Early Optical Observations of GRBs with ROTSE-III and their implications

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Abstract:

Early observations of afterglows of GRBs by ROTSE-III telescopes taken between January 2008 to October 2009 are presented. The burst optical afterglow properties are compared with that seen at XRT and BAT frequencies. The analysis of this subset of GRBs indicate that early time properties of GRBs have a diverse set of features, broadly consistent with the predictions made by the synchrotron 'fireball' model for afterglows though outliers exist. Specifically, the very early optical observations of GRBs do not trace the canonical decay nature seen at XRT frequencies and show signatures broadly suggesting the onset of the afterglow and/or off-axis emission for most of the observed features at early times.

Introduction:

Despite a small aperture, the ROTSE-III robotic telescopes continue to provide unique information about early optical emission from GRBs (Akerlof et al. 1999). With its rapid response ability, ROTSE-III has collected a unique sample of observations in the Swift era either starting during gamma-ray emission or shortly after its cessation. These events cover a range of burst properties in terms of energetics, temporal structure and spectral index that are requisite for understanding GRB behaviour during the transition from the prompt to afterglow phase.

Observations and data reduction:

ROTSE-III telescopes have responded to ~1/3 of the Swift triggers within 1000 sec after the burst. We present here 6 afterglows (see Fig. 1) for which ROTSE observations were performed within the prompt emission phase. These events along with 6 more GRBs observed by RTOSE have been used to study the very early time properties of the optical afterglows.

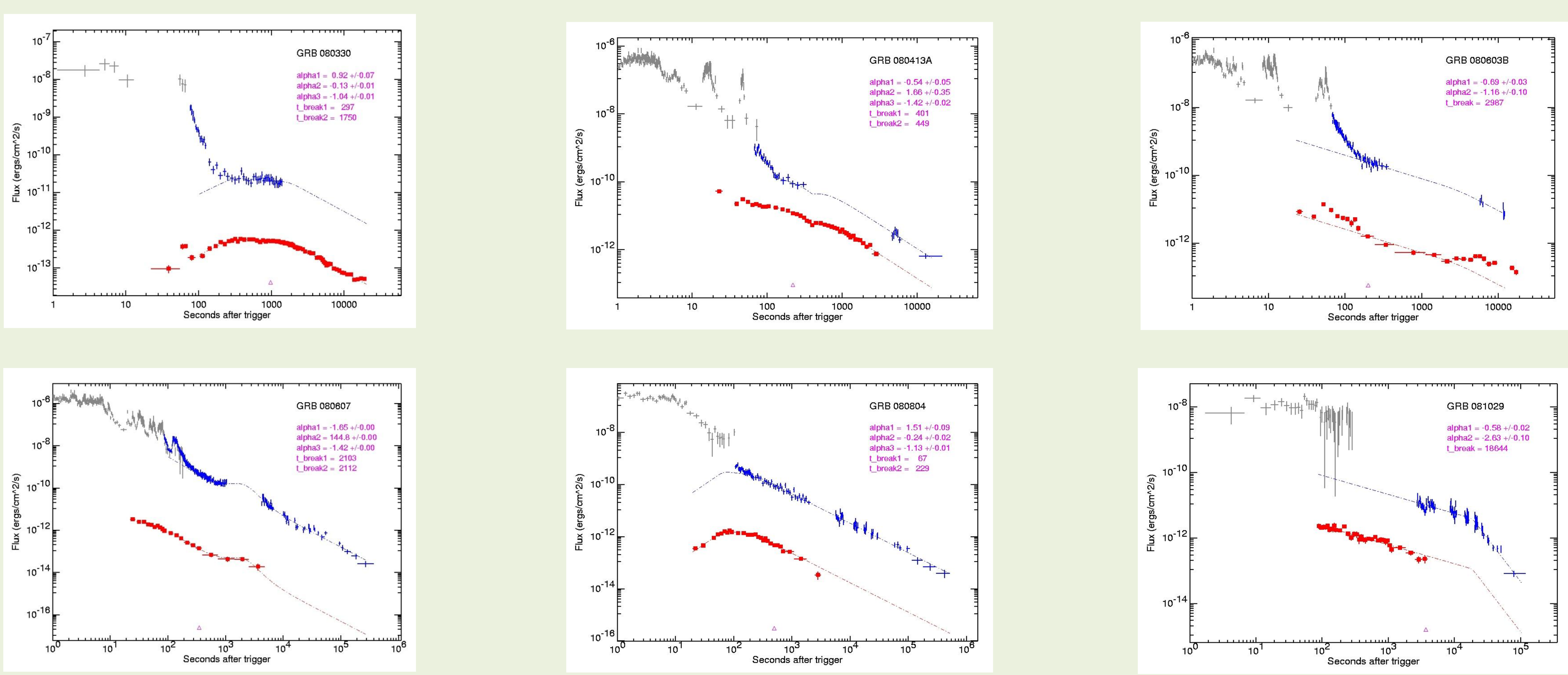

Figure 1: *Multi wavelength light curves of 6 GRBs observed by ROTSE-III telescopes during the prompt emission phase. Gray points indicate the BAT detections, blue points are XRT detections and the red squares show the ROTSE-III detections. The dashed lines show the broken power-law models simultaneously fitted for X-ray and optical. Values of the key parameters are listed at the upper-right corner in each figure. Apparent flares and the early steep decaying phase in X-rays are excluded from the fitting.*

The ROTSE-III images were bias-subtracted and flat-fielded by an automated pipeline. The images were processed with our custom RPHOT photometry program based on the DAOPHOT PSF-fitting photometry package (Quimby et al. 2006). The photometric response of ROTSE-III CCDs is similar to R-band. The magnitude zero point for each image was estimated from median offset of field stars to the USNO-B1.0 R-band. The BAT data were analyzed using the standard analysis software distributed within FTOOLS, version 6.5.1. The XRT data were obtained from the Swift/XRT GRB lightcurve repository (Evans et al. 2007).

Early Optical Afterglows and the models:

Figure 1 clearly shows that the ROTSE-III observations taken during the prompt emission phase possess a variety of features that only approximately trace the extended emission features seen at XRT frequencies, indicating a lack of a common origin. The peak time, derived from the early rise in couple of optical afterglows (as shown in Fig. 1, Fig. 2) occurs after the prompt emission phase and comply to the afterglow onset (Oates et al. 2009 and references therein). In a few cases, the observed shallower values of rise and decay temporal indices (<= 1.6) at early epochs are hard to reconcile in terms of reverse shock emission. However, for the observed early rise, decay or the plateaus are also expected in the off-axis emission models and in the models describing about the angular structure in the outflow (Granot et al. 2002, Panaitescu & Vestrand 2008). The observed temporal decay indices favors the onset of the afterglow explanation but does not rule out the possibility of off-axis emission mechanism.

From Fig. 2, it is also clear that within the limitations of response time and the detection limits of ROTSE-III, the observed temporal features at optical frequencies are diverse (Panaitescu & Vestrand 2008, Oates et al. 2009, Rykoff et al. 2009) and the very early rise in the light curves of optical afterglows may not be common feature for all the long-duration GRBs .

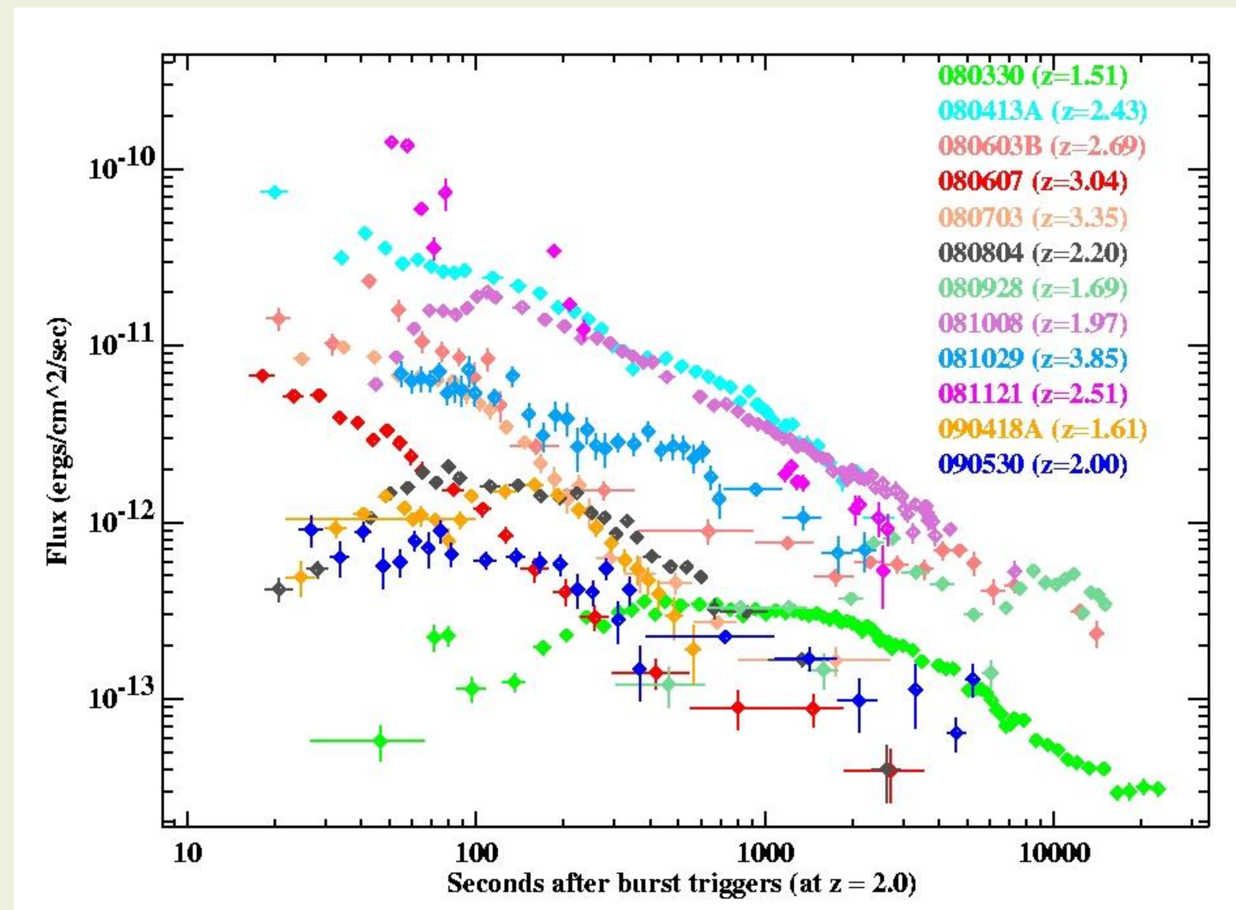

Figure 2: *ROTSE light curves of 12 afterglows, color-coded to their respective names, scaled to a common redshift of 2.0 . For GRB 090530 the value of redshift has been assumed to be 2.0. In this figure, the redshifted flux values have not been corrected for the possible host extinction, intergalactic absorption which might contribute to an additional ~10% uncertainly in the calculated flux values.*

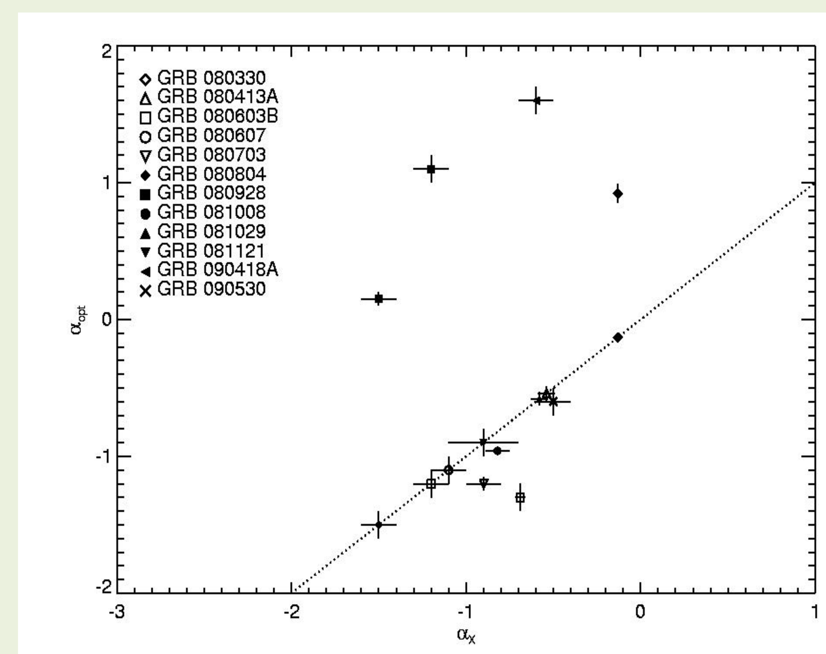

Figure3: *Power-law temporal index at optical α_{opt} Vs. XRT power-law index α_x for the 12 afterglows. The indices were calculated for the epochs with contemporaneous observations from ROTSE-III and XRT and for epochs after the extended emission XRT features. The dotted line is the line of equality.*

From Fig. 3, it is clear that the optical afterglows tend to fade slightly slower than the X-ray one (Rykoff et al. 2009) though outliers exists due to early rise at the optical frequencies. Also, the XRT spectral index is generally steeper than the spectral index at optical and XRT frequencies as predicted if the forward shock is expanding into a constant density medium.

Results:

The sub-sample of 12 ROTSE GRBs reveal the diverse nature of the early afterglow emission properties at optical frequencies. The observed rise in several afterglows can be attributed in terms of onset of the afterglow but the possibility of the off-axis emission and the structured outflow mechanism can not be ruled out based on the ROTSE data alone. The temporal and spectral analysis of the ROTSE-III and XRT data of the 12 GRBs (for the epochs greater than the tail emission seen at XRT frequencies) indicate towards their common origin favoring the forward shock synchrotron model for the afterglows.

Acknowledgments:

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References:

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