David Band's Contributions to GRB Science with BATSE

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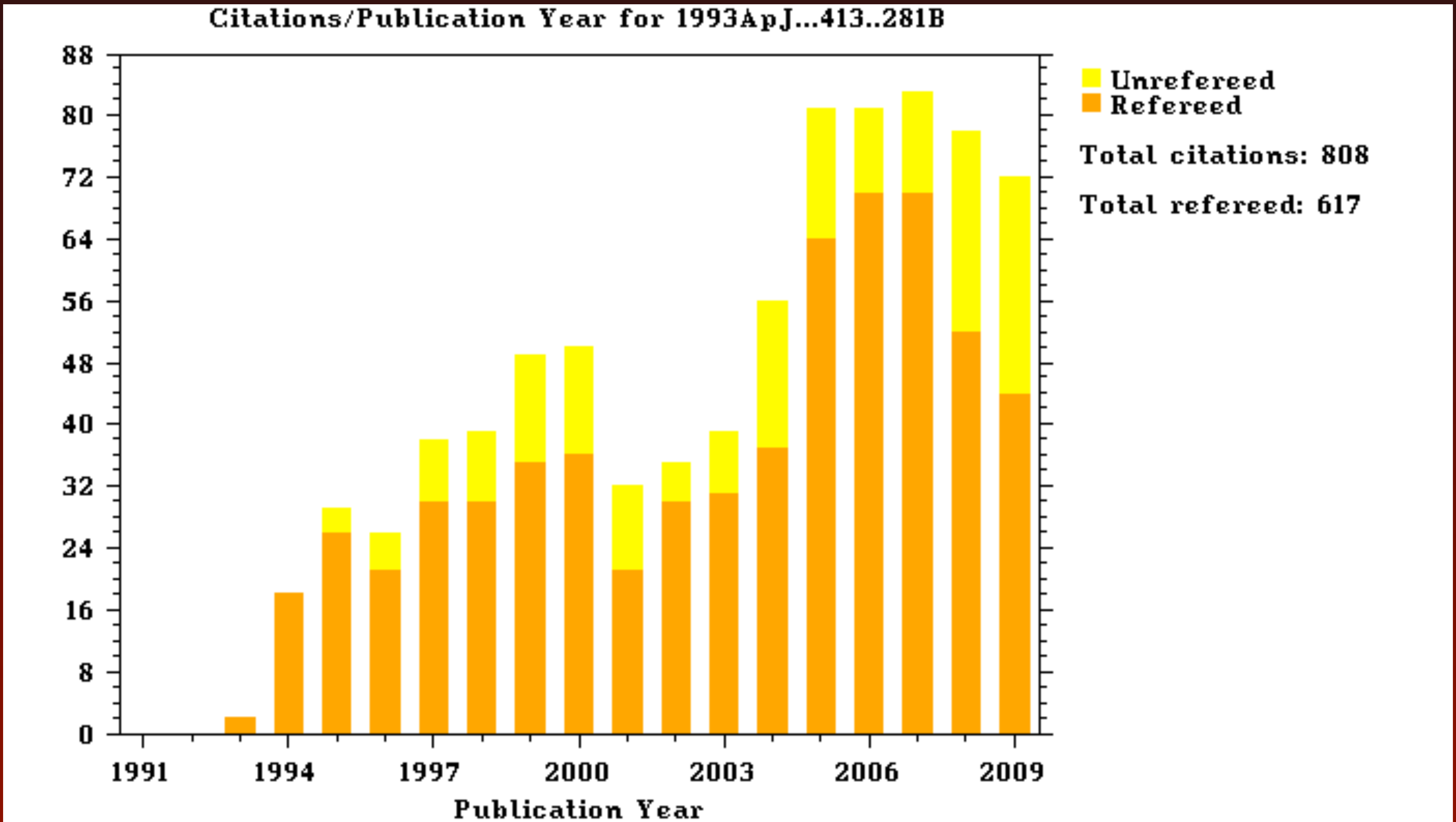
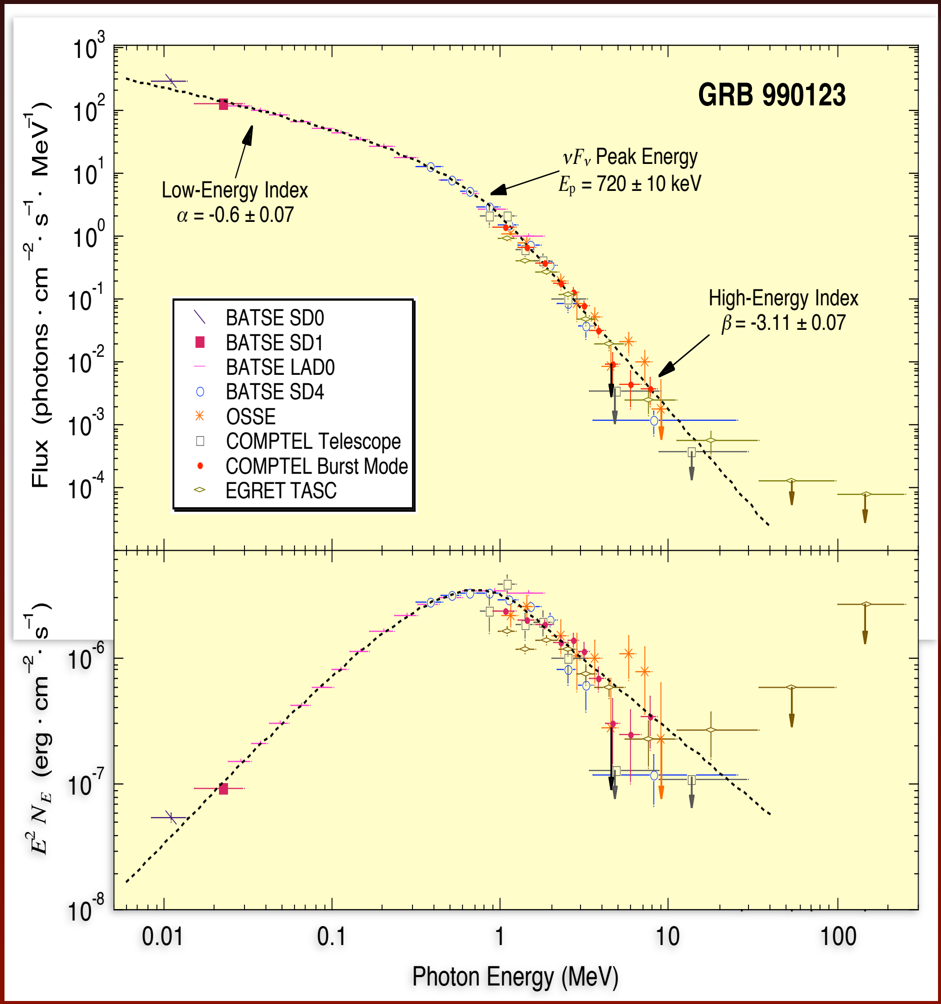
BATSE observations of gamma-ray burst spectra. I - Spectral diversity (Band '93)



The Band 'GRB' Function:



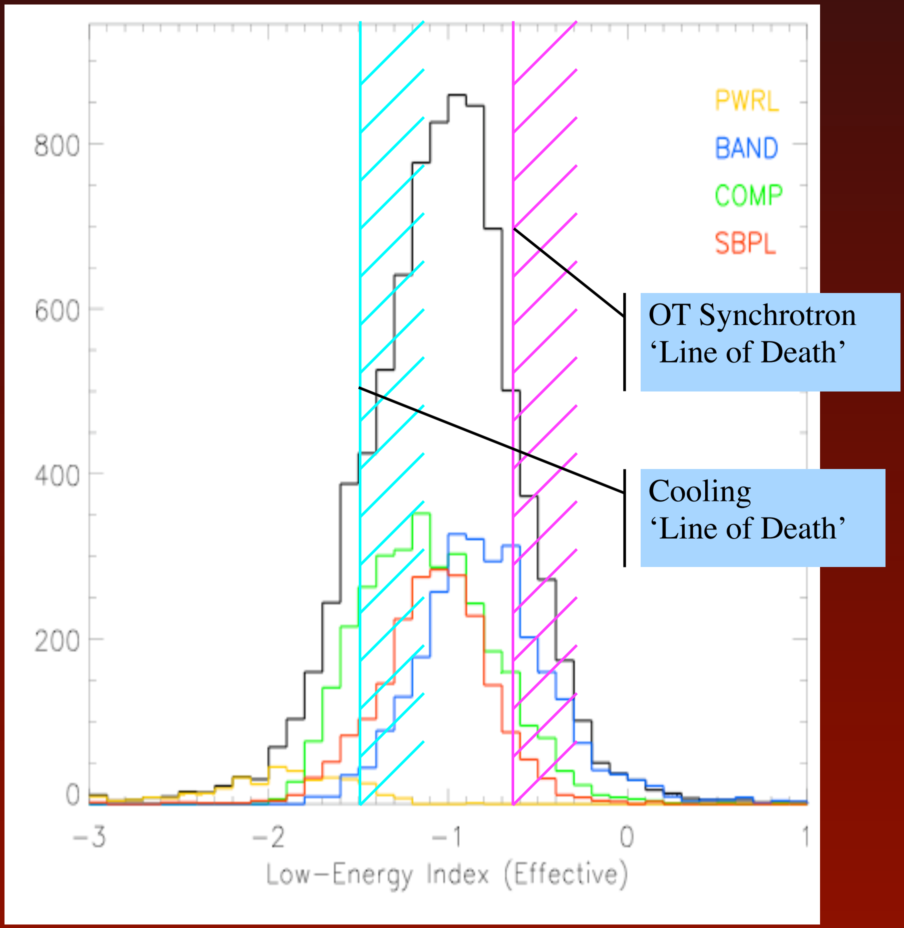
- Photon Number Flux:

$$f(E) = \begin{cases} A(E/100)^{\alpha} e^{-E(2+\alpha)/E_{\rm peak}} \\ \quad \text{if } E < \dfrac{(\alpha-\beta)E_{\rm peak}}{(2+\alpha)} \equiv E_{\rm break} \;, \\ A\left[\dfrac{(\alpha-\beta)E_{\rm peak}}{100(2+\alpha)}\right]^{(\alpha-\beta)} \exp(\beta-\alpha)(E/100)^{\beta} \\ \quad \text{if } E \geq \dfrac{(\alpha-\beta)E_{\rm peak}}{(2+\alpha)} \;. \end{cases}$$

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

Why is the Band Function so Useful?

~8900 spectral fits from
350 bright BATSE GRBs



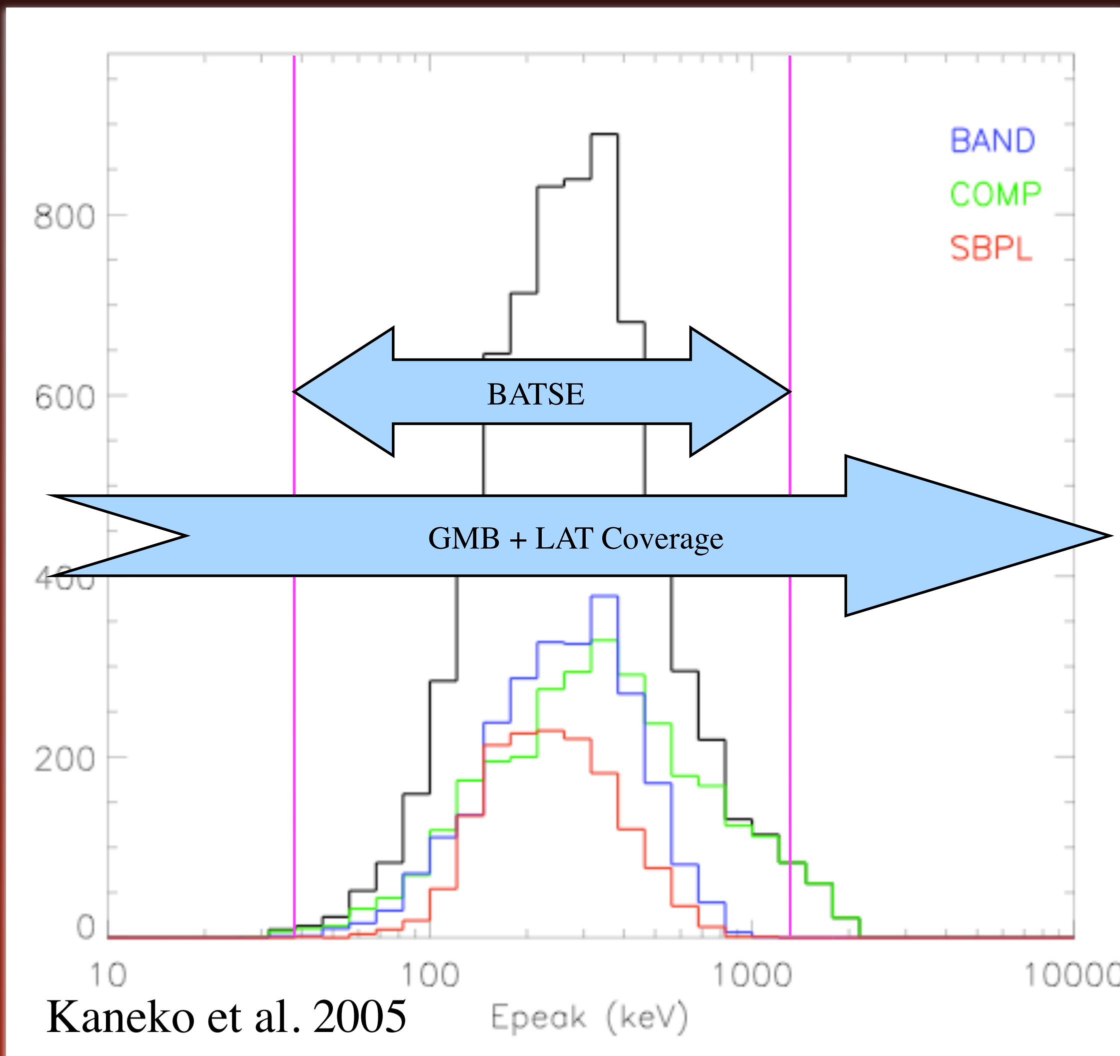
Preece et al. 1998 ApJL & Kaneko et al. 2005

- 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 nuF_{nu}
  - $E_{peak} = (2+\beta)E_0$
- E_{peak} evolution:
  - Hard-to-soft
  - Tracking pulse
- Technique of using Model Variances, rather than Data Variances in spectral fitting -> SOAR

What about E_{peak}?



- E_{peak} parameterization:
  - Energy of peak in EF_E
  - Indicates peak of gamma-ray SED
- Narrow distribution: intrinsic or instrumental?
- Some fits unbounded: (beta > –2) E_{peak} is actually only a break; true E_{peak} must be higher (or infinite power!)
- Red-shift? Cosmological + Bulk Lorentz Factor

Spectral Line Detectability:

- BATSE gamma-ray burst line search. 2: Bayesian consistency methodology (Band et al. ApJ '94)
  - Describes a framework to determine consistency if BATSE does not detect *Ginga*-like lines
- BATSE Gamma-Ray Burst Line Search. III. Line Detectability (Band et al. ApJ '95)
  - BATSE is sensitive enough to detect *Ginga*-like lines
- BATSE Gamma-Ray Burst Line Search. IV. Line Candidates from the Visual Search (Band et al. ApJ '96)
  - No significant lines are found from a visual search of BATSE spectra
- BATSE Gamma-Ray Burst Line Search. V. Probability of Detecting a Line in a Burst (Band et al. ApJ '97)
  - 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:

$$E_p = C_1 \left(\frac{E_{\rm iso}}{10^{52}\ {\rm ergs}} \right)^{\eta_1}$$

$$\xi_1 = \frac{E_{p,\rm obs}^2}{S_\gamma} = \frac{4\pi d_L^2 C_1^2}{(10^{52}\ {\rm ergs})(1+z)^3} = A_1(z)$$

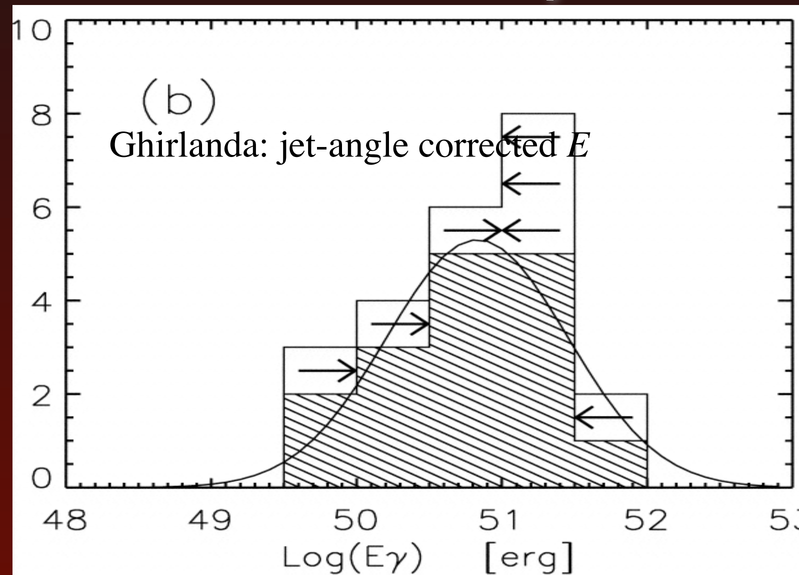
  - C_1 = 95 keV

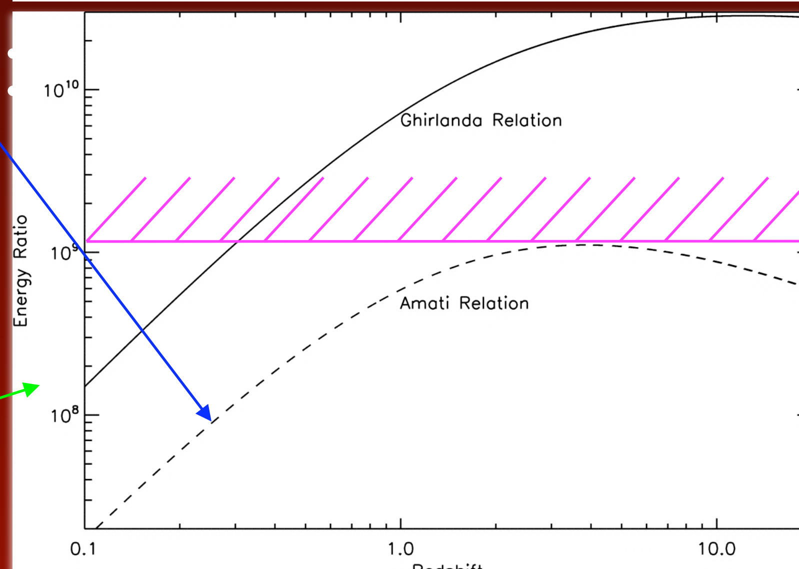
- Ghirlanda et al. 2004:

$$E_p = C_2 \left(\frac{E_\gamma}{10^{51}\ {\rm ergs}} \right)^{\eta_2}$$

$$\xi_2 = \frac{E_{p,\rm obs}^{1.429}}{S_\gamma} = f_B \frac{4\pi d_L^2 C_2^{1.429}}{(10^{51}\ {\rm ergs})(1+z)^{2.429}} = f_B A_2(z).$$

  – C_2 = 512 keV; $f_B = (1 + \cos\theta_{\rm jet})$





Consistency of the Amati Relation with BATSE E_p