Third Rome Workshop on Gamma-Ray Bursts in the Afterglow Era
ASP Conference Series, Vol. 312, 2004
M. Feroci, F. Frontera, N. Masetti, and L. Piro, eds.

Observing the GRB remnants

S. G. Bhargavi & R. Cowsik

Indian Institute of Astrophysics, Bangalore 560 034 India

R. Perna

Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138

Abstract. Following the predictions of Perna, Reymond & Loeb (2000) we have proposed an observational program to search for the GRB remnants in nearby galaxies using the telescopes of Indian Institute of Astrophysics, Bangalore. We will discuss the strategies, facilities and feasibilities of observations. Such a study would contribute to various aspects viz. progenitors, burst environment, GRB rate and so on.

1. Motivation

Knowledge of GRB environment is important to understand the nature of their progenitors. Afterglow observations have shown us that GRBs with long durations occur in faint galaxies at cosmological distances. We now have observational evidence that long bursts occur in gas-rich and dusty environment. Short bursts might be occuring in low density environments resulting from NS-NS mergers. But we do not have any observational evidence to support this view since no counterparts have been detected for the short bursts.

While it is important to understand the birth places of GRBs, it is also interesting to ask how GRBs affect their immediate surroundings. If GRBs would leave behind remnants with unique observable features, then one could search for such features elsewhere in the sky and hence identify unknown GRB explosion sites.

2. GRB remnants

Perna, Raymond & Loeb (2000) have shown that 2 kinds of GRB remnants are possible:

Cooling remnant : due to the effect of radiation of GRB and its afterglow.

The UV afterglow flux of a GRB heats and ionizes the surrounding medium. An emission spectrum is expected to be produced from the cooling ionized gas, the cooling rate being as slow as $\sim 10^5$ yrs

Slowing remnant : due to the slowing blast-wave.

The relativistically expanding blast wave resulting from a GRB explosion takes $\sim 10^7$ years to slow down and merge with the ISM.

Combining these time scales with the present GRB rate, it has been estimated that few such GRB remnants should be present in every galaxy at any given time.

2.1. Observables

In their detailed computation of emission spectra Perna, Raymond & Loeb (2000) have identified spectral signatures unique for GRB remnants as compared to other sources such as shock heated gas in SNRs or HII regions.

- High value for the line ratio [OIII]λ 5007/H_β.
- Unusally high value for He II λ4686 /H_β ratio.
- Time-dependent increase in the ratio [OIII]/[OII] indicating cooling of the gas.
- High SIIλ 6717/H_β as compared to HII regions.

The giant expanding HI supershells of kPc size have been suggested to be the remnants of GRBs (Loeb & Perna 1998). If the giant HI supershells were powered by multiple SN then one expects enhancement in the abundances of O, Ne and Si interior to a supershell (Perna & Raymond 2000).

Besides these it would be interesting to look for evidence for the presence of high energy particles and radiations in the remnant. For example, there might be a higher abundance of spallation or photodissociation products like Li, Be and B as well as spectral continuum arizing from bremsstrahlung, synchrotron radiation etc.

3. Observing techniques

3.1. Sample selection

- afterglow sites?

  The emission is weak when the remnants are < few hundred yr old therefore we will not be able to investigate the recent afterglow regions.

- nearby bright galaxies

  We propose to observe nearby bright galaxies as well as Virgo cluster of galaxies and measure the line ratios viz., [OIII]λ 5007/H_β, He II λ4686 /H_β etc.

- HI supershells

  (ii) Centers of selected giant HI supershell will be investigated to check for the enhancement in the abundances of O, Ne, Si elements as compared to normal ISM. This would allow us to constrain the models: GRB v/s multiple SN v/s that are believed to enpower the HI supershells.

3.2. Telescopes and detector system

We have initiated the observing program using the 2.34 m Vainu Bappu Telescope (VBT) at Kavalur, India since 2002 summer. Unfortunately, bad weather hampered our observations. We hope to obtain data from the new 2 meter Himalayan Chandra Telescope of Indian Astronomical Observatory (IOA), Hanle featured by cloudless skies low atmospheric water vapour. Table 1 shows the telescope parameters. (For further details see http://www.iiap.ernet.in/centers.html).

Table 1. Telescopes

	VBT Kavalur	IOA, Hanle
Size	234 cm	201cm
Longitude:	$78°49'36''$E	$78°57'51''$
latitude:	$12°34'36''$N	$32°46'46''$N
Altitude:	725 m	4500 m
Seeing (typ.):	$2''.5$	$< 1''$
F-ratio:	f/3.25 prime	f/9 cassegrain
Image scale:	$0''.6$/pix	$0''.17$/pix
FOV:	$10' \times 10'$	$7' \times 7'$

3.3. Feasibility of observations

narrow-band filter photometry: Perna *et al.* calculated that with 1 hr integration a GRB remnant is detectable at a distance of 20 Mpc with S/N $\approx$ 100 using the 10 m Keck telescope. We expect be able to detect a remnant at a distace of Virgo cluster with a S/N of 10 in 40 minute integration using our 2 m telescopes equipped with narrow-band filetrs.

spectroscopy: A photoionized remnant of radius $\sim$ 100 pc would subtend an angle of $2''$ on the sky at the distance of Virgo cluster ($\sim$ 20 Mpc), where as a typical galaxy would subtend 2 arcmin. We require a spectrograph like Integral Field Unit (IFU) which can take simultaneous spectra across the entire image of a nearby galaxy. Institute is in the process of acquring a multi-fibre spectragraph in near future.

Existing surveys: We would like to investigate the available data from surveys such as 2dF. In 2dF only a single fibre has been placed on each galaxy and mostly at the nucleus (Russell Cannon 2002; private communication). Although there are good chances of missing the emission from a GRB remnant, we can not rule out the possibility of detecting some of the remnants if they happened to be the dominant source within the $2''$ diameter of the the 2dF fibre. whereas in the case of distant galaxies (GRS survey) the signal from the GRB remnant could be lost in the integrated spectrum of the entire galaxy. However, it would be a good idea to examine the 2dF data as well as data from any other such surveys.

4. Conclusions

We plan to carry out a survey of nearby galaxies to search the GRB remnants. From the GRB statistics and timescales of remnants it certainly seems possible to see and positively identify a few GRB remnants in nearby galaxies. Spectroscopic observations using HFOSC on Himalayan Chandra telescope seem quite promissing to get started given the sub-arcsecond seeing as well as cloudless nights. The multiple-fibre spectrograph being acquired by our institute is idealy suited for this program.

References

Loeb, A., & Perna, R. 1998, ApJ, 533, L35

Perna, R., Raymond, J. & Loeb 2000, ApJ, 533, 658

Perna, R., & Raymond, J. 2000, ApJ, 539, 706