GRB 061121: Broad-band spectral evolution through the prompt and afterglow phases of a bright burst

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Abstract

Swift triggered on a precursor to the main burst of GRB 061121, allowing observations of the prompt phase to be made from the optical to gamma-ray bands: the gamma-ray, X-ray and UV/optical emission all showed a peak $\sim$ 75 s after the trigger. Spectral evolution was seen throughout the burst, with the prompt emission showing a clear positive correlation between brightness and hardness. The Spectral Energy Distribution of the prompt emission, stretching from 1 eV up to 1 MeV, is very flat, with a peak in the flux density at $\sim$ 1 keV, and shows spectral hardening as the afterglow evolves with time. This behaviour might be a symptom of Synchrotron Self-Comptonisation, although circumstellar densities similar to those found in the cores of molecular clouds would be required. The afterglow also decays too slowly to be accounted for by the standard models. GRB 061121 has the highest peak flux of all the long bursts detected by *Swift* to date, with a rest-frame isotropic energy of 2.8×10^{53} erg over 1 kev – 10 MeV (z = 1.314).

Key words: 98.70.Qy, 98.70.Rz
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1 Introduction

Gamma-Ray Bursts (GRBs) are intrinsically extremely luminous objects, emitting over all bands in the electromagnetic spectrum. To understand GRBs as fully as possible, panchromatic observations are required over all time frames of the burst. Although afterglows are frequently observed over a range of wavelengths, the prompt emission is typically only detected in gamma-rays. However, occasionally *Swift* triggers on precursor emission, allowing the spacecraft to slew and repoint the narrow-field instruments in the direction of the burst before the main event (e.g., GRB 050117 – [1]; GRB 050820A – [2]; GRB 060124 – [3]), which was the case for GRB 061121. In fact, GRB 061121

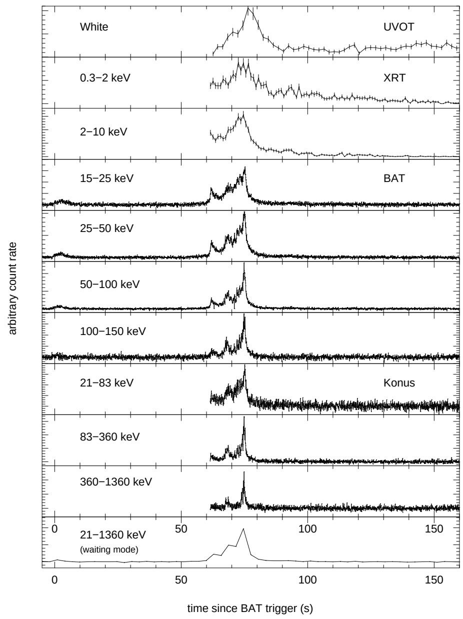

Fig. 1. *Swift* UVOT, XRT, mask-weighted BAT and *Konus-Wind* light-curves of GRB 061121. Each instrument detected the peak of the main burst.

has provided the best broad-band coverage of the prompt emission for any GRB thus far, and we report on these multi-wavelength observations here.

2 Observations and Analyses

The *Swift* [4] Burst Alert Telescope (BAT; [5]), X-ray Telescope (XRT; [6]) and UV/Optical Telescope (UVOT; [7]) all detected the prompt emission, as shown in Figure 1. It can be seen, and shown in more detail through the comparison of the width of the autocorrelation function, that the emission, and underlying structure, becomes shorter with increasing energy, in agreement with previous samples of bursts (e.g., [8–10]). Figure 2 shows the BAT data extrapolated into the XRT band, along with the UVOT flux density light-curve, positioned to line up with the X-ray 'plateau' stage. The gamma-ray and X-ray data are in good agreement with each other, while the optical emission increases in brightness during the main peak by a significantly smaller amount.

Spectral evolution occurs throughout the main burst, both over gamma-ray and X-ray energies. The precursor has a longer spectral lag (e.g., [10]) than the main burst ($\sim$ 600 ms compared to $\sim$ 1 ms); however, since the precursor is much less luminous, both values are consistent with the lag-luminosity relationship for long bursts. The gamma-ray emission is also found to be harder when brighter, both for the precursor and main burst, implying their formation processes may be similar.

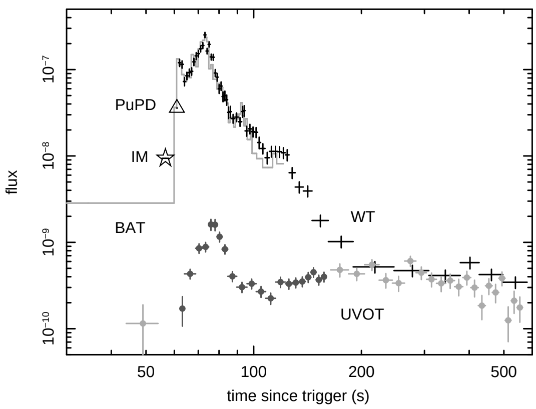

Fig. 2. *Swift* flux light-curve of GRB 061121, showing the early X-ray data (star, triangle and crosses) and the BAT data (grey histogram) extrapolated into the 0.3–10 keV band pass in units of erg cm^{-2} s^{-1}, together with the UVOT flux density light-curve (light grey circles – V-band; dark grey circles – White filter) in units of erg cm^{-2} s^{-1} Å^{-1}, scaled to match the XRT flux observed in the 'plateau' phase.

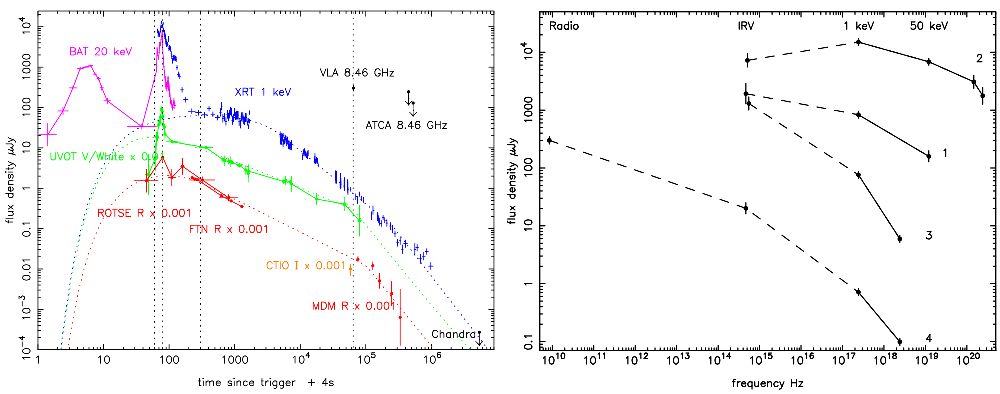

Fig. 3. The left panel shows flux density light-curves for the gamma-ray, X-ray, optical and radio data obtained for GRB 061121. The vertical dotted lines indicate the times used for the SED plots shown in the right-hand panel, while the curved dotted lines show the exponential-to-power-law model fitted to the data (see [11,12]).

Figure 3 plots the flux density light-curves, together with Spectral Energy Distributions which show that broad-band spectral evolution continued throughout the burst, and that there is a break in the spectrum between optical and X-ray. At the time of the main burst, this corresponds to the peak energy, though the spectrum at lower energies is harder than expected from the standard Synchrotron model. The afterglow closure relations (e.g., [13,14]) do not well explain the data, with the X-ray and V-band decays being slower than expected. Over time, the spectra appear to harden, in both the X-ray and optical bands. Although this could be explained by Synchrotron Self-Comptonisation, particle densities similar to those found in the core of a molecular cloud would be required.

3 Summary

Swift triggered on a precursor to GRB 061121, leading to amazing multi-wavelength observations of the prompt emission. The broad-band spectra show significant curvature and evolution, but standard afterglow models cannot readily explain the data, with the X-ray and V-band data decaying too slowly, and both X-ray and optical emission hardening over time.

More details of this work can be found in [15].

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