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Short-duration Gamma-ray bursts

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Abstract. Short-duration Gamma-ray bursts are supposed to be stellar explosions having T_{90} duration less than 2 sec. The duration T_{90} is defined as he time over which a burst emits from 5% of its total measured counts to 95%. These bursts were observed so far at comparatively lower redshifts (z < 1.5) and lower energies ($E_\gamma, iso < few \times 10^{51}$ erg) than those observed in case of long-duration gamma-ray bursts in general. Due to lack of associations of these bursts with the supernova collapse, studies were conducted to probe their origins and a new model called compact binary merger model was proposed with higher acceptance as compared to several other models. Study about these energetic cosmic events have far-reaching astrophysical implications recently. Considering the longitudinal advantage of India, the upcoming 3.6 m telescope at Devasthal is an unique facility to study these events in great detail.

Keywords : Short-duration – : Gamma-ray bursts – Kilo-novae – Observations

1. Introduction

Ever since their clear categorization (Kouveliotou et al. 1993) Short-duration Gamma Ray Bursts (SGRBs) have been identified as energetic cosmic transient sources of great scientific potentials (Berger 2014). During *Swift* era, sub-arc-sec XRT localization enabled discovery of the first afterglow of SGRB 050724 (Castro-Tirado et al. 2005). Since their discovery in 2005, more than 70 afterglows of SGRBs have been detected at various wavelengths exhibiting diverse properties (Gehrels et al. 2009).

Study about SGRBs have now been extended much beyond understanding about their progenitors and environments. Compact binary mergers are one of the most probable progenitors for SGRBs (Li and Paczynski 1998). Recently, It has also been proposed that during the process of compact binary merging, radioactive decay of

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heavy elements might give rise to a supernova-like feature, termed as “macro-nova or “kilo-nova (Kulkarni 2005; Hotokezaka et al. 2013; Kasan et al. 2015) and could be associated with the emissions from SGRBs. So, study about SGRBs could open a new window to understand about gravitational waves and neutrinos (Eichler et al. 1989) and also to study these energetic events as sources to understand heavy element nucleosynthesis processes in the nearby universe by understanding about compact binary mergers in more detail.

2. Properties of SGRBs

The prompt emission properties of SGRBs like harder spectra, higher E_{peak} relatively lower energy spectral slope, nearly zero spectral lag, T_{90} duration < 2 sec etc. distinguishes them from long-duration GRBs (LGRBs). Afterglows of SGRBs are in general less luminous, less energetic and favor rather lower circumburst densities than those seen in case of LGRBs (Berger 2014). In comparison to LGRBs, the observed lower redshift range (z $\sim$ 0.1 - 1.5) of SGRBs do not seem to be connected to morphology of the host galaxies rather the relatively lower values appears to be effected by the detection threshold of *Swift/BAT* (Fong et al. 2013). Based on the proposed theoretical models and the observational evidences, neutron star-neutron star (NS-NS) and/or neutron star-black hole (NS-BH) mergers (Narayan et al. 1992; Eichler et al. 1989) and magnetars (Kouveliotou et al. 1998) are the most-probable progenitor candidates for SGRBs. Afterglow properties of SGRBs also indicate that these bursts have rather jet-opening angles similar to those observed in case of LGRBs and have systematically larger radial offsets from the host galaxies, supporting the compact binary merger as possible progenitors of SGRBs (Fong and Berger 2013). Also, properties of the host galaxies of SGRBs are very similar to field galaxies contrary to the peculiar properties noticed in host galaxies of LGRBs.

3. Optical studies of afterglows of SGRBs

Optical-IR afterglows of SGRBs are of great importance not only to constrain afterglow properties and jet-breaks but also to increase the number of observed after-glows of SGRBs, so that the properties of SGBRs are well understood. Optical afterglows of SGRBs are generally fainter in comparison to those observed in case of LGRBs, enabling requirement for a faster and deeper afterglow observations using moderate to bigger size telescopes (Sagar and Pandey 2012). The upcoming 3.6m telescope at Devasthal will provide an unique opportunity to study afterglows and host galaxy properties of GRBs in detail. Figure 1 shows, the capability of 3.6m telescope along with the first-light instrument, a 4K$\times$4K CCD imager in several broad-band filters.

3.1 SGRB 130603B

SGRB 130603B, watershed event, was discovered on 2013 June 3 at 15:49:14 UT by the *Swift*-BAT (Barthelmy et al. 2013; Melandri et al. 2013), and by the Konus-Wind (Golenetskii et al. 2013). The γ- ray light-curve of GRB 130603B consists of a single pulse with a duration of T_{90} = 0.18$\pm$0.02 s (15 âĹŠ 150 keV; Barthelmy et al. (2013)) and do not show any extended emission and spectral lag (Norris et al.

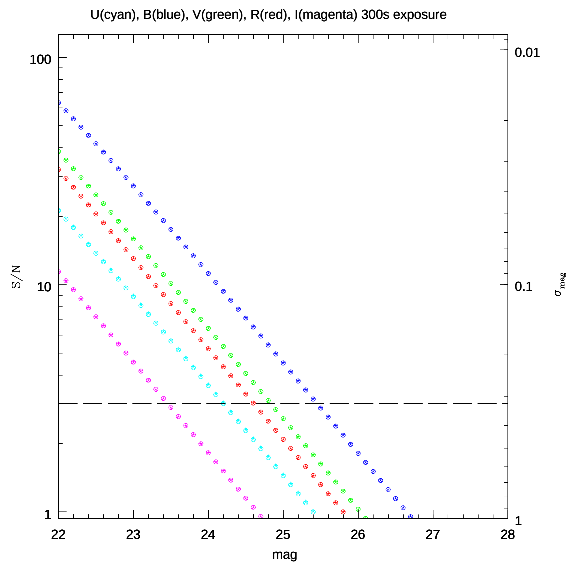

Figure 1. A simulated plot of magnitude (X-axis) Vs. signal-to-noise ratio (Y-axis, left) and corresponding error in the magnitude determinations(Y-axis, right) based on the throughput calculations Mayya (1991) of the 3.6m telescope with the proposed 15 micron 4K×4K CCD camera for set of Bessel *UBVRI* filters, for assumed exposure time of 300 sec each, seeing value of 1.5 arc-sec. and for other standard values of the observing site and the CCD chip.

2013). The spectroscopic redshift measurements for the afterglow were determined by many groups including Sanchez-Ramrez et al. (2013). The early time optical-NIR properties of this burst are close to afterglow models (Sari et al. 1999) whereas late time IR-excess indicate towards associated "Kilonova" emission. The detailed afterglow properties (Fong et al. 2014; Tanvir et al. 2013) of this burst are also discussed in Pandey et al. (2015).

4. Optical-NIR "Kilo-novae and 3.6m Devasthal Telescope

"Kilonova" or "macro-nova are electromagnetic transients powered by radioactive decay of r-process elements produced by accretion disk winds during a compact binary mergers with one component being a neutron star. The ejection of radioactive material during the merging process of the compact binaries could lead to faint optical-infrared emission. The brightness and duration of such an emission is function of opacity, velocity and mass of the ejecta (Matgzer et al. 2010; Bernes and Kasen 2013; Tanaka et al. 2014). Recently, hydrodynamical modeling of such a process have been studied by Kasan et al. (2015) speculating a brief bluer emission component produced in the outer lanthanide free ejecta and a rather larger duration infra-red transient produced in the inner lanthanide-blanketed regions. Using their model for a case with non-spinning black-hole, the optical bump observed in case of SGRB 080503 (Perley et al. 2009) was interpreted in terms of underlying "Kilonova" emission. However their models were unable to explain the observed infrared-excess in case of GRB 130603B which required higher accretion disk mass and perhaps a rapidly spinning black-hole (Just et al. 2014). It is also to be noted that the observed infrared excess in case of GRB 130603B was explained by Tanaka et al. (2014) and Hotokezaka et al. (2013) assuming equation of states and a rather larger accretion disk mass of $\sim 0.1 M_{\odot}$ both in case of NS-SN and NS-BH models.

Optical and IR observations of a much larger sample of nearby SGRBs are required to improve our understanding about nature of their host galaxies, progenitors and to put a constrain on the electromagnetic counterparts and number density of gravitational wave sources in near future (Matzger and Berger 2012). Taking longitudinal advantage of India and with the upcoming 3.6m telescope at Devasthal Nainital and the instruments, it would be possible to study SGRBs properties and the associated "Kilo-novae emission in great detail (see figure 1).

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