The Collimation and Energetics of *Fermi*-LAT Gamma-Ray Bursts

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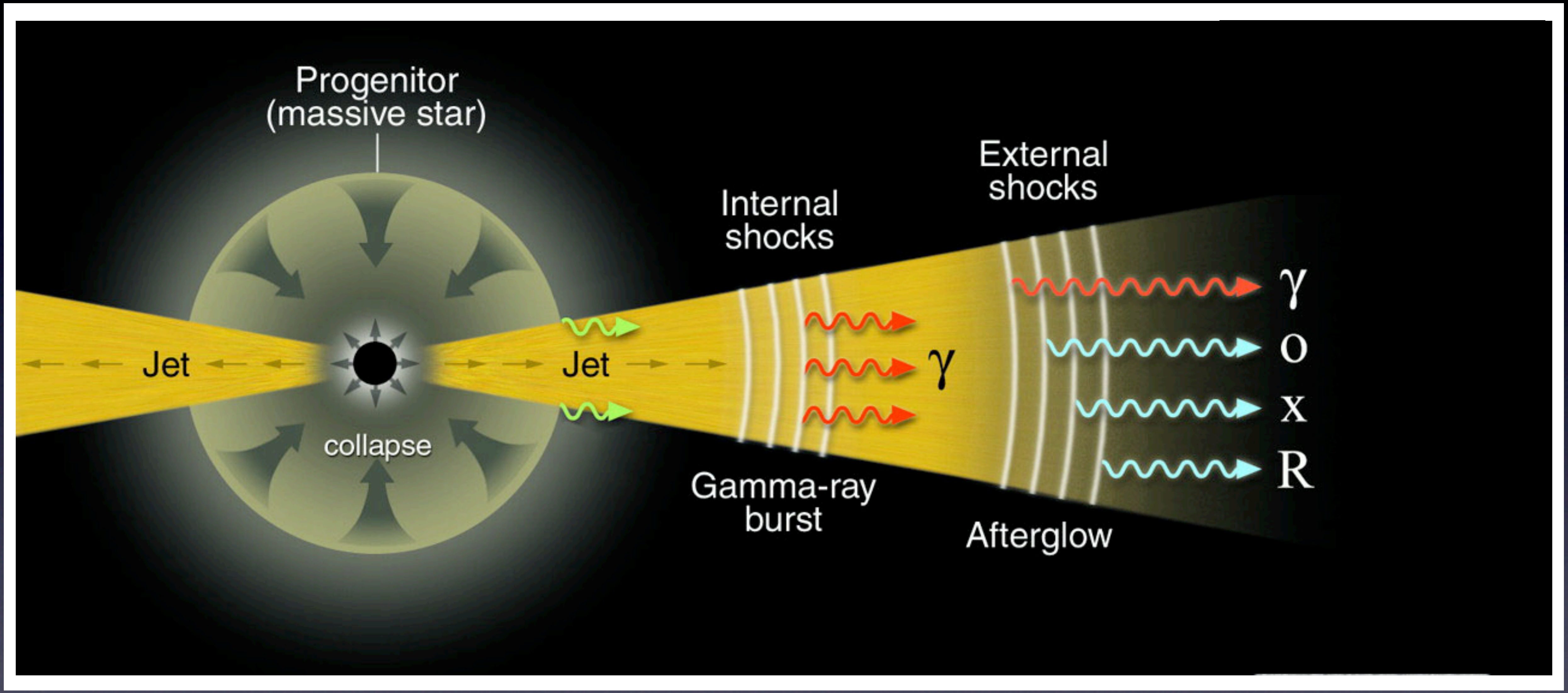
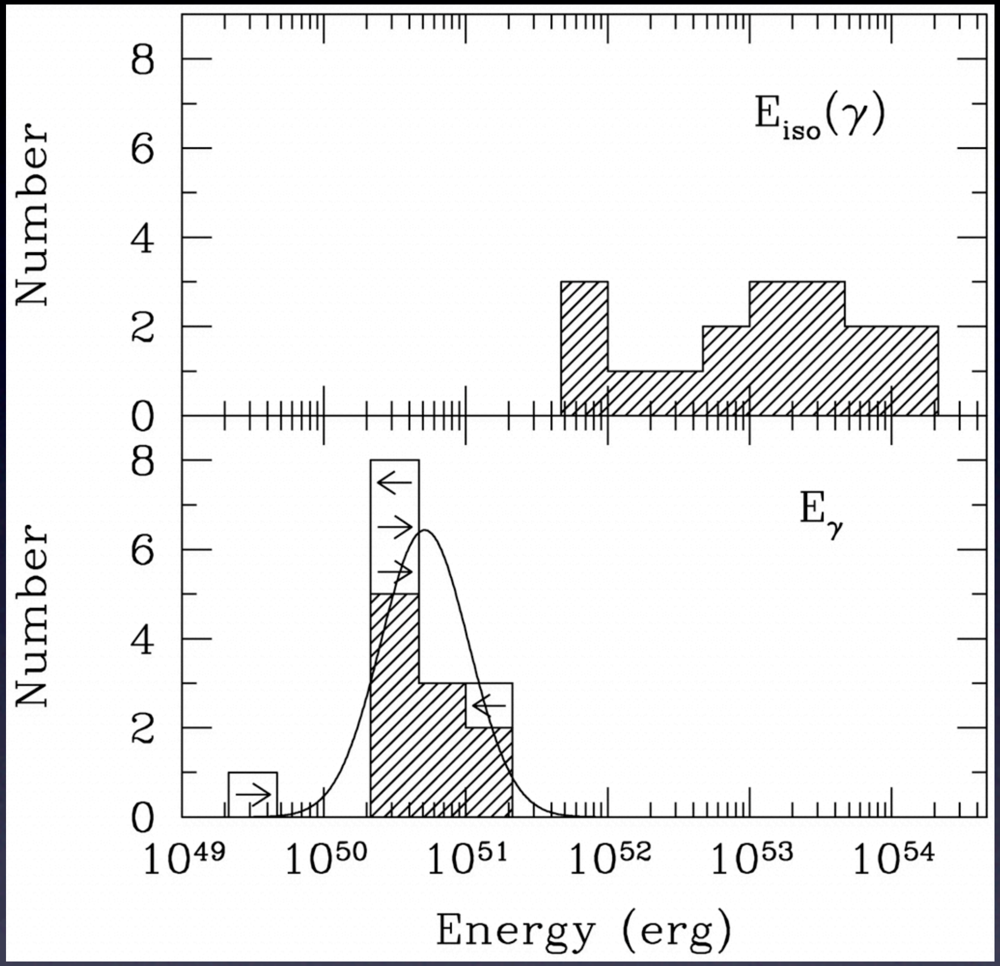
GRB Overview



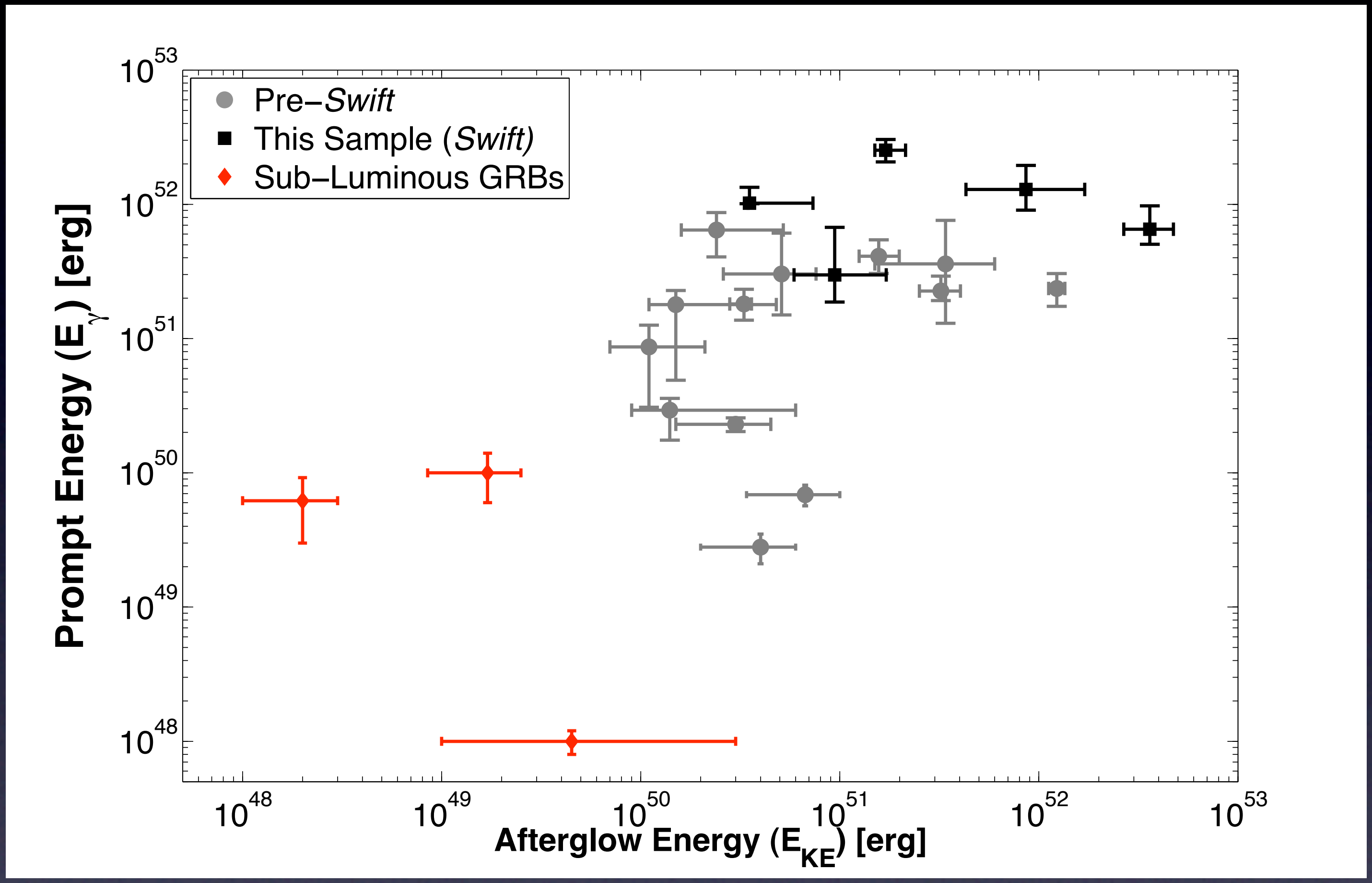
Meszaros, 2001

Prompt Energy ($E_{\gamma,iso}$) + Afterglow Energy ($E_{KE,iso}$)
+ Collimation (θ)

Motivation



Frail *et al.* 2001



Cenko *et al.* 2009

Beaming-corrected energetics fundamental to our understanding of progenitors, physics, and cosmological utility

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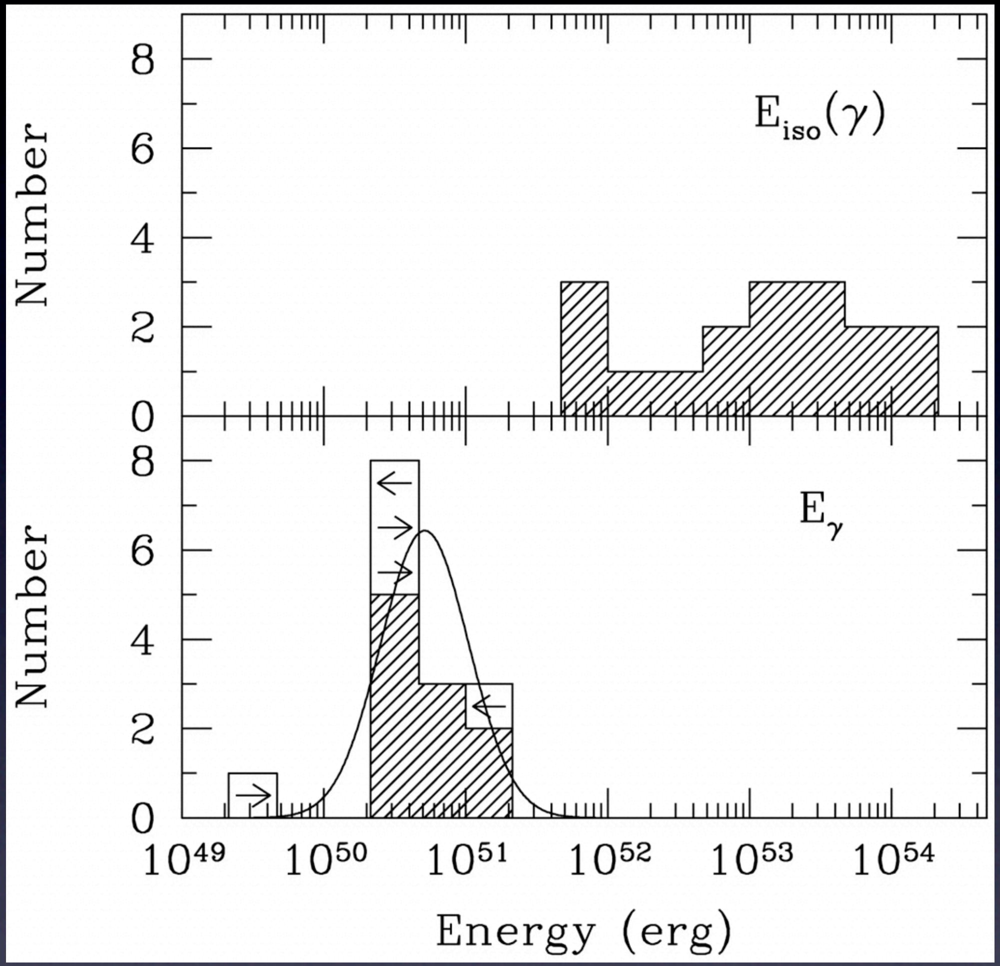
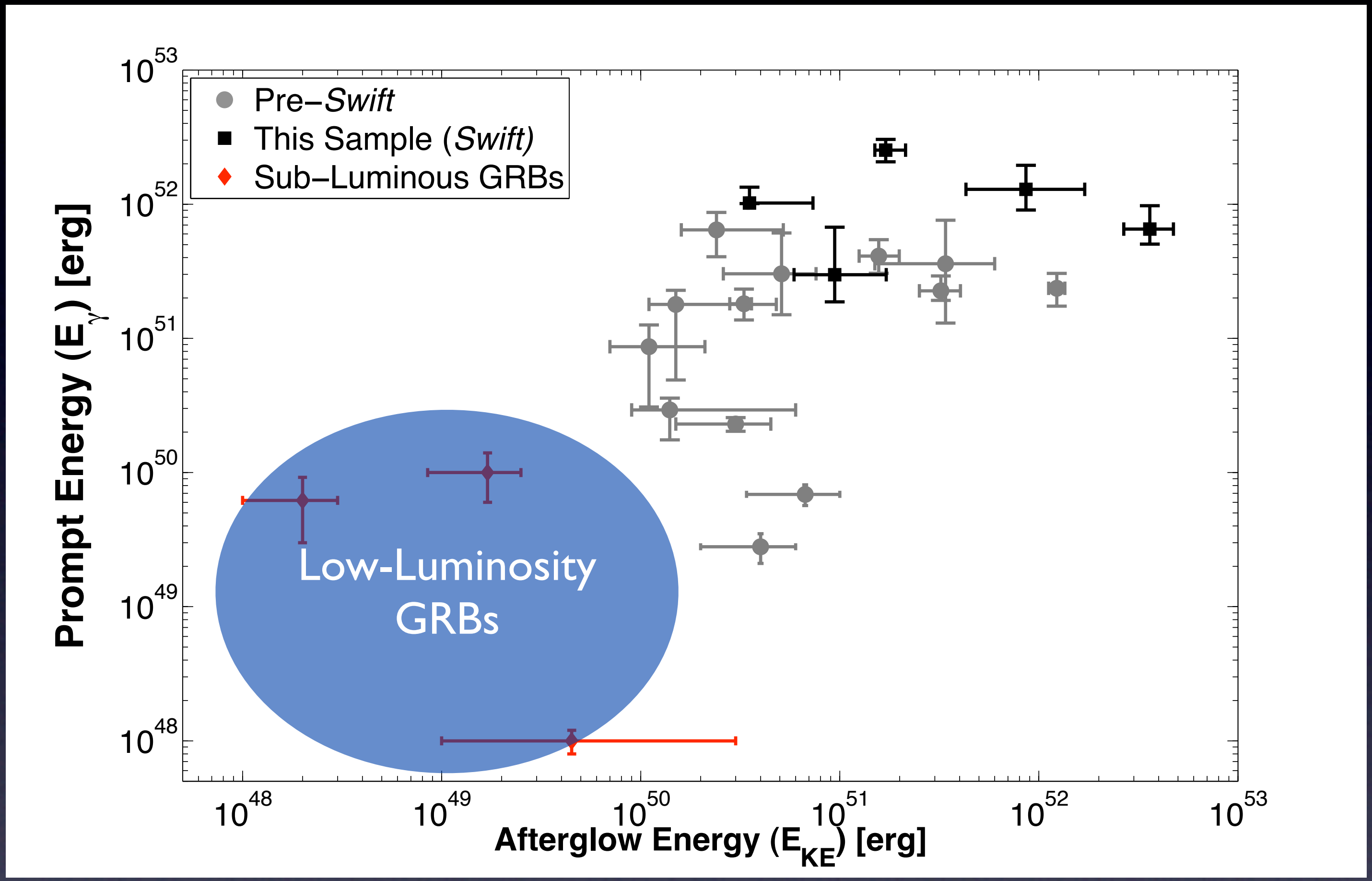


Frail *et al.* 2001



Cenko *et al.* 2009

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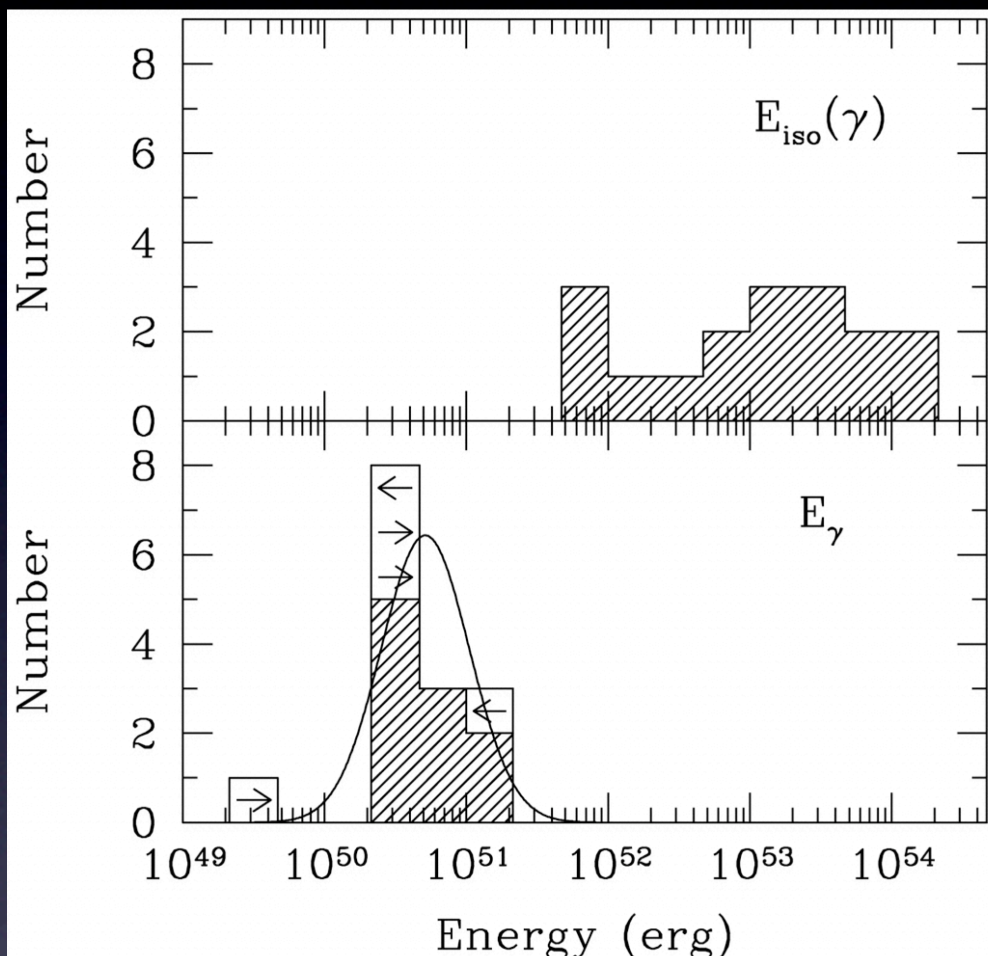
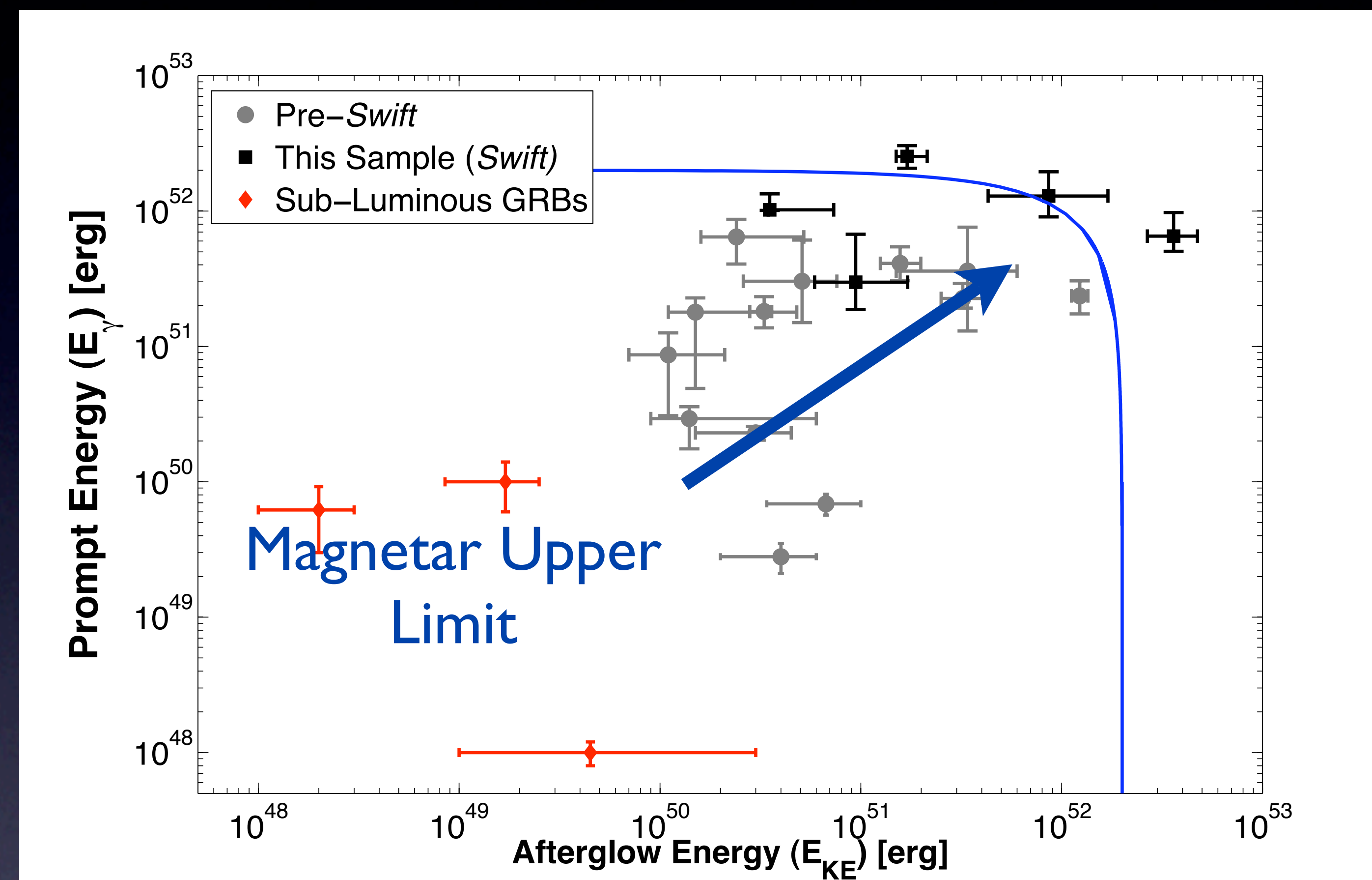


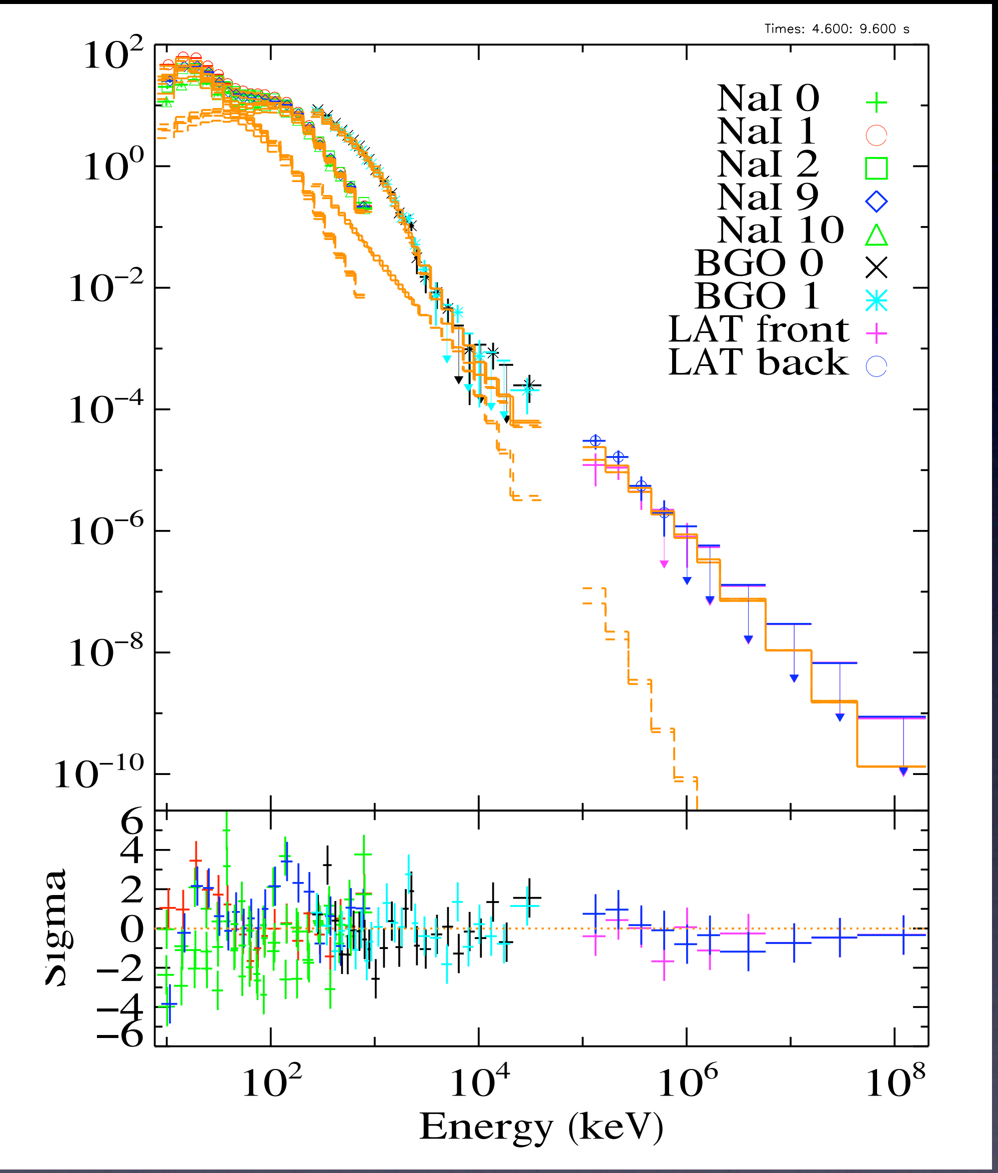


Frail *et al.* 2001

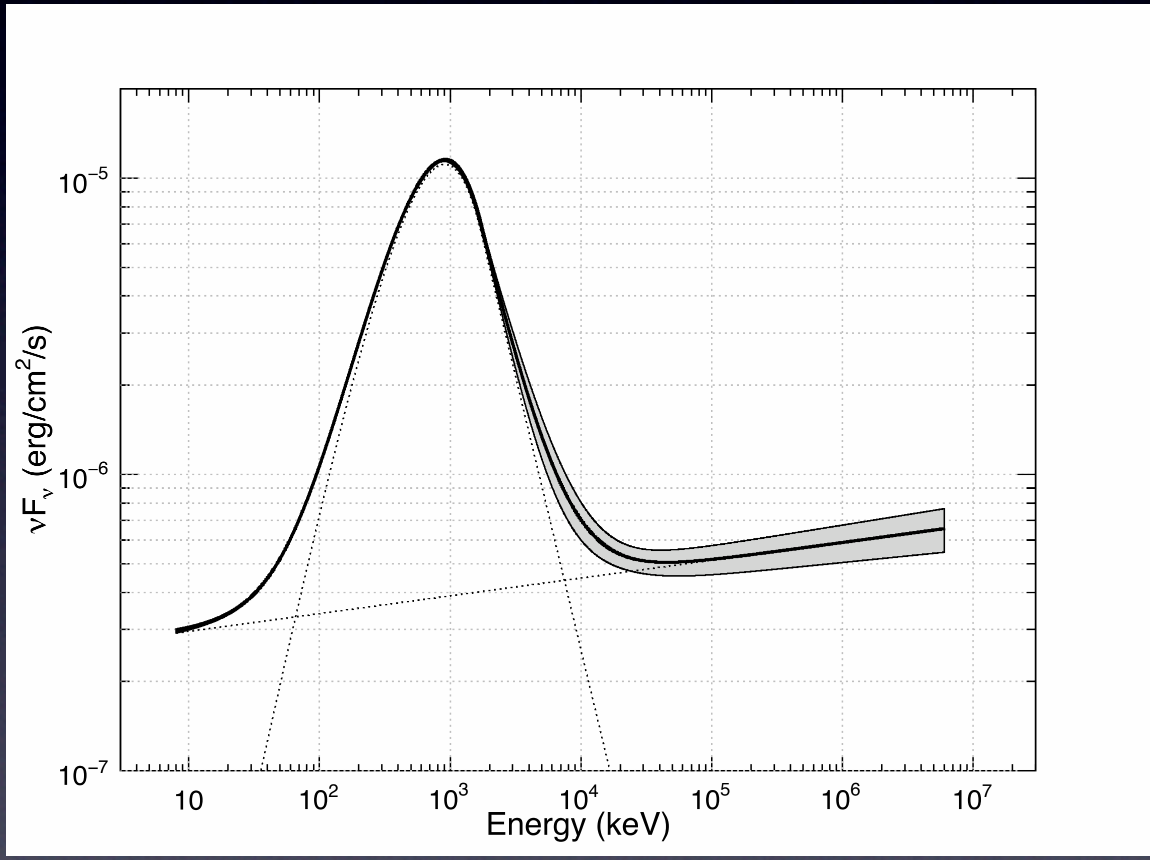
Cenko *et al.* 2009

Beaming-corrected energetics fundamental to our understanding of progenitors, physics, and cosmological utility

$E_{\gamma,iso}$: Prompt Energy



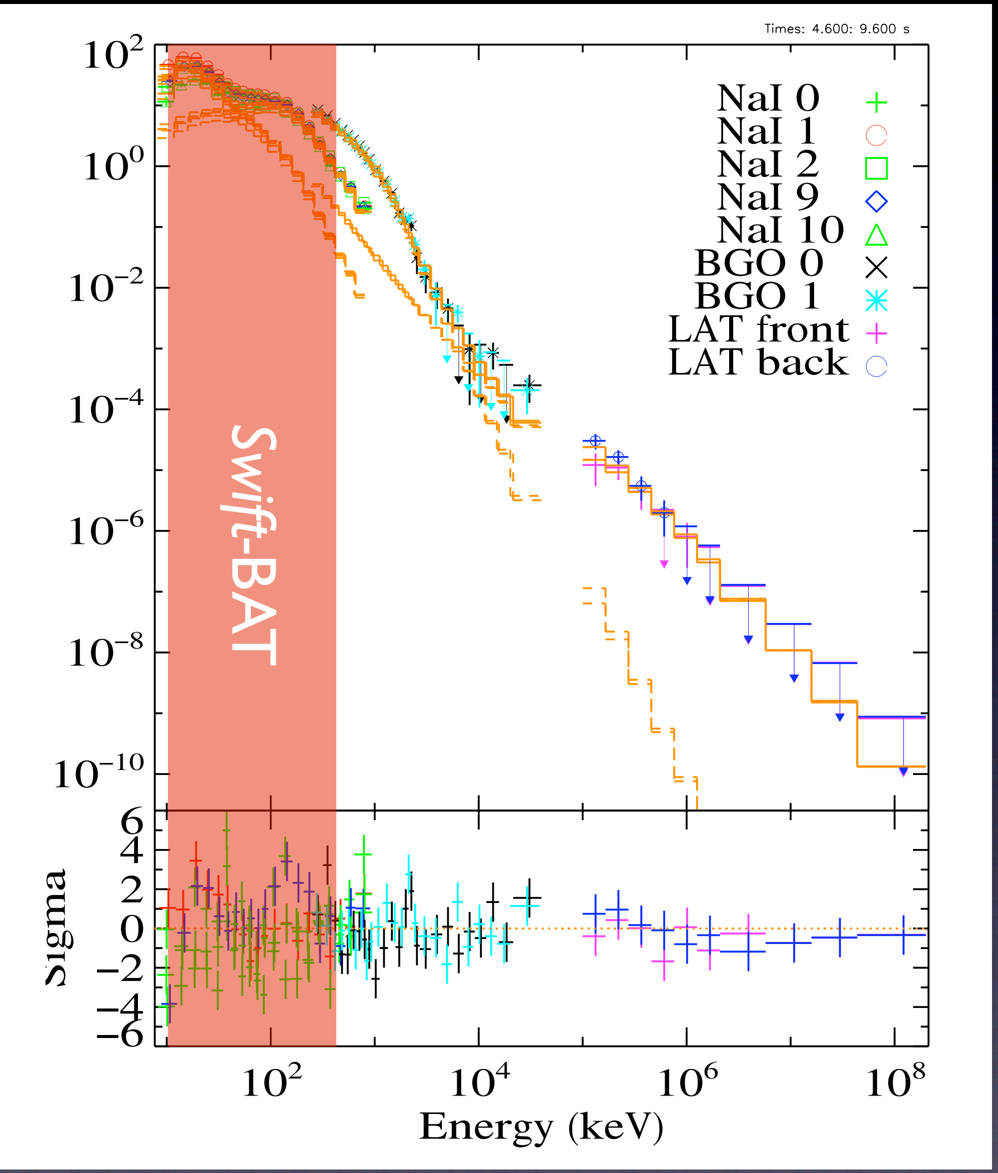
GRB 090902B



Abdo *et al.*, 2009

Broad coverage ⇒ Accurate and precise $E_{\gamma,iso}$

Why *Fermi* I: Spectral Coverage



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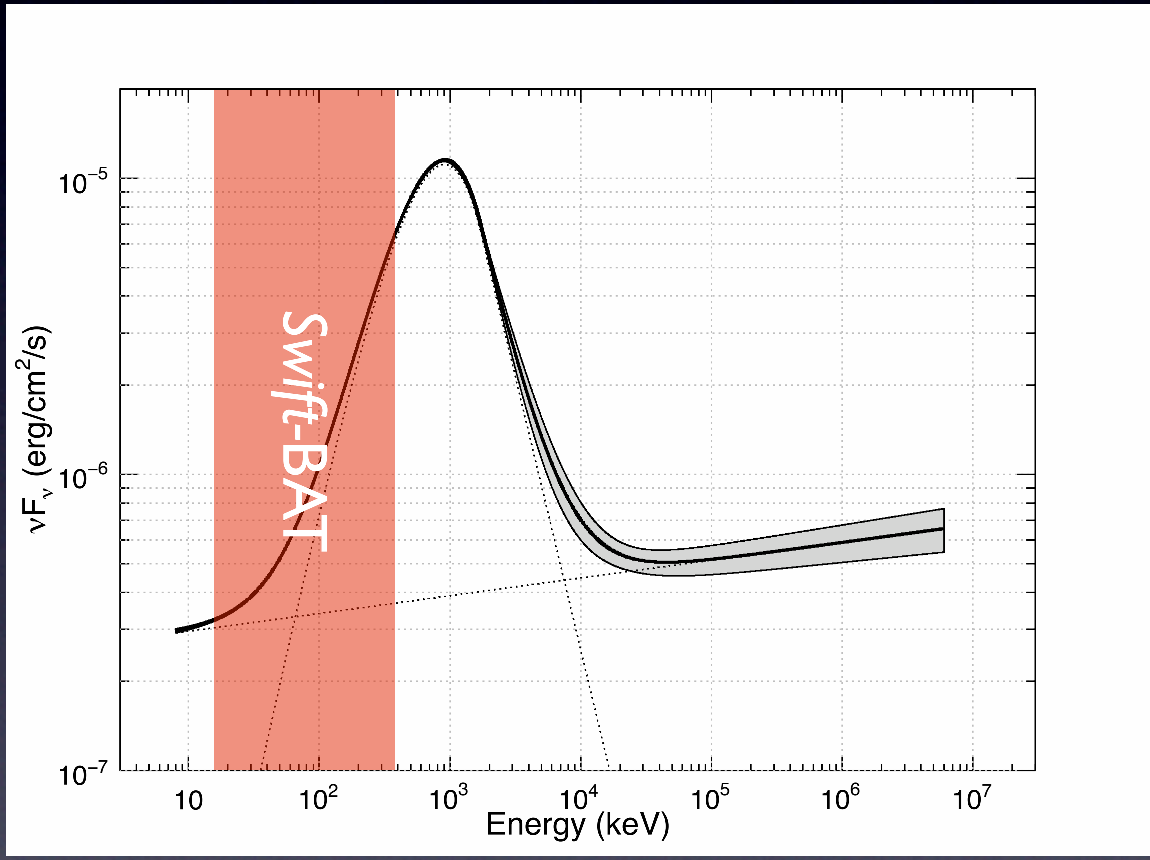
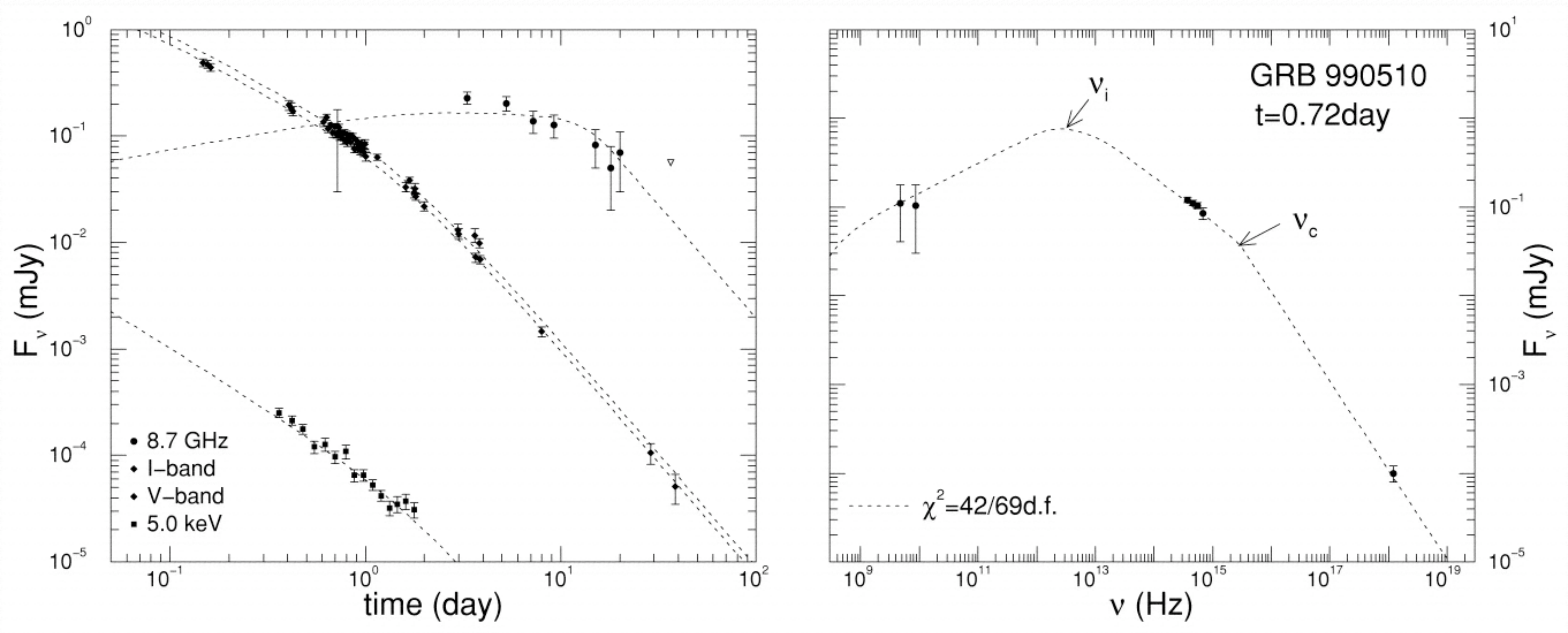


Abdo *et al.*, 2009

Broad coverage ⇒ Accurate and precise $E_{\gamma,iso}$

$E_{KE,iso}$: Afterglow Energy

Self-similar evolution | Synchrotron spectrum

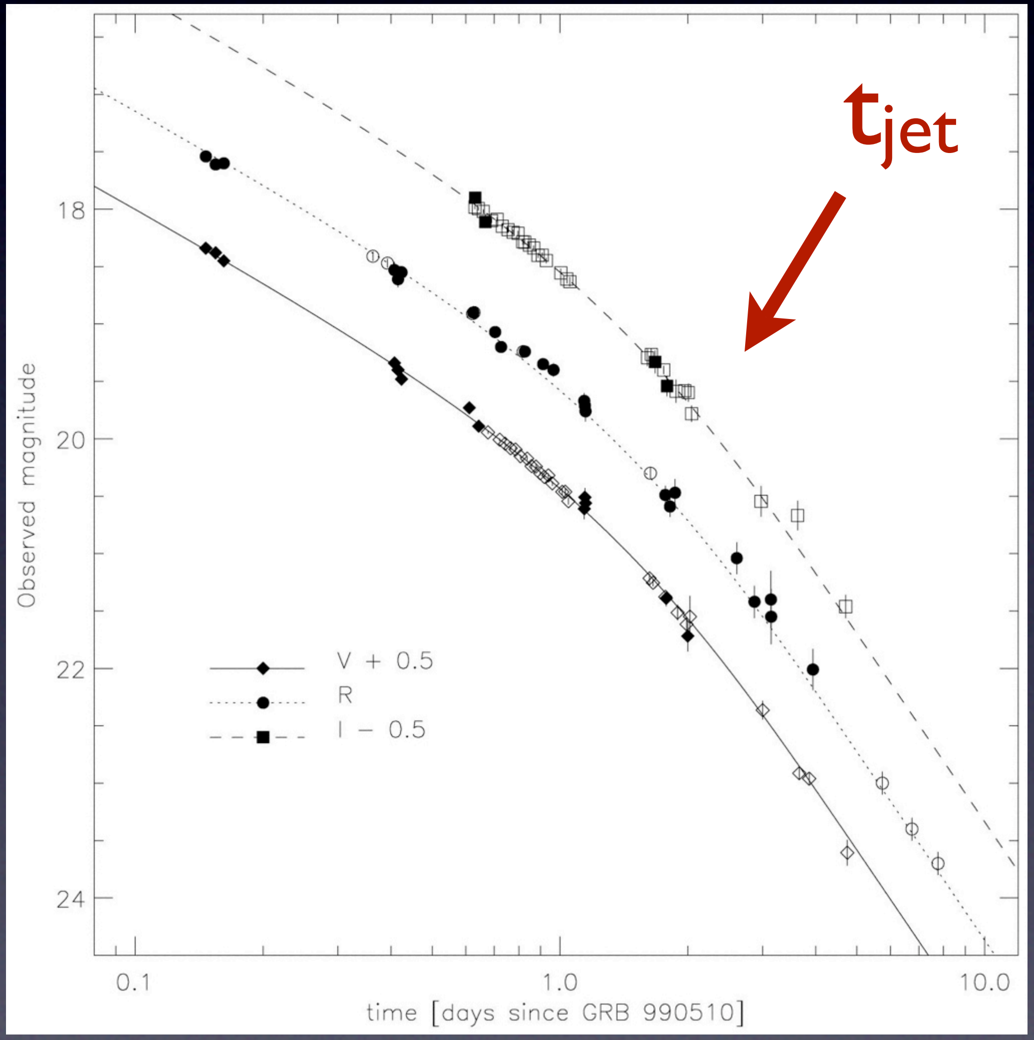


Panaitescu & Kumar, 2001

Afterglow energy indirectly inferred from modeling of broadband emission

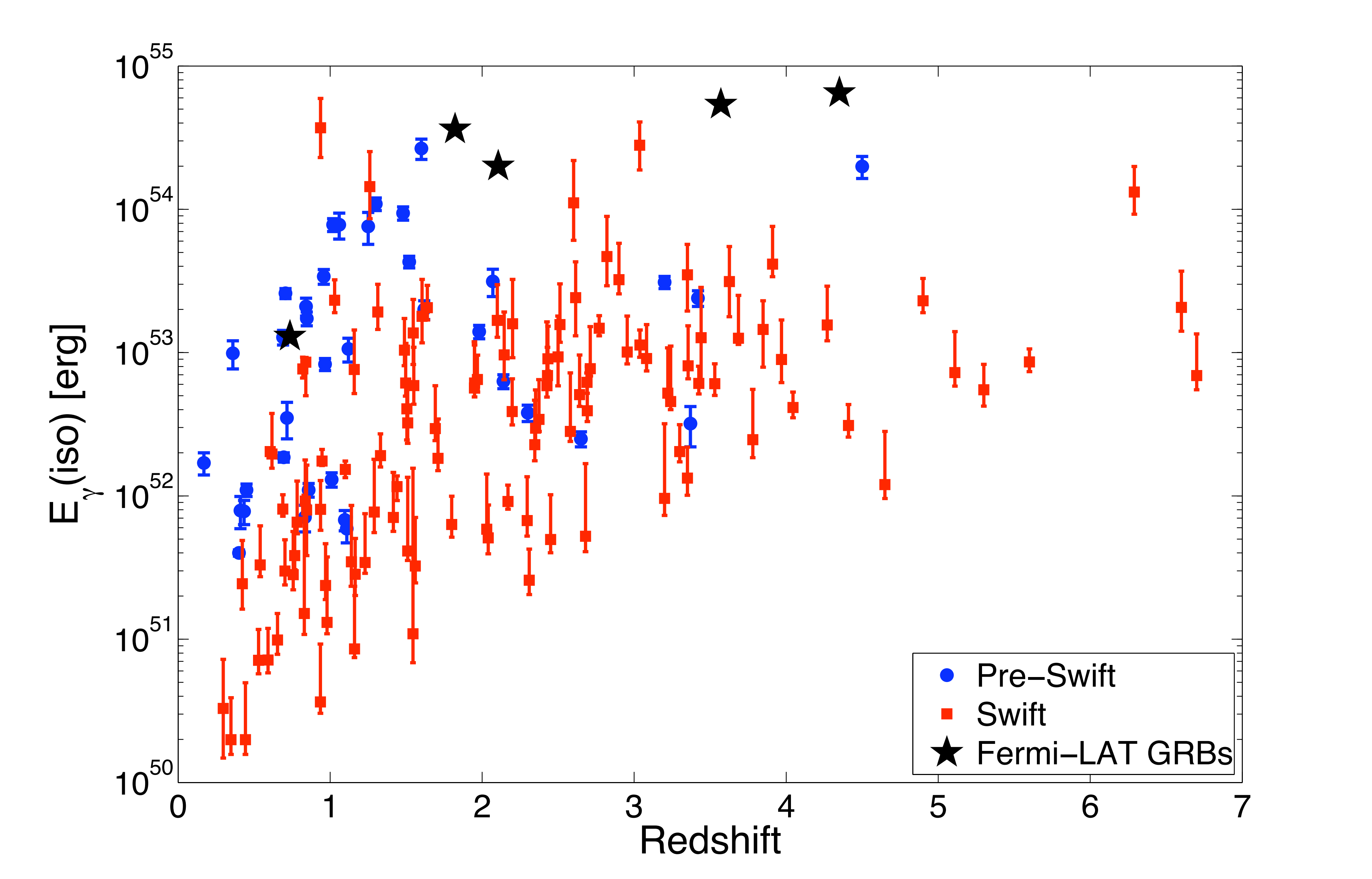
θ: Beaming Angle

- To avoid "energy catastrophe", GRB ejecta must be highly beamed (θ ~ 1-10 degrees)
- Relativistic beaming effects cause achromatic steepening in light curves when $\gamma \sim \theta^{-1}$
- By measuring time of "jet break", infer collimation angle of outflow



Harrison *et al.* 1999

Why *Fermi* II: Large $E_{\gamma,iso}$

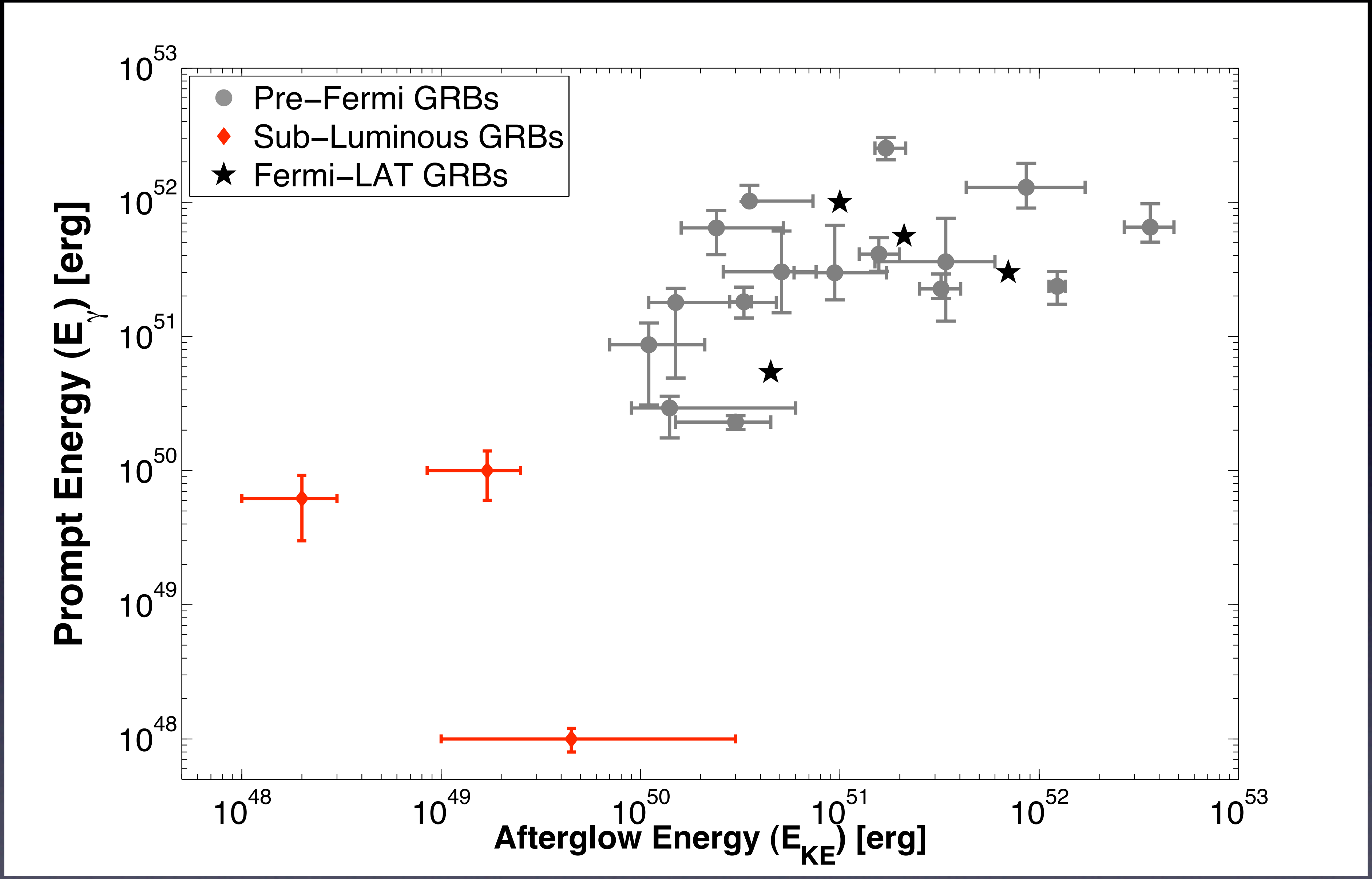


A clean and simple way to target large $E_{\gamma,iso}$

Our *Fermi* Energetics Campaign

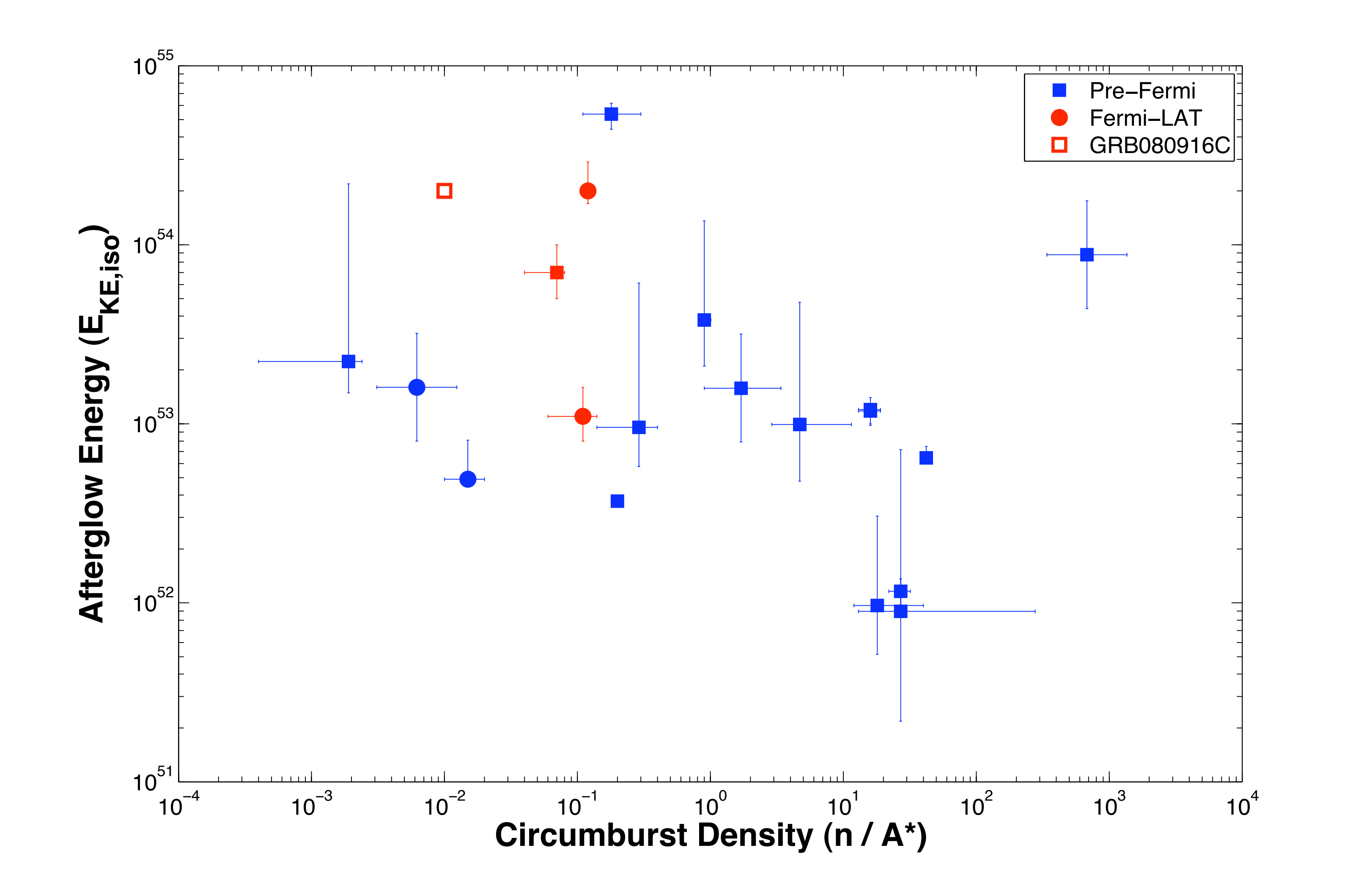
- Response to joint *Fermi* / VLA announcement
- Broadband (radio, optical, and X-ray) follow-up of *LAT* GRBs to constrain collimation and energetics
- Cycle 1 GRBs: 090323, 090328, 090902B, and 090926A (no radio)

Results I: Energetics



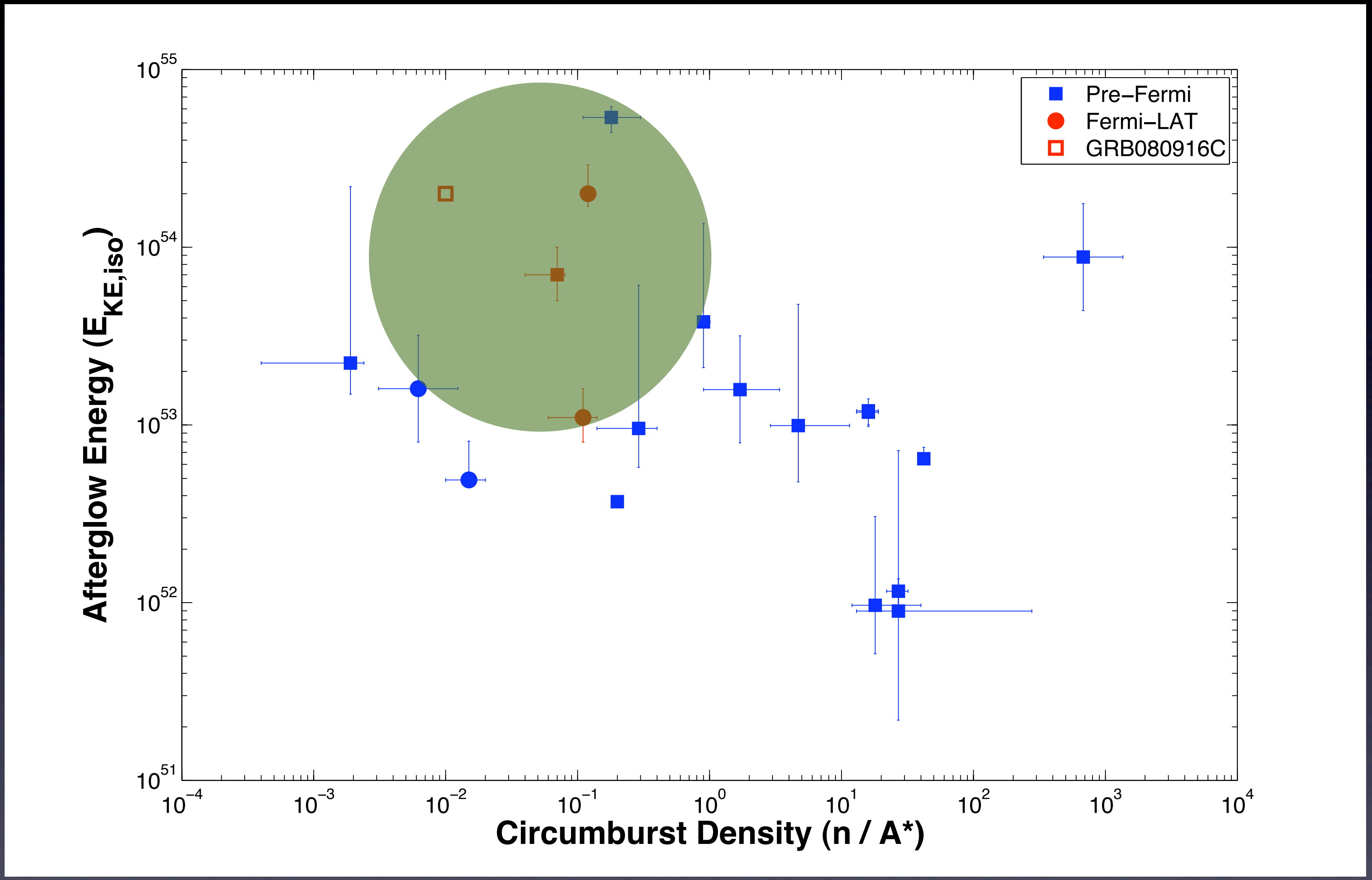
After beaming correction, energetic requirements ~ 10^{51} - 10^{52} erg

Results II: Density



Low circumburst densities consistent with expectation of low mass-loss

Results II: Density



Low circumburst densities consistent with expectation of low mass-loss

Conclusions

- Use broadband afterglow observations to constrain collimation and energetics from 4 *Fermi* LAT GRBs
- All 4 tightly collimated (θ <~ 10 deg)
- Energy release ~ 10^{51} - 10^{52} erg
- Low circumburst densities (consistent with rapidly rotating progenitors)
- Importance of follow-up observations (redshifts)