Search for an extended X-ray Counterpart of SGR 1900+14

J. Greiner

Max-Planck-Institut für Extraterrestrische Physik, 85740 Garching, Germany

While two of the three soft gamma repeaters have secure X-ray and radio counterparts, the case is still open for SGR 1900+14. Though a ROSAT all-sky-survey X-ray source had been proposed earlier as a possible candidate (Vashisht *et al.* 1994), follow-up observations at different wavelengths have raised doubts on its association with SGR 1900+14. Here we report on a comprehensive X-ray counterpart search of the full 5 degree BATSE error radius using the ROSAT all-sky-survey data. While the optical and radio identification of the point-like X-ray sources is still in progress, the search for extended X-ray sources has revealed only two supernova remnants: W49B and G41.1–0.3. We speculate that the latter source may be related to SGR 1900+14.

INTRODUCTION

The identification of a steady X-ray source with SGR 1806–20 (Murakami *et al.* 1994) motivated us to search for a similar source in the SGR 1900+14 error box. In an earlier work we had searched the central part of the KONUS error box (Mazets 1994) and proposed the ROSAT source RX J1907.2+0919 as a possible counterpart (Vashisht *et al.* 1994). A follow-up ROSAT HRI observation has confirmed the position, intensity and point-like nature of this X-ray source (Hurley *et al.* 1996). The upper limit on its extent excludes a plerionic SNR nature for any distance within our Galaxy, as does the lack of associated radio emission. If an association of the SNR G42.8+0.6 and this X-ray source (interpreted as a neutron star) is assumed, its implied transverse velocity would be larger than 1000 km/s (Hurley *et al.* 1996). Follow-up infrared and optical observations (Vrba *et al.* 1995) have identified a possibly gravitationally bound pair of M5 supergiants at a distance of $18''$ from the X-ray position. However, no signs of mass loss from the supergiants nor of an accretin disk around a speculative third, compact object (necessary to explain the steady X-ray emission) have been discovered.

The combined knowledge of the properties of the X-ray source and its possible counterpart at other wavelengths has thus raised doubts on the SGR 1900+14 association. We therefore extended our previous investigation of ROSAT all-sky-survey X-ray sources to the whole BATSE error box of 5° radius which nearly completely covers the $8' \times 11^\circ$ KONUS error box. Here we report on the first results of the X-ray source detection and the search for extended X-ray sources inside the BATSE location of SGR 1900+14.

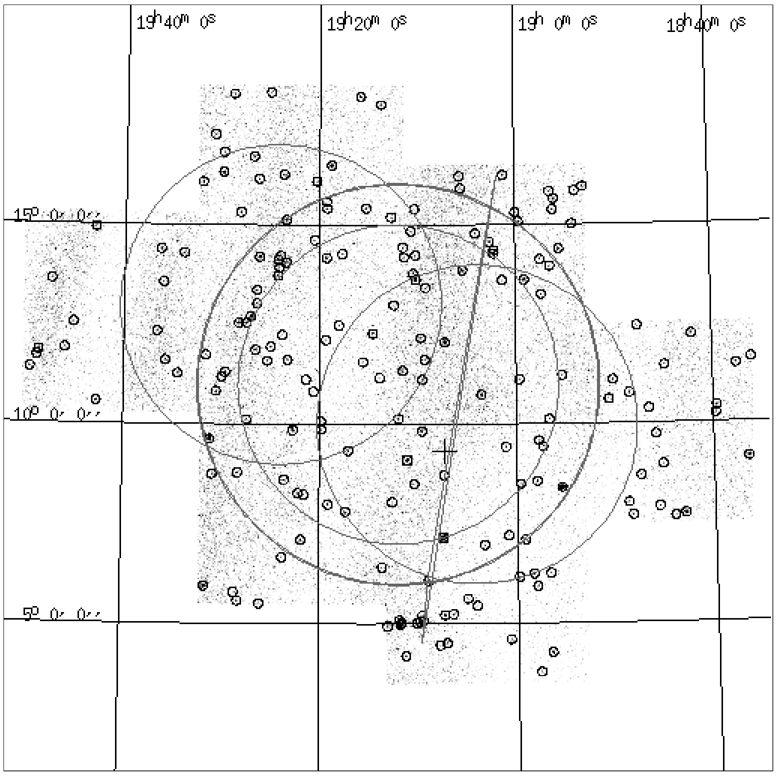

FIG. 1. ROSAT all-sky-survey image of the SGR 1900+14 location. Small circles denote X-ray sources, and the squares the two extended sources W49B and G41.1–0.3. The cross denotes the position of the all-sky-survey X-ray source proposed by Vashisht *et al.* (1994). The three large circles denote the BATSE error circle of the three repeater events seen between June and August 1992 (Kouveliotou *et al.* 1993), and the bold large circle corresponds to the mean locatin of all these events. The error box derived from the Venera detector events was kindly supplied by Mazets (1994).

X-RAY SOURCE STATISTICS

The location of SGR 1900+14 was scanned during the ROSAT all-sky-survey between September 18 and October 21, 1990 with a mean exposure time between 290–560 sec over the 10° by 10° field. Using a maximum likelihood method we detected 186 X-ray sources in this field with a likelihood larger than 8 (95% confidence). These sources are shown in Fig. 1 together with the BATSE location circles of the 1992 events, and the error box as determined from the three bursts detected with the KONUS detector onboard the Venera satellite (Mazets 1994).

Due to the low galactic latitude (–7° <bII<8°) the expected stellar content among the detected X-ray sources is high. Using Simbad and the Guide Star

Catalog we carried out a correlation with known objects within the typical error of the X-ray position of $30''$. In addition we use the X-ray hardness ratios as determined by the relative number of counts in the hard and soft band, respectively, as an indicator of distance (absorption) and spectral shape. Finally, we use the optical to X-ray flux ratios for known populations to assess the possible counterpart nature of objects found in the positional correlation. This procedure ends up in a number of 58 objects thought to be secure identifications (mostly HD stars, coronal X-ray emitters), and additional 65 objects as probable counterparts. The remaining objects have to be identified by detailed follow-up observations.

Only two objects out of the total sample of 186 show extended X-ray emission. Due to the scanning mode during the ROSAT all-sky-survey the lower limit of any extended emission is about $2'$. These two extended objects are the supernova remnants W49B (=G43.3–0.2) and G41.1–0.3 (=HSHN 111 = 3C 397).

DETAILS ON G41.1–0.3

G41.1–0.3 was first resolved by Fomalont (1968) from a $7'$ distant HII region (Caswell *et al.* 1975), and later observations showed the remnant which was classified as shell-type to be significantly non-spherical (Caswell *et al.* 1982). Based on the Σ-D relation the age of G41.1–0.3 was determined to be 600 yrs (Caswell *et al.* 1982), and the combination of youth (brightness) and non-sphericity makes this remnant unique among the youngest shell supernova remnants.

The integrated spectral index of the synchrotron emission is $\alpha = 0.4$ with a turnover below 100 MHz (Kassim 1989). Though this turnover might be due to the nearby HII region, there is no evidence of any interaction between the HII region and the remnant.

G41.1–0.3 has been observed in a dedicated ROSAT PSPC pointing (PI: S.P. Reynolds) in October 1992. The X-ray emission is clearly extended, exhibiting an oval shape with about $5'$ and $3'$ diameter. The general form is similar in size and orientation to that seen at 6 and 20 cm radio wavelengths (Anderson and Rudnick 1993), but the brightness distributions are completely different at X-rays (irregular with two bright central spots) and radio (filamentary with bright rims in the southwest and southeast).

A one temperature Raymond-Smith model fit (though very poor) results in a temperature of ≈ 1.9 keV, absorbed by a column density of 1.3×10^{22} cm^{-2}. A power law model fit is also possible, and the resulting photon index of –4.2 indicates that the emission is thermal in nature rather than synchrotron. Using N_H [10^{21} cm^{-2}] ≈ 1.35 A_V (Predehl and Schmitt 1995) and $A_V \approx$ 1.9 mag/kpc (Allen 1973), the measured absorbing column translates into a distance of about 5 kpc. The unabsorbed flux is estimated to 7.8×10^{-12} erg/cm^2/s which corresponds to a 0.1–2.4 keV luminosity of $\approx 2\times10^{34}$ erg/s (d/5 kpc)$^{-2}$.

DETAILS ON W49B

Also W49B belongs to the high radio surface brightness remnants in the Galaxy. The spectral index is 0.40 (Kassim 1989), and there is no evidence for a thermal component in its radio emission. HI observations indicate a distance of 8 kpc (Radhakrishnan *et al.* 1972, scaled to a Galactocentric radius of 8 kpc).

Recent high-resolution radio observations have shown that besides the large-scale box-shaped morphology, small-scale structures and filaments are present (Moffett and Reynolds 1994). The shell edge (for 75% of its circumference) remained unresolved, giving an upper limit of the emission region width of < 0.16 pc which indicates a short mean free path and high levels of MHD turbulence (Moffett and Reynolds 1994).

X-ray observations with the *Einstein* (Pye *et al.* 1984) satellite show a center-brightened morphology, but *EXOSAT* observations demonstrated the its thermal nature evidenced by emission lines of Fe, S, Ar and Ca (Smith *et al.* 1985).

DISCUSSION

The supernova remnant W49B is about 1° off the KONUS error box and nearly in the center of the mean BATSE error circle. With its sharp and nearly complete ring-like emission it is a rather classical shell remnant. Thus, we assess the probability of an association with SGR 1900+14 to be rather small.

G41.1–0.3 is located just at the border of the KONUS error box, and its position is also consistent with all three BATSE error circles. This makes it an interesting quiescent counterpart candidate for the SGR 1900+14 source. However, it differs from the X-ray and radio nebula G10.0–0.3 (Sonobe *et al.* 1994, Kulkarni *et al.* 1994) which has been convincingly associated with SGR 1908–20 (Murakami *et al.* 1994) in that there is no evidence for a plerionic nature of G41.1–0.3, neither in X-rays nor at radio wavelengths.

On the other hand, G41.1–0.3 ranks among the smallest (12.9 pc), brightest, and youngest (600 yrs) shell remnants in our Galaxy (Caswell *et al.* 1982), and combined with the discovery of spectral index variations across the remnant (Anderson and Rudnick 1993) and the positional coincidence with the KONUS error box of SGR 1900+14, more detailed studies of this object are encouraged. We note that G41.1–0.3 is the only remnant at the KONUS box border except G43.9+1.6 and G42.8+0.65 (for which the error box passes through, see Vashisht *et al.* 1994) listed in the Green (1995) catalog.

If G41.1–0.3 is not related to SGR 1900+14 we may use the observed properties of the SGR 1806–20 nebula together with the interstellar absorbing column to estimate a lower distance limit of the SGR 1900+14 source. The quiescent X-ray emission of SGR 1806–20 is characterized by a –2.2 power law photon index and a luminosity of 10^{35} erg/s in the 0.5–10 keV range (Sonobe *et al.* 1994). Along the KONUS error box the column density is varying between 0.4–1.9$\times10^{22}$ cm^{-2} (Dickey and Lockman 1990). Since no other extended X-ray source is detected in the ROSAT all-sky-survey, the upper limit is 0.027–0.014 cts/sec corresponding to unabsorbed fluxes of 1–5$\times10^{-12}$ erg/cm^2/s. Thus, even in the galactic mid-plane we would be sensitive to a 10^{35} erg/s source up to 12 kpc. However, beyond about 5 kpc the size of a plerionic supernova remnant (3 pc diameter assumed) would be too small to be detectable as extended source in the ROSAT all-sky-survey. The investigation of the point sources and their correlation with optical and radio observations will provide more information on the possible existence of plerions inside the BATSE error box of SGR 1900+14.

Acknowledgements: JG is supported by the Deutsche Agentur für Raumfahrtangelegenheiten (DARA) GmbH under contract FKZ 50 OR 9201 and is grateful to the Deutsche Forschungsgemeinschaft for a travel grant. We thank S.P. Reynolds for sharing unpublished information on the ROSAT observation of G41.1–0.3. The ROSAT project is supported by the German Bundesministerium für Bildung und Wissenschaft (BMBW/DARA) and the Max-Planck-Society. This research has made use of the Simbad database, operated at CDS, Strasbourg, France.

REFERENCES

Allen C.W., 1973, Astrophysical Quantities, Athlone Press, London
Anderson M.C., Rudnick L., 1993, ApJ 408, 514
Caswell J.L., *et al.* 1975, Aust. J. Phys. Astroph. Suppl. 37, 39
Caswell J.L., *et al.* 1982, MNRAS 200, 1143
Dickey J.M., Lockman F.J., 1990, Ann. Rev. Astron. Astrophys. 28, 215
Fomalont E.B., 1968, ApJ Suppl. 15, 203
Green D.A., 1995, catalog of Galactic supernova remnants, Cambridge (available on WWW at http://www.phy.cam.ac.uk/www/research/ra/SNRs/snrs.intro.html)
Hurley K., *et al.* 1996, ApJ (to be subm.)
Kassim N.E., 1989, ApJ 347, 915
Kouveliotou, C., *et al.* 1993, Nature 362, 728
Kulkarni S.R., *et al.* 1994, Nature 368, 129
Mazets E.P., 1994 (priv. comm.)
Murakami T., *et al.* 1994, Nature 368, 127
Predehl P., Schmitt J.H.M.M., 1995, A&A 293, 889
Pye J.P., Becker R.H., Seward F.D., Thomas N., 1984, MNRAS 207, 649
Radhakrishnan V., Goss W.M., Murray J.D., Brooks J.W., 1972, ApJS 24, 49
Smith A., Jones L.R., Peacock A., Pye J.P., 1985, ApJ 296, 469
Sonobe T., Murakami T., Kulkarni S.R., Aoki T., Yoshida A., 1994, ApJ 436, L23
Vasisht G., Kulkarni S.R., Frail D.A., Greiner J., 1994, ApJ 431, L35
Vrba F., *et al.* 1996, ApJ (to be subm.)
Zimmermann H.U., Becker W., Belloni T., Döbereiner S., Izzo C., Kahabka P., Schwentker O., 1994, MPE report 257