THE ASTROPHYSICAL JOURNAL, 193:535–537, 1974 November 1

UPPER LIMIT TO THE X-RAY FLUX FROM THE SUPERNOVA IN NGC 5253 ABOVE 7 keV FROM THE OSO-7

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Received 1974 May 22

ABSTRACT

We report upper limits to the X-ray flux from the supernova in NGC 5253 (SN 1972e, optical maximum ~1972 May 4). The observations were made with the UCSD OSO-7 X-ray telescope during 1972 March 29–April 20, August 26–28, and September 29–October 10. The 2 σ upper limits above zero flux were respectively 1.2, 5.2, and 1.7 × 10^{-10} ergs cm^{-2} s^{-1} in the ~7–27 keV range. If a distance of 3.5 Mpc to NGC 5253 is assumed, these limits correspond respectively to 1.7, 7.3, and 2.4 × 10^{41} ergs cm^{-2} s^{-1}.

Subject headings: galaxies, individual — supernovae — X-ray sources

I. INTRODUCTION

The bright (~8 m_v max [Barbon and Ciatti 1972]) Type I supernova in NGC 5253 (SN 1972e [Kowal 1972]) was scanned with the UCSD OSO-7 X-ray telescope (Peterson 1973) several times in the weeks preceding and months following the optical maximum (~1972 May 4). Since NGC 5253 is ~3.5 Mpc away (Sérsic, Pastoriza, and Carranza 1972), SN 1972e was one of the closest supernovae to be observed in recent times (Kowal and Sargent 1971). Our results, together with observations of SN 1972e by Palmieri *et al.* (1973) and Canizares, Neighbours, and Matilsky (1974), place constraints on various hypotheses which predict high X-ray fluxes from supernovae.

II. OBSERVATIONS AND RESULTS

The UCSD OSO-7 X-ray telescope (~6°.5 FWHM aperture), sensitive in the ~7–500 keV energy range, scanned NGC 5253 ($\alpha = 13^h37^m.1$, $\delta = -31°24'.5$, 1950) three times during 1972: March 29–April 20, August 26–28, and September 29–October 10. We determined the counting rates from the direction of NGC 5253 averaged over the ~40 min observing time out of each ~93-min satellite orbit as described by Ulmer *et al.* (1972*a*). The background counting rates were determined from portions of sky ~10°–12° away from NGC 5253. We then averaged these counting rates over intervals ranging from 24 hours to 24 days. Below we present data derived from periods of time when the telescope scan path was within 3°.75 of NGC 5253 at closest approach.

The UCSD OSO-7 data consist of 122 linearly spaced energy-loss channels between ~7 and 500 keV. We examined the lowest five energy-loss channels individually and combined these data and the higher-energy-loss data into various broad channels. We found no evidence of X-ray emission from NGC 5253 in any of these data at a level greater than 2.7 σ above zero flux. We quote our results in table 1 as 2 σ upper limits above zero in the ~7–27 keV range (the most sensitive for a $1/E^2$ spectral shape), and in the higher energy range ~27–67 keV. We also derived upper limits to the flux in the ~67–500 keV range. These limits, not given in table 1, were 20 or more times higher than those in the ~7–27 keV range. We converted our upper limits from counts cm^{-2} s^{-1} to the ergs cm^{-2} s^{-1} given in table 1 by assuming a spectral shape $dN/dE \propto 1/E^2$ photons cm^{-2} s^{-1} keV^{-1}. The UCSD OSO-7 X-ray telescope response is such that the conversion from counts cm^{-2} s^{-1} to ergs cm^{-2} s^{-1} varies by less than 20 percent for a change in the shape of dN/dE from $1/E$ to $1/E^3$. Two-sigma upper limits on time scales τ as short as one day may be estimated, with an accuracy of ~30 percent, from the data in table 1 by assuming the limit is proportional to $\tau^{-1/2}$.

III. DISCUSSION

Previously, upper limits to the X-ray fluxes from extragalactic supernovae have been reported by Canizares *et al.* (1974), Palmieri *et al.* (1973), Laros (1973), Ulmer *et al.* (1972*b*), Bradt *et al.* (1968), and Gorenstein, Kellogg, and Gursky (1969). The lowest limits have been by Palmieri *et al.* (1973) and Canizares *et al.* (1974), who both made observations of SN 1972e, covering the energy ranges 0.6–1.5 keV and 1–40 keV, respectively. These upper limits to the X-ray flux from SN 1972e span the time period from ~16 months before optical maximum to ~2 years after optical maximum, and range from ~3 × 10^{-9} to 3 × 10^{-11} ergs cm^{-2} s^{-1} depending on the specific energy range and time interval involved, a typical value being ~3 × 10^{-10} ergs cm^{-2} s^{-1}.

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TABLE 1

2 σ UPPER LIMITS TO THE X-RAY FLUX FROM SN 1972e IN NGC 5253

1972 DATE AND TIME RELATIVE TO OPTICAL MAXIMUM (1972 May 4)*	10^{10} ergs (cm^2 s)$^{-1}$		10^{41} ergs s^{-1}†		10^{47} ergs†	
	7–27 keV	27–67 keV	7–27 keV	27–67 keV	7–27 keV	27–67 keV
March 28.7–April 20.1: -36 days $\rightarrow$ -14 days	1.2	4.0	1.7	5.6	3.2	11.0
August 26.3–28.1: $+114$ days $\rightarrow$ 116 days	5.2	18.0	7.3	25.0	1.2	3.9
September 28.5–October 9.7: $+148$ days $\rightarrow$ 159 days	1.7	5.5	2.4	7.7	2.3	7.4

* Barbon and Ciatti 1972.

† Assuming distance from Earth is 3.5 Mpc (Sérsic *et al.* 1972).

Bahcall, Rees, and Salpeter (1970) and Shklovskii (1973) argue that the X-ray flux cannot be detected until $\sim$2–3 months after optical maximum and is best seen at energies $\geqslant$10 keV, due to the opacity of the material surrounding the supernova. Therefore, we can compare our observations in the $\sim$7–67 keV range with the hypothesis of Shklovskii (1973) that the light curve of Type I supernovae can be explained by the existence of an $\sim 3 \times 10^{42}$ ergs s^{-1} X-ray source within the supernova. This luminosity is well above the upper limits in table 1 four or five months after optical maximum; Canizares *et al.* set equally stringent limits in the 15–40 keV range. There are several ways to explain the contradiction with Shklovskii's hypothesis (see also Canizares *et al.* 1974, who have a similar discussion): (1) the gas surrounding the supernova had not yet become transparent to $\sim$7–67 keV X-rays, (2) most of the X-ray energy was not in the $\sim$7–67 keV range, or (3) there was no strong X-ray source embedded in the supernova. We remark that Bahcall *et al.* (1970) also made a suggestion similar to Shklovskii's, but they implicitly suggested the high X-ray flux for Type II supernovae only.

Tucker (1969) has proposed that possibly supernovae which radiate $\sim 3 \times 10^{50}$ ergs in the X-ray region are responsible for the diffuse X-ray background. Although upper limits (see references given above and table 1) to the total X-ray energy from supernovae are less than 3×10^{50} ergs, the results are not definitive because the high X-ray luminosity epoch of these supernovae might not have coincided with the X-ray observations; however, via an indirect argument, Mack and Robbins (1972) have shown that Tucker's hypothesis is implausible.

To place some constraints on X-ray emission mechanisms, we estimate the upper limit to the ratio $L_x/L_{opt} \equiv$ X-ray luminosity/optical luminosity. From the work of Ardeberg and de Groot (1973), Kirshner *et al.* (1973*a*, *b*), and Lee *et al.* (1973), assuming that the difference between the bolometric correction for the Sun and for the supernova was small (e.g., Minkowskii 1964), we estimate that the optical radiation was $\sim 3 \times 10^{-10}$ ergs cm^{-2} at the Earth during 1972 August–October. From table 1, $L_x/L_{opt} \leqslant 0.6$ in the 7–27 keV range and $L_x/L_{opt} \leqslant 1.8$ in the 27–67 keV range. Also, Canizares *et al.* (1974) set limits of L_x/L_{opt} of 0.005 near optical maximum and 0.02 about 3 months afterwards. In comparison (e.g., Ulmer *et al.* 1972*b*; Bradt *et al.* 1968), $L_x/L_{opt} \sim 1000$ for Sco X-1, $\sim$100 for the Crab pulsar, and $\sim$2 for the $\sim$900-year-old Crab Nebula remnant. Thus, if the dominant X-ray emission mechanism in SN 1972e were similar to Sco X-1, the Crab pulsar, or the Crab Nebula, the associated optical flux would have been undetectable. This is in agreement with the optical continuum from SN 1972e, which can be fitted by a $\sim$7000° K blackbody (Kirshner *et al.* 1973*b*) and with the failure to detect pulsed optical radiation from extragalactic supernovae (Papaliolios and Horowitz 1973; Beresford *et al.* 1973).

IV. SUMMARY

In summary, we have not detected hard X-rays from the recent supernova in NGC 5253 either $\sim$10 days before or $\sim$150 days after optical maximum. The limit to the 7–27 keV flux was $\sim 2 \times 10^{-10}$ ergs cm^{-2} s^{-1}, comparable with lower limits to the supernova X-ray flux that had been set at lower energies by Palmieri *et al.* (1973) and Canizares *et al.* (1974). From all of these data combined, it would appear unlikely that Type I supernovae radiate large quantities ($\geqslant 3 \times 10^{42}$ ergs s^{-1}) of $\sim$1–67 keV X-rays near optical maximum, placing constraints on, but not strictly excluding, the model proposed by Shklovskii (1973).

We are pleased to acknowledge the assistance of Janet Dingler in the data analysis. We thank Drs. Canizares, Neighbours, and Matilsky for providing us with their results prior to publication, and we thank Dr. Kirshner for discussions about the optical data.

This research was sponsored under NASA contract NAS5-11080. One of us (L. E. Peterson) was partly supported by a Guggenheim Foundation Fellowship.

REFERENCES

Ardeberg, A., and de Groot, M. 1973, *Astr. and Ap.*, **28**, 295.
Bahcall, J. N., Rees, M. J., and Salpeter, E. E. 1970, *Ap. J.*, **162**, 737.
Barbon, R., and Ciatti, F. 1972, *IAU Circ.*, No. 2411.
Beresford, I. R., Greenhill, J. G., Hamilton, P. A., and Watson, R. D. 1973, *Nature Phys. Sci.*, **241**, 126.
Bradt, H., Naranan, S., Rappaport, S., Zwicky, F., Ogelman, H., and Boldt, E. 1968, *Nature*, **218**, 856.

Canizares, C. R., Neighbours, J. E., and Matilsky, T. 1974, *Ap. J. (Letters)*, in press.
Gorenstein, P., Kellogg, E., and Gursky, H. 1969, *Ap. J.*, **156**, 315.
Kirshner, R. P., Oke, J. B., Penston, M. V., and Searle, L. 1973*a*, *Ap. J.*, **185**, 303.
Kirshner, R. P., Willner, S. P., Becklin, E. E., Neugebauer, G., and Oke, J. B. 1973*b*, *Ap. J. (Letters)*, **180**, L97.
Kowal, C. T. 1972, *IAU Circ.*, No. 2405.
Kowal, C. T., and Sargent, W. L. W. 1971, *A.J.*, **76**, 756.
Laros, J. G. 1973, thesis, University of California, San Diego.
Lee, T. A., Wamsteker, W., Wisniewski, W. Z., and Wdowick, T. J. 1972, *Ap. J. (Letters)*, **177**, L59.
Mack, J. E., and Robbins, D. E. 1972, *Ap. J.*, **176**, 99.
Minkowskii, E. 1964, *Ann. Rev. Astr. and Ap.*, **2**, 247.
Palmieri, T. M., Burginyon, G. A., Hill, R. W., Scudder, J. K., Seward, F. D., and Tour, A. 1973, *Ap. J.*, **182**, 411.
Papaliolios, C., and Horowitz, P. 1973, *Ap. J.*, **183**, 233.
Peterson, L. E. 1973, *X-Ray and Gamma Ray Astronomy (IAU Symposium 55)*, ed. H. Bradt and R. Giacconi (Dordrecht: Reidel), p. 51.
Sérsic, J. L., Pastoriza, G., and Carranza, M. 1972, *Ap. and Space Sci.*, **19**, 469.
Shklovskii, I. S. 1973, *Soviet Astr.—AJ*, **16**, 749.
Tucker, W. H. 1969, *Ap. J.*, **161**, 1161.
Ulmer, M. P., Baity, W. A., Wheaton, W. A., and Peterson, L. E. 1972*a*, *Ap. J. (Letters)*, **178**, L121.
Ulmer, M. P., Grace, V., Hudson, H. S., and Schwartz, D. A. 1972*b*, *Ap. J.*, **173**, 205.

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