X-RAY LIGHT CURVES OF GRBS WITHOUT FLARES

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THE X-RAY UNIVERSE 2011
THE X-RAY EMISSION OF GRBS:

- light curves differ from simple power-law behaviour
- some characteristic repeats in systematic way (canonical behaviour)
- flares superimposed to the smooth continuum

WHAT IS THE LIGHT CURVE MORPHOLOGY TELLING US?

- Nousek et al., 2006
- Chincarini et al., 2005
- O’Brien et al., 2006
- Zhang et al., 2006
- Chincarini et al. 2007, 2010
SAMPLE SELECTION

64 GRBs observed by Swift/XRT from April 2005 to April 2010:

- with redshift measurements
- without flaring activity

16 “Golden Sample” (GS): $t_{\text{start}} \leq 40\,\text{s}$, $t_{\text{stop}} \geq 10^5\,\text{s}$

FITTING PROCEDURE

A software automatically identifies the smooth behaviour of the light curves (see Margutti, MGB et al. 2011 for details)

$$L_0(t) = N \, t^{-\alpha_1}$$

$$L_1(t) = N \left( \left( \frac{t}{t_b} \right)^{\alpha_1/d_1} + \left( \frac{t}{t_b} \right)^{\alpha_2/d_1} \right)^{-d_1}$$

$$L_{11}(t) = N \left( \left( \frac{t}{t_{b1}} \right)^{\alpha_1/d_1} + \left( \frac{t}{t_{b1}} \right)^{\alpha_2/d_1} \right)^{-d_1} \left( 1 + \left( \frac{t}{t_{b2}} \right)^{\alpha_3/d_2} \right)^{-d_2}$$
THE LIGHT CURVE CLASSIFICATION

22 Type 0 (34%)
20 Type Ia (31%)
7 Type Ib (11%)
15 Type II (23%)

4 Type 0
5 Type Ia
0 Type Ib
7 Type II

In the GS
spectral evolution in Ib and II initial decay

moderate or absent in other segments
COMPARISON WITH LIGHT CURVES OF GRBS WITH FLARES

We use the sample adopted in Margutti, MGB et al. 2011, analysed with the same procedure. We find:

preferred temporal behaviour

Type II $\implies 23\%$ vs. $72\%$
COMPARISON WITH LIGHT CURVES OF GRBS WITH FLARES

We use the sample adopted in Margutti, MGB et al. 2011, analysed with the same procedure. We find:

- preferred temporal behaviour
- similar energetic
COMPARISON WITH LIGHT CURVES OF GRBS WITH FLARES

We use the sample adopted in Margutti, MGB et al. 2011, analysed with the same procedure. We find:

- preferred temporal behaviour
- similar energetic
- slightly different slope of the steep decay

\[
\langle \alpha^{FLC}_{\text{steep}} \rangle = 2.7 \\
\langle \alpha^{LC}_{\text{steep}} \rangle = 3.2
\]
THE STEEP DECAY

\[ \text{KSI} [\alpha^\text{ib}_1; \alpha^\text{II}_1] \Rightarrow 99\% \]
THE STEEP DECAY

- generally consistent with high latitude emission from structured jet **BUT**
  spectral evolution....

- prolonged activity of central engine $\Rightarrow L \sim t^{-3}$ or steeper ($\langle \alpha_{\text{steep}} \rangle = 3.2$)

- flares are perturbations in the mechanism powering the steep decay $\Rightarrow$
  connection flares/Type II

Kumar & Panaitescu, 2000
Barniol-Duran & Kumar, 2009
Zhang & Meszaros, 2002
Lyutikov, 2006
Kumar et al., 2008
Margutti, MGB et al., 2011
THE NORMAL DECAY

\[ \text{KS}[\alpha_{1}^{o}; \alpha_{2}^{lb}] \Rightarrow 46\% \]
\[ \text{KS}[\alpha_{1}^{o}; \alpha_{2}^{ll}] \Rightarrow 12\% \]
\[ \text{KS}[\alpha_{2}^{la}; \alpha_{3}^{ll}] \Rightarrow 36\% \]
THE NORMAL DECAY

- generally consistent with forward shock emission pre/post jet break
- supported by the absence of spectral evolution
- accretion model predicts an asymptotic behaviour \( L \sim t^{(1.3 \div 2.7)} \) but does not constraint the spectral index

Sari 1998
Chevalier & Li 2000
Zhang & Meszaros 2004
THE SHALLOW DECAY

\[ \text{KS} [\alpha^{\text{la}}_1; \alpha^{\text{lb}}_2] \Rightarrow 63\% \]

\[ \text{KS} [\alpha^{\text{la}}_1; \alpha^{\text{lb}}_2] \Rightarrow 49\% \]

Wednesday, June 29, 2011
ENERGY INJECTION FROM SPINNING-DOWN NEWLY BORN NS INTO THE FORWARD SHOCK

\[ L(t) = kL_i/T^{k+1} \int_{T_0}^T T^k/(1+aT)^2 + kE_0/T_0 (T_0/T)^{k+1} \]

Dall’Osso et al. 2011

**Table of the Type II GRBs fitted with Eq. B3.**

<table>
<thead>
<tr>
<th>GRB</th>
<th>z</th>
<th>( T_0 ) (s)</th>
<th>( B \times 10^{15} ) G</th>
<th>P (ms)</th>
<th>( k' )</th>
<th>( E_0 \times 10^{55} ) erg</th>
</tr>
</thead>
<tbody>
<tr>
<td>050101B</td>
<td>0.9364</td>
<td>600.5</td>
<td>7.0 ± 1.3</td>
<td>11.0 ± 1.0</td>
<td>0.80 ± 0.36</td>
<td>0.07 ± 1.3</td>
</tr>
<tr>
<td>051110A</td>
<td>2.346</td>
<td>100.</td>
<td>2.8 ± 0.1</td>
<td>1.5 ± 0.1</td>
<td>0.42 ± 0.06</td>
<td>10.0 ± 1.3</td>
</tr>
<tr>
<td>051221</td>
<td>0.5405</td>
<td>100.</td>
<td>4.0 ± 0.0</td>
<td>15.0 ± 0.9</td>
<td>0.52 ± 0.12</td>
<td>0.3 ± 0.2</td>
</tr>
<tr>
<td>060502A</td>
<td>1.51</td>
<td>400.</td>
<td>2.2 ± 0.5</td>
<td>2.7 ± 0.4</td>
<td>0.25 ± 0.13</td>
<td>3.0 ± 0.8</td>
</tr>
<tr>
<td>060605</td>
<td>3.78</td>
<td>300.</td>
<td>4.0 ± 1.8</td>
<td>2.14 ± 0.2</td>
<td>0.99 ± 0.56</td>
<td>3.0 ± 1.5</td>
</tr>
<tr>
<td>070301A</td>
<td>1.4959</td>
<td>100.</td>
<td>1.7 ± 0.9</td>
<td>2.8 ± 0.2</td>
<td>0.99 ± 0.33</td>
<td>1.5 ± 0.5</td>
</tr>
<tr>
<td>080707</td>
<td>1.23</td>
<td>100.</td>
<td>5.0 ± 0.8</td>
<td>10.2 ± 0.1</td>
<td>0.99 ± 0.60</td>
<td>0.15 ± 0.36</td>
</tr>
<tr>
<td>090529</td>
<td>2.025</td>
<td>1000.</td>
<td>1.2 ± 0.6</td>
<td>2.8 ± 0.1</td>
<td>0.89 ± 0.17</td>
<td>2.0 ± 0.8</td>
</tr>
<tr>
<td>090618</td>
<td>0.54</td>
<td>160.</td>
<td>3.0 ± 0.0</td>
<td>2.5 ± 0.0</td>
<td>0.81 ± 0.01</td>
<td>12.0 ± 5.0</td>
</tr>
<tr>
<td>090927</td>
<td>1.37</td>
<td>1000.</td>
<td>5.0 ± 0.3</td>
<td>5.1 ± 0.1</td>
<td>0.99 ± 0.12</td>
<td>0.8 ± 1.4</td>
</tr>
<tr>
<td>100425A</td>
<td>1.755</td>
<td>700.</td>
<td>4.0 ± 0.7</td>
<td>5.2 ± 0.3</td>
<td>0.51 ± 0.14</td>
<td>0.9 ± 0.4</td>
</tr>
<tr>
<td>100621</td>
<td>0.542</td>
<td>250.</td>
<td>3.0 ± 0.0</td>
<td>3.8 ± 0.0</td>
<td>0.70 ± 0.02</td>
<td>4.0 ± 0.3</td>
</tr>
<tr>
<td>060526</td>
<td>2.21</td>
<td>100.</td>
<td>3.2 ± 1.3</td>
<td>5.5 ± 1.0</td>
<td>0.70 ± 0.06</td>
<td>1.0 ± 0.6</td>
</tr>
<tr>
<td>060714</td>
<td>2.71</td>
<td>60.</td>
<td>5.0 ± 2.0</td>
<td>2.8 ± 0.2</td>
<td>0.43 ± 0.05</td>
<td>10.0 ± 6.0</td>
</tr>
<tr>
<td>080310</td>
<td>2.43</td>
<td>400.</td>
<td>6.3 ± 0.8</td>
<td>5.8 ± 1.0</td>
<td>0.80 ± 0.06</td>
<td>4.0 ± 1.2</td>
</tr>
<tr>
<td>091029</td>
<td>3.79</td>
<td>100.</td>
<td>1.99 ± 0.6</td>
<td>1.6 ± 0.3</td>
<td>0.32 ± 0.01</td>
<td>1.6 ± 0.4</td>
</tr>
</tbody>
</table>

**References:**
- Dall’Osso et al., 2011
- Zhang & Mészáros, 2002
- Zhang & Mészáros, 2001
- Metzger et al., 2011
- Dai & Lu, 1998
- Duncan & Thompson, 1992
The luminosity vs. duration correlation in shallow decay

Dainotti et al., 2008, 2011

\[ B, \sigma_B \quad \Rightarrow \quad a \sim B^2 / p^2 \]

\[ p, \sigma_p \quad \Rightarrow \quad L_i \sim B^2 / p^4 \]

\[ t_p = 1 / a \]

\[ L_p = L(t_p) \]
CONCLUSIONS

STEEP DECAY: slope, spectral evolution and connection with flares \(\Rightarrow\) ORIGINATES FROM CENTRAL ENGINE ACTIVITY. NOT SIMPLY THE TAIL OF THE PROMPT EMISSION

SHALLOW DECAY: energetic, duration, slope, absence of spectral evolution, correlations and following normal decay \(\Rightarrow\) INJECTION OF ENERGY FROM SPINNING-DOWN NS INTO THE FORWARD SHOCK
The Complete Study of GRB X-ray Afterglows: energetics, time-scales and luminosity (GRBs XRT Catalogue)

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The Sample

We analysed all the Gamma-Ray Bursts (GRBs) with spectroscopic analysis observed by the X-Ray Telescope (XRT), on board Swift satellite, from its launch (November 2004) to the end of 2010 (437 GRBs of 658 GRBs detected by Swift).

Complete catalogue of the GRBs observed by Swift/ XRT and characterisation of all the light curves and correlations

Data Reduction

- The XRT-data have been reduced with the method reported in Margutti et al. (2010). We obtained the XRT light curves in the 0.3-10 keV total energy band and in four sub-energy bands: 0.3-1 keV, 1-2 keV, 2-3 keV and 3-10 keV.
- Our XRT archive contains light curves in count-rate, flux and luminosity (for

POSTER E15

... so stay tuned!!