GRB100814A as a member of the growing set of bursts with sudden optical rebrightening

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Abstract

We show the gamma-ray, X-ray, optical and radio data of GRB100814A. At the end of the slow decline phase of the X-ray and optical afterglow, we have a sudden and prominent rebrightening in the optical band, followed by a fast decay in both bands. This optical rebrightening also appears to show chromatic variations. We discuss the possible interpretations, with their advantages and drawbacks. We find that it is rather difficult to explain the behavior of GRB100814A within a basic model of single component emission produced by external shocks.

We also indicate other Swift bursts that show optical rebrightenings with similar properties. Since a two-component model requires some degree of fine tuning to explain the observed feature, we point out that even this scenario may look contrived.

Observational data

GRB100814A was detected by *Swift*/BAT (15-150 *keV*), *Konus-Wind* (20-20000 *keV*), *Suzaku*/WAM (50-5000 *keV*) and *Fermi* GBM (8-30000 keV). The 15-150 *keV* fluence is 9×10^{-6} erg/cm^2. The redshift is z=1.44, and the isotropic energy emitted between 10 and 1000 *keV* is 3.4×10^{52} *erg*.

XRT detected a bright X-ray afterglow. Initially we have a steep decline, with $F\sim t^{\alpha}$ where α=-4.65.

After ≈500 *s*, the afterglow enters a shallow decline phase. Fitting the data from 500 *s* onwards with a broken power-law model, we have $\alpha_{\rm early,X}$= -0.66±.03, $t_{\rm break}$ = 132.7±7 *ks*, $\alpha_{\rm late,X}$= -2.06±0.13.

An optical source was detected by *Swift*/UVOT, ROTSE, Liverpool and Faulkes Telescope, Lulin Telescope, Northen Optical Telescope, CQUEAN at McDonald Observatory, Gran Telescopio Canarias, Calar Alto and BTA. We present the complex photometry in Figure 1.

After an early powerlaw decay with α_0 = -0.55 ± 0.03, **we have a conspicuous rebrightening**, which starts at ~15 *ks* and peaks between 40 and 100 *ks* after the trigger, depending on frequency.

At ≈200 *ks*, the rebrightening ends and the decay slope becomes α_3 = -1.97 ± 0.03.

No X-ray counterpart to the optical rebrightening is visible. Such behaviour is reminiscent of other bursts, such as GRB081029 (Holland et al. 2012, Nardini et al. 2011), and GRB080413 (Filgas et al. 2011).

The radio afterglow is detected by EVLA at 4.7 and 7.9 *GHz*. Modeled with a broken powerlaw, the radio lightcurves show a peak flux of ≈550 μJy at ≈ 10^6 *s* and decay slope of $\alpha_{\rm R,decay}$ ≈ -0.8, but different rise slope: the 4.7 *GHz* flux rises with a slope α = 1.1, while the 7.9 *GHz* has α = 0.2.

Fig 1

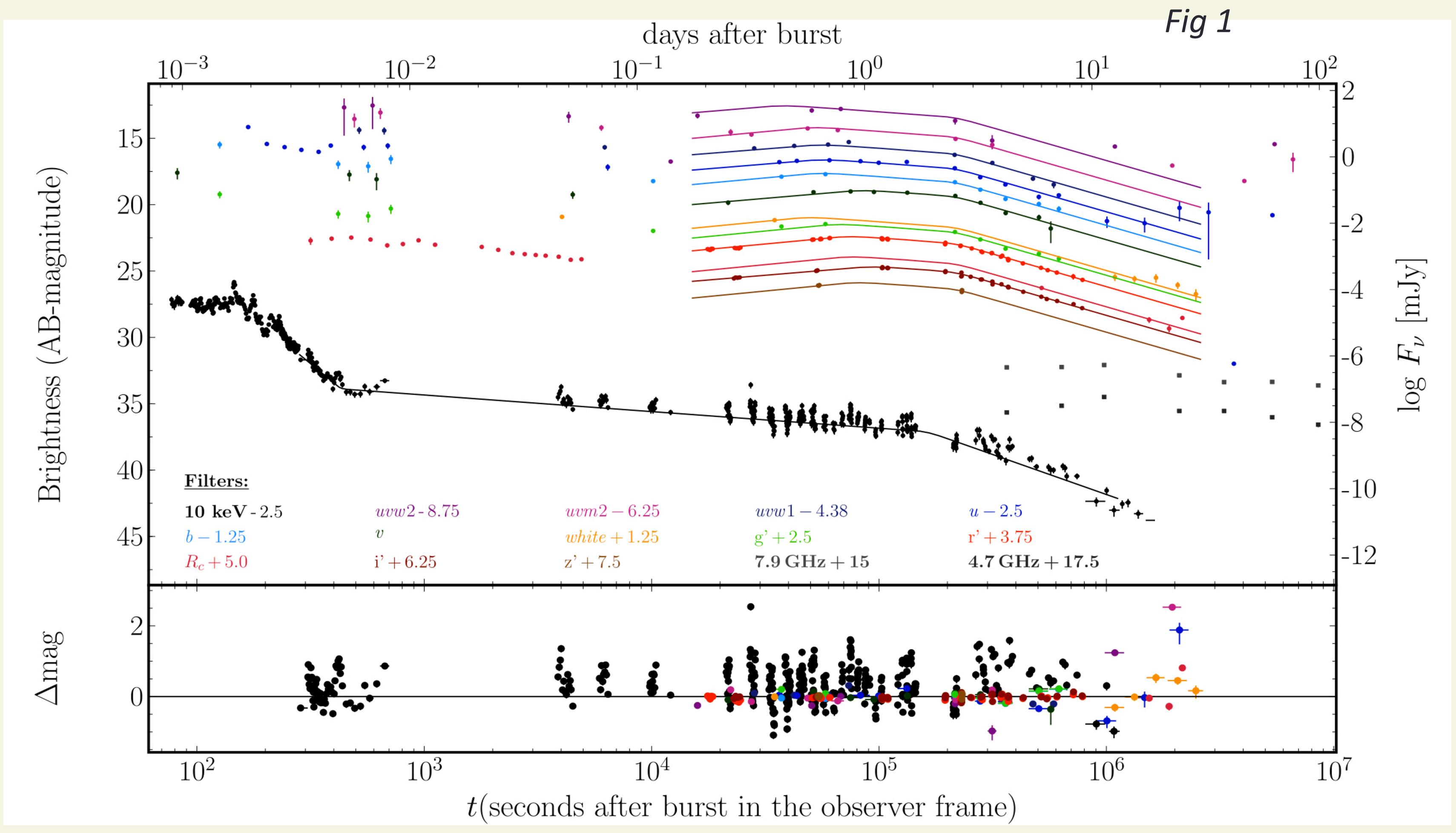
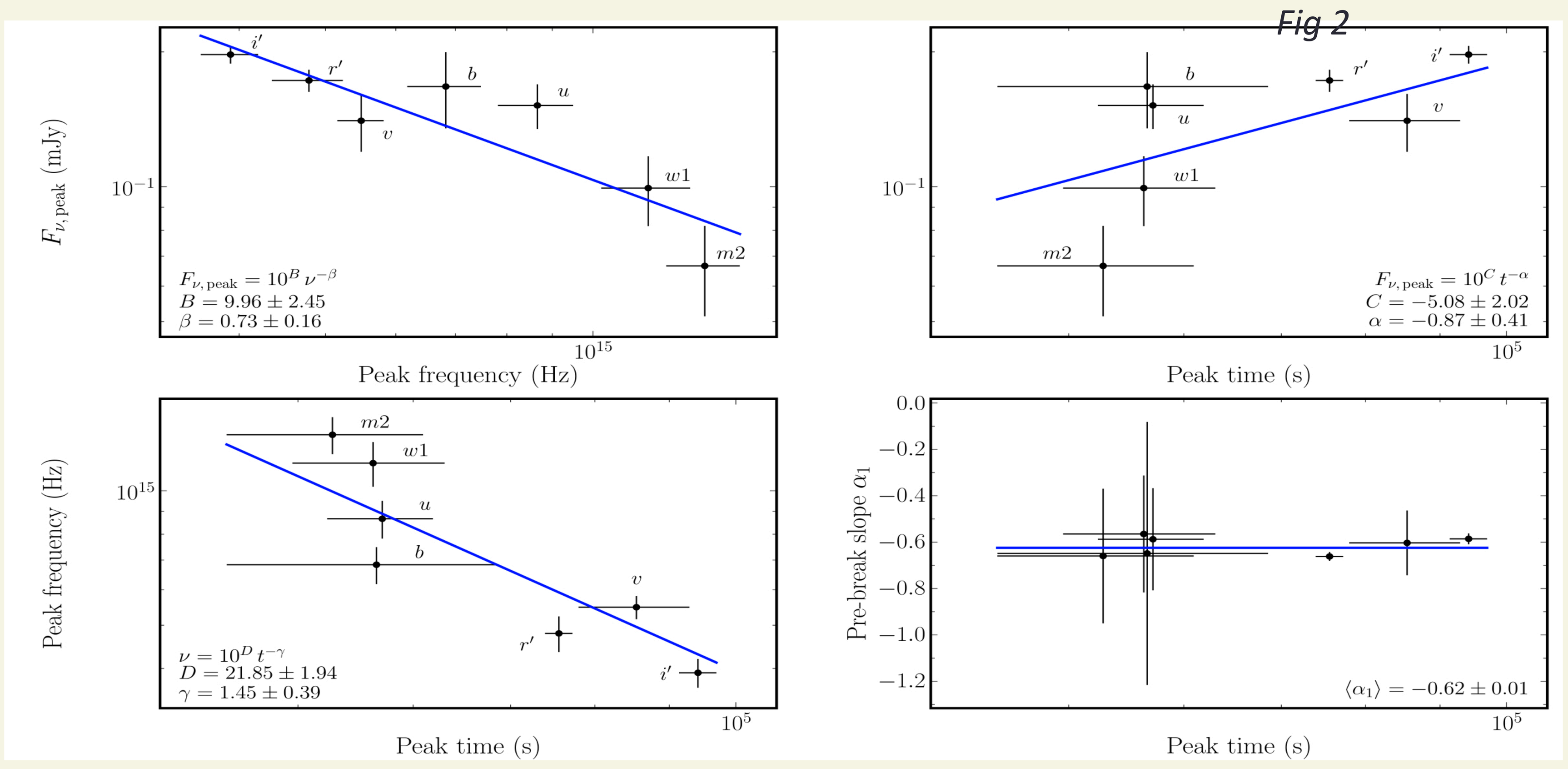


Fig 2



Properties of the optical rebrightening

Fitting the lightcurves built up in several filters at the optical rebrightening with a double broken powerlaw model, we find that the behaviour is likely chromatic. We find possible correlations between the peak time, the peak flux density $F(\nu_{peak})$ and peak frequency ν_{peak} (Fig. 2). The stronger correlation is between $F(\nu_{peak})$ and ν_{peak}, having a Spearman rank significance ≅ 2σ. Furthermore, ν_{peak} depends on time as $\nu_{peak}\sim t^{-1.45}$, close to $t^{-1.5}$ expected for the synchrotron injection frequency ν_m. The powerlaw slope of the rise α_1 is consistent with being constant for all filters, α_1≅0.6.

After the peak, we have a short plateau and then a fast flux decay. In these phases, the optical afterglow behaves achromatically, and we fix the parameters for all lightcurves. The short plateau has a slope α_2≅−0.48, and ends at a break time $t_{break,2}$ = 217.7±2.4 *ks*

Spectral Energy Distributions

We build Spectral Energy Distributions (SEDs) using X-ray and optical data at 4.5, 22, 50 and 400 *ks* and fit them with simple powerlaw and broken powerlaw models (see table). We find that the 22 and 50 *ks* SED fit show a blue spectrum, with spectral index β_1 ≈0.33. This value is expected in a synchrotron spectrum below the injection frequency ν_m or the cooling frequency ν_c (if $\nu_c < \nu_m$).

	4.5 *ks*	22 *ks*	50 *ks*	400 *ks*
β_1	$-0.54^{+0.42}_{-0.04}$	$0.29^{+0.03}_{-0.08}$	$0.35^{+0.03}_{-0.06}$	$-0.94^{+0.02}_{-0.01}$
E_{break} (eV)	845^{+600}_{-680}	$46.3^{+10.0}_{-3.0}$	$4.52^{+0.36}_{-0.18}$	
β_2	$-1.06^{+0.12}$	$-0.88_{-0.07}$	$-0.98^{+0.02}_{-0.01}$	
χ/d.o.f.	12.1/13	55.3/34	118.2/114	59.5/45

Discussion

We present and describe three possible scenarios to explain the observed behaviour, and we outline their pros and drawbacks.

Double jets seen sideways

Set up: The early X-ray and optical emission is due to a wide jet seen off-axis; the rebrightening is due to emission from a narrow jet, coaxial with the wide jet, entering the line of sight.

Pros: We find that if the observer is at angle $\theta_{obs}\approx 1.5\,\theta_{wide}$ and $\theta_{narrow} = 0.5\,\theta_{wide}$, the temporal slopes of the lightcurves can be explained. A few GRBs are thought to have double-component ejecta.

Drawbacks: Jets seen off-axis produce a dim afterglow. To explain the observed luminosity, the isotropic energy must be very high (~10^{56} *erg*). We also find that the density of the medium should be extremely low, of the order of a few 10^{-9} cm^{-3}. To decelerate early in such a thin medium, the initial Lorentz of the outflow should be ~2000. These parameters appear very improbable.

The chromatic behaviour at the optical peak is contrived.

Reverse Shock – Forward Shock interplay

Set up: the shallow X-ray decay may be explained by Forward Shock (FS) assuming energy injection, which powers a long-living Reverse Shock (RS; Sari & Meszaros 2000) as well. RS produces the early, slowly decaying optical emission.

The peak of the FS emission ν_m is initially between the X-ray and the optical band. ν_m decreases and when crosses the optical band, produces the chromatic rebrightening.

At ≈130 *ks*, we have a a jet break, and both the optical and the X-ray start to decay faster.

The radio peak at ≈10^6 *s* can be caused by ν_m crossing this band.

Pros: This model naturally explains the chromatic optical rebrightening, why it has no counterpart in the X-ray, and why optical and X-ray start to decay fast almost simultaneously.

Drawbacks: There is no consistent set of physical parameters, such as the energy injection parameter and circumburst density profile, that can reproduce the early shallow decay and then the faster decay.

If the break energy E_{break} is indeed ν_m , its time evolution between 22 and 50 *ks* is too rapid.

Internal dissipation emission

Set up: both the early optical and the X-ray emission are produced inside the ejecta. When this emission dies off, the afterglow optical peak, due to Forward Shock, is observed.

Pros: This scenario explains why the optical peak shows towards the end of the X-ray plateau.

Drawbacks: We do not know well yet the behaviour of the internal dissipation emission, so such identification is rather *ad hoc*.

The chromatic behaviour at the optical rebrightening is not clearly accounted for, nor is the late steep decay similar to that observed in the X-ray.

References

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