THE ASTROPHYSICAL JOURNAL, 528:L21–L23, 2000 January 1
© 2000. The American Astronomical Society. All rights reserved. Printed in U.S.A.

ASCA OBSERVATION OF THE QUIESCENT X-RAY COUNTERPART TO SGR 1627−41

K. HURLEY,[1] T. STROHMAYER,[2] P. LI,[1] C. KOUVELIOTOU,[3] P. WOODS,[4] J. VAN PARADIJS,[5] T. MURAKAMI,[6] D. HARTMANN,[7] I. SMITH,[8] M. ANDO,[6] A. YOSHIDA,[9] AND M. SUGIZAKI[10]

Received 1999 September 22; accepted 1999 October 29; published 1999 November 30

ABSTRACT

We present a 2–10 keV *ASCA* observation of the field around the soft gamma repeater SGR 1627−41. A quiescent X-ray source, whose position is consistent both with that of a recently discovered *BeppoSAX* X-ray source and with the Interplanetary Network localization for this soft gamma repeater, was detected in this observation. In 2–10 keV X-rays, the spectrum of the X-ray source may be fit equally well by a power-law, blackbody, or bremsstrahlung function, with unabsorbed flux $\approx 5 \times 10^{-12}$ ergs cm^{-2} s^{-1}. We do not confirm a continuation of a fading trend in the flux, and we find no evidence for periodicity, both of which were noted in the earlier *BeppoSAX* observations.

Subject headings: gamma rays: bursts — stars: neutron — supernova remnants — X-rays: stars

1. INTRODUCTION

SGR 1627−41, the fourth soft gamma repeater (SGR), was discovered in a series of observations between 1998 June and July by the Burst and Transient Source Experiment (BATSE) aboard the *Compton Gamma-Ray Observatory* (Woods et al. 1999), the Gamma-Ray Burst Experiment aboard *Ulysses* (Hurley et al. 1999), the KONUS experiment aboard the *Wind* spacecraft (Mazets et al. 1999), and the All-Sky Monitor (ASM) on the *Rossi X-Ray Timing Explorer* (*RXTE*; Smith, Bradt, & Levine 1999). The SGR error box derived from the Interplanetary Network (IPN) and the ASM passes through the Galactic supernova remnant (SNR) G337.0−0.1 (Hurley et al. 1999). Two *BeppoSAX* observations of this region on 1998 August 7 and September 16 revealed a quiescent X-ray source whose position was consistent with that of both the IPN/ASM localization and the SNR. Although no bursts were observed during this observation, the luminosity and the spectral index of the source were similar to those of the quiescent soft X-ray sources associated with other SGRs. Thus, a reasonable working hypothesis is that this is most likely the neutron star counterpart to SGR 1627−41. The source displayed a possible periodicity of 6.41 s (chance probability 6×10^{-3}, based on a limited number of trials; Woods et al. 1999).

Based on the peak luminosities of the SGR in outburst, Woods et al. (1999) estimated that the neutron star magnetic field strength was $\gtrsim 5 \times 10^{14}$ G. These properties would make the SGR counterpart a magnetar, an object in which magnetic energy dominates all other sources of energy, including rotation (Thompson & Duncan 1995, 1996). Evidence that other SGRs are also magnetars has been presented (Kouveliotou et al. 1998, 1999; but see also Marsden, Rothschild, & Lingenfelter 1999). In those cases, decisive evidence for the magnetic field strength came from the spin-down rates and their interpretation as dipole radiation. In an attempt to confirm the periodicity of SGR 1627−41 and measure its spin-down rate, we observed the source with the *Advanced Satellite for Cosmology and Astrophysics* (*ASCA*).

2. *ASCA* OBSERVATIONS

The *ASCA* observation took place between 1999 February 26 and 28. The nominal pointing direction was $\alpha(2000) = 16^{\rm h}36^{\rm m}14^{\rm s}$, $\delta(2000) = -47^\circ 32' 31''$, and the approximate exposures were 72.7 ks for the solid-state imaging spectrometer and 78.4 ks for the gas scintillation imaging spectrometer (GIS). We used the standard screening criteria for such parameters as Earth elevation angle, South Atlantic Anomaly, and cutoff rigidity to extract photons, as explained in the *ASCA* Data Reduction Guide, version 2.[11] No bursts from the source were observed by *Ulysses*, BATSE, or *ASCA* during the observation (the last burst from SGR 1627−41 was observed in 1998 August). Using the Ximage source detection tool, a quiescent source was detected at $\alpha(2000) = 16^{\rm h}35^{\rm m}46\overset{\rm s}{.}41$, $\delta(2000) = -47^\circ 35' 13\overset{''}{.}1$ with a 3 σ error radius of 55″, consistent with the 1′ radius error circle of the *BeppoSAX* source (Fig. 1). Approximately 3800 net counts were detected, versus ≈2850 in the first *BeppoSAX* observation. Two other sources were detected in this observation, but neither had a position consistent with either the IPN annulus or G337.0−0.1. Assuming that the *ASCA*, *BeppoSAX*, and SGR sources are the same object, the most likely position of the SGR is around the intersection of the IPN annulus with this new error circle, at $\alpha(2000) = 16^{\rm h}35^{\rm m}52^{\rm s}$, $\delta(2000) = -47^\circ 35' 14''$.

The region used for spectral analysis consisted of a 105″ radius circle centered at the source position; background was taken from the same observation, using a similar circle at a region in which no source was present, as determined by Ximage. Spectral fitting to the GIS2 and GIS3 data was done using XSPEC and three trial functions: blackbody, thermal bremsstrahlung, and a power law, all with absorption. These results

[1] University of California, Berkeley, Space Sciences Laboratory, Berkeley, CA 94720-7450.
[2] NASA Goddard Space Flight Center, Greenbelt, MD 20771.
[3] Universities Space Research Association at NASA Marshall Space Flight Center, ES-84, Huntsville, AL 35812.
[4] NASA Marshall Space Flight Center, ES-84, Huntsville, AL 35812; and University of Alabama in Huntsville, Huntsville, AL.
[5] University of Alabama in Huntsville, AL 35899; and Astronomical Institute "Anton Pannekoek," University of Amsterdam, Netherlands.
[6] ISAS, 3-1-1 Yoshinodai, Sagamihara, Kanagawa, Japan 229.
[7] Clemson University, Department of Physics and Astronomy, Clemson, SC 29634-0978.
[8] Department of Space Physics and Astronomy, Rice University, MS-108, 6100 South Main, Houston, TX 77005-1892.
[9] Institute of Chemical and Physical Research (RIKEN), 2-1 Hirosawa, Wako, Saitama 351-0198 Japan.
[10] Space Utilization Research Program, Tsukuba Space Center, National Space Development Agency of Japan, 2-1-1 Sengen, Tsukuba, Ibaraki, 305-8505 Japan.

[11] See http://heasarc.gsfc.nasa.gov/docs/asca/abc/abc.html.

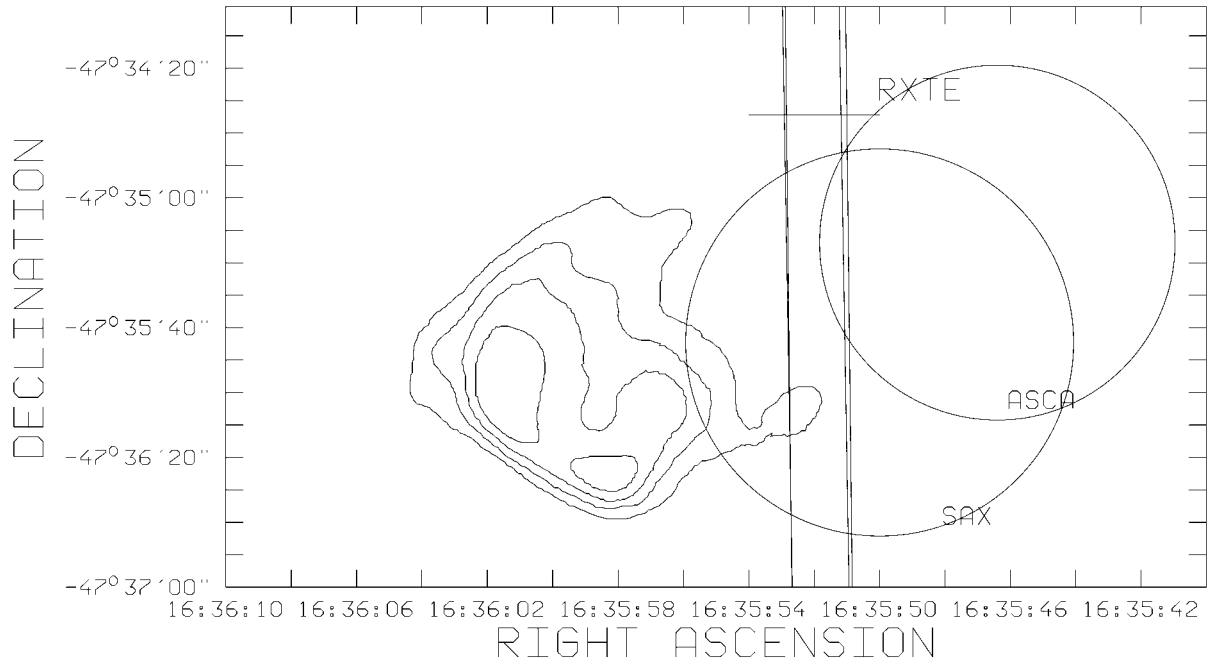

FIG. 1.—Two IPN annuli from Hurley et al. (1999), superposed on the inner 1380 MHz radio contours of G337.0−0.1 from Sarma et al. (1997). The *BeppoSAX* error circle from Woods et al. (1999) and the *ASCA* error circle from the present observation are indicated (the remnant extends over the *ASCA* source position). The horizontal line indicates the upper boundary to the error box from the *RXTE* ASM; the lower boundary is off the scale.

are reported in Table 1 along with the earlier *BeppoSAX* results. There is no clear preference for any of these models, but we adopt the power-law fit for further discussion.

To search for periodicity, barycentric light curves were constructed with 0.125 s binning from the sum of the GIS2 and GIS3 data by extracting ≈1–10 keV counts from a 4′ radius circular region around the source, and a fast Fourier transform was performed (Fig. 2). The most prominent peak in the power spectrum was at 0.10821 Hz (significance 0.12). The 90% confidence upper limit to the power of any signal in the spectrum with period between 0.01 and 1 Hz is ≈3% (rms). Woods et al. (1999) found a 6.413183 s period in the first of their two *BeppoSAX* observations, with an rms pulse fraction of 10% ± 2.6%. The upper limit to the signal power at this period from the folded *ASCA* light curve is 1.8% (rms). This limit would be appropriate only if the spin-down rate were zero; if the quiescent counterpart to SGR 1627−41 is characterized by a rate $\approx 10^{-10}$ s s^{-1}, as is the case for SGR 1900+14, the period could have changed by as much as 0.0015 s between the *BeppoSAX* and *ASCA* observations, and the 3% upper limit would be the appropriate one. We found no significant evidence for periodicities between 0.001 and 0.01 Hz. However, searches in this range are complicated by windowing effects from the data gaps and nonuniform sampling and are therefore less sensitive.

3. DISCUSSION AND CONCLUSION

The earlier *BeppoSAX* observations of the quiescent counterpart of SGR 1627−41 indicated a fading trend, significant at the ≈5.9 σ level in the raw data, over the ≈5 week period between the two pointings (Woods et al. 1999; Table 1). Indeed, variability in the quiescent emission of SGRs may not be unusual: such variability has been observed for SGR 1900+14 (Kouveliotou et al. 1999; Murakami et al. 1999). The unabsorbed 2–10 keV flux found in the *ASCA* observation reported here is consistent with that found in the second *BeppoSAX* observation and therefore indicates that this trend did not con-

TABLE 1
SPECTRAL FITS TO THE SOFT X-RAY COUNTERPART OF SGR 1627−41

Parameter	Power Law	Blackbody	Bremsstrahlung
	ASCA		
Index	−2.2 ± 0.3	...	...
kT (keV)	...	1.3 ± 0.1	6.5 ± 2
Reduced χ^2 (89 degrees of freedom)	0.90	0.91	0.86
Column density N_H (10^{22} cm^{-2})	6.9 ± 1	3.2 ± 0.7	5.9 ± 0.8
Unabsorbed 2–10 keV flux (ergs cm^{-2} s^{-1})	(5.1 ± 0.4) × 10^{-12}	(3.5 ± 0.3) × 10^{-12}	(4.6 ± 0.4) × 10^{-12}
	BeppoSAX[a]		
Index	−2.5 ± 0.2	...	...
Column density N_H (10^{22} cm^{-2})	7.7 ± 0.8	...	...
2–10 keV flux (ergs cm^{-2} s^{-1}), 1998 Aug 7	(6.7 ± 0.3) × 10^{-12}	...	...
2–10 keV flux (ergs cm^{-2} s^{-1}), 1998 Sep 16	(5.2 ± 0.4) × 10^{-12}	...	...

[a] From Woods et al. 1999.

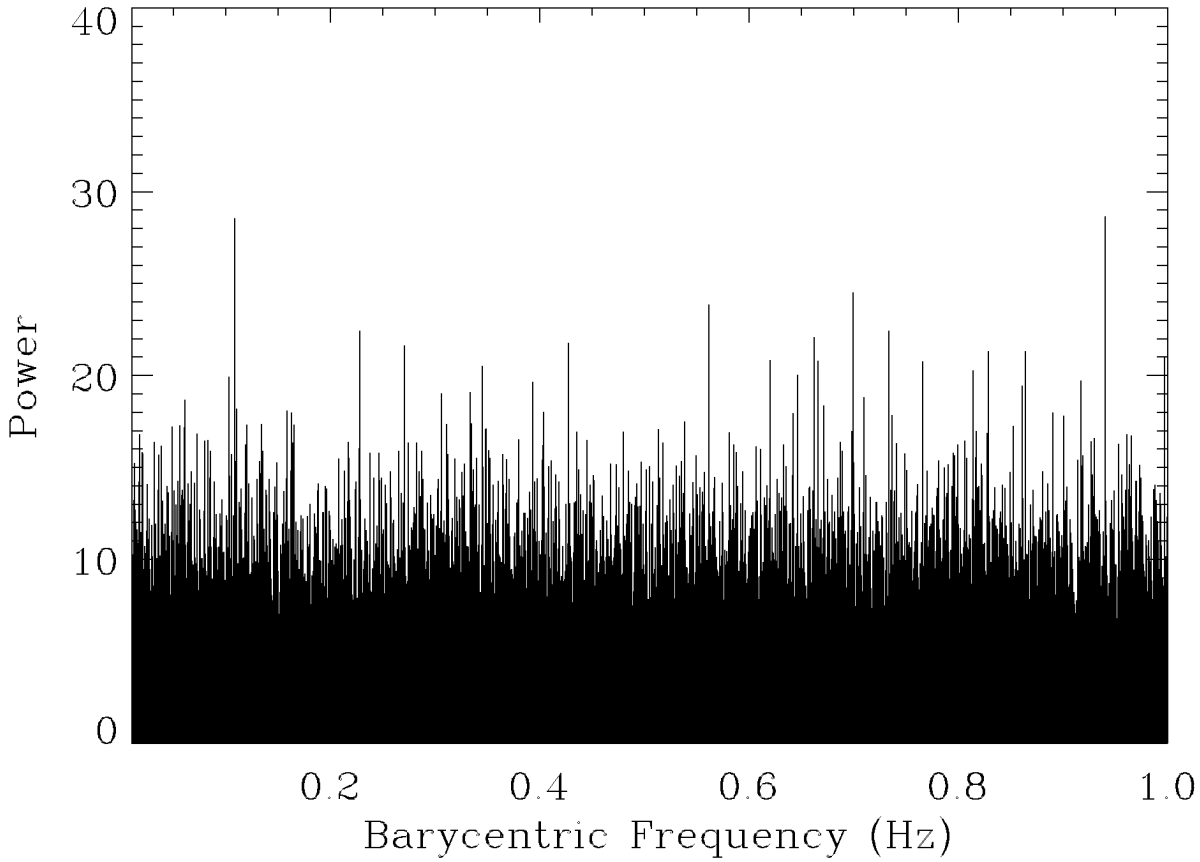

FIG. 2.—Power spectrum of the 2–10 keV soft X-ray source associated with SGR 1627−41. The spectrum is normalized such that pure Poisson counting noise would give a flat spectrum with a mean of 2 (the so-called Leahy normalization). If no signal is present, the powers should be distributed as the χ^2 function with 2 degrees of freedom. The frequency range shown is from 0.01 to 1 Hz, and there are ~260,000 independent powers in this range. We find no significant periodicity in this frequency range.

tinue. We have checked this conclusion in two ways. First, we performed a joint fit to the *BeppoSAX* and *ASCA* observations and found that they could be described well by a single power law with no change in normalization. Second, we calculated the unabsorbed 2–10 keV source flux, fixing the best-fit power-law index and $N_{\rm H}$ to those found in the *BeppoSAX* observations, and confirmed that it agreed with the *BeppoSAX* flux.

Relatively little is known about the mechanisms for variability in the quiescent soft X-ray counterparts to SGRs. It seems plausible that the quiescent steady emission from SGR 1627−41 could have been variable at an earlier time, but ceased to vary by the time of the observations reported here. It could also be argued that the periodic quiescent emission originated on a cooling hot spot on the neutron star surface and that it became undetectable by the time of the *ASCA* observations. In any case, a definitive measurement of the periodicity and the spin-down rate of the quiescent source would constitute more compelling evidence that SGR 1627−41 is indeed a magnetar. Short *Chandra* observations could resolve this and also determine the precise source position.

K. H. and P. L. are grateful to NASA for support under the *ASCA* AO-7 Guest Investigator Program.

REFERENCES

Hurley, K., Kouveliotou, C., Woods, P., Mazets, E., Golenetskii, S., Frederiks, D., Cline, T., & van Paradijs, J. 1999, ApJ, 519, L143
Kouveliotou, C., et al. 1998, Nature, 393, 235
———. 1999, ApJ, 510, L115
Marsden, D., Rothschild, R., & Lingenfelter, R. 1999, ApJ, 520, L107
Mazets, E., Aptekar, R., Butterworth, P., Cline, T., Frederiks, D., Golenetskii, S., Hurley, K., & Il'inskii, V. 1999, ApJ, 519, L151
Murakami, T., Kubo, S., Shibazaki, N., Takeshima, T., Yoshida, A., & Kawai, N. 1999, ApJ, 510, L119
Sarma, A., Goss, W., Green, A., & Frail, D. 1997, ApJ, 483, 335
Smith, D., Bradt, H., & Levine, A. 1999, ApJ, 519, L147
Thompson, C., & Duncan, R. 1995, MNRAS, 275, 255
———. 1996, ApJ, 473, 322
Woods, P., et al. 1999, ApJ, 519, L139