GeV-TeV Lightcurve of GRB Afterglow

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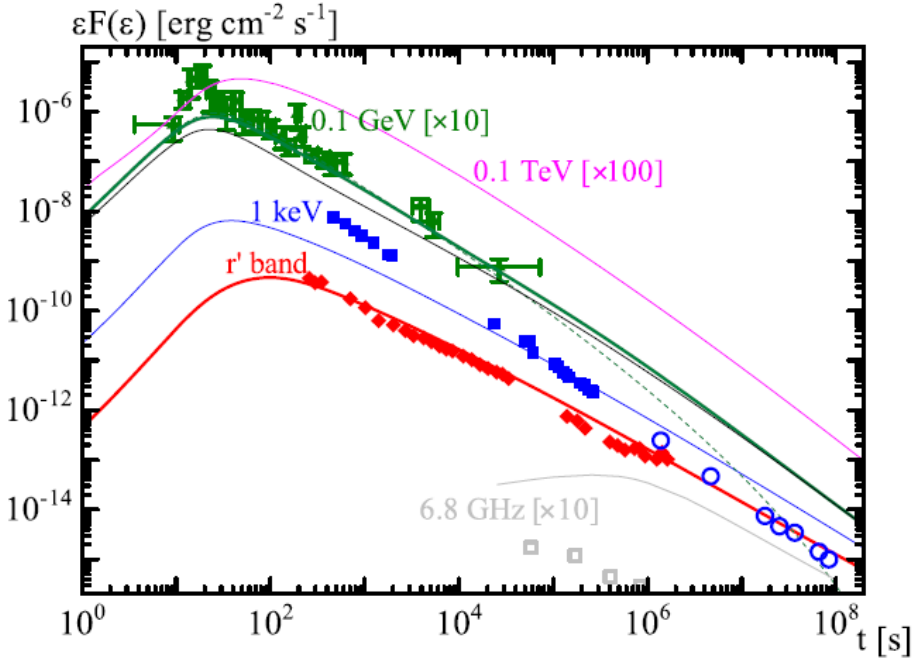

Numerical Simulations of the GRB afterglow following the full evolutions of the energy distributions of electrons and photons for a decelerating shell.

Our numerical simulations show that even if the emission mechanism is switching from synchrotron to SSC, the gamma-ray light curves can be a smooth power law, which agrees with the observed light curve and the late detection of a 32 GeV photon in GRB 130427A.

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Numerical Method (Follow the full evolutions of e, γ and shock)

Formulation

$$\frac{dM}{dt} = \frac{1}{\Gamma}\frac{dM}{dt'} = 4\pi R^2 c\beta_{\rm sh} n_{\rm ISM} m_{\rm p},$$

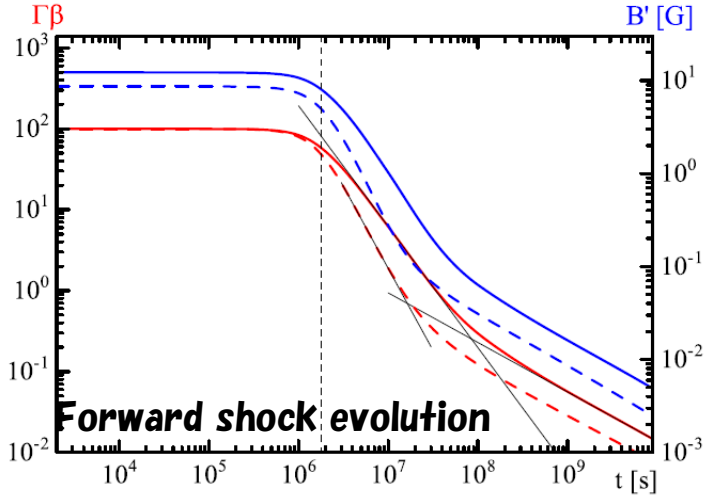
$$\frac{dE'_{\rm sh}}{dt'} = \Gamma c^2 \frac{dM}{dt'} - \frac{dE'_{\rm rad}}{dt'} - \frac{dE'_{\rm ad}}{dt'},$$

$$E_{\rm sh} = \Gamma E'_{\rm sh} = E_0 + Mc^2 - E_{\rm rad}.$$

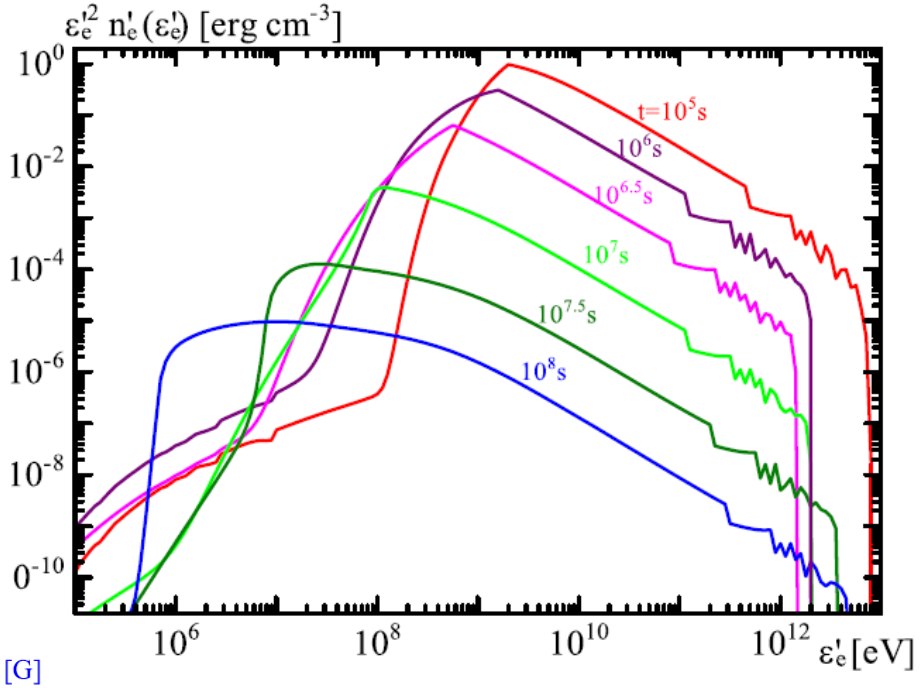
$$\frac{dE'_B}{dt'} = \epsilon_B(\Gamma - 1)c^2\frac{dM}{dt'}.$$

$$\frac{dN'_{\rm e}}{dt'} = \frac{\eta}{m_{\rm p}}\frac{dM}{dt'} = \int_{\varepsilon'_{\rm min}}^{\infty} d\varepsilon' \dot{N}'_{\rm e}(\varepsilon'_{\rm e}),$$

$$\frac{dE'_{\rm e}}{dt'} = \epsilon_{\rm e}(\Gamma - 1)c^2\frac{dM}{dt'} = \int_{\varepsilon'_{\rm min}}^{\infty} d\varepsilon' \varepsilon_{\rm e}' \dot{N}'_{\rm e}(\varepsilon'_{\rm e}).$$

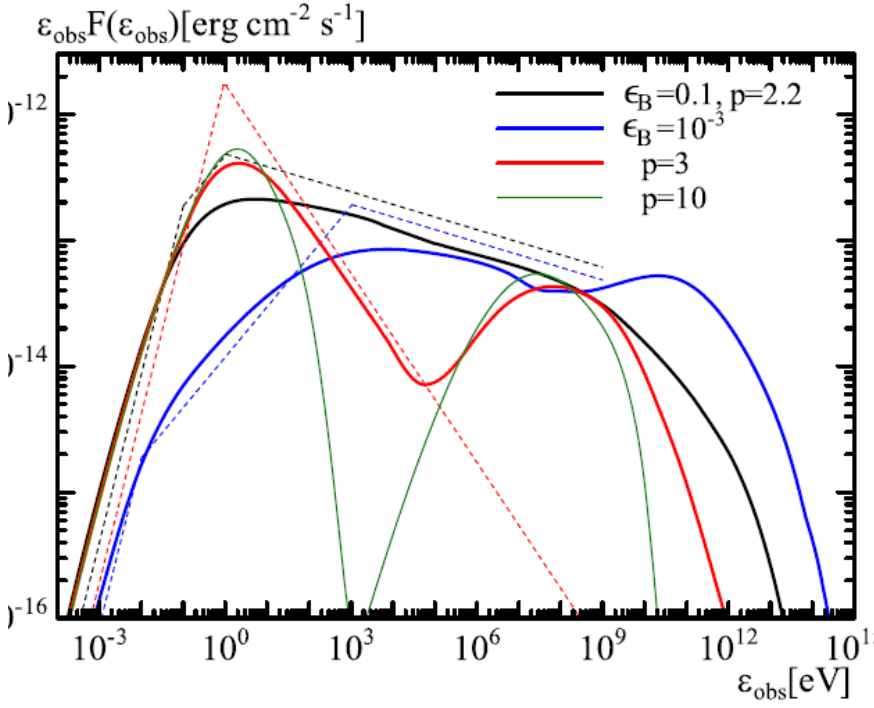


Evolution of the electron spectrum



$$\frac{\partial N_{\rm e}(\varepsilon_{\rm e})}{\partial t} = \frac{\partial}{\partial \varepsilon_{\rm e}}[(\langle \dot{\varepsilon}_{\rm e}\rangle_{\rm syn} + \langle \dot{\varepsilon}_{\rm e}\rangle_{\rm IC} + \langle \dot{\varepsilon}_{\rm e}\rangle_{\rm ad} - \langle \dot{\varepsilon}_{\rm e}\rangle_{\rm SSA})N_{\rm e}(\varepsilon_{\rm e})] + \dot{N}_{\rm e,\gamma\gamma}(\varepsilon_{\rm e}) + \dot{N}_{\rm inj}(\varepsilon_{\rm e}),$$

Photon spectra



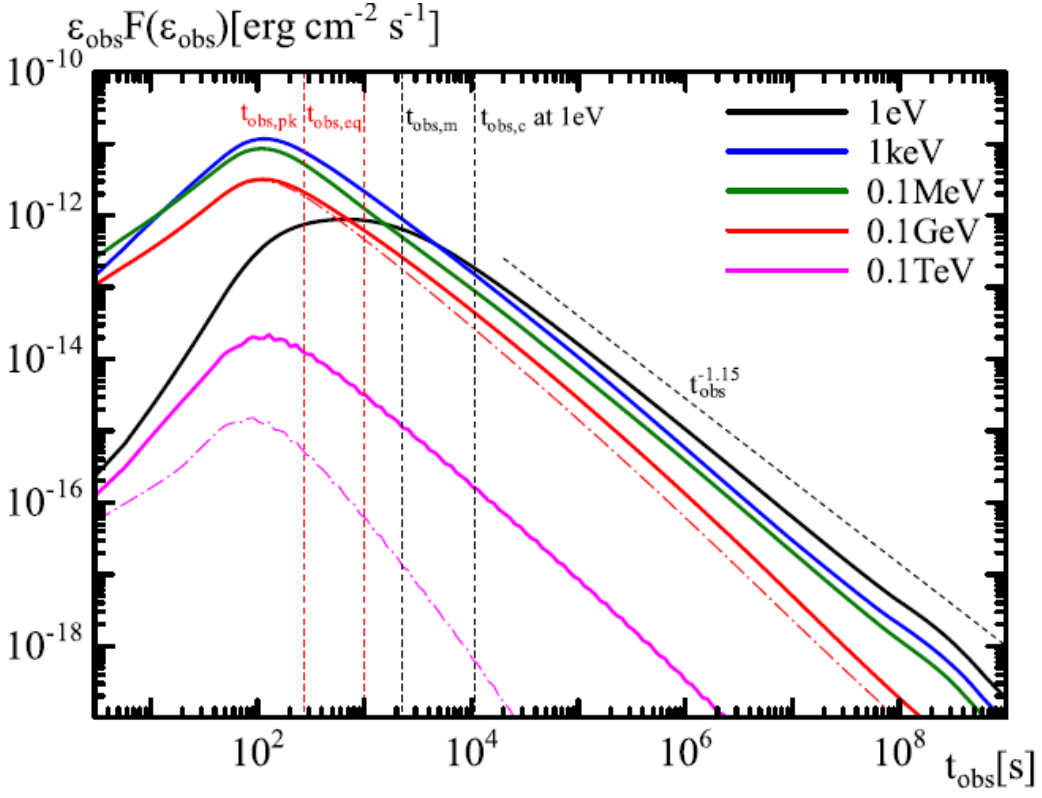
$$E_0 = 10^{52}\ {\rm erg},\ \Gamma_0 = 100,\ n_{\rm ISM} = 1\ {\rm cm}^{-3},$$

$$\frac{\partial N_\gamma(\varepsilon)}{\partial t} = \dot{N}_{\gamma,{\rm syn}}(\varepsilon) + \dot{N}_{\gamma,{\rm IC}}(\varepsilon) - \dot{N}_{\gamma,\gamma\gamma}(\varepsilon) - \dot{N}_{\gamma,{\rm SSA}}(\varepsilon) - \dot{N}_{\gamma,{\rm esc}}(\varepsilon),$$

$$\varepsilon_{\rm obs} = \frac{\varepsilon'}{\Gamma(1-\beta\cos\theta)(1+z)},$$

$$t_{\rm obs} = (1+z)\left[\left(t - \frac{R-R_0}{c}\cos\theta\right) + \frac{R_0}{c}(1-\cos\theta)\right],$$

Light curves and consistency



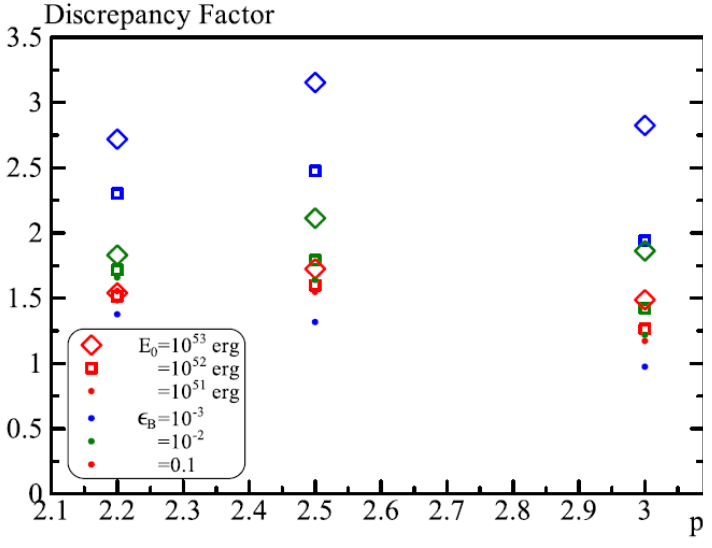
$E_0 = 10^{52}$ erg, $\Gamma_0 = 100$, $n_{\rm ISM} = 1$ cm^{-3},

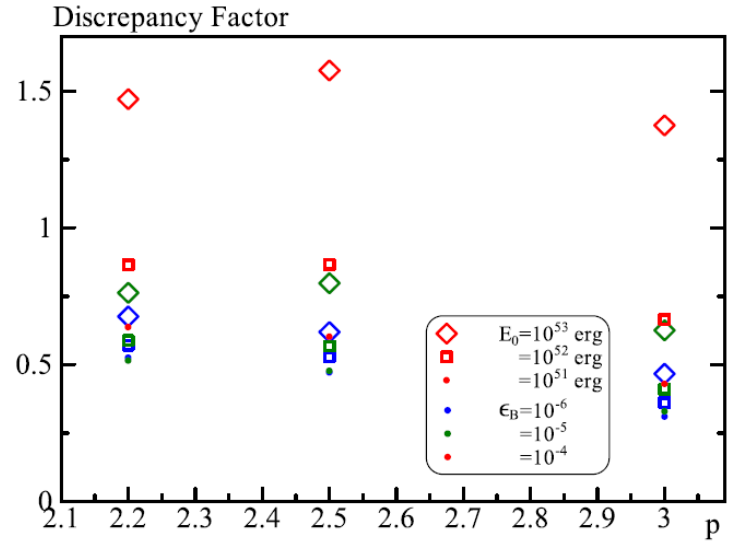
$p = 2.2$, $\epsilon_e = 0.1$, $\epsilon_B = 0.1$, and $\eta = 1$.

Discrepancy factor defined as

$$\frac{\text{Analytically Estimated Flux}}{\text{Numerically Obtained Flux}}$$

at 1 keV at $t_{\rm obs} = 10^4$ s assuming $z = 2$.



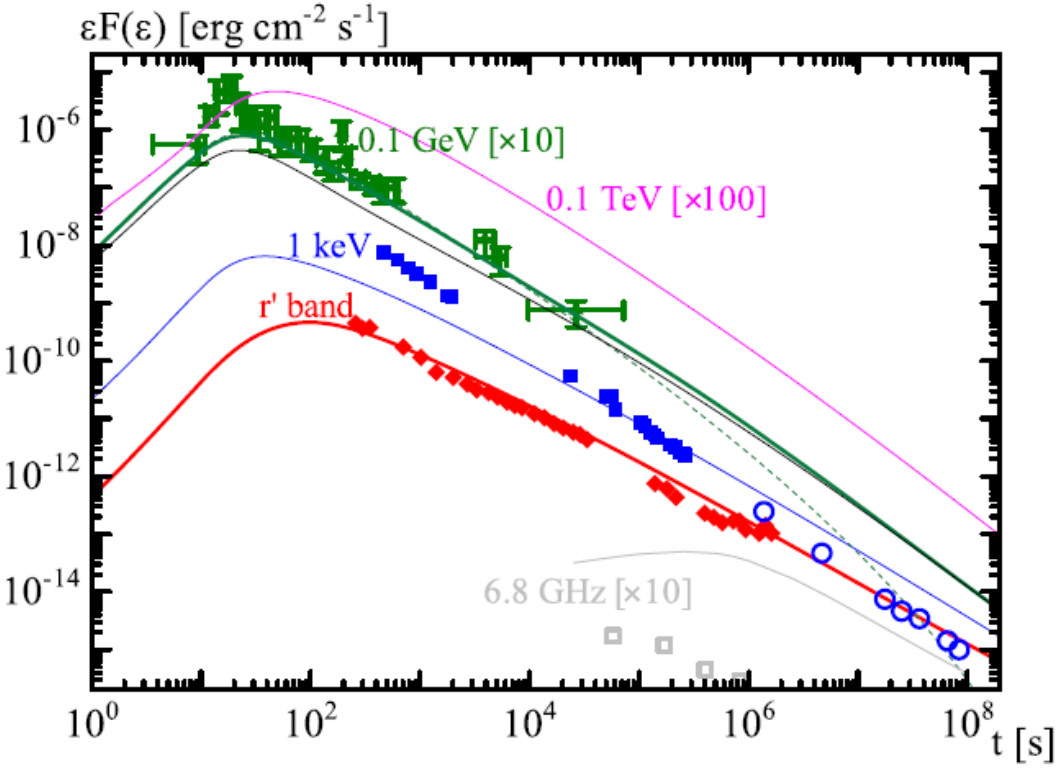


Roughly consistent with the conventional analytical approximation.

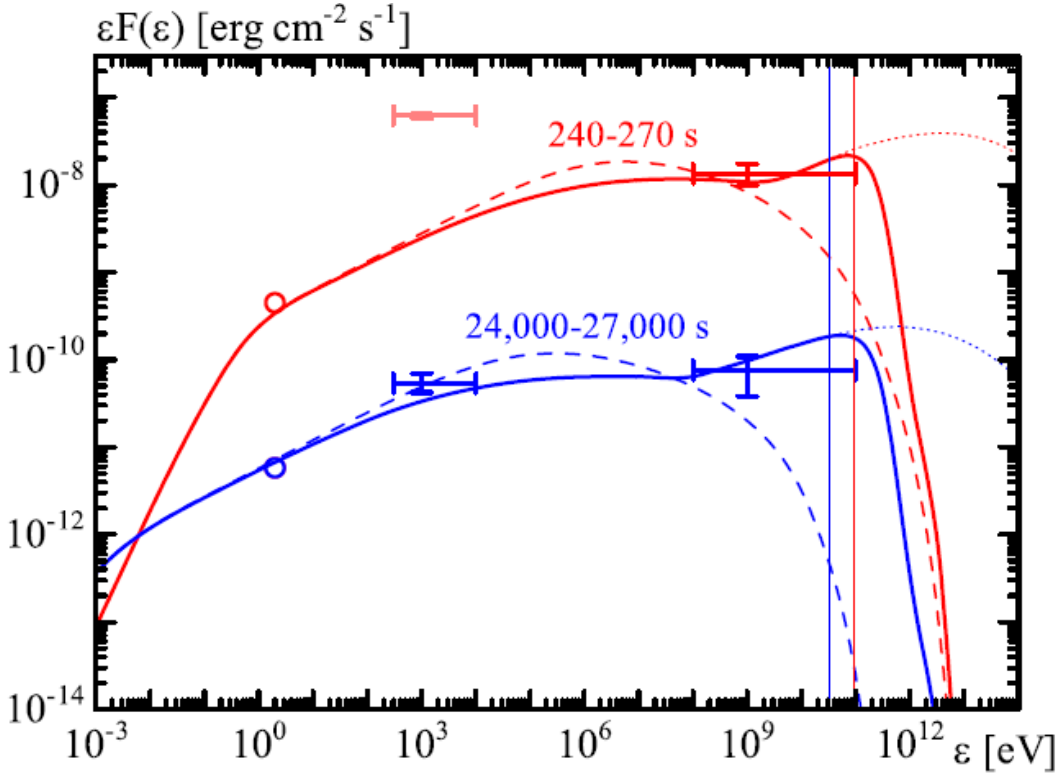
GRB 130427A

The 32 GeV photon detected at 30,000 s is beyond the limit for the synchrotron emission, but the GeV light curve is so simple that the switch from synchrotron to SSC is not seen??

E_0 (erg)	Γ_0	ϵ_e	ϵ_B	n_0	p
2.0×10^{55}	350	0.03	10^{-6}	1.0	2.35



Light curves



Photon spectra

The simple power-law decay at 0.1GeV is reproduced without fine tuning.
SSC emission is dominant at GeV including the 32 GeV photon detected at 30,000 s.