N49: THE SITE OF A GAMMA-RAY BURST.
PRELIMINARY RESULTS FROM X-RAY OBSERVATIONS.

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ABSTRACT

The error box of the unusual Gamma-Ray Burst of March 5, 1979 falls completely inside the optical and radio image of the Supernova Remnant N49 in the Large Magellanic Cloud. This region was observed twice in x-rays with the High Resolution Imager of the Einstein Observatory, six weeks and nearly two years after the Gamma-Ray Burst. We show the comparison between the two observations.

The location of the unusal Gamma-Ray Burst of March 5, 1979 (Evans et al., 1979; Evans et al., 1980) coincides with N49, a well known Supernova Remnant in the Large Magellanic Cloud. The burst error box falls completely inside the remnant (Cline et al., 1982). This is, until now, the only Gamma-Ray Burst location associated with a known astrophysical object. The probability of a fortuitous alignment is very low, 4×10^{-4} (Felten, 1981).

If the event originated in N49, that is at a distance of 55 Kpc, it had a peak luminosity $\gtrsim 5 \times 10^{44}$ erg s^{-1} and an integrated energy output $\simeq 10^{45}$ erg (for a description of this event see Cline, 1980 and references therein), but at least two burst models can produce such energies (Ramaty, Lingenfelter and Bussard, 1981; Woosley and Wallace, 1982). If the burst spectrum is interpreted as a synchrotron spectrum modified by inverse comptonization of e^{+}-e^{-} pairs (Liang, 1981), the high x-ray luminosity is still acceptable.

One of the practical advantages of the coincidence between a Gamma-Ray Burst location and a Supernova Remnant was that N49 had been observed by the Imaging Proportional Counter of the Einstein Observatory one week before the totally unexpected and unforeseeable March 5, 79 event (Helfand and Long, 1979) It was observed again by the same authors, this time both with the IPC and with the High Resolution Imager, one month after the event. They give upper limits of 2.2×10^{-12} erg/(cm^{2}s) to the flux of point sources inside the

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remnant after the event. In order to search for variations in the x-ray flux in the error box, we observed again N49 with the HRI two years after the burst. The results of our observation confirm those of Helfand and Long (op. cit.). With their permission we made a comparison of the two HRI images.

We present here our preliminary results (Table I). We give upper limits to the flux and to the change in flux between the two HRI observations for point sources in the remnant, which was divided into 8" x 8" squares. For each square we use as background the average of its eight nearest neighbours. One could argue that the upper limit to the change in flux should not exceed the upper limit to the flux of point sources, but we must consider also the possibility that a "dip" in the extended source has been filled, therefore we give the limits directly as we derive them from the data.

TABLE I

X-Ray observations of the March 5, 79 Gamma-Ray Burst error box (N49) Limits to point source fluxes and flux variations.

Observers	Date & Instrument	Duration (sec.)	CPS c/sec. $X10^{-3}$	Lx **	$\dot{M}$ ***	Δ Lx **	$\Delta\dot{M}$ ***
Helfand + Long (1979)	Feb. 26, 79 IPC					<1.3	<1.5
"	Apr. 13, 79 IPC						
"	" 19, 79 HRI	10200	<9.9	<1.3	<1.5	<1.2*	<1.4
Present work	Feb. 3, 81 HRI	7500	<7.3	<1.0	<1.1		
Present work + Helfand-Long	Apr. 19, 79 + Feb. 3, 81 HRI	17700	<6.7	<0.8	<1.0		

(*) See text for the difference in the upper limit to the flux of point sources and to the change in flux.

(**) Lx and ΔLx are in units of 10^{30} erg/s x $(d/100\ pc)^2$.

(***) $\dot{M}$ and $\Delta\dot{M}$ are in units of 10^{10} g/sec. x$(d/100\ pc)^2$.

By adding the two observations together we can also reduce the upper limits to the flux of point sources inside N49. This procedure should, however, be considered with caution, because of the two years elapsed between the two observations, even if no variability has been detected.

Until now, only one x-ray source has been detected in a Gamma-Ray Burst error box (Pizzichini et al., 1981; Grindlay et al., 1982). Upper limits to the x-ray flux of point sources have been obtained for three more burst locations (Pizzichini et al., 1982). Both the source detected and the upper limits are one order of magnitude smaller than the upper limits we give here, but the March 5, 79 burst was a very unusual and possibly unique event. Among other things, it was the largest one even detected both in peak flux and in total energy and it has been argued that it belongs to a different class altogether (Mazets and Golenetskii, 1979), therefore we shall derive our conclusions for the location of the March 5, 79 event only from the observations of N49.

If we assume that the sources of Gamma-Ray Bursts are accreting neutron stars, as proposed by several authors (Woosley and Wallace, 1982; Bonazzola et al., 1981 and 1982; Hameury et al., 1982), our upper limits put constraints on the mass accretion rate. For a ratio of x-ray to total luminosity $\eta_x = 0.1$, using the same method and parameters of Helfand and Long (op. cit.), even at the distance of the LMC we already get a low value, $\dot{M} < 3 \times 10^{15}$ g/s or 5×10^{-11} $M_\odot$/yr. At galactic distances we have $\dot{M} < 10^{-16}$ $M_\odot$/yr x (d/100 pc)^2 for an interstellar hydrogen density of 1 cm^{-3}.

The accretion rates required by current models for this event vary between 3×10^{-16} and 8×10^{-13} $M_\odot$/(yr km^2). If we take a 1 km^2 polar cap, the distance to the source must be at least 170 pc for any of these models to be compatible with our upper limits, unless the ratio of x-ray to total luminosity is much lower than usual or the accretion rate is variable.

If the burst energy is accumulated only by accretion, then the accretion rate should indeed be highly variable, as pointed out by Helfand and Long (op. cit.), because the same source produced a second, small burst on the following day and this requires an accretion rate of 1.6×10^{-13} $M_\odot$/yr x (d/100 pc)^2 for the time interval between the two events.

However, we have already four measurements which seem to have all been made when the source was in a low intensity state.

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REFERENCES

Bonazzola S., Hameury J.M., Heyvaerts J. and Ventura J.: 1981, Space Sci. Rev. 30, pp. 471-474.

Bonazzola S., Hameury J.M., Heyvaerts J., Ventura J.: 1982, in Accreting Neutron Stars, Brinkmann, W. and Trümper J., eds, MPE Report No. 177, Garching bei München, pp. 241-243.

Cline T.L.: 1980, Comments on Astrophys., 9, pp. 13-22.

Cline T.L., Desai U.D., Teegarden, B.J.,, Evans W.D., Klebesadel R.W., Laros J.G., Barat C., Hurley K., Niel M., Vedrenne G., Estulin I.V., Kurt V.G., Mersov G.A. and Zenchenko V.M.: 1982,

Astrophys. J. (Letters) 255, pp. L45-L48.
Evans D., Klebesadel R., Laros J., Cline T., Desai U., Teegarden B. and Pizzichini G.: 1979, I.A.U. circ. No. 3356.
Evans W.D., Klebesadel R.W., Laros J.G., Cline T.L., Desai U.D., Pizzichini G., Teegarden B.J., Hurley K., Niel M., Vedrenne G., Estoolin I.V., Kouznetsov A.V., Zenchenko V.M. and Kurt V.G.: 1980, Astrophys. J. (Letters) 237, pp. L7-L9.
Felten J.E.: 1981, Proceedings of the 17th International Cosmic Ray Conference, Paris, Late papers volume No. 52-55.
Grindlay J.E., Cline T., Desai U.D., Teegarden B.J., Pizzichini G., Evans W.D., Klebesadel R.W., Laros J.G., Hurley K., Niel M. and Vedrenne G.: 1982, CFA preprint series No. 1734, to appear in Nature.
Hameury J.M., Bonazzola S., Heyvaerts J. and Ventura J.: 1982, Astron. and Astrophys. 111, 242-251.
Helfand D.J. and Long K.S.: 1979, Nature 282, pp. 589-591.
Liang E.P.T.: 1981, Nature 292, pp. 319-321.
Mazets E.P. and Golenetskii S.V.: 1979, preprint Academy of Sciences of the USSR No. 632.
Pizzichini G., Danziger J., Grosbøl P., Tarenghi M., Cline T.L., Desai U.D., Mushotzky R., Teegarden B.J., Evans W.D., Klebesadel R.W., Laros J.G., Barat C., Hurley K., Niel M., Vedrenne G., Estulin I.V., Mersov G., Zenchenko V. and Kurt V.: 1981, Space Sci. Rev. 30, pp. 467-470.
Pizzichini G., Cline T.L., Desai U.D., Teegarden B.J., Hurley K., Niel M., Vedrenne G., Evans W.D., Fenimore E.E., Klebesadel R.W. and Laros J.G.: 1982, in Accreting Neutron Stars, Brinkmann, W. and Trümper J., eds, MPE report No. 177, Garching bei München, pp. 237-240.
Ramaty R., Lingenfelter R.E. and Bussard R.W.: 1981, Astrophys. and Space Sci., 75, pp. 193-203.
Ventura J.: 1982, preprint 82-II-AV1, COSPAR meeting, Ottawa, invited paper.
Woosley S.E. and Wallace R.K.: 1982, Astrophys. J. 258, pp. 716-732.

DISCUSSION

BISNOVATY-KOGAN:
I want to mention an additional difficulty in identification of 5 March 1979 Gamma-Ray Burst with SNR in LMC. The luminosity of this source in the quite hard x-ray pulsar phase is much greater than the Eddington optical luminosity, so the outer layers of the neutron star will be thrown away with a velocity almost equal to c. In this case it is very improbable to obtain the regular hard x-ray pulsations which have been observed.

KOCH-MIRAMOND:
Are there existing or planned observations of the Gamma-Ray Burst error box at higher energy x-rays?

PIZZICHINI:
Not to my knowledge.

DUROUCHROUX:
Your argument for correlation of the Gamma-Ray Burst with N49 is mainly based on variations of the x-ray flux before and after the burst. Is this phenomenon very unusual in the Einstein observations of the same region in the sky separated by a few months? (My question is not related to a sky region where a burst took place but to any region observed at least two times).

PIZZICHINI:
No; in fact no flux variations hav been detected. My argument in favour of the association of the March 5, 1979 Burst with N49 is based on the coincidence between the remnant and the burst error box (see Felten, op. cit.) and on the fact that it is possible to account for an origin of the burst in the LMC (Ramaty et al., 1981, Liang, 1981). Helfand and Long (op. cit.) who had IPC observations of N49 before and after the event find only an upper limit to the change in flux. We also find only an upper limit to the change between 1 month and 2 years after the event.

There are of course other objects which have been observed several times by the Einstein Observatory and found to be variable, but their locations do not coincide with Gamma-Ray Burst locations.