High Energy Transients in The TMT Era

Kuntal Misra
Aryabhatta Research Institute of observational sciencES (ARIES)
Nainital, India

On behalf of a larger collaboration

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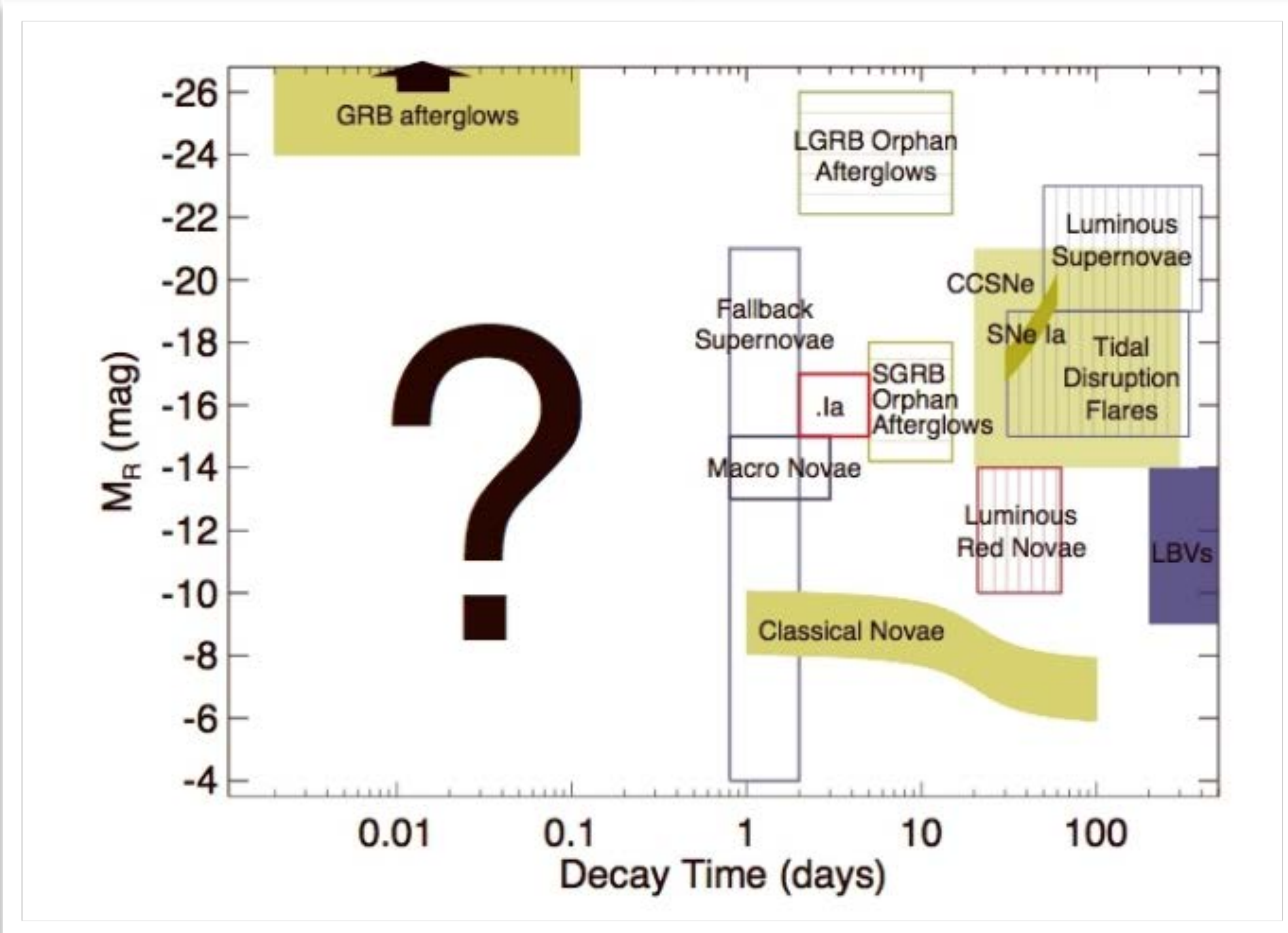
Discovery space for cosmic transients



Rau 2008; LSST handbook

GRBs: What we know

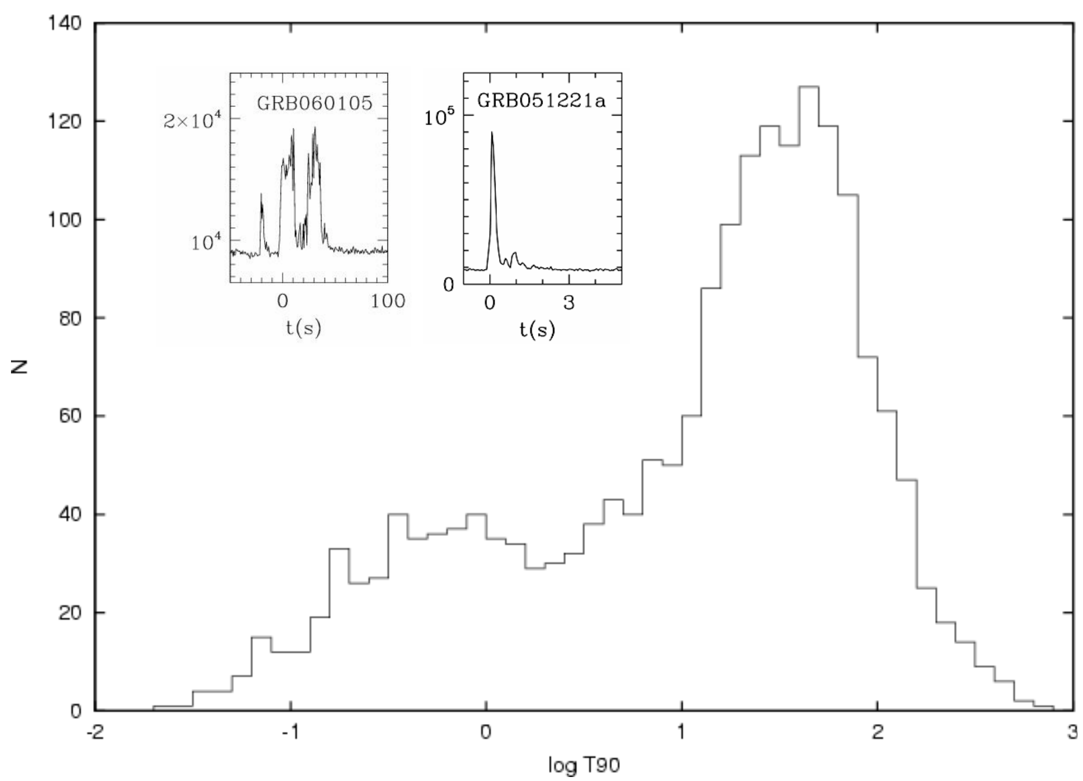
- Short intense pulses of gamma rays lasting for a few seconds

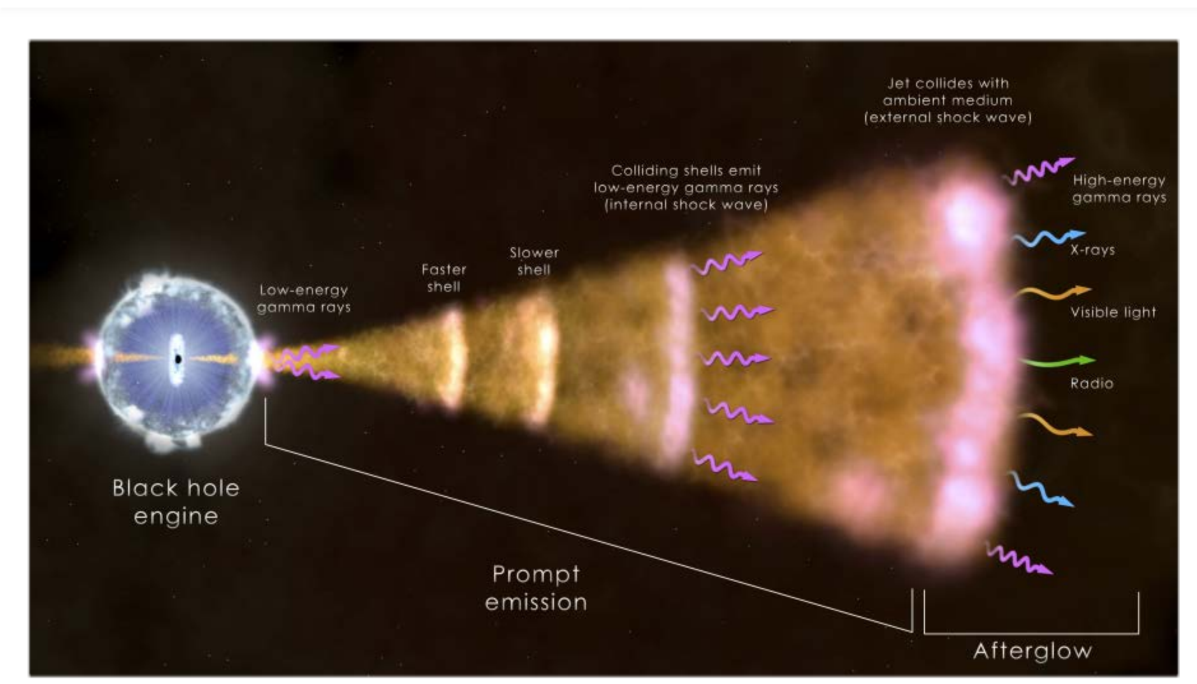
- Bimodal distribution - both are from gravitational collapse leading to the formation of a BH/magnetar

- Isotropically distributed: cosmological distances ($0.008 < z < 9.4$) & hence huge energy output (10^{51}erg)

- Two phase: Burst (prompt emission) & Afterglow (longer lasting longer wavelength counterparts; non-thermal synchrotron radiation; time varying flux (*@ 1hr ~ 16 to 24 (R band)*) follows a power law decay)

- *Swift* ~ 100 GRBs per year

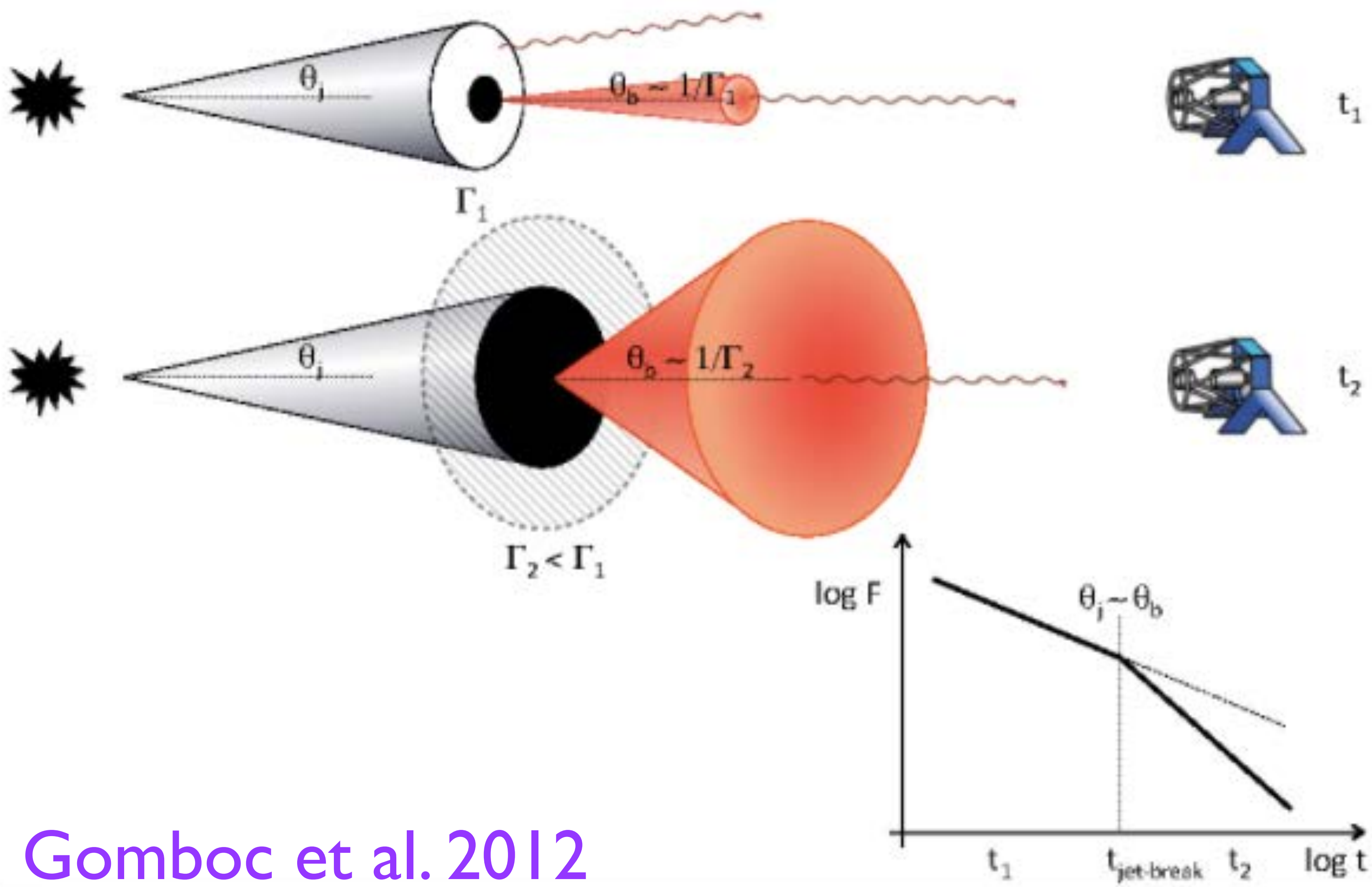




The Fireball Model

- Prompt energy ($E_{\gamma,iso}$)
- Afterglow energy ($E_{KE,iso}$)
- Collimation (θ)

Context: Jet geometry of GRB afterglows



Gomboc et al. 2012

As the relativistic ejecta slows and 1/Γ approaches the opening angle of the beam, the brightness of the burst should start to fall rapidly and produce an achromatic break in the light curve

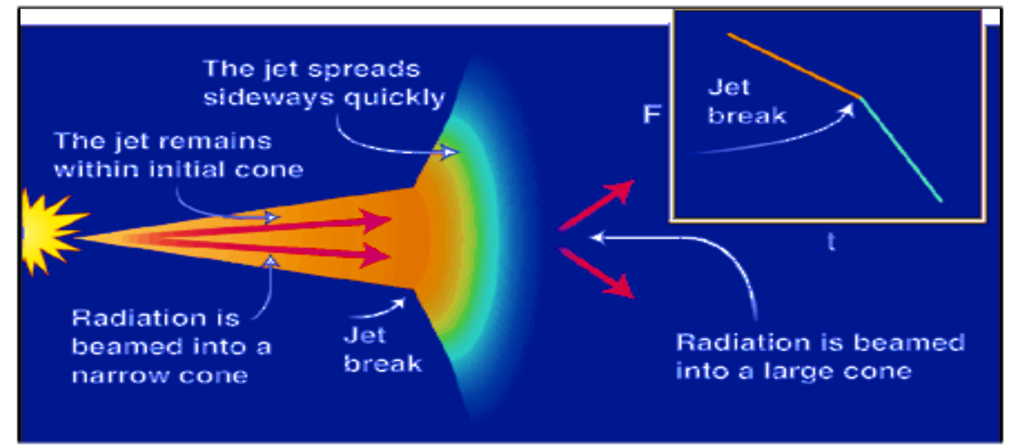
Context: Jet geometry of GRB afterglows

Afterglow studies so far

★Nature of the explosion - GRBs are highly beamed (jet opening angles of a few degrees)

★Extent of collimation through achromatic breaks in light curves

Signature of a jet-break



Constant density medium

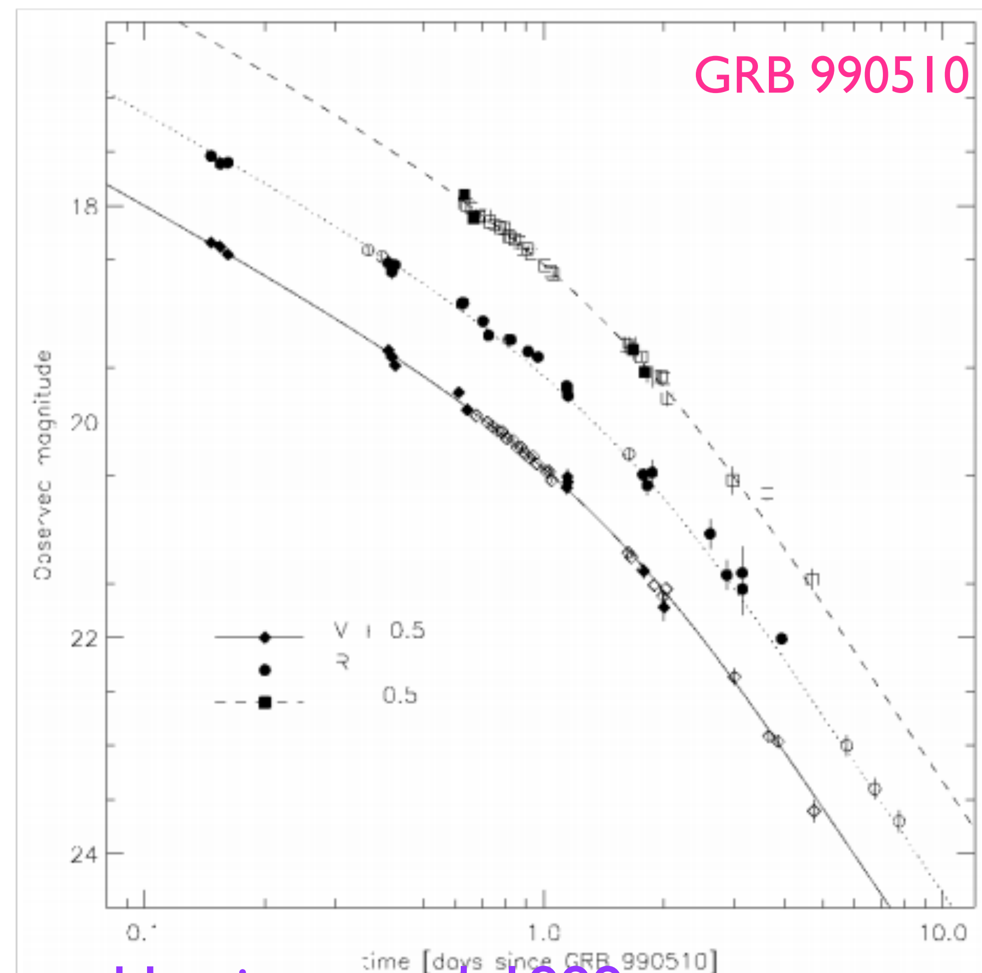
$$\theta_j = 0.057\left(\frac{t_j}{1\ \mathrm{day}}\right)^{3/8}\left(\frac{1+z}{2}\right)^{-3/8}\left[\frac{E_{\mathrm{iso}}(\gamma)}{10^{53}\ \mathrm{ergs}}\right]^{-1/8} \times \left(\frac{\eta_\gamma}{0.2}\right)^{1/8}\left(\frac{n}{0.1\ \mathrm{cm}^{-3}}\right)^{1/8},$$

Sari & Piran 1999
Frail et al. 2001

Wind medium

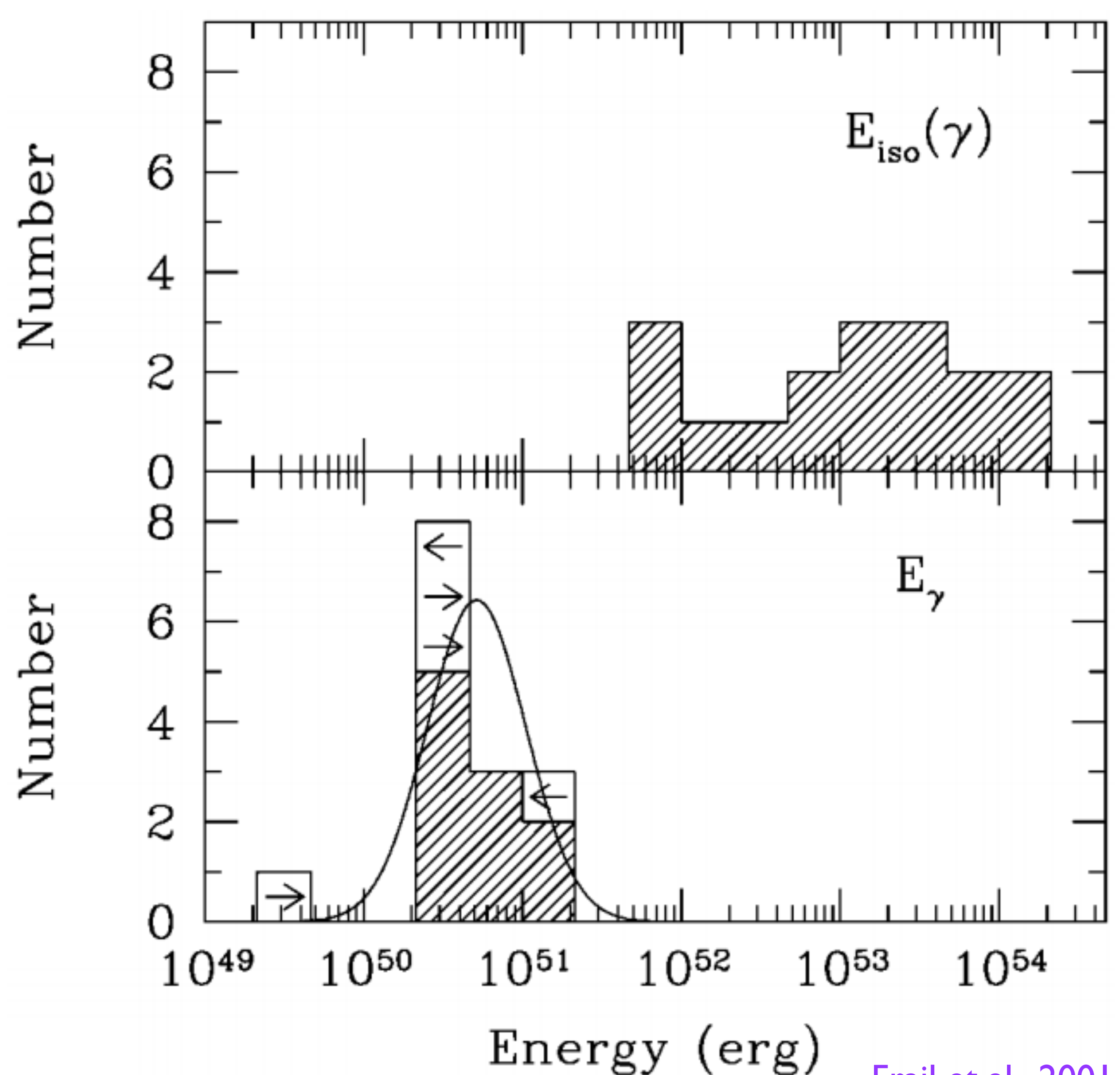
$$t_{\mathrm{jet}} = 2\left(\frac{1+z}{2}\right)\left(\frac{\theta_0}{0.2}\right)^4 E_{52} A_*^{-1}\ \mathrm{days}$$

Chevalier & Li 2000



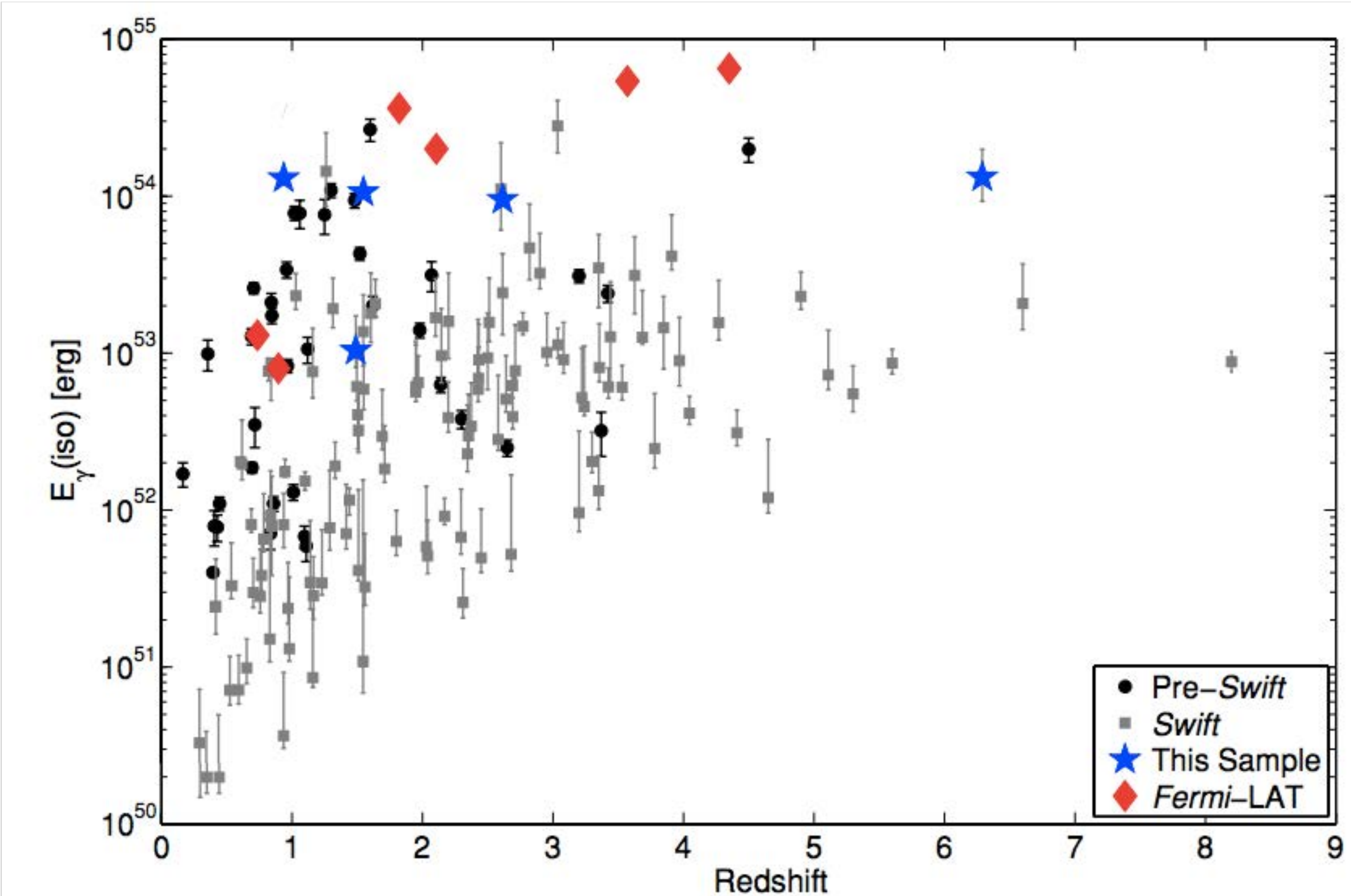
Harrison et al. 1999

Energetics - Pre-*Swift* GRBs



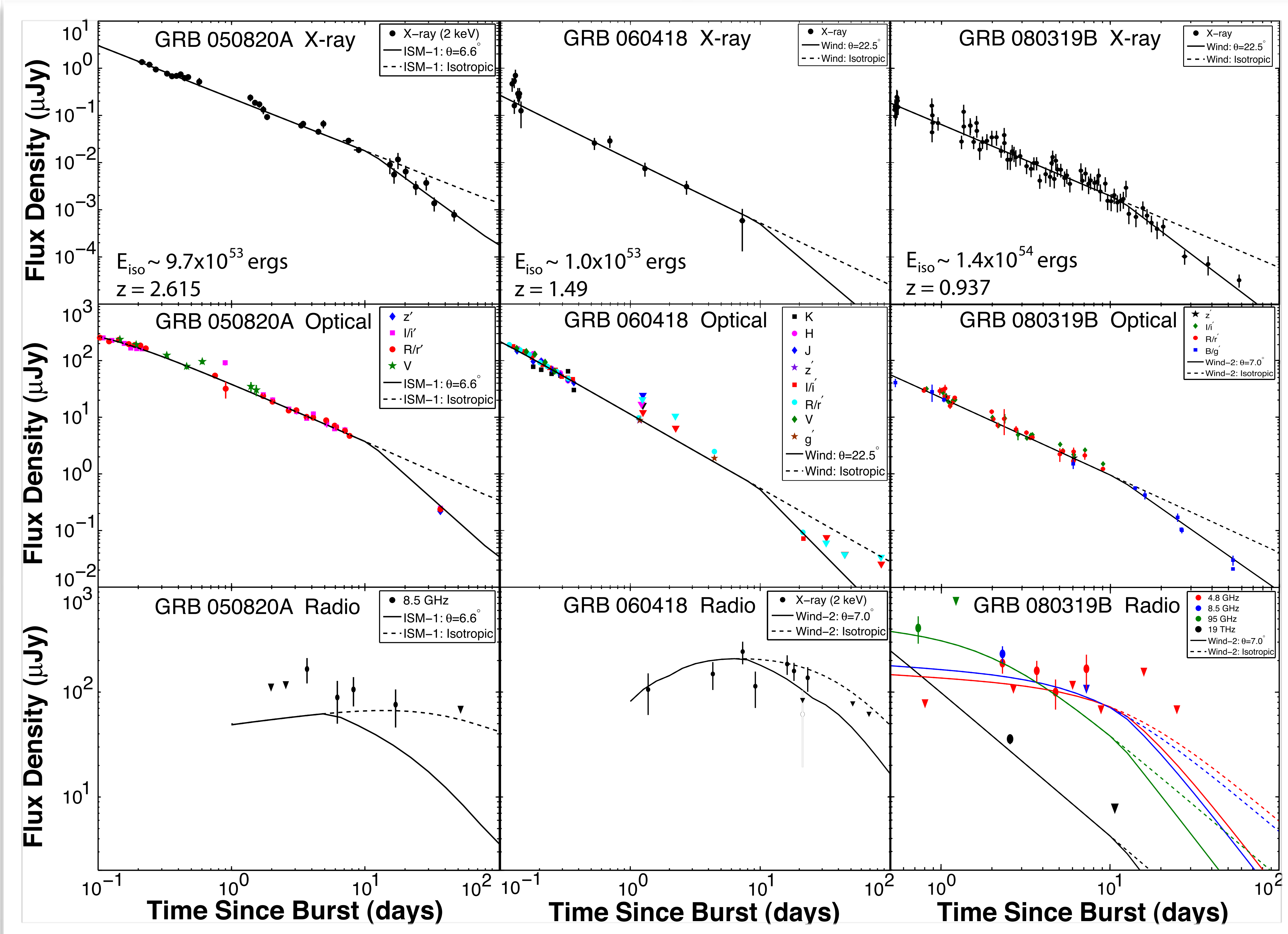
Frail et al. 2001

The brightest *Swift/Fermi* GRBs



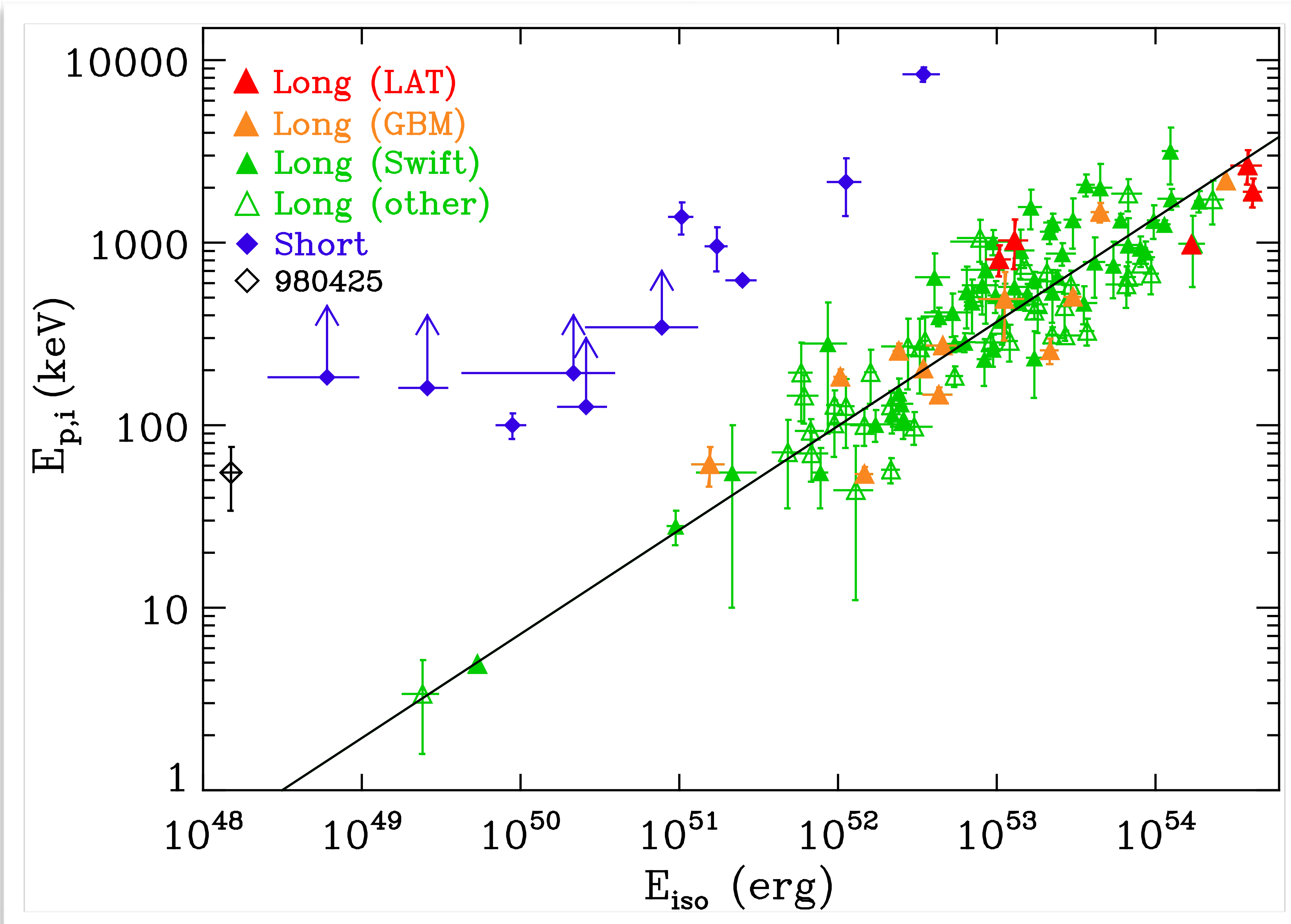
Cenko et al. 2010

The brightest *Swift* GRBs



Cenko et al. 2010

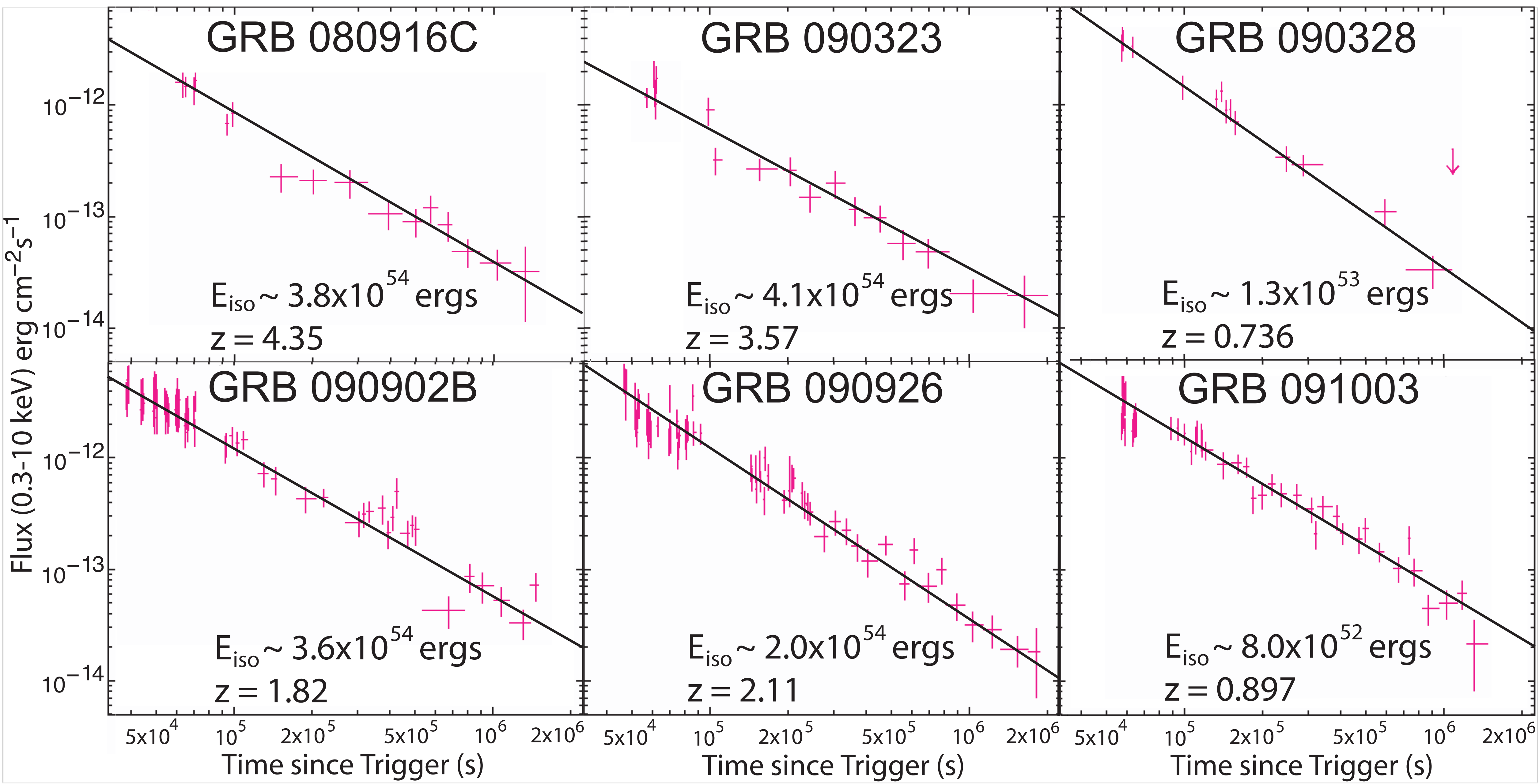
✓ Brightest ($E_{iso} \sim 10^{54}$ ergs) *Swift* bursts show an achromatic break



Long (LAT)
Long (GBM)
Long (Swift)
Long (other)
Short
980425
10000
1000
100
10
1
$E_{p,i}$ (keV)
10^{48}
10^{49}
10^{50}
10^{51}
10^{52}
10^{53}
10^{54}
E_{iso} (erg)

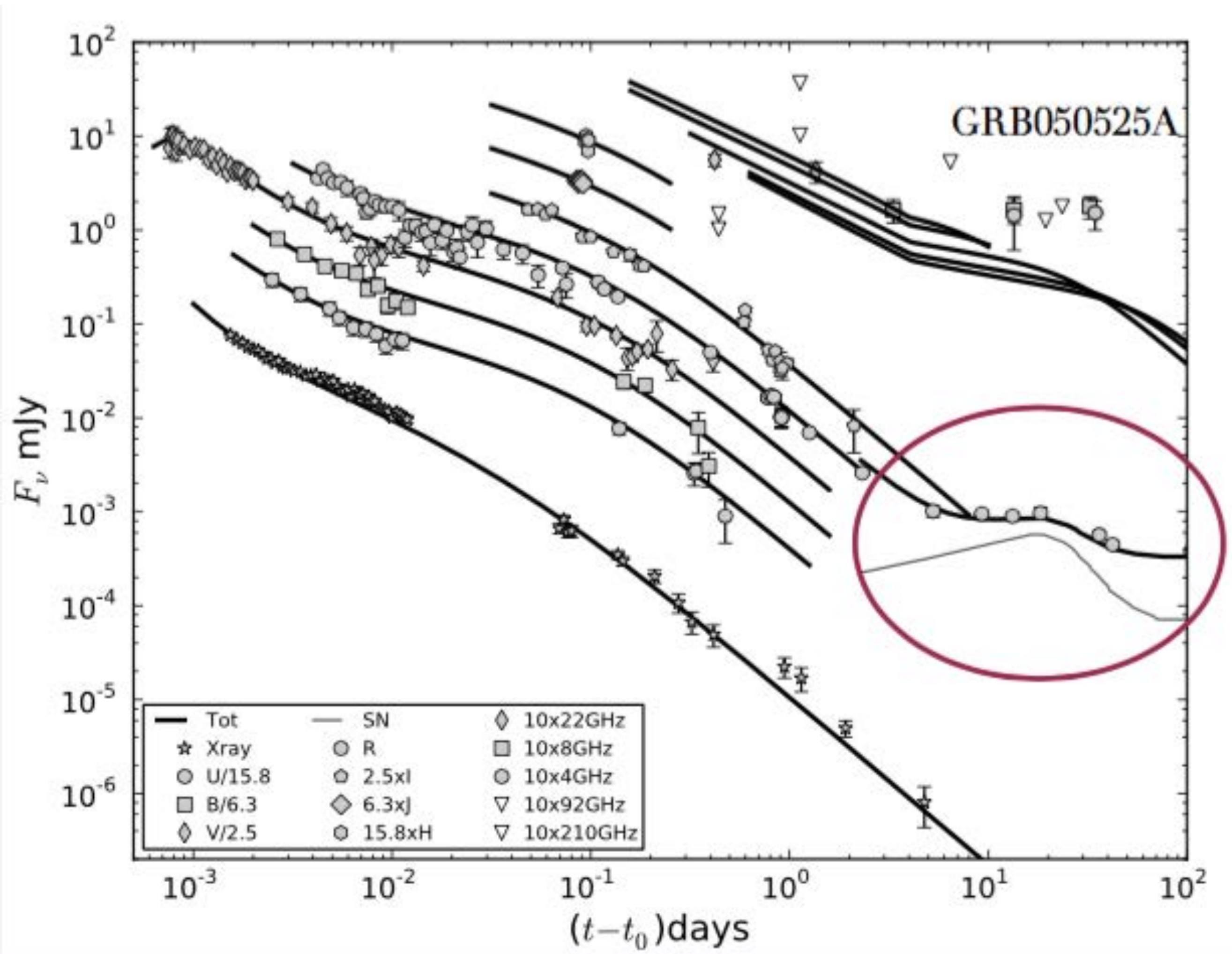
Amati 2010

The astrophysics of the most energetic bursts

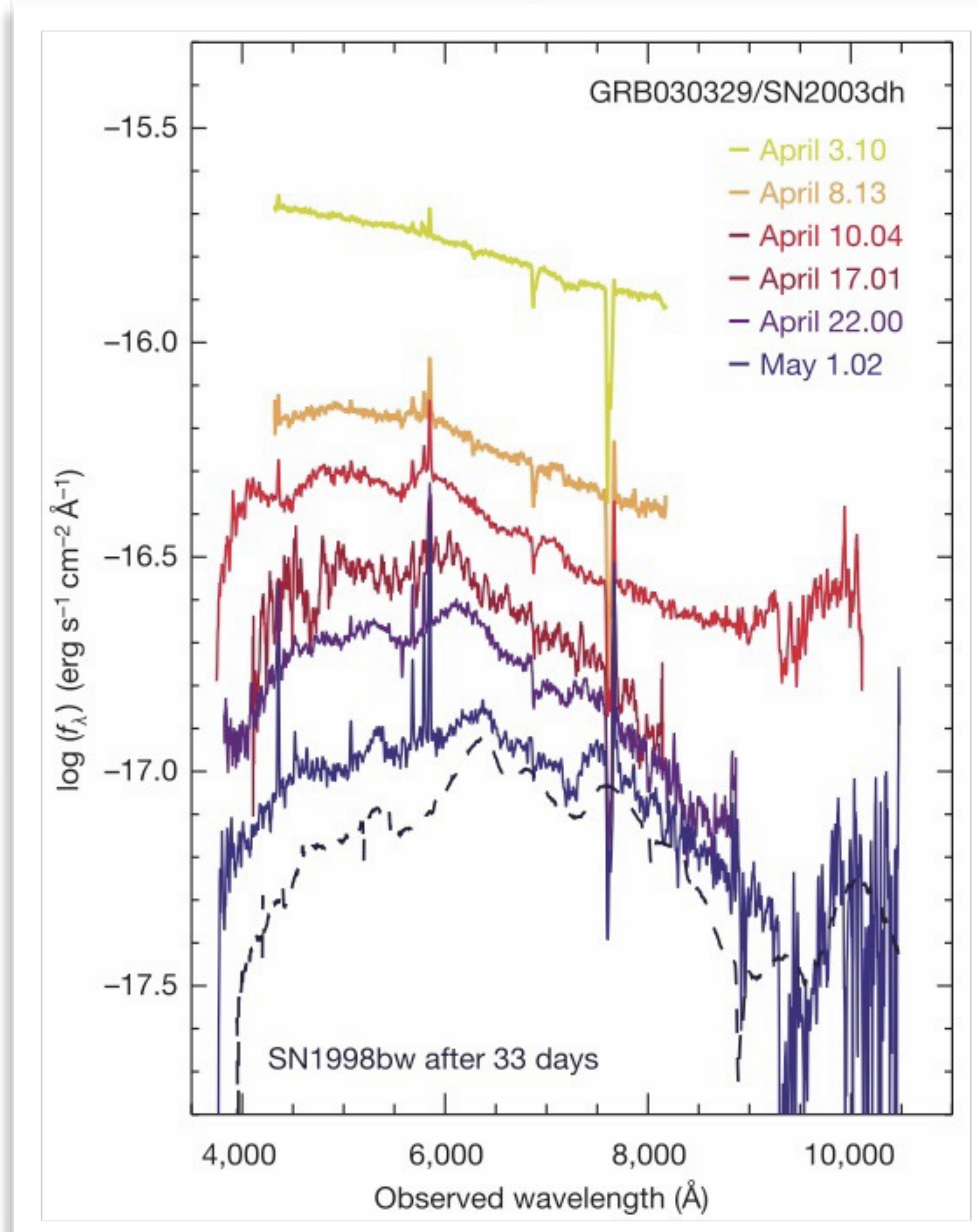


✓ *Swift* XRT light curves of *Fermi* LAT GRBs with no break

Long GRB Progenitors
Hypernovae signature



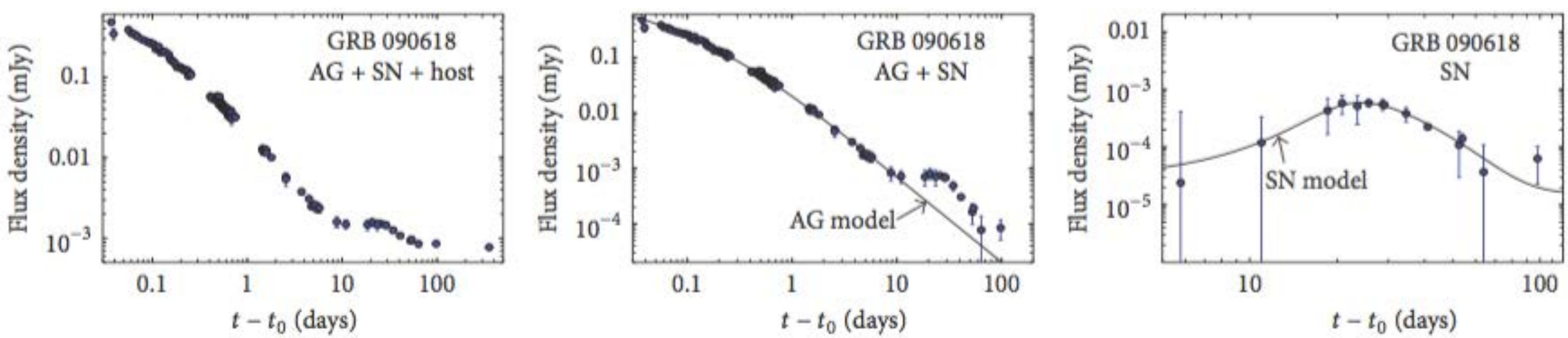
Resmi, Misra et al. 2012



Matheson et al. 2003

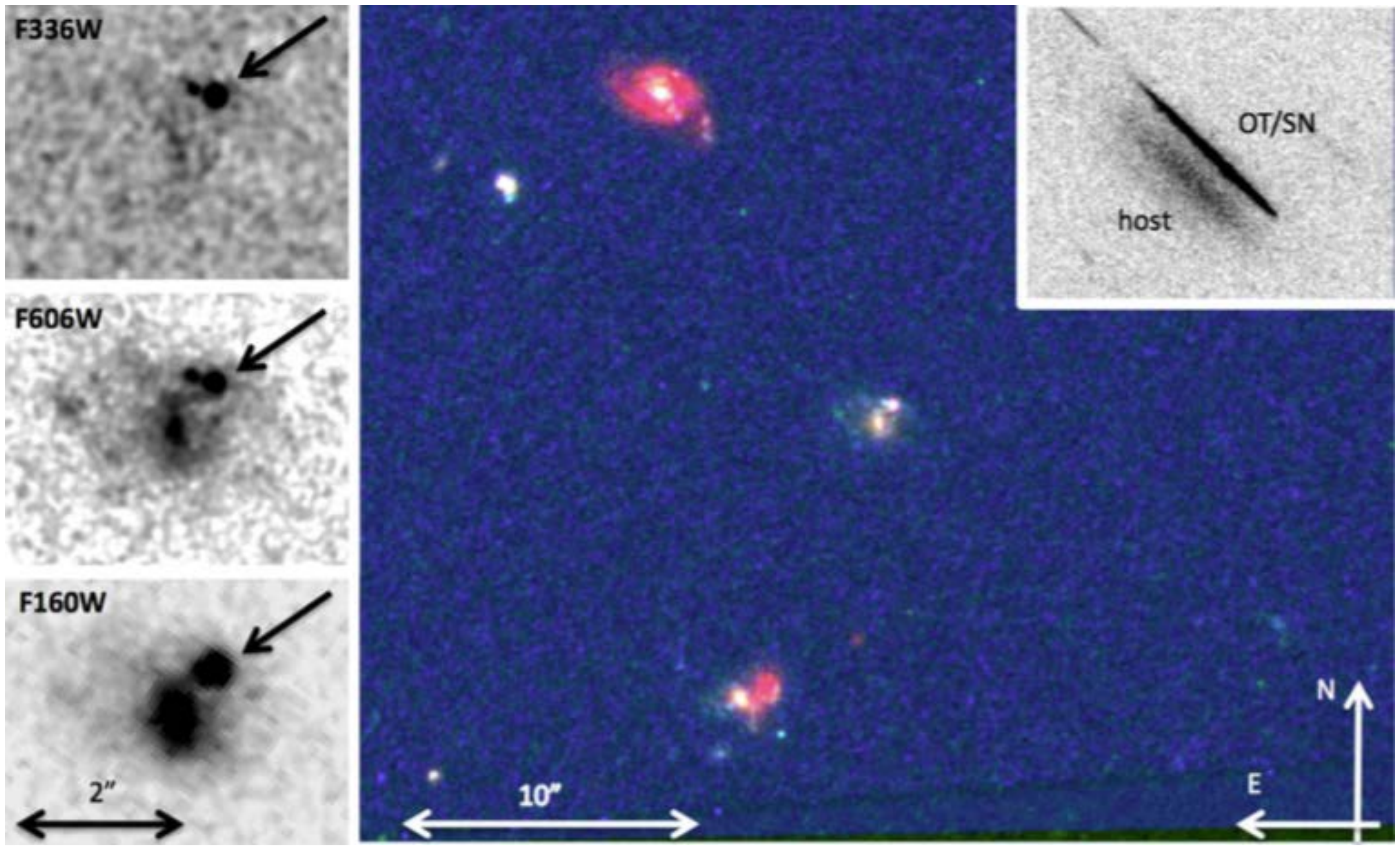
Isolating and Characterizing the SN

- Total Flux = Afterglow + SN + Host
- Afterglow: Powerlaw
- SN: 1998bw as template
  --Account for the effect of redshift in the shape of light curve and bandpass (k correction)
  --Apply a stretch factor in time and a shift in brightness
- Host: Constant

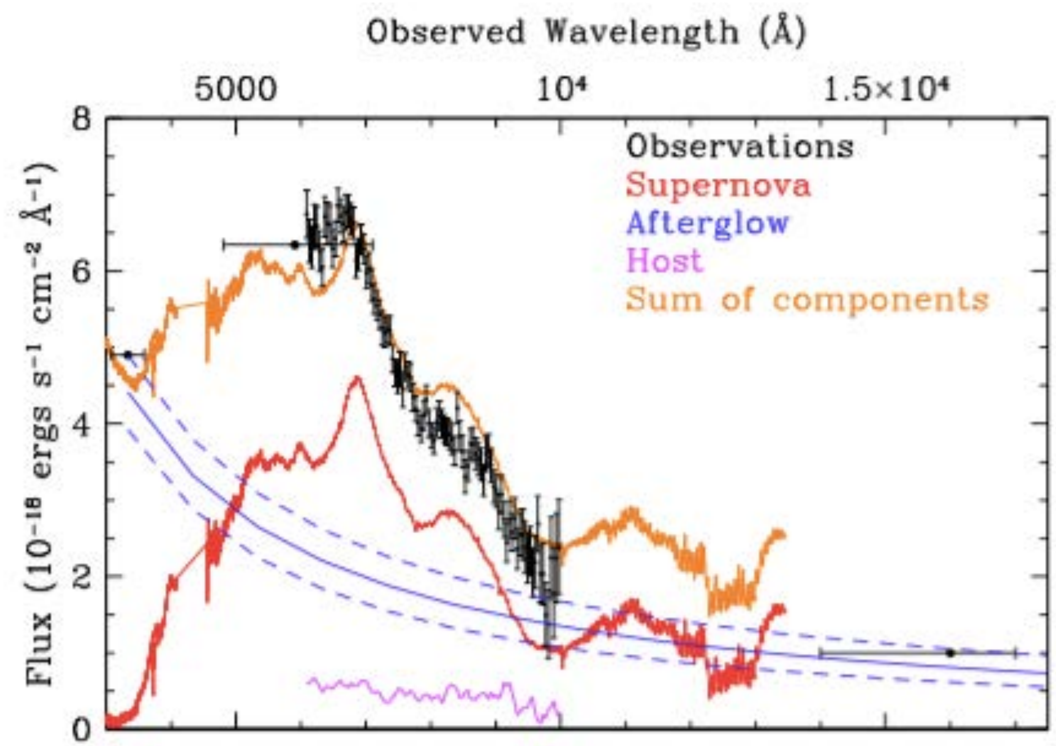


Cano et al. 2017

GRB 130427A



★Similarity of SNe from both the ***most luminous*** and ***least luminous*** GRBs suggests broadly similar progenitor stars can create GRBs across ***six orders of magnitude in*** E_{iso}



Levan et al. 2014

★GRB 130427A, at a redshift of 0.34, provides a unique opportunity to study the ***associated SN with an intrinsically extremely luminous burst***, much more luminous than any previously studied GRB-SN

★Image quality and UV capability of *HST* was used to ***separate the afterglow, SN and host***

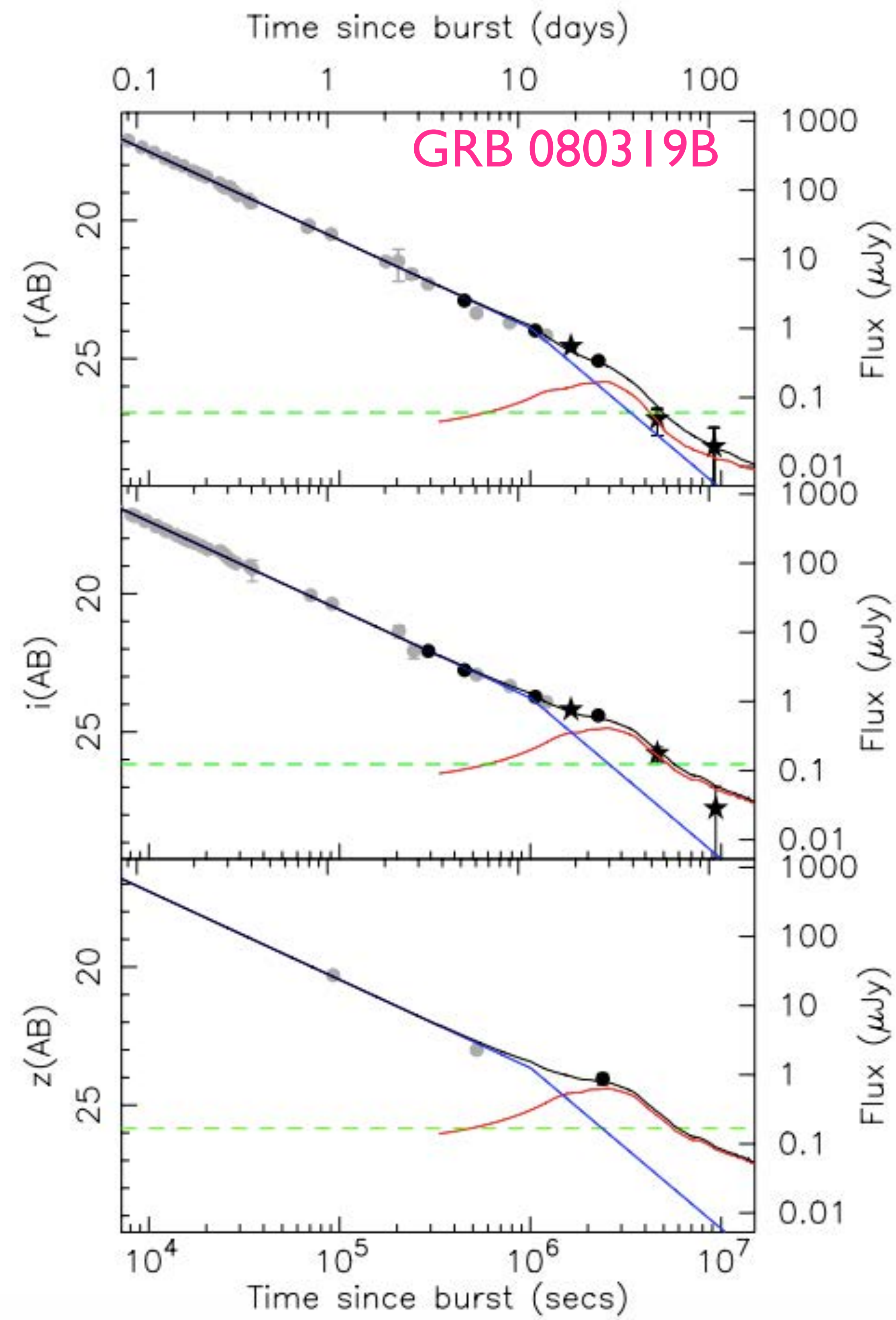
★*Broadband spectral coverage from UV to IR with a larger aperture; TMT*

Co-ordinated GRB science in TMT era

Many more photons

✓ *Missing Jet break signature in GRB afterglows - responsible for estimating the true energetics of the burst*

✓ *Spectroscopy of GRB-associated SNe - better understanding of GRB progenitors*



Tanvir et al. 2010

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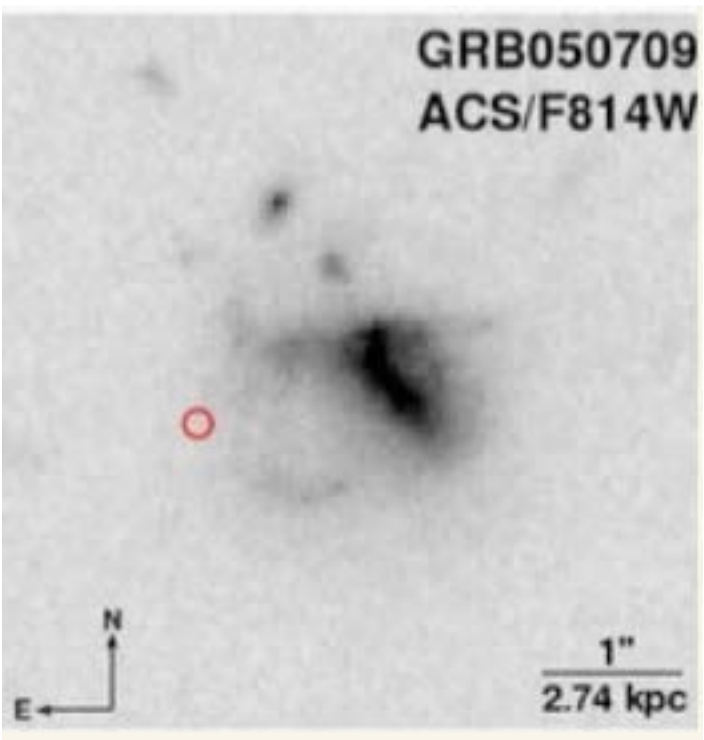
Wishlist

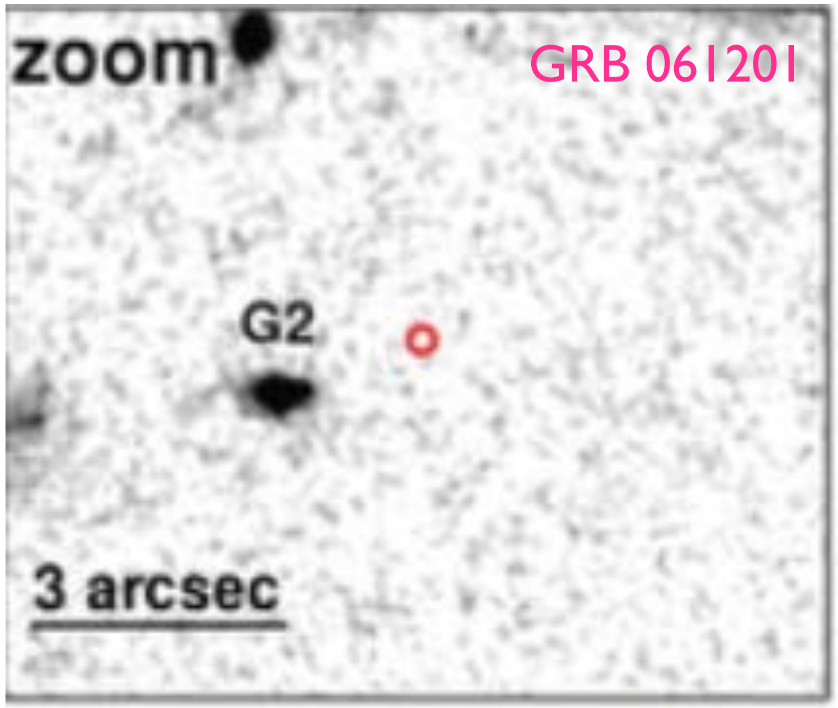
✓ *Optical afterglows of the elusive sub-class of GRBs - short GRBs, dark bursts (dust enshrouded)*

✓ *Redshift distribution of short GRBs (faint afterglows; z measurement from host)*

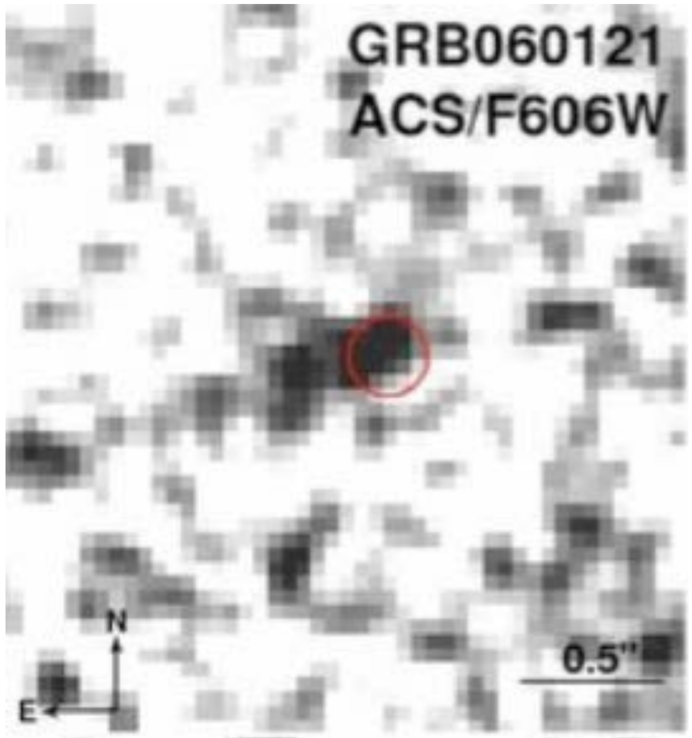
✓ *Host identification of short GRBs; faint hosts 24-27 mag at z~1*



~21 mag



No host



~26 mag

Berger et al. 2014

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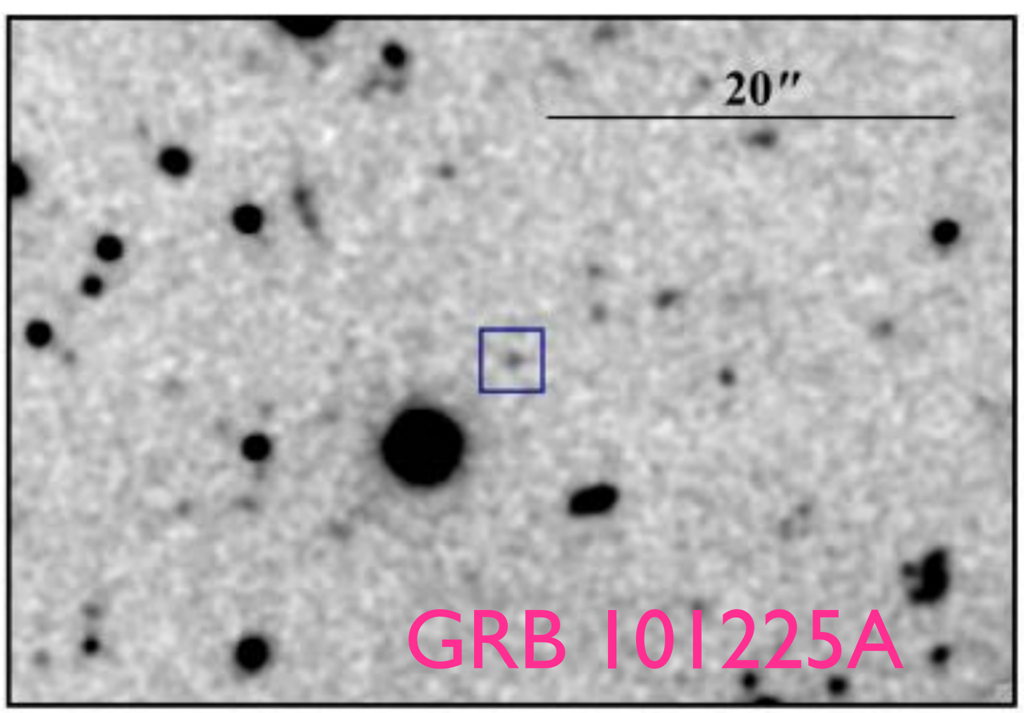
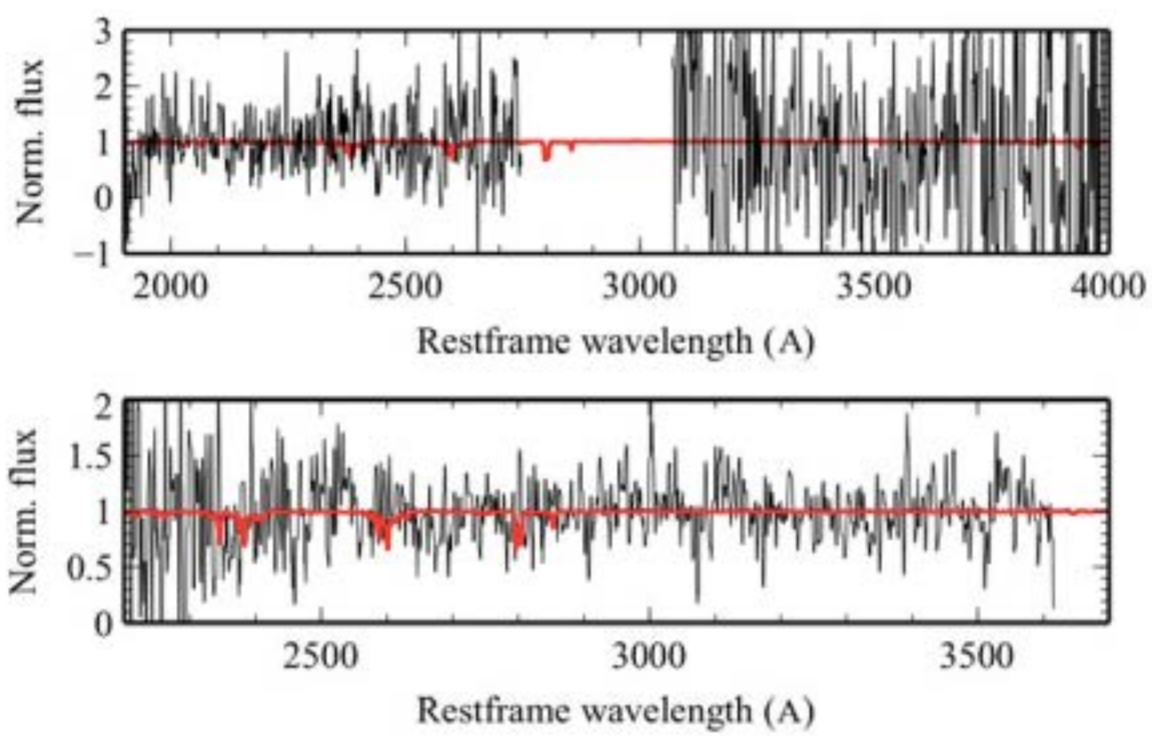
✓ *Spatially resolved host spectroscopy - probe burst environment (HROS)*





Levan et al. 2014

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✓ *Polarimetry of GRB afterglows - GRB jet structure*

✓ *EM counterparts of GW sources (short GRBs) (Masaomi Tanaka's talk)*

Desirables

✓ *Optical Broad spectral range - UV to IR (3000 to 25000 A) (WFOS)*
✓ *Medium to high resolution optical and NIR spectroscopy (IRIS)*
✓ *Response time of the telescope - power law decay - slow response with longer integration to probe the late-time (fainter) afterglows*

TMT & Friends

✓ *Adv LIGO: EM counterpart observations*

✓ *Space Variable Objects Monitor (SVOM): Provide fast reliable GRB positions; measure broadband spectral shape of the prompt emission (from visible to MeV)*

✓ *SKA: Fast transient mode, radio bright GRBs*

✓ *LSST/ZTF: Picking optical transients*

✓ *AstroSat: New transients*