

Multi-Frequency Analysis of GRB with GLAST

Hiroyasu Tajima

Stanford Linear Accelerator Center

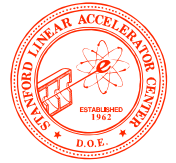
Outline

- **GRB overview.**
- **Blazar multi-frequency analysis.**
- **GRB multi-frequency analysis.**
- **Some model calculations.**

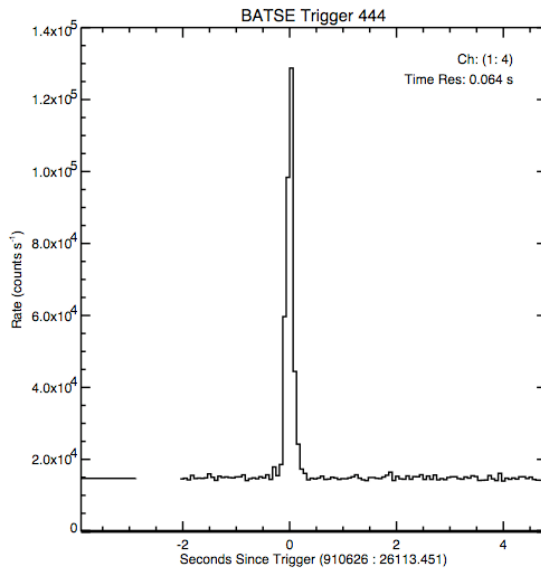
August 19, 2004
GLAST Science Talk
SLAC



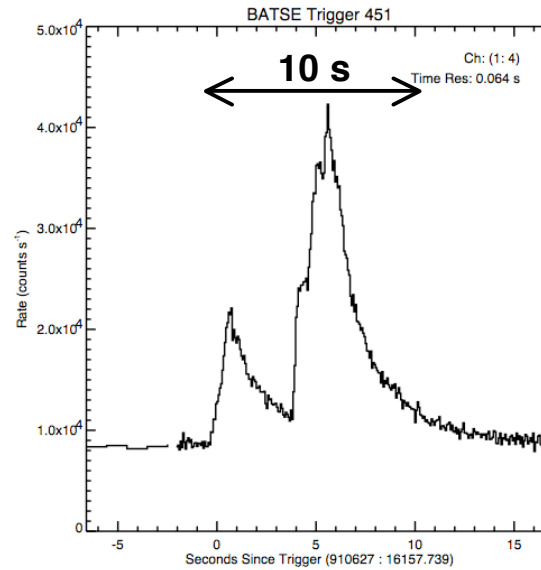
Gamma-Ray Bursts (GRB)



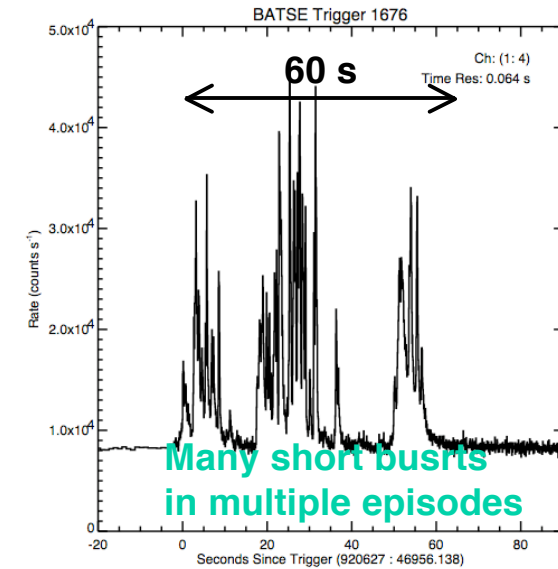
- Diverse time variability



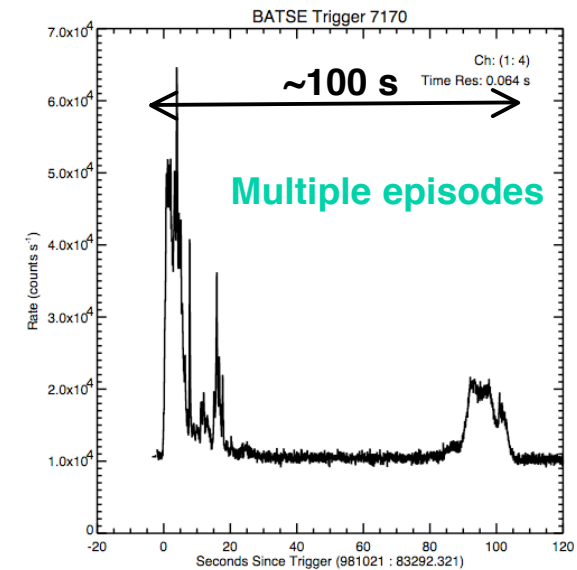
Short (0.4s) burst



Double peaked



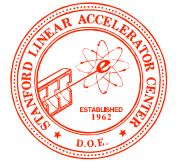
Many short bursts
in multiple episodes



Multiple episodes

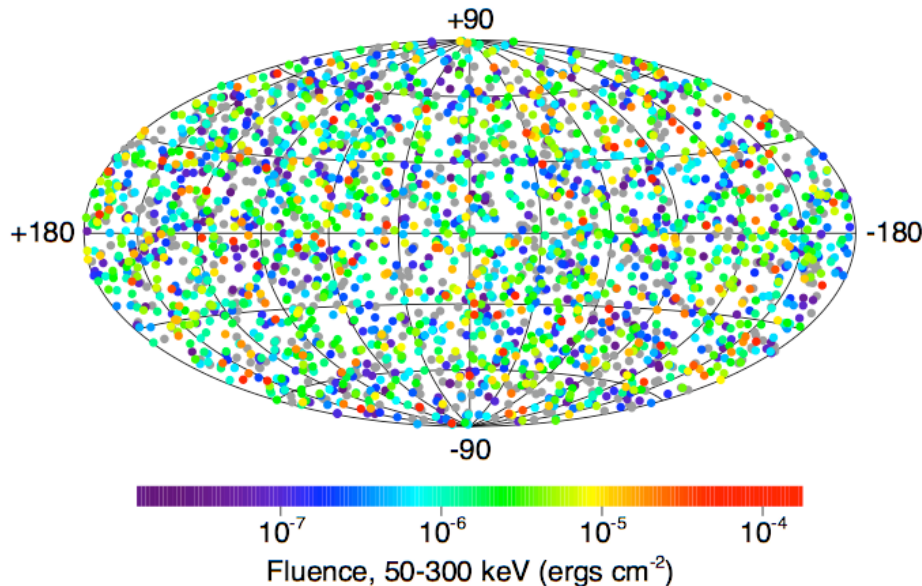


GRB Properties

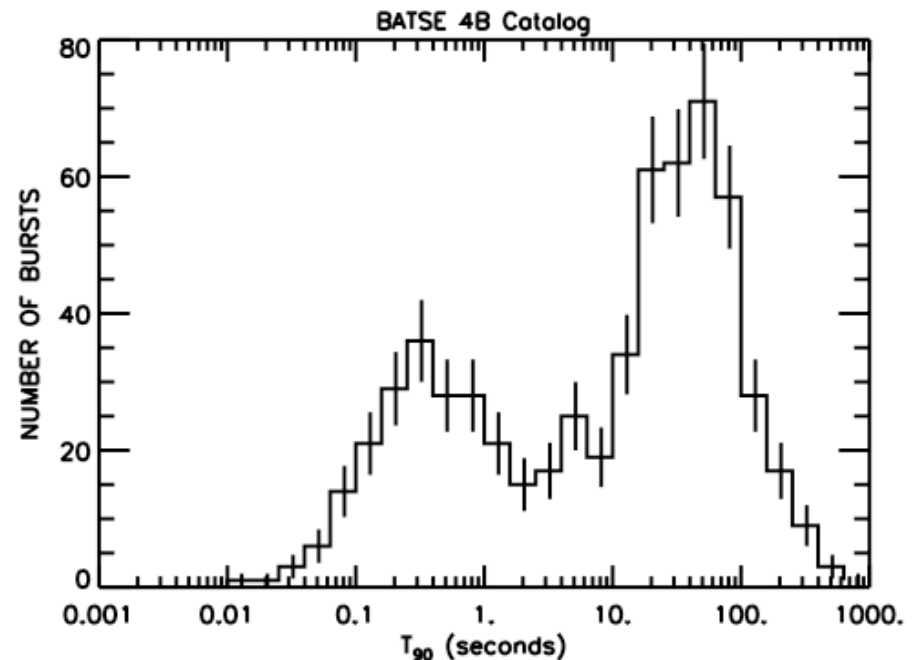


- **Isotropic spatial distribution: cosmological origin.**
- **Two categories of GRBs: “long” and “short”.**
 - **Afterglow of “long” GRBs facilitates extensive studies in optical and radio band.**
 - Leading candidate: Hypernova
 - **“Short” GRBs remain mystery.**

2704 BATSE Gamma-Ray Bursts



Multi-Frequency Analysis of GRB with GLAST,
GLAST Science Talk, SLAC, AUG 19, 2004

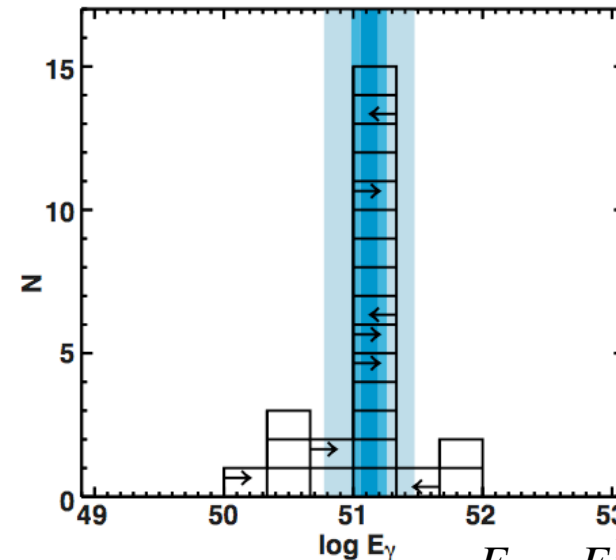
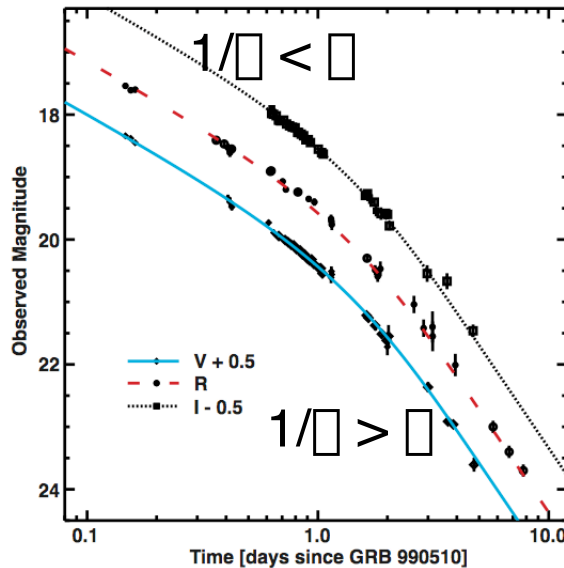
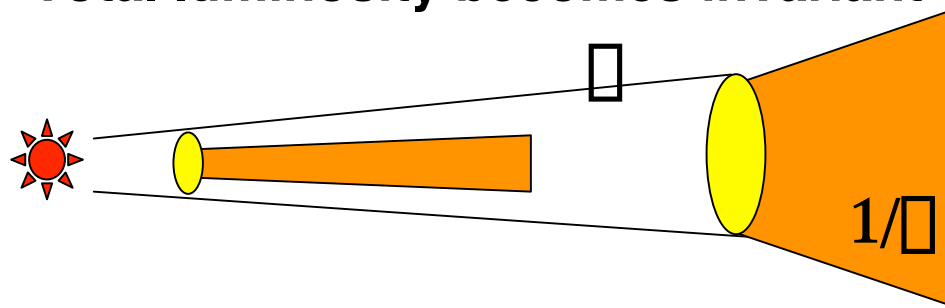




GRB Jet



- **Collimated relativistic outflow**
 - Natural interpretation for steepening of light curve.
 - Total luminosity becomes invariant with jet model.



$$E_{\square} = E_{\square}^{\text{ISO}} \cdot \square^2 / 2$$

Multi-Frequency Analysis of GRB with GLAST,
GLAST Science Talk, SLAC, AUG 19, 2004

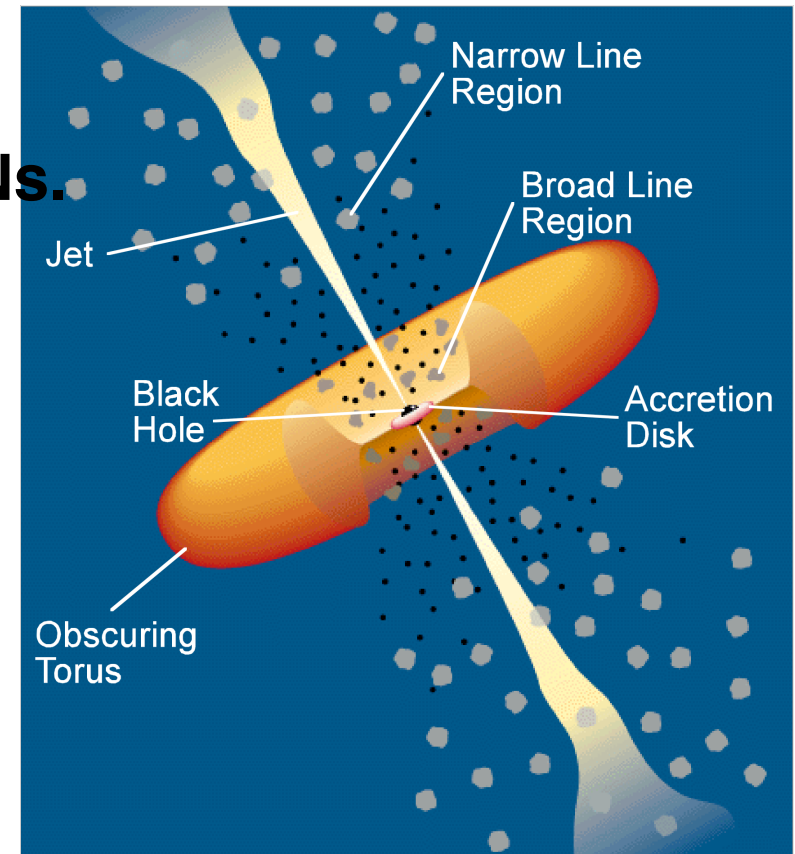
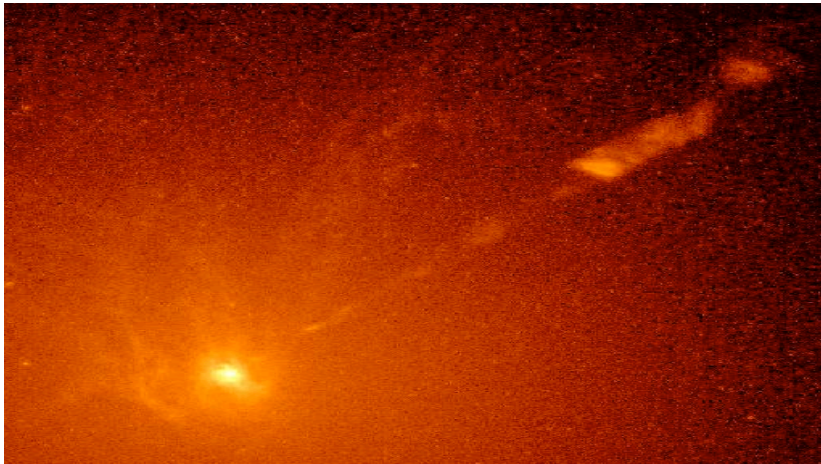


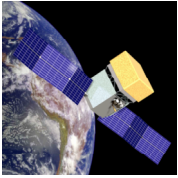
Active Galactic Nuclei (AGN)



- **Unified scheme for AGN**
 - Super-massive black holes ($10^6 - 10^{10}$ solar mass)
 - Different phenomenology is due to the orientation of jet with respect to the line of sight.
 - Quasars, seyfert galaxies, radio galaxies and blazars.
- **GLAST will detect >5000 AGNs.**

HST Image of M87 (1994)



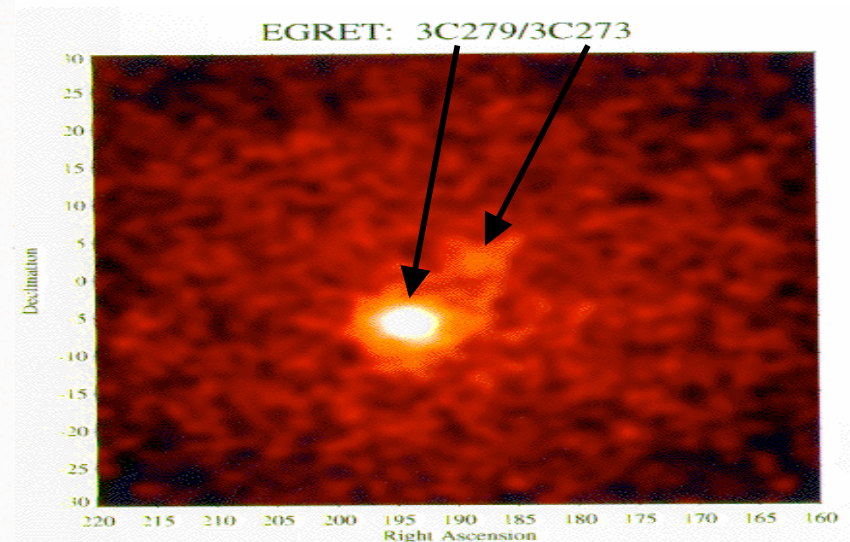
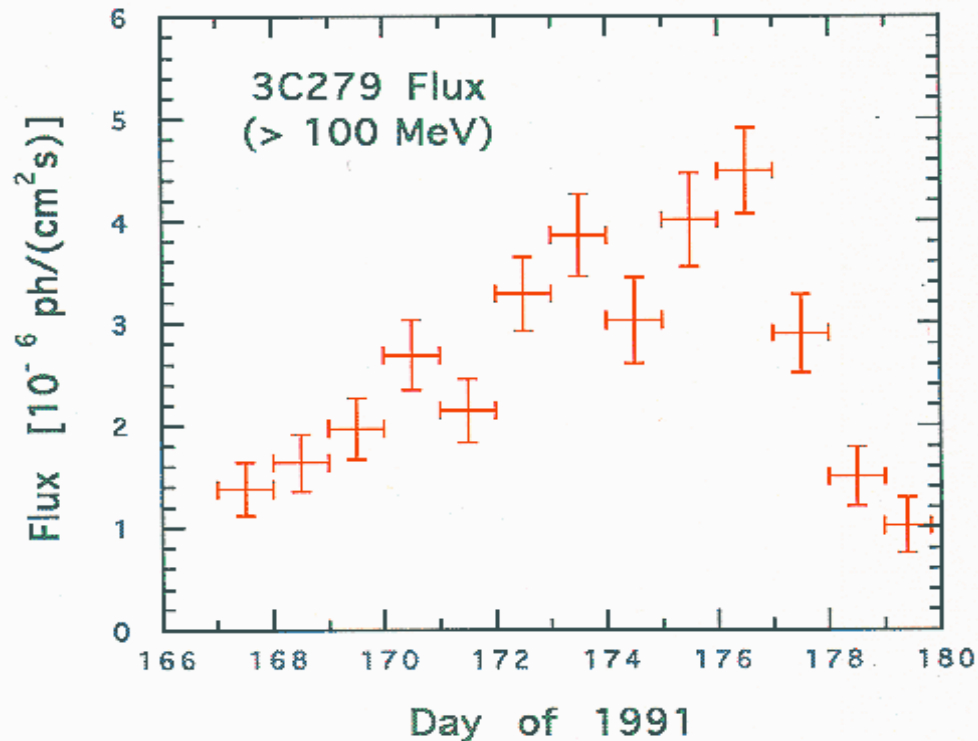


Blazar Flares

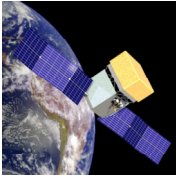


- **Blazar flux is highly variable.**
 - **Indicates very compact engine.**

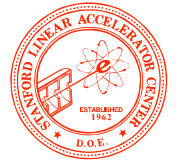
EGRET discovery image of gamma-ray blazar 3C279 ($z=0.54$) $E>100$ MeV (June 1991)



3C273 is usually brighter than 3C279.
3C279 is brighter than 3C273 when flaring.



Blazar Spectra



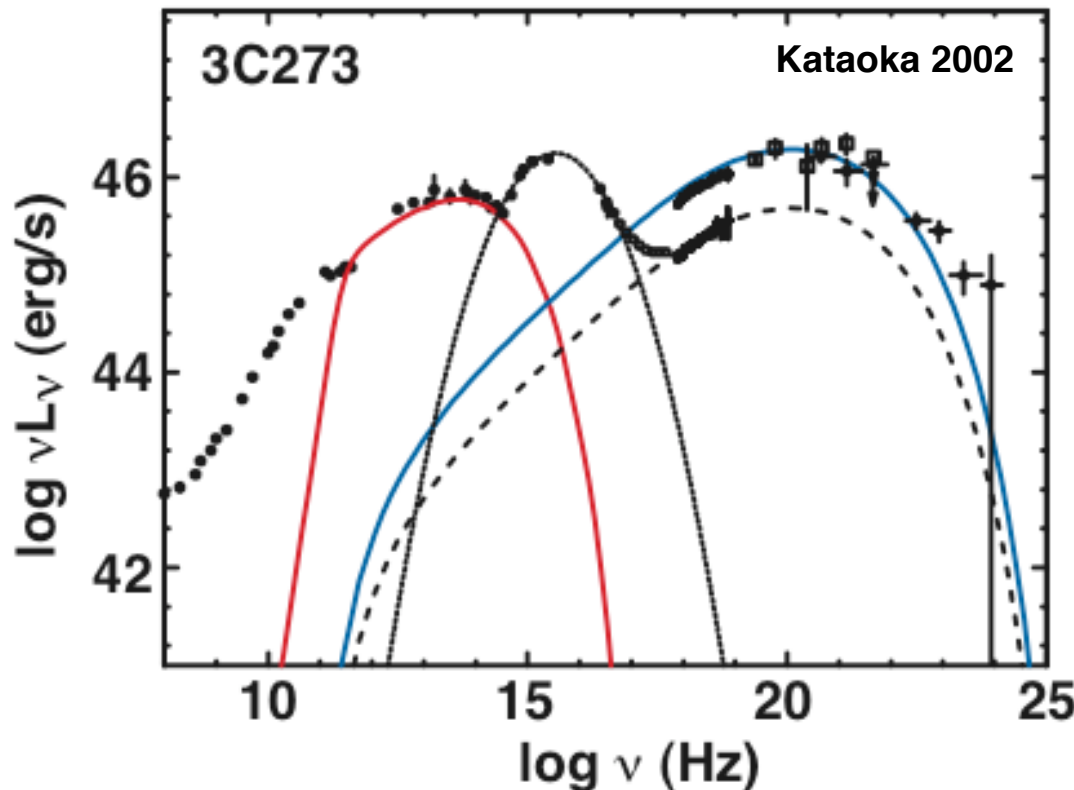
- Multi-wavelength analysis is crucial to understand photon emission mechanism in AGNs

SSC model calculations
(Synchrotron Self-Compton)

$$\nu_{LE} = 10^{13.5} \text{ Hz}, \quad \nu_{HE} = 10^{20} \text{ Hz}$$

$$L_{LE} = 10^{46.7} \text{ erg/s}, \quad L_{HE} = 10^{47.1} \text{ erg/s}$$

$$\gamma_e = \sqrt{\frac{3L_{HE}}{4L_{LE}}} = 1500, \quad \delta \approx 10$$



Multi-Frequency Analysis of GRB with GLAST,
GLAST Science Talk, SLAC, AUG 19, 2004

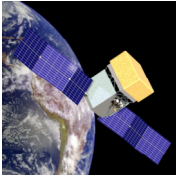
$$B = \frac{\nu_{LE} (1+z)}{3.7 \times 10^6 \gamma_e^2} = 7.2 \times 10^{11} \text{ G}$$

$$U_B = 1.1 \times 10^{12} \text{ erg/cm}^3$$

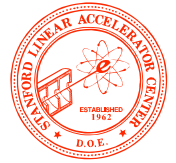
$$U_{\text{sync}} = \frac{L_{HE}}{L_{LE}} U_B = 2.84 \times 10^{12} \text{ erg/cm}^3$$

$$R = \sqrt{L_{LE} / (4 \pi c^4 U_{\text{sync}})}$$

$$t_{\text{var}} = R/c \approx 0.8 \text{ days}$$



Applying Blazar formula to GRB



- **Apply Blazar formula blindly to GRB.**

- **Assumptions:** $\nu_{LE} = 10^{20}$ Hz (≈ 400 keV), $L_{LE} = 10^{51}$ egs/s
 $\Gamma_e = 2000$, $\Gamma_{BULK} = 500$, $t_{var} \approx 0.1$ s

$$\nu_{HE} = \frac{4}{3} \Gamma_e^2 \nu_{LE} = 6.4 \text{ TeV}$$

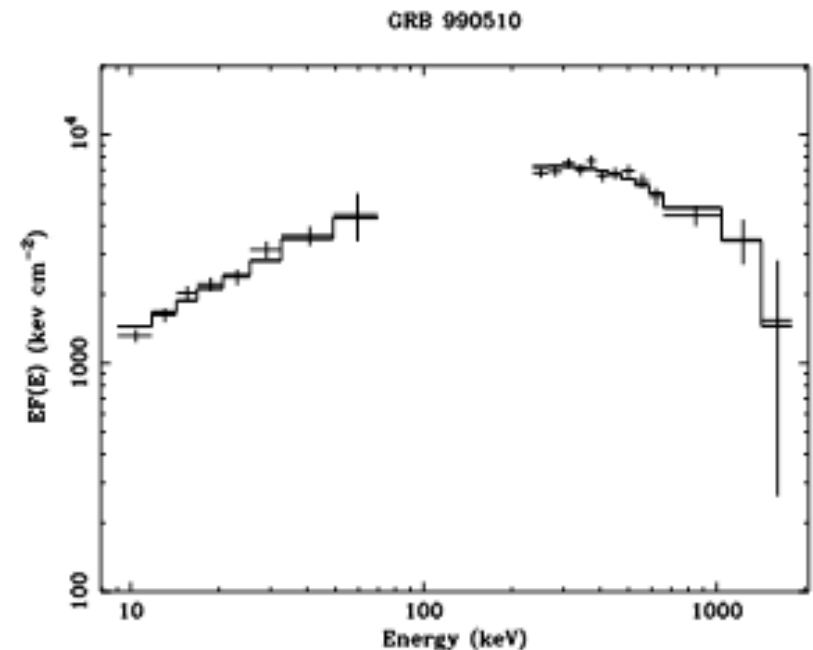
$$B = \frac{\nu_{LE} (1+z)}{3.7 \times 10^6 \Gamma_e^2} = 2.6 \times 10^4 \text{ G}$$

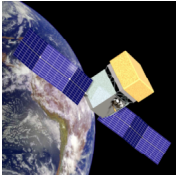
$$U_B = 8.2 \text{ erg/cm}^3$$

$$R = c t_{var} = 1.5 \times 10^{12} \text{ cm}$$

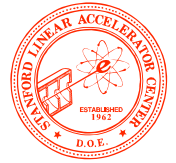
$$U_{sync} = L_{LE} / 4 \pi R^2 c \Gamma^4 = 1.9 \times 10^4 \text{ erg/cm}^3$$

$$L_{HE} = \frac{U_{sync}}{U_B} L_{LE} = 2.3 \times 10^{54} \text{ erg/s}$$

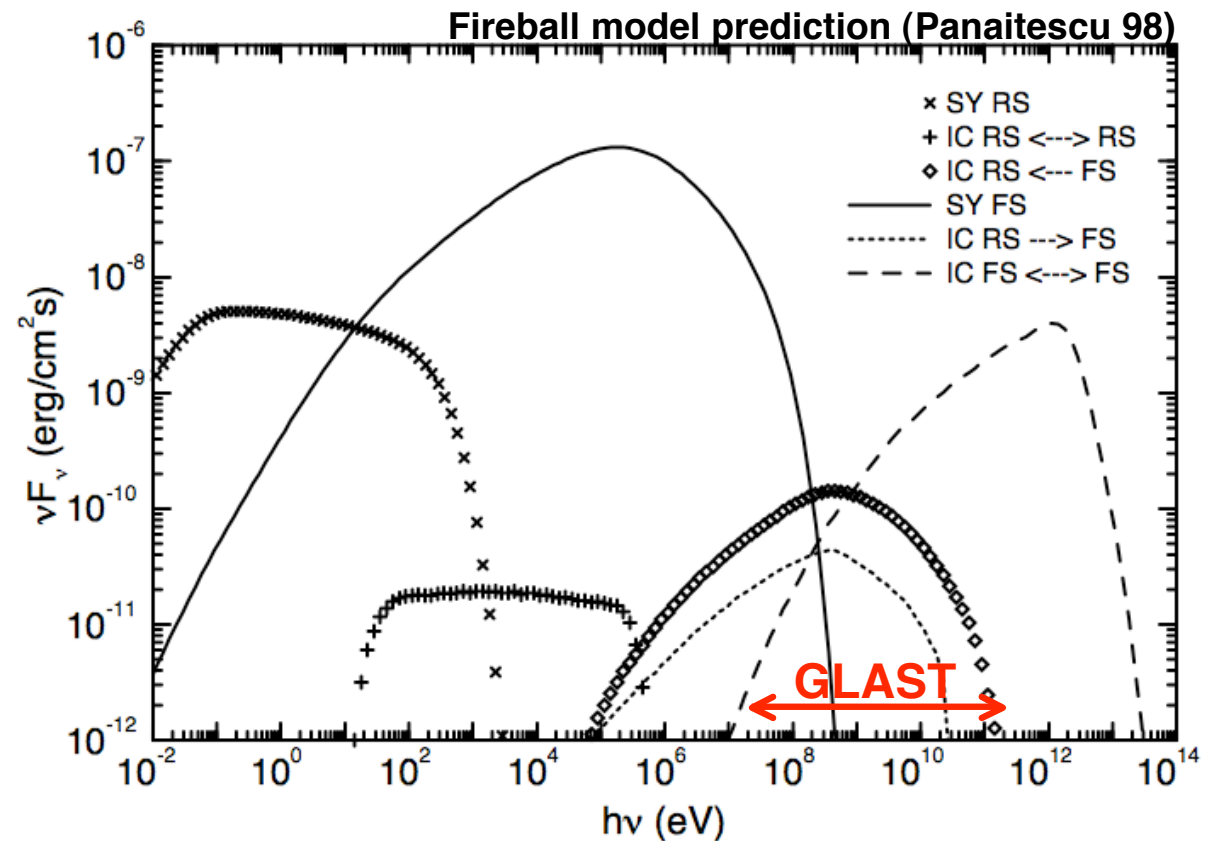




A Fireball Model Calculation

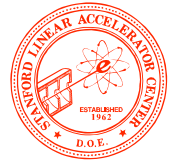


- Naïve fireball model calculation.
 - Self-absorption of low energy photons (radio and optical) and $\gamma\gamma$ interaction of high energy photons are not taken into account.





Parameter Dependence



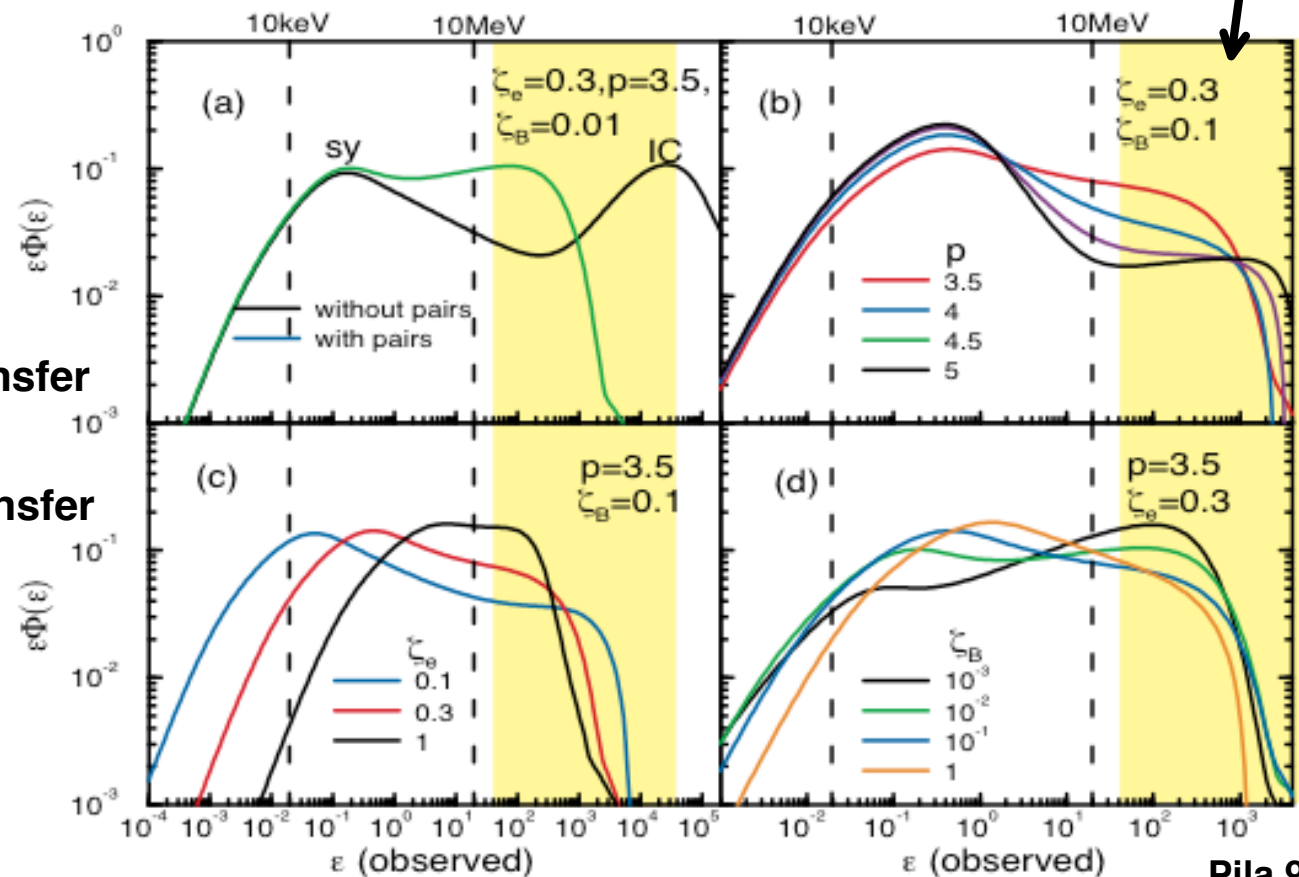
- More elaborate model calculation.
 - Pair creation taken into account.
 - Parameter dependence studied.

GLAST band

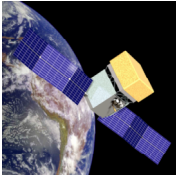
p : Fermi-acceleration index

ζ_e : fraction of energy transfer to electrons

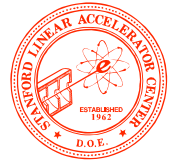
ζ_B : fraction of energy transfer to magnetic energy



Pila 97



Delayed Gamma-ray Emission



- **Pair Creation followed by CMB or CIB Compton up-scattering.**
 - **EGRET observation of delayed GeV photon from GRB.**

