THE ASTROPHYSICAL JOURNAL, 222, L13–15, 1978 May 15

SOFT X-RAY EMISSION FROM A NEWLY DISCOVERED SUPERNOVA REMNANT IN CYGNUS

W. A. SNYDER, A. F. DAVIDSEN,* AND R. C. HENRY
Department of Physics, The Johns Hopkins University

AND

S. SHULMAN, G. FRITZ, AND H. FRIEDMAN
E. O. Hulbert Center for Space Research, Naval Research Laboratory
Received 1978 January 3; accepted 1978 February 17

ABSTRACT

We have detected a significant soft X-ray flux consistent with emission from the newly discovered supernova remnant in the constellation Cygnus. Emission is observed in the 0.5–2.0 keV band, with a possible detection (2.4 σ) in the 0.1–0.4 keV region. Assuming thermal bremsstrahlung emission, we find that for temperatures between 1 and 7×10^6 K and interstellar absorption $N_H = 2.5$–260×10^{20} cm^{-2}, the observed 0.5–2.0 keV count rate corresponds to a flux of 2.4×10^{-10} ergs cm^{-2} s^{-1}, with an uncertainty of approximately 50%.

Subject headings: nebulae: supernova remnants — X-rays: sources

Recently Gull, Kirshner, and Parker (1977) have reported the discovery of a large filamentary structure in the constellation Cygnus. Centered at $\alpha = 19^h31^m$, $\delta = 31°10'$ ($l = 65.^\circ6$, $b = +6°$), this object has an angular diameter of approximately $3.^\circ5$. Based largely on its visual similarity to the Vela supernova remnant and Shajn 147, they have identified it as an optical supernova remnant.

In an earlier soft X-ray rocket observation (Davidsen *et al.* 1977) we scanned the Cygnus region with a sensitivity greater than any previously achieved. During part of this scan our detectors passed over the new supernova remnant. Our observation was made with two large-area proportional counters flown aboard an Aerobee 200 sounding rocket launched from White Sands Missile Range at 0435 UT 1974 September 7. Each detector had an effective area of 1080 cm^2, a 2 μm thick Kimfol (polycarbonate) window, and was filled with P-10 gas (90% argon, 10% methane) at 15.5 pounds per square inch absolute (1.05 bars). The detectors were sensitive in the 0.18–0.28 keV and 0.5–8.0 keV energy bands. Each had a circular field of view—one detector 5° FWHM, the other 3° FWHM. The detectors were coaligned to within $0.^\circ5$. A 35 mm camera provided information on the pointing direction every 1.3 seconds, allowing an aspect determination accurate to within $0.^\circ25$.

The rocket attitude control system was programmed to execute a series of maneuvers both parallel and perpendicular to the galactic plane in the Cygnus region. A schematic of the scan path is given by Davidsen *et al.* (1977). After an observation of the Cygnus Loop, the detectors were scanned at a rate of $1.^\circ6$ per second through the galactic plane to Her X-1. Plotted in Figure 1*a* is a schematic of the scan path immediately following the Cygnus Loop observation. The detector pointing position is marked at 1 s intervals. The positions of the only known X-ray sources in this region, Cyg X-1 and 3U 1953+31, are given in the figure. Their positional uncertainties (Giacconi *et al.* 1974) are insignificant compared to the scale of the figure and the detector field of view. Also shown are the O III λ5007 Å optical filaments of the new supernova remnant.

Given in Figures 1*b* and 1*c*, respectively, are the observed count rates in the 2.5–8.0 keV and 0.2–0.8 keV energy bands for the 5° FWHM detector. A very bright X-ray source is seen in the high-energy data consistent with a point source located along the Cyg X-1–3U 1953+31 line of position. This emission is due primarily to Cyg X-1. The low-energy bandpass has been picked so that no significant contribution from these sources to the low-energy count rate is expected to occur. The large initial count rate observed in the low-energy data is due to the Cygnus Loop as it leaves the detector field of view. As the detector scans to higher galactic latitude, a significant increase in the count rate is observed coincident with the detector crossing the new supernova remnant. Clearly this emission is not due to the known point X-ray sources, but is due to a new soft X-ray source.

We have plotted in Figure 1*d* the observed count rate for the 3° FWHM detector in the 0.5–2.2 keV energy range. Because of its smaller field of view, the contribution from Cyg X-1 is reduced, although it still produces the excess observed at 273–274 s. A similar excess is noted in the 5° FWHM detector data as well, but because of the greater degree of source confusion it is more difficult to isolate the remnant contribution. Both detectors fail to show any significant emission from the new source above 2 keV.

The 3° FWHM detector failed to detect any emission

---

* Alfred P. Sloan Foundation Research Fellow.

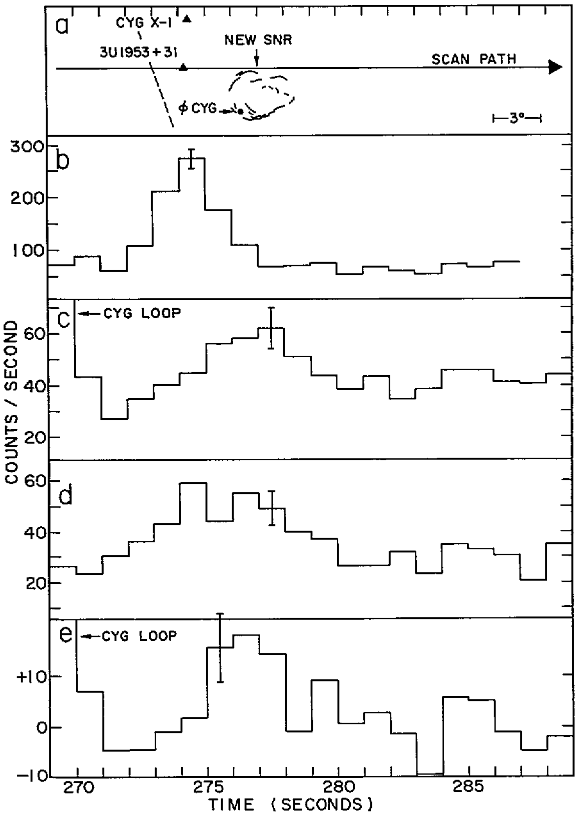

FIG. 1.—(*a*) Detector scan path in the vicinity of Cyg X-1 and the new SNR. The optical filaments (O III λ5007) of the SNR are indicated schematically. The dashed line represents the galactic plane. (*b*) 2.5–8.0 keV count rate for 5° FWHM detector. (*c*) 0.2–0.8 keV count rate for 5° FWHM detector. (*d*) 0.5–2.2 keV count rate for 3° FWHM detector. (*e*) Background-subtracted 0.1–0.4 keV count rate seen in 5° FWHM detector. The background level is not constant, but rises slightly as can be seen in Fig. 1*c*.

below 0.5 keV. However, in the 5° FWHM data, plotted in Figure 1*e* with background subtracted, an increase in the count rate is seen in the 0.1–0.4 keV energy band as the detector crosses the remnant. However, this emission is at a level of significance of only 2.4 σ, and we present it as only suggestive, requiring further confirmation in a new observation.

Because of the low level of emission, a variety of source distributions fit the count rate data. We can, however, rule out emission originating from only those filaments farthest removed from the scan path, as well as emission from ϕ Cyg. Our data are consistent with uniform emission confined within the limits of the optical supernova remnant, or with a ring defined by the O III filaments. A point source is consistent with our data as well. By fitting both detectors simultaneously, we obtain best fit positions of $\alpha = 19^{\mathrm{h}}36^{\mathrm{m}}$, $\delta = 31°25'$; and $\alpha = 19^{\mathrm{h}}37^{\mathrm{m}}$, $\delta = 33°52'$ (the ambiguity arising from the symmetry about the scan direction). In Figure 1*a* these points occur at 276.75 s and are located 1°.25 from the scan path. The 90% confidence contour (Lampton, Margon, and Bowyer 1976) defines an elliptical area oriented perpendicular to the scan direction and is centered at 276.75 s ($\alpha = 19^{\mathrm{h}}36^{\mathrm{m}}.5$, $\delta = 32°38'$). It has a semiminor axis of 0.4 s (0°.64) and a semimajor axis of 2°.2. This region includes the center of the remnant.

The failure to detect emission above 2 keV suggests that the remnant's temperature is less than 10^7 K. Assuming thermal bremsstrahlung emission, we have folded with our detector response a spectral distribution of the form $f(E) = A\ g(E, T)e^{-E/kT} \exp(-\sigma N_{\mathrm{H}})$ photons cm^{-2} s^{-1} keV^{-1}, where σ is the effective photoelectric cross section (Brown and Gould 1970) and $g(E, T)$ is the temperature-averaged Gaunt factor (Karzas and Latter 1961). By normalizing the predicted count rate in the 0.5–2.0 keV band to the observed value (59.5 ± 11.2 counts s^{-1}), we find that for temperatures between $T = 1$ and 7×10^6 K, and column densities of $N_{\mathrm{H}} = 2.5$–260×10^{20} cm^{-2}, the observed 0.5–2.0 keV count rate corresponds to a flux of 2.4×10^{-10} ergs cm^{-2} s^{-1}, with a possible uncertainty of 50%.

From the radio brightness at 850 MHz, which is approximately one-fifth the Cygnus Loop brightness, Gull, Kirshner, and Parker (1977) derive a remnant diameter D between 60 and 80 pc, and place the remnant at a distance of approximately 1200 pc. If we assume that the remnant is in the adiabatic phase, the standard model (Gorenstein, Harnden, and Tucker 1974) yields, for temperatures of 1–10×10^6 K, a remnant age of 1.5–4.6×10^4 (D/70 pc) years, and a shock velocity of 300–900 km s^{-1}. A shock velocity of this magnitude at such a large diameter indicates either that the remnant is expanding into a region of low interstellar density, or that the initial supernova energy release was of a larger magnitude than usual. We find, for instance, that for $D = 70$ pc and a typical energy release E_0 of 4×10^{50} ergs (Gorenstein *et al.* 1974), the interstellar density $N_1 < 0.07$ cm^{-3}. At a height of 125 pc above the galactic plane, this is somewhat lower than might be expected. On the other hand, the remnant can attain temperatures of 1–2×10^6 K, for $N_1 \approx 0.1$–0.2 cm^{-3}, if the initial energy release $E_0 \gtrsim 10^{51}$ ergs. By decreasing the remnant's diameter ($D \lesssim 50$ pc), temperatures in excess of 2×10^6 K can be attained for densities on the order of 0.1–0.5 cm^{-3} with typical values of E_0.

This work was partially supported by a NASA grant to the Naval Research Laboratory.

1978ApJ...222L..13S

REFERENCES

Brown, R. L., and Gould, R. J. 1970, *Phys. Rev.* D, **1**, 2252.

Davidsen, A. F., Henry, R. C., Snyder, W. A., Friedman, H., Fritz, G., Naranan, S., Shulman, S., and Yentis, D. 1977, *Ap. J.*, **215**, 541.

Giacconi, R., Murray, S., Gursky, H., Kellogg, E., Schreier, E., Matilsky, T., Koch, D., and Tananbaum, H. 1974, *Ap. J. Suppl.*, No. 237, **27**, 37.

Gorenstein, P., Harnden, F., and Tucker, W. 1974, *Ap. J.*, **192**, 661.

Gull, T., Kirshner, R., and Parker, R. 1977, *Ap. J.* (*Letters*), **215**, L69.

Karzas, W., and Latter, R. 1961, *Ap. J. Suppl.*, No. 55, **6**, 167.

Lampton, M., Margon, B., and Bowyer, S., 1976, *Ap. J.*, **208**, 177.

A. F. Davidsen, R. C. Henry, and W. A. Snyder: Department of Physics, The Johns Hopkins University, Baltimore, MD 21218

H. Friedman, G. Fritz, and S. Shulman: Code 7129, Naval Research Laboratory, Washington, DC 20375