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Are Gamma-Ray Bursts in Star Forming Regions?

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ABSTRACT

The optical afterglow of the gamma-ray burst GRB 970508 ($z = 0.835$) was a few hundred times more luminous than any supernova. Therefore, a name 'hypernova' is proposed for the whole GRB/afterglow event.

There is tentative evidence that the GRBs: 970228, 970508, and 970828 were close to star forming regions. If this case is strengthened with future afterglows then the popular model in which GRBs are caused be merging neutron stars will have to be abandoned, and a model linking GRBs to cataclysmic deaths of massive stars will be favored. The presence of X-ray precursors, first detected with Ginga, is easier to understand within a framework of a 'dirty' rather than a 'clean' fireball. A very energetic explosion of a massive star is likely to create a dirty fireball, rather than a clean one.

A specific speculative example of such an explosion is proposed, a microquasar. Its geometrical structure is similar to the 'failed supernova' of Woosley (1993a): the inner core of a massive, rapidly rotating star collapses into a ~ 10 $M_\odot$ Kerr black hole with $\sim 5 \times 10^{54}$ erg of rotational energy, while the outer core forms a massive disk/torus. A superstrong $\sim 10^{15}$ G magnetic field is needed to make the object operate as a microquasar similar to the Blandford & Znajek (1977) model. Such events must be vary rare, $10^4 - 10^5$ times less common than ordinary supernovae, if they are to account for the observed GRBs.

Subject headings: gamma-rays: bursts – stars: binaries: close – stars: neutron – stars: supernovae

1. Introduction

The recent detection of the afterglows following some gamma-ray bursts (GRB) detected by BeppoSAX opens up a new era in the studies of GRBs. Many afterglows were

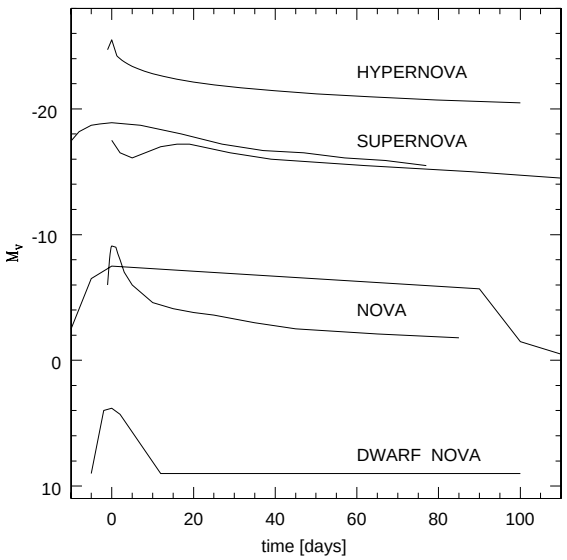

Fig. 1.— The absolute visual light curves are shown schematically for various eruptive variables. These include one case of a dwarf nova (U Gem, cf. Fig. 5.23 of Sterken & Jaschek 1996), two cases of a nova (V 1500 Cyg and DQ Her, cf. Fig. 40 of Hoffmeister et al. 1985), two cases of a supernova (SN 1993J, Richmond et al. 1994; SN 1994D, Richmond et al. 1995), and one case of a hypernova, i.e. the optical afterglow 970508 (Sokolov et al. 1997).

detected in X-rays (e.g. Costa et al. 1997), but so far only two were detected optically (970228: van Paradijs et al. 1997; 970508: Bond 1997), and just one in radio domain (970508: Frail et al. 1997). A major breakthrough was the determination of the absorption and emission line redshift $z = 0.835$ for 970508 (Metzger et al. 1997a,b).

An afterglow is created by a collision between GRB ejecta and ambient medium, be it circum-stellar, interstellar, or intergalactic, and it is a natural consequence of any relativistic fireball model (Rees & Mészáros 1992, Paczyński & Rhoads 1993, Wijers et al. 1997a, Waxman 1997a,b, Sari 1997, Vietri 1997, and many references therein). A very impressive confirmation of the relativistic expansion was provided by the change in the scintillation pattern of the 970508 radio emission, as detected by Frail et al. (1997), and predicted by Goodman (1997).

The observed optical emission of 970508 is compared in Fig. 1 with that of other cataclysmic variables: dwarf novae, novae, and supernovae. I adopted $z = 0.835$ as the