On the Extended Emission of the Magnetar 1E 1547.0–5408

Cite as: AIP Conference Proceedings **1357**, 193 (2011); https://doi.org/10.1063/1.3615114
Published Online: 02 September 2011

Scott Olausen, Victoria M. Kaspi, C.-Y. Ng, et al.

On the Extended Emission of the Magnetar 1E 1547.0–5408

Scott Olausen*, Victoria M. Kaspi*, C.-Y. Ng*, Rim Dib*, Weiwei Zhu*, Fotis Gavriil†,** and Peter Woods‡

*Department of Physics, McGill University, 3600 University St., Montreal, QC, H3A 2T8, Canada
†NASA GSFC, Astrophysics Science Division, Code 662, Greenbelt, MD, 20771, USA
**Center for Research and Exploration in Space Science and Technology, University of Maryland Baltimore County, 1000 Hilltop Circle, Baltimore, MD, 21250, USA
‡Corvid Technologies, 689 Discovery Drive, Huntsville, AL, 35806, USA

Abstract. Recently, Vink & Bamba (2009) detected extended emission around the magnetar 1E 1547.0–5408 in quiescence and characterized it as the result of a pulsar wind nebula (PWN). From analysis of a February 2010 *XMM-Newton* observation of the source, as well as three archival *XMM-Newton* observations, we confirm the detection of extended emission. However, we find that its X-ray flux is highly variable and tightly correlated with the X-ray flux of the magnetar itself. We conclude that it is most likely due to a dust-scattering halo and not a PWN as previously claimed.

Keywords: magnetar, neutron star
PACS: 97.60.Jd,97.60.Gb,95.85.Nv

Magnetars are a class of neutron stars whose X-ray luminosities and variable behavior are thought to be powered by the decay of their high $\left(10^{14}\text{–}10^{15}\,\mathrm{G}\right)$ magnetic fields. The X-ray source 1E 1547.0–5408 [1] is the fastest-rotating magnetar known, based on the radio detection of 2.1 s pulsations and an inferred magnetic field of $2.2 \times 10^{14}\,\mathrm{G}$ [2, 3]. For a more complete history of this source including its 2008 and 2009 outbursts, please see Israel et al. [4] and Ng et al. [5]. Vink & Bamba [6] detected extended emission about the source when it was in quiescence and characterized it as a pulsar wind nebula (PWN). This would make 1E 1547.0–5408 the only magnetar known to power a PWN.

Here we report on an analysis of the extended emission around 1E 1547.0–5408 based on an *XMM-Newton* observation of the source from February 2010, as well as three archival *XMM-Newton* observations from 2006, 2007, and 2009.

To search for extended emission around 1E 1547.0–5408 we first removed all detected point sources other than the magnetar, and then constructed a radial profile centered on the source position. The radial profile of a point source is given by the radially averaged *XMM-Newton* point spread function (PSF), which we extracted from the calibration files and weighted based on the spectrum of the magnetar. After normalizing the weighted PSF and adding a constant background we compared it with the observed radial profile.

The 2010 radial profile of 1E 1547.0–5408 in the 1–6 keV energy band is shown in Figure 1 (left), and an excess of counts is clearly visible above the expected point source profile. Conversely, above 6 keV the observed profile is consistent with a point source. The same results are also seen in the other observations; we therefore confirm the presence of extended emission around 1E 1547.0–5408 below 6 keV as previously reported [6, 7]. The extended emission is brighter below 3 keV, in line with the soft

Radio Pulsars: An Astrophysical Key to Unlock the Secrets of the Universe
AIP Conf. Proc. 1357, 193-194 (2011); doi: 10.1063/1.3615114

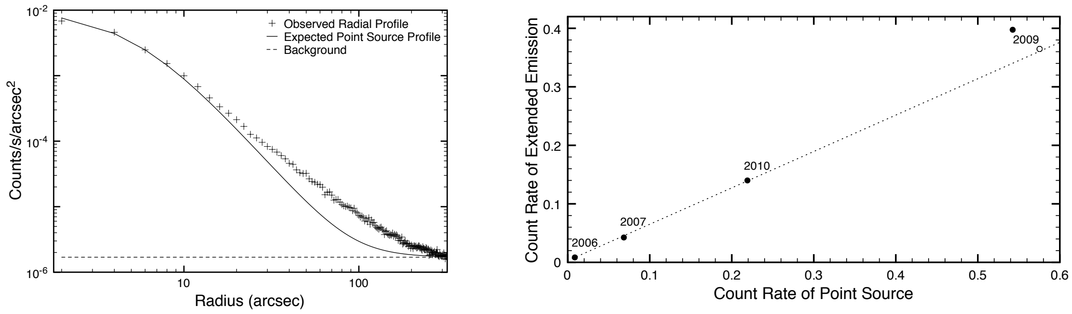

FIGURE 1. Left: February 2010 radial profile of 1E 1547.0–5408 in the 1–6 keV energy band. Right: Total background-subtracted 1–6 keV count rate of the point source and extended emission integrated over an annular region 20″–40″ away from 1E 1547.0–5408 for each of the four *XMM-Newton* observations (filled circles). The dotted line is fit to the first three points. The unfilled circle represents the count rates for the 2009 observation after attempting to compensate for the mild pile-up present in the data.

spectrum reported by Vink & Bamba [6]. We also find that the extended emission flux is highly variable and well correlated with the source flux (see Figure 1 right), changing on time scales of less than a year. Indeed, the tight correlation suggests that the extended emission flux is a constant fraction of the pulsar flux. The observed correlation is also consistent with passing through the origin, meaning we find no evidence that any of the extended emission within 40″ of the magnetar is uncorrelated with the source flux.

Vink & Bamba [6], based on a 2006 *Chandra* observation of 1E 1547.0–5408 in quiescence, characterized the extended emission within 45″ of the magnetar as being from a PWN. This interpretation is problematic in light of these results. PWNe in rotation-powered pulsars do not exhibit the order-of-magnitude variations in X-ray flux we observe for this source, nor is the tight correlation seen in Figure 1 (right) expected from a PWN. In particular, estimates of the synchrotron lifetime of electrons producing 1–6 keV X-rays argue against strong fading on a one-year timescale as seen from 2009 to 2010. Finally, the reported spectrum of the extended emission $(\Gamma = -3.4)$ is softer than all known PWNe. By contrast, our results are consistent with a dust-scattering halo, where a tight correlation and softer spectrum are expected. As well, Tiengo et al. [7] have shown from their analysis of the dust-scattering rings seen after the 2009 outburst that scattering material exists along the line-of-sight to the source. We therefore conclude that the *XMM-Newton* observations strongly support that the extended emission around 1E 1547.0–5408 is most likely a dust-scattering halo, with no evidence for the existence of a PWN component as has been claimed previously.

REFERENCES

1. R. C. Lamb and T. H. Markert, *ApJ* **244**, 94 (1981).
2. F. Camilo, S. M. Ransom, J. P. Halpern, and J. Reynolds, *ApJ* **666**, L93 (2007).
3. J. D. Gelfand, and B. M. Gaensler, *ApJ* **667**, 1111 (2007).
4. G. L. Israel, et al. *MNRAS* **408**, 1387 (2010).
5. C.-Y. Ng, *ApJ* submitted (arXiv:1008.1165) (2011).
6. J. Vink and A. Bamba, *ApJ* **707**, L148 (2009).
7. A. Tiengo, et al., *ApJ* **710**, 227 (2010).