The Collimation and Energetics of the Brightest Swift GRBs

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GRB Overview

Prompt Energy ($E_{\gamma,iso}$) + Afterglow Energy ($E_{KE,iso}$) $+$ Collimation ($\theta$)
The Pre-Swift View: Collimation

- “Energy Catastrophe” ⇒ GRBs are highly beamed ($\theta \sim 1$-10 degrees)
- Achromatic steepening signature of relativistic, collimated outflow
- Infer opening angle by measuring jet break ($\theta \sim 3 \ t_{\text{jet}}^{3/8}$ degrees)

Harrison et al. 1999
The Pre-Swift View: Energetics

Collimation correction greatly reduced spread in $E_\gamma$ and $E_{KE}$

With exception of most nearby events, $E_{total} \sim 10^{51}$ erg
Swift Complications: $E_{\gamma,\text{iso}}$

- 15-350 keV BAT bandpass provides limited spectral coverage
- Often miss $E_{\text{peak}}$
- Leads to large uncertainties in $E_{\gamma,\text{iso}}$

Abdo et al., 2009
Swift Complications: $E_{\gamma,iso}$

- 15-350 keV BAT bandpass provides limited spectral coverage
- Often miss $E_{\text{peak}}$
- Leads to large uncertainties in $E_{\gamma,iso}$

GRB 090902B

Abdo et al., 2009
Swift Complications: $E_{KE}$

- Bright flares and long-lived plateau phases in X-ray afterglows
- Can inject significant amount of energy into forward shock

Falcone et al. 2005
Swift Complications: $\theta$

- Many *Swift* events with no breaks or (worse) chromatic breaks
- *Swift* insensitive to jet breaks from a significant fraction of detected events

Kocevski & Butler 2008
Swift Complications: $\theta$

- Many Swift events with no breaks or (worse) chromatic breaks
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Kocevski & Butler 2008
The Brightest *Swift* GRB Sample

- Brightest events provided tightest energetics constraints
- Detected by other high-energy satellites
- X-ray, optical, and *radio* light curves to late times

Cenko et al. 2009
GRB 070125

Fig. 2.—Top: Optical (R- and i'-band) light curves of GRB 070125 as a result of joint optical and X-ray fits. Best-fit single power-law models are shown with dashed lines, while the broken power-law models are shown in solid lines. It is clear that in the optical bands, a broken power-law (indicating a jet break) is strongly favored.

Bottom: X-ray light curve of GRB 070125, the joint fit to optical and X-ray data. Again the single power-law model is shown as a dashed line, while the broken power-law model is shown as a solid line. Grey solid line indicates the independent fit to X-ray data. The independent fit is consistent with the joint fit in the optical bands but shifts the jet break to \( \sim 9 - 10 \) days. We discuss this in §3.1 and §5.

\[ t_{\text{jet}} \sim 4 \text{ days} \Rightarrow \theta \sim 13 \text{ degrees} \]

Chandra et al. 2008
GRB 050820A

Cenko et al. 2009

\[ t_{\text{jet}} \sim 10 \text{ days} \Rightarrow \theta \sim 7 \text{ degrees} \]
Energetics Results
Energetics Results

Prompt Energy ($E_p$) [erg] vs. Afterglow Energy ($E_{KE}$) [erg]

- Pre-Swift GRBs
- Swift GRBs
- Sub-Luminous GRBs
Energetics Results

![Diagram showing the relationship between prompt energy (E_p) and afterglow energy (E_{KE}) for different types of GRBs, with the Magnetar limit indicated.]
Conclusions

• All 5 events in our sample show evidence for collimation ($t_{\text{jet}} \sim 3 - 12$ days)

• Lack of collimation in Swift GRBs largely due to selection effects

• Beaming-corrected energy release spread over several orders of magnitude

• Most energetic GRBs release $>\sim 10^{52}$ erg in relativistic output

• Continuing to monitor Fermi-LAT GRBs