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X-RAY EMISSION FROM THE SUPERNOVA REMNANT G287.8−0.5

R. H. BECKER,* E. A. BOLDT, S. S. HOLT, S. H. PRAVDO,† R. E. ROTHSCHILD,
P. J. SERLEMITSOS, AND J. H. SWANK*
NASA/Goddard Space Flight Center, Greenbelt
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ABSTRACT

The GSFC Cosmic X-ray Spectroscopy experiment on OSO-8 observed a weak galactic X-ray source near $l^{II} \approx 288°$, $b^{II} \approx -1°$ for three days during 1975 July. The spectrum for this source between 2 and 20 keV is well represented by a thermal spectrum of $kT = 7.34\ (+3.6, -2.6)$ keV with an intense iron emission line centered at 6.5 ± 0.2 keV. However, a power-law continuum cannot be ruled out. The error box of the *Uhuru* source 4U 1043−59, the only known X-ray source in our field of view, contains the radio supernova remnant G287.8−0.5. The possible association of the X-ray source with this supernova remnant is discussed.

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

I. INTRODUCTION

The OSO-8 observing program includes long-term observations of some of the weakest known galactic sources so that detailed spectra can be obtained. Such a source at $l^{II} = 288.°0$ was detected in a survey of the galactic plane by *Uhuru* (Forman, Jones, and Tananbaum 1976) and subsequently designated 4U 1043−59 (Jones and Forman 1976). This *Letter* will report on observations of 4U 1043−59 by the GSFC Cosmic X-ray Spectroscopy Experiment made during three days in 1975 July, the results of which lead to the association of this X-ray source with the supernova remnant G287.8−0.5.

II. EXPERIMENT

The observations were made on 1975 July 17–19 with a pointed argon-filled proportional counter. The detector has an effective area of 36.7 cm^2 and an energy range from 2 to 20 keV divided into 63 channels. The 3° collimation isolated 4U 1043−59 in the field of view. During the 3-day observation, counting rates from the detector had a time resolution of 160 ms while spectral data had a 40 s time resolution. A total integration time of $\sim 10^5$ s was obtained. Background for the observation was accumulated 2 days prior to the observation when the detector was pointed 18° off the galactic plane.

The procedure used for analyzing the spectral data has been described in previous papers (Serlemitsos *et al.* 1975; Pravdo *et al.* 1976). Errors quoted on the best-fit spectral parameters are for 90 percent confidence and are calculated by allowing the minimum acceptable value for χ^2 to vary by an amount consistent with the number of parameters in the model (Lampton, Margon, and Bowyer 1975).

* NAS/NRC Resident Research Associate.

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III. RESULTS

The X-ray spectrum accumulated over the 3-day observation of 4U 1043−59 could not be adequately fitted by either a featureless power-law or a thermal spectrum, the principal discrepancy resulting from an excess of photons between 6 and 7 keV. With the addition of a narrow line centered at 6.5 ± 0.2 keV, both the power-law and thermal spectra gave acceptable fits.

To approximate a thermal spectrum we used the analytic form

$$\frac{dN}{dE} = Cg(E, kT) \exp\left[-(E_A/E)^{2.7}\right] \exp(-E/kT)/E\ ,$$

where C is a normalization constant, $g(E, kT) = (E/kT)^{-0.4}$ is an approximate form for the Gaunt factor, and E_A is related to the low-energy cutoff in the spectrum from cold matter along the line of sight. With the narrow line an acceptable fit to the data was obtained with $\chi^2 = 15.3$ for 14 degrees of freedom.

The best-fit values for the variable parameters and their errors are

$$kT = 7.34(+3.6, -2.6)\ \text{keV}\ ,$$

$$E_A = 0.09(+1.16, -0.09)\ \text{keV}\ ,$$

with $1.46 \pm 0.39 \times 10^{-3}$ photons cm^{-2} s^{-1} in the narrow line. The line has an equivalent continuum width of 1730 ± 460 eV.

Similarly, for a best-fit power-law spectrum, $E^{-\alpha}$, with low-energy absorption and a narrow line at 6.5 ± 0.2 keV, the best fit had $\chi^2 = 15.5$ with values for the variable parameters of

$$\alpha = 2.24(+0.36, -0.39)\ ,$$

$$E_A = 1.36(+0.42, -1.36)\ ,$$

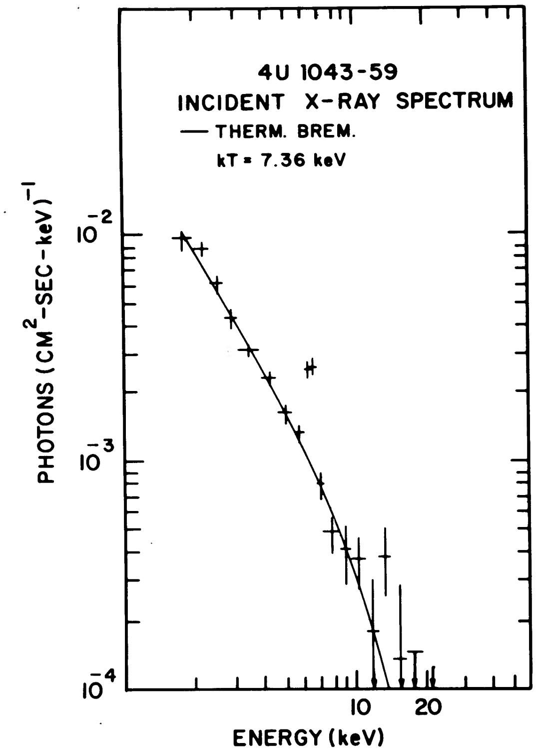

FIG. 1.—The inferred incident X-ray spectrum for 4U 1043−59. The solid curve represents the best-fit thermal continuum to the data.

with $1.52 \pm 0.41 \times 10^{-3}$ photons cm^{-2} s^{-1} in the narrow line. The observed spectrum of 4U 1043−59 is shown in Figure 1. The integrated flux between 2 and 6 keV is $7.4 \pm 0.2 \times 10^{-11}$ ergs s^{-1} cm^{-2}, where the error quoted is only the statistical error. The error in the flux due to the background subtraction may be as large as 10 percent.

IV. DISCUSSION

The X-ray intensity initially reported for 4U 1043−59 was $4.8 \pm 2.2 \times 10^{-11}$ ergs s^{-1} cm^{-2} between 2 and 6 keV (Forman, Jones, and Tananbaum 1976). Analysis of additional *Uhuru* data indicates an intensity of $5.8 \pm 1.2 \times 10^{-11}$ ergs s^{-1} cm^{-2} and an improved error box which is shown in Figure 2 (Jones and Forman 1976). This intensity is in fair agreement with our observed intensity and suggests the source has a constant luminosity.

Jones (1973) discovered a radio supernova remnant G287.8−0.5 with coordinates of

$$\text{R.A. (1950)} = 10^{h}45^{m}\,,$$

$$\text{Decl. (1950)} = -59°23'\,,$$

which is close to the position of 4U 1043−59 (see Fig. 2). This radio remnant is at a distance of less than 2.5 kpc with an angular diameter less than 0°42, implying a linear diameter less than 18 pc. There is good agreement between the position of the radio remnant and 4U 1043−59, but the size of the X-ray error box is too large to conclusively identify 4U 1043−59 with G287.8−0.5.

It is interesting to note that the position of the irregular variable η Carinae is consistent with both the X-ray and radio source positions. Visually, η Car appears as a small stellar nucleus within a nebulous halo. During the past 150 years, the visual magnitude of the stellar nucleus has varied as much as 8 magnitudes with time scales of ~50 years. Zwicky (1965) and Ostriker and Gunn (1971) suggested that η Car could be the remnant of a recent massive supernova. If so, η Car may also be associated with 4U 1043−59. Hill *et al.* (1972) have previously identified η Car as a possible source of soft X-rays.

The identification with G287.8−0.5 is supported by the X-ray properties of 4U 1043−59. The galactic X-ray sources which have thermal spectra of $kT \approx$ 4–5 keV with strong iron line emission are Cas A and Tycho's supernova remnant (Pravdo *et al.* 1976; Davison *et al.* 1976). In addition, the young remnant of SN 1006 is also a source of thermal X-rays of $kT \approx$ 4 keV (Winkler and Laird 1975). The apparently constant X-ray intensity of 4U 1043−59 is also consistent with its identification as a supernova remnant.

If the association between 4U 1043−59 and G287.8−0.5 is correct, we find an upper limit for the X-ray luminosity L_x above 2 keV of 3.4×10^{34} ergs s^{-1} based on the upper limit for the distance to G287.8−0.5. This is comparable to L_x above 2 keV for the remnants of SN 1006 and Tycho's supernova (Davison, Culhane, and Mitchell 1976; Winkler and Laird 1975).

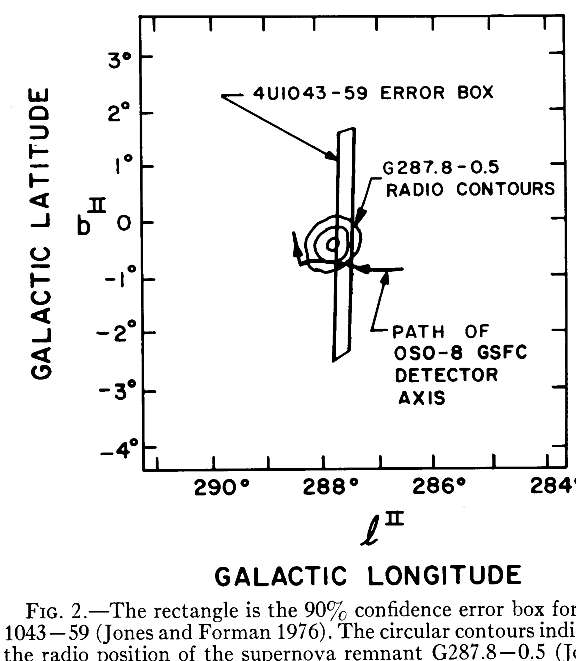

FIG. 2.—The rectangle is the 90% confidence error box for 4U 1043−59 (Jones and Forman 1976). The circular contours indicate the radio position of the supernova remnant G287.8−0.5 (Jones 1973). The path of the axis of the X-ray detector projected onto the sky is also shown.

If the X-rays from 4U 1043−59 are produced in a hot plasma with a temperature of 7.5 keV, then the presence of an iron-line emission feature is expected. Model calculations for such a plasma by Raymond and Smith (1975) which include Gaunt factor calculations of Mewe (1972), line emission contributions from dielectronic recombinations, new calculations of ionization equilibrium, predict an iron emission-line equivalent width of 913 eV for a cosmic abundance of iron. The observed width of 1730 eV suggests that iron is overabundant by a factor of $\sim$2 in the X-ray emitting plasma, 3 times the abundance of iron estimated for Cas A from an identical calculation (Pravdo *et al.* 1976). A high abundance of iron in a supernova remnant may be an indication that the remnant is very young. If the material ejected in a supernova event is iron-rich, then the remnant will be iron-rich until the mass ejected in the explosion is diluted by material swept up from the surrounding interstellar medium. Therefore, in the early evolution of a supernova remnant, the iron abundance will be at its highest. Both the relatively high iron abundance and the relatively high temperature of the X-ray emission from 4U 1043−59 suggest that the supernova remnant G287.8−0.5 is a young object.

Additional observations are needed to confirm the identification of 4U 1043−59 with G287.8−0.5. In particular, a smaller error box for the location of the X-ray source could be conclusive. It is also important that additional radio observations of G287.8−0.5 be made so that an accurate determination of the radio diameter is available. Nonetheless, the observations of 4U 1043−59 from OSO-8 and *Uhuru* already provide strong evidence that the association between 4U 1043−59 and G287.8−0.5 is real.

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R. H. Becker, E. A. Boldt, S. S. Holt, S. H. Pravdo, R. E. Rothschild, P. J. Serlemitsos, and J. H. Swank: Code 661, NASA/Goddard Space Flight Center, Greenbelt, MD 20771