذا يسمّى[٨٢] بفلك البروج. وبالسطوح الموهومة[٨٣] لهذه الدوائر تنقسم[٨٤] الأفلاك الممثّلة والفلك الاعظم ايضاً[٨٥] باثني عشر بُرجاً.

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[٦٧] نقطتا] نقطى: ب.

[٦٨] تمرّ] ثم: ك.

[٦٩] بنقطتي] سقصـ سقطه: ب.

[٧٠] نقطتا] نقطى: ب.

[٧١] والأخرى تمرّ بنقطتي الاعتدالين وقطباها نقطتا الانقلابين] –ف.

[٧٢] بالنقط] س، ل = بالنقطه: ب، ف = لنقط: ك.

[٧٣] الربعين] ربعين: ك.

[٧٤] نقط] نقطةٍ: ب.

[٧٥] أخر] أُخرى: ب.

[٧٦] هي على] وهي: ف.

[٧٧] ١٠آ: ك.

[٧٨] المقابلين] ف، ك، ل = المتقابلين: ب، س = +للمفـ: ب

[٧٩] كلّ قسم منها يسمّى] ك، ل = كل قسم منها تسمّى: س، ف = تسمّى كل قسم: ب.

[٨٠] منها] منهما: ب.

[٨١] تسمّى] ب، ل = يسمّى: س، ف، ك.

[٦] **دائرة الأفق** دائرة عظيمة تفصل[٨٦] بين ما يُرى من الفلك وبين ما لا يُرى، [٨٧]وبالنسبة اليها يُعرف الطلوع والغروب. وقطباها **سَمْتا**[٨٨] **الرأس والقدم** وتنصّف معدّل النهار بنقطتين: يُقال لإحداهما[٨٩] **نقطة المشرق** ومطلع الاعتدال وللأخرى **نقطة المغرب** ومغرب الاعتدال. ويقال للخطّ الواصل بينهما **خطّ المشرق والمغرب** وخطّ الاعتدال[٩٠]. والدوائر الموازية لها[٩١] يقال لها[٩٢] **المُقَنْطرات**[٩٣].

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[٨٢] يسمّى] س = تسمّى: ب = سمى: ف، ك، ل.

[٨٣] الموهومة] المتوهّمة: ب.

[٨٤] تنقسم] س، ك = نقسم: ب، ف = ينقسم: ل.

[٨٥] ايضاً] —ب.

[٨٦] تفصل] +ما: ك.

[٨٧] ٥٧آ: س.

[٨٨] سَمْتا] سمتى: ب.

[٨٩] لإحداهما] لاحدهما: س.

[٩٠] وخطّ الاعتدال] —ب.

[٩١] لها] فاس(مع رمز «صح»).

[٩٢] يقال لها] تسمّى: ب.

[٩٣] المُقَنْطرات] مقنطرات: ك.

[٧] **دائرة نصف النهار**[٩٤] [٩٥]دائرة عظيمة تمرّ بقطبي العالم وسمتي[٩٦] الرأس والقدم. وقطباها نقطتا[٩٧] المشرق والمغرب. وتنصّف[٩٨] دائرة الأفق بنقطتين تُدعى إحداهما[٩٩] **نقطة الجنوب** والأخرى **نقطة الشمال** ويقال للخطّ الواصل بينهما **خطّ نصف النهار**. وهذا الخطّ وخطّ المشرق والمغرب يُستخرجان في سطوح الرخامات.

[٨] **دائرة الارتفاع**[١٠٠] وتسمّى[١٠١] ايضاً **الدائرة السمتيّة**[١٠٢] هي[١٠٣] دائرة عظيمة تمرّ بسمتي الرأس والقدم وبطرف الخطّ[١٠٤] الخارج من مركز العالم إلى سطح الفلك الأعلى[١٠٥]ماراً[١٠٦] بمركز[١٠٧] الكوكب[١٠٨] أو

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[٩٤] النهار] هاك.

[٩٥] ص٢١: ب؛ ١١آ: ك.

[٩٦] وسمتي] وبستي: ك.

[٩٧] نقطتا] نقطةَ: ب.

[٩٨] وتنصّف] تتصف: س.

[٩٩] إحداهما] احدهما: س، ف.

[١٠٠] دائرة الارتفاع] ومنها دارة الارتفاع: س.

[١٠١] وتسمّى] ب، ك = ويسمى: س = وسمى: ف، ل.

[١٠٢] ايضاً الدائرة السمتيّة] الدائرة السمتيه ايضا: ك.

[١٠٣] هي] س = وهي: ب، ف = –ك، –ل.

[١٠٤] الخطّ] فاس(مع رمز «صح»).

[١٠٥] ٥٧ب: س؛ ٧ب: ف.

[١٠٦] ماراً] +بكوك: شاس.

[١٠٧] بمركز] بمراكز: ف.

[١٠٨] الكوكب] الكواكب: ك.

الشمس. وتقطع دائرة الأفق على زوايا قائمة بنقطتين غير ثابتتين، بل منتقلتين[١٠٩] على دائرة الأفق حسب[١١٠] انتقال [١١١]الكوكب[١١٢] أو الشمس. تسمّى[١١٣] كلّ واحدة[١١٤] منها **نقطة السمت**. والقوس من[١١٥] دائرة الأفق بينها وبين إحدى نقطتي المشرق والمغرب تسمّى **قوس السمت**، وما بينها وبين إحدى نقطتي[١١٦] الجنوب [١١٧]والشمال تسمّى[١١٨] **تمام السمت**. وهذه الدائرة تنطبق على دائرة نصف النهار في اليوم بليلته[١١٩] مرّتين.

[٩] **دائرة أوّل السُمُوت**[١٢٠] دائرة عظيمة تمرّ بسمتي الرأس والقدم وبنقطتي[١٢١] المشرق والمغرب [١٢٢]وقطباها نقطتا الجنوب والشمال وتقاطع دائرة[١٢٣] نصف النهار على نقطتي سمت[١٢٤] الراس والقدم، وإنّما

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[١٠٩] منتقلتين] س، ف، ل = متقالتين: ب = منقلتن: ك.

[١١٠] حسب] ك، ل = بحسب: ب = على حسب: س(الـ«على» مشطوب؟)، ف.

[١١١] ٦٨ب: ل.

[١١٢] الكوكب] الكواكب: ل.

[١١٣] تسمّى] ك = سمى: ب، ف = يسمى: س، ل.

[١١٤] واحدة] واحد: س.

[١١٥] من] التى من: ب.

[١١٦] نقطتي] +البروج: ك.

[١١٧] ١١آ: ك.

[١١٨] تسمّى] س = يسمى: ب، ك = سمى: ف، ل.

[١١٩] بليلته] س، ك، ل = بلليه: ب = بلله: ف.

[١٢٠] دائرة أوّل السُمُوت] ف، ك، ل = دائرة اول السموة وهى: ب = ومنها دائرة اول السموت: س .

[١٢١] وبنقطتي] وبنقطه: ب.

سمّيت بذلك لأنّ دائرة الارتفاع إذا انطبقت عليها كانت ليس لها قوس سمت. والمدار الذي يماسّها يسمّى مدار ذلك البلد الذي هذا سمت رأس أهله.

[١٠] **دائرة المَيل**[١٢٥] [١٢٦] دائرة عظيمة مارّة بقطبي معدّل النهار[١٢٧]. ويُعرف بها بُعد الكوكب عن معدّل النهار وميل فلك البروج عن معدّل النهار[١٢٨] أعني **الميل الأوّل** وستعرفه.

[١١] **دائرة العرض**[١٢٩] دائرة عظيمة تمرّ بقطبي البروج وبطرف الخطّ الخارج من مركز العالم المارّ بمركز الكوكب[١٣٠] إلى سطح[١٣١] [١٣٢] الفلك الاعظم[١٣٣]. ويُعرف بها[١٣٤] عرض الكوكب[١٣٥] **والميل الثاني** لفلك البروج عن معدّل النهار.

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[١٢٢] ص٢٢: ب.

[١٢٣] دائرة] هاس(مع رمز «صح»).

[١٢٤] سمت] سمتي: ك.

[١٢٥] دائرة المَيل] +وهي: ب.

[١٢٦] ٥٨آ: س.

[١٢٧] معدّل النهار] العالم: ب.

[١٢٨] عن معدّل النهار] عنه: ب.

[١٢٩] دائرة العرض] +وهى: ب.

[١٣٠] الكوكب] ب، ك = الكواكب: س، ف = —ل.

[١٣١] سطح] +الفلك: ك.

[١٣٢] ١١ب: ك.

[١٣٣] وبطرف الخطّ الخارج ... إلى سطح الفلك الاعظم] هاس(مع رمز «صح») = —ل.

[١٢] **الدوائر**[١٣٦] **المتوهّمة المرتسمة بدور النقط في أفلاك السيّارة**[١٣٧] وهي[١٣٨] إمّا مرتسمة على بسائط[١٣٩] الأكر[١٤٠] وإمّا مرتسمة[١٤١] لا على البسائط[١٤٢]. فالمرتسمة[١٤٣] على البسائط[١٤٤] هي المرتسمة من حركة مركز الشمس على محيط فلكها الخارج المركز، والمرتسمة من حركات[١٤٥] مراكز التداوير على محيطات الأفلاك الحاملة[١٤٦] ومن حركات مراكز الكواكب على محيطات أفلاك التداوير[١٤٧]. وكلّ دائرة منها تسمّى باسم

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[١٣٤] ويُعرف بها] وبها يعرف: ب.

[١٣٥] الكوكب] هاك(مع رمز «صح»).

[١٣٦] الدوائر] ومنها الدّواير: ب = الدائرة: ك = الدوابر(مع «و» تحت السطر): ل.

[١٣٧] **بدور النقط في أفلاك السيّارة**] هاس(مع رمز «صح»)، ك، ل = —ب = بدور النقطه فى افلاك السياره: هاف(مع رمز «صح»).

[١٣٨] وهي] هى: ل.

[١٣٩] بسائط] +«سطح» تحت السطر: س.

[١٤٠] الدوائر المتوهّمة ... الأكر] ومنها الدّواير المتوهّمةُ المرتسمةُ بحركه مركز الكوكب او فلك التدوير وهى اما مرتسمةٌ على سطح الأكر: ب.

[١٤١] على بسائط الأكر وامّا مرتسمة] —ك.

[١٤٢] البسائط] السطح: ب.

[١٤٣] فالمرتسمة] والمرتسمه: ل.

[١٤٤] البسائط] السطح: ب.

[١٤٥] حركات] حركة: ف.

[١٤٦] الحاملة] الحاصله: ك.

[١٤٧] على محيطات الأفلاك الحاملة ومن حركات مراكز الكواكب على محيطات أفلاك التداوير] —ب.

الفلك[١٤٨] الذي ترتسم على محيطه، فالمرتسمة من حركة مركز الشمس تسمّى بالفلك [١٤٩]الخارج المركز، والمرتسمة من حركات[١٥٠] مراكز التداوير بالأفلاك الحاملة[١٥١]، والمرتسمة من[١٥٢] مراكز الكواكب بأفلاك[١٥٣] التداوير. وهذه[١٥٤] الأفلاك [١٥٥]الحاملة[١٥٦] ومنطقة [١٥٧]الفلك المائل إذا فُرضت قاطعة للعالم حدثت [١٥٨]في سطوح الأفلاك الممثّلة وفلك البروج والفلك الأعظم [١٥٩]دوائر تسمّى **الأفلاك المائلة** لميلها عن فلك البروج. ولكون[١٦٠] حركات الأفلاك التي ارتسمت[١٦١] فيها على اقطاب غير قطبي البروج وقطبي[١٦٢] العالم، وهذه

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[١٤٨] الفلك] هاس(مع رمز «صح»).

[١٤٩] ص٢٣: ب.

[١٥٠] حركات] ب، س = حركة: ف، ك، ل.

[١٥١] الحاملة] الحاصله: ك.

[١٥٢] من] +حركات: ب.

[١٥٣] بأفلاك] بالافلاك: ف.

[١٥٤]وهذه] وهى («هى» مشطوب و«هذه» مكتوب فوق السطر بخط غير الناسخ).

[١٥٥] ١٠آ: ف.

[١٥٦] الحاملة] الحاصله: ك.

[١٥٧] ٥٨ب: س.

[١٥٨] ١٢آ: ك.

[١٥٩] ٦٩آ: ل.

[١٦٠] ولكون] +ولكون: هاف.

[١٦١] ارتسمت] اوارسمت: ف.

[١٦٢]البروج وقطبي] هال(مع رمز «صح»).

الأفلاك المائلة، تقاطع[١٦٣] الممثّلات على نقطتين، إحداهما[١٦٤] وهي مجاز الكوكب على[١٦٥] دائرة البروج إلى الشمال تسمّى[١٦٦] **بالرأس**، والأُخرى **بالذنب**.

[١٣] والمرتسمة لا على البسائط[١٦٧] هي المرتسمة من مركز الحامل[١٦٨] لعطارد والقمر بتحريك المدير حامل[١٦٩] عطارد وبتحريك المائل[١٧٠] حامل[١٧١] القمر. وتسمّى هذه المرتسمة الفلك[١٧٢] الحامل[١٧٣] لمركز الحامل[١٧٤] إذ مركز الحامل[١٧٥] يدور على محيطها.[١٧٦]

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[١٦٣] تقاطع] س، ل = تقطعُ الدّوائر المسمّاة بالافلاك: ب = تقاطع: ف = بقاطع: ك.

[١٦٤] إحداهما] –ك.

[١٦٥] على] عن: ب.

[١٦٦] تسمّى] س، ك = يسمّى: ب = سمّى: ف، ل .

[١٦٧] البسائط] السطوح: ب.

[١٦٨] الحامل] الحاصل: ك.

[١٦٩] حامل] حاصل: ك.

[١٧٠] المائل] هاف(مع رمز «صح»).

[١٧١] حامل] الحامل: ف = حاصل: ك.

[١٧٢] الفلك] س، ك، ل = بالفلك: ب، ف.

[١٧٣] الحامل] الحاصل: ك.

[١٧٤] لمركز الحامل] ب، ف، ل = هاس («الحامل» غير مقروء) = لمركز الحاصل: ك.

[١٧٥] اذ مركز الحامل] –ك.

[١٧٦] محيطها] +ومنها الفلك المعدّل للمسير وهى دايرةٌ ترتسم بحركة الخطّ الخارج من نقطهٍ بكون قطر التدوير على صوبها دايماً كيف ما دارتْ وسيزيد وضوح هذا فى باب الدوائر[!] : ب.

الباب الرابع

من المقالة الأولى

في القسيّ

[١] **القوس** قطعة [١] من محيط الدائرة. فإن نقصت تلك القطعة[٢] عن تسعين [٣]جزءاً بالأجزاء[٤] التي يتمّ بها[٥] المحيط ٣٦٠ [٦] جزءاً ففضل التسعين عليها يسمّى تمام تلك[٧] القوس. ومثاله [٨]ما سلف من قوس السمت وتمامها.[٩]

[٢] **طول البلد**[١٠] قوس من معدّل النهار فيما بين دائرة نصف النهار بآخر[١١] العمارة أعني مبدأ[١٢] طول العمارة من المغرب وستعرفه وبين دائرة نصف النهار في ذلك البلد.

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[١] ص٢٤: ب.

[٢] القطعة] القوس: ب.

[٣] ١٢ب: ك.

[٤] بالأجزاء] س، ف، ك = من الاجزآء: ب، ل.

[٥] يتمّ بها] س = بها نتمّ: ب = ىم ىها: ف = –ك = بها: ل.

[٦] ٣٦٠] س، ف، ك، ل = ثلثمائة وستين: ب، +هال.

[٧] تلك] –ك.

[٨] ٥٩آ: س.

[٩] وتمامها] +ومنها:هاس(مع رمز «صح»).

[٣] **مطالع** كلّ قوس من فلك البروج هي[١٣] ما يطلع[١٤] معها من معدّل النهار[١٥]. ويكون المطالع في خطّ الاستواء لا محالة محصورة[١٦] بين دائرتين من دوائر الميل[١٧] لأنّ أفقه مارّ بقطبي العالم فهو[١٨] ايضاً دائرة من دوائر الميل، أعني يكون ما بين دائرتي الميل من معدّل النهار مطالع لما بينهما من فلك البروج.

[٤] **مطالع**[١٩] **الجزء** من فلك البروج[٢٠] قوس[٢١] من معدّل النهار[٢٢] بين رأس الحمل والجزء الذي يطلع منه[٢٣] مع[٢٤] ذلك[٢٥] الجزء.

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[١٠] البلد] +وهي: ب، س(تحت السطر مع رمز «صح»).

[١١] بآخر] آخر وباحى: ف.

[١٢] مبدأ] بهذا: ك.

[١٣] هي] وهي: س(الـ«و» مشطوب).

[١٤] يطلع] س = نطلع: ف = تطلع: ك، ل.

[١٥] مطالع كلّ قوس من فلك البروج هي ما يطلع معها من معدّل النهار] س، ف، ك، ل = منها(ومنها: هاس) المطالع اذا طلع قوسٌ من دآيرة البروج فلا بد وان يطلع معهُ(معها: هاس) قوسٌ من معدّل النهار وهذا القوس(+الذى هو: هاس) من معدّل النهار يقال له مطالع تلك القوس التى هى من فلك البروج: ب، هاس(مع رمز «خ»).

[١٦] محصورة] +مقصورة: تاس(مع رمز «خ»).

[١٧] الميل] +الميول: تاس(مع رمز «خ»).

[١٨] فهو] ب، س، ف = هي: ك = فهى: ل.

[١٩] مطالع] ومنْها مطالع: ب = ومطالع: س، ف.

[٢٠] من فلك البروج] —س، —ف، هال(مع رمز «صح»).

[٢١] قوس] وهى قوس: ب.

[٢٢] النهار] +ما: ب.

[٥] **تعديل النهار**[٢٦] لجزء من فلك البروج هو[٢٧] الفضل بين مطالعه بخطّ الاستواء وبين مطالعه بالبلد. ولِنُمثّل لذلك مثالاً: إذا كان رأس الجوزاء ممّا يلي[٢٨] المشرق في [٢٩]أفق غير[٣٠] خطّ الاستواء، وفرضنا دائرة من دوائر الميل تمرّ به [٣١]وتقاطع معدّل النهار، [٣٢]حدث مُثلّث. أحد أضلاعه ميل[٣٣] رأس الجوزاء وستعرف الميل[٣٤]. والضلعان الأخران [٣٥]قوسان بين دائرة الميل وبين نقطة الاعتدال الربيعي، إحداهما من فلك البروج ويسمّى **بدرج**[٣٦] **السواء** والأخرى من معدّل النهار وهي **مطالع قوس البروج** بأفق خطّ الاستواء. وأفق البلد يقسّم[٣٧]

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[٢٣] منه] ب = ـــس، ـــك = هاف(مع رمز «صح»)، هال(مع رمز «صح»).

[٢٤]مع] +من: تاس(مع رمز «خ»).

[٢٥] ١٣آ: ك.

[٢٦] تعديل النهار] ومنها تعديل النهار: ب.

[٢٧] هو] وهي: ب، +تاس.

[٢٨] يلي] يل: ك.

[٢٩] ص٢٥: ب.

[٣٠] غير] ـــس، ـــف.

[٣١] ١٠ب: ف.

[٣٢] ٥٩ب: س.

[٣٣] ميل] مثل: ك.

[٣٤] الميل] +والجوزا: شاك.

[٣٥] ٦٩ب: ل.

[٣٦] بدرج] بفلك: ك.

[٣٧] يقسّم] يَقْسم: ب = يقسم: ك = يُقسِّمُ: س = يُقسم: ف = يُقسِّم: ل.

هذا المثلّث إلى مثلّثين[٣٨] إحداهما فوق الأرض وتحيط[٣٩] به **سعة المشرق**، وستعرفها، وقوس البروج المذكورة وقوس من[٤٠] معدّل النهار بين[٤١] نقطة الاعتدال الربيعي وبين الأفق. والمثلّث الآخر تحت الأرض ويحيط به سعة المشرق وميل رأس الجوزاء وقوس[٤٢] من معدّل النهار ما بين الأفق وبين[٤٣] نقطة التقاطع بين دائرة الميل وبين معدّل النهار[٤٤]. وهذه القوس التي هي من[٤٥] معدّل النهار تعديل النهار[٤٦] لرأس الجوزاء[٤٧] في ذلك البلد. ولمّا كانت الآفاق تختلف قطعها لمثل هذا المثلّث باختلاف عروض البلدان، وجب أن يكون[٤٨] المطالع يختلف[٤٩] باختلاف العروض.

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[٣٨] مثلّثين] هاس = المثلّثَ: س.

[٣٩] وتحيط] ب = وىحيط: س، ف، ل = ويحيط: ك.

[٤٠] من] –ك.

[٤١] بين] هاس(مع رمز «صح»).

[٤٢] وقوس] قوس: ك.

[٤٣] بين] –س.

[٤٤] ما بين الأفق وبين نقطة التقاطع بين دائرة الميل وبين معدّل النهار] ف، ك، ل = –ب = هاس(مع رمز «صح»).

[٤٥] من] –ف.

[٤٦] النهار] هاف(مع رمز «صح»).

[٤٧] النهار لرأس الجوزاء] ب، س = طاف = نهار راس الجوزا: ك، ل.

[٤٨] يكون] ك = ىكون: ب، ف، ل = تكون: س.

[٤٩] يختلف] ىحتلف: ب = ىختلف: س = ىحلف: ف = ىختلفه: ك = تحلف: ل.

[٦] **وسط الشمس**[50] وهو[51] قوس من فلك البروج ما بين أوّل الحمل [52] وبين رأس خطّ[53] يخرج من مركز فلكها الخارج المركز ويمرّ[54] بمركز[55] الشمس وينتهي إلى دائرة البروج. فإذا فرض ذلك الخطّ خارجاً من مركز العالم فالقوس التي [56] بين طرفه وبين أوّل الحمل من فلك البروج هي **تقويم الشمس**. وما بين طرفي الخطّين المذكورين هو [57] **تعديلها**. وزاوية الخطّين إذا تقاطعا[58] عند مركز الشمس، أعني الزاوية التي يُوترها قوس التعديل هي **زاوية التعديل**.[59]

[٧] **وسط الكوكب** قوس[60] من فلك البروج ما بين أوّل الحمل وطرف[61] الخطّ الخارج من مركز العالم المارّ بمركز التدوير المنتهي إلى فلك البروج، وذلك يكون عند مسامتة مركز التدوير إحدى نقطتي الجوزهريْن.

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[50] وسط الشمس] ومنها وسط الشمس: ب، س(«ومنها» في الهامش مع رمز «صح»).

[51] وهو] –ف، –ك، –ل.

[52] ٦٠آ: س.

[53] ما بين أوّل الحمل وبين رأس خطّ] وما بين اول ولراس : ك.

[54] ويمرّ] الى: شاس، ف = ويمر: فاس(مع رمز «صح») = ويمر بمركز: تاس (مع رمز «ح صح»).

[55] بمركز] مركز: ف.

[56] ص٢٦: ب.

[57] ١٤آ: ك.

[58] تقاطعا] هال(مع رمز «صح»).

[59] التعديل] +ومنها: ب، هاس(مع رمز «صح»).

[60] قوس] هو قوس: ب.

[61] وطرف] س، ك، ل = وبين طرف: ب، ف.

فإذا جاوزها وحصل له عرض كان موقع الخطّ خارجاً عن[٦٢] فلك البروج إمّا إلى الشمال وإمّا إلى الجنوب. فيتوهّم[٦٣] دائرة [٦٤]مارّة على موقعه وقطبي البروج مقاطعة[٦٥] لفلك البروج؛ فالقوس[٦٦] التي هي من فلك البروج بين أوّل الحمل وبين نقطة التقاطع [٦٧]بين [٦٨]تلك الدائرة ودائرة البروج هي **وسط** [٦٩]**الكوكب**. فإن فرضنا الخطّ الخارج من مركز العالم المنتهي إلى فلك البروج مارّا بمركز الكوكب، فالقوس التي بين أوّل الحمل وبين طرفه[٧٠] مع عدم عرض الكوكب أو بين أوّل الحمل وبين نقطة[٧١] التقاطع من[٧٢] فلك البروج والدائرة المارّة بقطبي البروج وبطرفه هي **تقويم الكوكب**. وما بين [٧٣]الوسط والتقويم من فلك البروج هو **التعديل**.

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[٦٢] عن] +من: تاس(مع رمز «ح»).

[٦٣] فيتوهّم] فنتوهّم: ل.

[٦٤] ١٣آ: ف.

[٦٥] مقاطعة] قاطعة: ب.

[٦٦] فالقوس] والقوس: ف.

[٦٧] ٦٠ب: س.

[٦٨] ٧٠ آ: ل.

[٦٩] ١٤ب: ك.

[٧٠] طرفه] طرفي: ب.

[٧١] نقطة] نقطتى: ب.

[٧٢] من] س، ف = بين: ب، ك، ل = +س: تاس(مع رمز «ح»).

[٧٣] ص٢٧: ب.

[٨] ولهذا المعنى: إذا كانت الشمس في الأوج أو الحضيض حيث ينطبق الخطّان الخارجان— أحدهما[٧٤] من مركز العالم والثاني من مركز فلكها الخارج المركز— المارّان[٧٥] بمركزها؛ أو كانت[٧٦] الكواكب[٧٧] في ذرى تداويرها أو في أسافلها حيث ينطبق[٧٨] الخطّان الخارجان من مركز العالم المارّ— أحدهما بمركز التدوير والثاني بمركز الكوكب— [٧٩]لم يكن هناك تعديل.

[٩] وقد قسموا الأفلاك الخارجة المراكز والتداوير كلّ واحد منها أربعة أقسام مختلفة، اثنان منها سفليّان متساويان [٨٠]واثنان[٨١] علويّان متساويان[٨٢]، سمّوها **نطاقات**[٨٣]. واختلفوا في مبادئ هذه الأقسام: فمنهم من اعتبر الأبعاد فقسم الخارج المركز بخطّين، يخرج أحدهما من مركز العالم إلى الأوج والحضيض، والآخر يمرّ[٨٤] بالبعدين

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[٧٤] أحدهما] احديهما: ب.

[٧٥] المارّان] ب = +المارّو: شاب.

[٧٦] أو كانت] —ك.

[٧٧] الكواكب] الكوكب: ف.

[٧٨] ينطبق] مطبق: ف.

[٧٩] ١٥آ: ك.

[٨٠] ٦١آ: س.

[٨١] واثنان] —ك.

[٨٢] متساويان] متساوان: ل.

[٨٣] نطاقات] نطاقان: ك.

[٨٤] يمرّ] ف = تمر: ب، س = بمر: ك، ل.

الأوسطين[٨٥]، وهما نقطتان متقابلتان على محيط الفلك الخارج المركز[٨٦] حيث يستوي الخطّان الخارجان[٨٧]، أحدهما[٨٨] من مركز العالم والآخر من مركز الخارج المركز المنتهيان إلى أيّتهما كانت. ويمرّ هذا الخطّ عند منتصف ما بين المركزين. وقسم التدوير بخطّين، يخرج [٨٩]أحدهما من مركز الحامل مارّاً بحضيض [٩٠]التدوير ومركزه[٩١] إلى ذروته، والآخر يمرّ[٩٢] بنقطتي التقاطع بين التدوير والحامل[٩٣].

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[٨٥] الأوسطين] الاولين: ف.

[٨٦] المركز] تاس(مع رمز «صح»).

[٨٧] الخارجان] الخارج: ف.

[٨٨] أحدهما] اهاحدهما: س.

[٨٩] ص٢٨: ب.

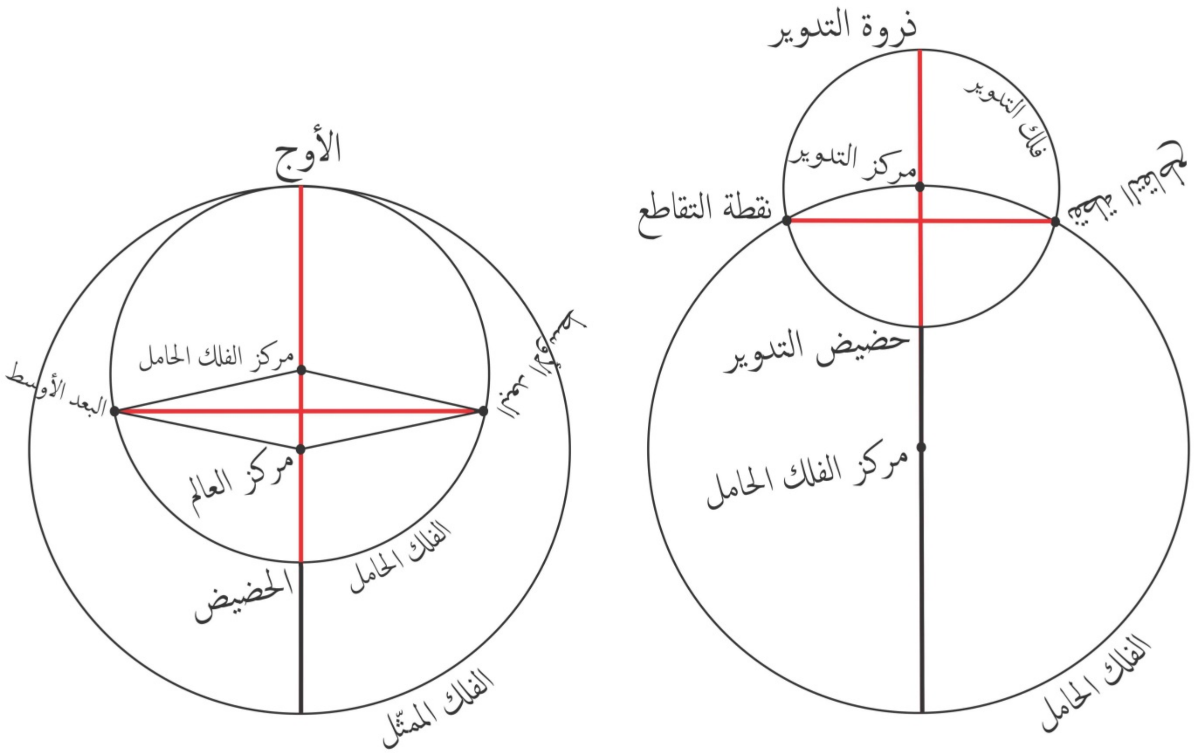
[٩٠] ١٥ب: ك.

[٩١] ومركزه] +التقاطع: شاك.

[٩٢] يمرّ] ك = تمر: ب، س = بمر: ف، ل.

[٩٣] والحامل] +وهذه صورتُهُ: ب = +بهذه الصورة: ك.

صورة النطاقات باعتبار الأبعاد



[شكل ٦]

[١٠] [٩٤] ومنهم من اعتبر [٩٥] اختلاف المسير. فقسم الخارج المركز بخطّين، يخرج أحدهما من مركز العالم إلى الأوج والحضيض، والآخر [٩٦] يمرّ [٩٧] بحيث [٩٨] يكون زاوية التعديل أعظم، وذلك من جانب [٩٩] الأوج على بعد

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[٩٤] ٦١ب: س؛ ٧٠ب: ل.

[٩٥] ١٣ب: ف.

[٩٦] والآخر] +هو: س.

[٩٧] يمرّ] تمر: ب، س = بمر: ف، ك، ل.

[٩٨] بحيث] به حث: ب.

[٩٩] جانب] جانبى: ب.

تسعين جزءاً[100] عنه من أجزاء فلك البروج. وقسم التدوير بخطّين، يخرج [101]أحدهما من مركز الحامل[102] ويمرّ[103] بالذروة والحضيض من التدوير، والآخر يقوم عليه وينتهي طرفاه إلى نقطتي[104] التماسّ بين محيط التدوير وبين خطّين يخرجان إليه من مركز الحامل[105]. وهناك ايضاً غاية التعديل [106]من جهة التدوير. فالنطاق الأوّل هو ما يصل إليه الكوكب بعد مجاوزته[107] الأوج أو ذروة التدوير والثاني والثالث والرابع على توالي حركته[108]. فما دام الكوكب يتحرّك من الأعلى إلى الأسفل أي كان في النطاق الأوّل والثاني من الخارج المركز [109]أو التدوير[110] [111]فهو هابط؛ وما دام يتحرّك من الحضيض إلى الأوج أي كان في النطاقين[112] الآخرين فهو صاعد[113].

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[100] جزءاً] +درجة: هاس(مع رمز «ح»).

[101] ١٦آ: ك.

[102] الحامل] الحاصل: ك.

[103] يمرّ] ك = تمر: ب، س = بمر: ف، ل.

[104] نقطتي] نقطه: ب.

[105] الحامل] الحاصل: ك.

[106] ص٢٩: ب.

[107] مجاوزته] مجاوزيه: ب.

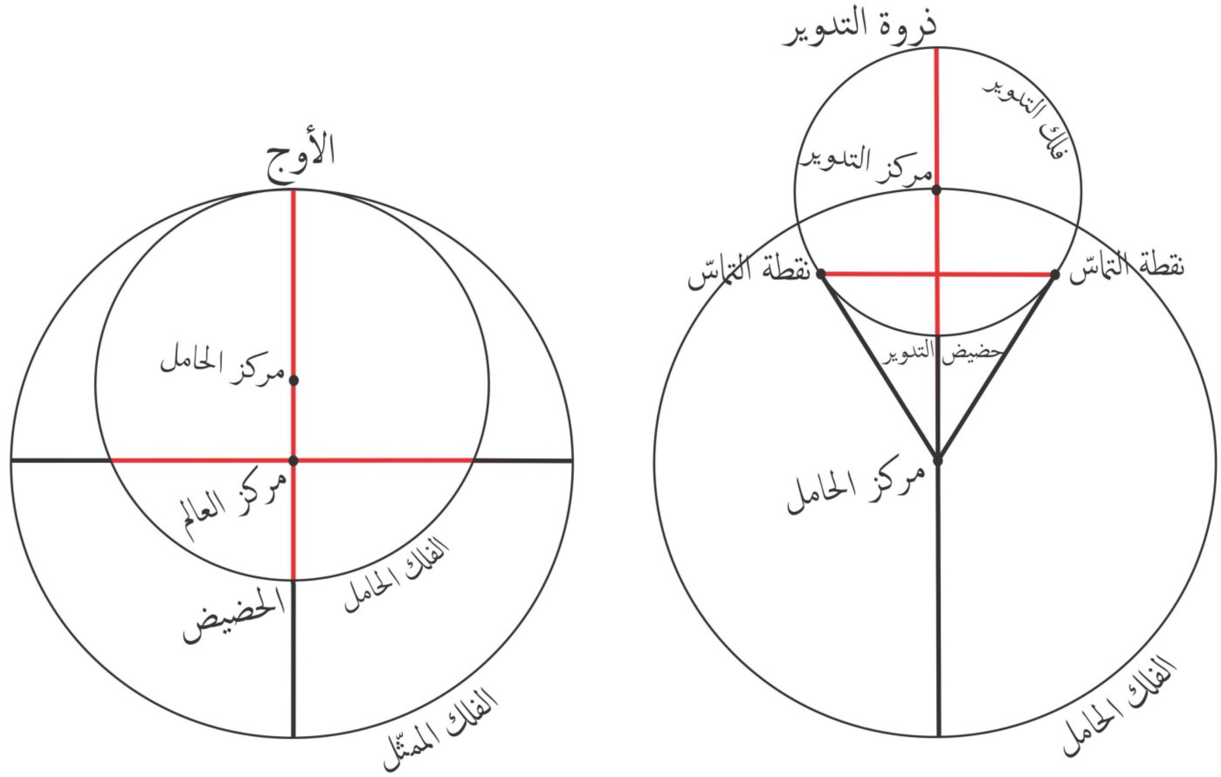
[108] على توالي حركته] +بهذه الصوره: ك.

[109] ٦٢آ: س.

[110] أو التدوير] س، ك = او التداوير: ب = والتدوير: ف، ل.

[111] ١٦ب: ك.

صورة النطاقات باعتبار اختلاف المسير



[شكل ٧]

[١١] **عرض البلد**[١١٤] هو[١١٥] قوس من دائرة نصف النهار ما بين معدّل النهار وسمت الرأس وهي مساوية لما بين الأفق[١١٦] والقطب من دائرة نصف النهار وهو[١١٧] ارتفاع القطب[١١٨]، أعني أقرب قطبي العالم إلى ذلك البلد.

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١١٢ النطاقين] النطاقتين: ك.

١١٣ فهو صاعد] +قد نُجعل صاعداً فى النطاق الاول والرابع هابط فى الاخرين وهذه صورتُهُ: ب.

١١٤ عرض البلد] (بياض في ب).

١١٥ هو] (مصحّح من «هى» في س).

[١٢] **الميل**[١١٩] قوس من دائرة الميل بين معدّل النهار ودائرة البروج، وهو **الميل الأوّل**. **والميل**[١٢٠] إذا أطلق يراد به الميل الأوّل. **والميل**[١٢١] **الثاني** قوس من دائرة العرض[١٢٢] بينهما، أعني بين معدّل النهار ودائرة البروج[١٢٣]. **غاية الميل**[١٢٤]، ويقال لها **الميل الكلّي**[١٢٥] **والميل الأعظم**، قوس[١٢٦] بينهما من دائرة المارّة[١٢٧] بالأقطاب الأربعة وهي تدخل تحت حدّ[١٢٨] الميل الاوّل والثاني [١٢٩]. وهي نهاية ميل دائرة البروج عن معدّل [١٣٠]النهار ومقدارها كجـ له[١٣١].

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[١١٦] ص٣٠: ب.

[١١٧] وهو] وذلك: ب = +ودلك: تاس(مع رمز «ح»).

[١١٨] القطب] +من دايرة نصف النهار: ك.

[١١٩] الميل] (بياض في ب).

[١٢٠] والميل] –ك.

[١٢١] والميل] الميل: ل.

[١٢٢] من دائرة العرض] –ب.

[١٢٣] البروج] +من دائرة العرض: ب.

[١٢٤] غاية الميل] –ب.

[١٢٥] الكلّي] ب، ك، ل = الكل: س، ف.

[١٢٦] قوس] هال(مع رمز «صح»).

[١٢٧] دائرة المارّة] الدايرة الماره: ك.

[١٢٨] حدّ] –ل.

[١٢٩] ١٧آ: ك.

[١٣] **عرض الكوكب**[١٣٢] قوس من دائرة العرض ما بين دائرة البروج وبين رأس الخطّ [١٣٣]الخارج من مركز العالم المارّ بمركز الكوكب[١٣٤] المنتهي إلى فلك البروج. فإن كانت[١٣٥] القوس من[١٣٦] دائرة الميل[١٣٧] بين معدّل النهار وبين [١٣٨]رأس الخطّ المذكور فهو بعد الكوكب عن معدّل النهار.

[١٤] **ارتفاع الكوكب**[١٣٩] قوس من دائرة الارتفاع ما بين رأس الخطّ المذكور آنفاً وبين الأفق. فإن انطبقت دائرة الارتفاع على[١٤٠] دائرة نصف النهار، فتلك القوس[١٤١] هي غاية ارتفاع الكوكب.

[١٥] **اختلاف المنظر**[١٤٢] قوس من دائرة الارتفاع ما بين موقعي [١٤٣]الخطّين المارّين بمركز الكوكب المنتهيين إلى فلك البروج، الخارج أحدهما من مركز العالم والآخر[١٤٤] [١٤٥]من منظر الأبصار، أعني[١٤٦] سطح

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[١٣٠] ١١آ: ف.

[١٣١] كجـ له] (بياض في ب).

[١٣٢] عرض الكوكب] (بياض في ب).

[١٣٣] ٦٢ب: س.

[١٣٤] الكوكب] الكواكب: ف.

[١٣٥]كانت] كان: ك.

[١٣٦] من] +من: ك.

[١٣٧] الميل] –ك.

[١٣٨] ٧١ آ: ل.

[١٣٩] ارتفاع الكوكب] (بياض في ب).

[١٤٠] على] هي: ب = +على: هاب.

[١٤١] وبين الأفق فإن انطبقت دائرة الارتفاع على دائرة نصف النهار فتلك القوس] هاف(مع رمز «صح»).

الأرض[١٤٧] ويوجد هذا فيما[١٤٨] تحت فلك الشمس وهو قليل في فلك الشمس، ولا يوجد فيما وراءه إذ ليس للأرض إلى ما وراءه نسبة محسوسة[١٤٩].

[١٦] **سعة المشرق**[١٥٠] قوس من دائرة[١٥١] الأفق ما بين مدار الكوكب ومطلع الاعتدال. ولمّا كانت المدارات موازية لمعدّل النهار كانت سعة مشرق [١٥٢]كلّ كوكب كسعة مغربه. وسعة المشرق[١٥٣] والمغرب تزيد بزيادة عرض البلد.

[١٧] **السمت** وتمامه قد[١٥٤] سلفا[١٥٥].

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[١٤٢] اختلاف المنظر] (بياض في ب).

[١٤٣] ص٣١: ب.

[١٤٤] والآخر] +من: ك.

[١٤٥] ١٧ب: ك.

[١٤٦] أعني] +بحط: ف.

[١٤٧] سطح الأرض] هاف(مع رمز «صح»).

[١٤٨] هذا فيما] –ك.

[١٤٩] محسوسة] محصوصة: ب.

[١٥٠] سعة المشرق] (بياض في ب).

[١٥١] قوس من دائرة] طاس.

[١٥٢] ٦٣آ: س.

[١٥٣] المشرق] هاك(مع رمز «صح»).

[١٥٤] قد] هاب.

[١٨] **السمت**[١٥٦] **من الطالع**[١٥٧] قوس من[١٥٨] الأفق ما بين فلك البروج ودائرة الارتفاع.

[١٩] **سمت القبلة** للبلد[١٥٩] قوس من الأفق ما بين دائرة نصف[١٦٠] نهار البلد[١٦١] والدائرة المارّة بسمت رؤوس[١٦٢] أهله ورؤوس [١٦٣] أهل مكّة[١٦٤].

[٢٠] **قوس النهار**[١٦٥] قوس من دائرة مدار الشمس فوق الأرض ما بين نقطتي مغربها [١٦٦]ومشرقها[١٦٧]. والقوس التي بينهما تحت الأرض من هذه الدائرة هي **قوس الليل**. **قوس نهار الكوكب**[١٦٨] قوس من دائرة مداره بين نقطتي مشرقه[١٦٩] ومغربه فوق الأرض[١٧٠]. والقوس التي[١٧١] بينهما منها[١٧٢] تحت الأرض[١٧٣] **قوس ليله**.

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[١٥٥] سلفا] +والله اعلم: ك.

[١٥٦] السمت] (بياض في ب).

[١٥٧] الطالع] ف، ل =المطالع: ب، س، ك.

[١٥٨] من] –س.

[١٥٩] سمت القبلة للبلد] (بياض في ب).

[١٦٠] نصف] +النهار: شاس.

[١٦١] البلد] –ب.

[١٦٢] رؤوس] راوس: ك.

[١٦٣] ورؤس] الروس وروس: ف(الروس مشطوب) = راوس: ك.

[١٦٤] مكّة] +شرفها الله: ك.

[١٦٥] قوس النهار] (بياض في ب).

[١٦٦] ١٨آ: ك.

[١٦٧] مغربها ومشرقها] مشرقها ومغربها: ب.

[٢١] **الدائر من الفلك**[١٧٤] [١٧٥]قوس من دائرة مدار الشمس ما بين جزئها وأفق المشرق بالنهار[١٧٦] وما بين نظير جزئها[١٧٧] وأفق المشرق بالليل من دائرة مدار نظير[١٧٨] جزئها.

[٢٢] ومقدار كلّ واحدة[١٧٩] من هذه القسّي الستّ شبيهتها من معدّل النهار.

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[١٦٨] قوس نهار الكوكب] (بياض في ب).

[١٦٩] مشرقه] مشرقى: ب.

[١٧٠] فوق الأرض] –ك.

[١٧١] التي] ب، هاس(مع رمز «صح»)، ك = –ف، –ل.

[١٧٢] منها] ف، ل = –ب، –ك = شاس.

[١٧٣] الأرض] +هي: ك.

[١٧٤] الدائر من الفلك] ف، ل = (بياض في ب) = الدايره من الفلك: س(الـ«ه» مشطوب و«الداير» تحت السطر مع رمز «ح»)، ك.

[١٧٥] ص٣٢: ب.

[١٧٦] بالنهار] +ما بن نطير حراها وافق (١١ب) وافق المشرق بالنهار: شاف.

[١٧٧] جزئها] +من معدل النهر: شال.

[١٧٨] نظير] هال(مع رمز «صح») = نطيره: س.

[١٧٩] واحدة] ل = واحد: ب، س، ف، ك.

الباب الخامس[1]

من المقالة الأولى

فيما يعرض للكواكب في حركاتها

[١] **ممّا يعرض للكواكب الاختلاف في الطول: للشمس** اختلاف واحد، وهو [2]أنّها لمّا كانت تدور على محيط دائرة مركزها خارج عن[3] [4] مركز[5] العالم، كان[6] [7]في أحد نصفي فلك البروج أكثر[8] من نصفها، وهو النصف الذي فيه أوجها، وفي النصف[9] الآخر من فلك البروج أقلّ من نصفها، وهو نصف الحضيض[10]، وكانت[11] لا

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[1] ٦٣ب: س.

[2] ٧١ب: ل.

[3] مركزها خارج عن] فال(مع رمز «صح»).

[4] عن] هاس(مع رمز «صح»).

[5] مركز] مركزها: ك(الـ«ها» مشطوب).

[6] كان] كانت: ب.

[7] ١٨ب: ك.

[8] أكثر] واكثر: س(الـ«و» مشطوب).

[9] النصف] هال(مع رمز «صح»).

[10] نصف الحضيض] ف، ك، ل = النصف الحضيض: ب، س = +الذى فيه: هاس(مع رمز «صح»).

[11] وكانت] س، ف = ولمّا كانت: ب، ك، ل(«لمّا» في الهامش مع رمز «صح»).

تقطع كل نصف من فلك البروج الا بقطعها ما فيه من دائرتها، لزم أن يخالف[١٢] زمان قطعها أحد نصفي البروج زمان قطعها النصف الثاني[١٣]. فترى[١٤] حركتها[١٥] في أحد نصفي البروج، وذلك نصف الأوج[١٦]، أبطاء منها في نصف الحضيض لكون زمان قطعها[١٧] إيّاه أطول من زمان قطعها نصف الحضيض. وحركتها[١٨] في فلكها الخارج المركز، وهي وسطها، لا تختلف فلذلك يُحتاج[١٩] إلى زيادة التعديل أو[٢٠] [٢١]نقصانه على [٢٢]وسطها[٢٣] أو منه[٢٤] لِيتحقق[٢٥] موضعها من فلك البروج.

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[١٢] يخالف] يختلف: ب.

[١٣] الثاني] الآخر: ب.

[١٤] فترى] س(نقطتان تحت الـ«ت» مشطوبتان) = فَتُرى: ب = فيرى: ف، ك، ل.

[١٥] حركتها] حركاتها: ب.

[١٦] الأوج] الاوجى: ب.

[١٧] قطعها] –ب.

[١٨] وحركتها] وحرتها: ب.

[١٩] يُحتاج] تُحتاج: ب، س، ف، ل = تحتاج: ك.

[٢٠] أو] و: ل.

[٢١] ص٣٣: ب.

[٢٢] ٦٤آ: س.

[٢٣] وسطها] +الوسط: تاس(مع رمز «ح»).

[٢٤] أو منه] ب، تاس(مع رمز «ح»)، ك، هال(مع رمز «صح») = –ف.

[٢٥] لِيتحقق] ك = لتتحقق: ب = لتحقق: س = لسحقق: ف = لتحقق: ل.

[٢] **وأمّا سائر الكواكب**، فلها عدّة من الاختلافات[٢٦] في الطول[٢٧]. أحدها[٢٨] ويُسمّى **الاختلاف**[٢٩] **الأوّل** [٣٠]ما يقع لها[٣١] من جهة حركتها على محيط التدوير. وهو أنّها إذا كانت على ذروة التدوير أو حضيضه، كان الخطّان الخارجان من مركز العالم المارّ أحدهما بمركز التدوير والآخر بمركز الكوكب[٣٢] انطبق أحدهما على الآخر فلم يكن اختلاف بين وسط الكوكب[٣٣] وتقويمه[٣٤] كما سلف. وأمّا إذا[٣٥] زايلت الذروة[٣٦] أو الحضيض اختلف موقع الخطّين المذكورين من فلك البروج لحصل اختلاف[٣٧] بين[٣٨] الوسط والتقويم. وغاية هذا الاختلاف[٣٩]

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[٢٦] الاختلافات] الاحلاف: ف.

[٢٧] الطول] –ك.

[٢٨] أحدها] احدهما: ب.

[٢٩] الاختلاف] +الاختلاف: ك.

[٣٠] ١٩آ: ك.

[٣١] لها] –ك.

[٣٢] الكوكب] الكواكب: س.

[٣٣] الكوكب] الكواكب: س.

[٣٤] وتقويمه] والتقويم: ب.

[٣٥] وأمّا إذا] س، ف، ل = فامّا اذا: ب = فاذا: ك.

[٣٦] الذروة] الدورة: س.

[٣٧] اختلاف] ب، ف، ل = الاختلاف: س(الـ«لا» فوق «خـ»)، ك.

[٣٨] بين] +بين: ب.

[٣٩] الاختلاف] هاف(مع رمز «صح»).

حيث تكون[٤٠] غاية التعديل في التداوير[٤١]، وقد عرفته في فصل النطاقات. ويكون هذا الاختلاف لا محالة بقدر نصف[٤٢] قطر التدوير. وانصاف[٤٣] أقطار التداوير[٤٤] في أبعادها الوسطى:

لزحل و ل [٤٥]

للمشتري يا ل [٤٦]

[٤٧]للمرّيخ لط ل [٤٨]

للزهرة مه ٠ [٤٩]

[٥٠]لعطارد كه ٠ [٥١]

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[٤٠] تكون] ب = يكون: س، ك = نكون: ف، ل.

[٤١] التداوير] التدوير: ب.

[٤٢] نصف] –ف.

[٤٣] وانصاف] وانصفاف: س

[٤٤] التداوير] التدوير: ب.

[٤٥] لزحل و ل] س، ف، ك، ل = ٦ اجزاءٍ و ١١٢ : ب.

[٤٦] للمشتري يا ل] س، ف، ك، ل = –ب.

[٤٧] ٦٤ب: س.

[٤٨] للمرّيخ لط ل] س، ل = –ب = ل ط ل : ف، ك.

[٤٩] للزهرة مه ٠] س، ف، ل = وللزهرة ٤٣ جزءً و ١١٦ : ب = م ه : ك.

للقمر و كـ.[٥٢]

[٣] **اختلاف**[٥٣] [٥٤]**ثانٍ**[٥٥] للكواكب[٥٦]، وهو ما يقع لها بسبب قرب[٥٧] مركز التدوير من [٥٨]الأرض، وبعده عنها بسبب كون الحامل[٥٩] خارج المركز. فيرى[٦٠] نصف قطر التدوير حال قربه أعظم، واختلافه أعظم[٦١]؛ [٦٢]وحال بعده بالخلاف.

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[٥٠] ١٢آ: ف.

[٥١] لعطارد كه ٠] س، ف، ل = ولعطارد ٢٢ جزءاً و ١١٢ جزءٍ : ب = كب ل : ك.

[٥٢] للقمر و كـ] س، ف، ك، ل = وللقمر ٥ اجزآءٍ ١١٤ : ب = +من كل ذلك بالاجزآء التى تكون بها نصف قطر حامل الكوكب او مايل القمر ستين جزءاً الى: ب.

[٥٣] اختلاف] الاختلاف: ب.

[٥٤] ١٩ب: ك.

[٥٥] ثانٍ] الثانى: ب.

[٥٦] للكواكب] –ب.

[٥٧] قرب] قريب: ك.

[٥٨] ص٣٤: ب.

[٥٩] الحامل] الحاصل: ك.

[٦٠] فيرى] س(يوجد «تـ» فوق «يـ»)، ف، ك، ل = ويُرى: ب.

[٦١] واختلافه أعظم] هال(مع رمز «صح»).

[٦٢] ٧٢آ: ل.

[٤] **اختلاف ثالث**[٦٣] وهو أنّ مراكز التداوير إذا كانت على الأوج أو الحضيض، فأقطارها المنطبقة حينئذ[٦٤] على الخطّ[٦٥] المارّ بمراكز[٦٦] العالم والحامل[٦٧] والتدوير لا تبقى منطبقة عليه إذا[٦٨] زايلت الأوج أو الحضيض[٦٩] ولا تبقى[٧٠] على صوب مركز الحامل ولا[٧١] مركز العالم، بل[٧٢] على صوب[٧٣] نقطة أخرى من ذلك الخطّ تسمّى في القمر **نقطة المحاذاة** وفي المتحيّرة[٧٤] مركز الخطّ المدير أو[٧٥] مركز الفلك المعدّل للمسير، وستعرف معنى هذا في هذا الفصل[٧٦].

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[٦٣] اختلاف ثالث] الاختلاف الثالث: ب.

[٦٤] حينئذ] ب، س، ل = ح̄ : ف = علي: ك.

[٦٥] الخطّ] +المستقيم: هاس(مع رمز «صح»).

[٦٦] بمراكز] بمركز: ب.

[٦٧] والحامل] والحاصل: ك.

[٦٨] إذا] اذ: ب.

[٦٩] أو الحضيض] س، ف = والحضيض: ب، ك، ل.

[٧٠] ولا تبقى] +مىطىمه عليه: شاف.

[٧١] ولا] +على: هاس(مع رمز «صح»).

[٧٢] بل] +هو: ب.

[٧٣] مركز الحامل ولا مركز العالم بل على صوب] –ك.

[٧٤] المتحيّرة] +؟: ب.

[٧٥] أو] و: ك.

[٧٦] هذا الفصل] ب، ف = هذا لفصل: س = هذا لفضل: ك.

[٥] أمّا في العلوية والزهرة، فعلى صوب نقطة ممّا يلي الأوج بُعدها عن مركز الحامل[٧٧] كبُعد مركز الحامل[٧٨] عن مركز [٧٩]العالم، [٨٠]أعني أنّ مركز الحامل فيما بينها[٨١] وبين مركز العالم.

[٦] وأمّا في عطارد، فعلى صوب نقطة[٨٢] في منتصف ما بين مركز العالم وبين[٨٣] مركز المدير. وأُزيدُكَ لهذا[٨٤] بياناً في هذا الفصل[٨٥].

[٧] وأمّا في القمر، فعلى صوب نقطة ممّا يلي البعد الأقرب بعدها عن مركز العالم ممّا يلي الحضيض كبعد مركز الحامل عنه، أعني عن[٨٦] مركز العالم ممّا يلي[٨٧] الأوج. فإذا دار[٨٨] [٨٩]الحامل[٩٠] ومركزه حول مركز العالم[٩١]

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[٧٧] الحامل] الحاصل: ك.

[٧٨] الحامل] الحاصل: ك.

[٧٩] ٢٠آ: ك.

[٨٠] ٦٥آ: س.

[٨١] بينها] ب، ك، ل = بينهما: س = طاف.

[٨٢] نقطة] +مما يلى الاوج بعدها: شاف.

[٨٣] بين] س، ف = –ب، –ك، –ل.

[٨٤] لهذا] ب، هاس(مع رمز «صح»)، ك، ل = بهذا: ف.

[٨٥] الفصل] الفضل: ك.

[٨٦] عن] –ك.

[٨٧] ممّا يلي] +الحضيض كبعد: شاف.

[٨٨] فإذا درا] فادار: ف.

[٨٩] ص٣٥: ب.

بدوران المائل دارت، هذه النقطة ومركز الحامل على محيط دائرة واحدة متقاطرين، أي يكونان على طرفي قطر من أقطارها.

[٨] فهذه النقط[٩٢] المذكورة[٩٣] تكون[٩٤] الأقطار المذكورة[٩٥] للتداوير على صوبها مسامتةً لها دائمة كيف ما دارت، أعني لو أخرج من هذه النقط[٩٦] خطوط إلى مراكز التداوير يكون كلّ خطّ منها منطبقاً[٩٧] [٩٨]على القطر المذكور للتدوير، لا ينفكّ عنه[٩٩]كيف ما[١٠٠] دار. وهذا الخطّ في المتحيّرة يسمّى **الخطّ المدير**، والدائرة المتوهّمة التي ترتسم بدوران[١٠١] هذا الخطّ مع مركز [١٠٢]التدوير تسمّى[١٠٣] **الفلك المعدّل للمسير** إذ يعتدل[١٠٤] مسير

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[٩٠] الحامل] الحمل: ب.

[٩١] العالم] +على دايرة واحدة: ب.

[٩٢] النقط] س، ف، ل = النقطة: ب، ك.

[٩٣] المذكورة] المذكوة: س.

[٩٤] تكون] ل = ىكون: ب، ك = يكون: س(يوجد«تـ» مشطوب فوق الـ«يـ»)، ف.

[٩٥] المذكورة] هال(مع رمز «صح»).

[٩٦] النقط] ف، ك؟، ل = النقطة: ب، س.

[٩٧] منطبقاً] +علي: ك.

[٩٨] ٢٠ب: ك.

[٩٩] عنه] عنها: ك.

[١٠٠]كيف ما] +دارت اعنى لو احرح من هذه النقط خطوط الى مراكز التداوير ىكون كل خطّ (١٢ب) منها منطبقا على القطر المدكور للتدور لا ىفك عنه كىف: ف.

[١٠١] بدوران] بدروان: ب.

المتحيّرة بالنسبة إليها، أي[١٠٥] تقطع من محيطها قسيّاً متساوية في أزمنة متساوية. وموقع هذا الخطّ من أعلى التدوير هو[١٠٦] **الذروة الوسطى**[١٠٧]، وموقع الخطّ الخارج من [١٠٨]مركز العالم المارّ بمركز التدوير هو[١٠٩] **الذروة**[١١٠] **المرئيّة**[١١١].

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[١٠٢] ٦٥ب: س.

[١٠٣] تسمّى] ك = سمّى: ب، ف، ل = وتسمى: س(يوجد «تـ» فوق الـ«يـ» والـ«و» مشطوب).

[١٠٤] يعتدل] ب، ك = تعدل: س(يوجد «يعتدل» تحت السطر مع رمز «ح») = نعدل: ف = نعتدل: ل.

[١٠٥] أي] +اى: شاف.

[١٠٦] هو] وهو: س(الـ«و» مشطوب).

[١٠٧] الوسطى] والوسطي: س(الـ«و» مشطوب).

[١٠٨] ٧٢ب: ل.

[١٠٩] هو] س، ك، ل = يسمّى: ب = وهو: ف.

[١١٠] الذروة] +المرتعبة؟: شاك.

[١١١] المرئيّة] +وليذكر: ب.

وأبعاد[١١٢] هذه النقط[١١٣] والمراكز بعضها عن بعض

[٩] أمّا بعد مركز الخارج المركز[١١٤] عن مركز العالم:

للشمس ب كط ل [١١٥]

للقمر[١١٦] ي يط [١١٧]، وهو[١١٨] مثل بعد نقطة المحاذاة عنه عن[١١٩] الجهة الأخرى.

[١٠] للمتحيّرة[١٢٠] ما خلا[١٢١] [١٢٢]عطارد مثل نصف بعد مركز المعدّل للمسير عنه وذلك[١٢٣]، أعني بعد مركز المعدّل للمسير[١٢٤] عن مركز العالم:

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[١١٢] وأبعاد] س، ف، ل = ابعاد: ب، ك.

[١١٣] النقط] لنقطه: ب.

[١١٤] المركز] –ب.

[١١٥] ب كط ل] س، ف، ك، ل = حزان ٢٩ دقفه ٣٠ ثانيةً: ب.

[١١٦] للقمر] وللقمر: ب.

[١١٧] ي يط] ك، ل = ١٠ اجزاءٍ ١٩ دقفه: ب = ى ىط(مع رمز «ح»): س = ى ىط ٠ : ف.

[١١٨] وهو] وهو هو: ل.

[١١٩] عن] س، ف = من: ب، ك، ل.

[١٢٠] للمتحيّرة] س، ف، ل = وللمتحيّرة: ب، ك.

[١٢١] خلا] هاس(يوجد «ح» تحت الـ«خـ »).

[١٢٢] ص٣٦: ب.

[١٢٣] وذلك] شاس = +وذلك: س.

لزحل[125] $\overline{\text{و}}$ $\overline{\text{ن}}$ [126]

للمشتري[127] $\overline{\text{ه}}$ $\overline{\text{ل}}$ [128]

للمرّيخ[129] $\overline{\text{يب}}$ [130]

للزهرة[131] $\overline{\text{ب}}$ $\overline{\text{ه}}$ [132].

[١١] **وأمّا عطارد**، فمركز فلكه[133] المعدّل للمسير على منتصف ما بين مركز مديره وبين مركز العالم. وبعد مركز حامله[134] عن مركز مديره[135] مثل نصف بعد مركز مديره عن مركز العالم. حتّى[136] إذا[137] انطبق

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[124] للمسير] +عنه وذلك اعنى بعد مركز المعدل للمسر: شاف.

[125] ٢١آ: ك.

[126] $\overline{\text{و}}$ $\overline{\text{ن}}$] س، ف، ك، ل = ٦ اجزاءٍ ٥٠ دقيقه: ب.

[127] للمشتري] وللمشترى: ب.

[128] $\overline{\text{ه}}$ $\overline{\text{ل}}$] س، ف، ك، ل = ٥ اجزاءٍ و ١١٢ : ب.

[129] للمرّيخ] وللمريخ: ب.

[130] $\overline{\text{يب}}$] ف، ك، ل = ١٢ جزءاً: ب = بت ح ٠: س.

[131] للزهرة] وللزهرة: ب.

[132] $\overline{\text{ب}}$ $\overline{\text{ه}}$] ف، ك، ل = جزءآن و ٥ دقايق: ب = باه: س.

[133] فلكه] فلكها: ب.

[134] حامله] خاملة: ب.

الخطّ المدير ممّا[١٣٨] يلي البعد الأقرب [١٣٩] على الخطّ المارّ بالمراكز، وقعت نقطة مركز الحامل على مركز المعدّل[١٤٠] للمسير. وإذا انطبق عليه ممّا يلي البعد الأبعد انتظمت المراكز على الخطّ المارّ بها: أوّلها مركز العالم ثمّ مركز المعدّل للمسير ثمّ مركز المدير ثمّ مركز الحامل. والأبعاد ما بينها متساوية كلّ[١٤١] بعد منها جـ ي [١٤٢]، فيكون ما بين مركزي العالم والحامل ط ل [١٤٣].

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[١٣٥] وبين مركز العالم وبعد مركز حامله عن مركز مديره] –ك.

[١٣٦] حتّى] تاس(مع رمز «صح»).

[١٣٧] إذا] هاف(مع رمز «صح»).

[١٣٨] ممّا] ما: ب.

[١٣٩] ٦٦آ: س.

[١٤٠] المعدّل] لمعدل: ب.

[١٤١] كلّ] وكل(الـ«و» مشطوب): س.

[١٤٢] جـ ي] س، ف، ك، ل = (بياض في ب).

[١٤٣] ط ل] س، ف، ك، ل = (بياض في ب) = +الله اعلم: ك.

وممّا يعرض للكواكب الاختلاف[١٤٤] في العرض:

[١٢] **الشمس**[١٤٥] لا عرض لها لأنّها لازمة في حركتها لسطح فلك[١٤٦] البروج.

[١٣] **وسائر الكواكب** تميل عن فلك البروج إلى الشمال والجنوب لميل الفلك[١٤٧] المائل عنه، ويسمّى[١٤٨] **عرض الخارج**[١٤٩] [١٥٠]**المركز** وغايته:

لزحل ب̄ ل̄ [١٥١]

للمشتري ا̄ ل̄ [١٥٢]

للمرّيخ ا̄ ٠̄ [١٥٣]

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[١٤٤] الاختلاف] ف، ك = الاختلافات: ب، س(الـ«ات» زائد)، ل.

[١٤٥] الشمس] فالشمس: ب.

[١٤٦] فلك] دايرة: ب.

[١٤٧] الفلك] +المل: شاك.

[١٤٨] ويسمى] ك، ل = وسمى: ب، ف = وتسمى: س.

[١٤٩] الخارج] الفلك الخارج: ك.

[١٥٠] ٢١ب: ك.

[١٥١] ب̄ ل̄] ف = (بياض في ب) = د̄ ؟ ل̄ : ك = و ل: س(يوجد«ب» فوق الـ«و» بخط ولون آخر)، ل.

[١٥٢] ا̄ ل̄] س، ف، ك، ل = (بياض في ب).

[١٥٣] ا̄ ٠̄] س، ف، ل(الـ«٠» متغيّر إلى «ه») = (بياض في ب) = ب̄ ي̄ : ك.

للزهرة ٠ ي [١٥٤]

[١٥٥]لعطارد ٠ مه[١٥٦]

للقمر ٥ ٠ [١٥٧].

وليس للقمر [١٥٨]عرض غير هذا لأنّ أفلاكه[١٥٩] المائل والحامل والتدوير في سطح واحد ونعني[١٦٠] بهذه الأفلاك الدوائر وقد[١٦١] عرفتها.

[١٤] وللمتحيّرة اختلاف آخر وهو ميل ذروة التدوير وحضيضه عن الفلك المائل ويسمّى[١٦٢] **عرض**[١٦٣] [١٦٤]**التدوير**[١٦٥] وغايته:

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[١٥٤] ٠ ي] ف، ل = (بياض في ب) = ٠ ي: هاس(مع رمز «صح») = د ي : ك.

[١٥٥] ص٣٧: ب.

[١٥٦] ٠ مه] س، ف، ل = (بياض في ب) = و مه : ك.

[١٥٧] ٥ ٠] س(مع رمز «صح» تحت الـ«٥»)، ف، ك، ل = (بياض في ب).

[١٥٨] ٨آ: ف.

[١٥٩] أفلاكه] –ك.

[١٦٠] ونعني] س، ك، ل = وتعنى: ب = وبعى: ف.

[١٦١] قد] هاف، فال(مع رمز «صح»).

[١٦٢] ويسمّى] ف = وسمّى: ب، ل = وتسمى: س = –ك.

[١٦٣] عرض] ب، س، ل = عروض: ف = –ك.

[١٦٤] ٦٦ب: س.

لزحل ٠ لب[١٦٦]

للمشتري ٠ لح[١٦٧]

للمرّيخ و يو[١٦٨]

للزهرة ا ب[١٦٩]

لعطارد ا مه[١٧٠].

[١٥] وللسفليين خاصّة اختلاف آخر وهو ميل القطر المارّ بالبعدين الأوسطين لفلك التدوير عن الفلك المائل ويسمّى[١٧١] **عرض الوراب** و**الانحراف** و**الالتواء** وغايته في كلّ واحد منهما ب ل[١٧٢].

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[١٦٥] وحضيضه عن الفلك المائل ويسمّى عرض التدوير] –ك.

[١٦٦] ٠ لب] ف، ل = (بياض في ب) = د ل : ك = و لب: س(يوجد«٠» على الـ«و» بخط ولون غير الناسخ).

[١٦٧] ٠ لح] س، ف، ل = (بياض في ب) = ب ل : ك.

[١٦٨] و يو] و يو: ل = و نو: س، ف = (بياض في ب) = ب ل : ك.

[١٦٩] ا ب] س، ف، ل = (بياض في ب) = د (؟) ل : ك.

[١٧٠] ا مه] س، ف، ل = (بياض في ب) = ا يه : ك.

[١٧١] ويسمّى] ك = وتُسمى: ب، ف، ل = وتسمى: س.

[١٧٢] ب ل] س، ف، ك، ل = (بياض في ب).

[١٦] أمّا ميل الفلك المائل عن فلك البروج، فثابت في الكواكب العلوية والقمر لا يتغيّر[١٧٣]. وغير ثابت في الزهرة وعطارد؛ بل كلّما بلغ مركز التدير إحدى نقطتي الجوزهريْن انطبق المائل على فلك البروج. فإذا جاوزها[١٧٤] [١٧٥]ابتداء نصف المائل، أعني نصفه الذي عليه[١٧٦] مركز التدوير في الميل، للزهرة إلى الشمال ولعطارد إلى الجنوب، ونصفه الآخر[١٧٧] بالخلاف. ثمّ لايزال يزداد الميل حتّى ينتهي المركز إلى منتصف ما بين النقطتين ثمّ يأخذ الميل في النقصان حتّى ينطبق المائل أيضاً على فلك[١٧٨] البروج عند بلوغ المركز [١٧٩]النقطة الأخرى. فإذا[١٨٠] جاوزها عادت[١٨١] إلى[١٨٢] الحالة[١٨٣] الأولى ويلزم[١٨٤] أن يكون [١٨٥]مركز التدوير أبداً للزهرة شماليّاً عن فلك البروج ولعطارد جنوبيّاً عنه[١٨٦].

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[١٧٣] ٧٣آ: ل.

[١٧٤] جاوزها] جا: ف(«وزها» في الهامش).

[١٧٥] ٢٢آ: ك.

[١٧٦] عليه] على: ب.

[١٧٧] الآخر] الآخرى: ب.

[١٧٨] فلك] +الفا: شاك.

[١٧٩] ص٣٨: ب.

[١٨٠] فإذا] +فإذا: ك.

[١٨١] عادت] عادة: س.

[١٨٢] إلى] س(مع رمز «صح»)، ف = –ب، –ك، –ل.

[١٨٣] الحالة] الحالت: ك.

[١٨٤] ويلزم] ب، س، ف = فيلزم: ك، ل.

[١٧] وأمّا ميل قطر التدوير، أعني القطر المارّ بذروته وحضيضه، فغير ثابت أيضاً؛ بل يصير منطبقاً على فلك البروج[١٨٧] في العلويّة عند كون المركز، أعني مركز التدوير، في إحدى نقطتي الرأس والذنب. ثمّ إذا جاوز المركز الرأس، أخذت الذروة في الميل إلى الجنوب[١٨٨]، ولا يزال يزداد حتّى يبلغ[١٨٩] [١٩٠]غايته عند بلوغ المركز منتصف ما بين النقطتين. ثمّ يأخذ في الانتقاص[١٩١] إلى أن ينطبق ثانياً[١٩٢] على فلك البروج[١٩٣] عند بلوغ المركز[١٩٤] الذنب. فإذا جاوزه[١٩٥] أخذت الذروة في الميل [١٩٦]إلى الشمال[١٩٧] وازدياده ومُنتهاه وانتقاصه[١٩٨] على الرسم ويلزم أن يكون ميل الذروة أبداً إلى فلك البروج وميل الحضيض عنه.

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[١٨٥] ٦٧آ: س.

[١٨٦] عنه] —ب.

[١٨٧] فلك البروج] +والمايل: ب.

[١٨٨] الجنوب] +عن المايل: ب.

[١٨٩] يبلغ] ب، ك(مع «نـ» فوق «يـ») = ببلغ: س، ف = سلغ: ل.

[١٩٠] ٢٢ب: ك.

[١٩١] الانتقاص] الاسقاض: ب.

[١٩٢] ثانياً] ثاثياً: ك.

[١٩٣] فلك البروج] المفلك الممثل: ك.

[١٩٤] المركز] س، ك، ل = —ب = مركز: ف.

[١٩٥] جاوزه] حاورب: ف.

[١٩٦] ٨ب: ف.

[١٩٧] الشمال] +عن المايل: ب.

[١٨] وفي السفليين[١٩٩] ينطبق على فلك[٢٠٠] المائل[٢٠١] عند بلوغ مركز التدوير منتصف ما بين النقطتين، أعني نقطتي الرأس والذنب وذلك عند غاية ميل الفلك المائل عن فلك البروج إمّا عند الأوج وإمّا عند الحضيض. [٢٠٢]فعند الأوج يبتدئ[٢٠٣] ذروة التدوير في الميل للزهرة إلى الشمال ولعطارد[٢٠٤] إلى[٢٠٥] الجنوب، [٢٠٦]وعند الحضيض بالخلاف فيهما. ويبلغ[٢٠٧] غايته[٢٠٨] عند النقطتين وازدياده[٢٠٩] وانتقاصه[٢١٠] والانطباق[٢١١] الرسم المذكور.

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[١٩٨] وانتقاصه] وانتقاضه: ب.

[١٩٩] السفليين] س، ف، ل = السفلين: ب، ك.

[٢٠٠] فلك] الفلك: ل.

[٢٠١] المائل] البروج: شال(+«المائل» في الهامش مع رمز «صح»).

[٢٠٢] ٦٧ب: س.

[٢٠٣] يبتدئ] ب، ك = يبتدى: س = سدى: ف، ل.

[٢٠٤] ولعطارد] لعطارد: ب.

[٢٠٥] إلى] –ك.

[٢٠٦] ص٣٩: ب.

[٢٠٧] ويبلغ] ك = وبلغ: س = وتبلغ: ب = وسلع: ف، ل.

[٢٠٨] غايته] غايتها: ب.

[٢٠٩] وازدياده] س، ف، ل = وازياده: ب، ك.

[٢١٠] وانتقاصه] وانتقاضه: ب.

[٢١١] والانطباق] –ك.

[١٩] وأمّا الانحراف[٢١٢]، فابتداؤه[٢١٣] عند بلوغ مركز التدوير إحدى نقطتي الرأس والذنب، وغايته عند منتصف[٢١٤] ما بينهما. فإن كان المنتصف هو الأوج، كان الطرف[٢١٥] الشرقي من القطر المارّ بالبعدين الأوسطين في غاية ميله[٢١٦] في الزهرة إلى الشمال وفي[٢١٧] عطارد إلى الجنوب والغربي في الزهرة[٢١٨] إلى الجنوب[٢١٩] وفي عطارد إلى الشمال. وإن[٢٢٠] كان المنتصف هو الحضيض فعلى الخلاف فيهما.

[٢٠] وقد ظهر من هذا كلّه أنّ[٢٢١] مدّة[٢٢٢] الدور للفلك الحامل ولقطري[٢٢٣] التدوير المذكورين متساوية، وأزمان أرباع دوراتها[٢٢٤] متساوية.

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[٢١٢] وأمّا الانحراف] +والالتواء: ب.

[٢١٣] فابتداؤه] فابتداه: س، ف.

[٢١٤] ٢٣آ: ك.

[٢١٥] ٧٣ب: ل.

[٢١٦] ميله] الميل: ب.

[٢١٧] وفي] في: ك.

[٢١٨] إلى الشمال وفي عطارد إلى الجنوب والغربي في الزهرة] هال(مع رمز «صح»).

[٢١٩] إلى الجنوب] –ب.

[٢٢٠] وإن] واذا: ب.

[٢٢١] أنّ] –ك.

[٢٢٢] مدّة] مداره: ف(الـ«دا» مشطوب).

[٢٢٣] ولقطري] ولقطر: ك.

[٢٢٤] أرباع دوراتها] بلوغ دووراتها: ك.

[٢١] ولنذكر ههنا[٢٢٥] الأوجات والجوزهرات: أمّا[٢٢٦] الأوجات والجوزهرات المتحركة بحركة فلك الثوابت: فأوج زحل متأخّر عن منتصف ما بين [٢٢٧]نقطتي جوزهريه، أعني عن غاية ميل المائل عن فلك البروج على التوالي بخمسين جزءاً، وأوج المشتري متقدّم على المنتصف لا على التوالي بعشرين جزءاً[٢٢٨]، [٢٢٩]ومعنى التقدّم أنّ بلوغ الكوكب إليه يتقدّم على[٢٣٠] بلوغه إلى المنتصف، وعلى هذا معنى التأخّر. وأوج الكواكب[٢٣١] الباقية في المنتصف.

[٢٢] [٢٣٢]أمّا[٢٣٣] موضع[٢٣٤] الأوجات فهي لأوّل[٢٣٥] سنة غثيز[٢٣٦] لذي القرنين:

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[٢٢٥] ولنذكر ههنا] ب، س = ولنذكر منها ههنا: ك(«منها» مشطوب) = ولنذكرها هي: ف = ولنذكرها هنا: ل.

[٢٢٦] أمّا] واما: ك = +واما: هاك.

[٢٢٧] ٦٨آ: س.

[٢٢٨] جزءاً] +واوج المشترى مىقدم عن المىصف لا على الىوالى بعشرىن جزا: ف.

[٢٢٩] ٢٣ب: ك.

[٢٣٠] على] س، ف = –ب، –ك، –ل.

[٢٣١] الكواكب] الكوكب: ب.

[٢٣٢] ص٤٠: ب.

[٢٣٣] أمّا] واما: ك.

[٢٣٤] موضع] س، ف = مواضع: ب، ك، ل.

[٢٣٥] فهي لأوّل] س، ف، ل = فهي في اوّل: ب = فهي الاول: ك.

[٢٣٦] غثيز] س(+«١٣١٧»(!) تحت السطر)، ف(؟) (+«غ»، «ى»، «ر» تحت السطر) = (بياض في ب) = غشيز: ك، ل.

للشمس في الجوزاء كز ي لج[٢٣٧]

لزحل[٢٣٨] [٢٣٩]في القوس ط كجـ لج[٢٤٠]

للمشتري في السنبلة يط كجـ لج[٢٤١]

للمرّيخ في الأسد يا نجـ مو [٢٤٢]

للزهرة في الجوزاء كز ي لج[٢٤٣]

لعطارد في الميزان كو كجـ لجـ[٢٤٤].

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[٢٣٧] كز ي لجـ] س، ف، ك، ل = (بياض في ب).

[٢٣٨] لزحل] +فى: ف .

[٢٣٩] ٩آ: ف.

[٢٤٠] ط كجـ لجـ] س، ف، ك، ل = (بياض في ب).

[٢٤١] يط كجـ لجـ] س، ف، ك، ل = (بياض في ب).

[٢٤٢] يا نجـ مو] س، ف، ك، ل = (بياض في ب).

[٢٤٣] كز ي لجـ] س، ف، ك، ل = (بياض في ب).

[٢٤٤] كو كجـ لجـ] ف(«ر» فوق«و» لـ كو) ، ك، ل = (بياض في ب) = كر كح لح: س.

[٢٣] وأمّا مواضع الجوزهرات لذلك التاريخ فرأس الجوزهريْ[٢٤٥]:

لزحل في السرطان يط كجـ لجـ[٢٤٦]

للمشتري[٢٤٧] في السرطان ط كجـ لجـ[٢٤٨]

للمرّيخ في الثور يا نجـ مو[٢٤٩]

للزهرة في الحُوت[٢٥٠] كز ي لجـ[٢٥١]

لعطارد في الجَدْي كو كجـ لجـ[٢٥٢].

[٢٤] ثمّ يُزاد[٢٥٣] على مواضعها لكلّ سنة ما يتحرّك فلك الثوابت في السنة، وقد عرفت ذلك.

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[٢٤٥] الجوزهريْ] س، ف، ك، ل = الجوزهرّ: ب.

[٢٤٦] يط كجـ لجـ] س، ف، ل = (بياض في ب) = يط لح لح: ك.

[٢٤٧] للمشتري] س، ف، ك ، ل = في المشترى: ب = +فيه ايضا: هاس(مع رمز «صح»).

[٢٤٨] ط كجـ لجـ] س، ف، ل = (بياض في ب) = ط لح لح : ك.

[٢٤٩] يا نجـ مو] س، ف، ك، ل = (بياض في ب).

[٢٥٠] الحُوت] الحوة: ب.

[٢٥١] كز ي لجـ] س، ف، ك، ل = (بياض في ب).

[٢٥٢] كو كجـ لجـ] س، ك، ل = (بياض في ب) = لر لح لح: ف.

[٢٥٣] يُزاد] يزد: ك.

[٢٥] **وممّا يعرض للمتحيّرة الرجوع**[٢٥٤] **والاستقامة والإقامة:** وذلك أنّ الكوكب[٢٥٥] إذا كان في أعلى تدويره، [٢٥٦]كانت[٢٥٧] حركة مركزه موافقة لحركة مركز التدوير على [٢٥٨]توالي البروج، فيُرى[٢٥٩] مُستقيماً سريع الحركة. فإذا قرب من أسفل التدوير، جعل يميل[٢٦٠] إلى خلاف التوالي، لما[٢٦١] تعرف[٢٦٢] من حركة التدوير مركزه. لكنّه ما دام حركة مركزه إلى الخلاف أقّل من حركة مركز التدوير إلى التوالي، يُرى مستقيماً لكن بطء السير. فإذا تساويا[٢٦٣]، يُرى مقيماً. فإذا زادت حركة مركزه على حركة مركز التدوير، يُرى راجعاً. [٢٦٤]ثمّ [٢٦٥]يقيم[٢٦٦] بعد الرجعة ثانياً ويستقيم لهذا[٢٦٧] المعنى بعينه. مع أنّه يُتمّ دورته[٢٦٨] في فلكه من غير اختلاف يقع له بالنسبة إلى فلكه. وإقامته قبل الرجعة تسمّى[٢٦٩] **المقام الأوّل**، وإقامته بعد الرجعة تسمّى[٢٧٠] **المقام الثاني**.

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[٢٥٤] الرجوع] والرجوع (الـ«و» مشطوب في س).

[٢٥٥] الكوكب] الكواكب: ف.

[٢٥٦] ٦٨ب: س.

[٢٥٧] وذلك أنّ الكوكب إذا كان في أعلى تدويره كانت] –ك.

[٢٥٨] ٢٤آ] ك.

[٢٥٩] فيُرى] فترى: ب.

[٢٦٠] جعل يميل] اخذ بميل: ك.

[٢٦١] لما] كما: ب.

[٢٦٢] تعرف] س(يوجد«يـ» تحت « تـ» وهو مشطوب) = يعرف: ب، ك = نعرف: ف = عرفت: ل.

[٢٦٣] تساويا] تساوتا: س.

[٢٦٤] ص٤١: ب.

[٢٦٥] ٧٤آ: ل.

[٢٦] وحركة مركز القمر على محيط فلك التدوير أقّل من حركة مركز التدوير على محيط الحامل، فلهذا لا يُرى القمر البتّة راجعاً بل قد يُرى بطء السير.

[٢٧] **وممّا يعرض لها بالقياس إلى الشمس:** أمّا في العلوية، فإنّ بعد[٢٧١] مراكزها عن ذُرى تداويرها [٢٧٢]أبداً[٢٧٣]كبعد مراكز تداويرها عن [٢٧٤]الشمس، فتقارن الشمس[٢٧٥] أبداً وهي في ذُرى التداوير. فكما تبعد[٢٧٦] الشمس عن مركز التدوير يبعد[٢٧٧] بمقدار[٢٧٨] بعدها مركز الكوكب[٢٧٩] عن ذروة[٢٨٠] التدوير[٢٨١] حتّى إذا قابلت

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[٢٦٦] يقيم] تقيم: ك.

[٢٦٧] لهذا] لهذ: ب.

[٢٦٨] دورته] س، ف = دوره: ب، ل = ذروته: ك.

[٢٦٩] تسمّى] ك = سمّى: ب، ف = يسمى: س، ل.

[٢٧٠] تسمّى] ك، س(يوجد«يـ» تحت « تـ» وهو مشطوب) = سمّى: ب، ف، ل.

[٢٧١] فإنّ بعد] فابعد: ك.

[٢٧٢] ٢٤ب: ك.

[٢٧٣] أبداً] ابد: ف، ك.

[٢٧٤] ٦٩آ: س.

[٢٧٥] الشمس] ب، ك، هال (مع رمز «صح») = —س، —ف.

[٢٧٦] تبعد] ك = ببعد: ب = بيعد: س = سعد: ف = يبعد: ل.

[٢٧٧] يبعد] ل = بيعد: س = سعد: ب، ف = ببعد: ك.

[٢٧٨] بمقدار] بمقدارها: ب.

[٢٧٩] الكوكب] الكواكب: س(الـ«ا» مشطوب؟).

[٢٨٠] ذروة] ذرة: ك.

الشمس مركز التدوير[282]، كان الكوكب قد نزل إلى حضيض التدوير[283]. فيكون احتراقاتها[284] أبداً وهي[285] في[286] ذروة التدوير [287]ومقابلاتها للشمس وهي[288] في الحضيض. ويقال إنّ المرّيخ إذا قارن الشمس، كان البعد بينه وبين الشمس أعظم من البعد بينه وبين الشمس إذا قابلها لأنّ قطر[289] تدويره أعظم من قطر ممثل[290] الشمس.

[٢٨] وأمّا السفليّان، فمركزا[291] تدويرهما أبداً يتسامتان[292] بمركز[293] الشمس، [294]فلا يبعدان[295] عنها إلاّ بمقدار نصف قطر التدوير، أعني بمقدار الاختلاف الأوّل، كما عرفت. ويلزم أن يقارناها[296] في نصف

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[281] التدوير] التداوير: س(الـ«ا» مشطوب).

[282] حتّى إذا قابلت الشمس مركز التدوير] —ك.

[283] حضيض التدوير] الحضيض التدور: س(الـ«الـ» مشطوب ويوجد «س» تحت «التدور» مع رمز «صح»)، ف.

[284] احتراقاتها] اختراقاتها: ك.

[285] وهي] —ب، —ك.

[286] في] فال(مع رمز «صح»).

[287] ٩ب: ف.

[288] وهي] —ك.

[289] قطر] +فلك: هاس(مع رمز «صح»).

[290] ممثل] مميل: ك.

[291] فمركزا] ب، س، ل = فمركز: ف، ك.

[292] يتسامتان] س، ف = مسامتان: ب، ك، ل.

[293] بمركز] س، ف = لمركز: ب، ك، ل.

الاستقامة، وذلك عند ذروة التدوير وفي نصف الرجوع، وذلك عند الحضيض[٢٩٧]. ولذلك[٢٩٨] يكون وسطها مثل وسط [٢٩٩]الشمس.

[٢٩] **وممّا يعرض للقمر بالقياس إلى الشمس: المُحاق**[٣٠٠]**، والزيادة، والكمال، والنقصان، وكسفه الشمس،** [٣٠١]**والخسوف**[٣٠٢]. وذلك أنّ جرم القمر في نفسه كَمِد مُظلم، إنّما[٣٠٣] يستضيء بضياء الشمس كالمرآة[٣٠٤]. فيكون نصفه المواجه[٣٠٥] للشمس أبداً مستضئاً[٣٠٦]، والنصف[٣٠٧] الآخر مظلماً. فعند الاجتماع يكون

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[٢٩٤] ص٤٢: ب.

[٢٩٥] يبعدان] بيعدان: س.

[٢٩٦] يقارناها] يقارنها: ك.

[٢٩٧] الحضيض] +اى ولكون مركزى تدويريهما ابدا مسامتان لمركز الشمس: هال(مع رمز «صح»).

[٢٩٨] عند ذروة التدوير وفي نصف الرجوع وذلك عند الحضيض ولذلك] –ف.

[٢٩٩] ٢٥آ: ك.

[٣٠٠] المُحاق] المحاف: ك.

[٣٠١] ٦٩ب: س.

[٣٠٢] وكسفه الشمس والخسوف] والكسوف والخسوف: س(يوجد «الشمس»(؟) تحت «الكسوف») .

[٣٠٣] إنّما] وانما: ك.

[٣٠٤]كالمرآة] –ب.

[٣٠٥] المواجه] المواجهة: س.

[٣٠٦] مستضئاً] مضئا: ب.

[٣٠٧] والنصف] والنص: ك.

القمر بيننا وبين الشمس، فيكون نصفه المظلم[٣٠٨] مواجهاً لنا فلا نرى[٣٠٩] شيئاً من ضوؤه وهو **المحاق**. فإذا[٣١٠] بَعُد عن الشمس مقداراً[٣١١] قريباً من اثني عشر جزءاً أو [٣١٢]أقّل أو أكثر على اختلاف أوضاع المساكن، مال نصفه المُضيء إلينا فنرى[٣١٣] طرفاً[٣١٤] منه وهو **الهلال**. ثمّ كلّما ازداد بعده عن الشمس، ازداد[٣١٥] ميل المضيء إلينا. فازداد ضياؤه حتّى إذا قابلها[٣١٦]، صرنا بينهما، وصار ما يواجه الشمس يواجهنا وهو **الكمال**. فإذا انحرف عن المقابلة مال إلينا شيء من نصفه المظلم؛ ثمّ يأخذ الظلام في الزيادة [٣١٧]والضياء في النقصان حتّى يمحق.

ولذلك [٣١٨]إذا كان القمر عند الاجتماع على طريقة الشمس، وذلك عند الرأس أو الذنب[٣١٩] أو بقربهما، حال بين

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[٣٠٨] المظلم] +هو هو جما: شاك.

[٣٠٩] نرى] تري: ك(+«فلا ىر» مشطوب).

[٣١٠] فإذا] واذا: س، ف.

[٣١١] مقداراً] +ما: ب.

[٣١٢] ٧٤ب: ل.

[٣١٣] فنرى] فنرا: ك.

[٣١٤] طرفاً] طرقا: ك.

[٣١٥] ازداد] ازد: ك.

[٣١٦] قابلها] قابلنا: ك.

[٣١٧] ٢٥ب: ك.

[٣١٨] ص٤٣: ب.

[٣١٩] أو الذنب] ب، ل = والذنب: س، ف، ك.

الشمس وبيننا فيستر ضوءها [٣٢٠]عنّا، وهو **كسوف**[٣٢١] **الشمس**. وهذا السواد الذي يظهر في الشمس هو لون[٣٢٢] جرم القمر؛ ولهذا يبتدئ سواد الشمس من جهة المغرب لأنّ القمر يلحقها من المغرب. ثمّ إذا أخذ يمرّ بها[٣٢٣] يبتدئ الانجلاء أيضاً[٣٢٤] [٣٢٥]من جهة المغرب لما ذكرنا من[٣٢٦] المعنى. وإذا كان القمر كذلك على طريقة الشمس عند الاستقبال، حال بينهما الأرض ووقع ظلّها على القمر[٣٢٧]. فلم يصل إليه[٣٢٨] ضوء الشمس، فيبقى[٣٢٩] على ظلامه الأصلي، وهو **خسوف القمر**.[٣٣٠] وابتداء خسوف القمر[٣٣١] وانجلائه من جهة المشرق لأنّه

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[٣٢٠] ٧٠آ: س.

[٣٢١] كسوف] كسف: ف.

[٣٢٢] هو لون] ولون: ب.

[٣٢٣] بها] –ب = ها: ك.

[٣٢٤] أيضاً] هاس(مع رمز «صح»).

[٣٢٥] ١٤آ: ف.

[٣٢٦] لما ذكرنا من] لذلك: ب، ل.

[٣٢٧] على القمر] +وابتداء خسوف القمر: شاس.

[٣٢٨] إليه] اليها: ك.

[٣٢٩] فيبقى] فنقى: ف، ل.

[٣٣٠] (يوجد صورتان لخسوف القمر في مخطوط س: ٦٩ب، ٧٠آ) .

[٣٣١] وابتداء خسوف القمر] س، ف= –ب، –ك = وسدى خسوف القمر: ل.

يلحقه[٣٣٢] ظلّ الأرض من جهة المغرب؛ فيصل طرفه الشرقي اوّلاً إلى الظلّ فيأخذ في السواد اوّلاً. وكذلك[٣٣٣] يكون مُرور طرفه الشرقي بالظلّ أوّلاً؛ فيبتدئ منه[٣٣٤] الانجلاء.

[٣٠] [٣٣٥] **وممّا يعرض**[٣٣٦] **للقمر توسّط الشمس بين أوجه ومركز تدويره أبداً**. وذلك أنّ[٣٣٧] مركز تدويره[٣٣٨] إذا قارن في أوجه مركز الشمس عند نقطة من فلك البروج، ولتكن[٣٣٩] مثلاً رأس الحمل[٣٤٠]، ثمّ تحرّك عنه[٣٤١] الأوج يوماً وليله بحركة[٣٤٢] المائل([٣٤٣] يا ط ز مجـ[٣٤٤]) وبحركة[٣٤٥] الجوزهر[٣٤٦] (٠

[٣٣٢] يلحقه] س، ف = يلحق: ب، ك، ل.

[٣٣٣] وكذلك] لذلك: ب.

[٣٣٤] منه] –ك.

[٣٣٥] ٢٦آ: ك.

[٣٣٦] يعرض] يعرف: ك.

[٣٣٧] أنّ] لان: ك.

[٣٣٨] تدويره] التدوير: ف.

[٣٣٩] ولتكن] ب، س(يوجد «يـ» تحت« تـ» وهو مشطوب)، ك = وليكن: ف = ولكن: ل.

[٣٤٠] مثلاً رأس الحمل] راس الحمل مثلا: ك.

[٣٤١] عنه] فاك.

[٣٤٢] بحركة] تحرك: ك.

[٣٤٣] ٧٠ب: س.

[٣٤٤] يا ط ز مجـ] س، ف، ك، ل = (بياض في ب).

[٣٤٥] وبحركة] وتحرك: ك.

جـ ي لز[٣٤٧])، فيصير[٣٤٨] حركته إلى خلاف التوالي يا يب يح ك[٣٤٩]. وتحرّك[٣٥٠] عنه الشمس قريباً من الدرجة، [٣٥١]وتحرك مركز التدوير بحركة الحامل كد كب نجـ كب[٣٥٢]. وكلتا حركتي الشمس والمركز إلى التوالي؛ لكنّ المائل[٣٥٣] يردّ الحامل إلى خلاف التوالي مقدار حركته، وهو يا يب يح ك[٣٥٤]، فيبقى[٣٥٥] للمركز[٣٥٦] إلى التوالي يجـ ي له له ب[٣٥٧] بالتقريب[٣٥٨]، وهو وسط القمر في اليوم بليلته.

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[٣٤٦] الجوزهر] جوزهر: س.

[٣٤٧] ٠ جـ ي لز] س، ف، ك، ل = (بياض في ب).

[٣٤٨] فيصير] ب، س(يوجد « تـ» فوق«يـ»)، ك = فصير: ف، ل.

[٣٤٩] يا يب يح ك] س، ف، ك، ل = (بياض في ب).

[٣٥٠] وتحرّك] وتحركت: ف.

[٣٥١] ص٤٤: ب.

[٣٥٢] كد كب نجـ كب] س، ف، ل = (بياض في ب) = كد كح نح لب: ك.

[٣٥٣] المائل] المسايل: ب.

[٣٥٤] يا يب يح ك] س، ف، ك، ل = (بياض في ب).

[٣٥٥] فيبقى] فبيقى: س.

[٣٥٦] للمركز] المركز: ك.

[٣٥٧] يجـ ي له له ب] س، ف، ك، ل = (بياض في ب).

[٣٥٨] بالتقريب] بالقرب: شاس(يوجد «بالتقريب» تحت السطر مع رمز «صح»).

فإذا نُقص وسط الشمس [٣٥٩] منه وزيد على حركة المائل، كان الحاصل بعد النقصان بُعد المركز عن [٣٦٠] الشمس، وبعد الزيادة بُعد أوج القمر عنها، وكلاهما [٣٦١] يب يا كو ما [٣٦٢] بالتقريب. فتكون [٣٦٣] الشمس متوسطة بينهما، ولذلك يقال لحركة المركز **البعد المضاعف** لأنّه إذا ضوعف البعد بين المركز والشمس، كان مثل البعد بين المركز والأوج. ويلزم أن يكون المركز عند تربيعه [٣٦٤] للشمس [٣٦٥] في الحضيض [٣٦٦] وعند الاستقبال والاجتماع [٣٦٧] في الأوج، فيكون [٣٦٨] المركز يبلغ [٣٦٩] الأوج والحضيض في كلّ دورة [٣٧٠] دفعتين.

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[٣٥٩] ٧٥آ: ل.

[٣٦٠] عن] من: ف.

[٣٦١] ٢٦ب: ك.

[٣٦٢] يب يا كو ما] ف، ك، ل = (بياض في ب) = يت نا كو ما : س.

[٣٦٣] فتكون] فيكون: ف.

[٣٦٤] تربيعه] تربيعة: س.

[٣٦٥] للشمس] س، ك، ل = الشمس: ب، ف.

[٣٦٦] الحضيض] حضيضه: س، ف.

[٣٦٧] الاستقبال والاجتماع] ب، س، ل = الاستقبال والاحما: ف = الاجتماع والاستقبال: ك.

[٣٦٨] فيكون] +الاوج: شاك.

[٣٦٩] يبلغ] بيلغ: س.

[٣٧٠] دورة] ذروة: ب.

[٣١] **ومثل هذا يعرض** [٣٧١]**لمركز تدوير عطارد** لأنّ حركة مركز تدويره بحركة الحامل [٣٧٢]ضعف حركة أوجه بحركة المدير. لكنّ[٣٧٣] المدير بمثل حركته يردّ الحامل، فيبقى فضل حركة المركز إلى التوالي مثل حركة المدير إلى غير التوالي. فإذا تقارنا — أعني المركز والأوج الذي في المدير — في الميزان عند الأوج الآخر[٣٧٤] المثلّيّ، ثمّ تحرّكا[٣٧٥] عنه، [٣٧٦]فأيّ بعد يحصل عنه للأوج[٣٧٧] إلى غير التوالي يحصل للمركز إلى التوالي. حتّى انهّما يقترنان في الدورة[٣٧٨] مرتين مرّة في الميزان ومرّة في الحمل؛ ويتقاطران[٣٧٩] مرّتين [٣٨٠]عند بلوغ أحدهما الجَدْي والآخر[٣٨١] السرطان[٣٨٢].

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[٣٧١] ١٧آ: س.

[٣٧٢] ١٤ب: ف.

[٣٧٣] لكنّ] ولكنّ: س(الـ«و» مشطوب).

[٣٧٤] الآخر] والاخر: س(الـ«و» مشطوب).

[٣٧٥] تحرّكا] تحرك: ك.

[٣٧٦] ص٤٥: ب.

[٣٧٧] للأوج] س، ف، ل = الاوج: ب، ك.

[٣٧٨] الدورة] الذروة: ب.

[٣٧٩] ويتقاطران] وتقاطران: ب.

[٣٨٠] ٢٧آ: ك.

[٣٨١] والآخر] –ل.

[٣٨٢] السرطان] +والله اعلم: ك، ل.

المقالة الثانية

في بيان الأرض[1] وما يتعلّق بها

وهي[2] ثلثة أبواب

الباب الأوّل

في المعمور من الأرض وعرضه وطوله وقسمته إلى الأقاليم[3]

[١] الأرض كرية الشكل كما سلف، ونفرض[4] عليها ثلث دوائر: إحداها[5] في سطح معدّل النهار وهي خطّ الاستواء[6] كما تعرف[7]؛ والثانية في سطح أفق[8] الاستواء؛ [9]والثالثة[10] في سطح دائرة نصف النهار في

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[1] في بيان الأرض] في هيئة الارض: ب.

[2] وهي] ك، فال = وفيها: ب = وهي على: س، ف.

[3] وقسمته إلى الأقاليم] —ب.

[4] ونفرض] س = يفرض: ب، ك، ل = بمرص: ف.

[5] إحداها] احدها: س = احديها: ب، ف، ك، ل.

[6] الاستواء] فال.

[7] تعرف] ب، ك = يعرف: س، ف، ل.

[8] أفق] الافق: ب.

[9] ٧١ب: س.

[10] والثالثة] والثالث: س.

منتصف العمارة بخطّ الاستواء. فالأولى تقطع[١١] الأرض بنصفين، جنوبي وشمالي. والثانية تنصّف[١٢] نصفيها[١٣] فيصير[١٤] أرباعاً. والمعمور منها أحد الرُبعين الشماليين[١٥] على ما يرى[١٦] فيه من الجبال، والصحارى، والمروج، والبحار، ونحوها من المواضع. الخربة وسائر الأرباع خراب. والدائرة [١٧]الثالثة تقطع[١٨] المعمور[١٩] بنصفين، غربي وشرقي. ونقطة [٢٠]التقاطع بين[٢١] الأولى والثالثة تسمّى **قُبّة الأرض.**

[٢] وعرض المعمور سو[٢٢] درجة وابتداؤه من خطّ الاستواء، إلّا أنّ **بطلميوس** بعد ما صنّف ***المجسطي*** زعم أنّه وجد وراء خطّ الاستواء عمارة إلى[٢٣] بعد[٢٤] [٢٥]يو كه[٢٦]. فيكون عرض العمارة على زعمه

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[١١] تقطع] ك = يقطع: ب، س = نقطع: ف، ل.

[١٢] تنصّف] ب، ل = ينصف: س = سصف: ف = +الارض بنصفين: شاك.

[١٣] نصفيها] ف، ل = نصفها: ب، س = نصفيهما: ك .

[١٤] فيصير] ب، ف = فنصير: س = فتصير: ك = فصير: ل.

[١٥] الشماليين] ب، ك، ل = الشمالين: س، ف.

[١٦] يرى] ترى: ب.

[١٧] ٢٧ب: ك.

[١٨] تقطع] ك = نقطع: ب، ف، ل = يقطع: س.

[١٩] المعمور] المعمورة: ف.

[٢٠] ٧٥ب: ل.

[٢١] بين] ب، س، ل = من: ف = —ك.

[٢٢] سو] س(ويوجد«٦٦٠» زائد تحت السطر)، ف، ك، ل = —ب.

[٢٣] إلى] على: ك.

هذا[٢٧] فب كه [٢٨]. وطول[٢٩] المعمور[٣٠] قف ٠ [٣١]، وابتداؤه من المغرب؛ إلّا أنّ بعضهم يأخذه[٣٢] من ساحل البحر المحيط[٣٣] وبعضهم[٣٤] من جزائر واغلة [٣٥] في هذا البحر، بُعدها عن[٣٦] ساحله[٣٧] ي ٠ [٣٨].

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[٢٤] عمارة إلى بعد] هاب.

[٢٥] ص٤٦:ب.

[٢٦] يو كه] س، ف، ل = ١٦ درجةً و٢٥ دقيقةً: ب = –ك.

[٢٧] هذا] –ب.

[٢٨] فب كه] س، ف، ل = ٨٢ درجة و٨٥ دقيقةً (!): ب = يو كه : ك.

[٢٩] وطول] فطول: ب.

[٣٠] المعمور] ب، ل، ك = العمارة: س = المعموره: ف.

[٣١] قف ٠] س، ف، ك، ل = (بياض في ب).

[٣٢] يأخذه] يأخذ: ب.

[٣٣] المحيط] –ك.

[٣٤] وبعضهم] +ياخذ: س.

[٣٥] واغلة] ب، ك، ل = داخله: س(يوجد «واغلة» تحت السطر مع رمز «صح»)، ف(يوجد «واغله» تحت السطر مع رمز «نخ»).

[٣٦] عن] من: ب.

[٣٧] ساحله] ساحلة: ب = ساحلها: ك.

[٣٨] ي ٠] س، ف، ك، ل = (بياض في ب).

[٣] ثم [٣٩] قسم [٤٠] هذا [٤١] المعمور [٤٢] سبع قطاع مستطيلة [٤٣] على موازاة خطّ الاستواء [٤٤]. وابتدأ [٤٥] **الإقليم الأول** منه [٤٦] [٤٧]، والنهار هناك أبداً يب [٤٨] ساعة، كما ستعرف؛ وعند بعضهم من حيث النهار، أعني

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[٣٩] ١٥آ: ف.

[٤٠] قسم] تقسم: ك.

[٤١] هذا] هاف(مع رمز «صح»).

[٤٢] المعمور] المعموره: ف.

[٤٣] ٧٢آ: س.

[٤٤] خطّ الاستواء] +وسمّى بها الاقاليم: ب = وتسمي وتسمي الاقاليم: ك.

[٤٥] وابتدأ] فابتدأ: ب، ك.

[٤٦] وابتداء الإقليم الأول منه] هال(مع رمز «صح»).

[٤٧] منه] من خط الاستوآء: ب.

[٤٨] يب] س، ف، ك، ل = ١٢: ب.

النهار[٤٩] الأطول من السنة يب مه[٥٠] والعرض يب ل[٥١]. ووسطه بالاتفاق حيث النهار يج ٠[٥٢]، والعرض[٥٣] يو كز[٥٤].

[٤] وابتدأ **الإقليم**[٥٥] **الثاني**، وهو لا محالة آخر الإقليم الأوّل، حيث النهار يج يه[٥٦] والعرض ك يد[٥٧]؛ ووسطه حيث النهار يج ل[٥٨] والعرض كجـ نا[٥٩].

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[٤٩] أعني النهار] –ل.

[٥٠] يب مه] س، ف، ك، ل = ١٢ ساعةً و ٤٥: ب = +ساعة: تاس، ك.

[٥١] يب ل] س، ف، ك، ل = (بياض في ب) = +درجه: تاس.

[٥٢] يج ٠] س، ف، ك، ل = (بياض في ب).

[٥٣] ٢٨آ: ك.

[٥٤] يو كز] س، ف، ل = (بياض في ب) = يو لز : ك.

[٥٥] الإقليم] س، ف، ك = –ب، –ل.

[٥٦] يج يه] س، ف، ك، ل = (بياض في ب).

[٥٧] ك يد] ل = (بياض في ب) = كد ٠ : س (الـ«كد» متغيّر إلى «ك» و«كز» تحت السطر) = كد ٠ : ف = كد يد : ك.

[٥٨] يج ل] س، ف، ك، ل = (بياض في ب).

[٥٩] كجـ نا] س، ف، ك، ل = (بياض في ب) = +«كد م» : هاس.

[٥] وابتدأ **الثالث** حيث النهار يجـ مه[٦٠] والعرض كز يب ؛[٦١] ووسطه حيث النهار يد ٠ [٦٢] والعرض ل كب [٦٣].

[٦] وابتدأ[٦٤] **الرابع** حيث النهار يد يه[٦٥] والعرض لجـ يح [٦٦]؛ ووسطه حيث النهار يد ل [٦٧] والعرض لو ٠ [٦٨] [٦٩].

[٧] وابتدأ[٧٠] **الخامس** حيث النهار يد مه[٧١] والعرض لح له [٧٢]؛ ووسطه حيث النهار يه ٠ [٧٣] والعرض[٧٤] م نو [٧٥].

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٦٠ يجـ مه] س، ف، ك، ل = (بياض في ب).

٦١ كز يب] (بياض في ب) = كط يب : س(الـ«كط» متغيّر إلى «كز»)، ف، ك، ل = كز: هال.

٦٢ يد ٠] س، ف، ك، ل = (بياض في ب) .

٦٣ ل كب] س، ف، ك، ل = (بياض في ب).

٦٤ وابتدأ] +الاقليم: ك.

٦٥ يد يه] س، ف، ك، ل.

٦٦ لجـ يح] س، ف، ل = لح لح : ك.

٦٧ يد ل] س، ف، ك، ل.

٦٨ لو ٠] س، ف، ل = لو كب : ك.

٦٩ وابتدأ الرابع حيث النهار يد يه والعرض لجـ يح ووسطه حيث النهار يد ل والعرض لو ٠] –ب.

[٨] وابتدأ[٧٦] **السادس** حيث النهار يه يه[٧٧] والعرض مجـ نا[٧٨]؛ ووسطه حيث النهار يه ل

[٧٩] والعرض مه ا[٨٠].

[٩] وابتدأ[٨١] **السابع** حيث النهار يه مه[٨٢] والعرض مو نا[٨٣]؛ ووسطه حيث النهار يو ٠

[٨٤] [٨٥]والعرض مح لب[٨٦] [٨٧].

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[٧٠] وابتدأ] +الاقليم: ك.

[٧١] يد مه] ف، ك، ل = (بياض في ب) = يد ٠: س(يوجد «مه» تحت السطر).

[٧٢] لح له] س، ف، ك، ل = (بياض في ب).

[٧٣] يه ٠] س، ف، ك، ل = (بياض في ب).

[٧٤] ص٤٧:ب.

[٧٥] م نو] س(يوجد «ما» متغيّر إلى « م») = (بياض في ب) = ما نو : ف = ما نه : ك = مد نو : ل(يوجد« م» في الهامش وتحته « ما يه»).

[٧٦] وابتدأ] +الاقليم: ك.

[٧٧] يه يه] س، ف، ك، ل = (بياض في ب).

[٧٨] مجـ نا] س(«ىه» زائد تحت السطر)، ف، ك، ل(يوجد نقطتان زائدان تحت الـ« نا » و«كب» أيضاً تحت السطر بخط غير الناسخ و«يه» في الهامش بخط غير الناسخ) = (بياض في ب).

[٧٩] يه ل] س، ف، ل = (بياض في ب) = يه لب : ك.

[٨٠] مه ا] س، ف، ل = (بياض في ب) = مد نا (؟): ك.

[١٠] وآخره آخر العمارة عند بعضهم، [٨٨]وعند بعضهم إلى حيث العرض ن كه[٨٩]. وإنّما صار عرض[٩٠] ابتداء[٩١] الإقليم الأوّل إلى وسطه[٩٢] وما بين وسط السابع إلى آخره أكثر لتفرّق[٩٣] العمارة فيهما. ولهذا المعنى لا يعدّون من الأقاليم[٩٤] ما وراء[٩٥] خطّ[٩٦] الاستواء من العمارة، ولهذا أيضاً لا يعدّ بعضهم ما بين خطّ

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[٨١] وابتدأ] +الاقليم: ك.

[٨٢] يه مه] س، ف، ك، ل = (بياض في ب).

[٨٣] مو نا] س، ف، ل = (بياض في ب) = مو نب : ك.

[٨٤] يو ٠] س، ف، ل = –ب، –ك.

[٨٥] ٧٢ب: س.

[٨٦] مح لب] س، ف، ل = (بياض في ب).

[٨٧] ووسطه حيث النهار يو ٠ والعرض مح لب] –ك.

[٨٨] ٢٨ب: ك.

[٨٩] ن كه] س، ف، ل = (بياض في ب) = ن له : ك.

[٩٠] عرض] +ما بين: ب، ك.

[٩١] ابتداء] هاس(مع رمز «صح»).

[٩٢] وسطه] وسط: ك.

[٩٣] لتفرّق] لتعرف: ك.

[٩٤] الأقاليم] س، ف، ل = الاقليم: ب = الاقليم الاول: ك.

[٩٥] وراء] تاس(مطموس في النصّ).

الاستواء إلى عرض[97] [98] يب ل[99] ولا[100] ما بين عرض ن كه[101] إلى آخر العمارة. فإنّ[102] وراء هذا العرض عمارات على ما زعموا أنّ في عرض سجـ[103] جزيرة[104] معمورة أهلها يسكنون[105] الحمّامات لشدّة البرد، وفي عرض سد[106] عمارة أهلها[107]قوم من الصقالبة[108] لا يُعرفون، وإلى عرض سو[109] عمارات سكّانها[110] شبيهة[111] الوحوش[112].

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[96] خطّ] وسط: ك.

[97] من العمارة ولهذا أيضاً لا يعدّ بعضهم ما بين خطّ الاستواء إلى عرض] هاس(مع رمز «صح»).

[98] عرض] –ف = +إلي: س.

[99] يب ل] س، ف، ك، ل = (بياض في ب).

[100] ولا] والي: ك.

[101] ن كه] س، ف، ك، ل = (بياض في ب).

[102] فإنّ] +ما: ب.

[103] سجـ] س، ف، ل = (بياض في ب) = ..ح: ك.

[104] جزيرة] +تسمّى تولى: ب.

[105] يسكنون] +في: ك.

[106] سد] ف، ك، ل = (بياض في ب) = شد: س.

[107] ٧٦آ: ل.

[108] الصقالبة] الصقاليه: ك.

[109] سو] س، ف، ك، ل = –ب.

[110] سكّانها] هال(مع رمز «صح»).

[111] شبيهة] ف، ك، ل = شبهة: ب = شبية: س.

[112] الوحوش] س، ف، ل = الوخوش ومن هذه الدائرة تصوّر الاقاليم: ب = بالوحوش: ك.

الباب الثاني

في خواصّ خطّ الاستواء [١]والمواضع التي[٢] لها عرض[٣]

[١] أمّا خطّ الاستواء، فمن خواصّه أنّ معدّل النهار يُسامت رؤوس أهله، وكذا[٤] الشمس عند بلوغها نقطتي الاعتدالين؛ وأنّ أفقه، ويسمّى [٥]**أفق الفلك المستقيم وأفق الكرة المنتصبة**، ينصّف معدّل[٦] النهار وجميع المدارات[٧] على [٨]زوايا قائمة. ويكون[٩] هناك دور الفلك دولابيّاً، أعني كما يخرج العصامير من سطح الماء على زوايا قائمة. ولا يكون كوكب ولا[١٠] نقطة في [١١]الفلك إلّا وهو يطلع ويغرب[١٢]، إلّا قطبي العالم فإنّهما يكونان على

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[١] ١٥ب: ف.

[٢] التي] +لا عرض: شاس.

[٣] الباب الثاني في خواصّ خطّ الاستواء والمواضع التي لها عرض] –ب.

[٤] وكذا] وكذى: ف، ك.

[٥] ٢٩آ: ك.

[٦] معدّل] المعدل: ف(الـ«الـ» مشطوب).

[٧] المدارات] المدرات: ف.

[٨] ٧٣آ: س.

[٩] ويكون] فيكون: ب.

[١٠] ولا] +كون: ب.

[١١] ص٤٩: ب.

[١٢] ويغرب] +هو: ف.

الأفق. وتكون[١٣] القسيّ الظاهرة للمدارات[١٤] كالتي[١٥] تحت الأرض. فلذلك[١٦] يكون النهار والليل أبداً متساويين، كلّ منهما يب ساعة، ويكون نهار كلّ كوكب كليله[١٧]. ويكون أكثر ميل الشمس عن سمت الرأس في الشمال والجنوب، بقدر واحد وذلك بقدر غاية ميل فلك[١٨] البروج عن معدّل النهار.

[٢] **وأمّا المواضع المائلة** إلى الشمال عن خطّ الاستواء التي لم يبلغ[١٩] عرضها تسعين جزءاً: فمن خواصّها أنّ آفاقها، وتسمّى **الآفاق**[٢٠] **المائلة**، تنصّف معدّل النهار وحده بنصفين[٢١]، لكن لا على زوايا [٢٢] قائمة، فيكون دور الفلك فيها حمائلياً. وتقطع[٢٣] المدارات[٢٤] كلّها بقطعتين[٢٥] مختلفتين[٢٦]؛ فالقسيّ[٢٧] الظاهرة للمدارات[٢٨]

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[١٣] وتكون] وكون: ب، ف = ويكون: س، ك، ل.

[١٤] للمدارات] للمدرات: ف = +التي فوق الارض متساويه للقسي: ك.

[١٥] كالتي] التي: ك.

[١٦] فلذلك] ولذلك: ب.

[١٧] كليله] كليلته: ب

[١٨] فلك] الفلك: ب(الـ«الـ» مشطوب).

[١٩] يبلغ] س = تبلغ ب، ك = سلع: ف = سلغ: ل.

[٢٠] الآفاق] هال(مع رمز «صح») = الافلاك: ل.

[٢١] بنصفين] —ك، —ل.

[٢٢] ٢٩ب: ك.

[٢٣] وتقطع] ل = نقطع: ب، ف، ك = ويقطع: س.

[٢٤] المدارات] المدرات: ف.

[٢٥] بقطعتين] بقطين بقطعتين: ب (الـ«بقطين» مشطوب) = بنقطتين: ك.

الشمالية أعظم من التي تحت الأرض، وللجنوبية[29] بالخلاف. ولذلك[30] [31]لا يستوي الليل والنهار فيها[32]، إلّا عند بلوغ الشمس نقطتي الاعتدالين، وذلك في يوم النيروز والمِهْرجان. ويكون النهار أطول من الليل عند كون الشمس في البروج الشمالية، وعند كونها في البروج الجنوبية أقصر. وكلّما كان عرض[33] البلد أكثر، كان مقدار [34]التفاوت بين الليل والنهار أكثر؛ وذلك لأنّ سمت الرأس مائل في هذه المواضع لا محالة عن معدّل النهار. وبقدر[35] ميله، يرتفع القطب الشمالي والمدارات[36] التي في ناحيته، وينحطّ القطب الجنوبي والمدارات التي تليه[37]. فكلّما[38] ازداد العرض، [39]ازداد ميل سمت الرأس عن معدّل [40]النهار، فازداد ارتفاع القطب الشمالي

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[26] مختلفتين] هال(مع رمز «صح»).

[27] فالقسيّ] س = والقسيّ: ب، ك، ل = القسى: ف.

[28] للمدارات] للمدرات: ف.

[29] وللجنوبية] والجنوبية: ل.

[30] ولذلك] +لا: س.

[31] ٧٣ب: س.

[32] يستوي الليل والنهار فيها] يستوي فيها الليل والنهار: ك.

[33] عرض] العرض اى عرض: ب.

[34] ص٥٠: ب.

[35] وبقدر] ف، ل = وتقدر: ب = ويقدر: س(الـ«يـ» مشطوب)، ك.

[36] المدارات] المدرات: ف.

[37] تليه] ك، ل = يليه: ب = نليه: س، ف.

[38] فكلّما] وكلما: ب، ل.

والمدارات التي تليه؛ فازداد[٤١] فضل قسيّها [٤٢]الظاهرة على التي تحت الأرض. فازداد[٤٣] انحطاط القطب الجنوبي والمدارات[٤٤] التي عنده، وفضل قسيّها التي تحت الأرض على[٤٥] الظاهرة. وكلّ مدار[٤٦] بُعده عن القطب الشمالي مثل ارتفاع القطب[٤٧]، [٤٨]فهو بجميع ما فيه وجميع ما تحويه[٤٩] دائرتُه إلى القطب الشمالي[٥٠] من الكواكب[٥١] أبديّ الظهور، ونظيره من ناحية الجنوب، بجميع[٥٢] ما فيه، أبديّ[٥٣] الخفاء.

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[٣٩] ١٦آ: ف.

[٤٠] ٧٦ب: ل.

[٤١] فازداد] وازداد: ب.

[٤٢] ٣٠آ: ك.

[٤٣] فازداد] س، ف = وازداد: ب، ك، ل.

[٤٤] والمدارات] والمدرات: ف.

[٤٥] على] +الارض: شاس.

[٤٦] مدار] ب، تاس(مع رمز «صح»)، ك، ل = مقدار: شاس، ف.

[٤٧] القطب] +او اقلّ: ك ، هال(مع رمز «صح» و«عن سطح دايرة الافق» تحت السطر).

[٤٨] ٧٤آ: س.

[٤٩] تحويه] نحويه: ب، س = بحويه: ك = يحويه: ل.

[٥٠] مثل ارتفاع القطب فهو بجميع ما فيه وجميع ما تحويه دائرته إلى القطب الشمالي] –ف.

[٥١] الكواكب] الكوكب: ب.

[٥٢] بجميع] ب، ل = نجميع: س = نجمع: ف = لجميع: ك.

[٥٣] أبديّ] ابدا: ك.

[٣] **وهذه المواضع التي لم**[٥٤] **يبلغ**[٥٥] **عرضها تسعين جزءاً**[٥٦] **أقسام**، يخصّ[٥٧] كلّ قسم منها خواصّ[٥٨]: منها[٥٩] **المواضع التي عرضها أقلّ من الميل الأعظم** الذي[٦٠] لفلك البروج عن معدّل النهار. فالشمس تسامت[٦١] رؤوس أهلها في السنة مرتين، وذلك عند بلوغها نقطتين عن جنبتي نقطة الانقلاب الصيفي ميلهما عن معدّل النهار مثل عرض البلد.

[٤] ومنها[٦٢] **المواضع التي** [٦٣]**عرضها**[٦٤] **مثل الميل الأعظم**. فالشمس تسامت[٦٥] رؤوسهم مرّة [٦٦]في السنة[٦٧]، وذلك عند[٦٨] بلوغها نقطة الانقلاب الصيفي. والمواضع التي هي من[٦٩] خطّ الاستواء إلى هذا العرض

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[٥٤] لم] –ب.

[٥٥] يبلغ] هاب، ك = تبلغ: س = سلع: ف، ل.

[٥٦] جزءاً] ب، ف، ل = جزء: س، ك.

[٥٧] يخصّ] +بعضها: شاس.

[٥٨] خواصّ] س، ف، ل = بخواصّ: ب = خواض: ك.

[٥٩] منها] –ب.

[٦٠] الذي] +لا: شاس.

[٦١] تسامت] ب، ك، ل = يسامت: س، ف.

[٦٢] ومنها] (بياض في ب).

[٦٣] ص٥١: ب.

[٦٤] عرضها] فاب.

[٦٥] تسامت] ب، ك، ل = يسامت: س، ف.

[٦٦] ٣٠ب: ك.

ذوات[٧٠] ظلّين، أعني أنّ الظل[٧١] المستوي فيها، وستعرفه، يكون في نصف النهار تارة[٧٢] إلى الجنوب وأخرى إلى الشمال. والتي من هذا [٧٣]العرض إلى عرض تسعين ذوات ظلّ واحد، أعني يكون الظلّ إلى الشمال فقط.

[٥] ومنها[٧٤] **التي عرضها أكثر من الميل الأعظم**. فإنّ الشمس لا تسامت[٧٥] رؤوس أهلها.

[٦] ومنها[٧٦] **التي عرضها مثل تمام الميل، وذلك** سو كه[٧٧]. فإنّ قطب البروج إذا بلغ دائرة نصف النهار بحركة الكلّ، وقع على سمت الرأس وحينئذ[٧٨] تنطبق[٧٩] دائرة البروج على الأفق؛ فيكون الحمل على نقطة

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[٦٧] مرّة في السنة] في السنه مرة: ك.

[٦٨] عند] –ك.

[٦٩] من] –ك.

[٧٠] ذوات] ذات: ب.

[٧١] الظل] ظل: ك.

[٧٢] تارة] مارّة: ب.

[٧٣] ٧٤ب: س.

[٧٤] ومنها] (بياض في ب).

[٧٥] تسامت] ب، س(قد تغيّر «يسامت» إلى ««تُسامت»)، ك، ل = يسامت: ف.

[٧٦] ومنها] (بياض في ب).

[٧٧] سو كه] (بياض في ب).

[٧٨] وحينئذ] ب، س، ل = و ح : ف، ك.

[٧٩] تنطبق] ىنطبق: ب، ل = ينطبق: س، ف، ك.

المشرق، والجدي على نقطة الجنوب، والميزان على نقطة المغرب، والسرطان على نقطة الشمال. فإذا زال[٨٠] عن سمت الرأس، طلعت [٨١]ستّة من البروج دفعةً، وهي التي في النصف [٨٢]الشرقي على[٨٣] الأفق، وهي من الجدي إلى السرطان؛ وغربت الستّة الأخرى دفعةً[٨٤]. [٨٥]ومدار السرطان هناك لا يغرب لما سلف، فإذا بلغته الشمس، لم تغرب حتّى تجاوزه. فيكون النهار الأطول [٨٦] كد[٨٧] ساعة وكذلك الليل الأطول، إذ بقدر[٨٨] ما[٨٩] يعرض للمدارات[٩٠] الشمالية من الظهور الأبدي[٩١]؛ [٩٢]وعظم القسيّ الظاهرة يعرض لنظائرها[٩٣] الخفاء الأبدي وعظم القسيّ التي تحت الأرض.

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[٨٠] زال] زالت: ك.

[٨١] ١٦ب: ف.

[٨٢] ٣١آ: ك.

[٨٣] على] س، ف، ل = من: ب، ك.

[٨٤] دفعةً] +ومدار: ل.

[٨٥] ٧٧آ: ل.

[٨٦] ص٥٢: ب.

[٨٧] كد] س، ف، ل = (بياض في ب) = كه : ك.

[٨٨] إذ بقدر] ب، س = اد بعدر: ف = اذا تقدر: ك = اذ نقدر: ل.

[٨٩] ما] (بياض في ب).

[٩٠] للمدارات] للمدرات: ف.

[٩١] الأبدي] الابد: ك.

[٩٢] ٧٥آ: س.

[٧] ومنها[٩٤] **التي عرضها زائد على تمام**[٩٥] **الميل**، أعني على سو كه[٩٦]. فيميل قطب البروج عن سمت الرأس إلى الجنوب بقدر زيادة العرض على سو كه[٩٧]؛ ويلزم أن لا تغرب[٩٨] من فلك البروج الأجزاء التي ميلها عن معدّل النهار أكثر من تمام عرض البلد.

[٨] وممّا يُسهّل تصوّر ذلك أن نفرض[٩٩] قطب البروج على دائرة نصف النهار فيكون مائلاً إلى الجنوب عن سمت الرأس ممّا يلي الجنوب[١٠٠]؛ وبقدر ميله ينحطّ رأس الجدي عن الأفق في الجنوب، ويرتفع[١٠١] [١٠٢]رأس[١٠٣] السرطان في الشمال. ويكون معدّل النهار ممّا يلي الجنوب فوق الأفق، وارتفاعه بقدر ما ينقص

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[٩٣] لنظائرها] ب، س(«الاند» زائد ومشطوب)، ف، ل = لتطايرها: ك.

[٩٤] ومنها] (بياض في ب).

[٩٥] تمام] —ف.

[٩٦] سو كه] س، ف، ل = (بياض في ب) = سو له: ك.

[٩٧] سو كه] (بياض في ب).

[٩٨] تغرب] س(قد تغيّر «يغرب» إلى «تغرب») = نغرب: ب، ل = يغرب: ف، ك.

[٩٩] نفرض] ل = نفرض: ب، س = يفرض: ف، ك.

[١٠٠] مما يلي الجنوب] س، ف، ك = —ب = شال.

[١٠١] ويرتفع] وبفع: ف.

[١٠٢] ٣١ب: ك.

[١٠٣] رأس] +الجدى: شاك.

العرض عن[١٠٤] تسعين[١٠٥] جزءاً، وهو تمام العرض، أعني كلّه ويعرف بتمام القوس. فالأجزاء من فلك البروج التي[١٠٦] ميلها عن معدّل النهار أقلّ من تمام العرض فإنها تكون[١٠٧] لا محالة[١٠٨] مع معدّل النهار [١٠٩]فوق الأفق ممّا يلي الجنوب؛ والتي ميلها تساوي[١١٠] تمام العرض فإنّها تماسّ الأفق ولا تنحطّ عنه؛ والتي ميلها[١١١] أكثر من تمام العرض فإنّها تنحطّ[١١٢] [١١٣]لا محالة فتكون[١١٤] أبديّة الخفاء. والأبديّة الخفاء تكون[١١٥] لا محالة[١١٦] قوساً من فلك البروج منتصفها نقطة الانقلاب الشتويّ. ومدّة قطع الشمس لتلك القوس بمسيرها الخاصّ[١١٧] طول الليل

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[١٠٤] عن] ب، ك، ل = على: س، ف.

[١٠٥] تسعين] ب، ك، ل = التسعين: س، ف.

[١٠٦] التي] هال(مع رمز «صح»).

[١٠٧] تكون] ك = نكون: ب، ف، ل= يكون: س.

[١٠٨] لا محالة] +معد: شاك.

[١٠٩] ٧٥ب: س.

[١١٠] تساوي] ب، ل = يساوي: س، ف، ك.

[١١١] تساوي تمام العرض فإنّها تماسّ الأفق ولا تنحطّ عنه والتي ميلها] تاب.

[١١٢] تنحطّ] ك، ل = ننحط: ب، ف = ينحط: س.

[١١٣] ص٥٣: ب.

[١١٤] فتكون] ل = فنكون: ب = فيكون: س، ف، ك.

[١١٥] تكون] ل = نكون: ب، ف = يكون: س، ك.

[١١٦] تكون لا محالة] لا محاله يكون: ك.

[١١٧] بمسيرها الخاصّ] هاب، ف، ك، ل = بميرها الحناص: ب = لمسيرها الخاص: س.

الأطول لذلك البلد؛ ونظيرة تلك القوس من البروج الشمالية أبديّة الظهور، كما عرفت، [١١٨] ومدّة قطع الشمس لتلك النظيرة[١١٩] طول النهار الأطول لذلك البلد[١٢٠]. فمن هذه البلاد ما يبلغ طول نهاره[١٢١] قريباً من ستّة [١٢٢]أشهر وكذلك طول الليل[١٢٣].

[٩] ويعرض لبعض ما يطلع من فلك البروج هناك أن يطلع منكوساً ويغرب[١٢٤] مستوياً. وذلك في نصف فلك البروج الذي من[١٢٥] الجدي إلى السرطان؛ فيطلع الجوزاء قبل[١٢٦] الثور، والثور قبل الحمل، وعلى [١٢٧]هذا القياس[١٢٨]. ولبعضه أن يطلع مستوياً ويغرب منكوساً، [١٢٩]وذلك في النصف الآخر[١٣٠] من فلك البروج؛ فيغرب القوس قبل العقرب، والعقرب قبل الميزان[١٣١]، وعلى هذا القياس.

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[١١٨] ١٧آ: ف.

[١١٩] النظيرة] النطره: ك.

[١٢٠] لذلك البلد] ك =كذلك: ب، س، ف = لذلك: ل.

[١٢١] نهاره] +الاطول: ل.

[١٢٢] ٣٢آ: ك.

[١٢٣] الليل] ليله: ك.

[١٢٤] ويغرب] ك = وبغرب: ب، ل = وتغرب: ف = وتغرب: س(يوجد «يـ» تحت الـ«تـ»).

[١٢٥] من] (بياض في ف).

[١٢٦] قبل] +السرطان: شاك.

[١٢٧] ٧٧ب: ل.

[١٢٨] القياس] (بياض في ف).

[١٢٩] ٧٦آ: س.

[١٠] وممّا يسهّل تصوّر ذلك أنّا إذا فرضنا قطب البروج على دائرة نصف النهار[١٣٢] ممّا يلي الجنوب عن سمت الرأس، فيكون نصف الفلك من الحمل إلى الميزان على التوالي ظاهراً ممّا يلي[١٣٣] الشمال، والنصف الآخر غائباً ممّا يلي الجنوب. ورأس الحمل[١٣٤] على نقطة المشرق، ورأس الميزان على نقطة المغرب. فيكون إذن[١٣٥] قد طلع الحمل قبل الحوت[١٣٦]، وغرب الميزان قبل السنبلة. فإذا مال[١٣٧] قطب البروج عن دائرة[١٣٨] نصف النهار إلى المغرب والحمل طالع، أخذ[١٣٩] في الطلوع[١٤٠] ما كان مُتّصلاً بالحمل ممّا يلي الجنوب، وهو آخر الحوت[١٤١]، على غير التوالي حتّى يتمّ[١٤٢] طلوع الحوت[١٤٣]. ثمّ يأخذ الدلو في الطلوع كذلك. والغروب كذلك: أعني أنّ الميزان كان

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١٣٠ الآخر] الاخير: ك.

١٣١ والعقرب قبل الميزان] هال(مع رمز «صح»).

١٣٢ النهار] —ف.

١٣٣ يلي] يلاى: س = نلي(؟): هاس(مع رمز «صح»).

١٣٤ ص٥٤: ب.

١٣٥ إذن] اذا: ك.

١٣٦ الحوت] الخوت: ب.

١٣٧ مال] مالت: س.

١٣٨ دائرة] داير: س.

١٣٩ ٣٢ب: ك.

١٤٠ في الطلوع] بالطلوع: ك.

١٤١ الحوت] الخوت: ب.

١٤٢ يتمّ] ب، س، ف = تتم: ك = نتم: ل.

غارباً ورأسه في نقطة[١٤٤] المغرب للغروب. فإذا[١٤٥] غرب وانحطّ[١٤٦]، أخذ في الغروب معه[١٤٧] ما هو[١٤٨] متصّل به[١٤٩] وهو آخر السنبلة على غير التوالي[١٥٠]، [١٥١]وعلى هذا القياس.

[١١] وإذا فرضنا رأس السرطان على دائرة نصف النهار ممّا يلي الجنوب، كان من الميزان إلى الحمل ممّا يلي الشمال تحت الأفق، والنصف الآخر ظاهر[١٥٢]. فيكون قد طلع السنبلة قبل الميزان على الاستواء. ثمّ إذا مال رأس السرطان عن[١٥٣] دائرة نصف النهار، أخذ الميزان في الطلوع [١٥٤]على الاستواء كما ذكرنا. ولمّا كان الغارب يقابل الطالع[١٥٥]، كان[١٥٦] ما يطلع منكوساً يغرب مقابله[١٥٧] منكوساً، وبالضدّ. ولمّا كان الطلوع في

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[١٤٣] الحوت] الخوت: ب.

[١٤٤] نقطة] +الحمل: ب.

[١٤٥] فإذا] وإذا: ب.

[١٤٦] وانحطّ] فانحطّ: ب = +في الغروب: شال.

[١٤٧] أخذ في الغروب معه] اخذ معه فى الغروب: ل.

[١٤٨] هو] كان: ك.

[١٤٩] متصّل به] ف، ل = متصل: ب، س = متصلا به: ك.

[١٥٠] التوالي] هاس(مع رمز «صح»).

[١٥١] ٧٦ب: س.

[١٥٢] ظاهر] ظاهرا: ك.

[١٥٣] عن] على: ب.

[١٥٤] ١٧ب: ف.

[١٥٥] الطالع] الطلوع: ف.

أحد[١٥٨] نصفي الفلك يخالف الطلوع في[١٥٩] الثاني في الاستواء ويوافق الغروب، لزم أن يكون طلوع كلّ [١٦٠]نصف يخالف[١٦١] غروبه، فما يطلع[١٦٢] منكوساً يغرب مستوياً، [١٦٣]وبالضّد.

[١٢] **وأمّا المواضع التي عرضها تسعون جزءاً**، فيوافق قطب العالم سمت الرأس فيها. ومعدّل النهار منطبق[١٦٤] على دائرة الأفق، ودور[١٦٥] الفلك رحويّ موازٍ للأفق. وتكون[١٦٦] السنة هناك يوماً وليلةً، ستّة أشهر [١٦٧]نهاراً، وذلك إذا كانت الشمس في البروج الشمالية، وستّة أشهر [١٦٨]ليلة، وذلك إذا كانت الشمس في

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[١٥٦] كان] كا: ب.

[١٥٧] مقابله] مقابلة: ب.

[١٥٨] أحد] +هى: ك.

[١٥٩] في] +النصف: هاس(مع رمز «صح») = +في: ك.

[١٦٠] ص٥٥: ب.

[١٦١] يخالف] خالف: ك.

[١٦٢] يطلع] بطلوع: ف.

[١٦٣] ٣٣آ: ك.

[١٦٤] منطبق] منطبق: ب

[١٦٥] ودور] ودرور: س.

[١٦٦] وتكون] فكون: ب = ويكون: س = وكون: ف، ك، ل.

[١٦٧] ٧٧آ: س.

[١٦٨] ٧٨آ: ل.

البروج[١٦٩] الجنوبية. وهناك لا يكون لشيء من الفلك طلوع ولا غروب؛ بل[١٧٠] نصفه الشمالي ظاهر[١٧١] أبداً ونصفه الجنوبي تحت الأرض أبداً.

[١٣] وإنّما خصّصنا المواضع الشمالية بالوصف لأنّ فيها العمارة. ولأنّ جميع ما يعرض لها ممّا وصفناه[١٧٢] بسبب ميلها عن خطّ الاستواء إلى الشمال، يعرض مثل ذلك للمواضع الجنوبية[١٧٣] بسبب ميلها إلى[١٧٤] الجنوب.

[١٤] فتعريف هذا يكفي في معرفة ذلك[١٧٥].

[١٦٩] الشمالية وستّة أشهر ليلة وذلك إذا كانت الشمس في البروج] –ف.

[١٧٠] بل] +يكون: ب.

[١٧١] ظاهر] س، ف، ل = ظاهراً: ب، ك.

[١٧٢] وصفناه] وصفنا: ب.

[١٧٣] للمواضع الجنوبية] للحنوسه: ل.

[١٧٤] إلى] +الى: ف.

[١٧٥] ذلك] +والله المستعان: ك.

الباب الثالث

في أشياء منفردة[١]

[١] **الطالع** جزء من فلك البروج على الأفق مما يلي المشرق. **درجة طلوع الكوكب** هي درجة من فلك البروج[٢] تطلع[٣] مع طلوع الكوكب[٤]. **درجة ممرّ[٥] الكوكب** درجة من فلك البروج تمّر بدائرة نصف النهار مع مرور [٦]الكوكب [٧]بها. فإن كان الكوكب على إحدى نقطتي الانقلابين [٨]أو كان لا عرض له، فدرجته، أعني مكانه من فلك البروج، هي درجة ممّره[٩]؛ وإن كان ذا عرض على غير نقطة الانقلاب، فلا. وذلك لأنّ الكوكب إذا كان فيما بين أوّل السرطان إلى آخر القوس وصل إلى دائرة نصف النهار بعد درجته إن كان شمالي العرض، وقبلها إن كان جنوبي العرض[١٠]. وإن كان في النصف الآخر من فلك البروج، فعلى الخلاف لأنّ قطب البروج [١١]*يكون

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[١] الباب الثالث في أشياء منفردة] س، ف، ل = (بياض في ب) = الباب الثالث من المقاله الثانيه في اشيا منفرده: ك.

[٢] البروج] –ف.

[٣] تطلع] ب، ك، ل = يطلع: س = ىطلع: ف.

[٤] الكوكب] الكواكب: ف.

[٥] ممرّ] ثم: ك.

[٦] ٣٣ب: ك.

[٧] ص٥٦: ب.

[٨] ٧٧ب: س.

[٩] ممّره] ممرّة: ب.

[١٠] العرض] هاس(مع رمز «صح») = الشكل: س.

شرقياً عند كون النصف الأوّل على[12] نصف النهار؛ فتكون[13] الدائرة المارّة به[14] وبدرجة الكوكب مائلةً[15] إلى المغرب وتنتهي[16] إلى الكوكب الشماليّ العرض أوّلاً ثُمَّ إلى درجته. فيكون الكوكب أبعد من درجته عن نصف النهار، فيصل[17] إليه[18] بعدها وقبلها إن كان جنوبي العرض لهذا بعينه. وما بين درجة الكوكب ودرجة ممرّه[19] يسمّى **اختلاف الممرّ**. وقِس على هذا **درجة طلوعه**. أمّا في الفلك المستقيم، فالحكم هذا بعينه. وأمّا [20]في الأفلاك[21] المائلة، فيعتبر الأفق.

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[11] (الظاهر أنّ ورقة ناقصة من مخطوطة ف بين ١٧ب و١٨آ أي من «*يكون شرقياً عند كون النصف الأوّل» إلى «فذلك الخطّ هو على صوب القبلة*»).

[12] على] +دايرة: ب.

[13] فتكون] س = فكون: ب، ل = فيكون: ك.

[14] به] +اى القطب الشمالى: تال.

[15] مائلةً] س، ل = مايلا: ب = المايله: ك.

[16] وتنتهي] ل = وينتهى: ب = وىنتهى: س = وتنتهي: ك.

[17] فيصل] س، ك = فصل: ب = فتصل: ل.

[18] إليه] ب، تاس(مع رمز «صح»)، ل = إليها: س، ك.

[19] ممرّه] س، ك، ل = ممرّة: ب.

[20] ٧٨آ: س.

[21] الأفلاك] س، ل = الأفاق: ب، ك.

[٢] **الظلّ** مُأخوذ إمّا[٢٢] [٢٣]من المِقْياس المنصوب على[٢٤] موازاة سطح الأفق، ويسمّى[٢٥] الظلّ الأوّل، والمعكوُس، والمنتصب؛ [٢٦]وإمّا من المقياس القائم عموداً على سطح الأفق[٢٧]، [٢٨]ويسمّى[٢٩] الظلّ الثاني[٣٠] والمستوي. وقد يقسم المقياس مرّة باثني عشر قسماً ويسمّى أقسامه أصابع، ومرّة بسبعة[٣١] أقسام[٣٢] أو ستّة ونصف ويسمّى أقسامه[٣٣] أقداماً، ومرّة بستّين قسماً ويسمّى أقسامه أجزاء. وإذا انتهى الظلّ نهايته عند[٣٤] غاية

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[٢٢] إمّا] ب، س، ل = —ك.

[٢٣] ٣٤آ: ك.

[٢٤] على] +مو: شاب.

[٢٥] ويسمّى] ك = وسمى: ب، ل = وتسمى: س.

[٢٦] ص٥٧: ب.

[٢٧] الأفق] +وسمّى: شال.

[٢٨] ٧٨ب: ل.

[٢٩] ويسمي] ك، ل = وسمّى: ب = وتسمى: س.

[٣٠] الثاني] +والمنبسط: ك.

[٣١] بسبعة] س، ك، ل = سبعة: ب.

[٣٢] أقسام] س، ك، ل = —ب.

[٣٣] أقسامه] +النالناما اقسامه: شاس.

[٣٤] عند] هاس(مع رمز «صح»).

ارتفاع الشمس فهو أوّل وقت الظهر؛ وأوّل وقت العصر إذا زاد على غايته تلك بمثل[٣٥] المقياس وهذا عند الشافعي رحمه الله[٣٦]، وعند ابي حنيفة رضي الله عنه[٣٧] إذا زاد عليه(!)[٣٨] بمثلي المقياس.

[٣] **في معرفة خطّ**[٣٩] **نصف النهار وخطّ الاعتدال:** تُسوَّى أرض[٤٠] بحيث لو صُبَّ فيها ماء[٤١] سال من جميع الجهات بالسويّة. ثمّ يُدار فيها دائرة بأيّ بُعد كان، وتسمّى[٤٢] هذه **الدائرة الدائرة**[٤٣] **الهنديّة**[٤٤]. ويُنصب[٤٥] على مركزها **مقياس مخروطي** طوله[٤٦] رُبع قطرها نصباً على زاوية قائمة،[٤٧] [٤٨]ويُعرف ذلك إمّا[٤٩]

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[٣٥] تلك بمثل] س، ك، ل = بمثل تلك: ب.

[٣٦] وهذا عند الشافعي رحمه الله] ك = وهذا عند الشافعى رضى الله عنه: ب = عند الشافعى(مع رمز «صح») رحمه الله تعالى(مع رمز «صح»): هاس = عند الشافعى رحمه: هال(مع رمز «صح»).

[٣٧] وعند ابي حنيفة رضي الله عنه] س، ك = وعند ابى حنيفه رحمه الله عليه: ب = وعند ابى حسفه رحمه الله: ل.

[٣٨] عليه] س، ك، ل = عليها: ب.

[٣٩] في معرفة خطّ] (بياض في ب).

[٤٠] تُسوَّى أرض] يُسوّى ارض: ب = يُسَوِّى وجه الارض: س = بسوي الارض: ك = نُسَوَّى ارضٌ: ل.

[٤١] ماء] مال: ك.

[٤٢] وتسمّى] ك = ويسمّى: س = وسمى: ب، ل.

[٤٣] ٧٨ب: س.

[٤٤] الهنديّة] هنديه: ك.

[٤٥] ويُنصب] وتنصب: ب.

[٤٦] طوله] ب، فاس(مع رمز «ح»)، ك = في طول: س، ل(يوجد«في» مشطوب والـ«طول» متغيّر إلى «طوله»).

[٤٧] قائمة] +ويعرف: ك.

[٤٨] ٣٤ب: ك.

بالشاقول وإمّا بأن[٥٠] يُقدّر[٥١] ما بين رأس المقياس والمحيط بمقدار واحد من ثلث نقط[٥٢] من المحيط. ويُرصد رأس الظلّ عند وصوله إلى محيطها ممّا يلي المغرب قبل الزوال وبعده مما يلي المشرق. ويُعلّم[٥٣] على كلتي نقطتي الوصول وتُنصَّف[٥٤] القوس التي بينهما؛ وتُخرِج[٥٥] [٥٦] من[٥٧] منتصفها[٥٨] خطّاً[٥٩] يمرّ بالمركز إلى أيّ بُعد شئت[٦٠]. فهو **خطّ نصف النهار** وقد قطع الدائرة[٦١] بنصفين. فتُخرِج من منتصفي النصفين خطّاً[٦٢] يقطع[٦٣] خطّ نصف النهار عند المركز على زوايا قائمة، وهو **خطّ المشرق والمغرب**[٦٤] [٦٥].

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[٤٩] إمّا] ـك.

[٥٠] بأن] ب، هاس(مع رمز «صح»)، ك = ـل.

[٥١] يُقدّر] س = نقدر: ب = بقد: ك = بمقدار: ل.

[٥٢] نقط] نقطه: ب.

[٥٣] ويُعلّم] س = وبعلم: ب، ل = وتعلِمُ: ك.

[٥٤] وتُنصَّف] ك = وبنصف: ب = ويُنصّف: س = ونُنَصَّفُ: ل.

[٥٥] وتُخرِج] ل = ويخراج: ب = نخرج: س = بحرج: ك.

[٥٦] ص٥٨: ب.

[٥٧] من] عن: ب.

[٥٨] منتصفها] منتصفهما: س.

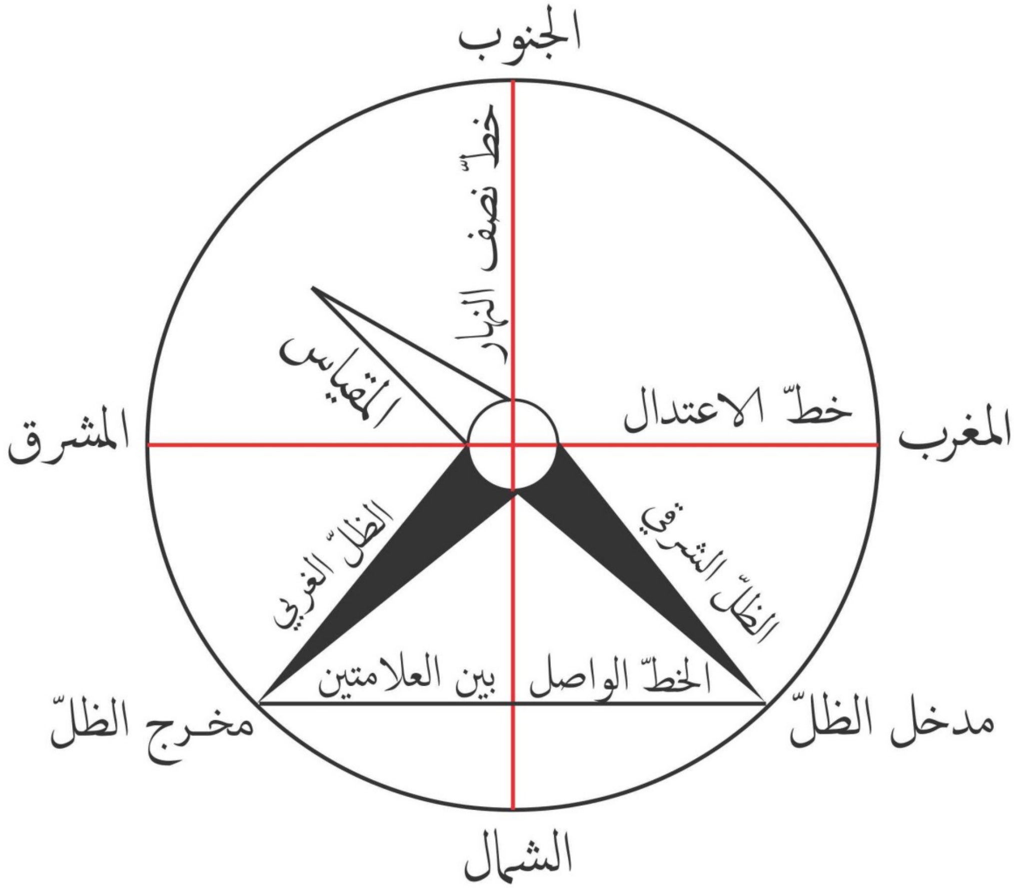
[٥٩] خطّاً] س(الـ«ا» مشطوب و«خطا» متغيّر إلى«خطّ»)، ك، ل = خط: ب.

[٦٠] شئت] يشب: ب.

[٦١] الدائرة] الدايرَ: س

[٦٢] خطّاً] س، ك، ل = خط: ب.

صورة الدائرة الهندية



[شكل ٨]

[٦٣] يقطع] +على: ب.

[٦٤] والمغرب] +والله اعلم وهده صوره الدايره: ك.

[٦٥] ٧٩آ: ل.

[٤] [٦٦] **في معرفة**[٦٧] **سمت القبلة** ونعني[٦٨] بسمت القبلة ههنا[٦٩] [٧٠] نقطة[٧١] في الأفق إذا واجهها الانسان كان مواجهاً للكعبة ايضاً. إذا[٧٢] كان طول مكّة وعرضها أقل من طول بلدنا وعرضه عددنا من الدائرة الهنديّة من نقطة الجنوب بقدر فضل ما بين الطولين إلى المغرب ومن نقطة الشمال مثله ونصل[٧٣] ما بين النهايتين بخطّ مستقيم. ونعدّ[٧٤] [٧٥] من[٧٦] نقطة المغرب إلى الجنوب بقدر ما بين العرضين ومن[٧٧] نقطة المشرق مثله، ونصل[٧٨] بين النهايتين بخطّ مستقيم. فيتقاطع الخطّان لامحالة. فنُخرِج من مركز الدائرة خطّاً إلى نقطة تقاطعهما[٧٩] وننفذه[٨٠]

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[٦٦] ٣٥آ: ك.

[٦٧] في معرفة] —ب.

[٦٨] ونعني] س، ل = ونعى: ب = ويعني: ك.

[٦٩] ههنا] ب، هاس(مع رمز «صح»)، ك = هاهنا: ل.

[٧٠] ٧٩آ: س.

[٧١] نقطة] هى نقطة هى نقطة: س.

[٧٢] إذا] ب، س = وإذا: ك، ل.

[٧٣] ونصل] س، ل = وىصل: ب = وتصل: ك.

[٧٤] ونعدّ] ل = يعدّ: ب = وتعد: ك = ونَعُدّه: س.

[٧٥] ص٥٩: ب.

[٧٦] من] هاب.

[٧٧] ومن] +ىطه: شاك.

[٧٨] ونصل] ل = وفصل: ب = ونصل ما: س = وتصل: ك.

[٧٩] تقاطعهما] ىقاطعها: ب.

[٨٠] وننفذه] ب، ل = وتُنَفِذُ: س= وتنفذه ك.

إلى المحيط. فذلك الخطّ هو[٨١] على صوب القبلة* [٨٢]والقوس التي بين طرفه ونقطة الجنوب هي **قوس**[٨٣] **سمت**[٨٤] **القبلة** وهي[٨٥] مقدار ما ينبغي أن ينحرف المصلّي عن نقطة الجنوب. وقِسْ على ذلك كون طول مكّة[٨٦] أو عرضها أو كليهما أكثر[٨٧].

[٥] وإن كان طول البلد يساوي[٨٨] طول مكّة، فالقبلة على [٨٩]نصف[٩٠] النهار. وإن ساوى[٩١] عرضه عرض مكّة [٩٢]فاعْرِف الأجزاء التي تسامت[٩٣] في الدورة من فلك البروج[٩٤] رؤوس أهل مكّة، وهي ز كا[٩٥]

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[٨١] هو] هو طه(؟): س = –ك.

[٨٢] ١٨آ: ف (الظاهر أنّ ورقة ناقصة من مخطوطة ف بين ١٧ب و١٨آ أي من «*يكون شرقياً عند كون النصف الأوّل» إلى «فذلك الخطّ هو على صوب القبلة*»).

[٨٣] قوس] +الانحراف: ب.

[٨٤] سمت] +سمت: ك.

[٨٥] وهي] وهو: ك.

[٨٦] مكّة] +فالقسله: شال.

[٨٧] أكثر] +طول مكة من جزاير الخالدات(+بياض) وعرضها(+بياض) طول خوارزم(+بياض) وعرضها(+بياض): ب.

[٨٨] يساوي] ب، س، ف = تساوي: ك = ساوى: ل.

[٨٩] ٧٩ب: س.

[٩٠] نصف] –ك.

[٩١] ساوى] تساوي: ك.

[٩٢] ٣٥ب: ك.

[٩٣] تسامت] س، ك، ل = سامت: ب = يسامت: ف.

من الجوزاء و كب لط [٩٦] من السرطان[٩٧]. [٩٨]وضَعْها أعني[٩٩] إحداهما على خطّ وسط السماء في الأسطرلاب[١٠٠] المعمول لعرض البلد. وأعْلِم على موضع المُرِيّ علامةً، ثمّ أدِر[١٠١] العنكبوت بقدر ما بين الطولين إلى المغرب إن كان البلد شرقيّاً، وبالخلاف إن كان غربيّاً[١٠٢]. فحيث[١٠٣] انتهت الأجزاء[١٠٤] من مُقنْطرات الارتفاع، رَصَدْتَ [١٠٥]بلوغ الشمس إلى ذلك الارتفاع، ونَصَبْتَ مقياساً؛ فظلّه في ذلك الوقت هو[١٠٦] المسامت للقبلة[١٠٧].

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[٩٤] التي تسامت في الدورة من فلك البروج] من فلك البروج التى سامت في الدورة: ب.

[٩٥] ز كا] س، ف، ك، ل = (بياض في ب).

[٩٦] و كب لط] س، ف، ل = (بياض في ب) =كب كط: ك.

[٩٧] السرطان] +وضَعْها: شال.

[٩٨] ٧٩ب: ل.

[٩٩] أعني] على: ك.

[١٠٠] الأسطرلاب] ب، ل = الاصطرلاب: س، ف، ك.

[١٠١] أدِر] ادار: ب.

[١٠٢] إن كان غربيّاً] ب، هاس، ك، هال(مع رمز «صح») = —ف.

[١٠٣] فحيث] فحسب: ف.

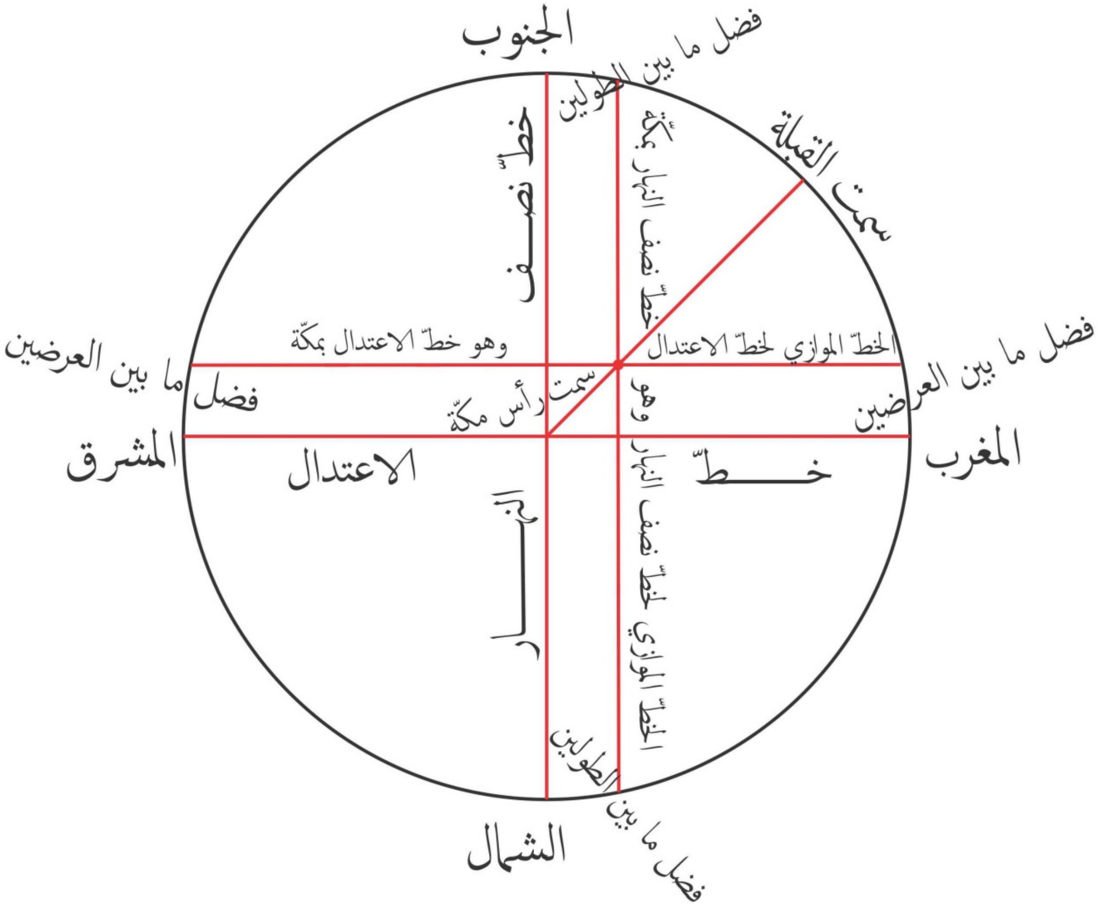
[١٠٤] الأجزاء] اجزاء: ب.

[١٠٥] ص٦٠: ب.

[١٠٦] هو] —ب.

[١٠٧] للقبلة] +بهذه الصوره: ك.

صورة المسامت للقبلة



[شكل ٩]

[٦] **في النهار والليل**[١٠٨] **والساعات والسنة والشهر:**[١٠٩] الشمس إذا وقع ضوؤها على الأرض [١١٠]استضاء وجهها المواجه للشمس، ووقع[١١١] ظلّها[١١٢] في مقابلة جهة الشمس. فإذا[١١٣]كانت الشمس[١١٤] فوق الأرض فهو النهار إذ ليس يخصّ النهار ضوء سوى ضوء الشمس؛ وإذا كانت تحت الأرض وقع ظلّها[١١٥] فوقها وهو الليل. ووقوع ظلّها[١١٦] [١١٧]يكون على شكل مخروط إذ[١١٨] الشمس أعظم جرماً من الأرض. فإذا[١١٩]كانت الشمس [١٢٠]تحت الأرض قريبةً من الأفق كان مخروط[١٢١] الظلّ مائلاً عن سمت الرأس وكان[١٢٢] الهواء

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١٠٨ في النهار والليل] ف = (بياض)+النهار والليل: ب = في النهار والليلة: س = في معرقة الليل والنهار: ك = في معرفة(في الهامش مع رمز «صح») النهار والليل: ل.

١٠٩ والسنة والشهر] س، ف، ل = والشهور والسنة: ب = والسنة والشهور: ك.

١١٠ ٨٠آ: س.

١١١ ووقع] وقع: ب.

١١٢ ظلّها] +الارض: تاس.

١١٣ فإذا] وإذا: ب.

١١٤ الشمس] ب، هاس(مع رمز «صح»)، ك، ل = –ف.

١١٥ ظلّها] الظل: ب.

١١٦ ظلّها] الظل: ب.

١١٧ ٨٠آ: ل.

١١٨ إذ] ك، ل = إذا: ب، ف.

١١٩ فإذا] ف، ك، ل = فان: ب.

١٢٠ ص٦١: ب.

المستضئ بضياء الشمس قريباً[١٢٣] فيظهر في الأفق النور، وكلّما كانت [١٢٤]الشمس أقرب، كانت الأنوار[١٢٥] أغلب ويظهر[١٢٦] الحمرة، كحال الشفق والفجر.

[٧] **واليوم بليلته** هو زمان ما بين مفارقة الشمس دائرة نصف النهار إلى عودها إليها بحركة الكلّ[١٢٧]؛ وعند العامّة من غروب الشمس[١٢٨] إلى مثله. وابتداؤه يمكن[١٢٩] من مفارقة كون[١٣٠] الشمس كلّ نقطة تُفرض في[١٣١] الفلك؛ لكنّ الحُسّاب والمُنجّمين[١٣٢] اصطلحوا على [١٣٣]ابتدائه من دائرة نصف النهار لأنّ اختلافات

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[١٢١] إذ الشمس أعظم جرماً من الأرض فإذا كانت الشمس تحت الأرض قريبةً من الأفق كان مخروط] هاس(مع رمز «صح»).

[١٢٢] وكان] فكان: ك.

[١٢٣] قريباً] +في الافق: شاك.

[١٢٤] ١٨ب: ف.

[١٢٥] الأنوار] ب، س، ل = +وربما فيطهر فى الافق النور وكلما كانت الشمس اقرب كانت الانوار: ف = النور: ك.

[١٢٦] ويظهر] س، ف، ل = ويظهر: ب = وتظهر: ك.

[١٢٧] الكلّ] +وهو الفلك الاطلس: تاس.

[١٢٨] من غروب الشمس] شاس= +من غروب الشمس: س.

[١٢٩] يمكن] ب، ك، ل = يكون: س(«يمكن» مشطوب مع رمز «صح»)، ف.

[١٣٠] كون] –ب، –ك.

[١٣١] في] من: ب، ل.

[١٣٢] والمُنجّمين] +هم: ب.

[١٣٣] ٣٦ب: ك.

المطالع بحسب الأفاق في المساكن[١٣٤] كثيرة، [١٣٥]واختلافها[١٣٦] واحدٌ[١٣٧] بحسب دائرة نصف النهار[١٣٨] لأنّ دائرة نصف النهار في جميع المساكن تقوم[١٣٩] مقام أفق خطّ الاستواء. وزمان اليوم بليلته يزيد على دور الكلّ[١٤٠] بمطالع ما سارت الشمس من فلك[١٤١] البروج ولمّا كانت الشمس تقطع[١٤٢] من فلك البروج قسيّاً مختلفةً فمطالعها مختلفة. وأيضاً لو كانت الشمس[١٤٣] بالتقدير تقطع[١٤٤] قسيّاً متساويةً، فليست مطالع القسيّ المتساوية متساويةً. فمن هذه الوجوه تختلف الأيّام بلياليها فقسموا اليوم بليلته إلى حقيقيّ ووسط[١٤٥]. فالحقيقيّ هو زمان عودة نقطة من معدّل النهار إلى نقطة مفروضة [١٤٦]مع زمان مُرور مطالع[١٤٧] ما سارت الشمس بتلك النقطة المفروضة؛

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[١٣٤] المساكن] +الاماكن: تاس(مع رمز «صح»).

[١٣٥] ٨٠ب: س.

[١٣٦] واختلافها] واختلافاتها: ب.

[١٣٧] واحدٌ] –ب.

[١٣٨] النهار] +واحده: ب.

[١٣٩] تقوم] ك = نقوب: ب، ل = يقوم: س، ف.

[١٤٠] الكلّ] الفلك: ب.

[١٤١] من فلك] في الفلك: ب.

[١٤٢] تقطع] ك، ل = يقطع: س = نقطع: ف.

[١٤٣] تقطع من فلك البروج قسيّاً مختلفةً فمطالعها مختلفة وأيضاً لو كانت الشمس] –ب.

[١٤٤] تقطع] ك = نقطع: ب، ف، ل = يقطع: س.

[١٤٥] ووسط] ووسطي: ك.

[١٤٦] ص٦٢: ب.

والوسط[١٤٨] هو زمان عودة نقطة من معدّل النهار إلى نقطة مفروضة مع زمان مرور قوس[١٤٩] من معدّل النهار[١٥٠] [١٥١] مساوية[١٥٢] لوسط الشمس وهو ٠ نط ح ك[١٥٣] بتلك النقطة[١٥٤] [١٥٥] وهو الموضوع في الزيجات والفضل بين الحقيقي والوسط[١٥٦] يُسمّى تعديل الأيّام بلياليها.

[٨] **وزمان النهار** من طلوع الشمس إلى غروبها[١٥٧]، وفي الشرع من طلوع الفجر إلى غروب الشمس؛ ومن غروبها[١٥٨] إلى طلوع الشمس[١٥٩] زمان الليل، وفي الشرع إلى طلوع الفجر.[١٦٠] ثمّ إنّهم قسموا اليوم

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١٤٧ مطالع] —ب.

١٤٨ والوسط] والوسطي: ك.

١٤٩ قوس] +متساوي: ب.

١٥٠ ٣٧آ: ك.

١٥١ من معدّل النهار] هال(مع رمز «صح»).

١٥٢ مساوية] —ب.

١٥٣ وهو ٠ نط ح ك] س = —ب، —ف، —ك، —ل.

١٥٤ النقطة] +وهو: س.

١٥٥ ٨١آ: س.

١٥٦ والوسط] والوسطي: ك.

١٥٧ غروبها] +من غروبها: ك.

١٥٨ ومن غروبها] +ومن غروبها: ف.

١٥٩ طلوع الشمس] س، ف، ل = طلوعها: ب، ك.

١٦٠ ١٩آ: ف.

والليلة[١٦١] إلى ساعات معتدلة وزمانيّة. [١٦٢]فالساعات[١٦٣] المعتدلة، وتسمّى **المستوية**، هي[١٦٤] بقدر ما يدور خمس عشرة درجة[١٦٥]. فإذا قُسمت قوس النهار أو قوس الليل أو قوس الدائر[١٦٦] من الفلك على خمسة عشر، كان ما يخرج عدد الساعات المعتدلة لذلك اليوم أو الليلة أو ما مضى من اليوم[١٦٧] أو الليلة[١٦٨]. **والساعة**[١٦٩] **الزمانية**، وتسمّى[١٧٠] **المُعْوَجّة** فهي[١٧١] جزء من اثنى عشر جزء من النهار أو الليل أبداً، فإذا كان النهار أطول من الليل كانت ساعاته أطول من ساعات [١٧٢]الليل، وإن كان[١٧٣] أقصر كانت ساعاته أقصر. وإذا قُسمت

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[١٦١] والليلة] بليله: ب.

[١٦٢] ٨٠ب: ل.

[١٦٣] فالساعات] والساعات: ب.

[١٦٤] هي] ب، ك، ل = هو: س، ف.

[١٦٥] خمس عشرة درجة] ب، ل = خمسة عشر درجة: س، ف، ك.

[١٦٦] الدائر] الدايرة: ك.

[١٦٧] اليوم] الليل: ف.

[١٦٨] أو الليلة] والليلة: س.

[١٦٩] والساعة] س، ك، ل = والساعات: ب، ف.

[١٧٠] وتسمّى] ك، ل = ويسمّى: ب، س = وسمّى: ف.

[١٧١] فهي] وهي: ب.

[١٧٢] ٨١ب: س.

[١٧٣] وإن كان] ولو كانت: ب.

قوس[١٧٤] النهار أو قوس الليل على اثنى عشر، كان ما يخرج هو ما يدور الفلك في كلّ ساعة زمانية، وهي[١٧٥] أجزاء الساعة[١٧٦] الزمانية وتسمّى **الأزمان**[١٧٧]. فقد تبيّن أنّ الساعات المعتدلة هي التي يختلف عددها على قدر طول النهار وقصره، ولا يختلف أزمانها؛ والساعات الزمانية هي التي تختلف أزمانها[١٧٨] ولا يختلف[١٧٩] عددها.

[٩] **السنة** هي زمان[١٨٠] مفارقة الشمس ايّة[١٨١] نقطة تُفرض من فلك البروج إلى عودها إليها بحركتها الخاصّة التي لها من المغرب إلى المشرق. وقد جعلوا ابتداء هذه السنة من حين[١٨٢] حُلول الشمس رأس الحمل، واختلفوا في مدّة[١٨٣] هذه السنة. فقال بعضهم شسه[١٨٤] يوماً وربع يوم؛ وعند **بطلميوس** شسه[١٨٥] يوماً

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١٧٤ ص٦٣: ب؛ ٣٧ب: ك.

١٧٥ وهي] وهو: ك.

١٧٦ الساعة] الساعات: س(الـ«عات» متغيّر إلى«عة»).

١٧٧ الأزمان] س(«الزمان» متغيّر إلى «الازمان»)، ف، ك، ل = للزمان: ب.

١٧٨ والساعات الزمانية هي التي تختلف أزمانها] –ك.

١٧٩ ازمانها والساعات الزمانية هي التي تختلف ازمانها ولا يختلف] –ب.

١٨٠ زمان] الزمان: ب = زمان: هاب.

١٨١ ايّة] ل = انه: ب، ف = انه: س = من اية: ك.

١٨٢ حين] –س.

١٨٣ مدّة] س، ف، ل = –ب، –ك.

١٨٤ شسه] س، ف، ك، ل = (بياض في ب) = +٣٦٥: تاس(مع رمز «صح»).

١٨٥ شسه] س، ف، ك، ل = (بياض في ب) = +٣٦٥ وربع(الـ«وربع» مشطوب): تاس(مع رمز «صح»).

وربع[١٨٦] إلّا جزاء من ثلثمائة جزء من يوم؛ وعند **البتّاني** شسه[١٨٧] يوماً [١٨٨]وربع إلّا ثلاثة[١٨٩] أجزاء واربعاً وعشرين دقيقةً من ثلثمائة وستين جزء[١٩٠] من يوم. والمراد باليوم هنا[١٩١] هي[١٩٢] اليوم بليلته. وهذه هي[١٩٣] السنة الشمسيّة؛ وأمّا السنة [١٩٤]القمرية، فهي[١٩٥] اثنا عشر شهراً.

[١٠] **والشهر** زمان مفارقة القمر[١٩٦] أيّ وضع[١٩٧] يُفرض [١٩٨]له من الشمس إلى عوده إليه. وأظهر الأوضاع هو الهلال لكنّ رؤية الهلال تختلف باختلاف [١٩٩]المساكن. فلم يلتفت[٢٠٠] إليها إلّا في الأُمور الشرعية.

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[١٨٦] وربع] +يوم: شاك.

[١٨٧] شسه] س، ف، ك، ل = (بياض في ب) = +٣٦٥: تاس(مع رمز «صح»).

[١٨٨] ٨٢آ: س.

[١٨٩] إلّا ثلاثة] بوم الّا ثلثه: ب.

[١٩٠] جزء] حز مما: س.

[١٩١] هنا] هاس(مع رمز «ح»)، ك، ل = ههنا: ب = —ف.

[١٩٢] هي] س، ف = —ب، —ك، —ل.

[١٩٣] هي] —ك.

[١٩٤] ٣٨آ: ك.

[١٩٥] فهي] +فهي: ف.

[١٩٦] القمر] +في: ك.

[١٩٧] أيّ وضع] اى موضع: س.

[١٩٨] ١٩ب: ف.

[١٩٩] ص٦٤: ب.

وجُعل ابتداء الشهر من اجتماع الشمس والقمر وزمانه[٢٠١] ما بين الاجتماعين[٢٠٢] بالمسير الوسط [٢٠٣]من النيّرين[٢٠٤]: بأن ألقَوا وسط الشمس من وسط القمر وقسموا على ما بقي[٢٠٥] دور الفلك، وهو شس[٢٠٦] جزء، فخرج[٢٠٧] كط لا ن ح[٢٠٨] من الأيّام، وهو مقدار الشهر. ثمّ ضربوا ذلك في اثنى عشر؛ فحصلت أيّام السنة القمريّة: شند[٢٠٩] يوماً وخُمس يوم وسُدسه[٢١٠]. وهذه السنة ناقصة عن السنة الشمسيّة [٢١١]بعشرة أيّام وعشرين ساعة ونصف ساعة بالتقريب.

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[٢٠٠] يلتفت] ىلىف: ف.

[٢٠١] وزمانه] ك، ل = فزمانه: ب = وزمان: س، ف.

[٢٠٢] الاجتماعين] الاجتماع: ف.

[٢٠٣] ٨١ب: ل.

[٢٠٤] النيّرين] +علي ما بقي: شاك.

[٢٠٥] بقي] +من: ك.

[٢٠٦] شس] س، ف، ك، ل = ٠ ٦ ٣ : ب، +تاس.

[٢٠٧] فخرج] +ذلك في اثني عشر وخمس يوم: ك.

[٢٠٨] كط لا ن ح] ب، س، ف، ك، ل.

[٢٠٩] شند] س، ف، ك، ل = +٣٥٤: تاس(مع رمز «صح») = ٤ ٠ ٦ ٣ (؟): ب.

[٢١٠] وسُدسه] ب، ف، ل = وسد وسدسه(الـ«سد» مشطوب): س = وسدس: ك.

[٢١١] ٨٢ب: س.

[١١] هذا[٢١٢] ما سمح به الطبْع[٢١٣] الطَبِع[٢١٤]، والخاطر المتوزّع، والفكر [٢١٥]المشوّش بأشغال لا يعدّ عديدها، وهُموم لا يُنادى وليدُها[٢١٦]. وقد بذلتُ الوُسْعَ في كَشْف[٢١٧] المعاني وإظهارها مع إيجاز الألفاظ[٢١٨] واختصارها أداءً لشرائط[٢١٩] الامتثال والخدمة مع التحرّز[٢٢٠] عن الإملال والزَحْمَة. ولعلّ هذا المقدار الذي[٢٢١] أوردتُ كافٍ[٢٢٢] لِتحصيل ما أردتُ، وافٍ بما جرت الإشارة إليه. فالأولى[٢٢٣] أن أقتصر عليه فليكن هذا خاتمة الكتاب.

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[٢١٢] هذا] +هذا: ك.

[٢١٣] به الطبع] –ب.

[٢١٤] الطبع] –ك.

[٢١٥] ٣٨ب: ك.

[٢١٦] وليدُها] ولديها: ك.

[٢١٧] كَشْف] الكشف: ب.

[٢١٨] الالْفاظ] اللفظ: ف.

[٢١٩] أداءً لشرائط] ب، هاس(مع رمز «صح»)، ف، ل = اذا الشرايط: س(الـ«اذا» مشطوب)، ك.

[٢٢٠] التحرّز] ب، ك، ل = التجوز: س، ف.

[٢٢١] الذي] التي: ك.

[٢٢٢] كافٍ] –ب.

[٢٢٣] فالأولى] والاولى: ب.

بيانات النسخ

مخطوطة ب (صفحة ٦٤):

والله أعلم بالصواب وإليه المرجع والمآب

مخطوطة س (٨٢ب):

والله الموفّق والمستعان وعليه التكلان اتّفق الفراغ عن كتابته ليلة الجمعة التاسع عشر من شهر ذي القعدة من سنه سبع وثمانين وسبعمائة الحمد لله وحده، وصلى الله على سيّدنا محمّد وآله وسلّم

[ملاحظة بيد آخر] وفرغ عن قراءته في أوّل شهر ربيع الآخر من سنة ثمان وثمانين وسبعمائة على الشيخ علاء الدين الموقّت بحلب فسح الله في مدته

مخطوطة ف (١٩ب):

والله الموفّق والمستعان وعليه الاعتماد والتكلان اتّفق الفراغ من كتابته يوم٢ ٢٩ شهر المبارك ربيع الأوّل سنة ٧٨٦ هجرية

مخطوطة ك (٣٨ب):

والله الموفّق للصواب والحمد لله وحده وصلى الله على سيّدنا محمّد وآله وصحبه وسلّم في تاريخ سنة ٧٦٤ أحسن الله عاقبتها بمنّه وكرمه

مخطوطة ل (٨١ب):

وبالله التوفيق تمّ الكتاب في شهور خمد («٦٤٤» في الهامش) هجرية

§ II.5 Figure Apparatus

المقدّمة

شكل ١: صورة الأفلاك

صورة الأفلاك] ل = كرة العالم: ب = ـس، ـف، ـك . فلك الأفلاك] ب، س، ك، ل = فلك الاعظم: ف. كرة النار] ب، س، ف = النار: ك، ل. كرة الهواء] ب، س، ف = الهواء: ك، ل. كرة الماء] س، ف = ـب = الما: ك، ل. كرة الأرض] ف = كرة الارض والمآء: ب = ارض: س = الارض: ك، ل. مركز العالم] ب، ف = ـس، ـك، ـل. قطب البروج(موقعان)] س = قطب فلك البروج(موقعان): ب، ل = ـف، ـك. قطب العالم(موقعان)] ب، س = ـف، ـك = قطب الجنوب؛ قطب الشمال: ل. («محور العالم» زائد في ب، ك). («محور البروج» زائد في ب = «محور فلك البروج» زائد في ك). («عالم العناصر» زائد في ب).

المقالة الأولى، الباب الأوّل

شكل ٢: صورة فلك الشمس

صورة فلك الشمس] ف، ك، ل = ـب = فلك السمس: س. الأوج] ب، ل = اوح: س، ك = ـف. («مركز الشمس» زائد في ب). جرم الشمس] ب، س، ف، ك، ل(موقعان). («الشمس» زائد في موقع آخر في ف). متتّم محوي] ف = المتمم المحوى: ب = المتمّم من الممثل: س = ممم الممثل: ك = المتمم: ل. مقعّر الخارج] معقر خارج: ف = ـب، ـس، ـك، ـل. مقعّر الممثّل] مقعر ممثل: ف = ـب، ـس، ـك، ـل. مركز الخارج] ب، ل = ـس، ـك = مركر حارج: ف. مركز الممثّل] مركز العالم: ب = ـس، ـك = مركز ممثل: ف = مركز عالم: ل. خارج المركز] ك = الفلك الخارج المركز: ب، س = حارح مركز: ف = الحامل: ل(أربعة

مواقع). محدّب الخارج] محدب خارح: ف = —ب، —س، —ك، —ل. الحضيض] ب، س، ك، ل = —ف. المثّل] ممل: ف = الفلك المثل: ب، ل(موقعان) = —س، —ك. محدّب الممثّل] محدب ممثل: ف = —ب، —س، —ك، —ل. متمّم حاوي] ف = المتمم الحاوى: ب = المتمم من الفلك الممثل: س = ممم ممثل: ك = المتمم: ل. (عدد رسوم أجرام الشمس في كل مخطوطة: ١- ب ؛ ٤ - س، ل ؛ ٢- ف ؛ ناقص في ك).

شكل ٣: صورة أفلاك الكواكب العلوية و الزهرة

(الشكل ناقص في ف). صورة أفلاك الكواكب العلويّة والزهرة] ك، ل = افلاك الكواكب العلوية والزهرة: س = صورة الافلاك الكواكب (فاب) العلوية والزهرة: ب. أوج] ك = —ب = اوج زهرة: س = الأوج: ل. («ذروة التدوير» زائد في ك، ل). فلك التدوير] ب(في موقع)، س = التدوير: ب(في موقع آخر)، ل(أربعة مواقع) = —ك. الفلك الحامل] س = —ب = الحامل: ك، ل(موقعان). المتمّم] ب، ك، ل = المتمم من المثل: س. جرم الكوكب] ب، ل = الكوكب(ثلاثة مواقع): س = —ك. حضيض] س = —ب = حضيض الذروه: ك = الحضيض: ل. المتمّم] ب، ك، ل = المتمم من الممثل: س. («مركز التدوير» زائد في ب). («الفلك الممثل» زائد في ب، ل[موقعان]). («مركز العالم» زائد في ب). («خارج المركز» زائد في س). («مركز الخط المدير» زائد في ك). («حضيض التدوير» زائد في ل). (عدد رسوم أجرام التداوير في كل مخطوطة: ٤ - ب، س، ل ؛ ناقص في ك).

شكل ٤: صورة فلك عطارد

صورة فلك عطارد] ب، ف، ك، ل = فلك عطارد: س. الأوجان] س = الاوج: ب = ـف = اوجا عطارد: ك، ل. («ذروة التدوير» زائد في ل). الكوكب] س(أربعة مواقع) = ـب، ـف، ـك، ـل. تدوير] ف = التدوير: ب، ل(أربعة مواقع) = فلك التدوير: س(ثلاثة مواقع) = ـك. المتمّم من المدير(موقعان)] س، ف = «المتمم» و«المتمم المدر»: ب = متمم المدير(موقعان): ك، ل. المتمّم من الممثّل(موقعان)] س، ف(موقع واحد فقط) = المتمم(موقعان): ب = ممم الممثل: ك(موقع واحد فقط) = طال(موقعان). مركز الحامل] ب = ـس، ـك، ـل = مركز حامل: ف. مركز المدر] ب = ـس، ـك، ـل = مركز مدير: ف. مركز العالم] ب = ـس، ـك، ـل = مركز عالم: ف. («مركز معدل المسير» زائد في ب). حامل] ف = الفلك الحامل: ب، س = الحامل: ك، ل(موقعان). مدير] ف(موقعان) = ـب، ـس، ـك، ـل. ممثّل] ف = الفلك الممثل: ب = ـس، ـك، ـل. الحضيضان] س = ـب، ـف = حضيص التدوير: ك = «حضص التدور» و«الحصض»: ل. (عدد رسوم أجرام التداوير في كل مخطوطة: ٤ - ب، س، ل ؛ ١- ف، ك).

شكل ٥: صورة فلك القمر

صورة فلك القمر] ك، ل = ـب، ـف = فلك العمر: س. الأوج] ب، ل = ـس، ـف، ـك. التدوير] ف، ل(أربعة مواقع) = فلك التدوير: ب = ـس، ـك. قمر] س(موقعان) = جرم القمر: ب = ـف، ـك، ـل. المتمّم من المائل(موقعان)] س = المتمم(موقعان): ب، ل = «المتمم من المابل» و«المتمم من المدير»[كذا]: ف = «المتمم المايل» و«متمم المايل»: ك. حامل] ف = الفلك الحامل: ب، س = الحامل: ك، ل(موقعان). مركز الحامل] ب، ف = ـس، ـك، ـل. مركز العالم] ب، ف = ـس، ـك، ـل. مائل] ف = الفلك المايل: ب = ـس، ـك = المايل(موقعان): ل. الحضيض] ب، س = ـف = حضيض التدوير: ك = «حضض التدور»

و«الحضض»: ل. («نقطة المحاذاة» زائد في ك). الفلك الجوزهر ويسمّى الممثّل] س = الفلك الممثل: ب = «فلك الجوزهر والممثل ايضا» و«حوزهر»: ف = جوزهر وسمى الممثل: ك = الجوزهر وسمى ممثل: ل. («وهذا فلك الحامل الذى هو فى ثخن المايل» زائد في ف). (عدد رسوم أجرام التداوير في كل مخطوطة: ٢- ب، س ؛ ٤- ل ؛ ١- ف ؛ ناقص في ك).

المقالة الأولى، الباب الرابع

شكل ٦: صورة النطاقات باعتبار الأبعاد

(الشكل ناقص في ف). (التسميات ناقصة في ل). الأوج] –ك. مركز الفلك الحامل(في الخارج المركز)] س = مركز الحامل: ب، ك. البعد الأوسط(موقعان)] –س. الفلك الحامل(في الخارج المركز)] –ك. الفلك الممثّل] –ك. («البعد الاقرب» زائد في الخارج المركز في ك). فلك التدوير] س= –ب، –ك. نقطة التقاطع] (يوجد مرة فقط على اليسار في ك) . حضيض التدوير] حضيض: ك. مركز الفلك الحامل(في التدوير)] مركز الحامل: ب، ك. (يوجد خطّ نصف قطر زائد في التدوير في ل).

شكل ٧: صورة النطاقات باعتبار اختلاف المسير

(بياض في ف، ل). مركز العالم] –ك. الفلك الحامل (في الخارج المركز)] –ك. («والبعد الابعد» زائد في الخارج المركز في ك). («غاية التعديل»(موقعان) زائد في الخارج المركز في ك). (يوجد خطّ من مركز الحامل زائد في الخارج المركز في ك). ذروة التدوير] ذروة: ك. فلك التدوير] –ب، –ك. مركز التدوير] –ب. نقطة التماسّ(موقعان)] ب = نقطه الشمال(يساراً)؛ غاية التعديل(يميناً): ك = –س. حضيض التدوير] –ك. مركز الحامل(في التدوير)] شاس = مركز العالم: س. الفلك الحامل(في التدوير)] –ك.

شكل ٨: صورة الدائرة الهندية

(الشكل ناقص في ف؛ التسميات ناقصة في ب). (الخطّ الواصل بين العلامتين ناقص في ب). (المقياس ناقص في ب، س؛ يوجد مقياسان في ك). الجنوب] ل = نقطه الجنوب: س = جنوب: ك. خطّ نصف النهار] س، ك، ل. المغرب] ك، ل = بعطه المغرب: س. خطّ الاعتدال] س، ك، ل. المقياس] ل =—س = («مقياس» مكتوب مرّتان في ك). المشرق] ك، ل = نقطه: س. الظلّ الشرقي] س، ك، ل. الظلّ الغربي] س، ك، ل. الخطّ الواصل بين العلامتين] س،ك، ل. مدخل الظلّ] ل = مخرج الطل: س = —ك. مخرج الظلّ] س، ل = —ك. الشمال] ك، ل = بقطه الشمال: س.

شكل ٩: صورة المسامت للقبلة

(التسميات ناقصة في ب). الجنوب] ك، ل = حوب: س، ف. فضل ما بين الطولين(موقعان)] ل = (موقع واحد فقط في س، ف، ك). الخطّ الموازي لخطّ نصف النهار وهو خطّ نصف النهار بمكّة] ل = —س، —ف، —ك. الخطّ الموازي لخطّ الاعتدال وهو خطّ الاعتدال بمكّة] ل = —س، —ف، —ك. سمت رأس مكّة] ل = —س، —ف، —ك. فضل ما بين العرضين(موقعان)] ل = (موقع واحد فقط في س، ف) = —ك. المغرب] ك، ل = نقطة المغرب: س، ف. المشرق] ك، ل = نقطة المشرق: س، ف. خطّ الاعتدال] ك، ل = —س، —ف. الشمال] ك، ل = شمال: س، ف.

PART III

§ III.1 English translation of *al-Mulakhkhaṣ fī al-hayʾa al-basīṭa*

[Preface]

[1]In the name of God, the Beneficent, the Merciful

[1] Praise be to God as much as His bestowal of bounty, and may a benediction be upon His Prophet Muḥammad and his family. / The proficient, highly esteemed, most learned Imām, teacher of mankind, most noble of the worthies, he without peer, king of the eminent ones, seal of the sages, **Maḥmūd ibn Muḥammad ibn ʿUmar al-Faqīhī al-Jaghmīnī al-Khwārizmī**, may God have mercy upon him, has said /[2]: the dearest of friends and the sincerest of companions conveyed to me that our master, the highly esteemed, proficient, refined Imām Badr al-Milla wa-l-Dīn, the pride of Islam and Muslims, cherished by kings and sultans, the healer of the spirits, the seal of the sages, Muḥammad ibn Bahrām al-Qalānisī, may God have mercy upon him, proposed that I compile on [the subject of] *ʿilm al-hayʾa*, a book that would tie together an abridgement and an exposition, and combine a succinctness of words with an expansiveness of meanings. I reckoned this a delightful entrustment and I hastened to comply with his lofty proposal, and composed a poem:

Oh what a proposal came my way;	it raised my rank and it advanced my standing.
It came to me from the noble one who inspires hope;	the highly esteemed Imām, the full moon [Badr] of the true religion.
He considered me worthy for a momentous task;	[but] the likes of me is not worthy of such a thing as that.
Nevertheless, I expended every effort for that;	complying with his command whatever sacrifice.
He called upon me for that in kindness and piety;	not requiring the offerings of such as myself.

[1] p. 6: MS B; f. 2b: MS F; f. 1b: MS K; f. 61b: MS L; f. 48b: MS S.

[2] MS B has the following variant for (/…/): The magnanimous, worthy, perfect, erudite Shaykh Imām Sharaf al-Dīn Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī, may God have mercy upon him, says

[2] I composed this book according to [my] ability, aiming for an epitome on [*hayʾa*] that is also an exposition, and I entitled it "The Epitome on Theoretical Astronomy" so that its name will be informative about its connotation, and its literal sense will be indicative of its signification; and I arranged it so as to comprise an introduction and two parts.[3] The Introduction

[3] The Preface up to this point varies considerably in what I have identified as the earliest versions of the text. MSS B, F, and S have the dedication and the poem (as translated); MS K has the dedication but no poem; MS L has neither. MS B is also contaminated with elements of MS L. Details are in the commentary and introduction; the translation of MSS K and L follow:

MS K:
In the name of God, the Beneficent, the Merciful. Praise be to God as much as His bestowal of bounty, and may a benediction be upon His messenger Muḥammad and his family. The highly esteemed, proficient, most learned Shaykh Imām, teacher of mankind, most noble of peers, king of the eminences, seal of the sages, Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī al-Khwārizmī, may God Almighty protect him with His grace, has said: the dearest of friends and the sincerest of companions, Badr al-Milla wa-'l-Dīn, the pride of Islam and Muslims, cherished by kings and sultans, comforter of Shaykhs, the restorer of the spirits, Muḥammad ibn Bahrām al-Qalānisī, may God find his outcomes praiseworthy, proposed that I compile a book on *ʿilm al-hayʾa* being both an abridgement and an exposition, and bringing together a succinctness of words with an elucidation of meanings. I considered this a delightful entrustment and I hastened to comply with his lofty proposal. I composed this book according to [my] ability, aiming for an epitome on [*hayʾa*] that is also an exposition, and I entitled it "The Epitome on Theoretical Astronomy," its name being informative about its connotation, and its literal sense being indicative of its signification; and I arranged it so as to comprise an introduction and two parts.

MS L:
In the name of God … an introduction and two parts] In the name of God, the Beneficent, the Merciful. Praise be to God as much as His bestowal of bounty, and may a benediction be upon His Prophet Muḥammad and his family. The servant of God in need of His compassion, Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī, may God have mercy upon him, states: I

is about an explanation of the divisions of the bodies in general terms. The First Part concerns an explanation of the orbs and what pertains to them, and there are five chapters: (1) On the configurations of the orbs; (2) On an explanation of the motions of the orbs; (3) On an explanation of the circles; (4) On an explanation of the arcs; (5) On what occurs to the planets in their motions and what is connected with this. The Second Part concerns an explanation of the configurations of the Earth and what pertains to it, and there are three chapters: (1) On the inhabited part of the Earth and its latitude, its longitude, and its division into the climes; (2) On the characteristics of the equator and locations having latitude; (3) On miscellaneous items.

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composed this book on *hayʾat al-ʿālam* [Cosmography of the World] as a memento from me for every scholar after me seeking an epitome on [*hayʾa*] with an exposition, and a succinctness of words with an elucidation of meanings, according to [my] ability. And I entitled it "The Epitome on Theoretical Astronomy" so that its name will be indicative of its connotation and its literal sense will be informative about its signification; and I arranged it so as to comprise an introduction and two parts.

After the poem, MS B has the following:
I composed this book … an introduction and two parts]: I composed this book on *hayʾat* [p. 7] *al-ʿālam* [Cosmography of the World] as a memento from me for every scholar after me seeking an epitome on [*hayʾa*] with an exposition, and a succinctness of words with an elucidation of meanings, according to [my] ability. And I entitled it "The Epitome on Theoretical Astronomy" so that its name will be indicative of its connotation and its literal sense will be informative about its signification; and I arranged it so as to comprise an introduction and two parts.

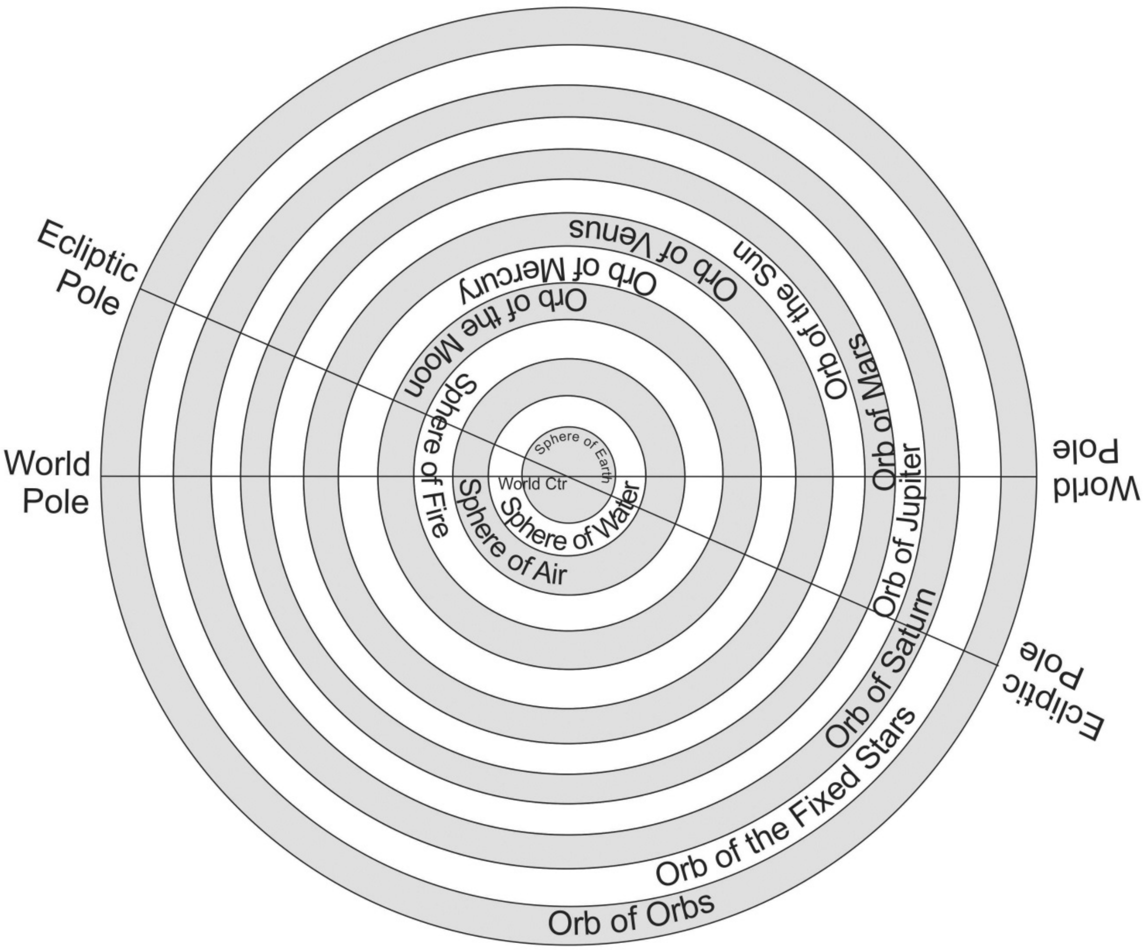
Introduction

On an Explanation of the Divisions of the Bodies in General Terms

[1] The bodies are two kinds: simple, which are those that cannot be [further] broken down into bodies of different natures; and composite, which are those that can be [further] broken down into bodies of different natures, such as minerals, plants, and animals. There are two kinds of simple bodies: elements, namely, earth, water, air, fire, and the aethereal bodies, which are the orbs with what is in them. Every simple body, when left unimpeded and in its natural state, is—as has been shown in another science— spherical in form. Hence, the elements, in their totality, and the aethereal bodies have spherical shapes. However on the Earth, inasmuch as it admits of [geological] formations, there are undulations that occur on its surface due to reasons external to it, such as we observe by way of valleys, hills, and so forth. But these undulations do not detract from its being spherical shape as a whole, like with an egg: if kernels of barleycorn were stuck on it, this would not detract from its overall shape. Similarly, the water is spherical, despite the fact that it is not completely round, since emerging from its surface are elevations from the earth. Likewise, the air is spherical yet its concave surface is irregular as well due to undulations in it from the water and the earth. The fire is a spherical shape that is truly round [both] convexly and concavely according to the most correct opinion.

[2] All the orbs are spherical in shape and these spheres enclose one another. The Earth is in the middle, then the water that encloses it, then the air, then the fire, then the orb of the Moon, then the orb of Mercury, then the orb of Venus, then the orb of the Sun, then the orb of Mars, then the orb of Jupiter; then the orb of Saturn, then the orb of the Fixed Stars, and then the Orb of Orbs, which is called the Greatest Orb; it is the orb that encloses all the bodies, nothing being beyond it, neither vacuum nor plenum. Every enclosing [orb] is contiguous with that enclosed by it, which is adjacent to it according to the aforementioned arrangement. To the totality of these bodies—the elements, the orbs and what is within them—is extended the name "The World." This is its illustration:

Illustration of the Orbs



[Figure 1]

The First Part

On an Explanation of the Orbs and What Pertains to Them

CHAPTER ONE

of the First Part

On the Configurations of the Orbs

[1] **The orb of the Sun** is a spherical body bounded by two parallel surfaces whose center is the center of the world. For every sphere whose two surfaces are parallel, the center of their two surfaces is the [sphere's] center. For every solid orb enclosing the Earth, its two surfaces are parallel. I mean here by two parallel [surfaces] that the distance between them is the same in all directions—not varying such that the sphere would [then] have a thinner part and a thicker part, but rather it is uniform in thickness.

[2] Inside the thickness of this orb, i.e., in what is between its two parallel surfaces, not in the [orb's] cavity, is a second orb which is a spherical body enclosing the Earth and bounded by two parallel surfaces whose center is away from the center of the world; the convex of its two surfaces is tangent to the convex of the first [orb's] two surfaces at a point common to both called the **apogee**. The concave of its two surfaces is tangent to the concave of the first [orb's] two surfaces at a point common to both and is called the **perigee**. In other words, this second [orb] is inside the thickness of the first [orb]—not in its cavity—and shifted to one side of it in such a way that a point on its convex [surface] will reach the convex of the first [orb], and a point on its concave [surface will reach] the concave of the first [orb].

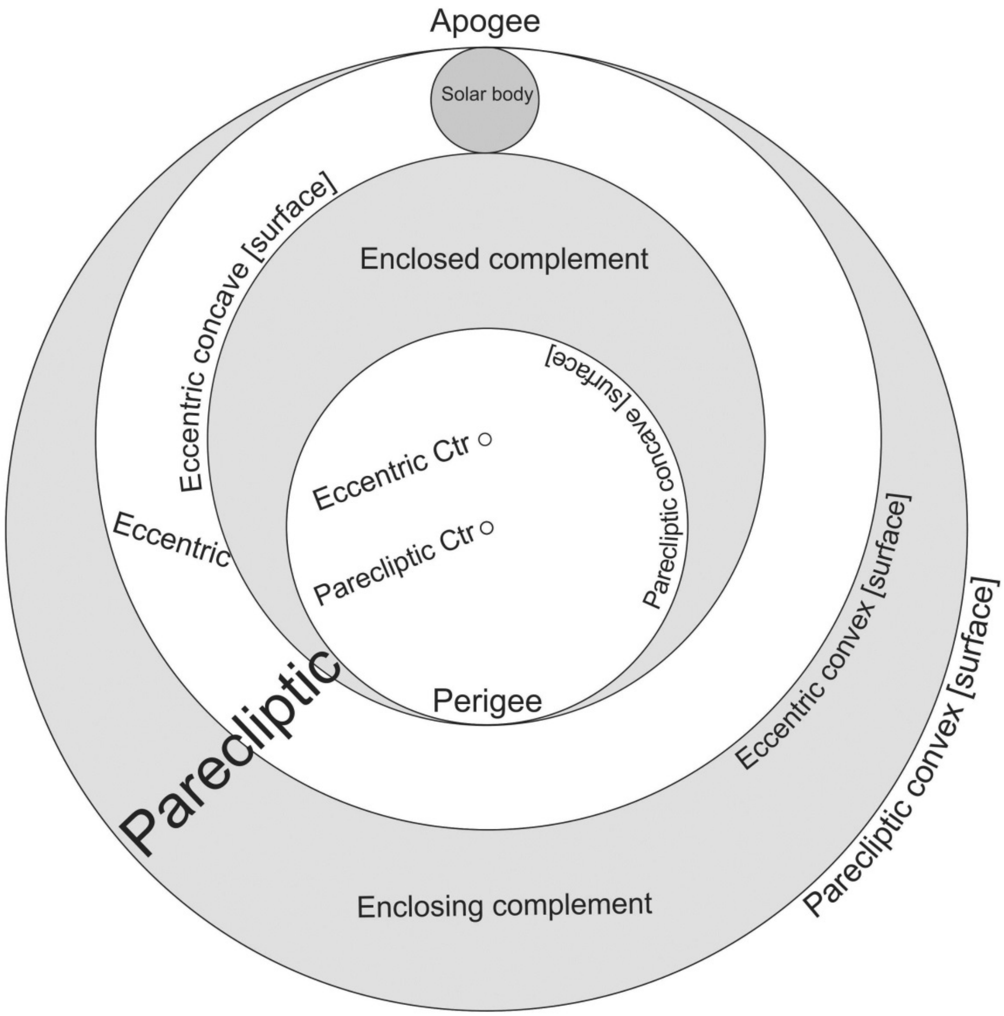
[3] Thus necessarily the first [orb] becomes by [the second orb] two spheres [i.e., two spherical bodies] whose surfaces are not parallel but rather of variable thickness, one of the two encloses [the second orb], and the other is enclosed in it. The thinner part of the enclosing [spherical body] is that which is adjacent to the apogee; and the thicker part is that which is adjacent to the perigee. And the thinner part of the enclosed [spherical body] and its thicker part are in reverse. Each one of them is a **complementary [body]**. This second orb is called the **eccentric**, and the first is called the **parecliptic orb** because on its circumference is the circle that is also called the parecliptic orb, which you will learn about in the chapter on circles.

[4] **The Sun** is a solid, spherical body fixed in the body of the eccentric orb, embedded in it in such a way that [the Sun's] diameter is equal to the thickness of the orb and its surface is tangent to [the orb's] two surfaces.

[5] **As for the orbs of the upper planets and Venus,** they are exactly the same as the orb of the Sun, there being no difference at all between them and it except that they have small orbs that do not enclose the Earth. Rather, they are fixed [and] embedded in the bodies of their eccentric orbs in such a way that the surface of each one of them is contiguous with the two surfaces of its deferent, in the manner of the body of the Sun in its eccentric orb. These small orbs are called **epicycle orbs**.

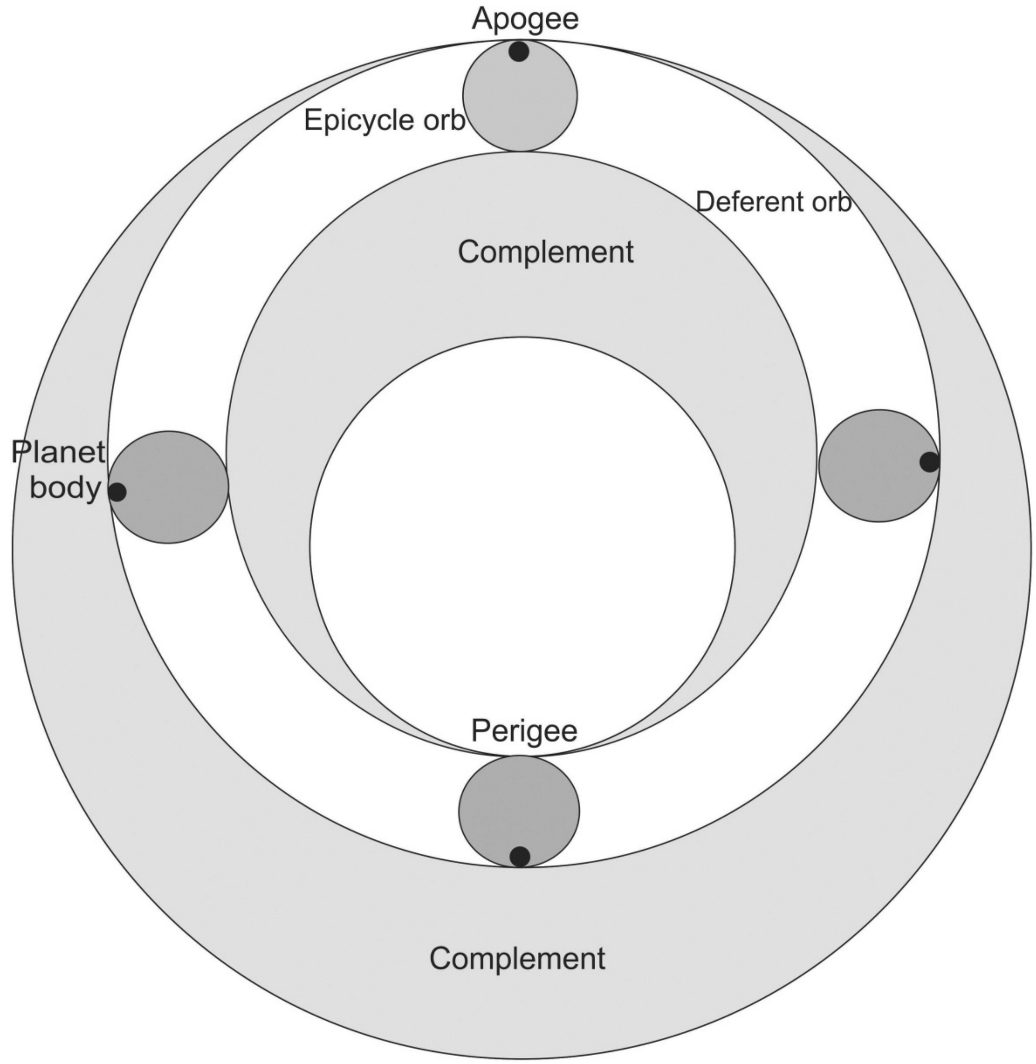
[6] **A planet** in [the epicycle orbs] is a solid, spherical body fixed in the body of the epicycle orb, embedded in it in such a way that its surface is tangent to the surface of the epicycle at a common point between them. The eccentric orbs, with the exception of the Sun, are called **deferents** [sing: *ḥāmil*] on account of their carrying [*ḥaml*] the centers of the epicycles, because they, I mean the centers, are like parts of them [i.e., the deferents].

Illustration of the Sun's Orbs



[Figure 2]

Illustration of the Orbs of the Upper Planets and Venus



[Figure 3]

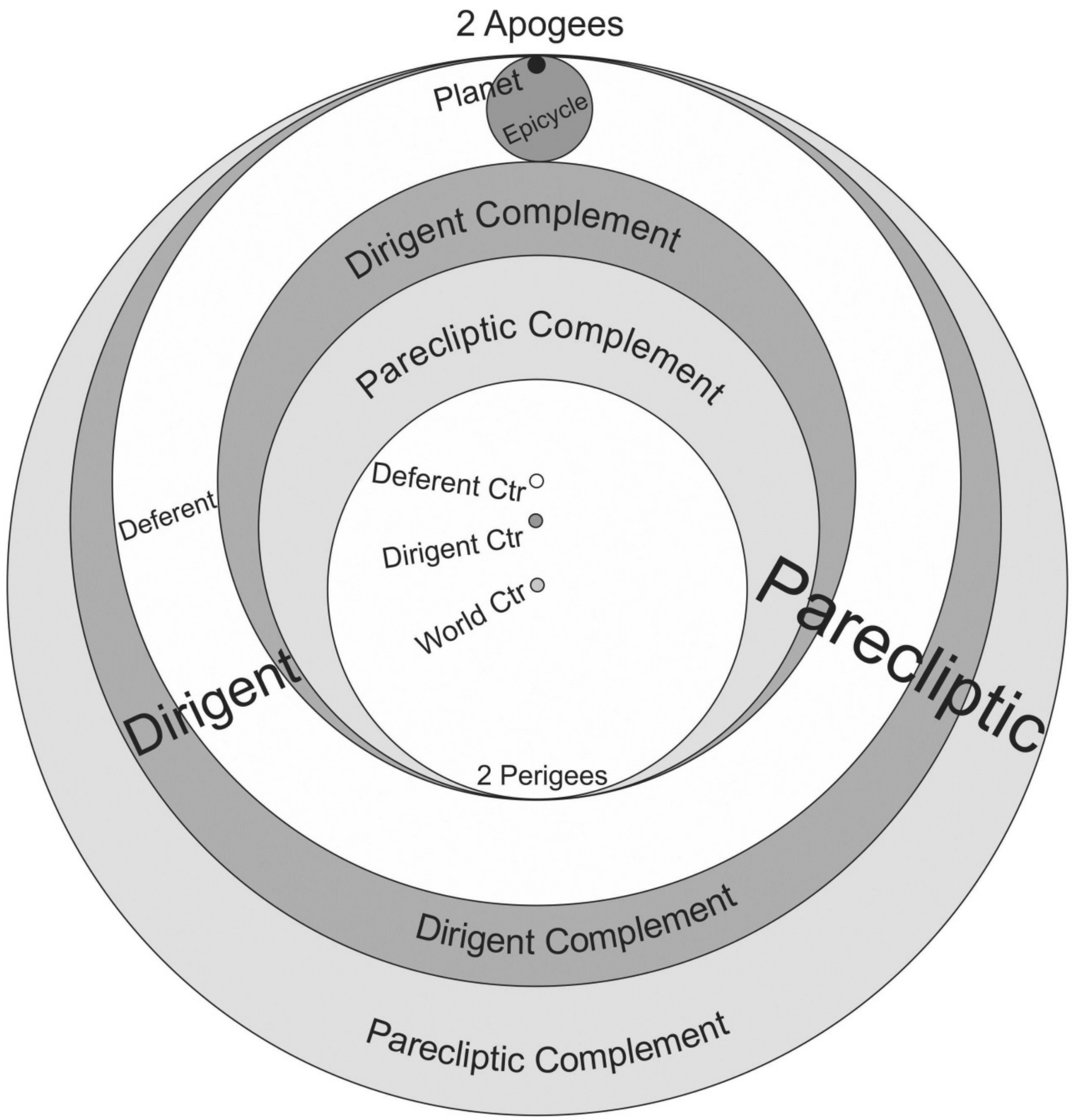
[7] **As for the two orbs of Mercury and the Moon**, each of them consists of three orbs enclosing the Earth and an epicycle orb; however, the orb of Mercury includes an orb, namely the parecliptic, whose center is the center of the world, and two eccentric orbs, one of which, enclosing the other and called the **dirigent**, is within the thickness of the parecliptic as in the illustration. In other words, it is like the other eccentric orbs that are in their parecliptics, whereby its convex [surface] is tangent to the convex [surface] of the parecliptic at a point common to both of them, this being the apogee, and its concave to its concave at a point, this

being the perigee. The second of the two eccentrics, this being the enclosed, is the **deferent** for the epicycle center within the thickness of the body of dirigent as in the illustration. The epicycle orb is in the body of the deferent, and the planet is in the epicycle, according to what we stated for other epicycles. It follows that Mercury has two apogees, one of them being as a part of its parecliptic, and the second as a part of its dirigent.

[8] **The Moon's orb** includes two orbs, their center being the center of the world, and a deferent orb. One of the first two, which encloses the second, is called the ***jawzaharī*** and the parecliptic. The second, called the **inclined,** is in the cavity of the *jawzaharī*, not in its thickness. The deferent is in the thickness of the inclined as in the illustration. The epicycle is in the deferent, and the Moon is in the epicycle, according to what we have stated.

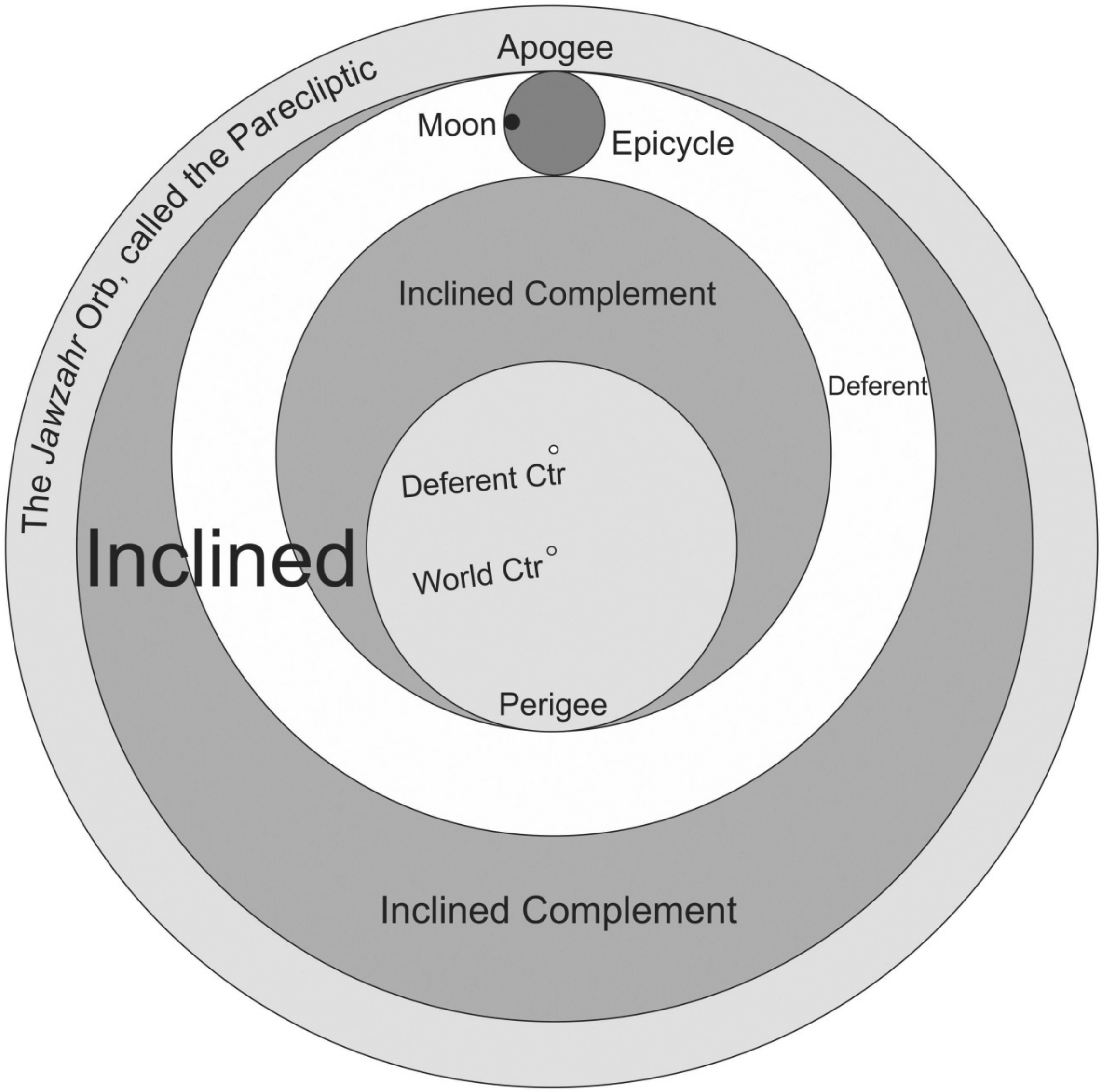
[9] From these circles one may conceive the manner of what we have stated regarding the configurations of the orbs.

Illustration of Mercury's Orb



[Figure 4]

Illustration of the Moon's Orb



[Figure 5]

[10] **As for the Orb of the Fixed Stars**, it being the eighth orb and called the **orb of the ecliptic** [*lit.*, of the signs] whose meaning you will learn about in the chapter on the circles, it is a spherical body whose center is the center of the world. It is a single sphere according to the most correct opinion; the concave of its two surfaces is contiguous with the convex of Saturn's sphere, and its convex is contiguous with the concave of the Great Orb. The fixed stars in their entirety are embedded [and] implanted in it.

[11] **The Great Orb**, called the **Orb of Orbs**, is a spherical body whose center is the center of the world. The concave of its two surfaces is contiguous with the convex of the orb of the fixed stars, and its convex is not contiguous with anything, since there is nothing beyond it, neither vacuum nor plenum.

CHAPTER TWO

of the First Part

On the Motions of the Orbs[4]

[1] The motions of the orbs, in their multiplicity, have two divisions: a motion from East to West and a motion from West to East. As for motion that is from East to West, among these are:

[2] the motion of the Great Orb about the center of the world, this being the rapid motion whereby the rotation [of the orb] is completed in approximately one day and one night. The motion of the remaining orbs and what is in them follows from it, since they are contained within the Great Orb, following as the motion of that contained to the motion of the container. Through it is the rising and setting of the Sun and other planets. This motion is called the **motion of the universe** and **the prime motion**, since among the motions of the celestial bodies it is the first [motion] one perceives and through it the Universe moves; and its two poles are called the **poles of the world**, and its equator the **equinoctial**;

[3] the motion of Mercury's dirigent about its eccentric center. It is called the **motion of the apogee** since in it is the second apogee of Mercury as has come before. [The motion] is upon two poles and an equator that are not the equinoctial and the two poles of the World, nor the ecliptic equator and its two poles; you will learn about both of them later. It is in each nychthemeron [*lit.*, a day with its night] **0;59,8,20**, this being equivalent to the mean [motion] of the Sun, which you will learn about later;

[4] the motion of the Moon's *jawzahar* about the center of the World upon the ecliptic equator and its two poles, it being in a nychthemeron **0;3,10,37**; this is the **motion of the head and the tail**;

[5] the motion of the Moon's inclined orb about the center of the World, upon an equator and two poles that are not the equinoctial nor the ecliptic equator, and not their poles, it being in a nychthemeron **11;9,7,43**; this is the **motion of the apogee of the Moon.**

[4] See the commentary for charts comparing Jaghmīnī's parameters in this chapter with other sources.

[6] As for motion that is from West to East, among these are: the motion of the Orb of the Fixed Stars, it being a slow motion about the center of the World, traverses, according to the opinion of most Moderns, one degree in sixty-six solar years or sixty-eight lunar [years]—and you will learn about both later—upon an equator, also called the **ecliptic orb**, and the **ecliptic equator** [*lit.*, orb of the zodiacal signs and equator of the zodiacal signs], and upon two poles, which are not the World poles, called the **ecliptic poles**. It follows that its equator intersects the equinoctial; this discussion will be completed in the chapter on circles;

[7] the motions of the parecliptic orbs about the center of the World, equivalent to the motion of the Orb of the Fixed Stars and upon its equator and two poles, as if they move with it. These are the motions of the apogees and nodes [*jawzahar*s], except for one of Mercury's two apogees, namely that in the dirigent, and except for the Moon's apogee, its paraecliptic, and its nodes;

[8] the motion of the Sun's eccentric orb upon an equator in alignment with the ecliptic equator, two poles that are not its two poles, and an axis that is parallel to the axis of the ecliptic orb, it being in a nychthemeron **0;59,8,20**;

[9] the motions of the deferent orbs about their eccentric centers, upon equators and poles that are not the two equators of the Great Orb nor the ecliptic orb and their [respective] poles, it being in each nychthemeron:

for Saturn: **0;2,0,35**
for Jupiter: **0;4,59,16**
for Mars: **0;31,26,40**
for Venus: **0;59,8,20**
for Mercury: **1;58,16,40**
for the Moon: **24;22,53,22**.

This motion is called the **mean [motion] of the planet**; it is also called the **motion of latitude**, which is just the **motion of longitude** when added to the ecliptic orb; we will make clearer the explanation of this in the chapter on circles. It is also called the **motion of the center**.

[10] As for the motions of the orbs of the epicycles about their centers, they deviate from what we mentioned, namely the two divisions of motions, because the motions in their upper

parts obviously differ in direction from motions in their lower parts since they do not enclose the Earth. In other words, if the upper motion is from West to East, then the lower motion is from East to West; this is the case for the epicycles of the five vacillating planets.[5] If the upper motion is from East to West, then the lower motion is in reverse; and this is the case for the Moon's epicycle. Nevertheless, what is stated and accepted concerning the course of the epicycles with respect to the ecliptic, this being established in the astronomical handbooks [*zīj*es], is that which is in the sequence of the signs, whether it is for the upper motion as in the case of the vacillating planets or the lower motion as for the Moon. The motions of the epicycles in each nychthemeron are:

for Saturn: **0;57,7,44**
for Jupiter: **0;54,9,3**
for Mars: **0;27,41,40**
for Venus: **0;36,59,29**
for Mercury: **3;6,24,7**
for the Moon: **13;3,53,56**.

This motion is called the **motion of anomaly** and the **proper motion** of the planet; and God knows best.

[5] Jaghmīnī makes a distinction between the word *mutaḥayyira* [vacillating planets], which designates the five retrograding planets, i.e., Saturn, Jupiter, Mars, Mercury and Venus, and the more general term *al-sayyāra*, which designates all seven planets, including the Sun and Moon. For a fuller discussion, see commentary **I.2 [10]**).

CHAPTER THREE

of the First Part

On the Circles

[1] The circle is either a **great [circle]**, which bisects the World and its center is obviously the center of the World, or it is not a great [circle], which does not bisect it, and let it be called a **small [circle].**

[2] **The equinoctial [circle]** [*lit.*, that which balances the day], called the **right orb**, you already know. In fact it is called the equinoctial because when the Sun is on line with it, day and night are "balanced" in all regions, i.e., are equal. The circle located in its plane upon the face of the Earth is called the **equator**, I mean the circle that occurs upon the Earth's surface as we imagine the equinoctial intersecting the World. The circles parallel to [the equinoctial circle] are called **day-circuits**; they are small imagined [circles] that are traced by the rotation of the Great Orb by every point assumed on it.

[3] **The ecliptic circle**, also called the ecliptic orb and the ecliptic equator, you have already learned. The circles that are in its plane, I mean the circles that occur upon the surfaces of the parecliptic orbs when we imagine the ecliptic circle intersecting with the World, are also called parecliptic orbs. With reference to these circles one determines the quantity of **longitude** for the motions of the planets and the Sun; since when we imagine a line extending from the center of the World to the plane of the ecliptic orb passing through the centers of the planets, then if it happens that the endpoint of that line falls on the ecliptic equator, then its point of incidence will be the [projected] position of the planet along the ecliptic equator, and thereupon the planet will have no latitude. [But] if the [endpoint] falls away from the ecliptic equator, we imagine a circle passing through the ecliptic's two poles and the endpoint of that line that intersects the ecliptic equator; then the intersection point between that circle and the ecliptic equator is the position of the [projected] planet along the ecliptic orb, and thereupon the planet will have latitude. So the position of the [projected] planet is one of these indicated points. Then as the planet moves forth, the [projected] point moves along the ecliptic orb; this is the meaning of the motion of the planet in longitude.

[4] The circles parallel to [the ecliptic equator] are called **parallels of latitude**. They are imagined small [circles] that are traced with the rotation of the Eighth Orb by each point assumed on it.

[5] Since the two poles of the ecliptic are not the two poles of the World, it follows that the ecliptic circle will intersect the equinoctial at two opposite points. One of the two, from which the ecliptic orb sets out northward in the sequence [of the signs], is called the **vernal equinox point**; the other [is called] the **autumnal equinox point**. Its maximum distance from it, I mean the distance of the ecliptic circle from the equinoctial, will be at two points: one of the two is toward the north and is called the **summer solstice point**; the other is toward the south and is called the **winter solstice point**. Thereby, then, are designated four points on the ecliptic circle by which it becomes four parts. The period of time the Sun traverses each fourth of [the ecliptic] is the period of one of the four seasons of the year. Then we imagine for each one of two adjoining quarters of the [ecliptic] two points, the distance of each one of them from the other is the same as the distance of the other from the nearest of the two endpoints of the quarter to it. Then we imagine six great circles, all intersecting one another at two opposite points, namely the two poles of the ecliptic: one of them passes through the two poles of the World, the two poles of the ecliptic, and the two solstice points; this is called the **solstitial colure** (*lit.,* the **[great] circle passing through the four poles)**, and its two poles are the two equinox points. The other passes through the two equinox points and its two poles are the two solstice points. The remaining [great circles] pass through the four imaginary points lying in the two designated quarters, and through four other points, being opposite the designated ones, that are on the two remaining quarters facing the designated ones. So the Eighth Orb is thus divided by these six circles into 12 divisions, each division called a **zodiacal sign.** The arc that is between every two of these circles along the ecliptic equator is also called a zodiacal sign; for this reason it is called the ecliptic orb. The parecliptic orbs and also the Great Orb are likewise divided by the imagined planes of these circles into 12 zodiacal signs.

[6] **The horizon circle** is a great circle that separates what is seen of the [celestial] orb from what is not seen; and with reference to it one determines rising and setting. Its two poles are the **zenith** and the **nadir**, and it bisects the equinoctial at two points: one is called the **east point** and [place of] rising of the equinox; the other the **west point** and [place of] setting of the

equinox. The line connecting them is called the **east-west line** and the equinox line. The circles parallel to it are called **almucantars**.

[7] **The meridian circle** is a great circle that passes through the two poles of the World, and the zenith and nadir. Its two poles are the east and west points. It bisects the horizon circle at two points, one of them called the **south point** and the other **the north point**; and the line connecting them is called the **meridian line**. This line and the east-west line are etched on sundials [*rukhāmāt*].

[8] **The altitude circle**, also called **the azimuth circle**, is a great circle that passes through the zenith and nadir, and through the endpoint of a line extending from the World center to the surface of the celestial orb having passed through the center of a star or the Sun. It intersects the horizon circle at right angles at two points that are not fixed but rather shift along the horizon circle commensurate with the shifting of the star or the Sun. Each one of them is called an **azimuth point**. The arc along the horizon circle that is between [one of] them and either the east or west point is called the **arc of the azimuth**; what is between [one of] them and either the north or south point is called the **complement of the azimuth.** This circle coincides with the meridian circle twice in a nychthemeron.

[9] **The circle of the initial azimuth [prime vertical]** is a great circle that passes through the zenith and nadir, and through the east and west points. Its two poles are the north and south points. It intersects the meridian circle at the zenith and nadir points; in fact, it is called by that [name] because when an altitude circle coincides with it, it does not have an azimuth arc. The circuit that is tangent to it is called the circuit of that locality, this [passing through] the zenith for its residents.

[10] **The declination circle** is a great circle passing through the two poles of the equinoctial. With it one determines the distance of a star from the equinoctial and the inclination of the ecliptic orb from the equinoctial, in other words the **first declination,** which you will learn about later.

[11] **The latitude circle** is a great circle that passes through the two poles of the ecliptic, and through the endpoint of a line extending from the World center and passing through the center of a star until the surface of the Great Orb. With it one determines the latitude of the star and the **second declination** of the ecliptic orb from the equinoctial.

[12] The imaginary circles that are traced by the rotation of points in the planetary orbs are either traced on the surfaces of spheres or else not traced on surfaces. The traced [circles] on the surfaces are then: that traced from the motion of the center of the Sun on the circumference of its eccentric orb; and those traced from the motions of the centers of the epicycles on the circumferences of the deferent orbs and from the motions of the centers of the planets on the circumferences of the epicycle orbs. Each of these circles bears the name of the orb on whose circumference it is traced; thus the traced [circle] from the motion of the Sun's center is called the eccentric orb, the traced [circles] from the motions of the epicycle centers [are called] deferent orbs, and the traced [circles] from the planet centers [are called] epicycle orbs. If these deferent orbs and the equator of the inclined orb are assumed to intersect the World, there occurs on the surfaces of the parecliptic orbs, the ecliptic orb, and the Great Orb circles that are called **declination orbs** due to their inclination from the ecliptic orb. Because the motions of the orbs in which [these circles] have been traced occur about poles that are neither the two ecliptic poles nor the two World poles, these being the inclined orbs, they intersect the parecliptics at two points, one of them being the crossing point of the planet on the ecliptic circle toward the north, called the **head**, and the other the **tail.**

[13] Those not traced on surfaces are traced by the deferent center of Mercury and of the Moon through the dirigent's moving of Mercury's deferent and through the incline's moving of the Moon's deferent. These traced [circles] are called the deferent orb of the deferent center, since the deferent center revolves on its circumference.

CHAPTER FOUR

of the First Part

On the Arcs

[1] **The arc** is a segment of the circle's circumference. If that segment is then subtracted from 90 parts, [these] parts being those by which the circumference is 360 parts in total, the excess of 90 over it is called the complement of that arc. An example is what has preceded regarding the arc of the azimuth and its complement.

[2] **The longitude of a locality** is the arc along the equinoctial between the meridian circle at the end of the inhabited region, in other words the beginning of the inhabited region's longitude in the west, which you will learn about later, and the meridian circle for that locality.

[3] **The co-ascension** of each arc along the ecliptic orb is that which rises with it along the equinoctial. The co-ascension will obviously be bounded on the equator between two declination circles since its horizon passes through the two poles of the World and so it is also one of the declination circles. In other words, what is between two declination circles along the equinoctial is the co-ascension for what is between them along the ecliptic orb.

[4] **The co-ascension of a [discrete] part** of the ecliptic orb is an arc along the equinoctial between the head of Aries and the [discrete] part of the [equinoctial] that rises with that part.

[5] **The equation of daylight** for a [discrete] part on the ecliptic orb is the difference between its co-ascension at the equator and its co-ascension at a locality. Let us take an example for this:[6] When the head of Gemini is found toward the east for a horizon other than the equator, and we assume one of the declination circles passes through it and intersects the equinoctial, there occurs a triangle. One of its sides is the declination of the head of Gemini, and you will learn about the declination later. The other two sides are two arcs between the declination circle and the vernal equinox point: one of them is along the ecliptic orb and is called the **equal degrees**; the other is along the equinoctial and is the **co-ascension of the ecliptic arc** for the horizon of the equator. The horizon of the locality divides this triangle into two triangles: one of them is above the Earth and is bounded by the **ortive amplitude** (which you will learn about

[6] For further clarification of the equation of daylight, see Commentary, **Figure C1**.

later) by the aforementioned ecliptic arc, and by the arc along the equinoctial between the vernal equinox point and the horizon. The other triangle is below the Earth and is bounded by the ortive amplitude, by the declination of the head of Gemini, and by an arc along the equinoctial that is between the horizon and the intersection point between the declination circle and the equinoctial. This arc, which is on the equinoctial, is the equation of daylight for the head of Gemini at that locality. Since the sections for horizons will differ from the example of this triangle with the varying latitudes of localities, it necessarily follows that the co-ascension will vary with different latitudes.

[6] **The solar mean** is an arc along the ecliptic orb that is between the first of Aries and the tip of a line extending from the center of [the Sun's] eccentric orb that passes through the center of the Sun and terminates at the ecliptic circle. If that line is assumed to extend from the World center, then the arc along the ecliptic orb that is between its endpoint and the first of Aries is the **true position** [*taqwīm*] of the Sun. What is between the endpoints of the two aforementioned lines is its **equation**. The angle of the two lines intersecting at the sun's center, I mean the angle subtended by the arc of the equation, is the **angle of the equation**.

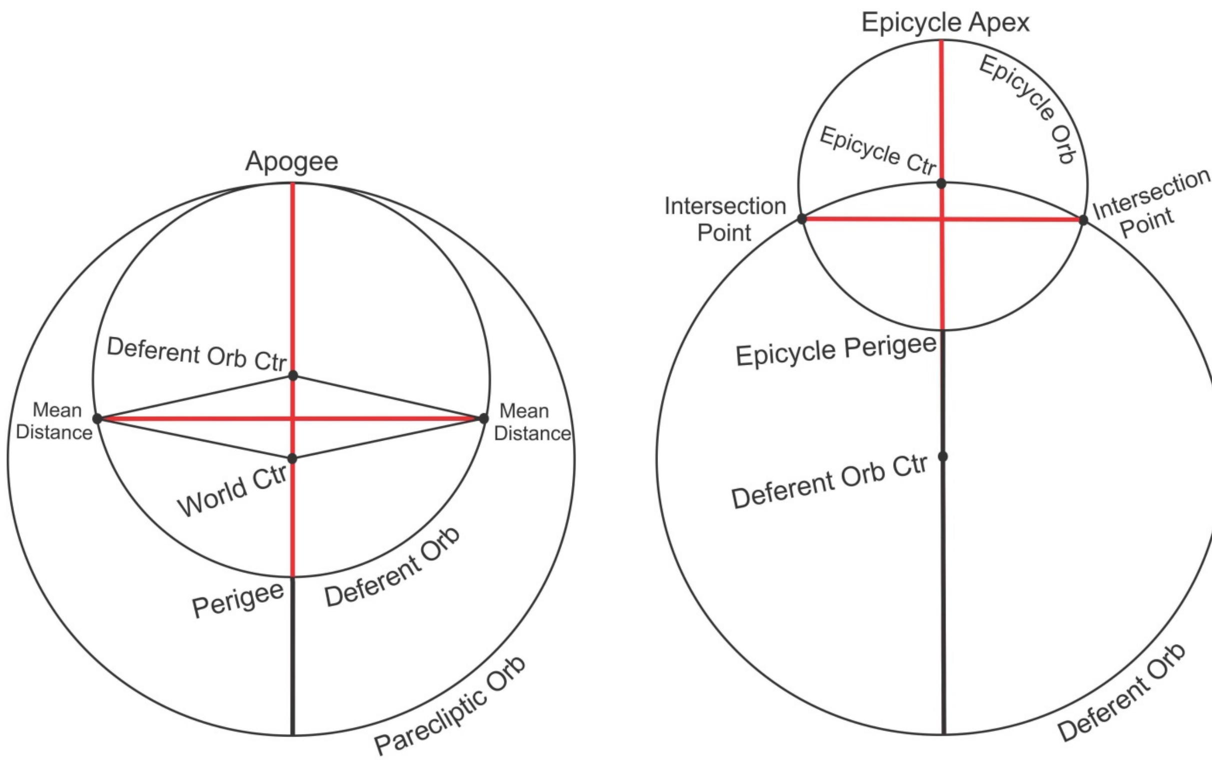
[7] **The planet's mean** is an arc along the ecliptic orb that is between the first of Aries and the endpoint of the line extending from the World center that passes through the epicycle center and terminates at the ecliptic orb, this being when the epicycle center is aligned with one of the two nodal points. Then when it moves beyond [the nodal point] and obtains latitude, the position of the line will fall outside the ecliptic orb, either to the north or to the south. One then imagines a circle passing through its position and the two poles of the ecliptic that intersects the ecliptic orb; then the arc along the ecliptic orb that is between the first of Aries and the intersection point of that circle and the ecliptic circle is **the planet's mean**. If we then assume a line extending from the World center terminating at the ecliptic orb and passing through the center of the planet, then the arc that is between the first of Aries and the endpoint for a planet lacking latitude, or between the first of Aries and the intersection point of the ecliptic orb and the circle passing through the two poles of the ecliptic and the endpoint is the **planet's true position.** What is between the mean and the true position along the ecliptic orb is the **equation**.

[8] On the basis of this meaning [for equation]: when the sun is at the apogee or perigee whereupon the two extended lines coincide—one of them from the World center and the second from the center of its eccentric orb—both passing through [the Sun's] center; or [when] the

planets are at the apices of their epicycles or at their lowest [points], whereupon the two lines extending from the World center coincide—one of them passing through the epicycle center and the second through the center of the planet—there is thereupon no equation.

[9] They divided each one of the eccentric orbs and the epicycles into four disparate parts, two of them being lower and equal, and two upper and equal, that they called **sectors**. They differed concerning the initial [points] of these divisions. Some of them took distance into account, so the eccentric was divided by two lines, one of them extending from the World center to the apogee and perigee, and the other passing through the two mean distances, these being two facing points on the circumference of the eccentric orb where two produced lines are equal, one being from the World center and the other from the eccentric center, that terminate at either [point]. This latter line passes through the midpoint between the two centers. The epicycle is divided by two lines, one of them extending from the deferent center and passing through the epicycle's perigee and center to its apex, and the other passing through the two points of intersection between the epicycle and the deferent.

Illustration of Sectors with Respect to Distance

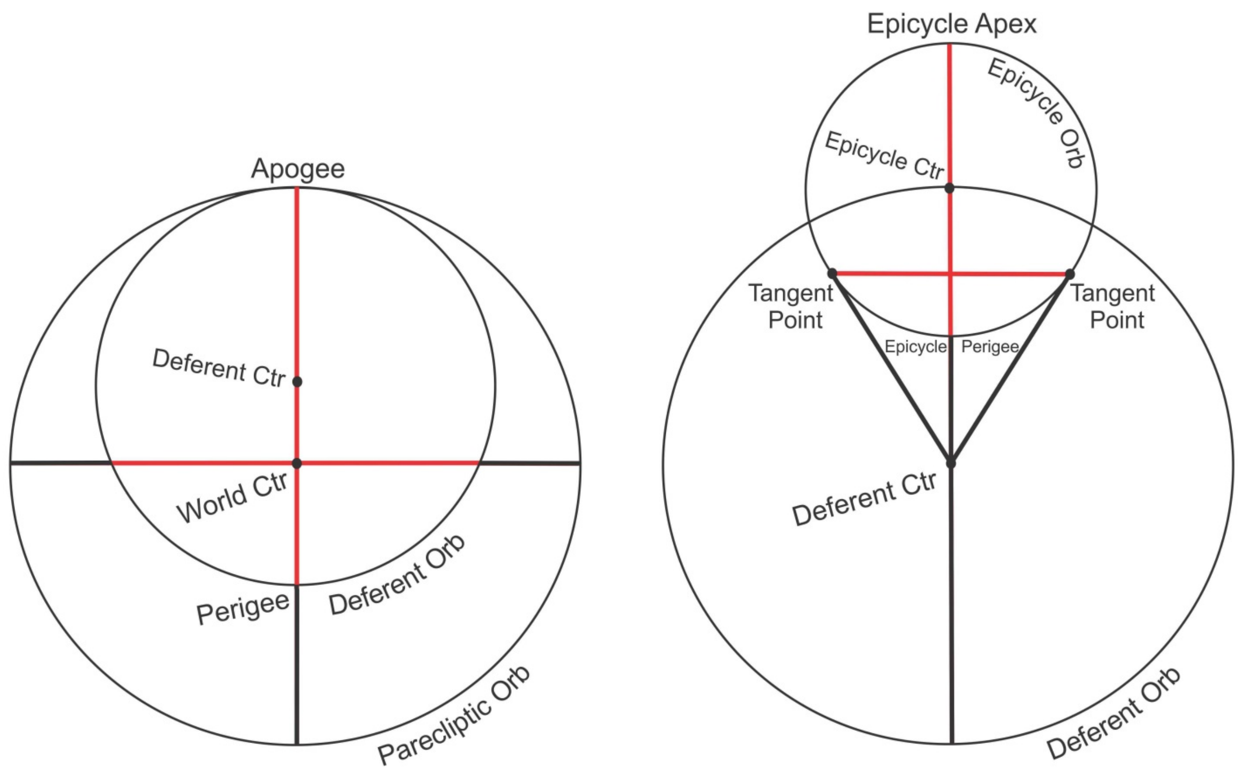


[Figure 6]

[10] Some of them took variable movement into account [in determining the sectors]. Thus the eccentric was divided by two lines, one of them extending from the World center to the apogee and perigee, and the other passing through where the angle of equation is greatest, this being on the apogee side at a distance of 90 parts from it along the parts of the ecliptic orb. The epicycle was divided by two lines, one of them extending from the deferent center and passing through the epicycle's apex and perigee, and the other being perpendicular to it, its two endpoints terminating at the two tangent points between the epicycle circumference and two lines extending to it from the deferent center. Here too is the maximum equation with respect to the epicycle. So the first sector is what the planet reaches after it crosses the apogee or the epicycle's apex, and the second, third, and fourth [sectors] are in the sequence of its motion. As

long as the planet moves from the highest part to the lowest part, i.e., when it is in the first and second sectors of the eccentric or the epicycle, it is descending; and as long as it moves from the perigee to the apogee, i.e., when it is the other two sectors, it is ascending.

Illustration of Sectors with Respect to Variable Movement



[Figure 7]

[11] **The latitude of a locality** is an arc along the meridian circle between the equinoctial and the zenith, and it is equivalent to what is between the horizon and the pole that is on the meridian circle, which is the altitude of the pole, i.e., the nearest of the two World poles to that locality.

[12] **The declination** is an arc along a declination circle between the equinoctial and the ecliptic circle, this being the **first declination. Declination**, when used by itself**,** means the first declination. The **second declination** is an arc along a latitude circle between the two of them, I mean between the equinoctial and the ecliptic circle. **The maximum declination**, called the **total obliquity** [*lit.,* the complete declination] and the **greatest declination**, is an arc between them along the solstitial colure circle; it falls under the definition of [either] the first or second declination. It is the limit of the inclination of the ecliptic circle from the equinoctial, and its amount is **23;35**.

[13] **The planet's latitude** is an arc along the latitude circle between the ecliptic circle and the tip of a line extending from the World center, passing through the planet's center, and terminating at the ecliptic orb. If the arc is along a declination circle between the equinoctial and the aforementioned tip of the line, then it is the planet's distance from the equinoctial.

[14] **The planet's altitude** is an arc along the altitude circle between the tip of the previously mentioned line and the horizon. If the altitude circle coincides with the meridian circle, then this arc is the maximum altitude of the planet.

[15] **Parallax** [*lit.,* divergence of sight] is the arc along the altitude circle between the positions of two lines passing through a planet's center and terminating at the ecliptic orb, one [line] extending from the World center and the other from the perspective of sight, I mean [from] the Earth's surface. This can be found below the Sun's orb, it being small for the Sun's orb, and it is not found beyond it, since the Earth does have a perceptible ratio with respect to what is beyond it.

[16] **The ortive amplitude** is an arc along the horizon circle between the planet's circuit and the rising place of the equinox. Since circuits are parallel to the equinoctial, the ortive amplitude for each planet is the same as its occasive amplitude. The ortive and occasive amplitudes increase with the increase of local latitude.

[17] The **azimuth** and its complement have come before.[7]

[18] The **ascendant azimuth** is an arc along the horizon between the ecliptic orb and an altitude circle.

[7] This was discussed within Part One, Chapter Three: on "On the Circles" (see zenith and azimuth).

[19] The ***qibla*** **azimuth** for a locality is an arc along the horizon between the meridian circle of the locality and a circle passing through the zenith for its residents and through the zenith for the residents of Mecca.

[20] The **arc of daylight** is an arc along the Sun's circuit above the Earth between its setting and rising points. The arc which is between them below the Earth along this circle is the **arc of night**. The **planet's arc of daylight** is an arc along its circuit above the Earth between its rising and setting points. The arc along it that is between them below the Earth is **the [planet's] arc of night**.

[21] **The turning of the orb** is an arc along the circle of the Sun's circuit between its [ecliptic] part and the eastern horizon during daylight; and [an arc] between its facing part and the eastern horizon along the circle of the circuit of its facing part during the night.

[22] The measure of each one of these six arcs[8] is similar to its [corresponding arc] along the equinoctial.

[8] The six arcs are: (1) the arc of daylight; (2) the arc of night; (3) the planet's arc of daylight; (4) the planet's arc of night; (5) the turning of the orb [daylight]; and (6) the turning of the orb [night].

CHAPTER FIVE

of the First Part

On What Occurs to the Planets in Their Motions

[1] **Among what occurs to the planets is longitudinal anomaly: The Sun** has a single anomaly: since it revolves on the circumference of a circle whose center is eccentric from the World center, more than half of it being in one of the halves of the ecliptic orb, namely the half that contains its apogee, and less than half of it in the other half of the ecliptic orb, namely the half of the perigee, and [since the Sun] will only traverse each half of the ecliptic orb by traversing what is on its own circle, it follows that the period in which it traverses one of the halves of ecliptic will differ from the period in which it traverses the other half. Thus its motion is seen in one half of the ecliptic, this being the apogee half, to be slower than its [motion] in the perigee half, since the period in which it traverses the former is longer than the period in which it traverses the perigee half. Its motion on its eccentric orb, this being its mean, does not vary, so therefore one needs to add the equation[9] to or subtract it from its mean in order to ascertain its position on the ecliptic orb.[10]

[2] As for **the remaining planets**, they have numerous anomalies in longitude. One of them, called the **first anomaly**, is what occurs to them on account of their motion along the epicycle circumference. When they [i.e., the planets] are at the epicycle apex or its perigee, the two lines extending from the World center—one of them passing through the center of the epicycle and the other through the center of the planet—will coincide one on the other, and so there will be no difference between the planet's mean and its true position, according to what has come before. As for when [the planets] depart from the apex or perigee, the location of the two aforementioned lines on the ecliptic orb will be different, so there will result a difference between the mean and the true position. The maximum of this anomaly [*lit.*, difference] is where the maximum equation is in the epicycles, and you have learned about this in the chapter on the

[9] See Part I, Chapter 4 ("On the Arcs") where the equation is defined and discussed.

[10] See Commentary, **Figure C2**.

sectors.[11] This anomaly will obviously be in the amount of the radius of the epicycle. The radii of the epicycles at their mean distances are:[12]

for Saturn: 6;30
for Jupiter: 11;30
for Mars: 39;30
for Venus: 45;0
for Mercury: 25;0
for the Moon: 6;20.

[3] **The second anomaly** for the planets is what occurs to them on account of the nearness of the epicycle center to the Earth, and its farness from it on account of the deferent being an eccentric. So the epicycle radius is seen to be greater when it is closer, and its anomaly is greater; and when it is farther away, it is the opposite.

[4] The **third anomaly** is when the centers of the epicycles are at the apogee or perigee, their diameters thereupon coinciding with the line passing through the centers of the World, the deferent, and the epicycle; [but the diameters] do not remain coincident with [this line] when [the centers] depart from the apogee or perigee. Neither do they remain directed toward the deferent center nor the World center, but rather are directed toward another point on that line, which is called the **alignment point** for the Moon and the center of the dirigent line or center of the equant orb for the vacillating [planets]. You will come to know the meaning of this [later] in this chapter.

[5] As for the upper planets and Venus, [the epicycle diameters] are directed toward a point on the side of the apogee whose distance from the deferent center is equal to the distance of the deferent center from the World center, in other words the deferent center is between [that point] and the World center.

[11] See Chapter 4 of Part I (“On the Arcs”).

[12] For this chapter see commentary notes for charts comparing Jaghmīnī’s parameters with Ptolemy’s values and other sources.

[6] As for Mercury, [the epicycle diameter] is directed toward a point midway between the World center and the dirigent center. I will explain this further to you [later] in this chapter.

[7] As for the Moon, [the epicycle diameter] is directed toward a point on the side of the nearest distance whose distance from the World center toward the perigee is equal to the distance of the deferent center from it, in other words from the World center toward the apogee. So when the deferent and its center rotate about the World center by the rotation of the inclined [orb], this point and the deferent center will revolve in alignment upon the circumference of a single circle, i.e., they are at the endpoints of one of its diameters.

[8] So the aforementioned diameters of the epicycles are directed towards these aforementioned points, always being in alignment with them, however they rotate; in other words, if lines are extended from these points to the epicycle centers, every line from them will coincide with the aforementioned epicycle diameter, not separating from it, however it rotates. For the vacillating [planets], this line is called the **dirigent line**; the imagined circle that is traced through the rotation of this line by the epicycle center is called the **equant orb** [*lit*., the orb that equalizes the movement], since the movement of the vacillating [planets] is equalized in relation to it, i.e., [the lines] describe equal arcs on its circumference in equal times. The place this line falls at the upper part of the epicycle is the **mean apex**, and the place the line extending from the World center passing through the epicycle center falls is the **apparent apex**.

The distances of these points and their centers, one from the other

[9] The distance of the eccentric center from the World center is:

for the Sun: 2;29,30

for the Moon: 10;19, and it is equal to the distance of the alignment point from [the World center] in the other direction.

[10] For the vacillating [planets], with the exception of Mercury, [the distance of the eccentric center from the World center] is equal to half the distance of the equant center to it, and that, namely the distance of the equant center from the World center, is:

for Saturn: 6;50
for Jupiter: 5;30
for Mars: 12;0
for Venus: 2;5.

[11] For Mercury, the center of its orb that is the equant is at the midpoint between the center of its dirigent and the World center. The distance of its deferent center from its dirigent center is equal to half the distance of its dirigent center from the World center. As a result, when the dirigent line on the side of the nearest distance coincides with line passing through the centers, the deferent center point falls on the equant center. When it coincides with it on the side of the farthest distance, the centers will be arranged along the line passing through them: first the World center, then the equant center, then the dirigent center, then the deferent center. The distances between them are equal, each of their distances being 3;10, so what is between the centers of the World and the deferent is 9;30.

Among what occurs to the planets is latitudinal anomaly:

[12] **The Sun** has no latitude since in its motion it adheres to the plane of the ecliptic orb.

[13] **The remaining planets** incline from the ecliptic orb to the north and south due to inclination of the inclined orb from it, and it is called the **eccentric latitude**. Its maximum is:

for Saturn: 2;30
for Jupiter: 1;30
for Mars: 1;0
for Venus: 0;10
for Mercury: 0;45
for the Moon: 5;0.

The Moon has only this latitude because its inclined, deferent, and epicycle orbs are in a single plane; by these orbs we mean circles, which you have already learned about.

[14] The vacillating [planets] have another anomaly, namely the inclination of its epicycle apex and its perigee from the inclined orb. It is called the **epicycle latitude** and its maximum is:

for Saturn: 0;32
for Jupiter: 0;38
for Mars: 6;16
for Venus: 1;2
for Mercury: 1;45.

[15] The two lower planets have another proper anomaly, and it is the inclination from the inclined orb of the diameter that passes through the two mean distances of the epicycle orb. It is called the **latitude of the slope** [*wirāb*], **the slant** [*inḥirāf*], and the **twist** [*iltiwāʾ*]. Its maximum for both [i.e., Mercury and Venus] is: 2;30.

[16] As for the inclination of the inclined orb from the ecliptic orb, it is fixed for the upper planets and the Moon and does not change. It is not fixed for Venus and Mercury; rather, whenever the epicycle center reaches one of the two nodal points, the inclined [orb] will coincide with the ecliptic orb. Then when it crosses it, half the inclined [orb], i.e., the half upon which is the epicycle center, inclines: for Venus to the north and for Mercury to the south; its other half is the opposite. The inclination then continues to increase until the [epicycle] center reaches midway between the two [nodal] points, and then the inclination begins to decrease until the inclined [orb] coincides again with the ecliptic orb when the center reaches the other [nodal] point. Then when it crosses it, it returns to its original situation. So it follows that the epicycle center is always north of the ecliptic orb for Venus, and south of it for Mercury.

[17] As for the inclination of the epicycle diameter, I mean the diameter passing through its apex and its perigee, it also is not fixed; rather, for the upper planets it will coincide with the ecliptic orb when the center, i.e., the epicycle center, is at either the point of the head or the tail. Then when the [epicycle] center crosses the head, the apex begins inclining to the south, and it will continue to increase until it attains its maximum when the center reaches midway between the two [nodal] points. Then it begins to decrease until it coincides a second time with the ecliptic orb when the [epicycle] center reaches the tail. Then when it crosses it, the apex begins inclining to the north, its increase, maximum, and decrease as described. It follows that the

inclination of the apex will always be toward the ecliptic orb, and the inclination of the perigee away from it.

[18] For the lower planets, [the epicycle diameter] coincides with the inclined orb when the epicycle center reaches midway between the two [nodal] points, i.e., the two points of the head and the tail; and this [occurs] when the inclination of the inclined orb from the ecliptic orb is at maximum, either at the apogee or at the perigee. Then at the apogee, the epicycle apex begins inclining: for Venus toward the north and for Mercury toward the south; at perigee it is the opposite for each of them. It attains its maximum at the two [nodal] points; and its increase, decrease, and coincidence [occurs] according to the aforementioned description.

[19] As for the slant, it starts when the epicycle center reaches either the point of the head or the tail, and its maximum is when it is midway between the two of them. If the midway [point] is the apogee, the eastern endpoint of the diameter passing through the two mean distances will be at its maximum inclination for Venus to the north and for Mercury to the south, and the western [endpoint] for Venus to the south and for Mercury to the north. And if the midway [point] is the perigee, it is the opposite for both of them.

[20] It has become evident from all of this that the period of rotation for the deferent orb and for the two aforementioned epicycle diameters[13] are equal to one other, and the four quarters of their rotation are equal to one other.

[21] Let us mention here the apogees and the nodes: As for the apogees and the nodes that move with the motion of the orb of the fixed stars: Saturn's apogee is 50 degrees beyond the midpoint between its two nodal points, i.e., from the maximum inclination of the inclined orb from the ecliptic orb, in the sequence of the signs; and Jupiter's apogee is 20 degrees in advance of the midpoint in the counter-sequence [of the signs]. "In advance" means the planet reaches it in advance of reaching the midpoint; as opposed to this is the meaning of beyond. The apogee of the remaining planets is at the midpoint [between the nodes].

[22] As for the position of the apogees, they are for the beginning of the year 1517 of Dhū al-Qarnayn [the two-horned, i.e., the era of Alexander the Great]:[14]

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[13] I.e., one passing through the apex and perigee, and one through the two mean distances.

[14] The date 1517 and Jaghmīnī's parameters for the apogee and nodes are important in establishing that he was alive in 1206 CE (=603 H). Note some copyists and commentators

for the Sun: Gemini 27;10,33
for Saturn: Sagittarius 9;23,33
for Jupiter: Virgo 19;23,33
for Mars: Leo 11;53,46
for Venus: Gemini 27;10,33
for Mercury: Libra 26;23,33.

[23] As for the positions of the nodes for that date, the head node is:

for Saturn: Cancer 19;23,33
for Jupiter: Cancer 9;23,33
for Mars: Taurus 11;53,46
for Venus: Pisces 27;10,33
for Mercury: Capricorn 26;23,33.

[24] Then for every year, one adds to their positions what the orb of the fixed stars moves in the year, and this you have already learned.

[25] **What occurs to the vacillating planets regarding retrogradation, direct motion, and stations:** When the planet is in the upper part of its epicycle, the motion of its center corresponds to the motion of the epicycle center in the sequence of the signs, so it is seen in direct motion, moving swiftly. Then when [the planet] approaches the lower part of the epicycle, it starts to incline counter-sequentially, according to what you have learned regarding the motion of the epicycle about its center.[15] However, as long as the motion of [the planet's] center is counter-[sequential] by a lesser [amount] than the motion of the epicycle center [moving]

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misdate the year as 1317 due to reading ش (300) for ث (500). Rudloff and Hochheim omitted the year altogether in their German translation (see "Die Astronomie des Maḥmûd ibn Muḥammed ibn 'Omar al-Ǵagmînî," p. 253). For more on the significance of this, see the commentary and the chapter on dating Jaghmīnī.

[15] See Part I, Chapter 2 ("On the Motions of the Orbs") on the motion of the epicycle about its center.

sequentially, it is seen in direct motion, but slow in speed. Then when the two [opposite motions] are equal, it is seen to be stationary. Then when the [counter-sequential] motion of the [planet's] center is greater than the motion of the epicycle center, it is seen retrograding. Then after retrogradation, [the planet] is stationary a second time and [then] moves in direct motion for the same reason [as before]. Despite this, [the planet] completes its rotation on its [epicycle] orb without variation occurring to it with respect to its orb. Its stationary position before retrogradation is called the **first station**, and its stationary position after retrogradation is called the **second station**.

[26] The motion of the Moon's center on the circumference of the epicycle orb is less than the motion of the epicycle center on the deferent circumference; on account of this, the Moon is not seen retrograding at all, rather it is seen to be slow in speed.

[27] **What occurs to [the vacillating planets] in relation to the Sun**: As for the upper [planets], the distance of their centers from the apices of their epicycles is always equal to the distance of their epicycle centers from the Sun; thus they will always be in conjunction with the Sun when they are at the apices of the epicycles. So as the Sun moves away from the epicycle center, the planet's center moves away from the epicycle apex in the amount of the [sun's] distance [from the epicycle center], so when the Sun is in opposition to the epicycle center, the planet will have descended to the epicycle perigee. Thus their combusts will always be when they are at the epicycle apex, and their oppositions to the Sun will be when they are at the perigee. It has been said that when Mars is in conjunction with the Sun, the distance between it and the Sun is greater than the distance between it and the Sun when [Mars] is at opposition because the diameter of its epicycle is greater than the diameter of the Sun's parecliptic [orb].

[28] As for the two lower [planets], their two epicycle centers are always aligned with the Sun's center, so both distance themselves from [the Sun] only by the amount of the epicycle radius, i.e., by the amount of the first anomaly, as you have already learned. It follows that both are in conjunction [with the Sun] halfway through direct motion, that being at the epicycle apex and halfway through retrogradation, that being at perigee.[16] Therefore, their mean is the same as the Sun's mean.

[16] Istanbul, Süleymaniye Library, Laleli MS 2141/3, f. 74a adds in the margin: "I.e., since their two epicycle centers are always aligned with the Sun's center."

[29] **What occurs to the Moon in relation to the Sun: the new Moon [*muḥāq*], waxing, full Moon, waning, its eclipsing of the Sun, and lunar eclipses.** The reason for [all] this is that the Moon's body in and of itself is opaque and dark, only becoming illuminated by the light of the Sun, like a mirror. Thus its half facing toward the Sun will always be illuminated, and the other half dark. Then at conjunction the Moon will be between us and the Sun, its dark half is facing us so we will not see any of its light, which is **the new Moon**. Then when it moves away from the Sun an amount of nearly 12 degrees, more or less according to different locations in the inhabited zone, its luminous half will incline toward us so that we see an edge of it, which is **the crescent**. Then as its distance from the Sun increases, the inclination of the luminous [part] toward us increases. So its light increases until when it is in opposition, we come to be between the two and that which faces the Sun faces us, which is **the full Moon**. Then when it departs from being in opposition, some of its dark half inclines toward us; the darkness then begins to increase and the luminous [part] decrease until it is effaced. For this reason, when the Moon is in conjunction on the Sun's path, this being at the head or tail or close to them, it is interposed between the Sun and us, thus concealing its light from us, which is **a solar eclipse**. This blackness that appears in the Sun is the color of the Moon's body; for this reason the blackness of the Sun begins from the western side because the Moon catches up with it from the west. Then when [the Moon] proceeds to transit [the Sun], the reappearance will also begin from the western side due to the explanation we have mentioned. Similarly, when the Moon is on the path of the Sun in opposition, the Earth will interpose between them and its shadow falls on the Moon. So the Sun's light will not reach it, and it then remains in its original darkness, which is **a lunar eclipse**. The beginning of a lunar eclipse and its reappearance will be from the eastern side because the Earth's shadow catches up with it from the western side; so [the Moon's] eastern edge will arrive first into the shadow, and then proceed to blacken first. Similarly, the transit of the [Moon's] eastern edge through the shadow will be first; then it begins to reappear from it.[17]

[30] **Among what occurs to the Moon is that the Sun is always in the middle between the [Moon's] apogee and the center of its epicycle**. The reason for this is that when the [Moon's] epicycle center at apogee is in conjunction with the Sun's center at a point on the

[17] See Commentary for illustrations of the illumination of the Moon in relation to the Sun (**Figure C3**), a solar eclipse (**Figure C4**), and a lunar eclipse (**Figure C5**).

ecliptic orb, say, for example, the head of Aries, and then the apogee moves away from it over a day and its night due to the motion of the inclined [orb] (11;9,7,43) and to the motion of the *jawzahar* (0;3,10,37), then its [combined] motion in the counter-sequence of the signs becomes 11;12,18,20. The Sun moves from it approximately a degree, and the epicycle center moves due to the motion of the deferent 24;22,53,22. Both the motions of the Sun and the [epicycle] center are in the sequence [of the signs]; however, the inclined [orb] turns back the deferent counter-sequentially by the amount of its motion, namely, 11;12,18,20, so there remains for the [epicycle] center sequentially approximately 13;10,35,2, which is the mean motion of the Moon in a day and its night. Then when the solar mean is subtracted from it, and [when the solar mean is] added to the inclined [plus *jawzahar*] motion, the result after the subtraction is the distance of the [epicycle] center from the [mean] Sun, and after the addition, the distance of the apogee of the Moon from [the mean Sun], both being approximately 12;11,26,41.[18] So the Sun is midway between the two; for this reason the motion of the center is called the **double elongation** because when the distance between the [epicycle] center and the [mean] Sun is doubled, it equals the distance between the center and the apogee. It follows that the [epicycle] center at its quadrature to the Sun will be at the perigee, and at opposition and conjunction at the apogee; so the center will have reached the apogee and perigee twice for every rotation.

[31] **Similar to this is what occurs to Mercury's epicycle center** because the motion of its epicycle center, due to the deferent motion, is twice the motion of its apogee that is due to the dirigent motion. However, the dirigent, in the amount of its motion, turns back the deferent; so what remains from the excess motion of the [epicycle] center sequentially is equal to the dirigent motion counter-sequentially. Thus if the two are in conjunction—I mean the [epicycle] center and the apogee that is in the dirigent— in Libra with the other apogee, the parecliptic, [and] they then both move away from [the parecliptic apogee], then whatever distance the [dirigent] apogee reaches counter-sequentially will be reached by the center sequentially. Thus [it follows that] they will both be in conjunction twice per rotation, once in Libra and once in Aries; and they will be in opposition twice when one of them reaches Capricorn, and the other Cancer.

[18] 13;10,35,2 [lunar mean] **– 0;59,8,20 [solar mean]** = 12;11,26,42 and 11;12,18,20 [inclined motion and *jawzahar* motion] **+ 0;59,8,20 [solar mean]** = 12;11, 26,40.

The Second Part

On an Explanation of the Earth and what Pertains to it in Three Chapters

CHAPTER ONE

On the Inhabited Part of the Earth and Its Latitude, Its Longitude, and Its Division into the Climes

[1] The Earth is circular in shape as has been [mentioned] before, and we assume three circles upon it: one of them is in the plane of the equinoctial, and it is the equator as you know; the second [circle] is in the plane of the equator's horizon; and the third is in the plane of the meridian circle that is in the middle of the habitable land through the equator. Then the first cuts the Earth into two halves, a southern and a northern. The second bisects its two halves, so it becomes quarters. The inhabited part of it is one of the two northern quarters as one observes in it mountains, deserts, pastures, seas, and other similar places. Wasteland and the remaining quarters are uninhabitable. The third circle cuts the inhabited part into two halves, a western and an eastern. The intersection point between the first and third [circles] is called the **cupola of the Earth**.

[2] The latitude of the inhabited part is **66** degrees, and its beginning is from the equator; however, **Ptolemy**, after writing the ***Almagest***, claimed that he found habitation below the equator to a distance of **16;25**.[19] So according to this claim of his, the latitude of habitable land is **82;25**. The longitude of the inhabited part is **180;0**, and its beginning is from the west; however, some of them take it to be from the coast of the enclosing ocean and some of them from islands well into this ocean, their distance from the its coast being **10;0**.[20]

[3] This inhabited part was then divided into seven longitudinal sections parallel to the equator. The **first clime** begins from it, and daylight there is always **12** hours, as you will learn; for some of them, it is from where daylight, I mean the longest daylight of the year, is **12;45**

[19] Jaghmīnī is here referring to Ptolemy's *Geography*, which Ptolemy wrote after his *Almagest*.

[20] Jaghmīnī is here referring to the Eternal Islands (*al-khālidāt*), also called the Fortunate Islands (*suʿadāʾ*) [also referred to as the Isles of the Blest, and usually thought to be the Canary Islands].

[hours] and the latitude is **12;30** [degrees]. By consensus, [the clime's] midpoint is where [maximum] daylight is **13;0** [hours] and the latitude is **16;27** [degrees].

[4] The beginning of the **second clime**, and obviously it is the end of the first clime, is where [maximum] daylight is **13;15** [hours] and the latitude is **20;14** [degrees]; and its midpoint is where [maximum] daylight is **13;30** [hours] and the latitude is **23;51** [degrees].

[5] The beginning of the **third** is where [maximum] daylight is **13;45** [hours] and the latitude is **27;12** [degrees]; and its midpoint is where [maximum] daylight is **14;0** [hours] and the latitude is **30;22** [degrees].

[6] The beginning of the **fourth** is where [maximum] daylight is **14;15** [hours] and the latitude is **33;18** [degrees]; and its midpoint is where [maximum] daylight is **14;30** [hours] and the latitude is **36;0** [degrees].

[7] The beginning of the **fifth** is where [maximum] daylight is **14;45** [hours] and the latitude is **38;35** [degrees]; and its midpoint is where [maximum] daylight is **15;0** [hours] and the latitude is **40;56** [degrees].

[8] The beginning of the **sixth** is where [maximum] daylight is **15;15** [hours] and the latitude is **43;51** [degrees] and its midpoint is where [maximum] daylight is **15;30** [hours] and the latitude is **45;1** [degrees].

[9] The beginning of the **seventh** is where [maximum] daylight is **15;45** [hours] and the latitude is **46;51** [degrees]; and its midpoint is where [maximum] daylight is **16;0** [hours] and the latitude is **48;32** [degrees].

[10] According to some of them, its end is at the end of the habitable land; according to others, it is up to where the latitude is **50;25** [degrees]. The latitude, though, from the beginning of the first clime to its midpoint and what is between the middle of the seventh to its end [in both cases] turns out to be greater due to the dispersal of habitation in them. For this reason, they do not count that part of the habitable land below the equator as part of the climes; for this [reason] as well, some of them do not count what is between the equator and latitude **12;30** nor what is between latitude **50:25** to the end of the habitable land. For beyond this latitude are habitations; according to what they have claimed, in latitude **63** is an inhabited island whose residents live in bath-houses due to the severity of the cold[21]; in latitude **64** is a habitation whose residents are an

[21] Jaghmīnī is probably referring to the island Thule, usually thought to be the Shetland Islands.

unknown Slavic people[22]; and [from there] up to latitude 66 are habitations whose residents resemble wild animals.

[22] The unknown Slavic people (the *Ṣaqāliba*) could be a reference to Ptolemy's "unknown Scythian peoples" at 64;30 degrees (*Almagest*, II.6 [30.], Toomer, *Ptolemy's Almagest*, p. 89).

CHAPTER TWO

On the Characteristics of the Equator and Locations Having Latitude

[1] Among the characteristics of the equator are: that the equinoctial is directly overhead for its inhabitants, similarly for the Sun when it reaches the two equinox points; and that its horizon, called the **horizon of the right orb** and the **horizon of the erect sphere**, bisects the equinoctial and all the day-circuits at right angles. The turning of the orb there is wheel-like, I mean similar to the buckets of waterwheels emerging from the surface of the water at right angles. There is no star or point on the orb that does not rise or set, with the exception of the two poles of the World since they are both on the horizon. The arcs of the visible day-circuits are always the same as those below Earth. For this reason, daytime and nighttime are always equal, each of them 12 hours, and the daytime of each star is the same as its nighttime. The greatest inclination of the Sun from the zenith is the same amount northward and southward, this being in the amount of the maximum obliquity of the ecliptic orb from the equinoctial.

[2] **As for the oblique locations** to the north of the equator whose latitude does not reach 90 degrees: among their characteristics is that their horizons, called **oblique horizons**, bisect the equinoctial alone into two [equal] halves, but not at right angles, so the turning of the orb for them is slanted. The [horizons] cut all the day-circuits into two unequal sections; thus the visible arcs for the northern day-circuits are greater than those below the Earth, and for the southern [day-circuits] it is the opposite. For this reason nighttime and daytime are not equal for them, except when the Sun reaches the two equinox points, this being the days of Nayrūz and Mihrjān. Daytime is longer than nighttime when the Sun is in the northern signs, and shorter when it is in the southern signs. The greater the local latitude, the greater will be the difference in amount between nighttime and daytime; obviously, this is due to the zenith being inclined in these locations to the equinoctial. By the amount of its inclination, the northern pole and the day-circuits that are in its direction will be elevated, and the southern pole and the day-circuits that are adjacent to it will be depressed. As the latitude increases, the inclination of the zenith from the equinoctial will increase, so the altitude of the northern pole and the day-circuits adjacent to it increase; the excess of their visible arcs will then increase over those below the Earth. The depression of the southern pole and the day-circuits near it will then increase as [also] the excess of their arcs that are below the Earth over the visible ones. For each day-circuit whose distance

from the northern pole is equal to the pole's altitude, then all that is in it and all the stars up to the northern pole that its circle contains will be permanently visible; its corresponding [day-circuit] on the southern side, with all that is in it, is permanently invisible.

[3] **Those locations whose latitude does not reach 90 degrees have divisions**, each division having characteristics: Among them are **the locations whose latitude is less than the maximum obliquity** of the ecliptic orb from the equinoctial. The Sun is directly overhead for its inhabitants twice per year, this being when it reaches two points, each on [one of] the two sides of the summer solstice point, whose declination from the equinoctial is equal to the local latitude.

[4] Among them are **the locations whose latitude equals the maximum obliquity**. The Sun is thus directly overhead once per year, this being when it reaches the summer solstice point. Those locations from the equator to this latitude have two shadows, i.e., the straight shadow [*umbra recta*] in them, which you will learn about, will sometimes at noon be toward the south and at other times to the north. [Locations] from this latitude to latitude 90 have one shadow, i.e., the shadow is only toward the north.

[5] Among them are **[the locations] whose latitude is greater than the maximum obliquity**. The Sun is thus not directly overhead for its inhabitants.

[6] Among them are **[the locations] whose latitude equals the complement of the obliquity, this being 66;25.**[23] When the ecliptic pole reaches the meridian circle by the motion of the Universe, it will be at the zenith, whereupon the ecliptic circle coincides with the horizon; so Aries is at the east point, Capricorn is at the south point, Libra at the west point, and Cancer is at the north point. Then when [the pole] departs from the zenith, six zodiacal signs rise in one stroke, and they are those in the eastern half along the horizon, namely from Capricorn to Cancer; and the other six set in one stroke. The circuit of Cancer[24] here does not set because of what was [said] before, so when the Sun reaches it, it does not set until it has passed it. So the longest day is 24 hours and similarly the longest night, since [the former] is in the amount that occurs for the northern day-circuits of permanent visibility; and the magnitude of the visible arcs

[23] 66;25 is the complement of Jaghmīnī's value for the total obliquity, i.e., 23;35 (see his discussion on the declination in Part One, Chapter Four, "On the Arcs").

[24] "Cancer" here should be understood as Cancer 0˚.

ensues in their counterparts of permanent invisibility and in the magnitude of the arcs that are below the Earth.

[7] Among them are **[the locations] whose latitude exceeds the complement of the obliquity**, i.e., over 66;25. So the ecliptic pole[25] is inclined away from the zenith toward the south in the amount of the excess of the latitude over 66;25; and it follows that those [northern] parts of the ecliptic orb whose declination from the equinoctial is greater than the colatitude of the locality do not set.

[8] A way to facilitate conceiving this is for us to assume the ecliptic pole is on the meridian circle, which is then inclined southward from the zenith on the part [of the meridian] that is toward the south; and in the amount of its inclination, the head of Capricorn will be depressed below the horizon in the south, and the head of Cancer will be elevated in the north. [That part of] the equinoctial that is toward the south [on the meridian] is above the horizon, and its altitude is in the amount of the difference of the latitude from 90 degrees, which is the colatitude, I mean [the latitude's] "completion", and it is known as the complement of the arc.[26] So the [southern] parts on the ecliptic orb whose declination from the equinoctial is less than the colatitude will therefore be, along with the equinoctial, obviously above the horizon [when] toward the south; those whose declination is equal to the colatitude will touch the horizon, not being depressed from it [at that time]; and those whose declination is greater than the colatitude will obviously be depressed [below the horizon] and will thus be permanently invisible. The permanently invisible is obviously an arc along the ecliptic orb whose midpoint is the winter solstice point. The period of time the Sun traverses this arc with its proper movement is the length of the longest nighttime for that locality; and the counterpart of this arc along the northern signs is permanently visible, as you have learned, and the period of time the Sun traverses this counterpart is the length of the longest daytime for that locality. Among these localities are those where the length of their daytime amounts to approximately six months and likewise the length of nighttime.

[25] As noted by ʿAbd al-Wājid, what is meant here is the ecliptic pole on the meridian at its highest altitude (Istanbul, Süleymaniye Library, Laleli MS 2127, f. 112b).

[26] See Part One, Chapter Four, "On the Arcs."

[9] It happens that for part of the ecliptic orb that rises there [i.e., locations whose latitude is between 66;25 and 90], it will rise in reverse order and set in regular order. This is in the half of the ecliptic orb that is from Capricorn to Cancer; so Gemini rises before Taurus, Taurus before Aries, and [continuing] according to this pattern. For part of it, it will rise in regular order and set in reverse order, this being in the other half of the ecliptic orb; so Sagittarius sets before Scorpio, Scorpio before Libra, and [continuing] according to this pattern.[27]

[10] A way to facilitate conceiving this is that if we take the ecliptic pole to be on the meridian circle toward the south from the zenith, then half of the [ecliptic] orb from Aries to Libra is visible in sequence toward the north, and the other half is invisible toward the south. The head of Aries is on the east point, and the head of Libra is on the west point. Hence Aries will have risen before Pisces, and Libra will have set before Virgo. Then when the ecliptic pole inclines away from the meridian circle toward the west while Aries is ascending, that which is contiguous with Aries toward the south, namely the end of Pisces, begins to rise counter-sequentially until the rising of Pisces is complete. Then Aquarius begins rising similarly. Setting is likewise: I mean that Libra having set, its head being at the west setting point. So when [Libra] has set and become depressed, that which is contiguous with it, namely the end of Virgo, begins to set counter-sequentially with it; and [continuing] according to this pattern.

[11] When we take the head of Cancer to be on the meridian circle toward the south, from Libra to Aries is toward the north below the horizon, and the other half is visible. Then Virgo will have risen before Libra in regular order. Then when the head of Cancer inclines away from the meridian circle, Libra begins to rise in regular order as we have stated. Since that which sets faces that which rises, then that facing what rises in reverse order will set in reverse order, and vice versa.[28] And since the rising in one of the two halves of the [ecliptic] orb in terms of order is

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[27] Note that the vernal equinox (Aries 0˚) is the midpoint in the first half of the ecliptic (i.e., rising in reverse order and setting in regular order), and the autumnal equinox (Libra 0˚) is the midpoint in the second half (i.e., rising in regular order and setting in reverse order) (cf. ʿAbd al-Wājid, Istanbul, Süleymaniye Library, Laleli MS 2127, f. 115a). Aries and Libra are obviously in the two different halves.

[28] According to ʿAbd al-Wājid, "vice versa" here means "that facing what rises in regular order will set in regular order" (Istanbul, Süleymaniye Library, Laleli MS 2127, ff. 118b-119a).

contrary to the rising in the second [half] but matches the setting,[29] it follows that the rising of each half will be contrary to its setting, so what rises in reverse order will set in regular order, and vice versa.[30]

[12] **As for the locations whose latitude is 90 degrees**, the World pole corresponds to the zenith there. The equinoctial is coincident with the horizon circle, and the rotation of the [celestial] orb is spinning parallel with the horizon. A year there is a day and a night, being six months of daytime—this when the Sun is in the northern signs—and six months of nighttime—this when the Sun is in the southern signs. There nothing of the orb has a rising or a setting; instead, its northern half is permanently visible and its southern half is permanently below the Earth.

[13] We have only described specifically the northern locations because in them is the inhabited world. Since everything pertaining to them that we have described is due to their inclination from the equator toward the north, a comparable situation pertains to southern locations due to their inclination toward the south.

[14] Now then, instruction of the above is sufficient for understanding this [topic].

[29] See Commentary chart.

[30] In other words, what rises in regular order sets in reverse order.

CHAPTER THREE

Miscellaneous Items

[1] The **ascendant** is the part [i.e., point] of the ecliptic orb on the horizon that is toward the east. The **degree of rising of the star** is the degree of the ecliptic orb that rises with the rising star. The **degree of transit of the star** is the degree of the ecliptic orb that transits the meridian circle along with the transit of the star. Then if the star is [aligned] with one of the two solstice points or it has no latitude, its degree, i.e., [the star's projected] place on the ecliptic orb, is its degree of transit; and if it has latitude and is not [aligned] with the solstice point, then not. This is because when the star is between the first of Cancer and the end of Sagittarius it reaches the meridian circle after its degree [of transit] if it has a northern latitude, and in advance of it if it has a southern latitude. When [the star] is in the other half of the ecliptic orb,[31] the reverse will hold since the [northern] ecliptic pole will be easterly when the first half is on the meridian; the circle passing through [the pole] and through the degree of the star is then inclined toward the west and will reach a star with northern latitude first and then its degree. Thus the star is farther from the meridian than its degree, so it arrives on it after it but before it if it has southern latitude for this very same reason. What is between the star's [longitudinal] degree and its degree of transit is called **the transit difference.** You should follow this same approach for **[the star's] degree of rising**. As for the right orb, the rules for this are exactly the same. As for the inclined orbs, one needs to take into account the horizons.

[2] **The shadow** is taken either: from a gnomon erected parallel to the plane of the horizon, and is called the first shadow, the *umbra versa*, and the erect; or from a vertical gnomon perpendicular to the plane of the horizon, and is called the second shadow and the *umbra recta*.[32] The gnomon is sometimes divided into twelve divisions called digits, sometimes into seven or six and a half divisions called feet, and sometimes into sixty divisions called units. When the

[31] I.e., between the first of Capricorn to the end of Gemini.

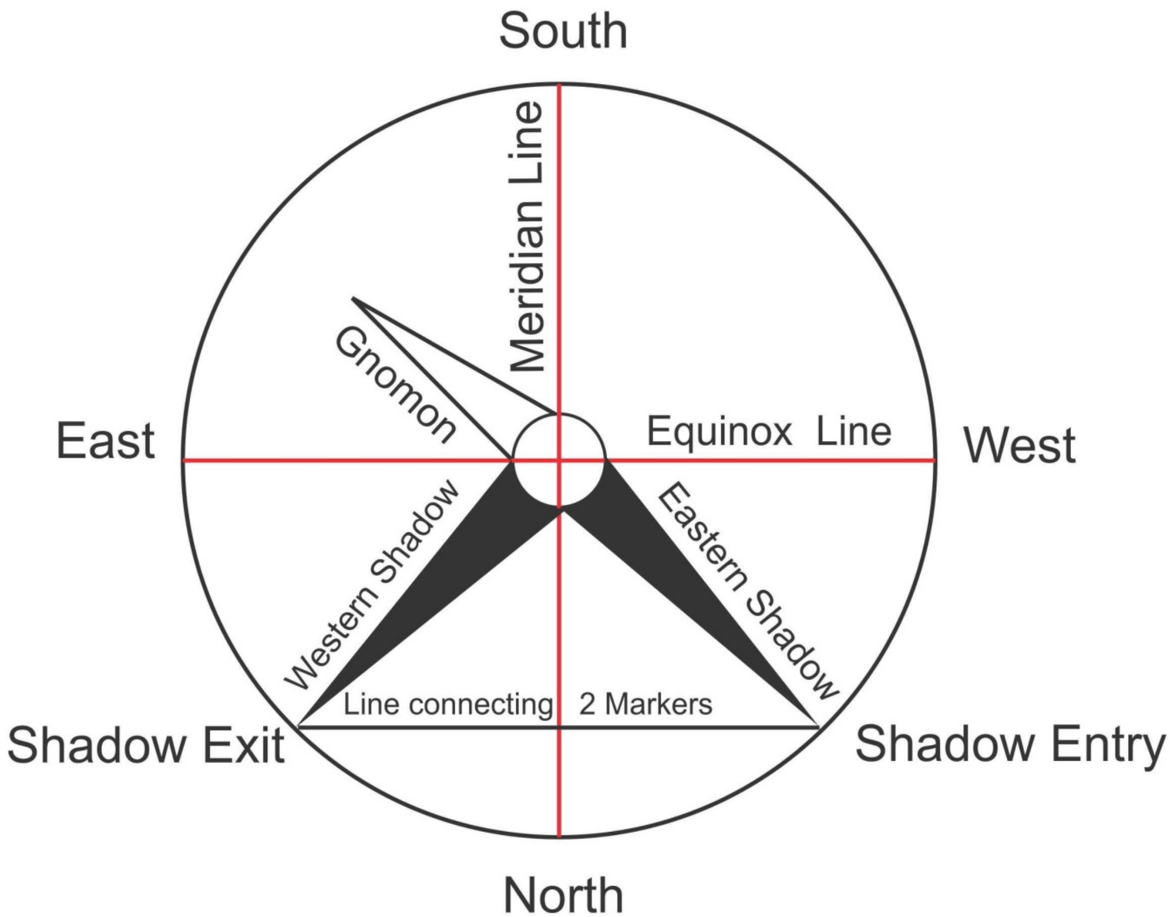
[32] The horizontal gnomon, parallel to the horizon plane, is called *maʿkūs* [*umbra versa*], because it produces a reversed shadow directed toward the ground, and erect (*muntaṣib*) in that the shadow is perpendicular to both gnomon and ground. The vertical gnomon, called the *mustawī* [*umbra recta*], produces a direct/straight shadow parallel to the horizon plane.

shadow reaches its limit at the Sun's maximum altitude, it is then the start-time for the noon [*ẓuhr*] prayer. The start-time for the afternoon [*ʿaṣr*] prayer is, according to al-Shāfiʿī— may God have mercy upon him—when that limit is increased by the equivalent of the gnomon [length], and according to Abū Ḥanīfa— may God be pleased with him —it is when it has increased by twice the gnomon [length].

[3] **On determining the meridian line and the equinox line**: land is leveled in such a way that if water were poured over it, it would flow evenly in all directions. Then a circle of any size is constructed on [the land]; this circle is called the **Indian circle**. A conic gnomon is erected at its center with a height one fourth its diameter at a right angle, which can be determined by either a plumb-line[33] or by measuring an equal amount between the tip of the gnomon and the circumference from three points on the circumference. The tip of the shadow is observed when it arrives at the circumference on the western part before diminishing [at noon], and afterwards on the eastern part. Each of the two arrival points is marked and the arc between them is bisected; you produce a line from [the arc's] midpoint that passes through the center to whatever distance you wish. This then is **the meridian line**, and it cuts the circle into two halves. Then you produce a line from the midpoints of the [circle's] two halves that intersects the meridian line at the center at right angles; this is the **east-west line**.

[33] *al-shāqūl* (the plumb-line or plummet) is a suspended string with an attached weight that points towards the Earth's center of gravity.

Illustration of the Indian Circle



[Figure 8]

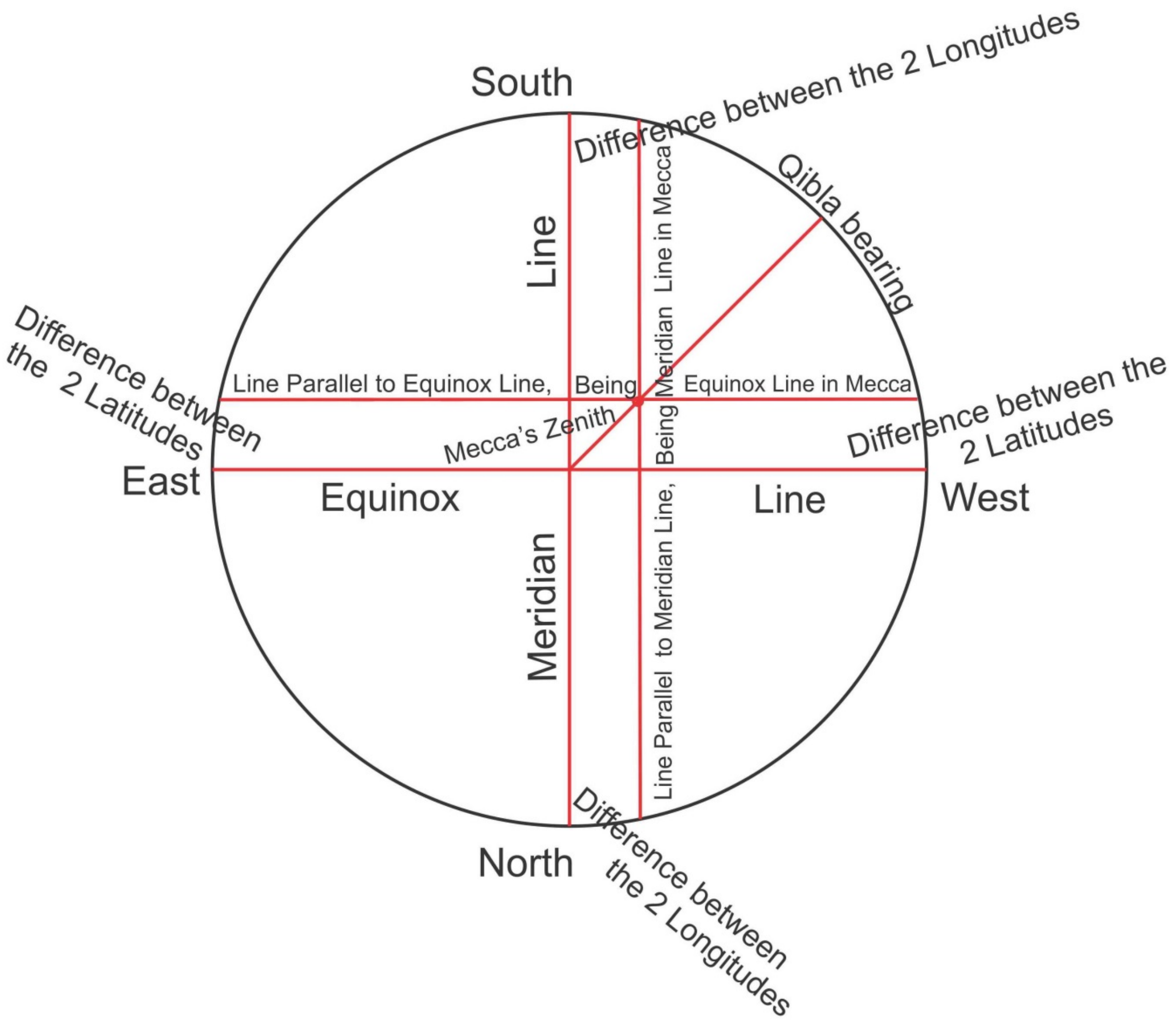
[4] **On determining the *qibla* bearing:** we mean here by the *qibla* bearing, a point on the horizon [such] that when a person faces it he will also be facing the Kaʿba. Since the longitude and latitude of Mecca are less than the longitude and latitude of our locality, we count along the Indian circle from the south point toward the west the amount of the difference between the two longitudes, and its equivalent from the north point. We join what is between the two endpoints with a straight line. We count from the west point toward the south the amount [of the difference] between the two latitudes, and its equivalent from the east point; we join the two endpoints with a straight line. The two lines will then obviously intersect one another. We now produce a line from the center of the circle to their intersection point, and we extend it to the circumference. This line then is in the direction of the *qibla*, and the arc between the [line's] endpoint and the south point is the **arc of the *qibla* bearing,** it being the amount that the

worshipper should incline away from the south point. Do something comparable when the longitude or latitude, or both, of Mecca is greater.

[5] If the longitude of the locality equals the longitude of Mecca, then the *qibla* is on the meridian. If its latitude equals Mecca's latitude, then make note that the degrees of the ecliptic orb that pass overhead for the people of Mecca during a rotation are Gemini 7;21 and Cancer 22;39. Place it, I mean one of two [ecliptic degrees], on the mid-heaven line of the astrolabe that has been constructed for the latitude of the locality. Put a mark at the position of the "almuri"[34]; then turn the rete [*lit.*, spider] toward the west by the difference between the two longitudes if the locality is toward the east, and the reverse if it is toward the west. So wherever the [chosen ecliptic] degree lands on the altitude almucantars, you will observe the Sun when it reaches that altitude and erect a gnomon; then its shadow at that time is the bearing for the *qibla*.

[34] The almuri, known as the tooth (or denticle) of Capricorn, is the marker located at the head of Capricorn which juts out from the astrolabe rete, and can be used for various calculations such as here for longitude difference. Cf. Bīrūnī, *Tafhīm*, pp. 194 (no. 325).

Illustration of the Qibla bearing



[Figure 9]

[6] **On daytime, nighttime, hours, the year, and the month:** When the Sun's light falls on the Earth, its face toward the Sun is illuminated and its shadow falls opposite the direction of the Sun. So when the Sun is above the Earth, then it is daytime since the only light distinguishing daytime is the Sun's light; when [the Sun] is below the Earth, its shadow falls above it, and it is nighttime. The [Earth's] shadow occurs in the shape of a cone, since the Sun is of a greater size than the Earth. Then when the Sun is below the Earth near the horizon, the shadow cone is inclined away from the zenith, and the air illuminated by the Sun's light is nearby so light

appears on the horizon; and as the Sun comes nearer, light predominates and red appears, as is the case of dusk and dawn.

[7] The **nychthemeron** [*lit*., a day with its night] is the time between the Sun's departure from the meridian circle until it returns to it with the motion of the Universe; but according to people at large, it is from the setting of the Sun to its equivalent. Its beginning could be the departure of the Sun from any assumed point on the orb; however, the calculators and the astral practitioners have conventionally taken its beginning to be from the meridian circle because the variations in the ascensions with respect to the horizons of the inhabited regions are many, [but] it has only one variation with respect to the meridian circle because the meridian circle for all inhabited regions serves as a horizon for the equator. The time of a nychthemeron exceeds one rotation of the Universe by the co-ascension of what the Sun has traveled along the ecliptic orb; and since the Sun cuts off arcs of variable [sizes] along the ecliptic orb, then its co-ascensions will be variable. Furthermore even if the Sun were presumed to cut off arcs of equal size, the co-ascension of the equal arcs would not be equal. So due to these factors the nychthemerons are variable. Thus [the practitioners] classified the nychthemeron into a true and a mean. The true is the time of return of an equinoctial point to a given point plus the time to traverse the co-ascension of what the Sun has traveled during [the motion of] that given(!) point; the mean is the time of return of an equinoctial point to a given point plus the time to traverse an equinoctial arc that is equal to the sun's [daily] mean, namely 0;59,8,20, during [the motion of] that point. This is recorded in the ***zījes*** [astronomical handbooks]**.** The difference between the true and the mean is called the **equation of the time** [*lit.,* the equation of the days with their nights].

[8] The **duration of daytime** is from the rising of the Sun to its setting, and in law [*sharʿ*] from the rising of dawn [*al-fajr*] to the setting of the Sun; and from its setting to the Sun's rising is the **duration of nighttime**, and in law to the rising of dawn. Then [practitioners] divide the daytime and the nighttime into regularized hours and **seasonal** [*lit.,* temporal] **hours**. Regularized hours, called **equal hours**, are in the amount by which the Universe rotates 15 degrees. Then if one divides the arc of daylight or the arc of night or an arc of the orb's rotation by 15, the result is the number of regularized hours for that day or night, or a period within the day or night. The seasonal hour, called **unequal** [*lit.,* distorted], is always one of 12 parts of daytime or nighttime; so if daytime is longer than nighttime, its hours are longer than the night hours, and if [daytime is] shorter, its hours are shorter. When the arc of daylight or the arc of

night is divided by 12, the result is what the orb rotates in each seasonal hour, which is in parts of the seasonal hour called **units of time.** It has thus become clear that regularized hours are those whose number varies according to the length and shortness of daytime, but their units of time do not vary; seasonal hours are those whose units of time vary, but their number does not vary.

[9] **The year** is the time from the Sun's departure from any given point on the ecliptic orb until it returns to it with its proper motion, which it has from west to east. [The practitioners] began this year from the time the Sun is situated at the head of Aries, but they differed on the duration of this year. For some of them said 365¼ days; according to Ptolemy, 365¼ days less 1/300 part of a day; and according to Battānī 365¼ days less 3 parts 24 seconds out of 360 parts of a day. What is intended here by a day is the nychthemeron. The above is a **solar year;** as for the **lunar year**, it is 12 months.

[10] **The month** is the time from the Moon's departure from any given position it has from the Sun until it returns to [that position]. The most obvious position is the crescent (*hilāl*). However, the sighting of the crescent varies according to changes in inhabited regions, so one only takes it into account for religious matters. The beginning of the month was set from the conjunction of the Sun and Moon, and [the month's] duration is between two conjunctions with the mean motion of the two luminaries: they take away the Sun's mean [motion] from the Moon's mean,[35] and they divide the remainder by the rotation of the orb, namely 360 degrees, thus resulting in 29;31,50,8 days, which is the amount of a month. They then multiplied that by 12, obtaining the days in a lunar year: 354 + 1/5 + 1/6 days. This year is less than the solar year by approximately 10 days and 20½ hours.

[11] This is as much as allowed by [my] ignoble character, a tormented mind, thought befuddled by preoccupations beyond counting, and concerns [so overwhelming] they would make a mother neglect her child. I have gone to great lengths to elucidate and illuminate the content with concise and succinct expressions, fulfilling the obligations of obeisance and service while guarding against the tedious and the cluttered. This volume that I have presented is perhaps enough to attain what I desired, faithful to what has been indicated above. So it is best that I limit myself to that, so let this be the end of the book.

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[35] 13;10,35,2 [Moon's mean] minus 0;59,8,20 [Sun's mean] = 12;11,26,42 [remainder] (see Part One, Chapter 5).

Colophons

MS B, p. 64 (ب):

And God is most knowing of truth, and to Him are the refuge and the final return.

MS S, f. 82b (س):

And God is the One who bestows success and from Whom one seeks assistance, and in Whom is the greatest trust. The completion of its copying occurred during the night of Friday, the nineteenth of the month of Dhū al-qaʿda of the year 787 [Thursday evening-Friday morning, 21-22 December 1385 CE]. Praise be to God alone, and may God bless our master Muḥammad and his family and grant them salvation.

[A note in another hand]: The reading of this under the Shaykh ʿAlāʾ al-Dīn the Timekeeper was completed at the beginning of the month of Rabīʿ II of the year 788 [early May 1386 CE] in Aleppo, may God extend its duration.

MS F, f. 19b (ف):

And God is the One who bestows success and from Whom one seeks assistance, and in Whom is the greatest support and trust. The completion of its copying occurred on day 2 [i.e., Monday], the 29th of the blessed month of Rabīʿ I in the year 786 hijra [probably, Sunday-Monday, 22-23 May 1384 CE].

MS K, f. 38b (ك):

And God is the One who bestows truth. Praise be to God alone, and may God bless our master Muḥammad and his family and companions and grant them salvation. On the date of the year 764 [1362-3 CE], may God make its outcome favorable by His grace and munificence.

MS L, f. 81a (ل)

With God is success. The book was completed, the book was completed [*sic*] in the months of 644 hijra [1246-7 CE].

PART III

§ III.2 Commentary to the Edition and Translation

[Preface]

The *Mulakhkhaṣ* has three different preface versions; however starting with **Pref. [2]**, **"The Introduction is about an explanation of the divisions of the bodies in general terms,"** the three versions converge enough to allow them to be collated as a single version, with variants noted in the critical apparatus, and a full translation of the alternative prefaces given in the notes to the English translation.The five witnesses I selected for the Arabic edition and English translation all contain Jaghmīnī's "original" parameters; in general, these values are either Ptolemaic or ones that Jaghmīnī refers to as "Modern", usually meaning from the ninth century (see *al-Mulakhkhaṣ* **I.2 [6]**). Most of the later copies of the *Mulakhkhaṣ* and commentaries have updated at least some of these parameters, the most obvious examples occurring in the listing of the climes and their parameters (Part Two, Chapter One) that can be shown to derive from Ṭūsī's *Tadhkira* (see Commentary, **II.1 [4]**, on the second clime). This provides us with a convenient means of differentiating witnesses that are closer to Jaghmīnī's original version from those that have been "updated."

<u>**Version 1**</u>: The preface in this version contains both a dedication by Jaghmīnī to Badr al-Dīn al-Qalānisī and a poem he composed to commemorate being entrusted with such a lofty command. The poem, which I have metered below, has a *khafīf* rhyme*:

يا لَها مِن إشا رَ ةٍ صَدَ رَتْ لي / رَ فعَتْ رُتْـــبَتي وَأعْـــلَتْ مَحَلْلي

- - u u̲ | - u - u̲ | - - u u̲   - - u u̲ | - u - u̲ | - - u u̲

صَدَرَتْ لي مِنَ الْكَريـــمِ الْمُرَجْجي / بَدْرِدين الْـــهُدي الإمـا مُ الْأَجَلْلِ

- - u u̲ | - u - u̲ | - - u u̲   - - u u̲ | - u - u̲ | - - u u̲

قَدْ رَ آ نـــي أَهْلاً لِأمْـــرٍ خَطيرٍ / لَيْـسَ مَثْلي لِمِثْـلِ ذاْ كَ بِأَهْلِ

- - u u̲ | - u - u̲ | - - u u̲   - - u u̲ | - u - u̲ | - - u u̲

غير أنْ ني بَذَلْتُ في ذاْ كَ جُهْدِي / اِمْتِـــثالاً لِأَمْــرِهي أيْـيَ بَذْلِ

- - u u̲ | - u - u̲ | - - u u̲   - - u u̲ | - u - u̲ | - - u u̲

قَدْ دَعاني لِذاْكَ لُطْـــفاً وَبَرْراً / لا افْتِقاراً إلى بِضا عَة مِثْلي

- - u u̲ | - u - u̲ | - - u u̲   - - u u̲ | - u - u̲ | - - u u̲

Oh what a proposal came my way;	it raised my rank and it advanced my standing.
It came to me from the noble one who inspires hope;	the highly esteemed Imām, the full moon [Badr] of the true religion.
He considered me worthy for a momentous task;	[but] the likes of me is not worthy of such a thing as that.
Nevertheless, I expended every effort for that;	complying with his command whatever sacrifice.
He called upon me for that in kindness and piety;	not requiring the offerings of such as myself.

[*For the *khafīf* meter, see W. Stoetzer, "Prosody (*ʿarūḍ*)," in *Encyclopedia of Arabic Literature*, ed. Julie Scott Meisami and Paul Starkey (London, 1998), vol. 2, pp. 619-22, at p. 621. I am extremely grateful to Prof. Emeritus Issa Boulata for his assistance in this metering as well as for delightful discussions with him about Arabic verse.]

Unique to Version 1 is the added nisba ***al-faqīhī*** to Jaghmīnī's name **Maḥmūd ibn Muḥammad ibn ʿUmar al-Faqīhī al-Jaghmīnī al-Khwārizmī (Pref. [1])**. I did not translate this since it is not clear what it refers to. Most likely it simply means that he was someone who came from a family of jurists, but it could also be an indication that he was an esteemed scholar, a reciter of the Qurʾān, or a school master.

This version also contains honorifics for both Jaghmīnī and Qalānisī, implying both are deceased; however these were presumably added later by the copyists. In this version, Jaghmīnī informs us that his motivation for composing the *Mulakhkhaṣ* is that **the dearest of friends and the sincerest of companions** conveyed to him that master Badr al-Dīn proposed that he compile a book on *ʿilm al-hayʾa*.

For Version 1, I used the following 3 manuscripts:

- س [= S] Paris, Bibliothèque nationale MS ar. 2330, ff. 48b-82b;

  copied 787 hijra [1385 CE]
- ف [= F] Philadelphia, University of Pennsylvania, LJS 388, ff. 2b-19b; copied 786 hijra

  [1384 CE]
- ب [= B] Berlin, *Staatsbibliothek,* MS or. oct. 1511, pp. 6-64;

  copied 1275 hijra [1858-9]

MS B is contaminated (not surprising given its late copy date) and contains variants that distinguish it from MS F and MS S, both of which are more closely aligned. Its preface also has a part similar to MS L (Version 3); however, because it contains both the dedication and the poem, I included it in Version 1.

<u>Version 2</u>: The preface in this version contains only Jaghmīnī's dedication to Badr al-Dīn al-Qalānisī, and not his poem. Here Jaghmīnī states that his motivation for composing a work on *ʿilm al-hayʾa* came directly from Badr al-Dīn himself (and not from an intermediary) whom he describes as **the dearest of friends and the sincerest of companions**, rather than his "master." For Version 2, I used one manuscript:

- ك [= K] Cambridge UK, Cambridge University Library Or. 593(7), ff. 1b-38b; copied 764 hijra [1362-3 CE]

Version 3: This version contains neither the dedication nor the poem.Unique to Version 3 is that Jaghmīnī states that he **composed this book on *hayʾat al-ʿālam*** (Cosmography of the World), rather than *ʿilm al-hayʾa* (the science of *hayʾa*), **as a memento for every scholar seeking an epitome on [*hayʾa*]**.

The beginning to Version 3 (with minor variations on it) is the most widespread preface for the *Mulakhkhaṣ* as well as for the commentaries.

For Version 3, I used 1 manuscript:

- ل [= L] Istanbul, Süleymaniye Library, Laleli MS 2141/3, f. 61b-81a; copied 644 hijra [1246-7 CE], and the oldest witness to date

See **PART II, §II.1 – § II.2:** "Editorial Procedures" and a "Description of the Manuscripts."

The First Part: On an Explanation of the Orbs and What Pertains to Them

PART I, CHAPTER 1: On the Configurations of the Orbs

I.1 [1]. For every sphere whose two surfaces are parallel, the center of their two surfaces is the [sphere's] center: Clearly by "*kura*" Jaghmīnī means "*falak*". Cf. the *Tadhkira*, I.1 [10] and I.1[15], where Ṭūsī clearly differentiates between a complete sphere and an orb, which may be either a complete or hollowed-out sphere (F. J. Ragep, *Tadhkira*, pp 96-99).

I.1 [6]. The **Illustration of the Sun's Orbs [Figure 2]** is placed after this paragraph (i.e., **[6]**) in MS F (f. 4a) and MS S (f. 52a). MS S also juxtaposes this illustration with the illustration of the orbs of the Upper Planets and Venus [**Fig. 3**], whereas MS F omits the latter illustration entirely. MS S then places the illustrations for Mercury [**Fig. 4**] and the Moon [**Fig. 5**] together on f. 52b after **I.1 [9]**, whereas MS F places these last two illustrations consecutively on the next two pages (ff. 4b-5a), but also after **I.1 [9]**. MSS B, K, L place all four illustrations (i.e., the orbs of the Sun, Upper Planets and Venus, Mercury and the Moon) together after **I.1 [9] (**see MS B [p. 13]; MS K [f. 5a-5b]; and MS L [ff. 64a-65b]).

I.1 [8]. The Moon's orb includes two orbs, their center being the center of the world, and a deferent orb: Note that the Moon should consist of four, not three, orbs. Jaghmīnī does not count the epicycle orb as the fourth orb.

PART I, CHAPTER 2: On the Motions of the Orbs

I.2 [3]. It is in each nychthemeron [*lit.*, a day with its night]: For comparative technical definitions of nychthemeron, see Ṭūsī, *Tadhkira*, III.8 [1], "On the Lengths of the Nychthemerons" (Ragep, *Tadhkira,* pp. 286-87); and Bīrūnī, *Tafhīm*, p. 51 (no. 132).

I.2 [6]. … according to the opinion of most Moderns: "Moderns" here refers to the astronomers of Maʾmūn (r. 813-833) and their immediate successors, in distinction to Ptolemy who has a value of 1˚ /100 years. In comparison, Farghānī is committed to the Ptolemaic value of 1˚ /100 years, and states a complete revolution occurs in 36,000 years (*Jawāmiʿ*, ch. 13, pp. 49-50). However, al-Battānī uses 1˚ /66 years in his *Zīj* (vol. 3, ch. 52, pp. 192-93), which Jaghmīnī follows in his calculations for the values of the apogees and nodes (see *Mulakhkhaṣ*, Part I, Ch. 5). Kharaqī also gives 1˚/66 years in the *Muntahā* (p. 180: Bāb 8, Faṣl 2) as does Ṭūsī in his *Tadhkira,* II.4 [4] (Ragep, *Tadhkira*, pp. 122-25). See also F. J. Ragep, "Al-Battānī, Cosmology, and the Early History of Trepidation in Islam," pp. 282, 290.

I.2 [7]. These are the motions of the apogees and nodes [*jawzahar*s], except for one of Mercury's two apogees, namely that in the dirigent, and except for the Moon's apogee, its paraecliptic, and its nodes: Ṭūsī (II.7 [8]) may have had Jaghmīnī in mind when he criticizes those who say "the motion of the fixed starts is indistinguishable from the other lunar motions" for failing to point out that the reason for this is that the perceptible motion is a *composed* motion of the excess of the moon's nodes over the fixed stars (Ragep, *Tadhkira,* pp. 150-53).

I.2 [9]. It is also called the motion of the center: According to Ṭūsī (II.7 [10]): "It is called the motion of the center because the epicycle center is moved by it this amount" (Ragep, *Tadhkira*, pp. 152-53).

Below is the first of several charts I have compiled for this commentary that lists parameters contained in the *Mulakhkhaṣ* for various motions, and compares them with other sources.

ON THE SOURCES:

In the *Mulakhkhaṣ* Jaghmīnī mentions two authorities: Ptolemy (**II.1 [2]** and **II.3 [9]**) and Battānī (**II.3 [9]**). Regarding Ptolemy, he specifically mentions the *Almagest,* and he alludes to his *Geography* (**II.1 [2]**). For Ptolemy's parameters, I relied on G. J. Toomer, *Ptolemy's Almagest* and Olaf Pedersen, *A Survey of the Almagest* (and especially convenient is his listing of many Ptolemaic values in "Appendix B: Numerical Parameters," pp. 423-29). Ascertaining parameters attributed to Battānī proved more challenging than simply relying on Carlo Nallino's seminal 3-volume edition, translation, and commentary of Battānī's *Kitāb al-Zīj al-ṣābiʾ (Opus astronomicum)*; Nallino provides Battānī's values only to sexagesimal minutes whereas Jaghmīnī also give seconds. Consequently, I used the following sources: E. S. Kennedy's "A Survey of Islamic Astronomical Tables" **[=K]**; Battānī's parameters as reported by other primary sources such as Kūshyār ibn Labbān (fl. late-10th/early-11th c.) in his *Jāmiʿ Zīj* (Istanbul, Fatih 3418, f. 44a); and Battānī's parameters preserved in the fourteenth-century Persian *Zīj-i Ashrafī* by Abī ʿAbd Allāh Sanjar (see Fateme Savadi and Sajjad Nikfahm Khubravan **[=S-K]**, esp. p. 374). For Kharaqī, I used witness copies of his *Muntahā* and the *Tabṣira* (noting any discrepancies between the two treatises); page numbers refer to Ghalandari's edition and Persian translation of the *Muntahā* (2012).

[S]: sequence of the signs (west to east)

[CS]: counter sequence of the signs (east to west)

	Jaghmīnī, ***Mulakhkhaṣ*** **[=M]**	**Ptolemy,** ***Almagest*** **[=A]**	**Farghānī,** ***Jawāmiʿ*** **[=J]**	**Battānī,** ***Zīj*** **[=Z]**	**Ṭūsī,** ***Tadhkira*** **[=T]**
VARIOUS MOTIONS OF MERCURY AND THE MOON (I.2 [3-5])					
Mercury [dirigent**]** **[CS]**	**0;59,8,20** M: **I.2 [3]**	0;59,8,17,13,12,31 A: IX.4 (p. 441)	Same as mean Sun J: ch. 14 (p. 58)	**0;59,8,20**,46 S-K (p. 374)	Same as mean Sun T: II.8[9] (pp. 166-7)
Moon [parecliptic with jawzahar] **[CS]**	**0;3,10,37** M: **I.2 [4]**	--	3′ J: ch. 13 (p. 52)	**0;3,10,37**,18,40,26 K (p. 156) or **0;3,10,37**,17,40,26 S-K (p. 374) or approx. 0;3 Z: v. 3, ch. 30 (p. 76)	3′ plus a fraction T : II.7[8] (pp. 150-1)
Moon **[**inclined orb] **[CS]**	**11;9,7,43** M: **I.2 [5]**	--	11;9 J: ch. 13 (p. 52)	11;12 – 0;3 = 11;9 Z: v. 3, ch. 30 (p. 76)	11;9 T: II.7[9] (pp. 152-3)
MOTION IN A NYCHTHEMERON (I.2 [8])					
Sun	**0;59,8,20** M: **I.2 [8]**	0;59,8,17,13,12,31 A: III.2 (p. 143)	ca. 59′ J: ch. 13 (p. 50)	**0;59,8,20**,46,56,54,14 Fatih 3418, f. 44a; K (p. 156)	no value given T: II.6[5] (pp. 148-9)
Also: **Kharaqī's *Muntahā***, Bāb 8, Faṣl 2 (p. 180): ca. 59;8 ; **Bīrūnī, *Qanūn*** (p. 688): 0;59,8,40,7,56,33					

MOTIONS OF THE DEFERENT ORBS ABOUT THEIR ECCENTRIC CENTERS IN A NYCHTHEMERON (I.2 [9])					
	Jaghmīnī	**Ptolemy**	**Farghānī**	**Battānī**	**Ṭūsī**
Saturn **[S]**	**0;2,0,35** M: **I.2 [9]**	0; 2,0,33,31,28,51 A: IX.4 (p. 429)	ca. 2′ J: ch. 14 (p. 59)	**0;2,0,35**,55,48,3 Fatih 3418, f. 44a; or 0;2,0,36,4,43,2,8 K (p. 159)	2′ T: II.9[8] (pp. 180-1)
Jupiter **[S]**	**0;4,59,16** M: **I.2 [9]**	0;4,59,14,26,46,31 A: IX.4 (p. 432)	ca. 5′ J: ch. 14 (pp. 59- 60)	**0;4,59,16**,54,54,57 Fatih 3418, f. 44a or **0;4,59,16**,19,53,47,11, 20 [K (p. 159)]	5′ T: II.9[8] (pp. 180-1)
Mars **[S]**	**0;31,26,40** M: **I.2 [9]**	0;31,26,36,53,51,33 A: IX.4 (p. 435)	ca. 31′ J: ch. 14 (p. 60)	**0;31,26,40**,15,11,13 Fatih 3418, f. 44a; or **0;31,26,39**,**36**,34,5,16, 50 [K (p. 159)]	31′ T: II.9[8] (pp. 180-1)
Venus **[S]**	**0;59,8,20** M: **I.2 [9]**	0;59,8,17,13,12,31 A: IX.4 (p. 438)	same as Sun J: ch. 14 (p. 59)	**0;59,8,20**, 46 [see Sun] or for Sun 0;59,8,20,33,53,4,29, 40 [K (p. 159)]	same as sun T: II.9[8] (pp. 180-1)
Mercury **[S]**	**1;58,16, 40** M: **I.2 [9]**	0;59,08,17,13,12,31 [twice this amount] A: IX.4 (p. 441)	twice the Sun J: ch. 14 (p. 58)	twice the Sun [see Sun]	twice the Sun T: II.8[10] (pp. 168-9)
Moon **[S]**	**24;22,53,22** or 24;23,53,22 or 24;23 M: **I.2 [9] ***	12;11,26,41,20,17,59 [twice this amount or double elongation] A: IX.4 (p. 187)	24;23 J: ch. 13 (p. 51)	**24;23** Z: v. 3, ch. 30 (p. 76)	24;23 T: II.7[10] (pp. 152-3)

* **I.2 [9]. for the Moon: 24;<u>22</u>,53,22**. This value is in MS F (6a), MS K (f. 7b), and MS L (f. 66b). MS B (p. 16) rounds it to 24;**23**, as does Ṭūsī (II.7 [10]; Ragep, *Tadhkira*, pp. 152-53). These MSS then also agree with 24;23 found in Battānī's *Zīj*. Only MS S (f. 54b) has 24;**23,**53,22, which is the variant written unambiguously (since he wrote it out) in ʿAbd al-Wājid's commentary (Istanbul, Süleymaniye Library, Laleli MS 2127, f. 26b). Nevertheless, it is more decisive that Jaghmīnī repeats the value 24;**22,**53,22 in **I.5 [30]**, in his discussion of "What occurs to the Moon."

MOTIONS OF THE EPICYCLES IN EACH NYCHTHEMERON (I.2 [10])					
	Jaghmīnī	**Ptolemy**	**Farghānī**	**Battānī**	**Ṭūsī**
Saturn	**0;57,7, 44** M: **I.2 [10]**	**0;57,7,43**,41,43,40 A: IX.4 (p. 429)	57′ J: ch. 14 (p. 59)	**0;57,7,44**,48 S-K (p. 374)	='s excess of Sun's mean over planet's mean T: II.9[11] (pp. 182-3)
Jupiter	**0;54,9,3** M: **I.2 [10]**	**0;54,9**,**2**,**46**,26,0 A: IX.4 (p. 432)	54′ J: ch. 14 (p. 59)	**0;54,9,3**,52 S-K (p. 374)	='s excess of Sun's mean over planet's mean T: II.9[11] (pp. 182-3)
Mars	**0;27,41,40** M: **I.2 [10]**	0;27,41,0,19,20,58 A: IX.4 (p. 435)	28′ J: ch. 14 (p. 60)	**0;27,41,40** S-K (p. 374)	='s excess of Sun's mean over planet's mean T: II.9[11] (pp. 182-3)

Venus	**0;36,59,29** 0;37 or 0;37,19,29 M: **I.2 [10]***	0;36,59,25,53,11,28 A: IX.4 (p. 438)	37′ J: ch. 14 (p. 59)	**0;36,59,29**,27,42,45 Fatih 3418, f. 44a or **0;36,59,45**,27,42,45 S-K (p. 374) **0;36,59,29**,28,42,45 K (p. 156)	0;37 [S in upper half] T: II.9[11] (pp. 182-3)
Mercury	**3;6,24,7** M: **I.2 [10]**	**3;6,24,06,59**,35,50 p. 441: IX.4	3;6 J: ch. 14 (p. 58)	**3;6,24,7**,45,53,33 Fatih 3418, f. 44a or **3;6,[2]4,7**,45,53,33 K (p. 156)	3;6 T: II.8[13] (pp. 170-1)
Moon	**13;3,53,56** M: **I.2 [10]**	**13;3,53,56**,17,51,59 IV.3-4	13;4 J: ch. 14 (p. 51)	**13;3,53,56**,17,51,59 Fatih 3418, f. 44a or 13;4 Z: v. 3, ch. 30 (p. 77)	13;4 [CS in upper half] pp. 154-5 (II.7[13])

*** I.2 [10]. The motions of the epicycles in each nychthemeron are…for Venus: 0;36,59,29:** This value is in MS K (f. 7b), however it has been changed in MS F (f. 6a), MS L (67a), and MS S (f. 55a) to 0;37,19,29. The source of 0;37,19,29 is not clear, but ʿAbd al-Wājid's *Sharḥ al-Mulakhkhaṣ* gives it unambiguously (but without explanation) (Laleli MS 2127, f. 28b). MS B (p. 17) has 0;37 (and this is the value given by several sources such as Ṭūsī and Farghānī), but obviously this approximation could apply to either 0;36,59,29 or 0;37,19,29. On the other hand, our earliest *Mulakhkhaṣ* commentary by Alānī (Istanbul, Topkapı Sarayı Müzesi, Ahmet III MS 3308, f.25a) has 0;36,59,29; and so does Battānī, whose values Jaghmīnī seems to rely on throughout. See also E. S. Kennedy, *A Survey of Islamic Astronomical Tables*, pp. 156, 159.

I.2 [10]. … this is the case for the epicycles of the five vacillating planets:

Throughout the *Mulakhkhaṣ* Jaghmīnī uses the word *mutaḥayyira*, which I have translated as vacillating planets, in order to designate the five retrograding planets, namely Saturn, Jupiter, Mars, Mercury and Venus (see **I.2 [10]**, **I.5 [4]**, **I.5 [10]**, **I.5 [14]**, **I.5 [25]** and **[27]**). This term does not include the Sun and the Moon, which are also "planets" [i.e., "wandering stars" with respect to the "fixed stars"]; for the general term, Jaghmīnī uses the word *al-sayyāra,* but this only once (**I.3 [12]**). Jaghmīnī's distinction between *al-mutaḥayyira* (for the *five* planets) and the more general *al-sayyāra* (for the *seven* planets) is most likely due to his following Kharaqī in his *Muntahā al-idrāk fī taqāsīm al-aflāk*:

...الكواكب السيّارة، أعني الشمس والقمر والكواكب المتحيّرة...

The wandering planets [*al-kawākib al-sayyāra*], i.e., the Sun, Moon and the vacillating planets [*al-kawākib al-mutaḥayyira*]

(See Ghalandari, "A Survey of the Works of 'Hayʾa' in the Islamic Period with a Critical Edition, Translation and Commentary of the Treatise *Muntahā al-Idrāk fī Taqāsīm al-Aflāk* written by Bahāʾ al-Dīn al-Kharaqī (d. 553 AH/1158 AD)," p. 172 [42]; cf. Berlin, Staatsbibliothek, Landberg MS 33, f. 8b.)

Exactly when this distinction between *sayyāra* and *mutaḥayyira* came into general use is not clear. In the *Planetary Hypotheses*, planets [πλανώμενοι] is translated as *mutaḥayyira* (see Goldstein, "The Arabic Version of Ptolemy's Planetary Hypotheses," p. 13 [variant in MS L; Heiberg, 70, title], p. 15 [lines 10 and 15; Heiberg, 76, lines 20 and 29]). For the last case, MS L correctly translates τὰ ἀπόγεια τῶν ε̄ πλανωμένων as وأوجات الكواكب الخمسة المتحيّرة

[apogees of the five planets], seeming to imply that there is a special category for five of the planets. But already in Khwārazmī's tenth-century *Mafātīḥ al-ʿulūm* (pp. 210, 228) and Bīrūnī's eleventh-century *Qānūn* (vol. 3, p. 987) a clear distinction is made between *sayyāra* for the seven planets and *mutaḥayyira* for the five (Kunitzsch, "al-Nudj̲ūm," in *Encyclopaedia of Islam*, 2nd ed., vol. 8, p. 101a).

PART I, CHAPTER 3: On the Circles

I.3 [12]. The imaginary circles that are traced by the rotation of points in the planetary orbs are either traced on the surfaces of the spheres or else are not traced on the surfaces: It is not clear whether the words "by the rotation of points in the planetary orbs" were in the original version of the text; they are found in MSS K and L. MS S (f. 58) and MS F (f. 7b) added this in their margins (and both had correction marks). MS B (p. 22) had a variant that was an incomplete sentence.

I.3 [13]. Only MS B (p. 23) adds an additional sentence at the conclusion of this paragraph, which marks the end of Chapter 3, to the effect that the equant orb is one of "the traced circles": "it being a circle traced by the motion of the line extending from a point that toward which the epicycle's diameter is always directed however it turns." The fact that this variant also states that a further clarifying explanation of this is in the chapter on circles clearly makes it suspect given that this *is* the chapter on circles. Princeton, Garrett MS 373 (p. 343) also includes a modified version of this sentence; however it states that the clarifying explanation is given in chapter five, which is correct.

PART I, CHAPTER 4: On the Arcs

I.4 [3]. The co-ascension of each arc along the ecliptic orb is that which rises with it along the equinoctial: There is a variant in MS B (p. 24) that is also given as an alternative reading in the margin of MS S (f. 59a) with only minor variations. The variant states: "Among [the arcs] is the co-ascension: when an arc rises along the ecliptic circle, there then necessarily rises with it an arc on the equinoctial, and that arc on the equinoctial is called the co-ascension of that arc along the ecliptic orb."

I.4 [5]. The equation of daylight… Let us take an example for this: Below is a three-dimensional rendition of Jaghmīnī's passage.

Illustration of the Equation of Daylight

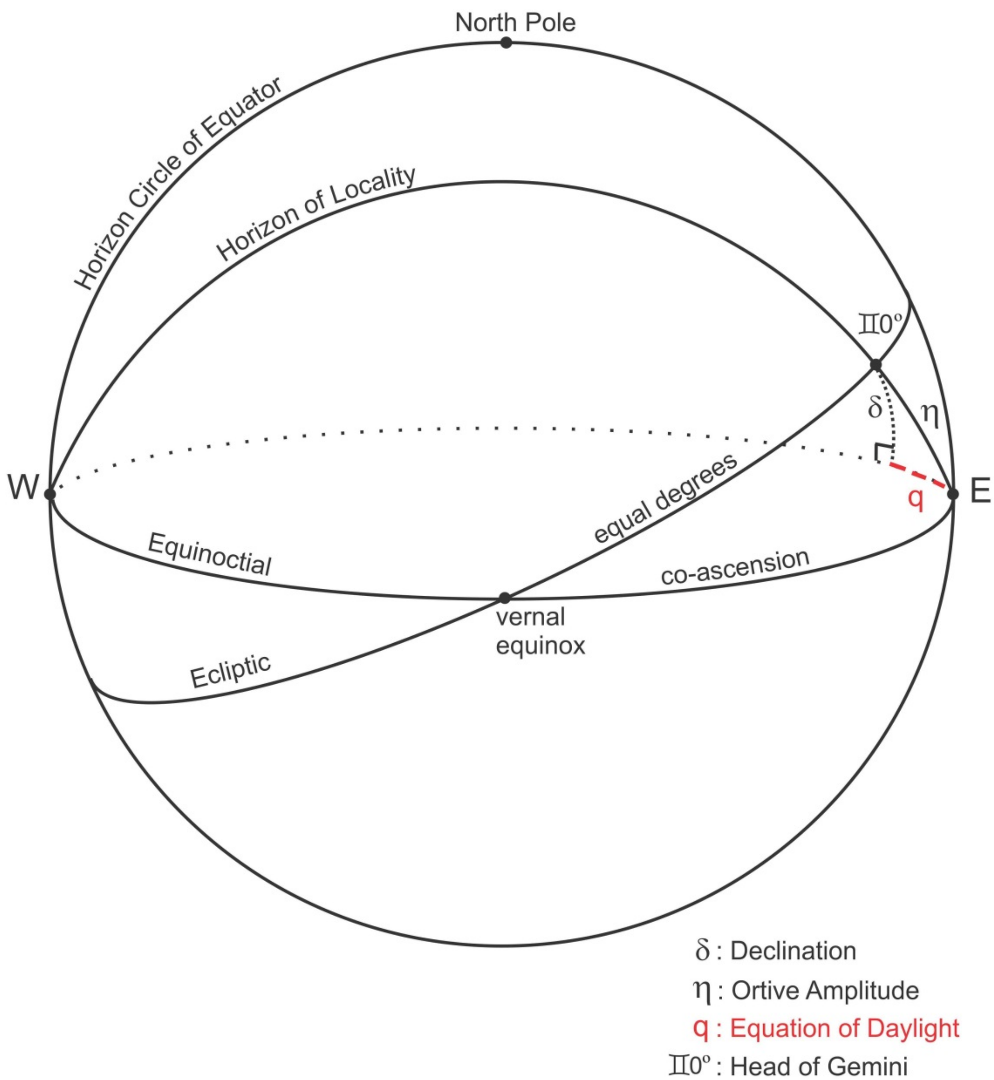

Figure C1

Cf. Ṭūsī: III.3 [2] (Ragep, *Tadkhira*, p. 260); "On the Co-ascensions of the Ecliptic," III.7 (pp. 282-86); and Fig. C28 (p. 363). For comparison, ʿAbd al-Wājid's commentary provides a two-dimensional diagram (see Laleli MS 2127, f. 49b).

I.4 [5]. When the head of Gemini is found toward the east for a horizon other than the equator: The omission of غير by two key texts (MS F [f. 8a] and MS S [f. 59a]) may be an indication of what was missing in an earlier version of the *Mulakhkhaṣ*, and then added later, perhaps in a revision by Jaghmīnī himself. It is also omitted in ʿUbaydī's commentary (Istanbul, Süleymaniye Library, Laleli MS 2128, f. 33b). However, it is included in MS B (p.25), MS K (f. 13a), and MS L (f. 69a). It is also in the commentaries of ʿAbd al-Wājid (Laleli MS 2127, f. 48b) and several copies of Qāḍīzāde's (UCLA, Caro Minasian 33, p. 246; Tehran, 18045 [not numbered]; Isfahan, Abū Barakāt 50 [not numbered]; and Qūm, Feyziyi 01832, p. 107).

I.4 [6]. … the angle of the equation: Cf. Bīrūnī, *Tafhīm*, nos. 172 -174 (pp. 89-90); and F. J. Ragep, *Tadhkira*, II.6 [5] (p. 148).

I.4 [9]. … they are called sectors: Cf. Bīrūnī, *Tafhīm,* no. 201 (pp. 107-110) and Ragep, *Tadhkira*, II.14 [1] (pp. 240, 463). See also E. S. Kennedy, "A Survey of Islamic Astronomical Tables," p. 143; Kennedy, "The Sasanian Astronomical Handbook Zīj-i Shāh," pp. 247-53; and Kennedy, *The Planetary Equatorium of Jamshīd Ghiyāth al-Dīn al-Kāshī*, pp. 218-22.

I.4 [9]. The epicycle is divided by two lines, one of them extending from the deferent center: For the epicycle orb, Ṭūsī states the line is produced from the World center rather than from the deferent center (Ragep, *Tadhkira*, II.14 [1] [pp. 240-41]). Also MS S (f. 61b) draws it from the World center. However the text clearly states it is from the deferent center, and MS B (p. 29) and MS K (f. 16a) have it drawn this way, as do several commentaries I also checked (see ʿAbd al-Wājid, Laleli MS 2127, f. 56a; ʿUbāydī, Laleli MS 2128, f. 38b; Qāḍīzāde, UCLA, Caro Minasian 33, p. 270).

I.4 [12]. The second declination is an arc along a latitude circle between the two of them, I mean between the equinoctial and the ecliptic circle: Given that this sentence could have been written more succinctly as "The second declination is an arc along a latitude circle between the equinoctial and the ecliptic circle," it does raise the question about the orality of the text, especially since he uses the first person "I mean."

I.4 [12]. … and its amount is 23;35: This is Jaghmīnī's value for the obliquity, not the Ptolemaic one of 23;51,20 (*Almagest*, I.12 [Toomer, *Ptolemy's Almagest*, pp. 61-63, esp. fn75]). Jaghmīnī's value is the one that derives from the time of Maʾmūn (r. 813-833). It is found in Farghānī's *Jawāmiʿ* (ch. 5, p. 18), who also reports Ptolemy's value 23;51; Battānī's *Zīj* (vol. 2, ch. 4, p.18); and Ṭūsī's *Tadhkira*, II.4 [1] as (23 + 1/3 + ¼)° (pp. 120-21, 394). However, Ṭūsī "updates" the value to 23;30 in his *Īlkhānī Zīj,* written some 4 years after the *Tadhkira*. Noteworthy, is that ʿAbd al-Wājid uses the value of 23;30 throughout his commentary, informing us (within his comments on Jaghmīnī's 23;35 value) that 23;30 is due to "new observations" (Laleli MS 2127, ff. 58a-58b). Ibn Sīnā found the value of the obliquity to be 23;33,30, but seemingly he had few followers (See S. P. Ragep, "Ibn Sīnā," in the *Biographical Encyclopedia of Astronomers*, pp. 570-72; and F. Jamil Ragep and Sally P. Ragep, "The Astronomical and Cosmological works of Ibn Sīnā," pp. 6, 10).

I.4 [15]. Parallax [*lit.,* divergence of sight]: Ṭūsī devotes an entire chapter to this subject. See Ragep, *Tadhkira*, II.12[1-8] (pp. 222-28, 458).

I.4 [16]. The ortive amplitude: See Bīrūnī, *Tafhīm* , no. 220 (p. 129) for a clear explanation of this term along with a diagram.

I.4 [22]. The measure of each one of these six arcs is similar to its [corresponding arc] along the equinoctial: The six arcs are: (1) the arc of daylight; (2) the arc of night; (3) the planet's arc of daylight; (4) the planet's arc of night; (5) the turning of the orb [daylight]; and (6) the turning of the orb [night]. Note the meaning here of **"these six arcs [are] similar"** is analogous to what is meant by similar triangles.

PART I, CHAPTER 5: On What Occurs to the Planets in Their Motions

I.5 [1]. The Sun has a single anomaly:

Illustration of the Sun's Single Anomaly

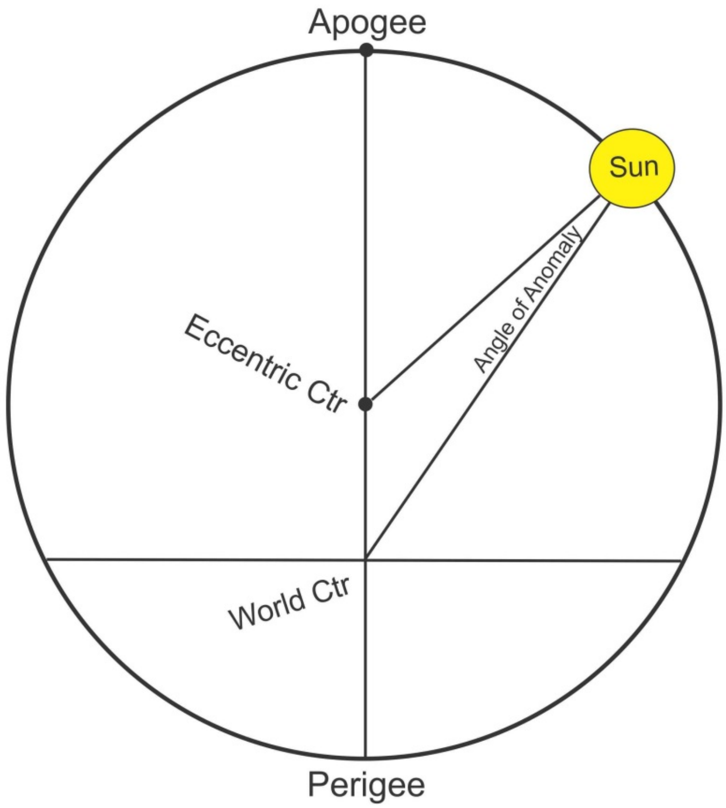

Figure C2

I.5 [2]. As for the remaining planets, they have numerous anomalies in longitude: I translated *ikhtilāf* (*lit.,* difference) as anomaly. Jaghmīnī is using the term in a technical sense and lists them in this chapter. It should be understood as an "irregular, or anomalous, speed, i.e. one that differs from the mean" (see Ragep, *Tadhkira*, II.7 [1]18-21 [p. 417]).

I.5 [2]. Starting with the parameters in this section, MS B (p. 33) has an interesting way of treating the fractional parts of the parameters, and provides us with an example of late Ottoman mathematical notation. These are given as variants in the apparatus. This is discussed in **§ II.1d: Parameters**.

THE RADII OF THE EPICYCLES AT THEIR MEAN DISTANCES (I.5 [2])						
	Jaghmīnī, ***Mulakhkhaṣ*** **[=M]**	**Ptolemy,** ***Almagest*** **[=A]**	**Battānī,** ***Zīj*** **[=Z]**	**Farghānī** ***Jawāmiʿ*** **[=J]**	**Ṭūsī,** ***Tadhkira*** **[=T]**	**Kharaqī,** ***Muntahā*** **[=M]** **[& *Tabṣira*]**
Saturn	**6;30** M: **I.5 [2]**	6;30 A: XI.6 (p. 540)	6;29,2 Z: v. 3, ch. 28, (p.73)	6½ J: ch. 16 (p. 65)	6½ T: II.9[13] (pp. 184-5)	6;30 M: Bāb 10, Faṣl 2 (p. 207)
Jupiter	**11;30** M: **I.5 [2]**	11;30 A: XII.3 (p. 570)	11;30,5 Z: v. 3, ch. 28 (p.73)	11½ J: ch. 16 (p. 65)	11½ T: II.9[13] (pp. 184-5)	11;30 M: Bāb 10, Faṣl 2 (p. 207)
Mars	**§§39;30** M: **I.5 [2]**	39;30 A: XII.4 (p. 574)	39;**25**,22 39;55,22 Z: v. 3, ch. 28 (p.73)	39 1/6 J: ch. 16 (p. 65)	39½ T: II.9[13] (pp. 184-5)	39;30 M: Bāb 10, Faṣl 2 (p. 207)
Venus	***45;0** or 43 1/6 [=43;10] M: **I.5 [2]**	43;10 A: X.2 (p. 472)	**44;9,5** Z: v. 3, ch. 28 (p.73)	43 1/6 J: ch. 16 (p. 65)	43 1/6 T: II.9[13] (pp. 184-5)	43;10 or 43;30 43;32 [*Tabṣira*]
Mercury	**** 25;0** or 22;30 M: **I.5 [2]**	22;30 A: IX.9 (459-60)	22;30,30 Z: v. 3, ch. 28 (p.73)	22½ J: ch. 16 (p. 65)	22½ T: II.8[13] (pp. 170-1)	22;30 M: Bāb 9, Faṣl 2, p. 218:
Moon	§**6;20** or 5;15 M: **I.5 [2]**	5;14 A: IV.6 (p. 202)	5;15 Z: v. 3, ch. 28 (p.73)	6 1/3 J: ch. 16 (p. 65)	5;15 T: II.7[16] (pp. 156-1)	ca. 5 M: Bāb 9, Faṣl 3 (p. 197)

§§ I.5 [2]. The radii of the epicycles at their mean distances are…for Mars: 39;30: Delambre gives the Battānī value as 39;55,22. However, the Arabic text, written alphanumerically as لطكه, is 39;**25**,22. Cf. Nallino, *Kitāb al-Zīj al-ṣābiʾ (Opus astronomicum)* of Battānī, vol. 3, Ch. 28, p.73 and Delambre, "Albategnius. Historire de l'astronomie du Moyen Age," p. 37.

***I.5 [2]. The radii of the epicycles at their mean distances are…for Venus: 45;0:** MS F (f. 10b), MS K (f. 19a), and MS L (f. 71b), and MS S (f. 64b) have a value of 45;0, which could be a rounding up of Battānī's parameter. MS B (p. 33) gives Ptolemy's value of 43 1/6, which is also found in Farghānī, Kharaqī, and Ṭūsī.

** **I.5 [2]. The radii of the epicycles at their mean distances are…for Mercury: 25;0:** MS F (f. 11a), and MS L (f. 71b), and MS S (f. 64b) all have the 25;0 value; however MS B (p. 33) and MS K (f. 19a) have the Ptolemaic value 22;30, which is also the value found in the other sources (and clearly closer to Battānī's value of 22;30,30 [*Zīj*, vol. 3, ch. 28, p. 73]).

§ I.5 [2]. The radii of the epicycles at their mean distances are…for the Moon: 6;20: The two values given for the Moon's parameters (6;20 and 5;15) derive from different reference radii: (1) 6;20 is based on the deferent orb having a radius of 60p; and (2) 5;15 is based on an inclined orb having a radius of 60p. Jaghmīnī has opted for the former, as does Farghānī. MSS F, S, K and L have 6;20; MS B has 5;15. Cf. Ptolemy, *Almagest*, IV.5; and Pedersen, *A Survey of the Almagest*, Ch. 6 on "The Theories of the Moon," pp. 159-202, 424.

I.5 [4]. The third anomaly [regarding what occurs to epicycle centers**]:** For Ṭūsī's explanation of this anomaly regarding the Moon, see *Tadhkira*, II.7 [25] (Ragep, pp. 158-61).

I.5 [8]. the mean apex: For Ṭūsī's definition of the mean apex, see "On the Orbs and Longitudinal Motions of the Remaining Planets," *Tadhkira*, II.9 [11] (Ragep, pp. 182-83).

THE DISTANCE OF THE ECCENTRIC CENTER FROM THE WORLD CENTER (I.5 [9])						
	Jaghmīnī ***Mulakhkhaṣ*** **[=M]**	**Ptolemy** ***Almagest*** **[=A]**	**Battānī** ***Zīj*** **[=Z]**	**Farghānī** ***Jawāmi*ʿ** **[=J]**	**Ṭūsī** ***Tadhkira*** **[=T]**	**Kharaqī** ***Muntahā**** **[=M]** **[& *Tabṣira*]**
Sun	**2;29,30** or 29:30 M: **I.5 [9]**	2;29,30 A: III.4 (pp. 153-5)	2;4,45 Z: v. 3, ch. 28 (p.73); v. 2 (p. 244)	2 ½ J: ch. 16 (pp. 64-5)	2;5 [also 2;30] T: II.6[4] (pp. 146-7, **416**)	ca. 2 M: Bāb 8, Faṣl 2 (p. 183)
***Moon**	**10;19** M: **I.5 [9]**	10;19 A: V.4 (p. 226)		12 ½ [=10;19] J: ch. 16 (pp. 64-5)	10;19 T: II.7[18] (pp. 156-9)	10 + 1/3 M: Bāb 9, Faṣl 1 (p. 189)
* The two values given for the Moon's parameters (10;19 and 12;30) derive from different radii (See Pedersen, *A Survey of the Almagest*, pp. 184-85, 424): (1) 12;30 is based on the deferent orb having a radius of 60; and (2) 10;19 is based on the inclined orb having a radius of 60p.						

THE DISTANCE OF EQUANT CENTER FROM WORLD CENTER (I.5 [10]) (amount from deferent center to World center)						
	Jaghmīnī	**Ptolemy**	**Battānī**	**Farghānī**	**Ṭūsī**	**Kharaqī**
Saturn	**6;50** M: **I.5 [10]**	6;50 [3;25 x 2] A: XI.5 (p. 537)	6;50	3 + ¼ + 1/6 [x 2] J: ch. 16 (pp. 64-5)	3 + ¼ + 1/6 [x 2] T: II.9 [9] (pp. 180-3)	6 + ½ + 1/3 M: Bāb 10, Faṣl 2 (p. 205)
Jupiter	**5;30** M: **I.5 [10]**	2;45 [x2] A: XI.3 (P. 524)	5;30	2 ½ + ¼ [x2] J: ch. 16 (pp. 64-5)	2 ¾ [x2] T: II.9[9] (pp. 180-3)	5 + ½ M: Bāb 10, Faṣl 2 (p. 205)

Mars	**12;0** M: **I.5 [10]**	6;0 [x 2] A: X.7 (p. 498)	12;0	6;0 [x 2] J: ch. 16 (pp. 64-5)	6;0 [x 2] T : II.9[9] (pp. 180-3)	12 M : Bāb 10, Faṣl 2 (p. 205)
Venus	***2;5** M: **I.5 [10]**	1;15 [x2] A: X.2 (pp. 472-4)	2;30	1;15 [x2] J: ch. 16 (pp. 64-5)	ca. ½ Sun [x2] T: II.9[9] (pp. 180-3)	2;**5** M: Bāb 10, Faṣl 2 (p. 205)
* Note Jaghmīnī's value for Venus is not the Ptolemaic one; rather it is the same as Kharaqī's value. This could be an indication that they are equating it with new values for the Sun.						
I.5 [11]. Distance between equant and dirigent, and between dirigent and deferent center						
Mercury	**3;10** M: **I.5 [11]**	3;0 A: IX.9 (p. 459)	3;0	3;0 J: ch. 16 (pp. 64-5)	half 6;0 T: II.8[14] (pp. 170-1)	**3 parts + 1/6** M: Bāb 11, Faṣl 2 (pp. 217-8)

LATITUDE OF THE PLANETS (I.5 [13]) (maximum inclination of the inclined orb from the ecliptic orb)						
	Jaghmīnī ***Mulakhkhaṣ***	**Ptolemy** ***Almagest***	**Battānī** ***Zīj* ****	**Farghānī,** ***Jawāmi*ʿ**	**Ṭūsī,** ***Tadhkira****	**Kharaqī** ***Muntahā***
Saturn	**2;30** M: **I.5 [13]**	2 ½˚ A: XIII.3 (p. 605)		-	2 ½ ˚	*Bāb*15, *Faṣl* 2
Jupiter	**1;30** M: **I.5 [13]**	1 ½˚ A: XIII.3 (p. 605)		-	1 ½ ˚	*Bāb*15, *Faṣl* 2
Mars	**1;0** M: **I.5 [13]**	1˚		-	1 ˚	*Bāb*15, *Faṣl* 2
Venus	**0;10** M: **I.5 [13]**	0˚ to + 0 ˚;10		-	1/6 ˚	*Bāb*15, *Faṣl* 3
Mercury	**0;45** M: **I.5 [13]**	0˚ to - 0;45	-		(½ + ¼) ˚	*Bāb*15, *Faṣl* 3

Moon	**5;0** M: **I.5 [13]**	5˚	5 Z: v. 3, ch. 30 (p. 83)	5 J: ch. 18 (pp. 73-4); ch. 18 (p. 67)	5 ˚	5 *Bāb*15, *Faṣl* 1 (p. 276); same in *Tabṣira*

* For Ṭūsī's discussion of the latitudes of the five planets (Saturn, Jupiter, Mars, and Venus, and Mercury), see *Tadhkira*, II.10 [1] (pp. 188-89); and for the Moon, see II.7[4] (pp. 150-51). Cf., Pedersen, *A Survey of the* Almagest, pp. 361-65.

** For Battānī, see tables, *Zīj*, vol. 2 (pp. 140-141).

§ Yūsuf ibn Mubārak al-Alānī's *Sharḥ al-Mulakhkhaṣ* (Topkapı Sarayı Müzesi, Ahmet III, MS 3308, f. 50b) has the same values as the original version of the *Mulakhkhaṣ*.

EPICYCLE LATITUDE AT MAXIMUM (I.5 [14]) (= maximum deviation in either direction of the apex [or epicyclic perigee] from the inclined deferent)						
	Jaghmīnī, ***Mulakhkhaṣ*** M: **I.5 [13]**	**Ptolemy,** ***Almagest***	**Ṭūsī,** ***Tadhkira*** T: II.10[4] (pp. 190-3)	**al-Alānī,** ***Sharḥ*** Ahmet III 3308, f. 51a	**§ʿAbd al-Wājid,** ***Sharḥ***	**Kharaqī,** ***Muntahā*** M: Bāb15, Faṣl 3 (p. 281)
Saturn	**0;32**	0;35*	0;35	0;32	4p + 1/2	0;35
Jupiter	**0;38**	0;38*	0;38	0;38	2p + 1/2	0;38
Mars	**6;16** **6:56	6 A: XIII.3 (pp. 603-4)	6 1/10 (=6;6)	6;16	2p + 1/4	6;7
Venus	**1;2**	1;2 A: XIII.3 (p. 602)	1;2	1;2	2p + 1/2	1;2

Mercury	**1;45**	1;45 A: XIII.3 (p. 602)	1;45	1;45	6p + 1/4	1;45
NOTE: Jaghmīnī's values for Saturn, Jupiter, and Mars are with respect to the maximum deviation of the perigee; however, for Venus and Mercury he gives the values for the maximum deviation of the apex.						

***** = value derivable from latitude tables *in Almagest*, XIII.5

****** = value found in MS S (f. 66b) and MS F (f. 8a).

§ = maximum deviation between the intersection of the planes of the epicyclic equator and the inclined equator measured from the epicycle center. These values, for a different deviation, are in MS K (f. 21b). It is not uncommon to find them in [later] witnesses and *Mulakhkhaṣ* commentaries (ʿAbd al-Wājid [Laleli MS 2127, ff. 75b-76a] and Qāḍīzāde). Rudloff and Hochheim also have them ("Die Astronomie des Maḥmûd ibn Muḥammed ibn 'Omar al-Ǵagmînî," p. 251).

Note that Kharaqī in the *Muntahā* (*Bāb*15, *Faṣl* 3 on latitudes of the planets) gives an extensive discussion on how to derive some of these parameters, and gratefully concludes this section with a chart (see Ghalandari, p. 281).

F. J. Ragep provides an extremely helpful table listing values for the deviation and slant of planet epicycles for Ptolemy and Ṭūsī (*Tadhkira*, II.10 [4] & [5], pp. 424-25) as well as a diagram of the deviation for the upper planets (Fig. C6a, p. 347). See also Swerdlow, "Ptolemy's Theories of the Latitude of the Planets in the *Almagest*, *Handy Tables*, and *Planetary Hypotheses*," pp. 41-71, esp. p. 63.

I.5 [15]. It is called the latitude of the slope [*wirāb*], the slant [*inḥirāf*], and the twist [*iltiwā*ʾ]. Its maximum for both [i.e., Mercury and Venus] is 2;30: These are Ptolemy's values for Mercury and Venus (*Almagest*, XIII.5 [Toomer, *Ptolemy's Almagest*, pp. 633-34]). Cf., Ṭūsī, *Tadhkira*, II.10[5] (pp. 192-95, 424-26).

I.5 [22]. As for the position of the apogees, they are for the beginning of the year 1517 (غشيز) of Dhū al-Qarnayn: Dhū al-Qarnayn [the two-horned, i.e., the era of Alexander the Great]: The term "Dhū al-Qarnayn" (the two-horned) is in reference to the era of Alexander the Great; see W. Montgomery Watt, "al-Iskandar," in *Encyclopaedia of Islam*, 2nd ed., vol. 4, p. 127. A variant reading of this number is 1317 (غشيز) due to a mistake in reading ش (300) instead of ث (500); for an example of this, see ʿAbd al-Wājid's commentary (f. 85a). However, some commentators removed all doubt by spelling the year out in addition to writing the number alphanumerically; two prominent examples are Alānī (f. 55b) and Qāḍīzāde (Ayasofya 2662, f. 42b). The date 1517 is also found in at least two fifteenth-century Persian commentaries (Muḥammad b. ʿUmar al-Andiqānī [Ayasofya 2592, f. 26a] and Ḥamza b. Ḥājjī Sulaymān [Ayasofya 2593, f. 121a]). It is also noted in the articles of Ghalandari ("Chagmīnī," *The Great Islamic Encyclopedia*) and Qāsimlu ("Chagmīnī," *Encyclopaedia of the World of Islam*). Surprisingly, Rudloff and Hochheim omitted the year entirely in their German translation ("Die Astronomie des Maḥmûd ibn Muḥammed ibn 'Omar al-Ǵagmînî," p. 253); had they included it much of the controversy regarding Jaghmīnī's dates could have been avoided.

The date 1517 and Jaghmīnī's parameters for the apogee and nodes are important in establishing that he was alive in 1206 CE (=603 H). An even more precise calculation of the date is 1517 years from Monday, 1 October 312 = 1 October 1206 [= 25 Ṣafar 603 H [+-2]]. This is because the beginning of the year of the Alexander epoch is calculated starting with Monday, 1 October 312 B.C. in the Julian calendar (see "Taʾrīkh," section 2.a. "Calendars and eras," TABLE 2 in *Encyclopaedia of Islam*, 2nd. ed., vol. 10, pp. 264-71; how to convert dates is also provided within the article); cf. Bīrūnī's listing of eras (*Tafhīm*, no. 282 [p. 174]).

JAGHMĪNĪ'S PARAMETERS FOR THE POSITIONS OF THE APOGEES (I.5 [22]) AND NODES (I.5 [23])				
These values are found in all 5 MSS and also the commentaries of Alānī (f. 55b) and Qāḍīzāde (Ayasofya MS 2662, ff. 42b-43a). Furthermore, since the planetary nodes are fixed with respect to the apogees (i.e., being 90 degrees apart), it provided additional confirmation that Jaghmīnī was internally consistent within the *Mulakhkhaṣ*.				
	Apogee Position	**Head Node Position**	**Tail Node Position**	**Midpoint (between head & tail)**
Saturn [**50**° beyond midpoint]	Sagittarius 9;23,33 =249;23,33 [=199;23;33+ **50**]	Cancer 19;23,33 =109;23,33	289;23,33	199;23;33
Jupiter [**20**° in advance of midpoint]	Virgo 19;23,33 =169;23,33 [=189;23,33 – **20**]	Cancer 9;23,33 =99;23,33	279;23,33	189;23,33
Mars [= midpoint]	Leo 11;53,46 =131;53,46	Taurus 11;53,46 =41;53,46	221;53,46	131;53,46
Venus [= midpoint]	Gemini 27;10,33 =87;10,33	Pisces 27;10,33 =357;10,33	177;10,33	87;10,33
Mercury [= midpoint]	Libra 26;23,33 =206;23,33	Capricorn 26;23,33 =296;23,33	116;23,33	206;23,33

Most likely, Jaghmīnī relied on Battānī's values for his computations **(see chart below).** My conclusion was facilitated by the fact that both Jaghmīnī and Battānī give their values in the era of Dhū al-Qarnayn (in contrast to Bīrūnī who uses the Yazdigird calendar), and both agree that the apogee moves 1˚ per 66 years. Based on this I calculated a constant value of **4;55,33** that the apogee would have moved between their two dates (1517 Dhū al-Qarnayn for Jaghmīnī; 1191 Dhū al-Qarnayn for Battānī. However, note that some tweaking was necessary since a 325-year (rather than 326) difference was necessary to make the calculation work out; and alternative readings for the alphanumerical values of Mars and Venus are suggested.

POSITION OF THE APOGEES			
	Jaghmīnī, ***Mulakhkhaṣ*** **I.5 [22].**	**Battānī, *Zīj*** (Ch. 45, pp. 172-3; Ch. 28, p. 67 [Sun])	**value of Jaghmīnī** **minus value of Battānī**
Year	1517 Dhū al-Qarnayn	1191 Dhū al-Qarnayn	
Sun	Gemini 27;10,33 = 87;10,33	[same as Venus]	
Saturn	Sagittarius 9;23,33 =249;23,33	244;28	249;23,33 244;28,00 **4;55,33**
Jupiter	Virgo 19;23,33 = 169;23,33	164; 28	169;23,33 164; 28,00 **4;55,33**
Mars	Leo 11;53,46* =131;53,46	126;**1**8	131;53,46 126;**1**8;00 5;35,46
Option		126;**5**8 [58 (نح) not 18 (يح) ?]	131;53,46 126;**5**8;00 **4;55**,46

* Note that Jaghmīnī repeats 33 seconds for all the apogee positions, except Mars has 46 seconds (with no variants on this to date); 46 is a mystery, seemingly a mistake introduced at an early time and repeated. The repetition of 33 seconds though I assume was based on a *zīj*. See Kennedy (*Survey*, p. 169) for his take on newly observed parameters versus calculated ones.

Venus	Gemini 27;10,33 =87;10,33	82;1**4**	87;10,33 82;1**4**,00 **4;56;33**
Option		82;1**5** [15 (يه) not (يد) ?]	87;10,33 82;1**5**,00 **4;55;33**
Mercury	Libra 26; 23,33 =206;23,33	201;28	206;23,33 201;28,00 **4;55,33**

I find it puzzling that Jaghmīni does not rely on Bīrūnī's often more accurate parameters (which clearly do not correspond with Jaghmīnī's); they were fellow Khwarizmians, and Bīrūnī flourished a century after Battānī. Perhaps Jaghmīni found working in the Alexandrian calendar more congenial and thus followed Battānī, but it is far more likely the authority of Battānī's *Zīj* still held sway despite the intervening centuries and the availability of better parameters.

I.5 [24]. Then for every year, one adds to their positions what the orb of the fixed stars moves in the year: Jaghmīnī has accepted the fact that precession is a fixed constant of 1 degree per 66 years, thus rejecting the notion of variable precession. This is in contrast to what one finds in the western Islamic world and the West.

I.5 [25]. What occurs to the vacillating planets regarding retrogradation, direct motion, and stations: Ṭūsī uses *wuqūf* not *maqām* for station (*Tadhkira*, II.5 [8]24 [pp. 136-37, 414]). Cf., *Almagest*, IX. 2 (Toomer, *Ptolemy's Almagest*, pp. 420-21).

I.5 [27]. What occurs to [the vacillating planets] in relation to the Sun: Cf. Ṭūsī, *Tadhkira*, II.9 [12] and [14] (Ragep, pp. 182-85) and IV. 6 [3] (p. 525). For Bīrūnī's definition of a planet in combust, see *Tafhīm*, no. 153 (pp. 64-65).

I.5 [29]. What occurs to the Moon in relation to the Sun: the new Moon [*muḥāq*], waxing, full Moon, waning, its eclipsing of the Sun, and lunar eclipses.:

Illumination of the Moon in Relation to the Sun

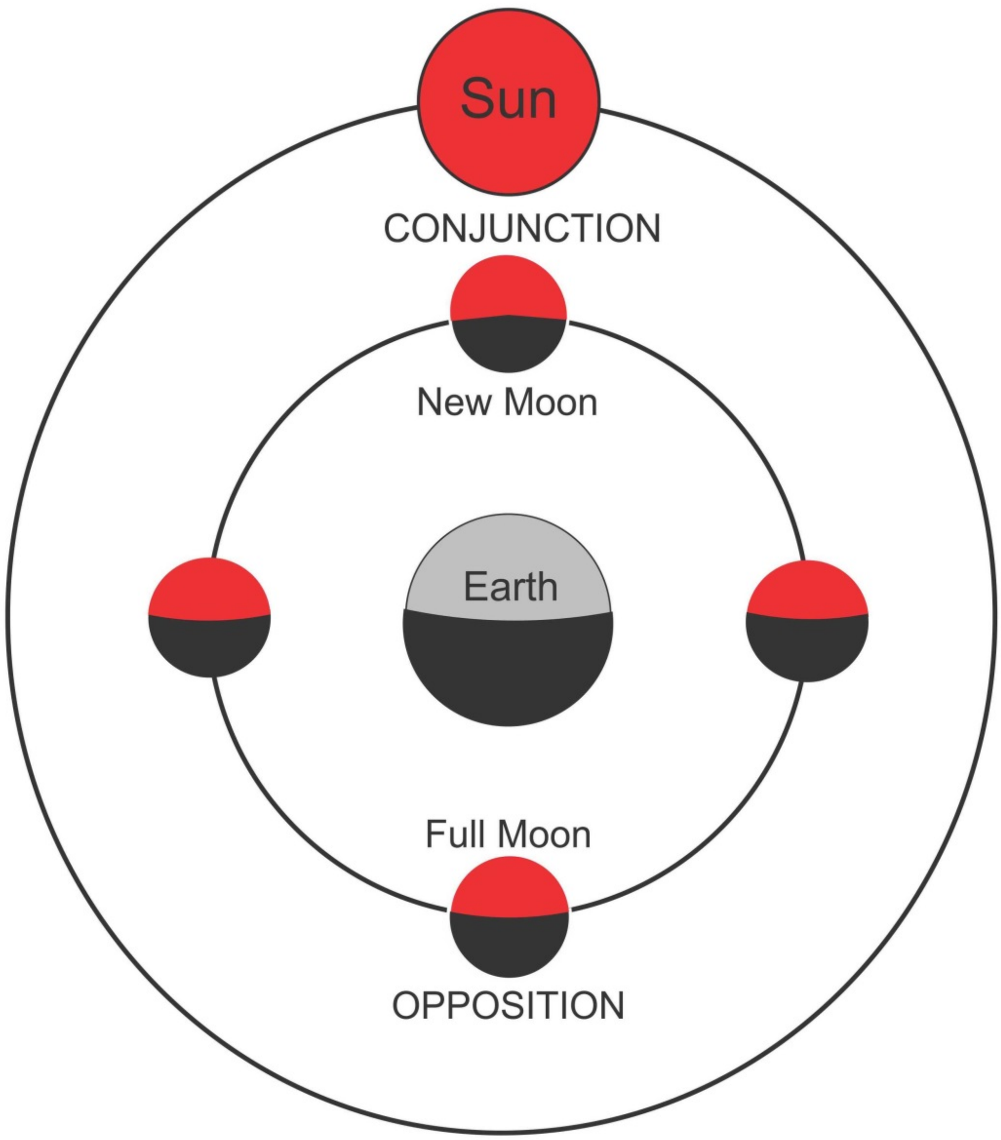

Figure C3

I.5 [29]. What occurs to the Moon in relation to the Sun: the new Moon [*muḥāq*]: According to Bīrūnī, this term technically applies to the Moon's setting or disappearance two days prior to appearing new in the west (*Tafhīm*, no. 154 [pp. 64-66]).

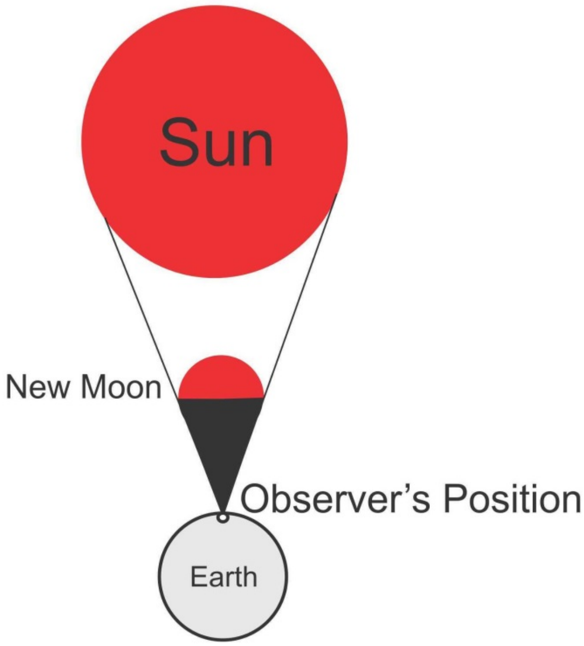

Figure C4

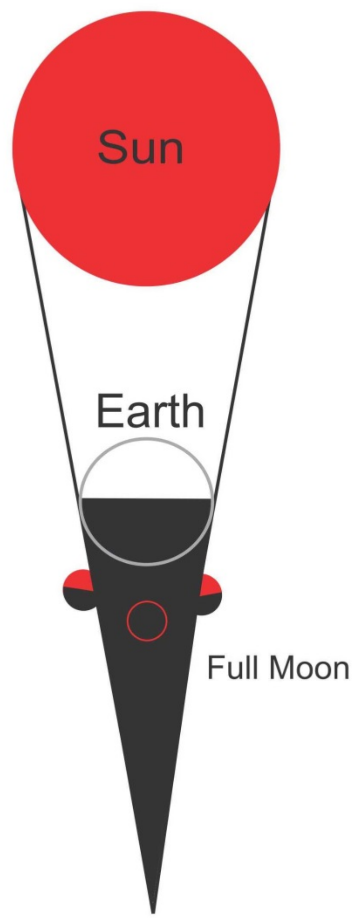

Figure C5

I.5 [30]. Among what occurs to the Moon is that the Sun is always in the middle between the [Moon's] apogee and the center of its epicycle: For an indication that the *Mulakhkhaṣ* was studied (and not merely copied), the mathematics of this is worked out in the margin of Princeton, Garrett 373 (pp. 358, 358A).

The Second Part: On an Explanation of the Earth and What Pertains to It

PART II, CHAPTER 1: On the Inhabited Part of the Earth and Its Latitude, Its Longitude, and Its Division into the Climes

II.1 [1]. the cupola of the Earth: Cf. Bīrūnī, *Tafhīm*, no. 239 (p. 140); and Ṭūsī, *Tadhkira*, III.1[7] (Ragep,. pp. 250-251).

II.1 [2]. Ptolemy, after writing the *Almagest*, claimed that he found habitation below the equator to a distance of 16;25: Jaghmīnī is here referring to Ptolemy's *Geography*, which Ptolemy wrote after his *Almagest*. Regarding habitation beneath the equator, Ptolemy states in the *Almagest*: "For those who live beneath the equator…It is said that the regions beneath the equator could be inhabited, since the climate must be quite temperate…But what these inhabited regions are we have no reliable grounds for saying. For up to now they are unexplored by men from our part of the inhabited world, and what people say about them must be considered guesswork rather than report" (Toomer, *Ptolemy's Almagest*, p. 83 [II, 6]). In comparison, in his *Geography*, Ptolemy gives the southern limit of habitation as 16 5/12° south of the equator (Berggren and Jones, *Ptolemy's* Geography, p. 85 [Bk 1.23, [4.] and [23.]]. Note that the *Mulakhkhaṣ* commentators are well aware that Jaghmīnī is referring to Ptolemy's *Geography* here (for examples, see Alānī, Ahmet III MS 3308, f. 65a; ʿAbd al-Wājid, Laleli MS 2127, f. 101a; and Qāḍīzāde (Ayasofya MS 2662, f. 48b).

II.1 [2]. The longitude of the inhabited part is 180;0, and its beginning is from the west; however, some of them take it to be from the coast of the enclosing ocean and some of them from islands well into this ocean, their distance from the coast being 10;0: Jaghmīnī is here referring to the Eternal Islands (*al-khālidāt*), also called the Fortunate Islands (*suʿadāʾ*) [also referred to as the Isles of the Blest, and usually thought to be the Canary Islands]. See Ragep, *Tadhkira*, [III.1 [7]10 (pp. 250-51 and 468).

II.1 [3]. This inhabited part was then divided into seven longitudinal sections parallel to the equator: The original versions of the *Mulakhkhaṣ* contain the Ptolemaic values found in the *Almagest* (II.6 [Toomer, *Ptolemy's Almagest*, pp. 82-90]). F. J. Ragep provides a comparative chart of the values of the maximum daylight and latitudes of climes for Ptolemy, Bīrūnī, Ṭūsī, and Qāḍīzāde's *Sharḥ* ("On Dating Jaghmīnī and His *Mulakhkhaṣ,*" pp. 463-64):

Chart: Maximum Daylight and Latitudes of Climes

	Maximum Daylight (Hours)	Latitudes					
		Ptolemy[*]	Bīrūnī[†]	Ṭūsī[‡]	Jaghmīnī (Laleli 2141.3)[§]	Jaghmīnī (Rudloff/ Hochheim)[**]	Qāḍīzāde's Sharḥ[††]
I	12¾	12;30°	12;39,5°	12;40°	12;30°	12;40°	12;40°
	13	16;27°	16;38,34°	16;37,30°	16;27°	15;37°[**]	16;37°
II	13¼	20;14°	20;27,29°	20;27°	20;14°	20;27°	20;27°
	13½	23;51°	24;4,30°	24;5°/24;40°	23;51°	24;40°	24;40°
III	13¾	27;12°	27;27,40°	27;30°	27;12°[§]	27;30°	27;30°
	14	30;22°	30;39,27°	30;40°	30;22°	30;40°	30;40°
IV	14¼	33;18°	33;36,56°	33;37,30°	33;18°	33;37°	33;37°
	14½	36;00°	36;21,29°	36;22°	36;00°	35;22°[**]	36;22°
V	14¾	38;35°	38;53,36°	38;54°	38;35°	38;54°	38;54°
	15	40;56°	41;13,52°	41;15°	40;56°[§]	41;15°	41;15°
VI	15¼	43;1°/ 43;15°*	43;23,5°	43;22,30°	43;11°/ 43;15°[§]	43;22°	43;22°
	15½	45;1°	45;22,8°	45;21°	45;1°	45;21°	45;21°
VII	15¾	46;51°	47;11,26°	47;12°	46;51°	47;12°	47;12°
	16	48;32°	48;52,21°	48;52,30°	48;32°	48;52°	48;52°
	16¼	50;4°	50;24,34°	50;20°	50;25°	50;20°	50;20°

[*] Ptolemy, *Almagest*, pp. 84-87 [H105-111]; 43;15° derives from the Arabic manuscript tradition of the *Almagest* (see ibid., p. 86, n. 43).

[†] Dallal, "Al-Bīrūnī," p. 14. Cf. Ragep, *Naṣīr al-Dīn*, 2: 470.

[‡] Ragep, *Naṣīr al-Dīn*, 1: 250-253 and 2: 469-471.

[§] Istanbul, Laleli MS 2141.3, f. 75b. For 27;12 one finds 27 (كز) in margin while the main text has 29 (كط). For 40;56 one has 40 (م) in the margin whereas the text has 44 (مد). For the Ptolemaic 43;1, one finds 43;11 in the text underneath which one finds 22 (كب) while in the margin someone has written 15 (يه); 43;15 would indeed correspond to what is usually given for the Ptolemaic value in the Arabic textual tradition of the *Almagest*.

[**] Rudloff and Hochheim. "Die Astronomie," pp. 260-261. 15;37 and 35;22 are no doubt due to scribal or typographical errors.

[††] Qāḍīzāde, *Sharḥ al-Mulakhkhaṣ*, pp. 122-126.

See also Ragep, *Tadhkira*, Commentary III.1 [8] (pp. 469-71), esp. Table 7 (p. 470); and III.I [8-9] (pp. 250-53). **Kharaqī's *Tabṣira*** (Book 2) has the Ptolemaic values for the climes (see Istanbul, Süleymaniye Library: Ayasofya MS 2579 (ff. 80b-82a); Ayasofya MS 2581 (ff. 121a-124a); and Laleli MS 2141 (ff. 45a-56b [note this is the same codex that contains the for *Mulakhkhaṣ* witness I used in establishing the Arabic edition [MS L]). Basically Kharaqī's values are the Ptolemaic ones listed in the chart above.For Clime VI, for the maximum daylight of 15 ¼ hours he gives the latitude as 43;15, however he does not go beyond 16 hours with a latitude of 48;32. Kharaqī has strikingly similar language for what Jaghmīnī presents for latitudes from 63 to 66 degrees.

II.1 [3]. The first clime: All 5 witnesses give the value 12 hours for the beginning of daylight, and 12;45 hours for the longest daylight of the year. MSS F, K, L, S have 12;30 degrees latitude, but MS B provides no value. In fact starting here MS B leaves blank values for the climes. MSS F, K, L, S all have a maximum daylight of 13;0 hours. MSS F, L, S give 16;27 degrees latitude. Alānī's *Sharḥ* (f. 66a) also gives this Ptolemaic value. But MS K (f. 28a) gives 16;37; this could be due either to the obvious scribal error of not changing the ل (30) into a ك (20), or another possibility is that the copyist is using Qāḍīzāde's parameter of 16;37 (Ayasofya MS 2662, f. 49a) or perhaps abridging Ṭūsī's parameter of 16;37,30 [16+ ½ + 1/8] degrees (*Tadhkira*, III.1 [8] [pp. 250-51]). Note that Ṭūsī, unlike Jaghmīnī, begins the first clime at 12;45 [12 + ½ + ¼] hours with a latitude of 12;40 (12 2/3 degrees).

II.1 [4]. The second clime: MSS F, K, L, S begin the second clime where maximum daylight is **13;15** [hours] and the value in MS B is blank. The Ptolemaic value of **20;14** degrees latitude is given in MS L (f. 75b) and MS S (f.72a), though in MS S someone has modified 20;14 to 20;27, which is the value found both in Ṭūsī (20;27 = 20 + ¼ + 1/5 [*Tadhkira*, III.1 [8] (pp. 250-51)] and in Qāḍīzāde, *Sharḥ Mulakhkhaṣ* (Ayasofya MS 2662, f. 49b). In other words, someone has tried to "update" the Ptolemaic 14 minutes to Ṭūsī's 27. MS B provides no value. MS F (f. 15a) has 24;0 and MS K (f. 28a) has 24;15. For MSS F, K 20;14 (ك يد) was most-likely misread from a copy that was missing the dots on the ي, leading to the combining of د and ك to form 24. For

MS K, the 24;15 is most likely a copyist error. Note that Alānī's commentary (Ahmet III, MS 3308, f. 66b) also has the Ptolemaic value.

<u>For 23;51 degrees latitude</u>: 4 out of 5 of my main manuscripts have Ptolemy's value for latitude of 23;51 degrees; MS B provides no values. This specific Ptolemaic value was an important factor in selecting manuscripts for this edition, since I chose those witnesses that contain the original Ptolemaic values. Though Alānī's commentary also has the Ptolemaic value of 23;51 degrees (f. 66b), the vast majority of *Mulakhkhaṣ* manuscripts and commentaries have changed the text here to **24;40**, which is found in many copies of the *Tadhkira*. (Note that someone has written 24;40 in the margin of MS S.) This value is itself the result of a copyist's error whereby Ṭūsī's correct value of **24;5** degrees [written as (24 + (1/2 **of** 1/6)] was misread as [24 + (1/2 **and** 1/6) *or* 24 2/3], which only involves the addition of a < و >. Because the 24;40 value could only have been transmitted after the *Tadhkira* was copied, and it is the predominant value in most copies and commentaries of the *Mulakhkhaṣ*, it was assumed by Birjandī (followed by F. J. Ragep in his commentary on the *Tadhkira*) that the *Mulakhkhaṣ* must postdate the *Tadhkira*. For more details on the significance of this scribal error, see *Tadhkira*, III.1 [8] (pp. 250-51 and p. 471); for J. Ragep's revision of his original assumption, see his "On Dating Jaghmīnī and His *Mulakhkhaṣ*."

II.1 [5]. the third [clime]: For 27;12 degrees latitude: MS B provides no value; the remaining 4 MSS all have the value 29;12 (i.e, كط). However, in MS S (f. 72a), someone has attempted to change 29 to 27 in the main text; and also in MS L (f. 75b), someone has written 27 (كز) in the margin. The value 29 remains a mystery. For comparison, 27;12 is in Alānī's commentary (f. 66b) and in Kharaqī's *Muntahā*; whereas Ṭūsī (*Tadhkira*, III.1 [8] [pp. 250-51]), Qāḍīzāde (Ayasofya MS 2662, f. 49b), and ʿAbd al-Wājid (Laleli MS 2127, f. 102b) all give 27;30. However, al-Andiqānī's 15th-century Persian translation of the *Mulakhkhaṣ* has 29;12 (Ayasofya MS 2592, f. 21b).

For **14** hours, and **30;22** degrees latitude: MS B provides no values; the remaining 4 MSS all have the Ptolemaic value of 30;22. For comparisons: Alānī's commentary also has 30;22 (f. 66b); however, Ṭūsī gives 30 2/3 (*Tadhkira*, III.1 [8] [pp. 250-51]) and this is equivalent to Qāḍīzāde's 30;40 (Ayasofya MS 2662, f. 49b). ʿAbd al-Wājid (ff. 102b-103a) gives 30;40 but in addition mentions that some versions have 30;22.

II.1 [6]. the fourth [clime]: The entire section on the fourth clime is omitted by MS B. MSS F, L, S have the Ptolemaic value of **33;18** for **14;15** hours. MS K (f. 28a) has the variant (لح لح), which can be read 33;38 or 33;33; however, 33;38 could be a rounding up of Ṭūsī's value of 33;37,30 (see chart and *Tadhkira*, III.1 [8] [pp. 250-51]). This assumption is supported by ʿAbd al-Wājid, who in his commentary (f. 103a) provides both the alphanumeric لح لح and Ṭūsī's value of 33 + ½ + 1/8 (=33;37,30). For other comparisons: Qāḍīzāde gives 33;37 (Ayasofya MS 2662, f. 49b); and both Kharaqī's *Tabṣira*, and Alānī give the Ptolemaic value of 33;18 (f. 66b).

MSS F, K, L, S all have **14;30** hours. MSS F, L, S give the Ptolemaic value of **36;0** degrees latitude (also found in Alānī (f. 66b) and Kharaqī's *Tabṣira*). However, MS K (f. 28a) has 36;22 which is found in Qāḍīzāde (Ayasofya MS 2662, f. 49b), and is equivalent to the 36 + 1/5 + 1/6 put forth by Ṭūsī (*Tadhkira*, III.1 [8] [pp. 252-53]) and also ʿAbd al-Wājid (f. 103a), who attributes his value to Ṭūsī.

II.1 [7]. the fifth [clime]: MS B provides no values for this clime. MSS F, K, L all have **14;45** hours, and MS S has 14;0 with 45 written beneath the 0. MSS F, K, L, S all have the Ptolemaic value of **38;35** for latitude. Alānī (f. 66b) also gives 38;35; however both Ṭūsī (*Tadhkira*, III.1 [8] [pp. 252-53]) and ʿAbd al-Wājid (f. 103a) give the value as 39 minus 1/10 which is equivalent to Qāḍīzāde's parameter of 38;54 degrees (Ayasofya MS 2662, f. 50a).

MSS F, K, L, S have **15** hours. For latitude: MS L (f. 75b) has 44;56, but the 44 has been corrected to 40 in the margin. MS S has been corrected from 41;56 to the Ptolemaic value **40;56**. MS F (f. 15a) has 41;56 (unaltered). MS K (f. 28a) has 41;55; this could be a case of a copyist mistaking نه [55] for يه [15] since 41;15 is the value given by Ṭūsī (41 ¼) (*Tadhkira*, pp. 252-53, III.1 [8]), Qāḍīzāde (Ayasofya MS 2662, f. 50a), and ʿAbd al-Wājid (f. 103a). Furthermore, in the margin of MS L someone has written 41;15 in a different hand from the 40 in the margin mentioned above. The Ptolemaic 40;56 degrees is also found in Alānī (f. 66b), and Kharaqī's *Tabṣira*.

II.1 [8]. the sixth [clime]: MS B provides no values for this clime. MS F (f. 15a), MS K (f. 28a), MS S (f. 72a), MS L (f. 75b) all have **15;15** hours with latitude **43;51** (clearly marked), as opposed to the Ptolemaic one of 43;15, which is also found in Kharaqī's *Tabṣira*. There are attempts to change the 51 to 15 in different hands: in MS S, 15 is added beneath 51; and in MS L, 2 dots are added beneath the ن with يه (15) added in the margin. Also in the main text of MS L, in another hand, someone has written **22** beneath the 51. The value **43;22** is found in Qāḍīzāde (Ayasofya MS 2662, f. 50a) and in Ṭūsī's *Tadhkira* (III.1 [8] [pp. 252-53]), written as 43 + ¼ +1/8. ʿAbd al-Wājid gives both 43;22 and forty-three parts and a quarter [=43;15] (Laleli MS 2127, f. 103a). Alānī also gives 43;15 degrees (ff. 66b-67a). The original source(s) of 43;51 remains a mystery to me (to date); however, it is contained in the fifteenth century Persian translation of the *Mulakhkhaṣ* (see Andiqānī, p. 903). Unfortunately the value was unreadable in Ayasofya MS 2592 (f. 22a), the only witness I was able to consult.

MSS F, L, S have **15;30** hours and **45;1** degree latitude. In MS K one finds the odd value of 15;32 hours and an ambiguous value for the latitude that might be read as 44;21, 44;51 or even 0;21, 0;51 since his 44 (مد) often is used to represent 0. For comparison, Qāḍīzāde (Ayasofya MS 2662, f. 50a) has 45;21 as does Ṭūsī (= 45 + ¼ +1/10) (*Tadhkira*, III.1 [8] [pp. 252-53]) and ʿAbd al-Wājid (Laleli MS 2127, f. 103a). Alānī has 45;1 (Ahmet III, MS 3308, f. 67a), which is also found in Kharaqī's *Tabṣira*.

II.1 [9]. the seventh [clime]: MSS F, L, S have the Ptolemaic value of 46;51 degrees (also found in Alānī, f. 67a and Kharaqī's *Tabṣira*); MS B has no value; and MS K has 46;52 (clearly marked). In comparison: Ṭūsī's value is 47 1/5 (*Tadhkira*, III.1 [8] [pp. 252-53]), which is also found in ʿAbd al-Wājid (Lāleli 2127, f. 103b), and is equivalent to Qāḍīzāde's value of 47;12 degrees (Ayasofya MS 2662, f. 50b).

MSS F, L, S all have 48;32 degrees latitude for 16 hours; these values are missing in both MS B and MS K. Kharaqī's *Tabṣira* and Alānī's *Sharḥ* also have these Ptolemaic values (f. 67a). Ṭūsī gives this value as 48 + ½ + ¼ + 1/8 (*Tadhkira*, III.1 [8] [pp. 252-53]); also found in ʿAbd al-Wājid (f. 103a), which is equivalent to Qāḍīzāde's 48;52 (Ayasofya MS 2662, f. 50b).

II.1 [10]. According to some of them, its end is at the end of the inhabitable land; accord to others, it is up to where the latitude is <u>50;25</u> [degrees]: In the *Almagest*, Ptolemy gives 16;25 hours for the end of the seventh clime at 50;4 degrees, this purportedly going through the middle of the Maiotic Lake (modern Sea of Azov) (Toomer, *Ptolemy's Almagest*, p. 87). MS B has no value, and MSS F, S, L give **50;25** degrees. MS K (f. 28b) has 50;35. Bīrūnī seems to be the origin of 50;25, which is what one finds in his *Tafhīm,* p. 138 [no. 236]). For other comparisons: Kharaqī has no value in his *Tabṣira*; and Ṭūsī gives 50 1/3 (*Tadhkira*, III.1 [8] [pp. 252253]), equivalent to 50;20 (found also in Qāḍīzāde [Ayasofya MS 2662, f. 50b] and Alānī [f. 67a]). ʿAbd al-Wājid (f. 103b) gives the otherwise unattested 55;20.

II.1 [10]. …**they do not count that part of the habitable land below the equator as part of the climes:** ʿAbd al-Wājid reminds us that this would be that part of the habitable land below the equator in Ptolemy's *Geography* (Laleli MS 2127, f. 103b).

II.1 [10]. …some of them do not count what is between the equator and latitude <u>12;30</u> nor what is between latitude <u>50:25</u> to the end of the habitable land: MSS F, K, L, S all give a latitude of 50;25; MS B has no value. ʿAbd al-Wājid gives 55;25 (= 55 + ¼ + 1/6) (Laleli MS 2127, f. 104a), which is close but not exactly the same as the 55;20 cited previously.

II.1 [10]. According to what they have claimed, in latitude <u>63</u> is an inhabited island whose residents live in bath-houses due to the severity of the cold: Jaghmīnī is probably referring to the island Thule, usually thought to be the Shetland Islands; see *Almagest*, II.6 [29] (Toomer, *Ptolemy's Almagest*, p. 89 and fn. 66) and Ptolemy's *Geography*, Book I.7 and II.3 [32] (Berggren and Jones, pp. 64-65, 180).

II.1 [10]. in latitude 64 is a habitation whose residents are an unknown Slavic people: The unknown Slavic people (the *Ṣaqāliba*) could be a reference to Ptolemy's "unknown Scythian peoples" at 64;30 degrees (*Almagest*, II.6 [30] [Toomer, *Ptolemy's Almagest*, p. 89]). It is not clear whether Jaghmīnī is aware of Ibn Faḍlān's tenth-century account of various peoples in the northern latitudes. For a recent study, see James E. Montgomery, "Ibn Faḍlān and the Rūsiyyah," *Journal of Arabic and Islamic Studies* 3 (2000): 1-25.

At the end of this chapter MS B (p. 48) includes an incomplete and unlabeled illustration for the climes. MSS F, L, K, S do not have a diagram, and there is no indication that one was ever intended here. However, one does find an illustration on the climes in Kharaqī's *Tabṣira* as well as in all the *Mulakhkhaṣ* commentaries I have checked.

PART II, CHAPTER 2: On the Characteristics of the Equator and Locations Having Latitude

II.2 [1]. The turning of the orb there is wheel-like, I mean similar to the buckets of waterwheels emerging from the surface of the water at right angles: Jaghmīnī here uses the word *ʿaṣāmīr* (plural of *ʿuṣmār*), which is defined as a waterwheel with a bucket; see F. Steingass, *Arabic-English Dictionary* (London, 1884), p. 701. Cf. *Tadhkira*, III.2 [1]23 (Ragep, p. 472), for a definition of *dūlābiyy*^{an} (wheel-like).

II.2 [2]. … when the Sun reaches the two equinox points, this being the days of Nayrūz and Mihrjān: For Bīrūnī's discussion of Nayrūz and Mihrjān, see *Tafhīm*, nos. 302 and 304, respectively (pp. 180-82). Jaghmīnī uses an "Arabized" spelling of Nayrūz < نيروز >, rather than < نوروز >; and I found no variant spellings in my main manuscripts as well as various commentaries I checked (ʿAbd al-Wājid [Laleli MS 2127, f. 106b]; Alānī [Ahmet III, MS 3308, f. 69a]). Also Jaghmīnī clearly connects the two holidays with the equinox points (Nayrūz: the vernal equinox; Mihrjān: the autumnal equinox). However according to Bīrūnī, Mihrjān falls on the 16th day of the month Mihr-māh, which does not necessary occur at the autumnal equniox.

II.2 [7]. **Among them are [the locations] whose latitude exceeds the complement of the obliquity, i.e., over 66;25:** Jaghmīnī's statements in this section are often obscure and seemingly contradictory, and certainly not "obvious" as he claims several times. His attempt to facilitate his points with an example further complicates this. This is due to Jaghmīnī not distinguishing clearly between what is occurring on the northern parts of the ecliptic and the southern parts; he begins the discussion with the former, but his example relates to the latter. In addition, he does not clearly delineate between those stars that are permanently visible or permanently invisible, and those that are temporarily visible/invisible (i.e., those that rise and set). I have therefore added clarifying phrases in brackets and also footnotes for his passage on these locations. Fortunately, here I was greatly assisted in comprehending this section by using ʿAbd al-Wājid's commentary. ʿAbd al-Wājid specifically provides a worked out example of a location of 70 degrees latitude (20 degrees colatitude) in Laleli MS 2127, ff. 112b-114b.

II.2 [8]. **…and its altitude is in the amount of the difference of the latitude from 90 degrees, which is the colatitude, I mean [the latitude's] "completion", and it is known as the complement of the arc.:** Jaghmīnī first introduces the meaning of the complement of the arc in **I.4 [1]** (on "The Arcs"). However, here he also terms the latitude's complement as its "completion". Cf. ʿAbd al-Wājid, Laleli MS 2127, f. 113b.

II.2 [11]. **Since that which sets faces that which rises, then that facing what rises in reverse order will set in reverse order, and vice versa:** According to ʿAbd al-Wājid, "vice versa" here means "that facing what rises in regular order will set in regular order" (Laleli MS 2127, ff. 118b-119a).

II.2 [11]. And since the rising in one of the two halves of the [ecliptic] orb in terms of order is contrary to the rising in the second [half] but matches the setting,…:

		Rising	**Setting**
Half 1	Capricorn 0˚ => Gemini 30˚	**reverse**	**regular**
Half 2	Cancer 0˚ => Sagittarius 30˚	**regular**	**reverse**

II.2 [11]. …it follows that the rising of each half will be contrary to its setting, so what rises in reverse order will set in regular order, and vice versa: vice versa meaning what rises in regular order sets in reverse order.

II.2 [14]. Now then, instruction of the above is sufficient for understanding this [topic]: The abrupt tone of this closing statement suggests that Jaghmīnī's target audience is a student, not a patron.

PART II, CHAPTER 3: Miscellaneous Items

A folio is missing in **MS F** which corresponds to **II.3 [1], line 6 to II.3 [4] line 6**. I have marked both where this missing information begins and ends with asterisks in the Arabic edition, and it is also noted in the critical apparatus. The missing section begins within the passage on the ascendant and returns within the section on determining the *qibla* bearing; so Figure 8, the illustration of the Indian circle, is also missing. See also **§ II.2: Description of the Manuscripts, MS F**.

II.3 [1]. Then if the star is [aligned] with one of the two solstice points or it has no latitude, its degree, i.e., [the star's projected] place on the ecliptic orb, is its degree of transit: Regarding the definition of the degree of transit of the star, it seems redundant that Jaghmīnī dichotomizes between a star *at* the solstice point with a star with no latitude, since a star at a solstice point is on the ecliptic and thus would have no latitude. However, ʿAbd al-Wājid comments that Jaghmīnī really meant that a star *aligned* with the solstice points on the solstitial colure will have the same degree of transit. See ʿAbd al-Wājid, Laleli MS 2127, f. 121a.

SUMMARY OF STAR TRANSIT		
	NORTH latitude	**SOUTH latitude**
Half 1 of ecliptic orb: Cancer 0˚ => Sagittarius 30˚	star reaches meridian after its degree	star reaches meridian before its degree
Half 2 of ecliptic orb Capricorn 0˚ => Gemini 30˚	star reaches meridian before its degree	star reaches meridian after degree

For discussions of the star's degree, see Bīrūnī, *Tafhīm*, pp. 147-48 (no. 243) and Ṭūsī's chapter entitled "On the Degrees of Transit of the Stars on the Meridian and on Their [Degrees of] Rising and Setting" (*Tadhkira*, [III.11 [1-3]; Ragep, pp. 302-5, 370 [Fig. C35] and pp. 495-96).

II.3 [1]. **As for the right orb, the rules for this are exactly the same. As for the inclined orbs, one needs to take into account the horizons:** The various latitudes for these cases are discussed by ʿAbd al-Wājid (Laleli MS 2127, ff. 123a and 123 b).

II.3 [2]. The horizontal gnomon, parallel to the horizon plane, is called ***maʿkūs*** [*umbra versa*], because it produces a reversed shadow directed toward the ground, and erect (***muntaṣib***) in that the shadow is perpendicular to both gnomon and ground. The vertical gnomon, called the ***mustawī*** [*umbra recta*], produces a direct/straight shadow parallel to the horizon plane.

Jaghmīnī informs us here how to determine the start-time for the afternoon [*ʿaṣr*] prayer using gnomon shadows according to both the rulings of al-Shāfiʿī and Abū Ḥanīfa. It is noteworthy that the attribution to al-Shāfiʿī has been added in the margins of both MS S (f. 78a) and MS L (f. 78b); since these manuscripts are witnesses to the earliest version of the text, this could indicate that in the original version Jaghmīnī did not think there was a need to cite al-Shāfiʿī explicitly, since, as a Shāfiʿī presumably teaching in a Shāfiʿī madrasa, Jaghmīnī probably assumed that Shāfiʿī's opinion on prayer would have been common knowledge. On the other hand, he did need to cite the source of the second opinion, i.e., that of Abū Ḥanīfa. In any event, someone writing after the first edition of the *Mulakhkhaṣ* felt the need to reference both.

For Bīrūnī on the various divisions of the gnomon and kinds of shadow, see *Tafhīm*, nos. 227, 228, and 229 (pp. 133-34); and E. S. Kennedy, "Al-Bīrūnī on the Muslim Times of Prayer," p. 88 (reprint, p. 304). See also Kennedy, *Bīrūnī's The Exhaustive Treatise on Shadows*, Ch. 6: "On the method by which the use of the shadow and the gnomon is arranged," pp. 62-67; Ch. 7, "On the divisions into which gnomons are divided" (pp. 68-80); and Ch. 25: "On the recital of the opinions of the Imams regarding the times of prayer and what is resorted to in determining them" (p. 219). Cf. David A. King, "On the Role of the Muezzin and the Muwaqqit in Medieval Islamic Society," especially the sections "On the Times of Prayer in Islam", p. 289 and "Simple Techniques for Time-Keeping by Day and Night," p. 296.

II.3 [3]. On determining the meridian line: On finding the meridian line and defining the **Indian circle**, cf. Ṭūsī, *Tadhkira*, III.12 [2-3] (pp. 306-7, 496-97); and on how to determine the Indian circle, see Bīrūnī, *Tafhīm*, no. 131 (pp. 49-52). There are some minor discrepancies between Jaghmīnī, Ṭūsī, and Bīrūnī: Both Bīrūnī and Ṭūsī prefer to define the gnomon length as half the radius, whereas Jaghmīnī uses the equivalent ¼ the diameter (cf. *Tafhīm,* p. 49; *Tahdkira*, pp. 306-7); and whereas Jaghmīnī gives 2 methods to determine that the gnomon is perpendicular, Bīrūnī uses the plumb-line option only and Ṭūsī is silent on this matter.

II.3 [4]. Since the longitude and latitude of Mecca are less than the longitude and latitude of <u>our locality</u> [emphasis added]: We have here an example of Jaghmīnī personalizing the exercise by referring to his hometown. Unfortunately, he does not mention the locale specifically (presumably the students knew where they lived), and the commentators I checked either omitted this information (see Alānī, Ahmet III, MS 3308, f. 83; and ʿAbd al-Wājid, Laleli MS 2127, f. 128a) or only cited the general region; for example, Qādīzāde just gives Khwārizm and (Ayasofya MS 2662, f. 62b).

II.3 [4]. In this passage Jaghmīni instructs us how to determine the *qibla* bearing for:

(1) locations whose longitude and latitude are greater or less than those of Mecca (by constructing **Figure 9**) using an Indian circle (constructed in **Figure 8**). Cf. ʿAbd al-Wājid, who discusses 8 different possibilities using various combinations of greater, equal to and less than for the latitudes and longitudes (ff. 128b-129a).

(2) locations whose longitude are the same as that of Mecca;

(3) locations whose latitude equals Mecca's latitude. This is not a simple determination based on facing due east or west. (ʿAbd al-Wājid points out Kūshyār ibn Labbān made this error [f. 129a].) Jaghmīni provides detailed instructions here on determining this qibla bearing using an astrolabe, for the two specific times of the year (Gemini 7;21 and Cancer 22;39) when the Sun would be directly overhead in Mecca.

Three points: [1] Gemini 7;21 and Cancer 22;39 are derived by using an altitude of 21;40 for Mecca and an obliquity of 23;35; [2] Jaghmīnī uses the term *khaṭṭ wasaṭ al-samāʾ* here, literally "mid-heaven line" (*linea medii coeli*) for the meridian; and [3] Jaghmīnī assumes the reader is already familiar with how to use the astrolabe, its parts and its various functions. Alternatively, we would have to speculate that he was providing basic definitions of its parts, its use, and applications while teaching the exercise.

II.3 [5]. **So wherever the [chosen ecliptic] degree lands on the altitude almucantars, you will observe the Sun when it reaches that altitude and erect a gnomon; then its shadow at that time is the bearing for the *qibla*:** Note that this process of determining the Sun's altitude for the location (using the astrolabe), then observing the Sun at that altitude in the sky, and then erecting a gnomon to observe the cast shadow can only be done twice a year (Gemini 7;21 and Cancer 22;39), namely when the Sun is directly overhead at Mecca at noon and will cast its shadow in a direct line to the location. Cf. Ṭūsī, who was able to use the idea behind Jaghmīnī's technique for latitudes equal to that of Mecca and generalize to all locations (*Tadhkira*, III.12 [3-4]; Ragep, pp. 306-9, 497). Also see David King, who points out that Battānī and Jaghmīnī both used methodological procedures that were cartographic (*World-maps for Finding the Direction and Distance to Mecca*, chapter 2: "On the Determination of the Sacred Direction in Islam," p. 59, footnote 25, no. 1).

Jaghmīnī's section on determining the *qibla* was most-likely taken from Kharaqī's *Tabṣira*, given that Kharaqī has the exact same astrolabe/gnomon exercise (Laleli MS 2141, *Bāb* 12, ff. 55a-56b).

II.3 [7]. This is recorded in the *zīj*es [astronomical handbooks]: This is the only place in the *Mulakhkhaṣ* where Jaghmīnī mentions *zīj*es. According to E. S. Kennedy, these astronomical handbooks with tables were used by "the practicing astronomer, or astrologer, to solve all the standard problems of his profession" ("A Survey of Islamic Astronomical Tables," p. 123). See D. A. King and J. Samsó for a supplement to Kennedy's survey with additional tables that are not contained within *zīj*es ("Astronomical Handbooks and Tables from the Islamic World [750-1900]: an Interim Report").

II.3 [8]. the duration of daytime: For this section, cf. Ṭūsī, *Tadhkira*, III.10 (Ragep, pp. 298-303, 489-95).

II.3 [8]. It has thus become clear that regularized hours are those whose number varies according to the length and shortness of daytime, but their units of time do not vary; seasonal hours are those whose units of time vary, but their number does not vary:

In sum: in **case 1** the number of regularized hours during daytime can vary, say, between a short winter and a long summer, but one winter hour would still equal one summer hour; in **case 2,** 1 of the 12 summer hours would be longer than 1 of the 12 winter hours**,** but the 12 for daytime and night remains constant throughout the year.

II.3 [9]. For some of them said 365¼ days; according to Ptolemy, 365¼ days less 1/300 part of a day; and according to Battānī 365¼ days less 3 parts 24 seconds out of 360 parts of a day: F. J. Ragep provides comparative charts that summarize these reported values (see "al-Battānī, on Cosmology and Trepidation," p. 285; and *Tadhkira*, p. 493). See also Ptolemy *Almagest*, III.1 (Toomer, Ptolemy's *Almagest*, p. 140); and Battānī's *Zīj*, ch. 27, vol. 3 (pp. 61-62) and vol. 1 (pp. 40-41).

II.3 [10]. … **they take away the Sun's mean [motion] from the Moon's mean, and they divide the remainder by the rotation of the orb, namely 360 degrees, thus resulting in 29;31,50,8 days, which is the amount of a month. They then multiplied that by 12, obtaining the days in a lunar year 354 + 1/5 + 1/6 days. This year is less than the solar year by approximately 10 days and 20½ hours:**

This passage, including *all* Jaghmīnī's parameters, is found in Kharaqī's *Tabṣira* (Laleli MS 2141, *Bāb* 14 of *hayʾat al-arḍ*, esp. f. 58b). According to Jaghmīnī's parameters (see *Mulakhkhaṣ*, **I.2 [3]**, **I.2 [8]**, and **I.5 [30]**)—and Kharaqī's—one would subtract 0;59,8,20 [Sun's mean] from 13;10,35,2 [Moon's mean] and then divide 360 by the remainder of 12;11,26,42 for a result of **29;31,50,8 days**. The value 29;31,50,8,20 days is the mean length Ptolemy claims to derive for the synodic month; however, as Toomer points out, this value is not actually what one obtains by Ptolemy's calculation (nor by Jaghmīnī's) but instead is Hipparchus's value which he took from the Babylonian sources (see *Almagest* IV.2 [*Ptolemy's Almagest*, p. 176, esp. fn. 10]).

On the machinations of calculating the lunar calendar, and the value of **354 + 1/5 + 1/6 days** (or 354 11/30 days), see Ragep's commentary on Ṭūsī's *Tadhkira*, III.10[2] (pp. 491-92). As for the lunar year being less than the solar year by approximately **10 days and 20½ hours:** According to Qāḍīzāde, it would have been more correct for Jaghmīni (and presumably Kharaqī) to have stated that the difference was approximately **10 days and 21 hours** [Ayasofya MS 2662, f. 69a], which is closer to what I calculated.

II.3 [11]. **This is as much as allowed by [my] ignoble character, a tormented mind, thought befuddled by preoccupations beyond counting, and concerns [so overwhelming] <u>they would make a mother neglect her child</u> [emphasis added]:**

«لا يُنادى وليدُها» This is literally "her child will not be called out to." The idiom, which signifies difficulty or distress, is from a proverb whose original meaning implies that the distress is so overwhelming that a mother would forget her child and not call out to him (see E. W. Lane, *An Arabic-English Lexicon*, vol. 8, p. 2967).

APPENDICES

Appendix I

Jaghmīnī's Works

I. Astronomy

<table>
<tr><th></th><th>TITLE</th><th>NOTES</th></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">1</td><td>الملخّص في علم الهيئة البسيطة
Al-Mulakhkhaṣ fī ʿilm al-hayʾa al-basīta</td><td>An introductory work on the discipline of hayʾa basīṭa: dedicated to Badr al-Dīn al-Qalānisī; composed 603 [1206]</td></tr>
<tr><td colspan="2">See esp. Ch. 1 (On dating Jaghmīnī); GAL1, p. 473; GAL suppl. 1, p. 865 (I); Ghalandari, no. 1; Kaḥḥāla, vol. 12, p. 198; Qāsimlu, p. 62 (no. 8); Ziriklī, vol. 7, p. 181</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">2</td><td>رسالة في أقدار أجرام الكواكب وأبعادها
Risāla fī aqdār ajrām al-kawākib wa-abʿādiha</td><td>A treatise on planetary distances and sizes: dedicated to Badr al-Dīn al-Qalānisī</td></tr>
<tr><td colspan="2">King, Survey reference, p. 150 (G17, 1.27); King, Catalogue, vol. 2, p. 21 [2]) [al-Qalānisī is misread as "al-Falāsitī (?)"]. See also Bratislava Library, Bratislava, TG 15, Ordinal Number 291</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">3</td><td>تحرير القواعد لتحليل أستار الفرائد
Taḥrīr al-qawāʿid li-taḥlīl astār al-farāʾid</td><td>A treatise on rules for clarifying various miscellaneous items in astronomy</td></tr>
<tr><td colspan="2">GAL1, p. 625(1996 ed.); de Slane, p. 516, no. 2865</td></tr>
</table>

II. Astrology

<table>
<tr><td rowspan="2">4</td><td>الكتاب في قوى الكواكب وضعفها
al-Kitāb fī quwā al-kawākib wa-ḍaʿfihā</td><td>A work on the strengths and weaknesses of the planets: dedicated to Shihāb al-Dīn.* Based on a date given for the motion of the planetary apogees, this treatise was composed one year earlier than the Mulakhkhaṣ, i.e., in 602/1205</td></tr>
<tr><td colspan="2">*Paris, BnF, MS ar. 2589, f. 174b contains the abbreviated name of the dedicatee; this is missing in Talkhīṣ kitāb Ūqlīdis, p. 249. See also de Slane, p. 468, no. 2589; Ghalandari, no. 4; Kaḥḥāla, vol. 12, p. 198; Qāsimlu, p. 61 (no. 1); Ziriklī, vol. 7, p. 182</td></tr>
</table>

III. Mathematics

5	تلخيص كتاب أوقليدس *Talkhīṣ kitāb Ūqlīdis*	The Epitome of Euclid's *Elements*: Composed at the request of Shihāb al-Dīn Abī Saʿd bin ʿImrān al-Khwārizmī al-Khīwaqī.* Completed Sunday, 22 Ṣafar 615 H (= Saturday-Sunday, 19-20 May 1218 CE).
	GAS 5, p. 115 (no. 56); Ghalandari, no. 3; Qāsimlu, pp. 62 (no. 7), 63; *Talkhīṣ kitāb Ūqlīdis*, pp. 15-246 (*the dedicatee is stated on p. 16, and it is followed by seven verses of poetry)	
6	الموجز في الحساب [= الضرب ؟] *al-Mūjaz fī al-ḥisāb*	A summary on arithmetic; includes a discussion on the subject of multiplication
	Ghalandari, no. 6; Qāsimlu, p. 61 (lists these as two separate works: "*al-ḍarb*" [2] and "*ṣuwar al-hisāb*" [3]); *Talkhīṣ kitāb Ūqlīdis*, pp. 254-55	
7	رسالة صور الحساب التسع *Risālat ṣuwar al-ḥisāb al-tis*ʿ رسالة لطيفة في حساب *Risāla laṭīfa fī ḥisāb* رسالة في الحساب *Risāla fī al-ḥisāb*	A treatise on nine types of arithmetic
	GAL suppl. 1, p. 865 (II); Ghalandari, no. 5; Hitti, p. 324 (no. 1032 = Princeton University, Garrett no. 502H); Kaḥḥāla, vol. 12, p. 198; Qāsimlu, p. 61 (no. 4); Ziriklī, vol. 7, p. 182. See Tehran, Central Library of the University of Tehran, MS 6911. King ambiguously mentions a "***R. mukhtaṣara fi l-Ḥisāb,*** on simple arithmetic" (King, *Survey*, p. 150 [G17, 6.3.11]); *MAMS*2 lists it as this work (p. 198, M1)	
8	شرح طرق الحساب في مسائل الوصايا *Sharḥ Ṭuruq al-ḥisāb fī masāʾil al-waṣāyā*	A Commentary on using arithmetic in questions related to inheritance
	GAL suppl. 1, p. 865 (III); Ghalandari; Qāsimlu, p. 62 (no. 6); Kaḥḥāla, vol. 12, p. 198; Ziriklī, vol. 7, p. 182	

9	منظومة في الجبر والمقابلة *Manẓūma fī al-jabr wa-l-muqābala*	A treatise in rhyme on algebra: a poem in 25 verses on problems about algebraic equations.
	Qāsimlu, pp. 61-62 (no. 5)	

IV. Medicine

10	قانونچه *Qānūnča*	The "little Qānūn," an abridged treatise of Ibn Sīnā's medical text *al-Qānūn fī al-ṭibb*
	See Ch. 1; *GAL*2, p. 213; *GAL* suppl. 1, pp. 826, 865 (IV); Ghalandari, no. 2; Qāsimlu, pp. 62-63 (no. 9); earliest copy dated 12 Ramaḍān 601 H (= 3 May 1205 CE) (Istanbul, Süleymaniye Library, Ayasofya MS 3735)	

V. Other

11	*qaṣīda*	A poem
	Talkhīṣ kitāb Ūqlīdis pp. 247-249; Qāsimlu, p. 63	
12		A small fragment of a mathematical work attributed to Jaghmīnī
	Witkam, p. 88: Leiden, Leiden University, Or. 204 (2), f. 30a	

VI. Misattribution

	الكتاب القوامي في الحساب *al-Kitāb al-Qiwāmī fī al-ḥisāb*	Arithmetical treatise on extracting roots and operations with decimal fractions
	GAL suppl. 1, p.865; Ghalandari; Qāsimlu (p. 63). All three raise the possibility that this is a misattribution. Qāsimlu states it may be a treatise by Abū Naṣr Samawʾal ibn Yaḥyā al-Maghribī [composed in 1173] that bears this name. Cf. *MAMS*2, p. 185, M3; and Rashid, pp. 140-45 (for Samawʾal's text).	

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Appendix II

Commentaries and Supercommentaries on, and Translations of, Jaghmīnī's *Mulakhkhaṣ*

I. Commentaries, Supercommentaries, and Glosses (Arabic)

	AUTHOR	TITLE and COMMENTS	
1	Yūsuf ibn Mubārak al-Alānī (ca. 735/1334)	*Sharḥ al-Mulakhkhaṣ*: written 19 Ramaḍan 735 [1334] on Sunday and dedicated to Jānī Beg Khān (r. 1341-1357) of the Golden Horde of the Mongol Empire.	[1]
	Riyazî ilimler, p. 389, e.2		
2	Shams al-Dīn Muḥammad ibn Mubārak-shāh Mīrak al-Bukhārī (d. 741/1341)	*Sharḥ al-Mulakhkhaṣ*	[2]
	*MAMS*2: 256 (no. 753), A1 and (no. 694), A4; *OALT,* pp. lxxviii; *Riyazî ilimler*, p. 389, e.1		
3	Faḍl Allāh al-ʿUbaydī (d. 751/1350)	*Sharḥ al-Mulakhkhaṣ*: composed in three days at the request of professors and students; student of Quṭb al-Dīn al-Shīrāzī	[3]
	Fazlıoğlu, "ʿUbaydī," in *BEA*, p. 1157; *KZ1:* col. 1819; *KZ2:* vol. 6, p. 113; *OALT,* pp. lxxviii; *Riyazî ilimler*, p. 389, e.3; Ṭāshkubrīzāde, *Miftāḥ al-saʿāda,* p. 349		
4	Saʿd al-Dīn Ḥamza ibn ʿAlī al-Bayhaqī (early-8th/14th c.)	*Sharḥ al-Mulakhkhaṣ*	[4]
	*MAMS*2: 248 (no. 723); *Riyazî ilimler*, p. 391, e.11		
5	Kamāl al-Dīn al-Turkmānī: Muḥammad b. Aḥmad al-Ḥanafī (d. 758/1357)	*Sharḥ al-Mulakhkhaṣ*: written in 755/1354 in Gülistan/Saray, the capital city of the Golden Horde State, and was offered to Jānī Beg	[5]
	Fazlıoğlu "Kamāl al-Dīn al-Turkmānī," in *BEA*, p. 609; *KZ1:* col. 1819; *KZ2:* vol. 6, p. 113; *OALT,* pp. lxxix; *MAMS*2: 252 (no. 738), A1; *Riyazî ilimler*, pp. 389-90, e.4; Ṭāshkubrīzāde, *Miftāḥ al-saʿāda,* p. 349		

5a.	Faṣīḥ al-Dīn Muḥammad ibn ʿAbd al-Karīm Niẓāmī al-Kūhistānī (d. 1530)	*Ḥāshiya* on Kamāl al-Dīn al-Turkmānī's *Sharḥ al-Mulakhkhaṣ*	[6]
	KZ2: vol. 6, p. 114(?); *MAMS*2: 309, A6		
6	Muḥammad ibn al-Ḥusayn ibn al-Rashīd al-Mashhadī al-Khwārizmī (8th/14th c.)	*Sharḥ al-Mulakhkhaṣ*: its only extant copy bears a date of 774/1372-3	[7]
	KZ1: col. 1820 ; *KZ2:* vol. 6, p. 114; *Riyazî ilimler*, p. 390, e5		
7	Anonymous	*Sharḥ al-Mulakhkhaṣ*: parts missing	[8]
	Riyazî ilimler, p. 390, e.7		
8	Kamāl al-Dīn ʿAbd al-Raḥmān ibn Muḥammad ibn Ibrāhīm al-ʿAtāʾiqī (d. 790/1388)	*Sharḥ al-Mulakhkhaṣ*: compiled in 770/1368-9	[9]
	This information was provided to me by Sajjad Nikfahm Khubravan.		
9	Humām al-Ṭabīb: Muḥammad ibn Muḥammad ibn Abī Ṭālib (d. after 813/1410)	*Sharḥ al-Mulakhkhaṣ*	[10]
	KZ1: col. 1820; *KZ2:* vol. 6, p. 114; *MAMS*2: 267 (no. 794), A1; *Riyazî ilimler*, p. 390, e.8		
10	al-Sayyid al-Sharīf al-Jurjānī (d. 816/1413)	*Sharḥ al-Mulakhkhaṣ*	[11]
	KZ1: col. 1819; *KZ2:* vol. 6, pp. 113-14; *MAMS*2: 266 (no. 788), A2; *Riyazî ilimler*, pp. 390-91, e.9; Fazlıoğlu, "The Samarqand Mathematical-Astronomical School," pp. 34-36; Ṭāshkubrīzāde, *Miftāḥ al-saʿāda,* p. 349		
10a.	Anonymous	Gloss on al-Jurjānī's *Sharḥ al-Mulakhkhaṣ*: only extant witness copied in 880 H. by Muṣṭafā ibn ʿAbd Allāh	[12]
	Riyazî ilimler, pp. 390-91, e.9		
11	ʿAbd al-Wājid (wrongly: Wāḥid) ibn Muhammad ibn Muḥammad al-Ḥanafī al-Kutāhī (d. 838/1435)	*Sharḥ al-Mulakhkhaṣ*: it was presented to Sultan Murād II (r. 1421-1451)	[13]
	KZ1: col. 1820; *KZ2:* vol. 6, p. 114; *MAMS*2: 267 (no. 791), A3; *OALT*, p. 24 (no. 2); Ragep, "Astronomy in the Fanārī-Circle"; *Riyazî ilimler*, p. 388, d.2		

12	Qāḍīzāde al-Rūmī (d. ca. 835/1440)	*Sharḥ al-Mulakhkhaṣ*: written in 814/1412, dedicated to Ulugh Beg	[14]
	KZ1: col. 1819; *KZ2:* vol. 6, p. 113; *MAMS*2: 273-74, A1; *OALT,* pp. 8-21 (no. 3); *Riyazî ilimler*, pp. 372-73; Fazlıoğlu, "The Samarqand Mathematical-Astronomical School"; Ragep, "Qāḍīzāde" in *BEA*, p. 942; Ṭāshkubrīzāde, *Miftāḥ al-saʿāda,* p. 349.		
12(a)	Fatḥallāh al-Shirwānī (d. 891/1486)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde): Qāḍīzāde's student; presented personal copy to Mehmed II in 878/1473	[15]
	History, pp. 533, 535-36; *KZ1:* col. 1819; *KZ2:* vol. 6, p. 114; *MAMS*2: 292, A2; *OALT,* pp. 43-44 (no. 1); *Riyazî ilimler***,** p. 385, ç.1; Fazlıoğlu, "Shirwānī," *BEA*, pp. 1055-56; Fazlıoğlu, "The Samarqand Mathematical-Astronomical School"		
12(b)	Sinān Pāshā (d. 890/1486): Sinān al-Dīn Yūsuf ibn Khiḍr Beg ibn Jalāl al-Dīn ʿĀrif	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde): vizier of Mehmed II; dedicated to Bāyazīd II	[16]
	History, pp. 534-35; *KZ1:* col. 1819; *KZ2:* vol. 6, p. 114; *MAMS*2: 290, A2; *OALT,* p. 47 (no. 1); *Riyazî ilimler*, p. 385, ç.3		
12(c)	Fakhr al-Dīn al-ʿAjamī (9th/15th c.)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qaḍīzade): a student of ʿAlī Qushjī	[17]
	OALT, p. 54; *Riyazî ilimler*, p. 385, ç.4		
12(d)	Niksārī: Muḥyī al-Dīn Muḥammad ibn Ibrāhīm ibn Ḥasan al-Niksārī al-Rūmī (d. 901/1495)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde): dedicated to Bāyazid II; he was Shirwānī's student	[18]
	*MAMS*2: 293, A1; *OALT,* p. 62; *Riyazî ilimler*, p. 385, ç.5		
12(e)	Kubnawī: al-Ḥaqq ibn Abī Isḥāq Kubnawī (late-9th/15th c.)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qaḍīzade): worked in Diyarbakir court at Aq Qoyunlu Sultan Yaʿqūb Bahādur-Khān (1478-1490)	[19]
	*MAMS*2: 282, A2		
12(f)	Dellākoğlu: Ḥusām ibn Shams al-Dīn al-Khattābī al-Lāhijānī al-Jīlānī (d. 901/1495)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[20]
	OALT, pp. 20, 63-64		

12(g)	Akhawayn: Muḥyī al-Dīn Muḥammad ibn Qāsim (d. 904/1499)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[21]
	*MAMS*2: 303; *OALT,* pp. 20, 65-66 (no. 4); *Riyazî ilimler*, p. 385, ç.6		
12(h)	Mīrim Çelebī (d. 931/1525)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[22]
	OALT, pp. 100-1 (no. 4)		
12(i)	ʿAbd al-ʿAlī al-Bīrjandī (d. 935/1528)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde): Isfahan at court of Safavid Shāh Ismāʿīl I	[23]
	History, p. 548; *KZ1:* col. 1820; *KZ2:* vol. 6, p. 114; *MAMS*2: 315-16, A11; *OALT,* pp. 101-4 (no. 1); *Riyazî ilimler*, pp. 381-82, d.1		
12(i1)	ʿAbd al-Raḥmān ibn Ibrāhīm al-Suhrānī al-Shāfiʿī (d. 1066/1656)	Gloss on Birjāndī's *Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde) (*Taʿlīqāt ʿalā ḥāshiya ʿalā sharḥ al-Mulakhkhaṣ)*	[24]
	OALT, p. 294; *Riyazî ilimler*, p. 384, c.1		
12(i2)	Aḥmad al-ʿImādī: Mawlānā Aḥmad ibn Sayyid Aḥmad al-ʿImādī (11th/17th c.)	Gloss on Birjāndī's *Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[25]
	OALT, p. 331 (no. 2); *Riyazî ilimler*, p. 384, c.2		
12(i3)	See III. Turkish, no. 1		
12(j)	Faṣīḥ al-Dīn Muḥammad ibn ʿAbd al-Karīm Niẓāmī al-Kūhistānī (d. 1530)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[26]
	KZ2: vol. 6, p. 114(?); *MAMS*2: 309, A7		
12(k)	Manṣūr al-Dashtakī: Ghiyāth al-Dīn Manṣūr ibn Muḥammad al-Ḥusaynī al-Dashtakī al-Shīrāzī (d. 948/1541)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[27]
	Ḥusayn Rūḥallāhī, "Dashtakī," in *The Encyclopaedia of the World of Islam* (Tehran: Encyclopaedia Islamica Foundation, forthcoming), title 7.		
12(l)	Burhān al-Dīn Ibrāhīm ibn Muḥammad ibn Ibrāhīm al-Ḥalabī (d. 956/1549)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[28]
	*MAMS*2: 321, A1		

12(m)	Saçli Emir (d. 963/1555): Shams al-Dīn Muḥammad ibn ʿAbd al-Awwal ibn Ḥusayn ibn Ḥasan al-Qamarī al-Ḥusaynī al-Tabrīzī al-Ḥanafī (d. 963/1555)	*Risāla fī kashf mā dāra ʿalā istidārat al-arḍ wa kurawiyyatihā*: Gloss on the Earth's sphericity (and its relation with prayers as discussed in Qāḍīzāde's *Sharḥ al-Mulakhkhaṣ*); composed in 940/1533-4 and presented to the vizier Ibrāhīm Pasha	[29]
	OALT, pp. 135-36; *Riyazî ilimler*, p. 388, d.1		
12(n)	Qāḍī Ḥasan al-Makkī: Ḥasan ibn Muḥammad al-Faṣīḥī al-Makkī (fl. 1014/1605)	*Ḥāshiya ʿalā sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[30]
	OALT, p. 249		
12(o)	Aḥmad al-ʿImādī: Mawlānā Aḥmad ibn Sayyid Aḥmad al-ʿImādī (11th/17th c.)	*Ḥāshiya ʿalā baḥth al-shaʿīrāt fī Sharḥ al-Mulakhkhaṣ li- Qāḍīzāde*: Gloss on the study of barleycorns in Qāḍīzāde's *Sharḥ al-Mulakhkhaṣ*]	[31]
	OALT, p. 330 (no. 1)		
12(p)	ʿImād al-Dīn Ḥusayn al-Riyāḍī ibn Luṭfallāh al-Lāhūrī (d. 1732)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[32]
	*MAMS*2: 374, A2		
12(q)	Walī al-Dīn Jār Allāh Yanī Shahrī (d. 1154/1738)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[33]
	OALT, pp. 403-4; *Riyazî ilimler*, p. 385, ç.7		
12(r)	Kasīrī-zāde: Muḥammad Amīn ibn al-Shaykh Muḥammad al-Uskadārī al-Ḥanafī al-Mudarris (d. 1151/1738)	*Ḥāshiya ʿalā sharḥ al-Mulakhkhaṣ* (Qāḍīzāde): Gloss dealing with the standard size of a barleycorn (*Taqrīrāt wāfiya wa-taḥrīrāt kāfiya li-ḥall al-masʾala al-mashhūra bi-l-masʾala al-shaʿīriyya fī sharḥ risālat al-Jaghmīnī li-l-shāriḥ al-mashhūr bi-Qāḍīzāde al-Rūmī*)	[34]
	OALT, pp. 405-6		
12(s)	Ḥasan al-Jabartī: Badr al-Dīn Ḥasan ibn Burhān al-Dīn Ibrāhīm al-Jabartī (d. 1188/1774)	*Ḥāshiya ʿalā sharḥ al-Mulakhkhaṣ* (Qāḍīzāde): extant? reported by his son ʿAbd al-Raḥman al-Jabartī	[35]
	History, pp. 586-87; *MAMS*2: 410; *OALT,* p. 479 (no. 19); *Riyazî ilimler*, p. 386, ç.8		

12(t)	Fakrī-zāde al-Mawṣilī (d. 1188/1774)	*Ḥāshiya ʿalā sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[36]
	*MAMS*2: 411; *OALT,* p. 482 (no. 3)		
12(u)	Anonymous	*Ḥāshiya ʿalā sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[37]
	OALT, pp. 744-45		
12(v)	Anonymous	*Ḥāshiya ʿalā sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[38]
	OALT, p. 745		
12(w)	See II. Persian, no. 4		
12(x)	See II. Persian, no. 11		
13	Kāfiyājī: Muḥyī al-Dīn Abū ʿAbd Allāh Muḥammad ibn Sulaymān al-Bargamawī (d. 879/1474)	*Sharḥ al-Mulakhkhaṣ*	[39]
	*MAMS*2: 291, A2; *OALT*, p. 27 (no. 2); *Riyazî ilimler*, p. 388, d.3		
14	Qarā Sinān: Sinān al-Dīn Yūsuf ibn ʿAbd al-Malik ibn Bahshāyish (d. c. 885/1480-1)	*Sharḥ al-Mulakhkhaṣ*: dedicated to Bāyazīd II	[40]
	History, pp. 535-36; *KZ1:* col. 1819; *KZ2:* vol. 6, p. 114; *OALT,* pp. 40-41 (no. 1); *Riyazî ilimler*, p. 385, ç.2		
15	Mollā-zāde al-Rūmī (d. ca. 900/1495)	*Sharḥ al-Mulakhkhaṣ*	[41]
	History, pp. 545-46; *OALT,* pp. 58-59		
16	Muʾayyad-zāde: ʿAbd al-Raḥmān ibn ʿAlī ibn Muʾayyad al-Amasī (d. 922/1516)	*Sharḥ al-Mulakhkhaṣ*: also studied with Jalāl al-Dīn Muḥammad ibn Asʿad al-Siddīqī al-Dawānī (d. 908/1502) in Shiraz	[42]
	Riyazî ilimler, p. 373		
17	ʿAbd al-Salām al-Muhtadī al-Muḥammadī (d. after 918/1512-3) = Hoja Īliyā al-Yahūdī	*Ḥāshiya* (Gloss)?: migrated to Ottoman Empire from Andalusia; lived during reigns of Sultan Bāyazīd II and Sultan Selīm I	[43]
	History, p. 546; *OALT,* p. 71		

18	Anonymous (late-8th/14th c.)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ*: It was copied by ʿAlī ibn Fatḥ Allāh al-Maʿdānī al-Isfahānī (=al-Sābirī), and has the seal of Mehmed II.	[44]
	Riyazî ilimler, p. 390, e.6		
19	Faṣīḥ al-Dīn ʿAbd al-Karīm al-Niẓāmī al-Nīsābūrī (d. ca. 850/1446)	*Ḥāshiya ʿalā Sharḥ al-Mulakhkhaṣ*: oldest copy dated 9th century H	[45]
	Riyazî ilimler, p. 391, e.10		
20	Faṣīḥ al-Dīn Muḥammad ibn ʿAbd al-Karīm Niẓāmī al-Kūhistānī (d. 936-7/1530)	*Sharḥ al-Mulakhkhaṣ*: Qushjī's student	[46]
	*MAMS*2: 309, A2		
21	ʿAlī ibn Ḥusayn al-Qūnawī (fl. mid-11th/17th c.)	*Tawḍīḥ al-Mulakhkhaṣ*	[47]
	This information was provided to me by İhsan Fazlıoğlu		
22	Anonymous	*Ḥāshiya ʿalā sharḥ al-Mulakhkhaṣ*	[48]
	OALT, p. 745		

II. Translations, Commentaries, Supercommentaries, and Glosses (Persian)

1	Muḥammad ibn ʿUmar al-Andiqānī (8th/14th c.)	Persian translation: the Ayasofya MS 2592 bears a copy date of 796, so he flourished prior to this	[49]
	Andiqānī; *Riyazî ilimler*, p. 388, e1.1		
2	Ḥusayn ibn al-Ḥusayn al-Khwārizmī al-Kubrawī (d. 839/1435-6)	Persian commentary: dedicated to Ulugh Beg	[50]
	*MAMS*2: 272, A2; *PL*, p. 50 (no. 88a), 73 (no. 106[2])		
3	Ḥamza ibn Ḥājj ibn Sulaymān (9th/15th c)	Persian translation: it was done by the order of Mehmed II	[51]
	OALT, pp. 21, 56-57; *Riyazî ilimler***,** p. 388, e1.2		

4	Anonymous	Persian: *Ḥāshiya ʿalā baḥth al-taḍārīs* (on the Earth's undulations as found in Qāḍīzāde's *Sharḥ*); presented to Sultan Bāyazīd II (r. 886-918 [1481-1513])	[52]
	Riyazî ilimler, pp. 387-88, d2.4		
5	Maḥmūd ibn Muḥammad ibn Muḥammad al-Qāḍī al-Wālishtānī al-Harawī (15th c.)	A Persian revision of the *Mulakhkhaṣ* compiled for Ghiyāth al-Dīn Aḥmad; Harawī worked at the court of Shāhrukh ibn Tīmūr	[53]
	Andiqānī, p. 873; *MAMS*2: 282, A1		
6	Kamāl al-Dīn Ḥusayn ibn ʿAbd al-Ḥaqq Ardabīlī (fl. 15th/16th centuries)	Persian commentary on *al-Mulakhkhaṣ*	[54]
	Andiqānī, p. 869 (no. 8)		
7	Qāḍī Nūr Allāh Shūshtarī (d. 1019/1610)	Persian commentary on *al-Mulakhkhaṣ*	[55]
	Andiqānī, p. 869 (no. 9)		
8	Muḥammad Zamān ibn Muḥammad Ṣādiq ibn Abī Yazīd Anbālajī Dihlawī	Persian commentary: *Ḥikam al-riyāḍī* completed 1130/1718-19	[56]
	PL, p. 50 (no. 88b)		
9	Mullā Muḥammad Jaʿfar Sharīʿatmadār Astarābādī (1198-1263/1783-1847)	Persian commentary on *al-Mulakhkhaṣ*; Astarābādī was a member of the ʿulamāʾ who traveled (e.g., Karbalā, Mecca, and Tehran) and had various teaching circles [Astarābād is in Gorgān province in northeastern Iran]	[57]
	Abada, pp. 92-95 (3.6); Andiqānī, p. 869 (no. 10)		
10	Sayyid Muḥammad Taqī bin Ḥusayn ibn Dildār ʿAlī Naqwī (19th c)	Persian commentary on *al-Mulakhkhaṣ*	[58]
	Andiqānī, p. 869 (no. 11)		
11	Anonymous	*Sharḥ al-Mulakhkhaṣ* (Qāḍīzāde)	[59]
	OALT, p. 786		

III. Translation (Turkish)

1	ʿAbbās Wasīm Efendi (d. 1173/1760)	Turkish translation of chapter 10 of Birjandī's *Ḥāshiya* on Qāḍīzāde's *Sharḥ al-Mulakhkhaṣ* dealing with lunar and solar eclipses [*Tarjamat kitāb al-Birjandī min al-khusūf wa-l-kusūf*]	[60]
	OALT, pp. 446-47 (no. 3); *Riyazî ilimler*, p. 385, c.3		

IV. Translation (Hebrew)

1	Moses Ben Elijah the Greek (late-$8^{th}/14^{th}$ c.)	Hebrew translation of the *Mulakhkhaṣ* [= The Purified Book]	[61]
	Morrison, forthcoming; Vajda 1959		

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