Thermal component in the early X-ray afterglow of Gamma-Ray Bursts

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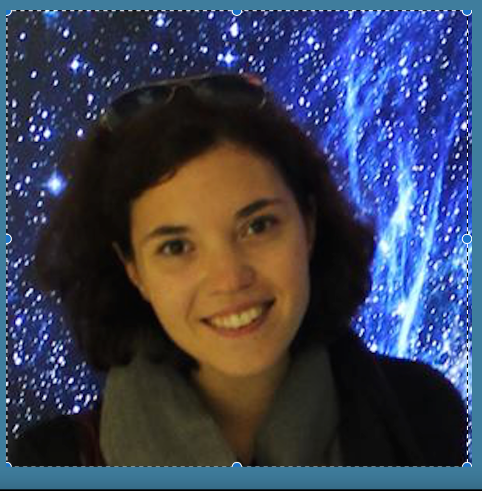

Summary

After the detection of GRB 060218 it became clear that a simple power law fails in representing some of the early afterglow spectra of GRBs. For this GRB it was shown that in order to explain its spectra an additional thermal component was needed. In recent years there has been a dozen new detections of GRBs with a thermal component present in the spectrum. We are investigating 76 GBRs observed by the Swift telescope from 2011-2015 and search for a thermal component in their soft X-ray spectra. We find 6 new cases of GRBs with a significant thermal component and confirm several previously reported GRBs with a thermal component. We investigate the possible origin of the thermal component, whether it is a SN shock breakout, cocoon surrounding the jet or the jet itself.

The dataset

✴ 76 GRBs observed in the period 2011-01-01 - 2015-12-31

✴Redshift interval: 0.282 - 6.32

✴ SWIFT XRT WT mode data used

✴ We analysed soft X-rays (energy range 0.3 - 10 keV)

✴Observed time-averaged WT mode flux > 2 x 10^{-10} erg cm^{-2} s^{-1}

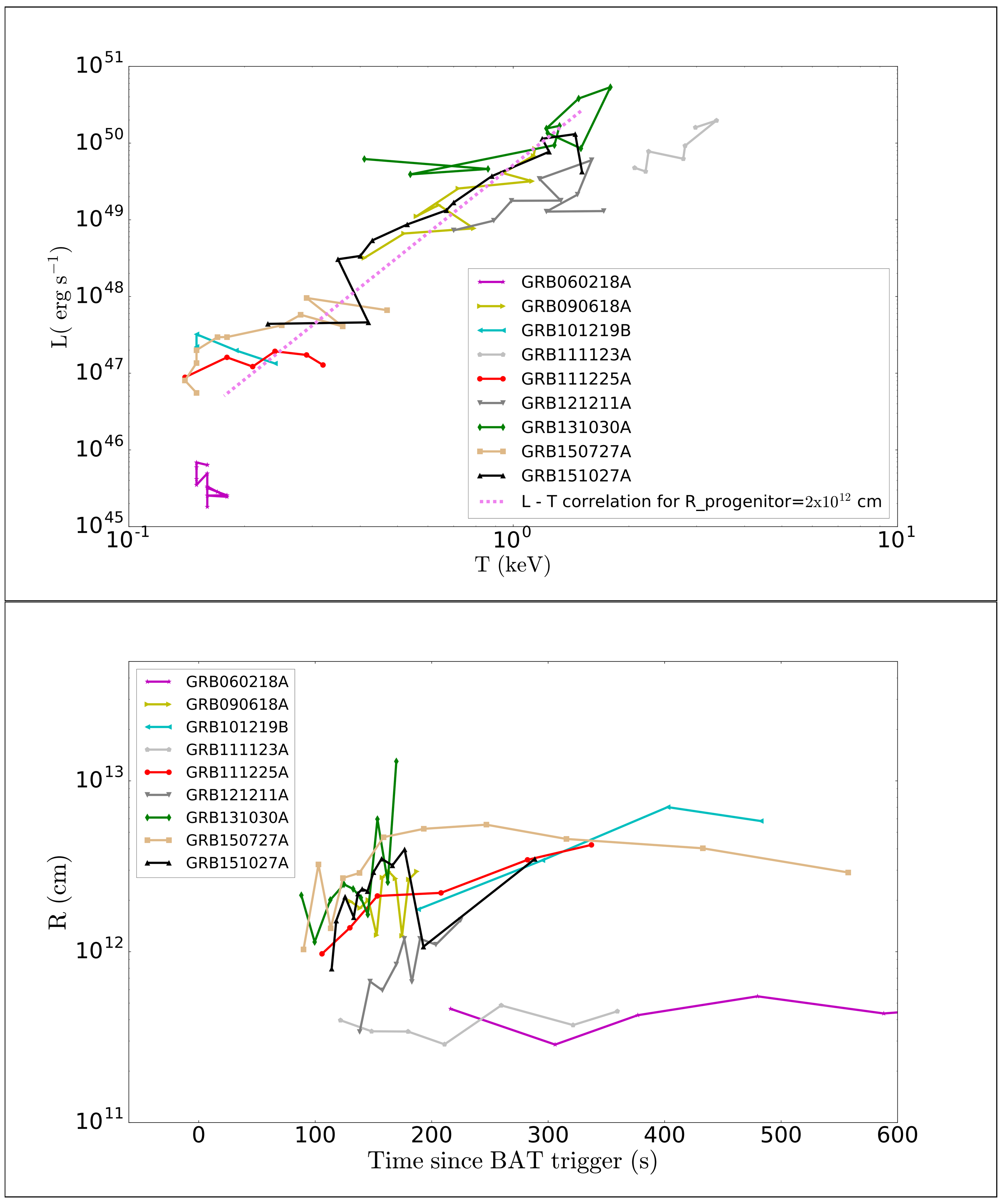

Figure 2: Upper panel: L - T correlation; Lower panel: time evolution of the radius

Methods

✦Bin the light curve using Bayesian blocks and produce spectra in each interval

✦ Fit all the blocks simultaneously to derive $N_{H,INTR}$ with $N_{H,INTR}$ tied between the time-intervals

✦ Fit all the blocks with an absorbed power law and an absorbed power law + blackbody (a fit to GRB 150727A time-interval 84 - 96 s is shown in Fig. 1)

✦ Compare the improvement in the χ^2 between the two models

✦ If improvement in the χ^2 is bigger than the added number of degrees of freedom we performed Monte Carlo simulations to asses the significance of the blackbody

✦ We say that the thermal component is present in the GRB X-ray spectra if the blackbody is significant at > 3 σ in 3 consecutive time-bins

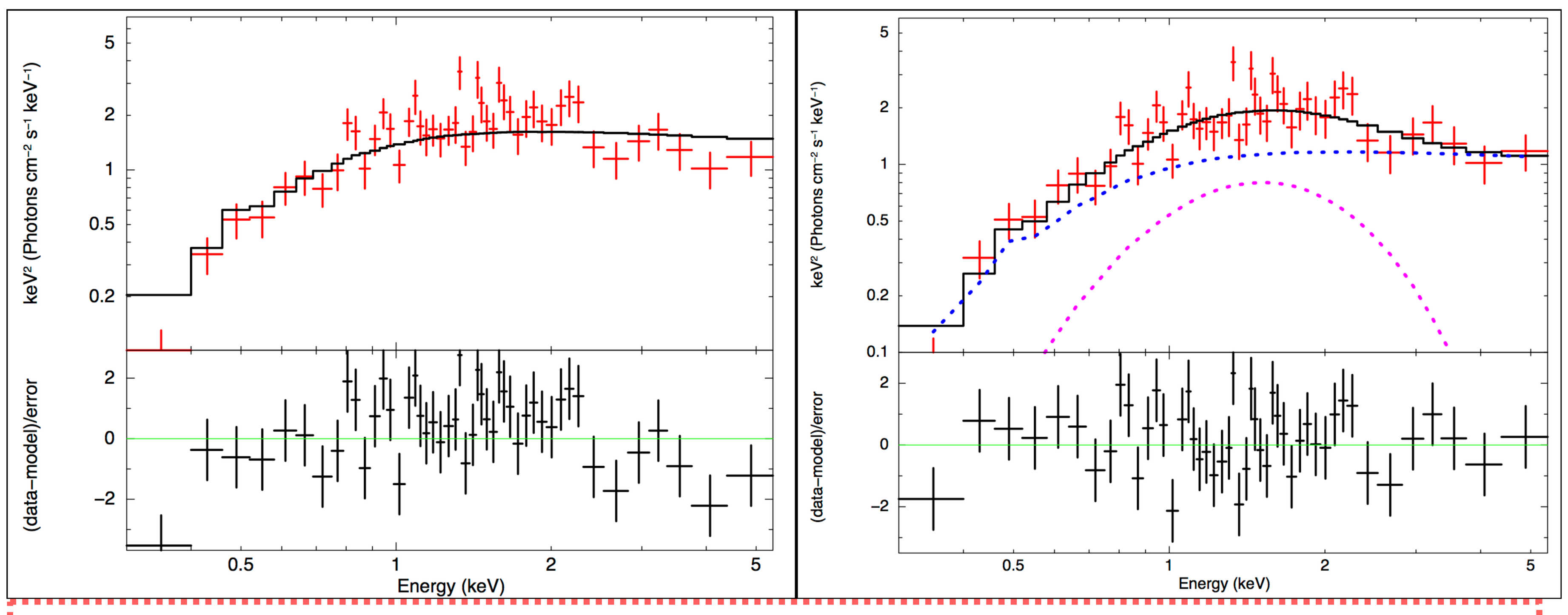

Figure 1: Fits to the power law and power law+blackbody for GRB 150727A in the interval 84 - 96 s

Results

✴ 6 new reported detections of a significant thermal component: GRB 111123A,GRB 111225A, GRB 121211A. GRB 131030A, GRB 150727A and GRB 151027A

✴ confirmed 3 out of 15 previously reported GRBs with a thermal component: GRB 060218A, GRB 090618A and GRB101219B

✴ we observe a correlation between L and T (close to L~T^4) and a narrow range of radii for majority of bursts as shown in Fig. 2

Conclusions

From a comparison of our observational results with different theoretical models we conclude the following:

Supernova shock breakout: Ruled out by the high luminosities in all cases except possibly GRB 060218A.

Late prompt emission from the jet: Most likely explanation for GRB 111123A and GRB 121211A. A possibility also for the other cases.

Emission from a cocoon surrounding the jet: A likely explanation for the majority of the sample. In this case, the narrow range of radii around ~ 2 x 10^{12} cm suggests breakout from thick winds and that all the progenitors are similar. In this model, on the other hand, the highest luminosities may be hard to explain.

In order for the thermal component to be detectable certain conditions are needed that the intrinsic afterglow component needs to be faint, the redshift of the GRB should be <1 and $N_{H,INTR}$ should be < 1 x 10^{22} cm^{-2}.

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