

Discovery of X-rays from the supernova remnant G0.9+0.1

L. Sidoli^a, G.L. Israel^b, L. Chiappetti^c, A. Treves^a, M. Orlandini^d, E. Kuulkers^e, P. Predehl^f, J. Heise^g and S. Mereghetti^c

^aDipartimento di Fisica, Università di Milano, Via Celoria 16, I-20133 Milano, Italy

^bOsservatorio Astronomico di Roma, Via dell'Osservatorio 2, I-00040 Monteporzio Catone (Roma), Italy

^cIstituto di Fisica Cosmica del C.N.R., Via Bassini 15, I-20133 Milano, Italy

^dTeSRE, Via P. Gobetti 101, I-40129 Bologna, Italy

^eUniversity of Oxford, Nuclear and Astrophysics Laboratory, Keble Road, Oxford OX1 3RH, UK

^fMPE, Garching, Germany

^gSRON-Utrecht, Sorbonnelaan 2, 3584 CA Utrecht, The Netherlands

During the *BeppoSAX* survey of the Galactic Center region, we have discovered X-ray emission from the central region of the supernova remnant G0.9+0.1. The high interstellar absorption ($N_H \sim 3 \times 10^{23} \text{ cm}^{-2}$) is consistent with a distance of order of 10 kpc and, correspondingly, an X-ray luminosity of $\sim 10^{35} \text{ erg s}^{-1}$.

Although we cannot completely rule out a thermal origin of the X-ray emission, its small angular extent (radius $\sim 2'$), the good fit with a power law, the presence of a flat spectrum radio core, and the estimated SNR age of a few thousand years, favour the interpretation in terms of synchrotron emission powered by a young, energetic pulsar.

1. THE BeppoSAX GALACTIC CENTER SURVEY

The BeppoSAX satellite [1] is performing a survey of the Galactic Center region using its Narrow Field Instruments.

The MECS instrument [2], with its good imaging capabilities up to energies of $\sim 10 \text{ keV}$, is particularly indicated to study this crowded and highly absorbed region of the sky.

Figure 1 shows a mosaic of the MECS images obtained during the first year of this project. Several known point sources are visible (including one at the position of SgrA*), as well as diffuse emission. Here we concentrate on the discovery of X-ray emission from G0.9+0.1, one of the radio supernova remnants in the Galactic Center region.

2. OBSERVATIONS AND RESULTS

A new source, located about 14 arcmin north of the molecular cloud SgrB2 and coincident with the radio supernova remnant G0.9+0.1 was discovered during a 49 ksec long pointing performed in April 1997 [3]. The source was reobserved for 51 ksec in September 1997, but only with two MECS, due to the failure of MECS1 in May 1997.

The source flux was consistent with a constant value in both observations. The spectra extracted by combining both observations are equally well fitted by power law, blackbody and thermal bremsstrahlung models, while a Raymond-Smith thermal plasma model with abundances fixed at the solar values gives a slightly worse result ($\chi^2 = 1.20$). The best fit parameters, similar to those derived from the April observation alone [3], are given in Table 1.

All the models give values of N_H greater than $2 \times 10^{23} \text{ cm}^{-2}$, indicating a distance of several

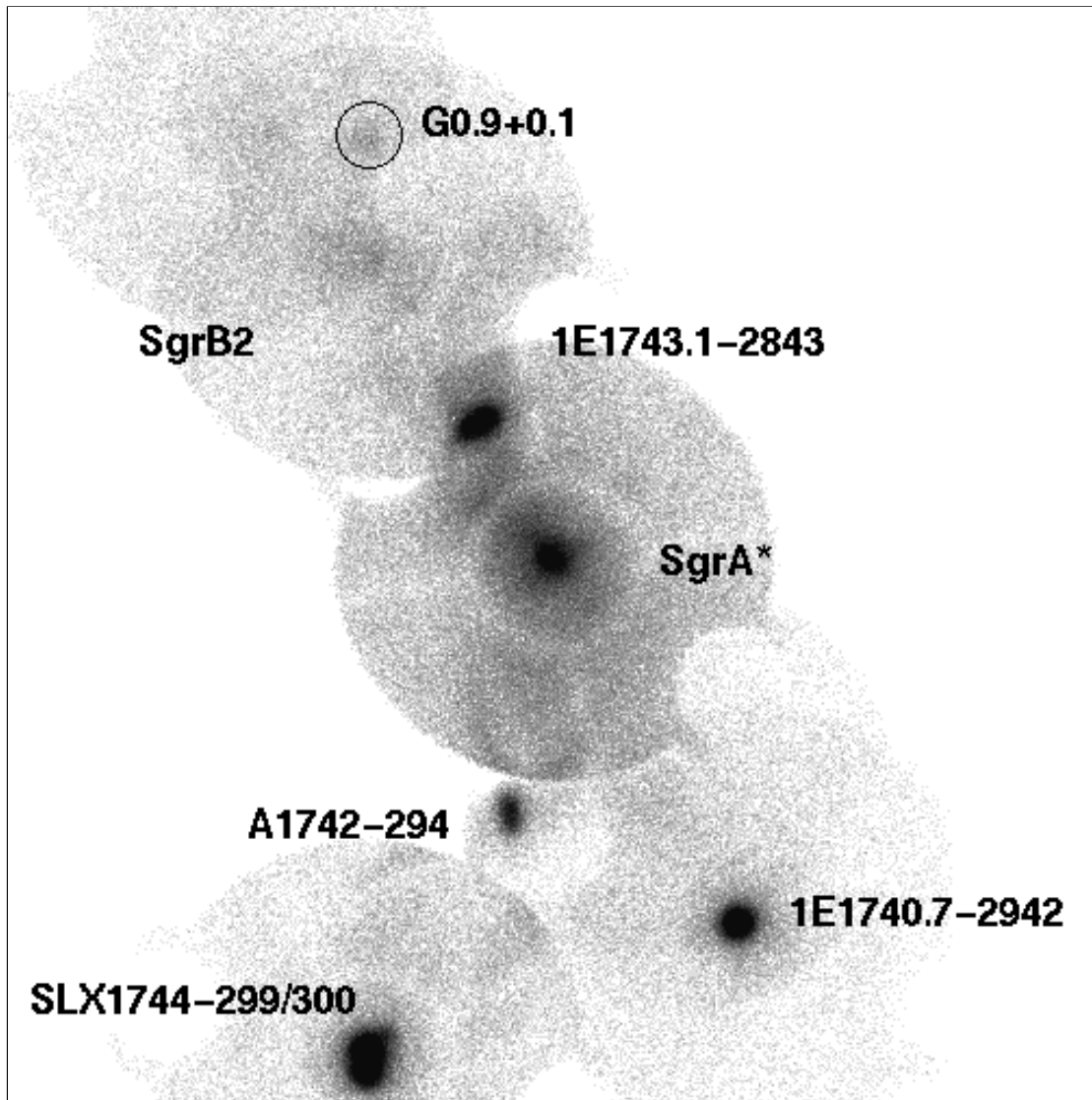


Figure 1. *BeppoSAX* image of the Galactic Center Region ($-1.5 < l < 1.5$) in the 2-10 keV energy range.

kiloparsecs, and thus supporting the identification with G0.9+0.1 that is probably close to the Galactic Center or even beyond it [4].

Assuming a distance of 10 kpc, the luminosity in the 2–10 keV range is $L_X = 1.5 \times 10^{35} d_{10}^2 \text{ erg s}^{-1}$, for the power law best fit.

A search for pulsations for periods in the range 2048 s to 8 ms gave a negative result, with the following upper limits on the pulsed fraction: 53% for $8 < P < 16$ ms, 38% for $16 < P < 32$ ms, and 33% for $P > 32$ ms.

3. G0.9+0.1:

A COMPOSITE RADIO/X-RAY SUPERNOVA REMNANT

In the radio band G0.9+0.1 consists of a steep-spectrum radio shell of $\sim 8'$ diameter surrounding a core component with a flatter spectrum and significant polarization [5,6].

Thus G0.9+0.1 belongs to the class of “composite” supernova remnants [7], that, in addition to the radio/X-ray shell formed by the expanding ejecta, show the signature of a central neutron star powering non-thermal emission through the loss of rotational energy.

Due to the high absorption along this direction, G0.9+0.1 was not detected with ROSAT. Our *BeppoSAX* observations provide the first information on the X-ray emission from G0.9+0.1 (only a questionable marginal detection with the Einstein satellite IPC [5] had been previously reported).

The peak of the X-ray emission is coincident with the SNR radio core and there is no evidence for a spatial extension greater than the instrumental resolution at this off-axis angle ($R < 2'$). Therefore, we are clearly seeing X-rays emitted from the central region of the remnant and not from the $8'$ shell that would appear clearly resolved in the MECS images.

Some SNRs, like for example W44 [8], present a centrally peaked X-ray emission of thermal origin. The thermal nature of the emission is clearly demonstrated by the detection of lines in their X-ray spectra. All the SNRs of this kind have a limb-brightened radio morphology without a flat-spectrum core, contrary to the case of G0.9+0.1.

Also considering that the thermal plasma model gave the worst fit to our data, we favour the alternative interpretations related to the likely presence of a neutron star at the center of G0.9+0.1.

3.1. Thermal Emission from a Neutron Star?

The blackbody spectral fit imply an emitting surface with radius $R = 0.3_{-0.1}^{+0.3} d_{10}$ km, consistent with emission from a small polar cap region, hotter than the rest of the neutron star due to anisotropic heat diffusion from the interior and/or to reheating by relativistic particles backward accelerated in the magnetosphere [9].

In general, this should produce a periodic flux modulation, but the strong gravitational bending effects severely reduce the observed pulsed fractions [10]. Our upper limits on the possible flux modulations are not strong enough to pose serious problems to this interpretation. However, the fitted blackbody temperature is higher than that observed in all the other X-ray emitting radio pulsars [11].

3.2. An X-Ray Synchrotron Nebula?

A different explanation involves non-thermal emission powered by the rotational energy loss of a relatively young neutron star. The radio shell radius of ~ 10 pc implies a lower limit to the remnant age of ~ 1100 yr, for a free-expansion phase with $v \sim 10^4 \text{ km s}^{-1}$. If the remnant is expanding adiabatically, from the Sedov model we have a shell radius $R \sim 14(E_{51}/n_o)^{1/5} t_4^{2/5} \text{ pc}$. For typical values $(E_{51}/n_o)^{1/5} \sim 1$, we derive an age of 6,800 years.

Our best fit power law photon index 3.7 is rather steep, compared to other X-ray synchrotron nebulae. A more typical value of 2 is also consistent with our data within 99% confidence level (for $N_H \sim 2 \times 10^{23} \text{ cm}^{-2}$). The corresponding X-ray luminosity (2–10 keV), $L_X = 4.4 \times 10^{34} d_{10}^2 \text{ erg s}^{-1}$, is within the range observed in the central components of other SNRs and can be easily powered by a neutron star with an age of a few thousand years.

Table 1

Results of the Spectral Fits (errors are 90% c.l.).

| Model | Column density (10^{23} cm^{-2}) | Parameter | Red. χ^2 (49 d.o.f.) | Flux (2–10 keV) ($10^{-11} \text{ ergs cm}^{-2} \text{ s}^{-1}$) |
|----------------|---|---|------------------------------|---|
| Power law | $3.4^{+1.6}_{-0.9}$ | $\alpha = 3.7^{+1.3}_{-1.0}$ | 0.70 | $1.36^{+3.74}_{-0.72}$ |
| Bremsstrahlung | $2.8^{+0.2}_{-0.8}$ | $T_{\text{br}} = 3.2^{+2.3}_{-0.7} \text{ keV}$ | 0.71 | $0.71^{+0.14}_{-0.26}$ |
| Black body | $2.2^{+0.8}_{-1.2}$ | $T_{\text{bb}} = 1.2^{+0.3}_{-0.1} \text{ keV}$ | 0.74 | $0.41^{+0.14}_{-0.16}$ |
| Raymond–Smith | $4.4^{+1.6}_{-0.9}$ | $T_{\text{RS}} = 1.1^{+0.2}_{-0.2} \text{ keV}$ | 1.20 | $4.2^{+6.8}_{-2.3}$ |

4. CONCLUSIONS

The *BeppoSAX* discovery of X–ray emission from the central region of G0.9+0.1 has confirmed its plerionic morphology derived from the radio observations. The high interstellar absorption is consistent with a distance of the order of 10 kpc and, correspondingly, an X–ray luminosity of $\geq 10^{35} d_{10}^2 \text{ erg s}^{-1}$.

Although we cannot completely rule out a thermal origin of the X–ray emission, its small angular extent, the good fit with a power–law, the presence of a flat spectrum radio core, and the estimated SNR age of a few thousand years, favour the interpretation in terms of synchrotron emission.

High angular resolution observations with AXAF and XMM can test this interpretation and possibly lead to the discovery of a relatively young, energetic pulsar in G0.9+0.1.

(1993) 286.

10. D. Page, ApJ 442 (1995), 273.

11. W. Becker, these proceedings

REFERENCES

1. G. Boella, R.C. Butler, G.C. Perola et al., A&AS 122 (1997) 299
2. G. Boella, L. Chiappetti, G. Conti et al., A&AS 122 (1997) 327
3. S. Mereghetti, L. Sidoli and G.L. Israel, A&A Letters in press
4. D. Downes, AJ 76 (1971) 305
5. D.J. Helfand and R.H. Becker, ApJ 314 (1987) 203.
6. A.D. Gray, MNRAS 270 (1994), 835.
7. K.W. Weiler, and R.A. Sramek, ARA&A 26 (1988) 295
8. J. Rho, R. Petre, E.M. Schlegel and J.J. Hester, ApJ 430 (1994) 757
9. J.P. Halpern and M. Rudermann, ApJ 415