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Evidences for a double component in the emission of GRB 101023

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Abstract. We present the results of a preliminar analysis of GRB 101023 in the fireshell scenario [1]. Its redshift has not been determined due to the lack of optical data, so we tried to infer it applying two different methods, following two different works by Amati et al. and Grupe et al. Its light curve presents a double emission, which makes it very similar to the already studied GRB 090618. We called each part episode 1 and 2, respectively. We performed a time-resolved spectral analysis with RMFIT and XSPEC using different spectral models, and fitted the light curve with a numerical code. We used Fermi GBM data [3] to build the light curve, in particular the second and fifth NaI detectors, in the range (8.5-1000 keV). We considered different hypothesis regarding which part of the light curve could be the GRB and performed the analysis to all of them. We noticed a great variation of the temperature with time in the first episode, as well as almost no variation of the progenitor radius. We concluded that the second episode perfectly agrees with being a canonical GRB, with a P-GRB lasting 4s, while the first episode does not match the fireshell requirements for a GRB. Indeed, as we concluded within the fireshell scenario, it makes reference to the early stages of the formation of a black hole, as the core of the progenitor collapses.

Key words. Gamma-Ray Bursts: individual:GRB 101023- Black hole physics

1. Introduction

GRB 101023 has been observed by many satellites, as Konus Wind, Swift BAT and Fermi in gamma rays, Swift XRT in X-rays and Swift UVOT, Gemini and GROND in the optical band. Its redshift cannot be determined due to the lack of data, but we tried to infer it by using different methods. The source appears to be morphologically very similar to GRB 090618, with a total energy of $E_{iso} = 2.7 \times 10^{53}$erg. The aim is to compare and contrast these two sources; from this comparison identify the redshift of GRB 101023, and consequently determine all the physical parameters. In this work we present two methods we used to constrain the redshift. Then we proceed to examine episode 1 and episode 2 of this GRB, building its light curve and spectrum. We identify episode 2 with a canonical GRB, identifying also the P-GRB. We simulate the light curve and spectrum of this second episode with a

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Send offprint requests to: luca.izzo@icra.it numerical code called GRBsim. Afterwards, we go into further detail in the analysis of the first episode, making clear the evolution of the thermal component and the radius of the outermost shell, establishing the complete correspondence with GRB 090618. Finally, we present the conclusions.

2. Observations

The 23rd October, 2010 the Fermi GBM (GCN circular 2010) detector triggered on GRB 101023, with a trigger time of 309567006.726968 (in MET seconds). The burst was also detected by BAT (Saxton et al. 2010), on board Swift satellite (Geherels et al. 2005) , with a trigger time of 436981 (in MET seconds) and the following location coordinates: $RA(J2000) = 21h11m49s$, $Dec(J2000) = -65°23'37”$ with an uncertainty of 3 arcmin. Swift-XRT detector (Page et al. 2010; Burrows et al. 2005) has also triggered on this source from 88 s to 6.0 ks after the BAT trigger. GRB 101023 was also detected by the Wind instrument on board Konus satellite, in the energy range (10 – 770) keV (Golenetskii et al. 2010). The inferred location is in complete agreement with that determined by Swift and Fermi. Moreover, there have been detections in the optical band by the Gemini telescope (Levan et al. 2010).

The GBM light curve (Fig. 1) shows two major pulses.The first one starts at the trigger time and lasts 45 s. It consists of a small peak that lasts about 10 s, followed by a higher emission that decays slowly with time. The second pulse starts at 45 s after the trigger time and lasts 44 s. It presents a peaky structure, composed by a short and weak peak at the beginning, followed by several bumps, big not only in magnitude but also in duration. This second emission, on the contrary, does have all the characteristics which describe a canonical GRB (Ruffini et al. 2010).

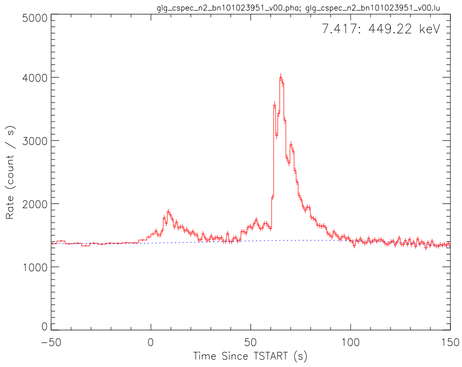

Fig. 1. Count light curve of GRB 101023 obtained from Fermi GBM detector, with a bin time of 1 s. The time is given with respect to the GBM trigger time of 22:50:04.73 UT, 23 October, 2010. The plot was obtained with the RMFIT program.

3. Pseudo-redshift determination

The redshift of this source is unknown, due to the lack of data in the optical band. However, to constrain it, we carried out an analysis making use of the program XSPEC. We took the data, spectrum and response files from the XRT website[1], selected the part of interest and fit the model wabs, which is the photoelectric absorption using Wisconsin cross sections (Morrison et al. 1983): $M(E) = exp[-n_H\sigma(E)]$, where $\sigma(E)$ is the photoelectric cross section (not including Thomson scattering) and n_H is the equivalent hydrogen column density, in units of 10^{22} atoms/cm^2. We need to know the value of the hydrogen column density of the galaxy in the direction of the GRB. To do this, we considered the galactic absorption component taken from (Kalberla et al. 2005), with the following values of the galactic coordinates of the GRB: $RA = 317.949$, $Dec = 65.389$ deg, which is $RA(J2000) = 21h11m47.8s$, $Dec(J2000) = -65d23'20.1”$. We obtained the value of $n_H = 2.59 \times 10^{20} cm^{-2}$ for the galactic H column density. We fit the data with a power-law model, considering a wabs component related to the galactic column density and a second wabs component to represent the intrinsic absorption. We obtained a value of $n_H^{intr} = 3.4 \times 10^{21} cm^{-2}$, with a reduced Chi squared value of $\chi^2 = 0.97$. Having obtained

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[1] http://www.swift.ac.uk/xrt_curves/

this results, we put them in formula (1) of **?** paper:

$$log(1+z) < 1.3 - 0.5[log(1+\Delta N_H)], \qquad (1)$$

and we obtained an upper limit for the redshift of 8.51.

This upper limit is too high and does not lead to any conclusion, so we made use of another method for constraining the redshift, via the Amati relation (Amati 2006), shown in Fig. 2. This relates the isotropic energy E_{iso} emitted by a GRB to the peak energy in the rest frame $E_{p,i}$ of its νF_ν electromagnetic spectrum (Amati et al. 2008). E_{iso} is the isotropic-equivalent radiated energy, while $E_{p,i}$ is the photon energy at which the time averaged νF_ν spectrum peaks. The analytical expression of E_{iso} is

$$E_{iso} = \frac{4\pi d_l^2}{(1+z)} S_{bol}, \qquad (2)$$

where d_l^2 is the luminosity distance, z is the redshift and S_{bol} is the bolometric fluence, related to the observed fluence in a given detection band (E_{min}, E_{max}) by

$$S_{bol} = S_{obs} \frac{\int_{1/(1+z)}^{10^4/(1+z)} E\phi(E)dE}{\int_{E^{min}}^{E^{max}} E\phi(E)dE}, \qquad (3)$$

with ϕ the spectral model considered for the spectral data fit. $E_{p,i}$ is related to the peak energy E_p in the observer frame by

$$E_{p,i} = E_p(1+z). \qquad (4)$$

We computed the values of $E_{p,i}$ and E_{iso} for episode 1 and 2 for different given values of z, ranging from 0.1 to 8. As we know that the Amati relation is followed by long GRBs, as this is the case, we plotted the curves in Fig. 2. It is supposed that both episodes take place at the same redshift. We found that the Amati relation is followed by both events at the same time for values of z in the range 0.7 – 1.0. From this, we chose $z = 0.9$ for two reasons: 1) it is a mean value; 2) for this value of the redshift the energetics of this source are very similar to those of GRB 090618, whose redshift is known to be z=0.54 (Izzo et al. 2010).

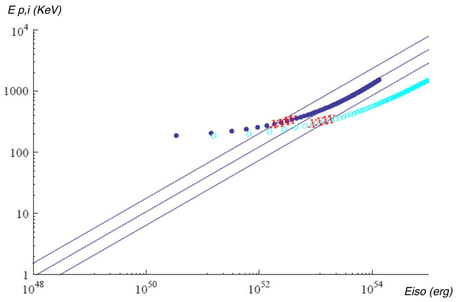

Fig. 2. Plot of the relation between $E_{p,i}$ and E_{iso} for the first (blue) and second (light blue) emission of GRB 101023, considering different values of the redshift. It can be seen that, within the error range, both plots coincide in the points corresponding to z= 0.7, z= 0.8, z= 0.9 and z= 1.0. The value we decided to work with for this GRB is $z = 0.9$.

4. Analysis of data and results

To obtain the Fermi GBM light-curve and spectra in the band 8 – 440 keV (see Fig 1) we made use of the RMFIT program **??**. We downloaded the data from the gsfc website[2]. We used the lightcurves corresponding to the second and fifth NaI detectors, and the b0 BGO detector. We subtracted the background by fitting a cubic function from the intervals before and after the GRB, where we suppose there is no data. Then we proceeded with the time resolved spectral analysis. We defined first of all the time intervals we wanted to analyze: the first interval starts at the trigger time $t_0 = 0$ and lasts 45 s, while the other starts at $t_0 + 45$ s and lasts 44 s. For this source we considered two models: the black body plus a power-law model (BB+po from now on) and the Band (Band et al. 2003) spectral model. We first analyzed the whole emission as if it were a single GRB; then we analyzed each of the events separately, as if they were two GRBs and subdivided each of the two emissions in the light curve into two other parts: the one that we think

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[2] ftp://legacy.gsfc.nasa.gov/fermi/data/gbm/bursts

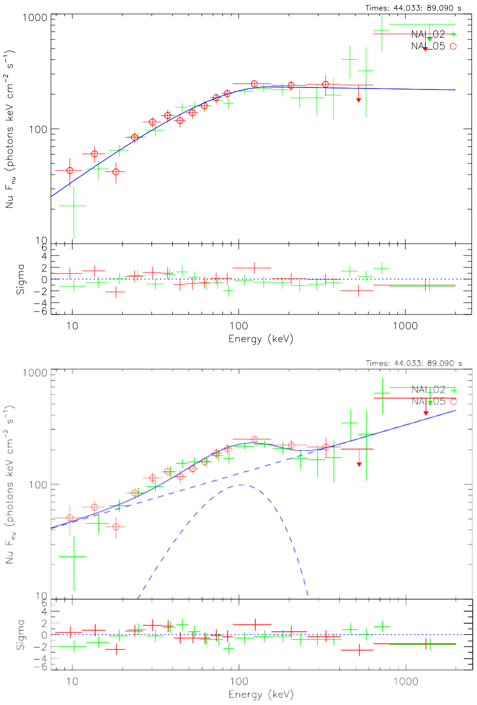

Fig. 3. Fit of the spectrum of episode 2, with a Band model (upper panel) and a BB+po model (lower panel). Both models fit well the entire energy range, with a Chi squared of 0.79 and 0.84, respectively. The data points have been grouped according a signal to noise ratio of SNR=10, and rebinned at higher energies in order to have better statistics and reduce the error bars.

would correspond to the P-GRB emission and the one that would correspond to the afterglow. The fit of the spectrum of the second episode with both models is shown in Fig. 3.

A detailed spectral analysis of the first episode shows a strong spectral evolution. If we plot the temperature of the black body component with time, we notice a broken power-law behavior up to 20s. We also computed the evolution of the BB radius from the observed luminosity as a function of time, resulting in a non-relativistic expansion(see Fig. 4).

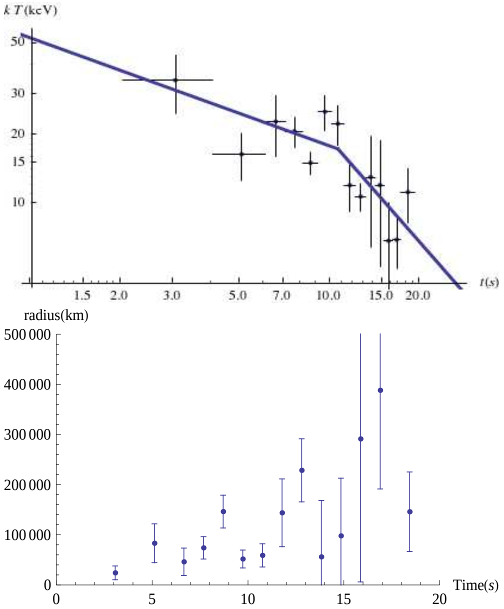

Fig. 4. Up: Evolution of the observed temperature kT of the BB component. The blue line corresponds to a broken power-law fit. The break occurs at 11 s after the trigger time. Down: Evolution of the radius of the first episode progenitor.

5. Conclusions

As we can see from the results, the goodness of the spectral fits and the accordance between predicted and observed energies lead us to conclude that the second episode is indeed a canonical GRB, with a P-GRB that lasts 4 s. On the contrary, the first episode does not present these characteristics. Within the fireshell scenario, we can conclude that we are in presence of some kind of mechanism that gives place to the formation of the black hole, when the core of the progenitor is collapsing. We call this a ”proto-black hole”. After this, it occurs the emission of the GRB as we already know it.

More details of this work will be presented in Penacchioni et al., 2011(to be submitted).

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