Gamma-Ray Bursters and Orphan Afterglows (GRB)

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Abstract. Optical transients associated with Gamma-Ray Bursters (GRBs) and Orphan GRB Afterglows will be detected by PanSTARRs. GRBs themselves have peak brightnesses $V \sim 8$ or 9 declining to $V \sim 20$ in 1 day). Orphan Afterglows — off-axis optical transients that have no gamma-ray signal — will be much fainter $R \geq 23$ but could have a detection rate as high as one per night. Study of GRBs and Orphan Afterglows will probe the physics of the final collapse phases of massive stars, the radiation mechanisms of the GRBs, and any correlations with the host galaxies such as low metallicity. The optical counterparts of GRBs, if identified early enough, could be the most powerful probes of the IGM to high redshift.

This project will take advantage of all Pan-STARRs time - any repeat visit will be a potential search. If we estimate that the first year of PanSTARRs establishes the first epoch, then GRBs will make use of the 9 remaining PanSTARR years.

1 Introduction

Gamma ray bursters have been identified as being at cosmological distances, revealing their tremendous intrinsic luminosities and hinting at their origin in the final phases of collapse of massive stars. The exact nature of the central engine is uncertain, but could be a collapsar or failed supernovae that has collapsed to black hole and accreted the remaining helium core. The optical afterglows are thought to be synchrotron radiation from highly shocked ejecta and the emission is likely to be highly beamed.

True GRBs are detected as gamma-ray bursts by satellite, and if optically identified early enough, might be used as probes of the intergalactic medium — potentially out to very high redshift. Models and data (Akerlof et al. 1999) show peak brightnesses $V \sim 8$ or 9 declining to $V \sim 20$ in 1 day). And there are hints that the GRB sources might preferentially lie in faint blue galaxies.

Models of GRBs as on-axis relativistically beamed jets (e.g. Dalal et al. 2002) predict the opening angle of the jet to increase with time, producing a less intense optical signal over a wider opening angle. In these models a slightly off-axis observer would not see the gamma-rays burst, but could see this optical transient signal. (See Figure 1.) This optical transient is called an Orphan Afterglows — as the duration of the afterglow is much longer - days to weeks - rather than the seconds of the GRB itself.

The expected rate at $m_R = 24$ is about 10^{-4} deg^{-2}, corresponding roughly to one event every few nights of imaging with Pan STARRS, or of order 100 per year. With a sample of a few $\times 10^2$ optical events, we can begin to correlate these events with the properties of their host galaxies. A small fraction of the events will, serendipitously, be detected early enough to motivate immediate follow-up spectroscopy on another telescope, so far obtained only for one GRB (Barth et al. 2003).

Alternative models exist, (e.g. Ruffini et al. 2001, 2002) and the field is rapidly progressing. New and better data on optical counterparts and afterglows is crucial, and Pan STARRS will inevitably be an important player in the field.

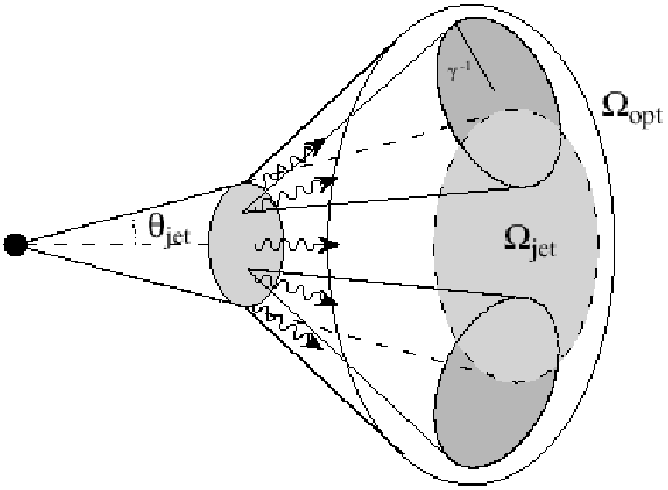

Fig. 1. Schematic depiction of the emission geometry of a GRB. The ejecta are collimated into an angle Θ_{jet}. As time progresses, the Lorentz factor decays, while the beaming angle grows. Adapted from Dalal 2002.

Early in the survey it may be difficult to recognize afterglows, but as the accumulated broad-band image and ephemeris of moving sources grows, they will become more recognizable. If a workable detection algorithm can be implemented, PanSTARRs has the potential of making a significant contribution to GRB studies.

2 Scientific Questions

- What is the physical nature of GRBs?
- What is redshift distribution of afterglows? This is needed to determine the energetics, cosmic evolution, and luminosity function of GRBs.
- Do the afterglow properties correlate with host galaxy properties, e.g. location, or metallicity?
- Can the burst environment be constrained using reddening of an intrinsic power-law spectrum?

- Can we determine the evolution of the blastwave from follow-up observations?
- Do GRBs signal star formation to very high redshifts?
- Can we respond quickly enough to use them as a probe of the IGM to very high redshifts?

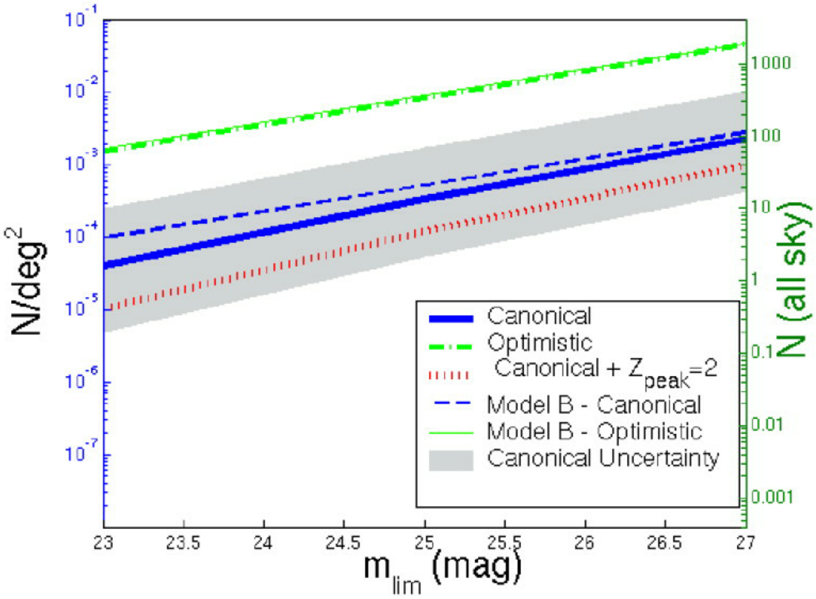

Fig. 2. Number of observed orphan afterglows per square degree in a single exposure as a function of the limiting magnitude of detection. From Nakar et al. 2002.

3 Survey Requirements

3.1 Filters

For GRBs and Afterglows the filter is unimportant. and of the *grizY* or the solar system broad band filter will do.

3.2 Depth

For on axis GRBs, reaching 9 magnitude, any depth will do. The can be astonishingly bright if we happen to catch on at peak, which is possible over the lenght of the survey.

For the Orphan Afterglows, the target depth of $m_R = 24$ will give an expected rate of about 10^{-4} deg^{-2}, corresponding roughly to one event every few nights of imaging with Pan STARRS, or of order 100 per year.

3.3 Sky Coverage and Cadence

With the extraordinary sensitivity of PanSTARRS of $m_R = 24$ in one minute, the optimum cadence for GRBs and afterglows would be to cover 6000 square degrees every night with one minute exposures, and repeat every 4 nights.

3.4 Astrometry

We require only that the astrometry be good enough to reject known variable stars and AGN from the Pan-STARRS database, i.e. 0.5 arcsec.

3.5 Image Quality and Sky Brightness

FWHM = 0.7 arcsec maximum.

3.6 Photometric Accuracy

Nominal photometric accuacy is acceptable.

3.7 Follow Up Strategy

Optimum follow up strategy would be a www site that broadcast any clear detection of a bright optical transient for potential robotic photometric telescopes to follow-up, and larger spectroscopic follow-ups of bright confirmed sources.

IfA could potentially provide the ideal real-time response spectrographic telescope with AEOS. AEOS is a fast slewing telescope eventually expected to operate in queue mode. Potentially it could respond under computer control very rapidly to confirmed events. Ideally a small robotic telescope would be triggered by optical transients detected by PanSTARRS. If the the small robotic telescope confirmed the detection as real, the astronomical community would be alerted, and the AEOS telescope on Haleakula would automatically obtain an optical spectrum.

References

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