Freeing Astronomy from Philosophy

An Aspect of Islamic Influence on Science

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I. INTRODUCTION

IF ONE IS ALLOWED to speak of progress in historical research, one may note with satisfaction the growing sophistication with which the relationship between science and religion has been examined in recent years. The "warfare" model, the "separation" paradigm, and the "partnership" ideal have been subjected to critical scrutiny and the glaring light of historical evidence. As John Hedley Brooke has so astutely noted, "Serious scholarship in the history of science has revealed so extraordinarily rich and complex a relationship between science and religion in the past that general theses are difficult to sustain."[1] Unfortunately, this more nuanced approach has not been as evident in studies of Islam and science. Though there has been some serious scholarship on the relation between science and religion in Islam,[2] such work has made barely a dent in either the general accounts or the general perceptions of that relationship. These latter continue to be characterized by reductionism, essentialism, apologetics, and barely masked agendas.[3]

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Earlier versions of this essay were presented at the "Symposium on Science and Technology in the Turkish and Islamic World" (Istanbul, June 1994) and at the October 1994 meeting of the History of Science Society in New Orleans. My sincere thanks to those who offered comments and suggestions on both occasions and to two anonymous reviewers, all of whom helped in my own "deliverance from error."

[1] John Hedley Brooke, *Science and Religion: Some Historical Perspectives* (Cambridge: Cambridge Univ. Press, 1991), p. 5.

[2] Two works that deserve especial mention are A. I. Sabra, "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement," *Hist. Sci.* 25 (1987):223–43 (reprinted in idem, *Optics, Astronomy and Logic: Studies in Arabic Science and Philosophy* [Aldershot, U.K.: Variorum, 1994], no. 1, and in *Tradition, Transmission, Transformation,* ed. F. Jamil Ragep and Sally P. Ragep [Leiden: Brill, 1996], pp. 3–27); and A. I. Sabra, "Science and Philosophy in Medieval Islamic Theology," *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 9 (1994):1–42. David King and George Saliba have also made valuable contributions (in works cited later in the notes).

[3] Three fairly recent books illustrate the point nicely. Although they represent vastly different viewpoints, Pervez Hoodbhoy (*Islam and Science* [London: Zed, 1991]), Toby Huff (*The Rise of Early Modern Science* [Cambridge: Cambridge Univ. Press, 1993]), and S. H. Nasr (*Science and Civilization in Islam,* 2nd ed. [Cambridge: Islamic Texts Society, 1987]) blithely move from century to century and from region to region, applying their own particular vision to whatever historical event or personage comes their way. Hoodbhoy, a contemporary physicist who is confronting religious fanaticism in Pakistan, finds religious fanaticism to be the dominant aspect of science and religion in Islam. Huff, a sociologist intent on demonstrating that science could have arisen only in the West,

But even a cursory examination of sources, many of which unfortunately remain in manuscript, reveals a remarkable diversity of opinion in Islam regarding various aspects of the relationship between science and religion, which makes attempts to generalize an "Islamic" attitude toward science especially foolhardy. And the influence of the religion of Islam upon science, and vice versa, took a surprising number of forms, sometimes unexpectedly "progressive" from a modern viewpoint.[4]

When Hellenistic astronomy found a home in Islam in the eighth and ninth centuries A.D., it was adapted in numerous ways to fit into this new domicile. There are many reasons for this transformation, but here I concentrate on how Islam—understood as both doctrine and ritual—affected and influenced the course of astronomy. I first give an overview of these influences and then examine a specific case in which one can see how a religious discourse on the compatibility of the Aristotelian natural world and God's omnipotence made itself felt within theoretical astronomy, pushing it in various degrees toward independence from natural philosophy and metaphysics. I suggest that there was no single "Islamic" viewpoint, but rather divergent views arising from a variety of historical, intellectual, and individual factors. Though it is not the focus of the essay, I occasionally point to similarities between views of Islamic scholars and their European peers, similarities that may not be completely coincidental.

II. OVERVIEW OF THE RELATION BETWEEN HELLENISTIC ASTRONOMY AND ISLAM

Broadly speaking, one can identify two distinct ways in which religious influence manifested itself in medieval Islamic astronomy. First, there was the attempt to give religious value to astronomy, what David King has called "astronomy in the service of Islam." (One might also call this, to appropriate another context, the "handmaiden rationale.") The second general way in which religious influence shows up is in the attempt to make astronomy as metaphysically neutral as possible, in order to ensure that it did not directly challenge Islamic doctrine. As we shall see, some took this to mean that Hellenistic astronomy had not only to be reconceived but also stripped of its philosophical baggage.

Let us begin by looking briefly at the first type of influence, "astronomy in the service of Islam." Astronomy could and did provide the faithful (at least those who were interested) with extensive tables and techniques for determining prayer times,

attempts unconvincingly to show that "there was an absence [in Islamic civilization] of the rationalist view of man and nature" that effectively prevented the breakthroughs that occurred in early modern Europe (p. 88). Nasr, who wishes to point the way to a new "Islamic science" that would avoid the dehumanizing and despiritualizing mistakes of Western science, finds wherever he looks in the past an Islamic science that was spiritual and antisecular, so much so that even though "all that is astronomically new in Copernicus can be found essentially in the school of al-Ṭūsī," Islamic astronomers were prescient enough not to break with the traditional Ptolemaic cosmology, "because that would have meant not only a revolution in astronomy, but also an upheaval in the religious, philosophical and social domains" (p. 174). Essentialism, endemic in Islamic studies whether produced in the East or West, is pervasive throughout these works. Huff, for whom historical context seems an especially alien concept, does not hesitate to move from Ayatollah Khomeini to medieval jurists and back again (p. 203), akin to using Jerry Falwell to analyze Thomas Aquinas.

[4] An example is provided by B. F. Musallam in his *Sex and Society in Islam* (Cambridge: Cambridge Univ. Press, 1983), where he documents the use of ancient sources by numerous Islamic jurists of various stripes to bolster their sanction of contraception and abortion; see especially pp. 39–59.

for finding the sacred direction of Mecca, for calculating the beginning of Ramadan (the month of fasting), and so on. Since Muslim ritual could have survived perfectly well without the astronomers (does God really demand that one pray to within a minute or less of arc?), it does not take too great a leap of imagination to realize that this "service to religion" was really religion's service to the astronomers, both Muslim and non-Muslim,[5] providing on the one hand a degree of social legitimation and on the other a set of interesting mathematical problems to solve.[6]

One may also find instances of a different type of "service" that astronomy could provide, namely to reveal the glory of God's creation, a point made by no less a personage than Ibn al-Shāṭir, the fourteenth-century timekeeper of the Umayyad Mosque in Damascus.[7] This type of service was not new with Islam, of course; Ptolemy, Plato, and Aristotle, among others, saw astronomy as a way toward the divine (though in practice, admittedly, this meant something different for each of them).[8] But if I were to hazard here a particular "Islamic" influence and difference, I would say that it is in the emphasis on "God's creation" rather than on some Platonic, otherworldly reality. Islamic astronomers were thus less disposed toward the two-tiered reality that one sees in Neoplatonists such as Proclus (d. A.D. 485) or even in Ptolemy himself.[9] If I am right about this difference, it would go a long way toward explaining the surprising ambiguity one finds in Ptolemy about the reality of his planetary models and the much more realist approach taken generally by Islamic

[5] An example of a non-Muslim, indeed pagan, astronomer who worked "in the service of Islam" is Thābit ibn Qurra (d. A.D. 901), who wrote at least two treatises on crescent visibility; see Régis Morelon, *Thābit ibn Qurra: Œuvres d'astronomie* (Paris: Belles Lettres, 1987), pp. XCIII–XCVI.

[6] David King has been in the forefront of research dealing with both aspects. For social legitimation, see his essay "On the Role of the Muezzin and the *Muwaqqit* in Medieval Islamic Society," in Ragep and Ragep, *Tradition, Transmission, Transformation* (cit. n. 2), pp. 285–346, where King discusses the history of timekeeping and the role of the Mosque timekeeper *(muwaqqit)* both in Islamic civilization and in the history of astronomy. For more detailed, technical studies, see his *Astronomy in the Service of Islam* (Aldershot, U.K.: Variorum, 1993).

[7] Ibn al-Shāṭir is today best remembered for his treatise on theoretical astronomy in which he presented astronomical models that are virtually identical to ones used by Copernicus. The passage referred to, though, occurs in the introduction to his *al-Zīj al-jadīd,* a book on practical astronomy; see Sabra, "Science and Philosophy" (cit. n. 2), pp. 39–40. In addition to the scientific contexts where such praise for astronomy occurs, there is a religious cosmological literature dedicated to the glorification of God's creation; see Anton M. Heinen, *Islamic Cosmology: A Study of As-Suyūṭī's al-Hay'a as-sanīya fī l-hay'a as-sunnīya* (Beirut: Steiner, 1982), especially pp. 37–52.

[8] Plato discusses the importance of astronomy for finding true Reality in *Republic* 528E–530C, especially 530A, and for understanding the Divine in *Laws* 820E–822C; Ptolemy extols the study of astronomy for making "its followers lovers of this divine beauty, accustoming them and reforming their natures, as it were, to a similar spiritual state" (*Ptolemy's Almagest,* trans. and annot. G. J. Toomer [New York: Springer, 1984], I.1, p. 37). Though Aristotle is a bit more mundane, he is not averse to associating his study of the celestial aether with the divine (*De Caelo,* I.3, especially 270b6–12) nor to recommending the use of astronomers' results for ascertaining the number of divine beings (*Metaphysics,* XII.8, 1073b1–17).

[9] This manifests itself with Proclus in his contrast between human beings, who can only approximate the truth, and the gods, who alone can know it, and in his ambivalence regarding the reality of astronomical models such as eccentrics and epicycles. This position was called "instrumentalist" by Pierre Duhem in his influential but deeply flawed *Saving the Phenomena* ("ΣΟΖΕΙΝ ΤΑ ΦΑΙΝΟΜΕΝΑ: Essai sur la notion de théorie physique de Platon à Galilée," *Ann. Philo. Chrétienne,* 4th ser., 6 (1908):113–39, 277–302, 352–77, 482–514, 561–92; issued in book form [Paris: Hermann, 1908; reprinted Paris: Vrin, 1982]; Englished as *To Save the Phenomena: An Essay on the Idea of Physical Theory from Plato to Galileo,* trans. Edmund Doland and Chaninah Maschler [Chicago: Univ. of Chicago Press, 1969]). Duhem's views have been carefully analyzed by G. E. R. Lloyd in "Saving the Appearances," *Cl. Quart.,* n. s., 28 (1978):202–22, especially pp. 204–11 (reprinted with new introduction in idem, *Methods and Problems in Greek Science* [Cambridge: Cambridge Univ.

astronomers—an approach, I should add, that led a large number of them to attempt to reform Ptolemy by proposing more physically acceptable models.[10]

So much for astronomy in the service of Islam. Let us now move on to those religious influences that led to a more "metaphysically neutral" astronomy. The first example need not detain us. Clearly the most religiously objectionable part of Hellenistic astral science was astrology, which seemed to give powers to the stars that should be reserved for God. Attacks on astrology in Islam are not difficult to find, and they came, predictably, from religious quarters but also, more surprisingly, from some Hellenized philosophers such as Ibn Sīnā (= Avicenna [d. A.D. 1037]). It is instructive that Avicenna, not noted for conventional religious piety, did not hesitate to use Qur'ānic verses and a tradition from the Prophet to bolster his case against astrology; this tends to strengthen the argument that even those scientists committed to a Hellenistic outlook were sensitive to religious objections and willing to forgo parts of their Greek heritage.[11] A more subtle influence can be detected in the separation of astrology from astronomy. In early Islamic astronomical texts and in works categorizing the sciences, astronomy and astrology, following standard Hellenistic practice, were usually listed together under a rubric such as "science of the stars" (*'ilm al-nujūm*) or even *astronomia* (i.e., the transliterated Greek term). Starting with Avicenna, however, astrology came to be categorized as a part of natural philosophy (or physics), whereas astronomy (which became known as *'ilm al-hay'a*) was categorized as a strictly mathematical discipline.[12] As we shall see, this was just one of several moves whose purpose seems to have been to free a reconstituted *mathematical* astronomy, which, it was claimed, was objectively true, from the religiously objectionable parts of Greek physics and metaphysics.

In addition to these predictable objections to astrology, there were religious objec-

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Press, 1991], pp. 248–77). Lloyd provides a useful corrective to Duhem and argues that Proclus, somewhat surprisingly for a Platonist, had realist attitudes regarding phenomenal astronomy even while claiming that the "true philosopher" should "say goodbye to the senses" (p. 207; reprint, p. 259). Although, unlike Proclus, Ptolemy was a working astronomer and certainly not a Platonist (at least not in any simple sense), he does warn that "it is not appropriate to compare human [constructions] with divine" and, with faint echoes of Plato's insistence in the *Timaeus* that any account of the phenomenal world is only a "likely story," admits that "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" (*Almagest* [cit. n. 8], XIII.2, p. 600). But these seemingly instrumentalist remarks should be balanced against his bold confidence, in the introduction to the *Almagest,* "that only mathematics [including astronomy] can provide sure and unshakeable knowledge to its devotees" and that "this is the best science to help theology along its way" (p. 36), as well as against his later attempt to provide a cosmology in his *Planetary Hypotheses.* Clearly this aspect of Greek astronomy and cosmology deserves a much more elaborate and serious study than is possible here.

[10] To connect certain aspects of Islamic religious doctrine with the Islamic tradition of reforming Ptolemaic astronomy, itself part of a seemingly more substantial interest exhibited by Islamic astronomers (compared with their Greek predecessors) in discovering a true phenomenal cosmology, would require a significant historical study that is at best in its preliminary stages. My remarks here are meant simply as a working hypothesis.

[11] For a competent discussion of the objections to astrology by both religious and philosophical writers, see George Saliba, *A History of Arabic Astronomy: Planetary Theories during the Golden Age of Islam* (New York: New York Univ. Press, 1994), pp. 53–61, 66–72. Cf. Ignaz Goldziher, "The Attitude of Orthodox Islam toward the 'Ancient Sciences,'" in *Studies on Islam,* ed. and trans. Merlin L. Swartz (New York: Oxford Univ. Press, 1981), pp. 185–215, especially pp. 195–6 (German original: "Stellung der alten islamischen Orthodoxie zu den antiken Wissenschaften," *Abhandlungen der Königlich Preussischen Akademie der Wissenschaften* 8 (Berlin, 1916).

[12] For a further elaboration of this point, see F. J. Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy,* 2 vols. (New York: Springer, 1993), vol. 1, pp. 34–5.

tions to Hellenistic astronomy as a whole. It is to these and their effects upon Islamic astronomy that we now turn.

III. ON SAVING ASTRONOMY FROM THE TAINT OF PHILOSOPHY

Because it was one of the "ancient sciences" (i.e., pre-Islamic), astronomy was sometimes tarred with the same brush that besmirched any knowledge that fell outside the domain of the religious sciences. This taint took several forms. There were certainly those who condemned all the "ancient" or "foreign" sciences.[13] On the one hand, some singled out astronomy because of its presumably close association with astrology and even magic.[14] Others saw it as advancing strange and dangerous ideas, such as the notion of regions with a midnight sun, which was a consequence of the astronomers' circular motions and spherical bodies. If true, this would make it virtually impossible under some circumstances for Muslims in extreme northern climes to maintain the daylight fast during Ramadan.[15] Al-Ghazālī (d. A.D. 1111), certainly a more subtle and profound thinker, accepts that there are parts of astronomy (for example, the theory of solar and lunar eclipses) that are based on apodeictic demonstration and are thus "impossible to deny"; such things are, in and of themselves, unconnected with religious matters. However, these "neutral" and true aspects of mathematics may seduce the unwary student into believing that certainty also exists in the physical and metaphysical theories of the philosophers, some of which stand in contradiction to Islamic religious dogma. Thus the study of these sciences must be limited and constrained, for "few there are who devote themselves to this study without being stripped of religion and having the bridle of godly fear removed from their heads."[16]

But besides these more general warnings against astronomy as a representative of the "ancient sciences," there was another, more specific objection. Ghazālī tells us that

> [t]he basis of all these objections [to natural philosophy] is the recognition that nature is in subjection to God most high, not acting of itself but serving as an instrument in the hands of its Creator. Sun and moon, stars and elements, are in subjection to His command. There is none of them whose activity is produced by or proceeds from its own essence.[17]

This is part of Ghazālī's criticism of what we might term Aristotelian natural causation.

[13] Goldziher, "The Attitude of Orthodox Islam" (cit. n. 11), provides several examples.

[14] This is the insinuation made by Qādī (Judge) Tāj al-Dīn al-Subkī (14th c.); see David King, "On the Role of the Muezzin" (cit. n. 6), pp. 306–7 (p. 329 for the Arabic text). For Subkī's hostile attitude toward all of philosophy (with the exception of logic), which could well be the underlying reason for his disdain of astronomy, see Goldziher, "The Attitude of Orthodox Islam" (cit. n. 11), p. 207.

[15] Cf. Goldziher, "The Attitude of Orthodox Islam" (cit. n. 11), p. 197.

[16] Abū Ḥāmid al-Ghazālī, *al-Munqidh min al-ḍalāl,* ed. ʿAbd al-Karīm al-Marrāq (Tunis: al-Dār al-Tūnisiyya li-'l-Nashr, 1984), pp. 49–52. The translation used here is from W. Montgomery Watt, *The Faith and Practice of al-Ghazālī* (London: George Allen & Unwin, 1953), pp. 33–5. Cf. the more recent English translation by Richard J. McCarthy, *Freedom and Fulfillment* (Boston: Twayne, 1980), pp. 73–4, which is somewhat less elegant but rather more reliable. For an informed discussion of Ghazālī's attitude and its possible implications for the course of Islamic science, see Sabra, "Appropriation and Subsequent Naturalization" (cit. n. 2), pp. 239–41.

[17] Ghazālī, *Munqidh,* p. 54; translation by Watt, *The Faith and Practice of al-Ghazālī* (both cit. n. 16), p. 37; cf. McCarthy, *Freedom and Fulfillment* (cit. n. 16), p. 76. This point is closely related to the issue of cause and effect and to the occasionalist position of the Ashʿarite *mutakallims* (theologians).

> The connection between what is habitually believed to be a cause and what is habitually believed to be an effect is not necessary, according to us. . . . Their connection is due to the prior decree of God, who creates them side by side, not to its being necessary in itself, incapable of separation. On the contrary, it is within [divine] power to create satiety without eating, to create death without decapitation, to continue life after decapitation, and so on to all connected things. The philosophers denied the possibility of [this] and claimed it to be impossible.[18]

This is the well-known position of the Ash'arite theologians,[19] sometimes referred to as Islamic "occasionalism."[20] Exactly how this might work for establishing, say, a science of astronomy (something Ghazālī is not particularly interested in) is unclear. But there are some intriguing hints. For example, in Ghazālī's *al-Munqidh min al-ḍalāl* (Deliverance from error), written as an intellectual biography in the latter part of his life, he warns against the man, "loyal to Islam but ignorant," who tries to defend the faith by "the denial of the mathematical sciences." Such a person "even rejects their theory of the eclipse of sun and moon, considering what they say is contrary to the sacred Law." Ghazālī perceptively notes that someone who understands the certainty of the mathematical proofs involved might conclude "that Islam is based on ignorance and the denial of apodeictic proof" and that such a person "grows in love for philosophy and hatred for Islam." After quoting the Prophet, Ghazālī judges that "there is nothing here obliging us to deny the science of arithmetic which informs us in a specific manner of the paths of sun and moon, and of their conjunction and opposition."[21]

What Ghazālī seems to be proposing is an acceptance of the mathematical aspect of astronomy but not the physical part of that discipline, which might compel one to accept a "natural" motion in the heavens that was somehow independent of God's will. This view has been called "instrumentalist" inasmuch as it would tend to remove astronomers from theoretical considerations regarding the causes of celestial motion and confine them, presumably, to matters of calculation, more likely than not in the service of religion.[22] Of course, interpreted another way, "instrumentalism" could also free astronomers to pursue alternative hypotheses regarding celestial motion and the configuration of the heavens, a point to which we shall return later in this essay.[23]

[18] Al-Ghazālī, *The Incoherence of the Philosophers,* ed. and trans. Michael E. Marmura (Provo, Utah: Brigham Young Univ. Press, 1997), p. 170.

[19] From the eleventh century or so, the Ash'arites became the dominant theological *(kalām)* group among the Sunnī Muslims, succeeding the Mu'tazilites. They did, though, continue the atomist tradition of their predecessors as well as, for the most part, a rationalist approach to physical and theological matters.

[20] For a lucid discussion of this position in the context of Islamic *kalām,* see Sabra, "Science and Philosophy" (cit. n. 2); he also compares it with the position of Descartes (pp. 29–32).

[21] Ghazālī, *Munqidh,* pp. 51–2. I have somewhat modified Watt's translation, *The Faith and Practice of al-Ghazālī* (cit. n. 16), pp. 34–5; cf. McCarthy, *Freedom and Fulfillment* (cit. n. 16), p. 74.

[22] This position has been laid out by Sabra, "The Appropriation and Subsequent Naturalization of Greek Science" (cit. n. 2), pp. 238–42.

[23] It is worth noting that Ghazālī himself proposes possible alternatives to the view (held by both philosophers and astronomers such as Ptolemy) that the entire heaven is an animal with a soul that causes its motion. On this latter view, see Ragep, *Naṣīr al-Dīn* (cit. n. 12), vol. 2, pp. 408–10. For Ghazālī's alternatives, see *The Incoherence* (cit. n. 18), pp. 149–51. The possibility, *pace* Sabra, that Ghazālī's position could open up theoretical as well as instrumentalist possibilities needs a much more careful and sustained study than is possible here. (Cf. P. Duhem's controversial views regarding the liberating effects of the medieval European condemnations of Aristotle.)

Ghazālī's warnings about being overly zealous in condemning all of ancient science, even the apodeictic parts, indicates that he was trying to establish some "middle position." But what was the extreme theological position, and how might it work for understanding celestial phenomena? We learn from al-Qūshjī (d. A.D. 1474), a Central Asian scientist associated first with the Samarqand observatory and later with the scientific community of Constantinople (after its conquest by the Ottomans), what these may have been. In his major theological *(kalām)* work, a commentary on Naṣīr al-Dīn al-Ṭūsī's *Tajrīd al-ʿaqāʾid,* he presents what he sees as some of the absurd implications of the standard Ashʿarite denial of natural causation:

> On the assumption {*taqdīr*} of the validity {*thubūt*} of the volitional Omnipotent, it is conceivable that the volitional Omnipotent could by His will {*irāda*} darken the face of the Moon during a lunar eclipse without the interposition of the Earth and likewise during a solar eclipse the face of the Sun [would darken] without the interposition of the Moon; likewise, he could darken and lighten the face of the Moon according to the observed full and crescent shapes.[24]

It is not clear whether he was setting up a straw man or whether Qūshjī was responding to an actual argument he had encountered. Whichever, it is interesting that Ghazālī had, as we have seen, raised just this sort of example in his warning against taking the condemnation of the ancient sciences too far. But in one of the most, if not the most, influential of the late Ashʿarite textbooks, the *Mawāqif fī ʿilm al-kalām* by the Persian ʿAḍud al-Dīn al-Ījī (ca. A.D. 1281–1355), we do not find this extreme viewpoint regarding the explanation of eclipses but, surprisingly, a full and quite well-informed exposition of Ptolemaic astronomy.[25]

By this time, the Ashʿarites had adopted much of the terminology of Greek philosophy, and Ījī was no exception; this did not mean, however, that he adopted the doctrines of Greek philosophy.[26] In particular, he maintained, contra Aristotle, that the universe was atomistic in structure and contingent, depending on God's will to exist from instant to instant. When it came to astronomy, Ījī, who was well acquainted with the basic picture of Ptolemaic astronomy, held that the orbs were "imaginary things" *(umūr mawhūma)* and more tenuous than a spider's web *(bayt al-ʿankabūt).*[27] But Ījī did not draw the conclusion that astronomers' constructions were to be censured or condemned, as implied in the passage from Qūshjī's *Sharḥ al-tajrīd.* Rather he insisted, echoing Ghazālī, that "[religious] prohibition does not extend to them, being neither an object of belief nor subject to affirmation or negation."[28]

Viewed from the perspective of the possible range of religious positions on this matter, one would have thought that the astronomers would have been grateful for this seemingly generous solution to their problems; they could use whatever mathematical tools they needed for their craft as long as they did not declare them real. In

[24] ʿAlī b. Muḥammad al-Qūshjī, *Sharḥ Tajrīd al-ʿaqāʾid* [Tehran, 1890 (?)], p. 186 (line 28) through p. 187 (line 2). A translation and Arabic text of the larger passage of which this is a part is contained in the Appendix. Square brackets ([ ]) are used for editorial additions and explanations. Curly brackets ({ }) are used for original Arabic words or an English translation.

[25] For a brief but informative exposition of this section of Ījī's text, see Sabra, "Science and Philosophy" (cit. n. 2), pp. 34–8.

[26] The adoption by a number of Muslim theologians of the terminology but not necessarily the doctrines of Greek philosophy is a fascinating story, for which see ibid., pp. 11–23.

[27] Ibid., p. 37.

[28] Ibid.

essence, they were being given an "instrumentalist" option. But the astronomers, as we shall see, were hardly thrilled with this solution to the science–religion problem, and we will need to explore why they were not. But before that, we need to ask ourselves another question: Why did Ījī feel the necessity to offer them a solution in the first place? After all, he was not an astronomer himself, and in the main he rejected many of their most fundamental claims about the nature of the universe.

To answer this question, we need to understand something of the context and historical period in which this debate was occurring. For the most part, the participants were either Persians or Central Asians; the period was the aftermath of the Mongol invasions of the thirteenth century, which considerably reshaped the political and intellectual landscape of the area. Not only the traditional political but also the religious leadership in the East was either destroyed or considerably weakened. The Mongols preferred to fill their courts and bureaucracies with some relatively heterodox figures. (The reasons for this are fairly easy to grasp.) The most significant of these from an intellectual standpoint was Naṣīr al-Dīn al-Ṭūsī (A.D. 1201–1274). Ṭūsī was a crucial figure for a number of reasons, but especially because he left behind a corpus of writings that became the main vehicle not only for studying but also for defending Greek science and philosophy, at least in eastern Islam, until modern times. He also wrote on religious matters, and in these works he continued the process of bringing Greek philosophical terms and ideas into the theological context. Though he was born a mainstream Shīʿite and had dabbled for a time with Ismāʿīlism, a much more heterodox Shīʿite doctrine, by the time Ṭūsī began working for the Mongols in 1256, his intellectual allegiance was firmly with the Hellenistic tradition of Islam, which for him was not only a way of unifying the sciences but also a means of transcending religious differences and disputes. As such he hearkens back to an earlier period of Islamic intellectual history, to the Kindīs, the Fārābīs, and especially to Avicenna, for whom Greek philosophy became a kind of transcendent religion. For this Ṭūsī was bitterly reviled by the religious establishment in Mameluke Egypt and Syria, which had mostly escaped the Mongol onslaught. Curiously, though, the Persian theologians, such as Ījī, seem to have been mostly respectful toward him—but not simply respectful. I have no doubt that Ījī, who was born less than ten years after Ṭūsī's death, learned his astronomy, and perhaps even his Greek philosophy, from Ṭūsī's writings; in that case, he was swept up in Ṭūsī's discourse even while disagreeing with it. It should therefore not surprise us that Ījī would try to reassure the Ashʿarite faithful that they had nothing to fear from the surging tide of Hellenistic science and philosophy in Iran while at the same time accommodating Ṭūsī and his many followers by offering them a respectable way to be both good astronomers and good Muslims.[29]

Returning to the astronomers, why would some of them feel uneasy with Ījī's, and for that matter Ghazālī's, compromise? That they would reject this accommodation tells us something about their self-confidence and the strength of their tradition during these centuries.[30] But this was not simply a case of disciplinary pride. Some

[29] For a more detailed and documented discussion of the points made in this paragraph, see Ragep, *Naṣīr al-Dīn* (cit. n. 12), vol. 1, pp. 3–20.

[30] The continuing strength of the tradition of science in Islam after A.D. 1200 has only recently been recognized by researchers in the field. The reasons for this long neglect have a great deal to do with the Eurocentric nature of most history of science, which has tended to assume, whether consciously or not, that once the twelfth-century translation movement from Arabic into Latin was com-

were led to this rejection by what they saw as the requirements of an astronomy that could provide a correct picture *(hay'a)* of the universe as well as insight into God's creation (as we have seen). This can be clearly observed in the response of al-Sharīf al-Jurjānī (A.D. 1339–1413) to Ījī's dismissive remarks regarding the "imaginary" and "tenuous" nature of the astronomers' orbs. In addition to his many other hats, which included being a renowned theologian, Jurjānī was an astronomer who wrote a widely read and appreciated commentary to Ṭūsī's astronomical masterpiece, the *Tadhkira.* With his astronomer's turban firmly in place, he responded to Ījī as follows, by trying to explain that the mathematical objects of the astronomers, though "imagined," do have a correspondence with reality:

> Even if they do not have an external reality, yet they are things that are correctly imagined and correspond to what [exists] in actuality {*fī nafs al-amr*} as attested by sound instinct {*al-fiṭra al-salīma*}; they are not false imaginings such as ghouls' fangs, ruby mountains and two-headed men. By means of these [astronomical] notions, the conditions of [celestial] movements are regulated in regard to speed and direction, as perceived [directly] or observed with [the aid of] instruments. [By means of these notions also] discovery is made of the characteristics {*aḥkām*} of the celestial orbs and the earth, and of what they reveal of subtle wisdom and wondrous creation—things that overcome whoever apprehends them with awe, and facing him with the glory of their Creator, prompt him to say: "Our Lord, thou has not created this in vain." This then is a valuable lesson that lies hidden in those words [of the astronomers] and that ought to be cherished, while ignoring whoever is driven to disdain them by mere prejudice.[31]

It is important to note here that Jurjānī's commentary quickly became an integral part of Ījī's textbook and was studied with it in the school tradition. (It was still being studied in Islamic theological schools, such as Cairo's al-Azhar, into the twentieth century!) Thus Ījī's conventionalist/instrumentalist view of astronomical models would have been read with Jurjānī's forceful rejoinder.[32]

Jurjānī, though, while defending astronomy's integrity and its religious value against Ījī's dismissive remarks, does not here deal with the issue of astronomy's alleged dependence upon suspect religious doctrines, such as natural causation and the eternity of the world. Most, though not all, Islamic astronomers felt that at least some of these doctrines were indispensable. As Ṭūsī says in the *Tadhkira,* "Every science has . . . principles, which are either self-evident or else obscure, in which case they are proved in another science and are taken for granted in this science . . . [T]hose of its principles that need proof are demonstrated in three sciences: metaphysics, geometry, and natural philosophy."[33] Thus in addition to mathematics and observation, Ṭūsī is claiming that certain physical and metaphysical principles need to be imported from philosophy. This importation was not taken lightly; indeed, in general one finds among Islamic astronomers a great reluctance to use physical principles from philosophy as a substitute for basing their conclusions on what they

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pleted, Islamic intellectuals, having fulfilled their historical mission of preservation for Europe, must have given up their scientific endeavors.

[31] al-Ījī, *Kitāb al-Mawāqif fī 'ilm al-kalām* (with the commentary of al-Jurjānī), ed. Muḥammad Badr al-Dīn al-Na'sānī (Cairo, A.H. 1325/A.D. 1907), pt. vii, p. 108. This is mostly Sabra's translation (with minor changes) from his "Science and Philosophy" (cit. n. 2), p. 39.

[32] One hopes that such examples might give pause to those who insist on treating Islamic religious views as monolithic.

[33] Ragep, *Naṣīr al-Dīn* (cit. n. 12), vol. 1, pp. 90–1.

saw as mathematics, which included observation. In this they seem to have followed trends that had already been established in antiquity. In a passage preserved by Simplicius (6th c. A.D.) in his commentary on Aristotle's *Physics,* he quoted Geminus (ca. 1st c. A.D.), who was, we are told, "inspired by the views of Aristotle," to the effect that a clear demarcation can be made between the role of the physicist and the role of the astronomer.[34] "The physicist will in many cases reach the cause by looking to creative force; but the astronomer, when he proves facts from external conditions, is not qualified to judge of the cause, as when, for instance, he declares the earth or the stars to be spherical." This is elucidated in an earlier part of the passage:

> Now in many cases the astronomer and the physicist will propose to prove the same point, e.g., that the sun is of great size or that the Earth is spherical, but they will not proceed by the same road. The physicist will prove each fact by considerations of essence or substance, of force, of its being better that things should be as they are, or of coming into being and change; the astronomer will prove them by the properties of figures or magnitudes, or by the amount of movement and the time that is appropriate to it.[35]

Geminus, no doubt "inspired by the views of Aristotle," declares that the astronomer "must go to the physicist for his first principles, namely, that the movements of the stars are simple, uniform and ordered." But this was a view that was not universally held in antiquity. Ptolemy, for example, refers to physics and metaphysics as "guesswork" and proclaims that "only mathematics can provide sure and unshakeable knowledge to its devotees."[36] One would assume that he would therefore try to avoid physical and metaphysical principles in his astronomy, and, indeed, in the introductory cosmological sections of the *Almagest,* he generally establishes such things as the sphericity of the heavens and the Earth, the Earth's centrality and its lack of motion, according to observational and mathematical principles, in contrast to the more physical means used by Aristotle in, say, *De Caelo.*[37]

Ptolemy's stated position had some major support among Islamic astronomers. The Persian scholar Quṭb al-Dīn al-Shīrāzī (A.D. 1236–1311), onetime student and associate of Naṣīr al-Dīn al-Ṭūsī, paraphrases Ptolemy: "Astronomy is the noblest of the sciences. . . . [I]ts proofs are secure—being of number and geometry—about which there can be no doubt, unlike the proofs in physics and theology."[38]

But several Islamic astronomers note, often with dismay, that Ptolemy had broken his own rule and had used "physical" principles. In particular, the eminent Central Asian scientist Abū Rayḥān al-Bīrūnī (A.D. 973–1048) chides him for using arguments based on physics to prove the sphericity of the heavens in the *Almagest* (I.3) and insists that "each discipline has a methodology and rules and that which is exter-

[34] This is probably in reference to Aristotle, *Physics* II.2; cf. Lloyd, "Saving the Appearances" (cit. n. 9), pp. 212–13.

[35] Translation by T. L. Heath in his *Aristarchus of Samos* (Oxford: Clarendon, 1913), p. 276; reprinted in Morris R. Cohen and I. E. Drabkin, *A Source Book in Greek Science* (Cambridge, Mass.: Harvard Univ. Press, 1948), pp. 90–1. Cf. Lloyd, "Saving the Appearances" (cit. n. 9), pp. 212–14.

[36] *Ptolemy's Almagest* (cit. n. 8), I.1, p. 36.

[37] For a discussion of how this is viewed in the Islamic context, see Ragep, *Naṣīr al-Dīn* (cit. n. 12), vol. 1, pp. 38–41; vol. 2, pp. 382–8.

[38] Quṭb al-Dīn al-Shīrāzī, preface to "Nihāyat al-idrāk fī dirāyat al-aflāk," Ahmet III MS 3333 (2), fol. 34b, Topkapı Saray, Istanbul.

nal to it cannot be imposed {*yastaḥkimu*} upon them; therefore, what [Ptolemy] has set forth that is external to this discipline is persuasive rather than necessary."[39]

Looking at Bīrūnī's insistence upon a clear separation of astronomy from physics (or natural philosophy) and Ṭūsī's introductory remarks regarding the need of astronomy for principles from natural philosophy and metaphysics, one might well be tempted to conclude that what we have is a continuation of the ancient debate between the mathematicians (such as Ptolemy, who insisted upon an autonomous astronomy) and the philosophers (represented, as we have seen, by Aristotle and Geminus, who placed the astronomers in a dependent role).[40] But this would be misleading. Even the more philosophically inclined of the Islamic astronomers seem, for the most part, to be intent not only on demarcating astronomy from natural philosophy but also on making it as independent as possible. We have already seen how Avicenna separated astronomy (as a mathematical discipline) from astrology (considered to be part of natural philosophy). Furthermore Ṭūsī himself made clear in the *Tadhkira* that an astronomer should prove most cosmological matters using "proofs of the fact" (that simply establish their existence using observations and mathematics) rather than "proofs of the reasoned fact" (that "convey the necessity of that existence" using physical and/or metaphysical principles); the latter kind of proofs, he tells us, are given by Aristotle in *De Caelo*.[41] In other words, the astronomer should avoid dealing with ultimate causes and instead establish the foundations of his discipline by employing the apodeictic tools of mathematics. This attitude is reinforced as well in the physical principles that Ṭūsī uses to explain regular motion. He analyzes it in such a way that the source of that motion, whether an Aristotelian "nature" (as in the case of the four elements) or a soul (as in the case of the celestial orbs) becomes irrelevant for astronomy; in both cases, he maintains (departing here from Aristotle) that regular motion is always due to an innate principle (*mabda'* = αρχή) called a "nature" (*ṭab'*), thus sidestepping the problem of ultimate causation.[42] Muḥammad A'lā al-Tahānawī (18th c. A.D.) nicely summarizes the situation: "In this science [i.e., astronomy], motion is investigated [in terms of] its quantity and direction. The inquiry into the origin (*aṣl*) of this motion and its attribution {*ithbāt*} to the orbs is part of Natural Philosophy (*al-ṭab'iyyāt* [sic])."[43]

[39] Abū Rayḥān al-Bīrūnī, *Al-Qānūn al-Mas'ūdī*, 3 vols. (Hyderabad: Dā'irat al-ma'ārif al-'Uthmāniyya, 1954–1956), vol. 1, p. 27. The criticism is directed at Ptolemy's use of "certain physical considerations" regarding the aether to prove the sphericity and circular motion of the heavens (*Ptolemy's Almagest* [cit. n. 8], I.3, p. 40). Elsewhere in the *Qānūn* (vol. 2, pp. 634–5), Bīrūnī strongly criticizes Ptolemy for using assumptions and ideas from outside of astronomy in his *Planetary Hypotheses;* see Ragep, *Naṣīr al-Dīn* (cit. n. 12), vol. 1, p. 40, for a translation and discussion of this passage.

[40] Thanks to the recent work of Lloyd and others, we can make such a distinction without resorting to Duhem's reductionist rhetoric of "instrumentalists" versus "realists"; cf. n. 9.

[41] Ragep, *Naṣīr al-Dīn* (cit. n. 12), vol. 1, pp. 106–7. For an examination of this passage and its relation to the *quia–propter quid* distinction made in Aristotle's *Posterior Analytics,* see vol. 1, pp. 38–41, and vol. 2, pp. 382, 386–8.

[42] Ṭūsī seems to be trying to account for the fact that the ensouled celestial orbs, even though they have volition, "choose" to move uniformly, unlike entities with souls in the sublunar realm. This was obviously a problem with a long history from ancient to early modern times; see Ragep, *Naṣīr al-Dīn* (cit. n. 12), vol. 1, pp. 44–6; vol. 2, p. 380. Cf. Harry Wolfson, "The Problem of the Souls of the Spheres from the Byzantine Commentaries on Aristotle through the Arabs and St. Thomas to Kepler," *Dumbarton Oaks Papers* 16 (1962):67–93, and Richard C. Dales, "The De-Animation of the Heavens in the Middle Ages," *J. Hist. Ideas,* 41 (1980):531–50.

[43] Muḥammad A'lā b. 'Alī al-Tahānawī, *Kashshāf iṣṭilāḥāt al-funūn: A Dictionary of the Technical Terms Used in the Sciences of the Musalmans,* edited by Mawlawies Mohammad Wajih, Abd

Let us take stock. Islamic scientists inherited an astronomy from the ancients that already had been differentiated to a lesser or greater degree from natural philosophy. Islamic astronomers, though, carried this process much farther along, and it does not seem unreasonable to see this, at least in part, as a response to religious objections directed at Hellenistic physics and metaphysics, on the one hand, and to religious neutrality toward mathematics, on the other. An attentive reader, though, might still have questions about these tentative conclusions. Why, for example, did someone like Ṭūsī still insist that astronomy needed physical and metaphysical principles even while he contributed toward making it more independent? Did any Islamic astronomer ever defend an astronomy completely independent of philosophy? And finally, can we make a stronger, more explicit and less circumstantial case for a connection between religion and this freeing of astronomy from philosophy? In the remaining part of the essay, I explore these questions.

As we have seen, Bīrūnī implies that the physics one needs for astronomy could be generated within the astronomical context using mathematics and observation; hence one would not need to import "philosophical physics." But was this really feasible? Could one claim that uniform circular motion in the heavens, the straight-line motions of the sublunar realm, and, most important of all, the Earth's state of rest were not based upon Aristotelian physics? As mentioned earlier, Ṭūsī certainly did not believe one could go that far. In part, this was due to one particular instance that became a *cause célèbre* of late medieval Islamic astronomy.[44] In a famous and controversial passage, Ṭūsī explicitly says that the Earth's state of rest cannot be observationally determined and explicitly denies Ptolemy's claim that it can be.[45] In at least this one instance, mathematics and observation fail us, and we therefore need to import from natural philosophy the physical principle that the element earth's natural motion is rectilinear and therefore the Earth cannot rotate naturally. In a more general form, this position was reiterated forcefully and at some length by Ṭūsī's sixteenth-century commentator al-Bīrjandī.[46] This, then, was a bottom line that shows us why some astronomers could not abide Ījī's compromise and why Ṭūsī and others insisted on astronomy's need for natural philosophy.

But not every astronomer agreed with Ṭūsī. In fact his own student Quṭb al-Dīn

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al-Haqq, and Gholam Kadir under the superintendence of A. Sprenger and W. Nassau Lees, 2 vols. (Calcutta: W. N. Lees' Press, 1862), vol. 1, p. 47.

[44] This question, namely whether the Earth's state of rest could be determined by observational tests, is dealt with in my "Ṭūsī and Copernicus: The Earth's Motion in Context," to appear in *Science in Context*. It is also discussed, more summarily, in Ragep, *Naṣīr al-Dīn* (cit. n. 12), vol. 2, pp. 383–5.

[45] The passage, which is from the *Tadhkira* (Ragep, *Naṣīr al-Dīn* [cit. n. 12], vol. 1, pp. 106–7), is as follows: "It is not possible to attribute the primary motion to the Earth. This is not, however, because of what has been maintained, namely that this would cause an object thrown up in the air not to fall to its original position but instead it would necessarily fall to the west of it, or that this would cause the motion of whatever leaves the [Earth], such as an arrow or a bird, in the direction of the [Earth's] motion to be slower, while in the direction opposite to it to be faster. For the part of the air adjacent to the [Earth] could conceivably conform *(yushāyiʿu)* to the Earth's motion along with whatever is joined to it, just as the aether [(here) = upper level of air] conforms *(yushāyiʿu)* to the orb as evidenced by the comets, which move with its motion. Rather, it is on account of the [Earth] having a principle of rectilinear inclination that it is precluded from moving naturally with a circular motion." The similarity to Copernicus, *De Revolutionibus* (Nuremburg, 1543), 6a, lines 16–34, is discussed in the references listed in the preceding footnote.

[46] ʿAbd al-ʿAlī al-Bīrjandī, "Sharḥ al-Tadhkira," Houghton MS Arabic 4285, fol. 39b, Harvard College Library, Cambridge, Mass.; for his more general statements defending the use of natural philosophy in astronomy, see fols. 7a–7b and 38a.

al-Shīrāzī took issue with his sometime master and claimed that one could establish the Earth's state of rest by an observational test, thus obviating the need for importing a physical principle from philosophy.[47] This position, of course, goes well with what we have seen of Shīrāzī's insistence, following Ptolemy, that the mathematical proofs of astronomy were more secure than those of physics and theology; by claiming that observational tests could establish the Earth's state of rest, one could protect astronomy's integrity from the encroachment of natural philosophy and metaphysics.

But because this debate was mainly being carried out within the confines of the scientific literature, the religious dimensions are not very explicit. We may feel justified in claiming that Bīrūnī and Shīrāzī were being influenced by religious considerations in trying to separate astronomy from philosophy, but this is merely a conjecture. In contrast, there can be no doubt as to the religious context of this debate in the already mentioned commentary on Ṭūsī's theological work, the *Tajrīd al-ʿaqāʾid* (Epitome of belief), written by ʿAlī al-Qūshjī.

Qūshjī was the son of Prince Ulugh Beg's falconer and grew up in or close to the Timurid court in Samarqand in the fifteenth century. Samarqand at the time, with its observatory, large scientific staff, brilliant individuals, and scientifically accomplished patron Ulugh Beg, was without a doubt the major center of science in the world and certainly could rival its thirteenth-century predecessor that had been established by Ṭūsī in Marāgha under Mongol patronage.[48] After the assassination of his patron Ulugh Beg, Qūshjī traveled through Iran and Anatolia and eventually assumed a chair in astronomy and mathematics at the college *(madrasa)* of Aya Sofia in the newly Islamic city of Istanbul.[49] It should be emphasized that the teaching of science in the religious schools, and later the establishment of an observatory in Istanbul, were opposed, sometimes bitterly, by the religious establishment.[50] Qūshjī, writing his commentary on Ṭūsī's "Epitome of Belief" after the assassination but before assuming his chair, was no doubt mindful of this religious opposition and sought to answer the objection to astronomy that I have previously quoted from him.

Let us summarize some of the key points he makes. (The entire Arabic text, with my translation, is in the Appendix.) Qūshjī is clearly sensitive to the Ashʿarite

[47] Shīrāzī's discussion can be found in maqāla II, bāb 1, faṣl 4 (fols. 46a–47b) of his "Nihāyat al-idrāk fī dirāyat al-aflāk" (cit. n. 38), which was completed in A.D. 1281. A similar passage is in his "al-Tuḥfa al-shāhiyya fī al-hayʾa," which appeared in A.D. 1284 (bāb II, faṣl 4 [Jāmiʿ al-Bāshā MS 287, Mosul (= Arab League *falak muṣannaf ghayr mufahras* Film 346), fols. 15a–18a, and MS Add. 7477, British Museum, London, fols. 9b–11a]). This section of the "Nihāya" was translated into German by Eilhard Wiedemann in "Ueber die Gestalt, Lage und Bewegung der Erde, sowie philosophisch-astronomische Betrachtungen von Qutb al-Dīn al-Schīrāzī," *Archiv für die Geschichte der Naturwissenschaften und der Technik* 3 (1912):395–422 (reprinted in E. Wiedemann, *Gesammelte Schriften zur arabisch-islamischen Wissenschaftsgeschichte,* 3 vols. [Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1984], vol. 2, pp. 637–64).

[48] On the Samarqand observatory, see Aydin Sayılı, *The Observatory in Islam* (Ankara: Turkish Historical Society, 1960), pp. 259–89. See also E. S. Kennedy, "The Heritage of Ulugh Beg," in idem, *Astronomy and Astrology in the Medieval Islamic World* (Brookfield, Vt.: Ashgate, 1998), no. XI.

[49] See A. Adnan Adivar, "ʿAlī b. Muḥammad al-Ḳūshdjī," *Encyclopedia of Islam,* 2nd ed. (Leiden: Brill, 1960), vol. 1, p. 393, and idem, *La Science chez les Turcs ottomans* (Paris: Maisonneuve, 1939), pp. 33–5.

[50] Adivar discusses this in his *La Science chez les Turcs ottomans* (cit. n. 49). For the Istanbul observatory, which the religious establishment forced to be demolished, see Sayılı, *The Observatory* (cit. n. 48), pp. 289–305.

position on causality, and he makes the interesting observation that part of their objection to it, at least as regards astronomy, has to do with the astrological contention of a causal link between the positions of the orbs and terrestrial events (especially "unusual circumstances"). To get around such objections, Qūshjī insists that astronomy does not need philosophy, since one could build the entire edifice of orbs necessary for the astronomical enterprise using only geometry, reasonable suppositions, appropriate judgments, and provisional hypotheses. These premises allow astronomers

> to conceive {*takhayyalū*} from among the possible approaches the one by which the circumstances of the planets with their manifold irregularities may be put in order in such a way as to facilitate their determination of the positions and conjunctions of these planets for any time they might wish and so as to conform with perception {*ḥiss*} and sight {*ʿiyān*}.

What this will allow us to do is make presumptions that best explain "or save" the phenomena. Of course God might, by His will, cause the phenomena directly; Qūshjī gives the example of God darkening the Moon without the Earth's shadow and causing an eclipse. But just as we go about our everyday lives using what he calls ordinary *(ʿādiyya)* and practical *(tajribiyya)* knowledge, thus should we proceed in science. Here he allows himself a bit of sarcasm, arguing that we could (for example) claim that after we had left our house one day, God turned all the pots and pans into human scholars who took to investigating the sciences of theology and geometry; insofar as we feel confident in assuming that this has not happened, so also should we have confidence that the heavens normally follow a regular pattern that we have the capacity to explain. We do not, however, need to make the further claim that our explanation represents the only possible one; in this way, Qūshjī believes he has made astronomy independent of philosophy.

What makes Qūshjī's position especially fascinating are some of the repercussions it had for his astronomical work. Since he claims to be no longer tied to the principles of Aristotelian physics, he feels free to explore other possibilities, including the Earth's rotation. Clearly within the tradition of the debate that we outlined earlier, he agrees with Ṭūsī, thus countering Ptolemy and Shīrāzī, and argues that the question of the Earth's motion cannot be determined by observation. But unlike Ṭūsī, he refuses to settle the matter by appealing to Aristotelian natural philosophy. Instead he states that "it is not established that what has a principle of rectilinear inclination is prevented from [having] circular motion."[51] He then ends with a startling conclusion: "Thus nothing false *(fāsid)* follows [from the assumption of a rotating Earth]."[52]

Qūshjī also showed that he was true to his principles in his elementary astronomy work, *Risālah dar ʿilm-i hayʾa;* in it, he took the highly unusual step of dispensing with the section on natural philosophy with which almost all other similar treatises began.[53]

[51] Qūshjī, *Sharḥ Tajrīd* (cit. n. 24), p. 195. The same point is made by Copernicus in *De Revolutionibus* (cit. n. 45), I.8.

[52] Ibid. Qūshjī's position, and the possible relation of this Islamic debate to Copernicus, is dealt with more fully in my "Ṭūsī and Copernicus" (cit. n. 44).

[53] This work was originally in Persian and, given the evidence of the extant manuscripts, quite popular. It was translated by Qūshjī himself into Arabic and dedicated to Mehmet, the Conqueror (Fātiḥ) of Constantinople, whence it was called *al-Risāla al-Fatḥiyya.* Cf. Tofigh Heidarzadeh, "The Astronomical Works of ʿAlī Qūshjī" (in Turkish), M. A. thesis, (İstanbul Univ., 1997), pp. 24, 30–32,

But in freeing himself from Aristotle, did Qūshjī also free himself from seeking reality? In other words, instead of being the precursor of Copernicus, is he rather the predecessor of Osiander, the Lutheran minister whose anonymous preface to *De Revolutionibus* proclaimed, "[L]et no one expect anything certain from astronomy"? My tentative answer is that I do not think Qūshjī's position is instrumentalist in the same sense as Ījī's (or Osiander's).[54] And the reason, in a way, is quite simple. Ījī was a theologian, whereas Qūshjī, in his heart of hearts, was a scientist, whose work was ultimately a way to know and understand God's creation. Qūshjī makes this clear with his remarks at the end of his discussion of premises. The astronomers' models may be calculating devices that cannot be claimed as unique, but nevertheless they are, he tells us, a source of wonder, because of their correspondence with the observed phenomena. He continues, "Whoever contemplates the situation of shadows on the surfaces of sundials will bear witness that this is due to something wondrous and will praise [the astronomers] with the most laudatory praise." Qūshjī here seems to echo the words of Jurjānī, cited earlier, in which the latter countered Ījī by insisting that through astronomy we can behold God's subtle wisdom and wondrous creation. Qūshjī, though, in rejecting the view that somehow we can know true reality, is attempting to present a rather more sophisticated position: that the correspondence between our human constructions and external reality is itself a source of wonder.[55]

Ultimately, then, for Jurjānī, Qūshjī, and many other Islamic scientists, Ījī's well-meant instrumentalist compromise was rejected. As would also occur in Europe, they held that one could glorify God with science; one could not glorify God with conventions.

IV. CONCLUSION

In the generation or two following Qūshjī, science in the Islamic East continued to thrive. Several major astronomical works were produced by two contemporaries of Copernicus, ʿAbd al-ʿAlī al-Bīrjandī (d. A.D. 1525 or 1526) and Shams al-Dīn al-Khafrī (fl. A.D. 1525). As we have already noted, Bīrjandī continued the debate regarding the Earth's motion and strongly defended the need to use both natural philosophy and metaphysics in astronomy. In fact, he quotes and directly argues against the passage that I have quoted from Qūshjī.[56] In developing his position, Bīrjandī

41; E. Ihsanoğlu et al., *Osmanlı Astronomi Literatürü Tarihi,* 2 vols. (Istanbul: IRCICA, 1997), vol. 1, pp. 27–35; and David Pingree, "Indian Reception of Muslim Versions of Ptolemaic Astronomy," in *Tradition, Transmission, Transformation* (cit. n. 2), p. 474.

[54] For a comparison of Ījī and Osiander, see Sabra, "Science and Philosophy" (cit. n. 2), pp. 38–9. It would be quite interesting to compare the later manifestations of Ījī's position in the Islamic schools with what Robert Westman has called the "Wittenberg interpretation" of Copernican theory, which allowed the hypothesis of a Sun-centered universe to be studied in sixteenth-century Lutheran circles while it condemned any attempt to embrace it as true or real.

[55] Cf. Albert Einstein, *Ideas and Opinions* (New York: Dell, 1973), p. 285: "The very fact that the totality of our sense experiences is such that by means of thinking (operations with concepts, and the creation and use of definite functional relations between them, and the coordination of sense experiences to these concepts) it can be put in order, this fact is one which leaves us in awe, but which we shall never understand. One may say 'the eternal mystery of the world is its comprehensibility.' It is one of the great realizations of Immanuel Kant that the postulation of a real external world would be senseless without this comprehensibility."

[56] Bīrjandī, "Sharḥ al-Tadhkira" (cit. n. 46), fol. 7a–7b. Curiously, Bīrjandī does not mention Qūshjī by name but simply refers to him as "one of the eminent scholars" *(baʿḍ al-afāḍil).*

makes an interesting analysis of what might occur if the Earth were rotating (which he himself rejects) and hypothesizes something quite close to Galileo's notion of "circular inertia."[57]

The point is not to claim that Copernicus (or Galileo) read Bīrjandī (though this does not now seem as far-fetched as it might once have appeared), but rather to indicate the remarkable intensity of scholarship and diversity of opinion that continued in Islamic lands well into the sixteenth century (and in fact even later). This is a time that until recently was seen as a period characterized by the steep decline, or even absence of scientific work. Since the vast majority of texts written during this late period in the history of Islamic science have yet to be studied (much less published), many exciting surprises might well be anticipated. But whether or not this proves to be the case, the present discussion of one small aspect of the situation of science in Islam should alert us to the fact that science was still a major force well into the early modern period and can shed light not only on Islamic intellectual history but the history of European science as well. And one hopes that part of that light will help us to understand the relation between science and religion in both the Islamic world and in Christendom.

That religion played a role in Islamic science—perhaps even a crucial role—should not surprise us. What is surprising, especially to a Western audience in the twenty-first century, is that that role was not simply one of opposition and obstruction but rather, at least sometimes, of constructive engagement. I hope I will not be misunderstood as being an apologist for religion if I make the historical observation that religious attacks on aspects of science and philosophy in both Islam and Christendom led to a more critical attitude toward scientific and philosophical doctrines and that this often resulted in some interesting and even productive outcomes. This has been a point increasingly accepted by historians of European science, and one that would greatly help Islamists, and those who write on Islam, to understand the complexity of the interaction of secular and religious knowledge in Islamic civilization.

[57] Ibid., fol. 37a. See further my "Ṭūsī and Copernicus" (cit. n. 44).

Appendix

Concerning the Supposed Dependence of Astronomy upon Philosophy

By ʿAlī al-Qūshjī

[186] It is stated that the positing of the orbs in [that] particular way depends upon false principles taken from philosophy {*falsafa*}, for example, the denial of the volitional Omnipotent and the lack of possibility of tearing and mending of the orbs, and that they do not intensify nor weaken in their motions, and that they do not reverse direction, turn, stop, nor undergo any change of state but rather always move with a simple motion in the direction in which they are going, as well as other physical and theological matters, some of which go against the Law {*sharʿ*} and some of which are not established inasmuch as their proofs are defective {*madkhūla*}. For if it were not based upon those principles, we could say that the volitional Omnipotent by His will moves those orbs in the observed order, or we could say that the stars move in the orb as fish do in water, speeding up and slowing down, going backward, stopping and moving forward without need for those many orbs. But by assuming the validity {*thubūt*} of those principles, what they have stated is an affirmation {*ithbāt*} of a cause based upon the existence of an effect; but this will not be valid unless one knows the correlation {*musāwāt*} [note under the line: "i.e., the correlation of the effect to the cause"]. But this is not known, since there is no necessary [connection]; nor is there a demonstration {*burhān*} of the impossibility that the observed irregularities are for reasons other than the ones they have stated.

However, there is nothing to the above, since it stems from a lack of study of the problems and proofs of this discipline. Most of [its principles] are suppositions [{*muqaddamāt ḥadsiyya*} = (literally) conjectural premises] that the mind {*ʿaql*}, upon observing the above-mentioned irregularities, resolves to posit according to an observed order and a reliance upon geometrical premises that are not open to even a scintilla of doubt. For example: the sighting of the full and crescent shapes [of the Moon] in the manner in which they are observed makes it certain that the light of the Moon is derived from the Sun and that a lunar eclipse occurs because of the interposition of the Earth between the Sun and Moon, and that a solar eclipse occurs because of the interposition of the Moon between the Sun and the eye, this despite the assertion of the validity of the volitional Omnipotent and the denial

This appendix is my translation of ʿAlī al-Qūshjī's *Sharḥ tajrīd al-ʿaqā'id* (cit. n. 24), p. 186 (line 11) through p. 187 (line 29); part of this passage is cited by Bīrjandī in his "Sharḥ al-Tadhkira" (cit. n. 46), fol. 7a–7b, and a good part of it is quoted by Tahānawī in his *Kashshāf iṣṭilāḥāt al-funūn* (cit. n. 43), vol. 1, pp. 48–9.

شرح تجريد العقائد

لعلي القوشجي

(ص ١٨٦-١٨٧)

وما يقال من أنّ إثبات الأفلاك على الوجه المخصوص مبنيّ على أصول فاسدة مأخوذة من الفلاسفة من نفي القادر المختار وعدم تجويز الخرق والالتيام على الأفلاك وأنّها لا تشتدّ في حركاتها ولا تضعف ولا يكون لها رجوع ولا انعطاف ولا وقوف ولا اختلاف حال غيرها بل تكون أبداً متحرّكة حركة بسيطة في الجهة التي تتحرّك إليها إلى غير ذلك من المسائل الطبيعيّة والإلهيّة التي بعضها مخالف للشرع وبعضها لم يثبت لكون أدلّتها مدخولة إذ لو لم يُبْنَ على تلك الأصول نقول إنّ القادر المختار بحسب إرادته يحرّك تلك الأفلاك على النظام المشاهد أو نقول إنّ الكواكب تتحرّك في الفلك كالحيتان في الماء تسرع وتبطئ وترجع وتقف وتقيم من غير حاجة إلى تلك الأفلاك الكثيرة وعلى تقدير ثبوت تلك الأصول فما ذكروا إثبات للملزوم بناء على وجود لازمة ولا يصحّ إلّا إذا علم المساواة ﴿تحت السطر : «أي مساواة اللازم للملزوم»﴾ وليست بمعلومة إذ لا ضرورة ولا برهان على امتناع أن يكون تلك الاختلافات المشاهدة لأسباب أخر غير ما ذكروا : فليس بشيء إذ منشاؤه عدم الاطّلاع على مسائل هذه الفنّ ودلائله فإنّ أكثرها مقدّمات حدسيّة يجزم العقل بثبوتها عند مشاهدة الاختلافات المذكورة على النظام المشاهد والاستعانة بالمقدّمات الهندسيّة التي لا يتطرّق إليها شائبة اشتباه مثلاً مشاهدة التشكّلات البدرية والهلاليّة على الوجه المرصود يوجب اليقين بأنّ نور القمر مستفاد من الشمس وأنّ الخسوف إنّما هو بسبب حيلولة الأرض بين الشمس والقمر والكسوف إنّما هو بسبب حيلولة القمر بين الشمس والإبصار مع القول بثبوت القادر المختار ونفي

of those above-mentioned principles. For the validity of the volitional Omnipotent and the denial of those principles does not preclude the situation being as stated; at most, they would allow for other possibilities. For example: on the assumption of the validity {*thubūt*} of the volitional Omnipotent, it is conceivable that the volitional Omnipotent could by His will {*irāda*} darken the face of the Moon during a lunar eclipse without the interposition of the Earth and likewise during [187] a solar eclipse the face of the Sun [would darken] without the interposition of the Moon; likewise, he could darken and lighten the face of the Moon according to the observed full and crescent shapes. Furthermore, on the assumption of the possibility of the irregularity in the motions as well as the other circumstances of the celestial bodies {*falakiyyāt*}, it is possible that one half of each of the luminaries is luminous whereas the other is dark. The luminaries would then move about their centers in such a way that their dark sides would face us during lunar and solar eclipses, either completely, when they are total, or partially in magnitude, when they are not total. By an analogous argument, the situation of the full and crescent shapes [can be explained]. Nevertheless, despite the raising of the previously mentioned possibilities {*iḥtimālāt*}, we affirm {*najzimu*} that the situation is as stated, namely that the Moon derives its light from the Sun and that lunar and solar eclipses occur because of the interposition of the Earth and Moon. This same sort of presumption {*iḥtimāl*} is made in ordinary {*ʿādiyya*} and practical {*tajribiyya*} knowledge {*ʿulūm*}—indeed, for all necessary [direct?] knowledge {*ḍarūriyyāt*}. For we assert that after leaving a house the pots and pans inside do not turn into human scholars who take to investigating the sciences of theology and geometry, despite the fact that the volitional Omnipotent might make it thus in virtue of His will.

But [on the other hand], on the assumption that the principle {*mabdaʾ*} is made causal {*mūjab*}, an unusual circumstance {*waḍʿ gharīb*} may be realized {*yataḥaqqaqu*} from the positions of the orbs; according to the doctrine of the proponents of causality, the manifestation of that unusual occurrence is required by the dependency of events upon the positions of the orbs. This and other examples are embedded in the skepticism {*shubah*} of those who condemn necessary knowledge.

The upshot is that that which is stated in the science of astronomy {*ʿilm al-hayʾa*} does not depend upon physical {*ṭabīʿiyya*} and theological {*ilāhiyya*} premises {*muqaddamāt*}. The common practice by authors of introducing their books with them is by way of following the philosophers; this, however, is not something necessary, and it is indeed possible to establish [this science] without basing it upon them. For of what is stated in [this science]: (1) some things are geometrical premises, which are not open to doubt; (2) others are suppositions {*muqaddamāt ḥadsiyya*}, as we have stated; (3) others are premises determined by {*yaḥkumu bihā*} the mind {*al-ʿaql*} in accordance with the apprehension {*al-akhdh*} of what is most suitable and appropriate. Thus they say that

تلك الأصول المذكورة فإنّ ثبوت القادر المختار وانتفاء تلك الأصول لا ينفيان أن يكون الحال على ما ذكر غاية الأمر أنّهما يجوّزان الاحتمالات الأخر مثلاً على تقدير ثبوت القادر المختار يجوز أن يسوّد القادر المختار بحسب إرادته وجه القمر عند الخسوف من غير حيلولة الأرض وكذا عند /١٨٧/ الكسوف وجه الشمس من غير حيلولة القمر وكذا يجوز أن يُسَوِّدَ وينوّر وجه القمر على ما يشاهد من التشكّلات البدريّة والهلاليّة وأيضاً على تقدير جواز الاختلاف في حركات الفلكيّات وسائر أحوالها يجوز أن يكون أحد نصفي كلّ من النيّرين مضيئاً والآخر مظلماً ويتحرّك النيّران على مركزيهما بحيث يصير وجهاهما المظلمان مواجهين لنا في حالتي الخسوف والكسوف إمّا بالتمام وذلك إذا كانا تامّين وإمّا بالبعض على قدرهما إذا كانا غير تامّين وعلى هذا القياس حال التشكّلات البدرية والهلالية لكنّا نجزم مع قيام الاحتمالات المذكورة على أنّ الحال على ما ذكر من استفادة القمر نوره من الشمس وأنّ الخسوف والكسوف إنّما يكونان بسبب حيلولة الأرض والقمر ومثل هذا الاحتمال قائم في العلوم العاديّة والتجربيّة بل في جميع الضروريّات فإنّا نجزم بأن أواني البيت بعد خروجنا عنه لم تصر أناساً فضلاء محقّقين في العلوم الإلهيّة والهندسيّة مع أنّ القادر المختار يجوز أن يجعلها كذلك بحسب إرادته بل على تقدير أن يكون المبدأ موجَباً ﴿تحت السطر : «أي مضطرا»﴾ يجوز أن يتحقّق وضع غريب من الأوضاع الفلكيّة فيقتضي ظهور ذلك الأمر الغريب على ما هو مذهب القائلين بالإيجاب من استناد الحوادث إلى الأوضاع الفلكيّة وغير ذلك ممّا هو مركوز في شبه القادحين في الضروريّات والحاصل أنّ المذكور في علم الهيئة ليس مبنيّاً على المقدّمات الطبيعيّة والإلهيّة وما جرت به العادة من تصدير المصنّفين كتبهم بها إنّما هو بطريق المتابعة للفلاسفة وليس ذلك أمراً واجباً بل يمكن إثباته من غير ابتناء عليها فإنّ المذكور فيه بعضه مقدّمات هندسيّة لا يتطرّق إليها شبهة وبعضه مقدّمات حدسيّة كما ذكرنا وبعضه مقدّمات يحكم بها العقل بحسب الأخذ بما هو الأليق والأولى كما يقولون إنّ

the convexity of the deferent touches the convexity of the parecliptic at a common point, as is the case with the concavities. They have no other reason {*mustanad*} [for this] except that it is more proper that there not be any useless part in the heavens. Similarly they say that the Sun's orb is above the orb of Venus and of Mercury, since the best arrangement and order dictate that that which is farther away or having a larger circuit has the slowest motion among the planets; or that in the order and arrangement the Sun is in the middle—in the manner of the tassel of a necklace—between those that reach the four elongations from it, i.e., the sextiles, quadratures, trines, and oppositions, and those whose elongation is only the least, i.e., the sextile; and (4) other premises that they state are indefinite {*ʿalā sabīl al-taraddud*}, there being no final determination {*al-jazm*}. Thus they say that the irregular speed in the Sun's motion is either due to an eccentric or to an epicyclic hypothesis without there being a definitive decision for one or the other.

If one were to grant that the establishing of the orbs in the manner in which they have stated was based on those false principles, this would doubtless be due to a claim by the practitioners of this science that there was no possibility other than the approach we have stated. But if their claim was that it was possible for it to be by this approach, even though it was possible that it could be by other approaches, one could not then imagine a dependency. It is more than sufficient for them to conceive {*takhayyalū*} from among the possible approaches the one by which the circumstances of the planets with their manifold irregularities may be put in order in such a way as to facilitate their determination of the positions and conjunctions of these planets for any time they might wish and so as to conform with perception {*ḥiss*} and sight {*ʿiyān*}, this in a way that the intellect and the mind find wondrous {*tataḥayyaru*}. Whoever contemplates the situation of shadows on the surfaces of sundials will bear witness that this is due to something wondrous and will praise [the astronomers] with the most laudatory praise.

محدّب الحامل مماس محدّب الممثّل على نقطة مشتركة وكذا مقعّره لمقعّره ولا مستند لهم غير أنّ الأولى أن لا يكون في الفلكيات فضل لا يحتاج إليه وكما يقولون إنّ فلك الشمس فوق فلك الزهرة وعطارد لأنّ حسن الترتيب والنظام يقتضي أن يكون ما هو أكثر بعداً أو أعظم مداراً أبطأ حركة من الكواكب وأن يكون الشمس واسطة في النظم والترتيب بمنزلة شمسة القلادة بين ما يبعد عنها الأبعاد الأربعة أعني التسديس والتربيع والتثليث والمقابلة وبين ما لا يبعد عنها إلّا أقلّ الأبعاد المذكورة أعني التسديس وبعض مقدّمات يذكرونها على سبيل التردّد دون الجزم كما يقولون إنّ اختلاف حركة الشمس بالسرعة والبطؤ إمّا بناءً على أصل الخارج وإمّا بناءً على أصل التدوير من غير جزم بأحدهما ولو سلّم أنّ إثبات الأفلاك على الوجه الذي ذكروه يتوقّف على تلك الأصول الفاسدة فلا شكّ أنّه إنّما يكون ذلك إذا ادّعى أصحاب هذا الفنّ أنّه لا يمكن إلّا على الوجه الذي ذكرنا أمّا إذا كان دعواهم أنّه يمكن أن يكون على ذلك الوجه وإن أمكن أن يكون على الوجوه الأخر فلا يتصوّر التوقّف حينئذ وكفى بهم فضلاً أنّهم تخيّلوا من الوجوه الممكنة ما ينضبط به أحوال تلك الكواكب مع كثرة اختلافاتها على وجه تيسّر لهم أن يعيّنوا مواضع تلك الكواكب واتّصالات بعضها مع بعض في كلّ وقت أرادوا بحيث يطابق الحسّ والعيان مطابقة تتحيّر فيها العقول والأذهان ومن تأمّل في أحوال الأظلال على سطوح الرخامات شهد بأنّ هذا لشيء عجاب وأثنى عليهم بثناء مستطاب