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# Modeling the High-Energy Gamma-ray Emission of Fermi/LAT GRBs

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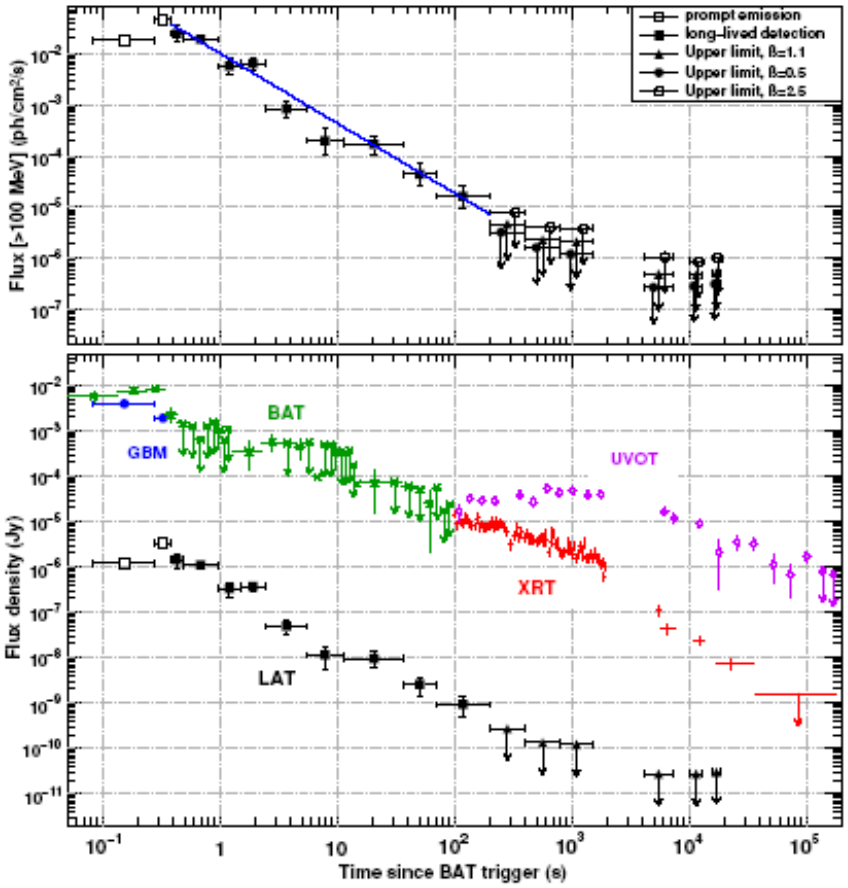
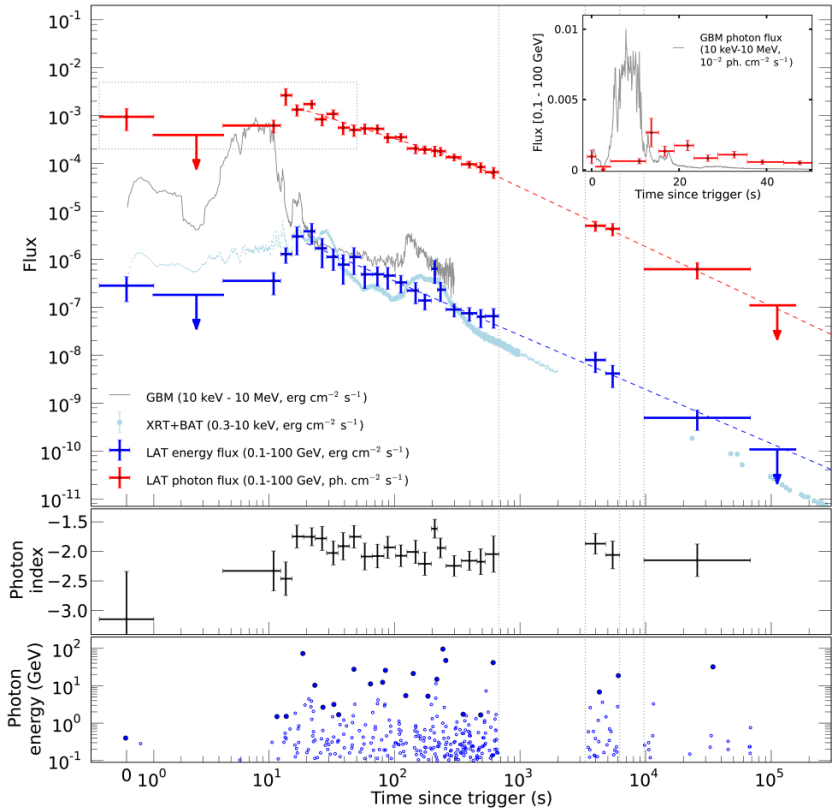
# Fermi GRB light curves

GRB090510




GRB130427A

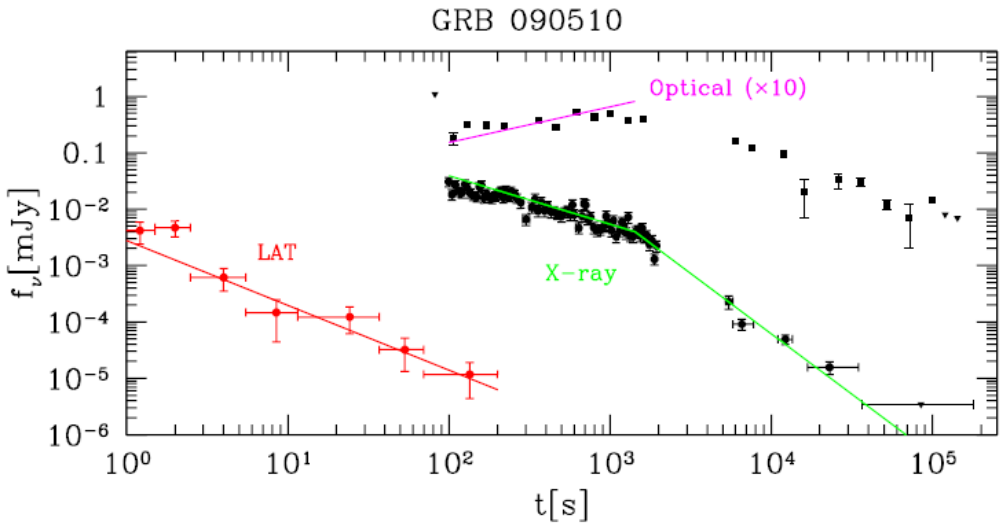



◆ **>100 MeV: much more extended**

# Synchrotron afterglow scenario ?

(Kumar & Barniol Duran 09, Ghisellini et al. 09, Wang et al. 10)

- afterglow synchrotron emission to account for all the LAT emission:
  - Simple PL decay: similar to X-ray/optical afterglows
  - Synchrotron flux could match the observed level



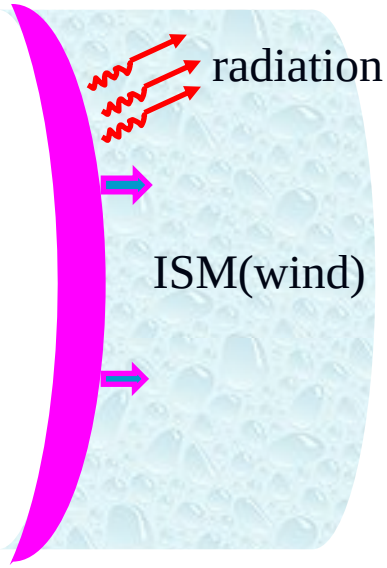

(Kumar & Barniol Duran 09)

# Broadband modeling

- Dynamics:
  Relativistic blast wave

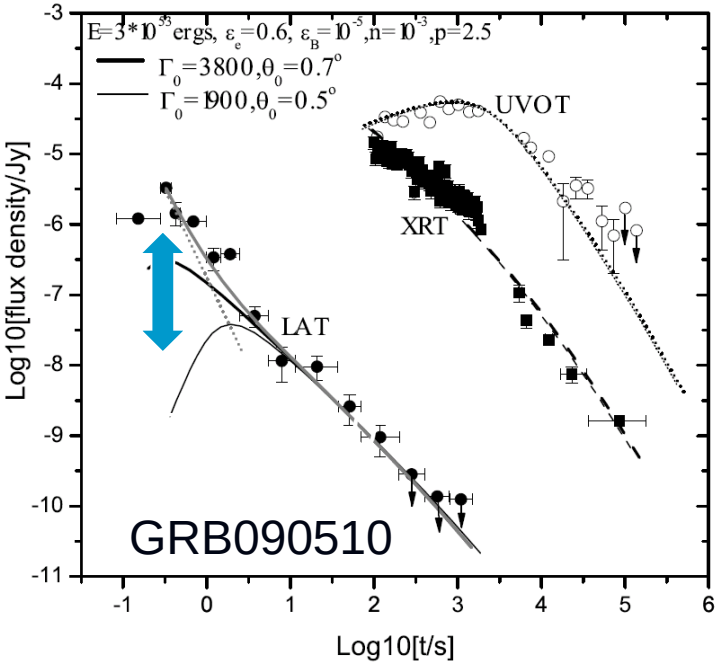
- Radiation:
  Synchrotron, IC

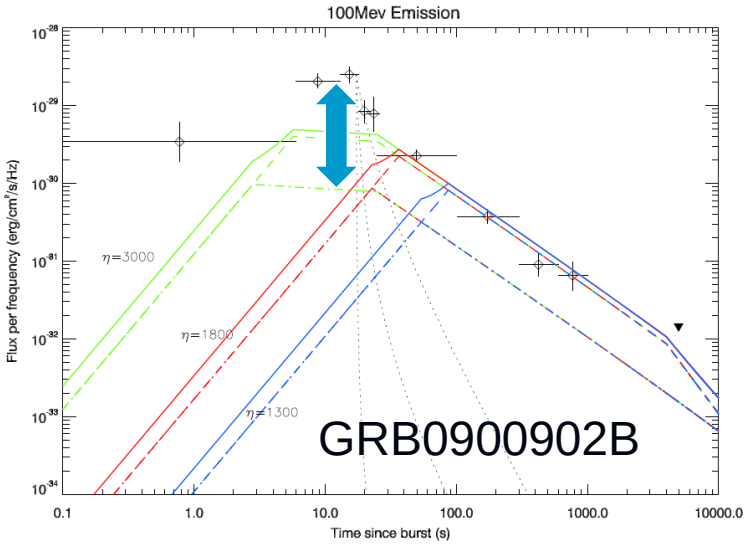
- Input parameters:
  E, θ, Γ, n, p, ε_e, ε_B



# Detailed broadband modeling…

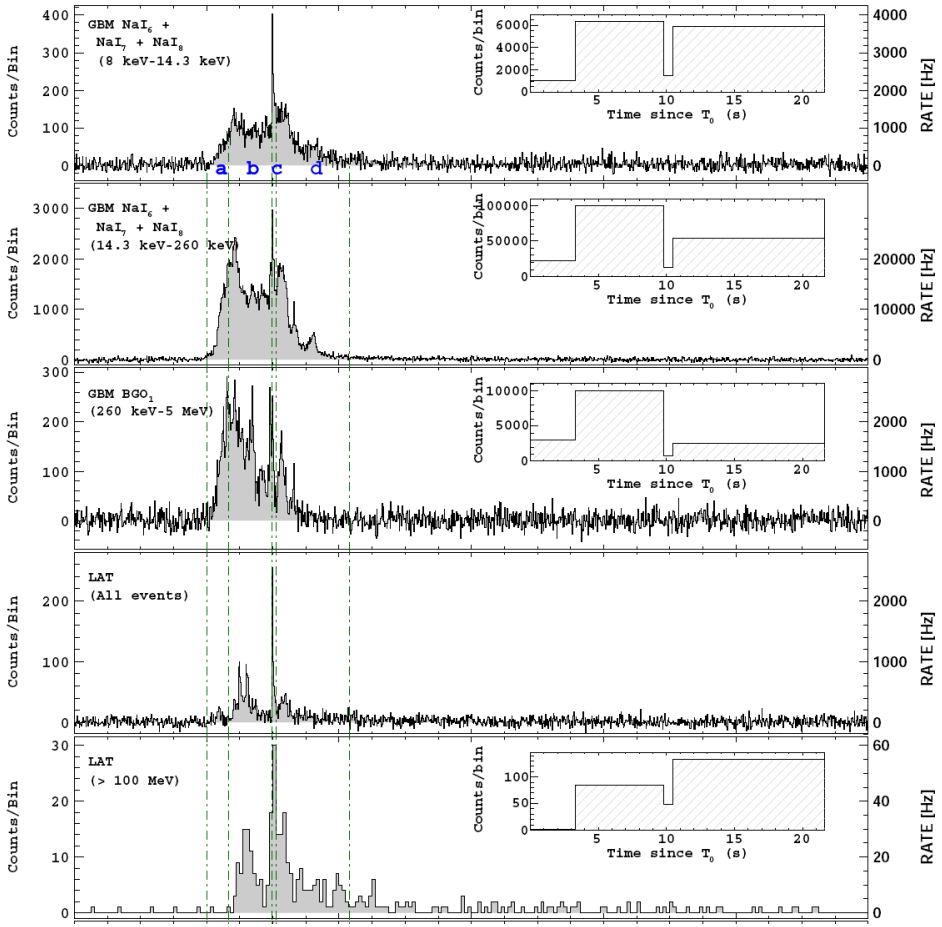
(He, Toma, Wu, Wang & Meszaros 2011; Liu & Wang 2011)




☐ At early time, afterglow synchrotron emission model falls below the observed flux -> Internal origin

# Correlated spikes seen by Fermi

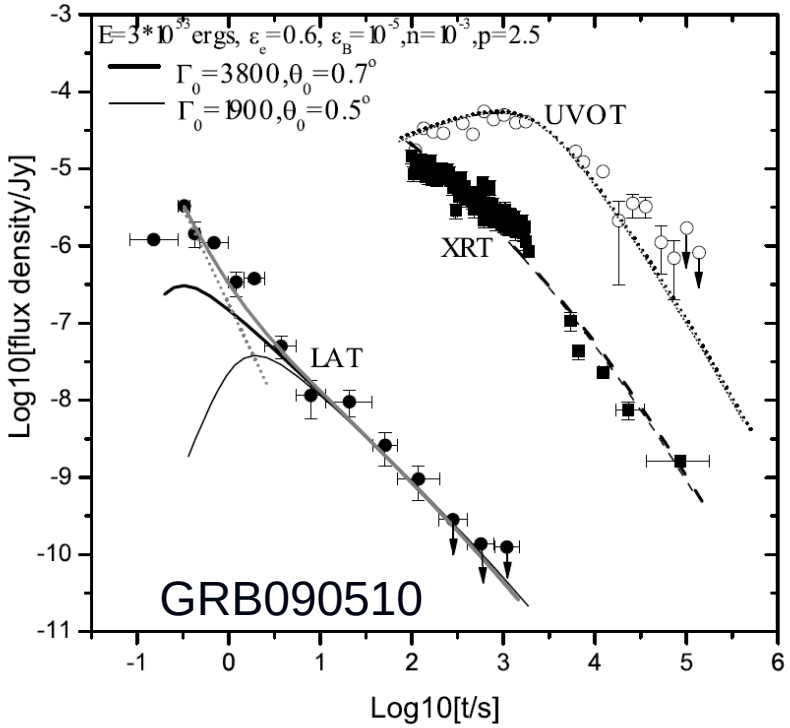


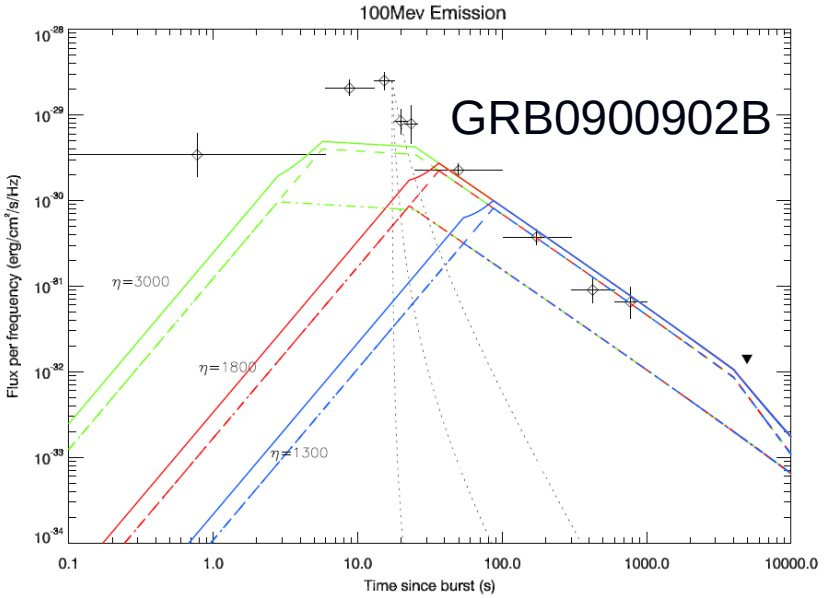

Abdo et al. 2011

- Support internal origin for the early prompt LAT emission

# Detailed broadband modeling…

(He, Toma, Wu, Wang & Meszaros 2011; Liu & Wang 2011)




- At early time, afterglow synchrotron emission model falls below the observed flux -> Internal origin
- **For late GeV emission, the afterglow synchrotron scenario fits the data well**

# One issue for the synchrotron scenario of late GeV emission

- **Expected:** maximum synchrotron energy:
  - ~50 MeV in the shock rest frame (Bohm acceleration approximation)
  - Observer frame： 50MeVxΓ, Γ<100 at 1-10ks

$$\Gamma = 200 E_{54}^{1/8} n_{-2}^{-1/8} (t_2/(1+z))^{-3/8}$$

- **Observed:** E_max~5GeV at 1-10ks

- **>10 GeV photons challenge the synchrotron scenario** (e.g. Piran & Nakar 10; see, however, Kumar 2014)

# Even worse …

(Lemoine 2012)

- Bohm approximation breaks down for microturblence magnetic field

$$\lambda = 10 - 30(c/\omega_{pi})$$

$$\frac{R_L(\gamma_{e,max})}{\lambda} = 25\lambda_1^{-2/3} n_{-2}^{-1/24} \epsilon_{B+,-2}^{-1/2} E_{54}^{-1/8} t_2^{3/8} \gg 1$$

- Lead to an even lower maximum synchrotron energy…

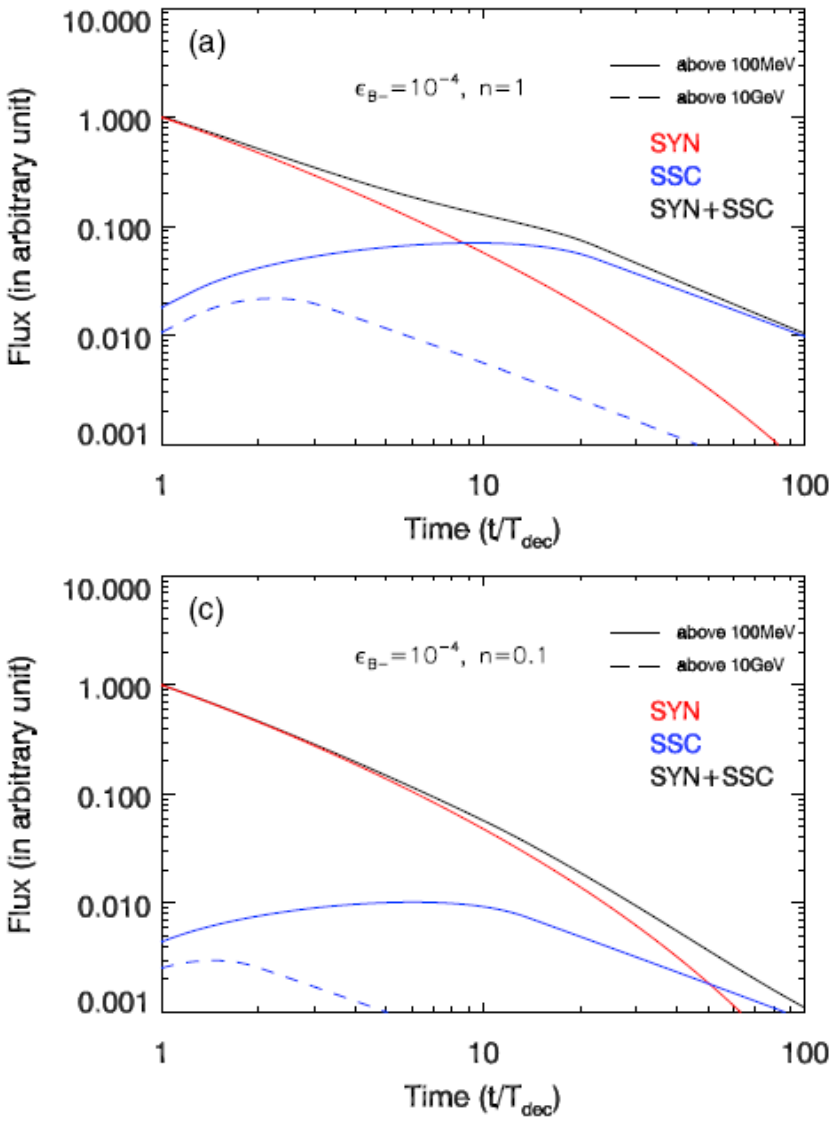
# Origin of >10 GeV photons ?

**A natural way out :**

- Electron inverse Compton (IC) processes:
  - Afterglow synchrotron self-Compton (SSC) emission (Zhang & Meszaros 2001; Wang, Liu & Lemoine 2103)
  - External IC process of the inner photons (He et al. 2012; Beloborodov et al. 2014)

# Synchrotron + SSC components

(Wang, Liu & Lemoine 2103)

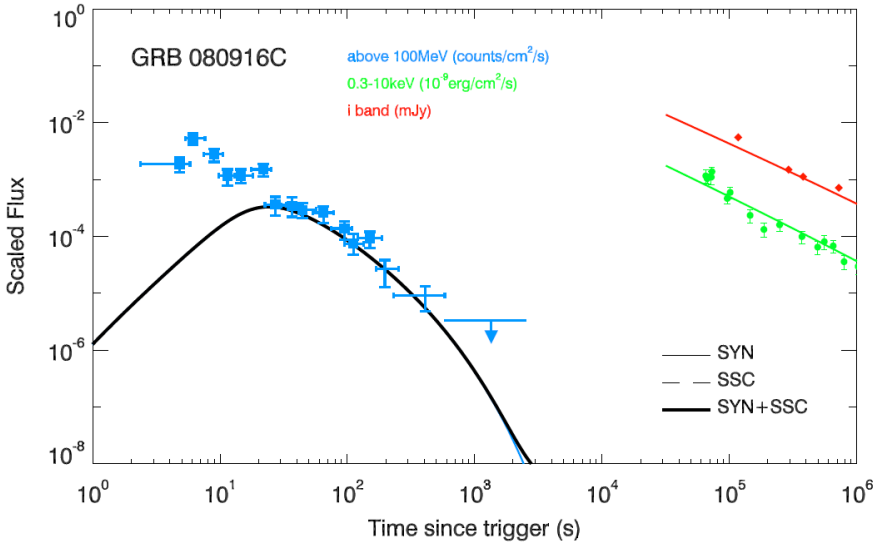



- The SSC intensity is sensitive to the circumburst density
- No obvious flattening seen at the transition

# Modeling light curves with different ISM densities

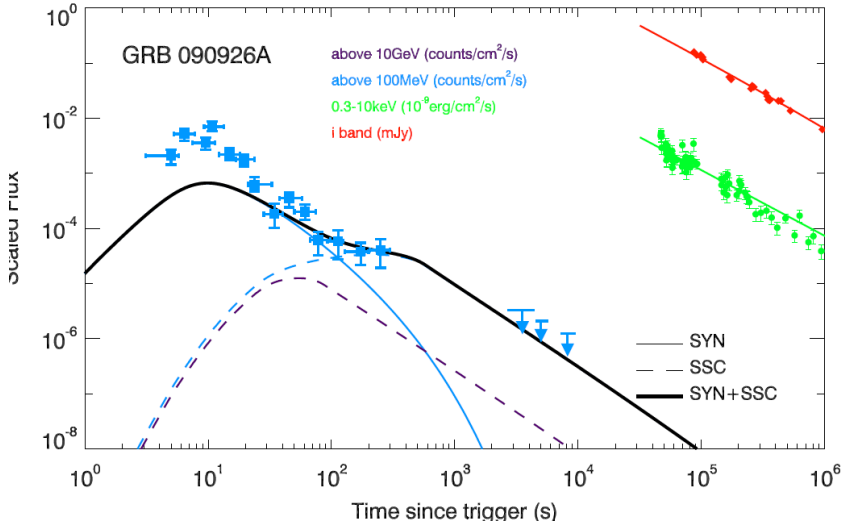
(Wang, Liu & Lemoine 2103)

*n = 0.003 cm^−3*




Rapid decay due to limited maximum synchrotron energy

*n = 1.2 cm^−3*

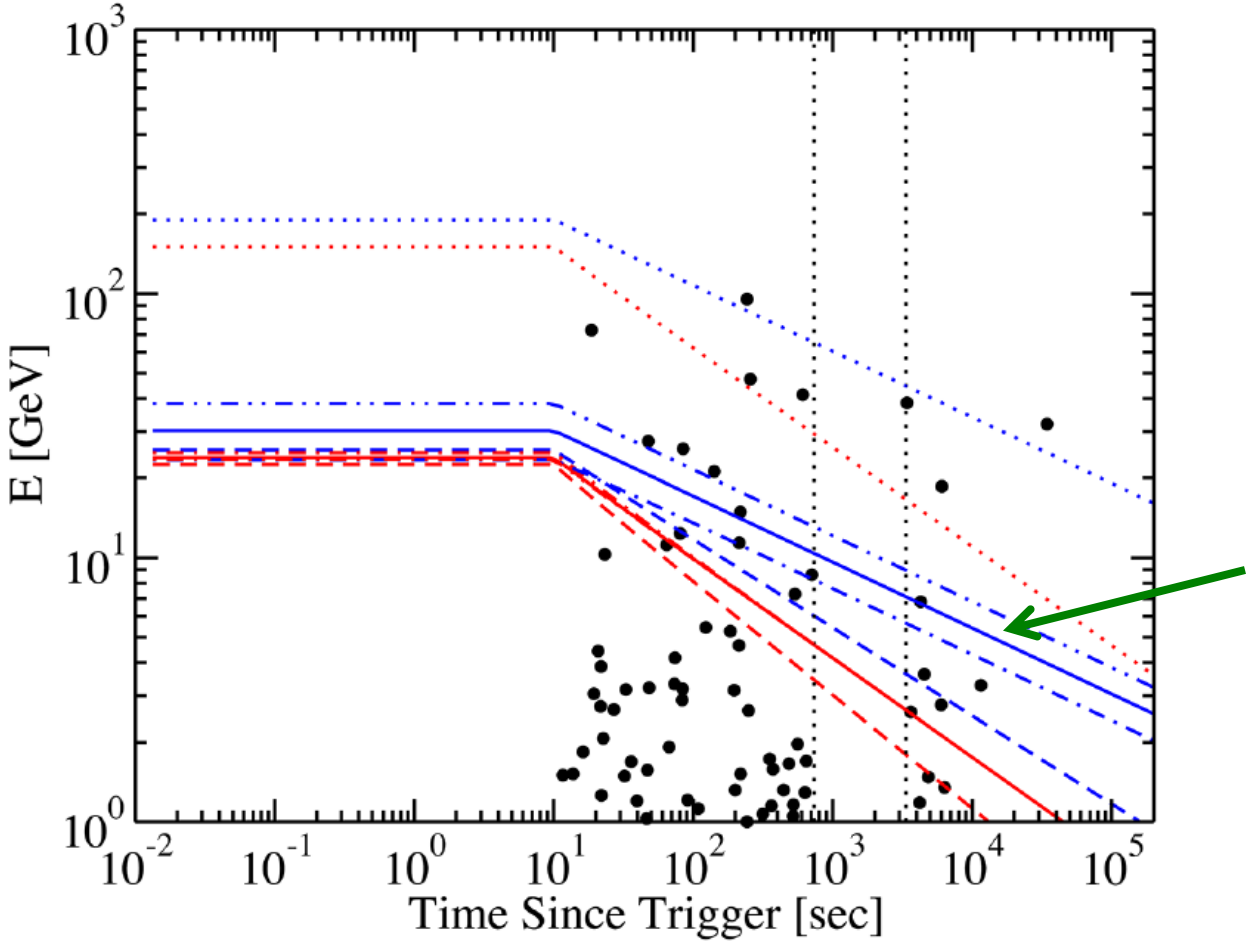



90 GeV photon at 80 s comes from SSC

# GRB130427A

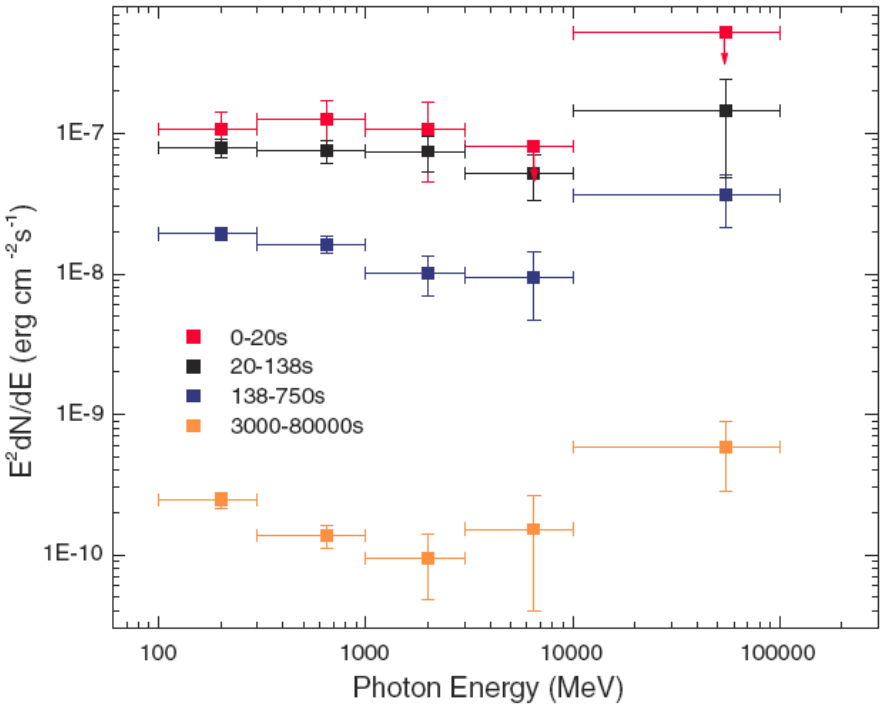
Fermi collaboration 2013

- the brightest GRB so far

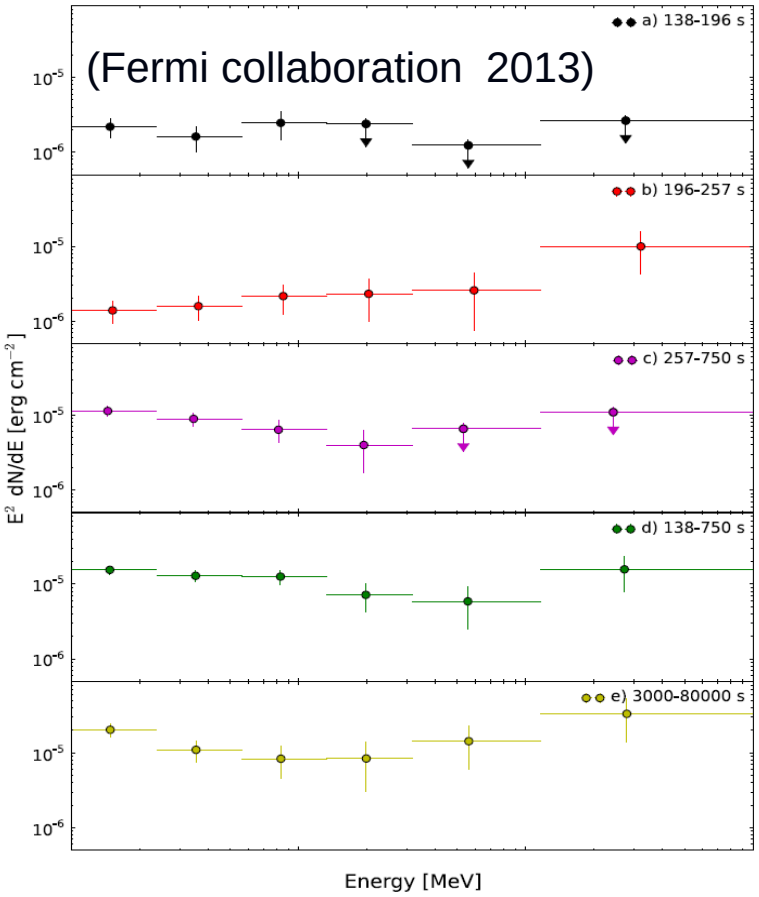


# LAT data of 130427A

(Tam, Tang, Hou, Liu & Wang 2013)




(Fermi collaboration 2013)

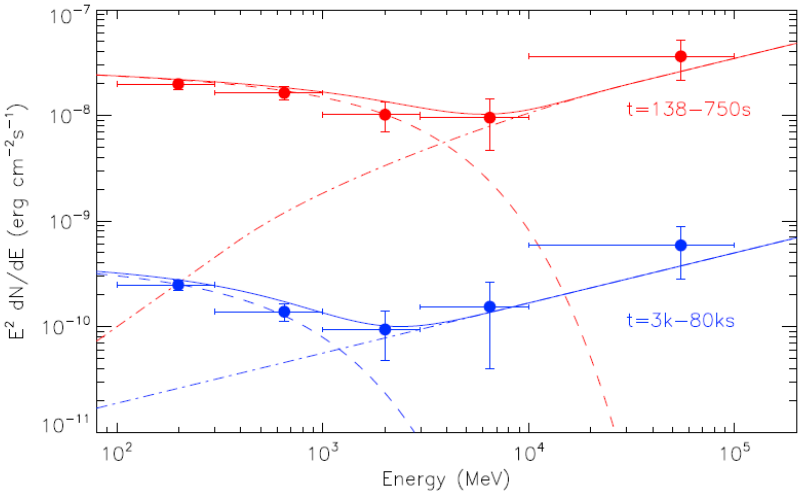



◆Possible signature of spectral hardening at ~10 GeV (~2.9 σ for 3-80 ks)

◆Interpreted as spectral hardening

# 100 GeV flux

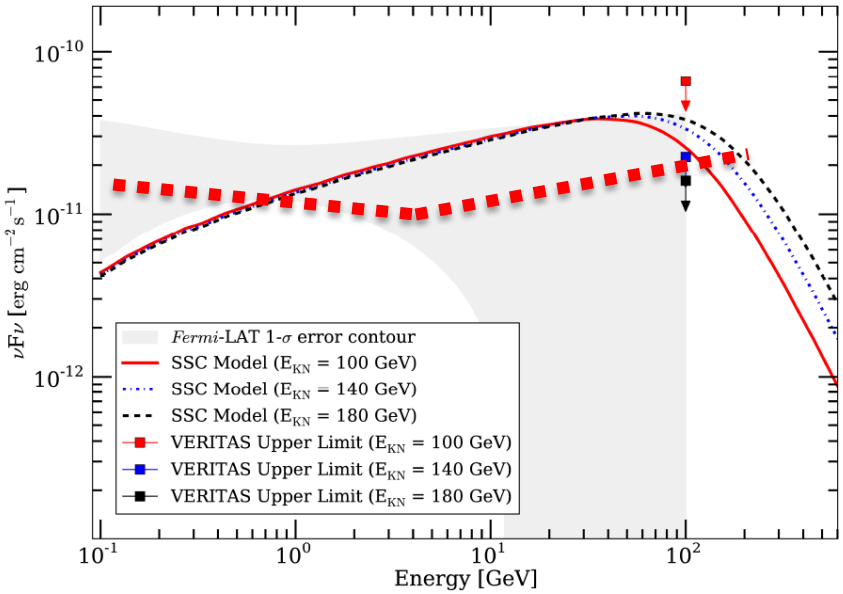
Liu et al. 2013




◆ Below ~3GeV, synchrotron flux is still the dominant component

◆VERITAS data inconsistent with SSC ?

Aliu et al. 2014




● SSC flux @100GeV is 3*10^-8 erg/cm^2/s at t~200s

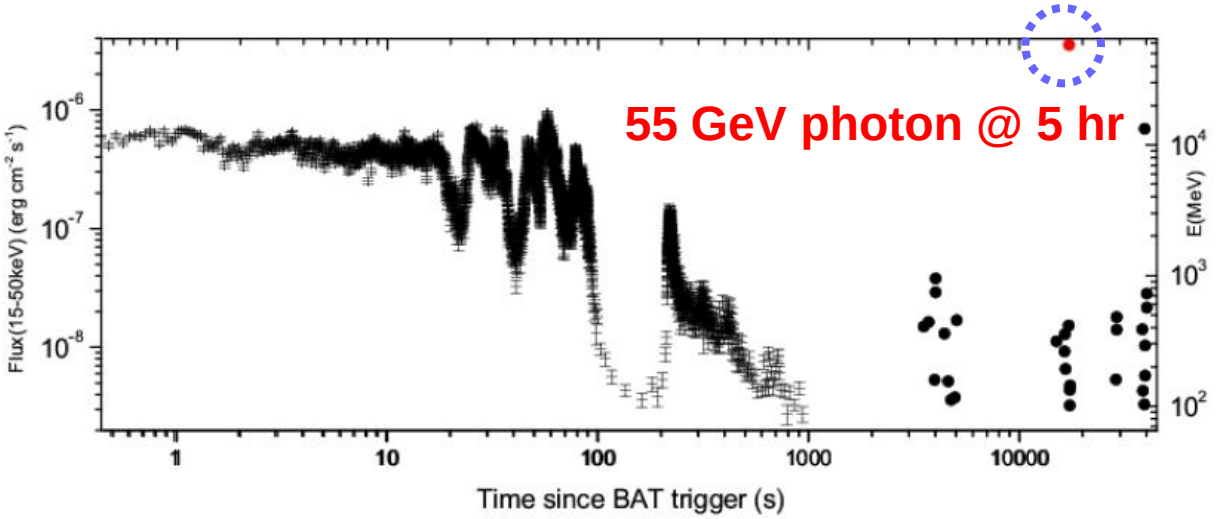
● F(100GeV)~t^-1.35

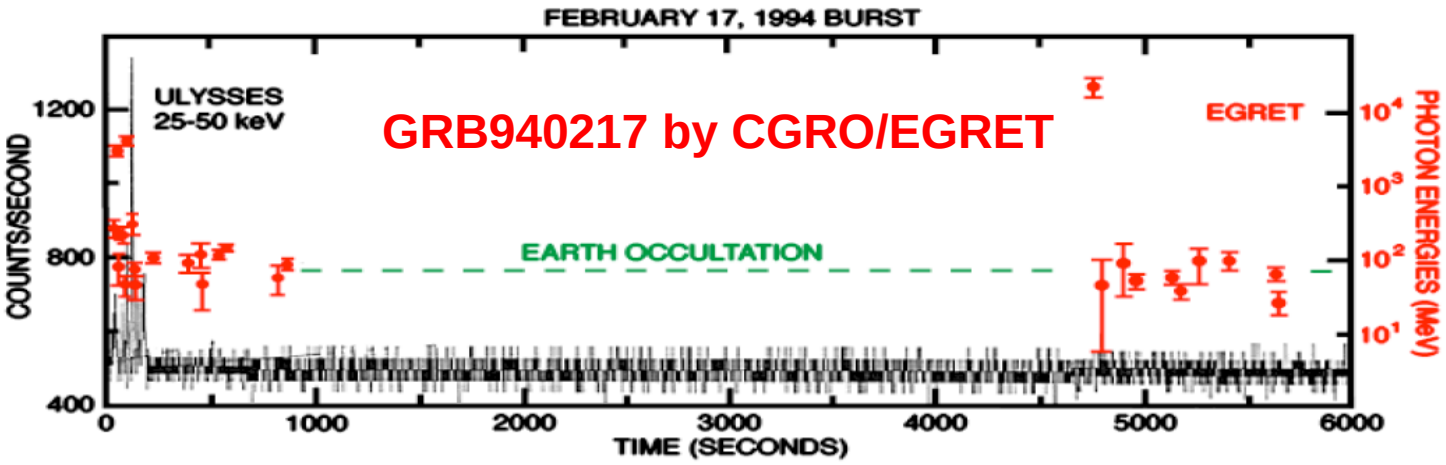
● At 70 ks, SSC flux @100GeV is 1.1*10^-11 erg/cm^2/s

●SSC model not ruled out…

# GRB 130907A

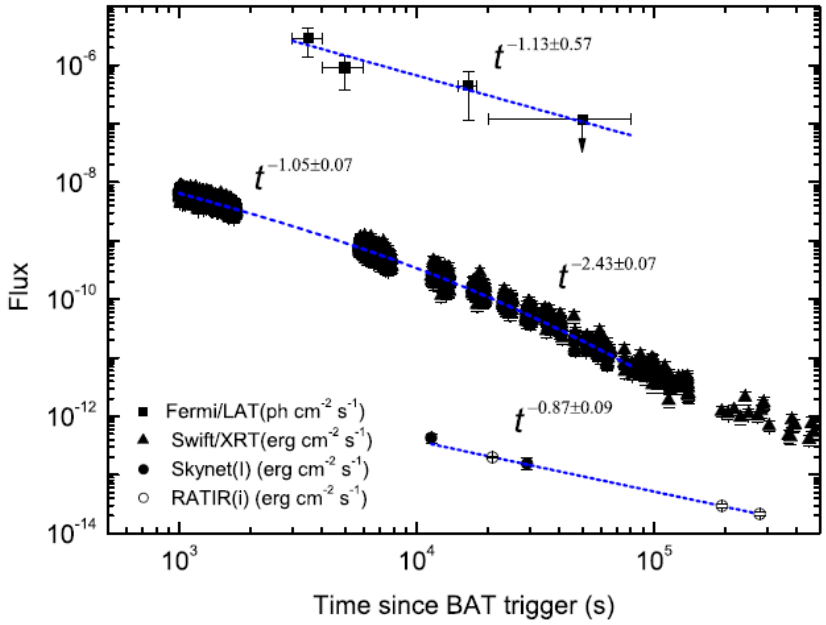
(Tang, Tam & Wang 2014)

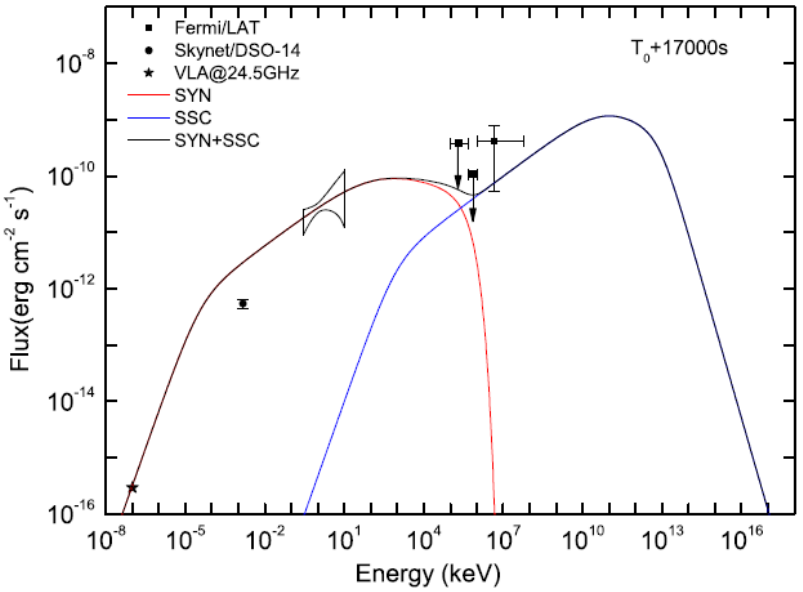


# Broad-band modeling of GRB130907A

(Tang, Tam & Wang 2014)



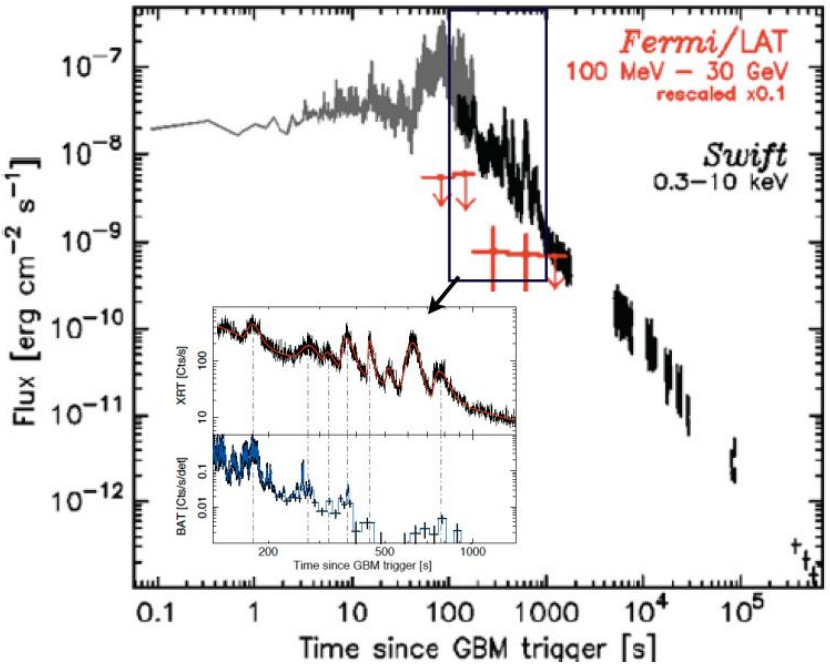
# Conclusions

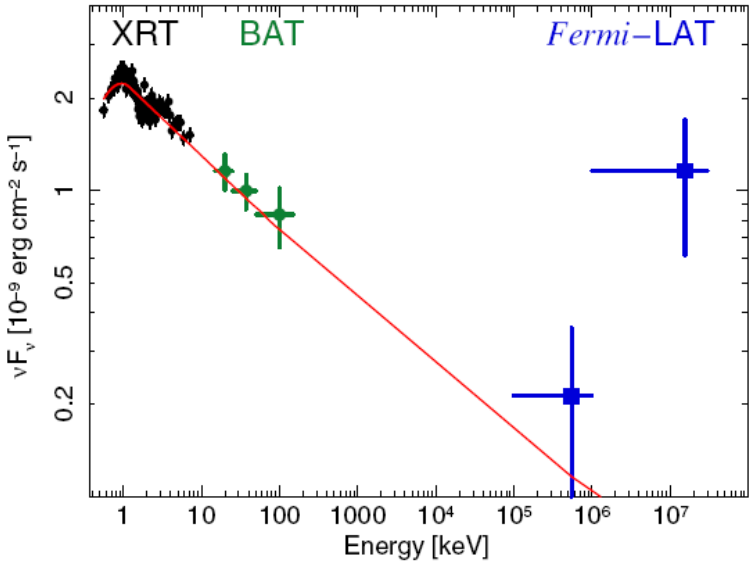
- Early HE emission **during the prompt** phase is likely of internal origin
- Late HE emission **well after the prompt phase** is probably due to afterglow emission
- 100MeV-GeV may come from **synchrotron** radiation
- >10 GeV photons consistent with **IC** emission

# GRB100728A

Discovery of GeV emission during the X-ray flare activity

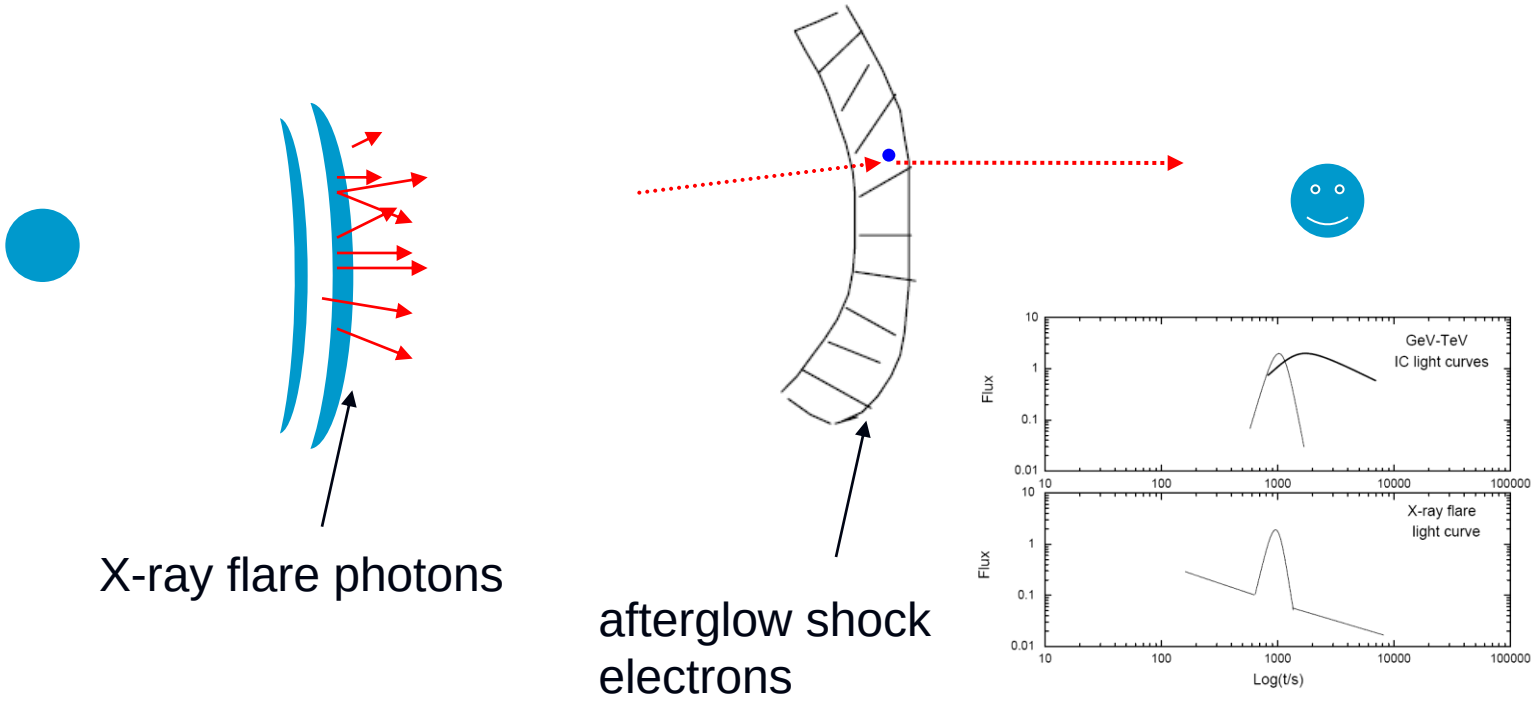
(Abdo et al. 2012)



# External IC emission from X-ray flares

Cartoon




**(Wang, Li & Meszaros 2006)**

# External IC model

(He, Zhang, Wang et al. 2012)