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Letter to the Editor

On the possible source of GRB 930131

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Abstract. A series of recent papers (Kouveliotou et al., 1994; Sommer et al., 1994; Ryan et al., 1994) have discussed the localization and properties of GRB930131, the brightest gamma ray burst (GRB) observed by the *Compton Gamma Ray Observatory* (*CGRO*). Schaefer et al. (1994) have looked for objects in the neighbourhood of this GRB. They have shown that there are two X-ray sources near the *CGRO* localization, which were identified with the stars HD 106225 and HR 4657. In the present *Letter* we discuss these two sources in detail. HR 4657 is a visual binary of spectral type F at a distance of 34 pc and it is unlikely to be the source of GRB930131. The object HD 106225 is one of the most active RS CVn type of binaries at a distance of 220 pc and it exhibits surface magnetic activity in all wavelengths from radio to X-rays (Strassmeier et al., 1993). Vahia and Rao (1988) have suggested that the GRBs arise from flares on Magnetically Active Stellar Systems (MASS) consisting of flare stars, RS CVn binaries and cataclysmic variables of which about 300 sources are known. The probability of finding a magnetically active system in the *CGRO* error box is about 3 10^{-3}. Other properties of the GRB also agree well with our expectations of flares on such a binary.

Key words: Gamma rays: bursts - Stars: flare - Stars: activity - Binaries: general

1. Introduction

The question of the origin of gamma ray bursts (GRBs) has become more clouded with the recent results obtained from the *CGRO* which show that the GRBs are isotropically distributed in the sky but their number density increases less steeply with distance. This has created serious problems for the general view that GRBs arise on neutron stars since neutron stars would be expected to have a galactic plane distribution. Several recent studies have shown that the *CGRO* observations can be explained well by multiple types of sources (Hakkila et al., 1994; Lingenfelter and Higdon, 1992).

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Vahia and Rao (1988) had suggested that the GRBs are flares on magnetically active stellar systems (MASS) consisting of flare stars, RS CVn binaries and cataclysmic variables (see also Vahia, Rao and Singh, 1991). The energetics of such systems are further discussed in Vahia and Rao (1990). Rao and Vahia (1994) have shown that the above suggestion is consistent with *CGRO* observations (see also Liang and Li, 1993).

In the present *Letter* we have studied the objects found in the localization of GRB930131 observed by various instruments on *CGRO* (Kouveliotou et al. 1994; Sommer et al. 1994; Ryan et al., 1994). The search for optical, radio and X-ray counterparts was performed by Schaefer et al. (1994) and we examine closely the sources found by them in the GRB error box and show that it is very likely that the GRB930131 arose from an inter binary flare on HD106225.

2. The *CGRO* observations

Three detectors on *CGRO* namely *BATSE*, *EGRET* and *COMPTEL* observed the gamma ray burst GRB930131. Of these, the observations from *BATSE* (Kouveliotou et al., 1994) were the most extensive. They report a burst spectrum from 10 keV to 4 MeV. The rise time of the burst was less than 64 msec. Starting from the onboard trigger time, the spectrum was recorded with 2 msec time resolution. The burst had two sharp spikes lasting a total of 1.7 sec after which the flux returned gradually back to the background value in 50 sec. The time characteristics in the 10 keV to 4 MeV and 4 MeV to 7 MeV energy bands were similar. The integrated spectrum could be best fitted by a broken power law with a break at 170 $\pm$ 27 keV with the power law index changing from -1.30 $\pm$ 0.05 to -1.9. The observations by *EGRET* (Sommer et al., 1994) consisted of 16 gamma ray photons above 30 MeV. The data could be best fitted by a power law of index -2.0 $\pm$ 0.4. *COMPTEL* observations (Ryan et al., 1994) are also consistent with the other observations. The duration of the burst recorded by *COMPTEL* for energies above 600 keV was about 2 sec. The spectral fit to the data from 600 keV to beyond 10 MeV was fitted by the spectral index of -1.8 $\pm$ 0.4. The total gamma ray flux is a few times 10^{-5} ergs cm^{-2} based on the *BATSE* and *EGRET* data. The rapid fluctuations and the high intensity of the burst above 10 MeV indicated that the burst was no farther than 250 pc if the emission was not beamed (Ryan et al., 1994).

3. X-ray sources seen in the error box of GRB930131

Schaefer et al. (1994) have reported two X-ray sources that are seen in the GRB930131 error box, based on the archival *ROSAT* data. These two sources are identified with HR 4657 and HD 106225. We discuss below the properties of these two sources and investigate whether they could be the counterparts of GRB930131.

3.1. HR 4657

This is a visual binary (separation 73."3) at a distance of 34 pc. The primary is a normal main sequence star of spectral type F5V with a visual magnitude of 6.11. The companion, of unknown spectral type, is of visual magnitude 12.9 (Hoffleit and Jaschek, 1982). If GRB930131 is associated with HR 4657, the total gamma ray energy emitted during the burst (L_γ) will be 6.9 10^{36} ergs. It is unlikely that a normal main sequence star can emit such gamma ray energy. The secondary of HR 4657 has an absolute visual magnitude of 10.2 (at a distance of 34 pc) and it is most likely a normal M type main sequence star. Again, a gamma ray energy of $> 10^{36}$ ergs is unlikely to originate from such a star.

3.2. HD 106225

This object is one of the most active regular period RS CVn type of binaries (Strassmeier et al., 1990; 1993). It is object number 99 in the catalog of chromospherically active binary stars (CABS) (Strassmeier et al., 1993) and its properties are listed in table 1. The CaII H & K flux normalized to the bolometric flux (R_{HK}) is $\sim 3\ 10^{-4}$, which is one of the highest value seen in a survey of CABS (Strassmeier et al. 1990). The ratio of its X-ray luminosity to the bolometric luminosity is 1.3 10^{-4} (Dempsey et al., 1993), a value typically seen in active RS CVn type of binaries.

If GRB930131 is associated with HD106225, the value of L_γ will be 2.9 10^{38} ergs. Vahia and Rao (1988) have pointed out that such large values of L_γ are possible for RS CVn type of binaries. This value of L_γ agrees very well with the gamma ray luminosity predicted for RS CVn binaries to fit the observed Log (N)/ Log (P) distribution of GRBs (Rao and Vahia, 1994). Infrequent, very energetic X-ray flares have been detected in RS CVn type of binaries (Pye and McHardy, 1983; Rao and Vahia, 1987) and the observed X-ray energy is in the range of $\sim 10^{37} - 10^{38}$ ergs.

There are several other features which support the identification of GRB 930131 with a RS CVn type of binary. In particular, the break in the spectrum from harder to softer spectral index is common in solar flares (see e.g. Kane et al., 1983). The upper limit of 250 pc put by the *COMPTEL* satellite also agree well with the distance of HD 106225.

Table 1. Observed properties of HD106225 (Strassmeier et al., 1993)

Property	Value	Comments
Name	HU Vir	
Type	RS CVn	very active
Spectral type	K0IV	SB1
T_{eff}	4750	°K
Binary period	10.3876	days
Distance	220	pc
Maximum visual magnitude	8.57	variation 0.25
Absolute visual magnitude	1.8	
V sin i	25	km s^{-1}
Photometric period	10.28	days
Radio flux	1.34	mJy (at 6 cm)
Colors		
<U-B>	0.66	
<B-V>	1.02	
<V-R>	0.602	
<R-I>	0.573	
X-ray luminosity	1.3 10^{31}	ergs s^{-1}

The source HD 106225 is well within the error boxes of *BATSE* and *COMPTEL* and within 0.3 degree of the 1 degree 2 σ error box of *EGRET*. It is 7' away from the Interplanetary network (IPN) localization. Vahia and Rao (1988) have pointed out that as a standard procedure in the IPN localizations, it is assumed that the delay in the start time of various detectors is entirely due to the delay in the arrival time of the signal. However, it has been shown that even *within* the same instrument, the arrival time of the signal may vary by several hundred milliseconds, depending on the energy band considered for the study (Golenetskii et al., 1985). In view of this we have taken a conservative error box area of 0.4 square degrees and the probability of finding a magnetically active stellar system inside such an error box is 3 10^{-3}.

Recently McNamara and Harrison (1994) have reported CCD observations of the central region of GRB930131 error box. They find that HD106225 had a <B-V> color of 0.89 which is much bluer than its normal color of 1.02 (see table 1. They conclude that eleven weeks after the GRB930131 event HD106225 was in an active state.

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