David Band’s Contributions to GRB Science with BATSE

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BATSE observations of gamma-ray burst spectra. I - Spectral diversity (Band ’93)
The Band ‘GRB’ Function:

- **Photon Number Flux:**
  - Unique function of two power laws, continuous and smoothly joined.
  - Originally parameterized with an e-folding: $E_0$
  - Empirical only; no direct physical motivation.

### Equation for $f(E)$

$$f(E) = \begin{cases} A(E/100)^{\alpha} e^{-(E/100)^{2+\alpha}} & \text{if } E < \frac{(\alpha - \beta)E_{\text{peak}}}{(2 + \alpha)} \equiv E_{\text{break}}, \\ A \left[ \frac{(\alpha - \beta)E_{\text{peak}}}{100(2 + \alpha)} \right]^{\alpha - \beta} \exp(\beta - \alpha)(E/100)^{\beta} & \text{if } E \geq \frac{(\alpha - \beta)E_{\text{peak}}}{(2 + \alpha)}. \end{cases}$$
Why is the Band Function so Useful?

~8900 spectral fits from 350 bright BATSE GRBs

- It has several useful limits:
  - If Beta -> - Infinity: PL + Exponential
  - If Alpha -> Beta: Single PL
  - If Alpha -> -2/3: OT Synchrotron
  - If Alpha -> -3/2: Cooling spectrum
  - If Synchrotron: Beta can be related to electron distribution

- Statistically, BATSE spectra favor 4 parameters, no more (additional parameters poorly determined).

- It fits a huge number of spectra!
BATSE observations of gamma-ray burst spectra. 2: Peak energy evolution in bright, long bursts (Ford & Band et al. ’95)

• Introduced:
  – Peak in $\nu F_{\nu}$
  – $E_{\text{peak}} = (2+\beta)E_0$

• $E_{\text{peak}}$ evolution:
  – Hard-to-soft
  – Tracking pulse

• Technique of using Model Variances, rather than Data Variances in spectral fitting -> SOAR
What about $E_{\text{peak}}$?

- $E_{\text{peak}}$ parameterization:
  - Energy of peak in $E_F$
  - Indicates peak of gamma-ray SED

- Narrow distribution: intrinsic or instrumental?

- Some fits unbounded: $(\beta > -2)$ $E_{\text{peak}}$ is actually only a break; true $E_{\text{peak}}$ must be higher (or infinite power!)

- Red-shift? Cosmological + Bulk Lorentz Factor

Kaneko et al. 2005
Spectral Line Detectability:

  - Describes a framework to determine consistency if BATSE does not detect Ginga-like lines
  - BATSE is sensitive enough to detect Ginga-like lines
  - No significant lines are found from a visual search of BATSE spectra
  - What is the probability of seeing Ginga-like lines in actual BATSE data?
Various Other Projects:

- **BATSE spectroscopy detector calibration** (Band et al., Exp Astron '92)
  - The reference for NaI detector nonlinearity
- **On the use of V/V(max) for gamma-ray bursts** (Band ApJ '92)
  - Don’t try and fit V/V_{max} curve (it’s a statistical test)!
- **The effect of repeating gamma-ray bursts on V/Vmax** (Band ApJ ‘94a)
  - Repeaters won’t skew V/V_{max} as a test for homogeneity
- **Is there cosmological time dilation in gamma-ray bursts?** (Band ApJ ‘94b)
  - Maybe... (Norris et al. analysis not strong enough to tell)
- **Gamma-Ray Burst Spectral Evolution through Cross-Correlations of Discriminator Light Curves** (Band ApJ ‘97)
  - Usage of the auto- and cross-correlation between BATSE discriminator channels to show ubiquitous hard-to-soft evolution
Testing the Gamma-Ray Burst Energy Relationships (Band & Preece 2005)

- **Amati et al. 2002:**
  \[ E_p = C_1 \left( \frac{E_{\text{iso}}}{10^{52} \text{ ergs}} \right)^\eta_1 \]
  \[ \xi_1 = \frac{E_{p,\text{obs}}^2}{S_\gamma} = \frac{4\pi d_L^2 C_4^2}{\left(10^{52} \text{ ergs})(1 + z)^3 \right)^3} = A_1(z) \]

  - \( C_1 = 95 \text{ keV} \)

- **Ghirlanda et al. 2004:**
  \[ E_p = C_2 \left( \frac{E_\gamma}{10^{51} \text{ ergs}} \right)^\eta_2 \]
  \[ \xi_2 = \frac{E_{p,\text{obs}}^{1.429}}{S_\gamma} = f_B \frac{4\pi d_L^2 C_4^{1.429}}{(10^{51} \text{ ergs})(1 + z)^{2.429}} = f_B A_2(z). \]

  - \( C_2 = 512 \text{ keV}; f_B = (1 + \cos \theta_{\text{jet}}) \)
Consistency of the Amati Relation with BATSE $E_p$

Amati lower limit

Ghirlanda ($f_B = 1$)