GeV early afterglow emission from GRB

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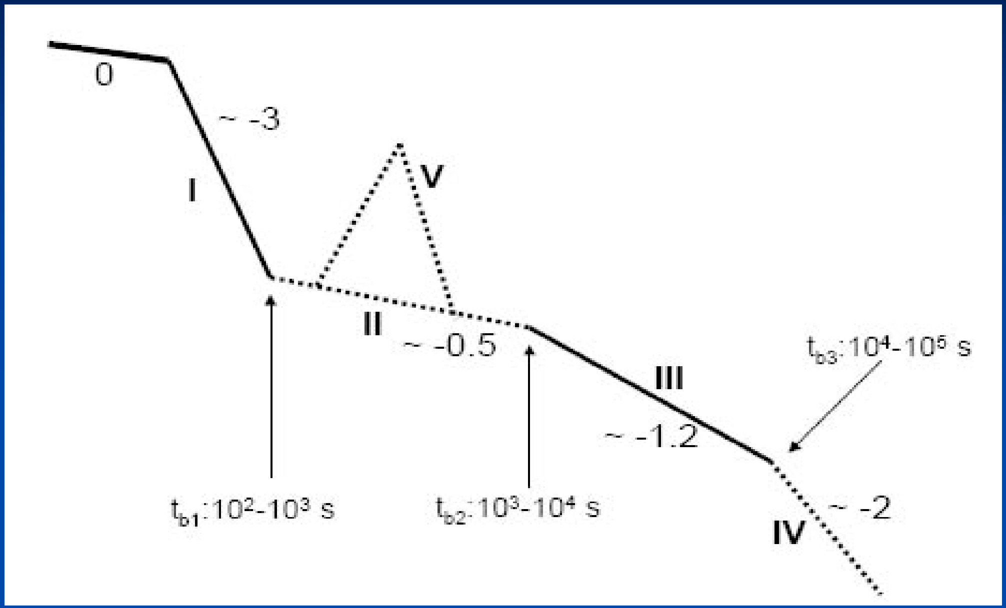
Exploring the High Energy Universe

GRB X-ray flares



Prompt-to-afterglow transition characterized by initial steep decay, flattening, and flares

X-ray flares present in ~ 40% of Swift GRB sample.

X-ray flares globally softer than the prompt emission but:

✓Several X-ray flares show hard-to-soft spectral evolution ⇒ Late Internal Shock (Zhang et al. 2005, Burrows et al. 2005)

✓Other flares do not show spectral evolution and have a spectrum consistent with that of the afterglow ⇒ External Shock by thick shell fireball (Piro et al. 2005, Galli & Piro 2006)

A not "standard" External Shock: thick shell fireballs

In thick shells case $\Delta = ct_{eng}$, thus $t_{eng} > t_{dec}$.

Most of the energy is transferred to the surrounding material around the end of the engine activity.

Th ... ed
fr ... .

Th ... gy
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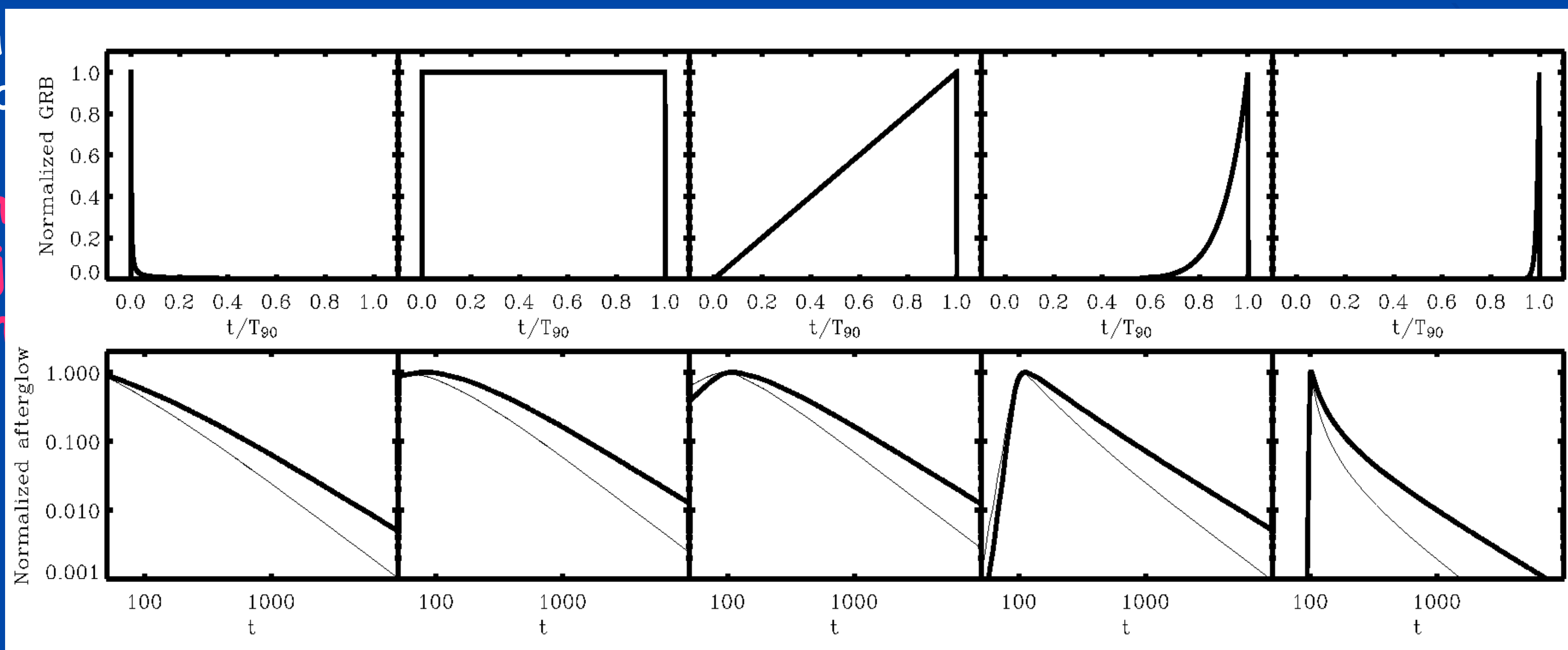
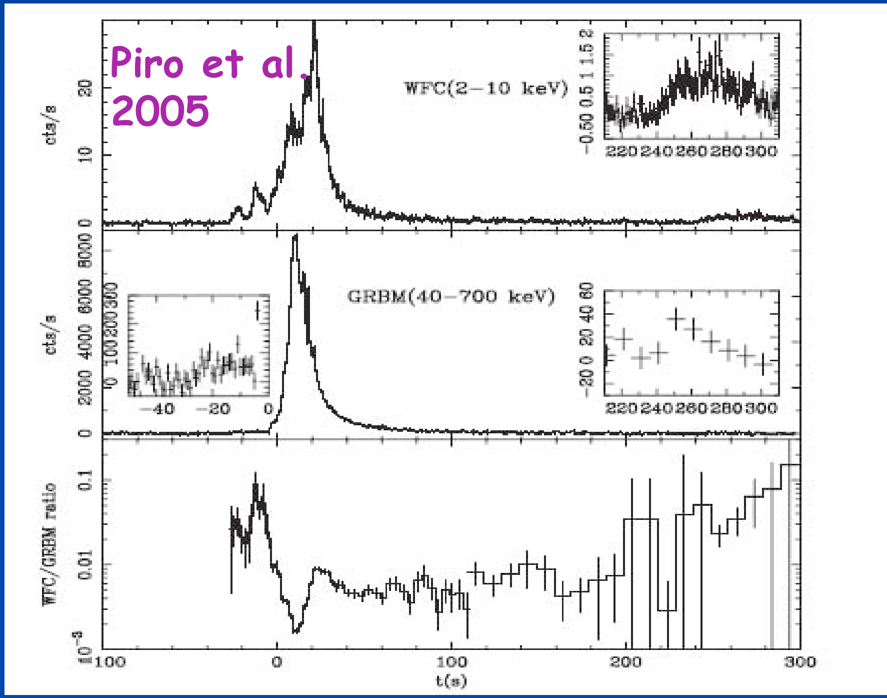
lon

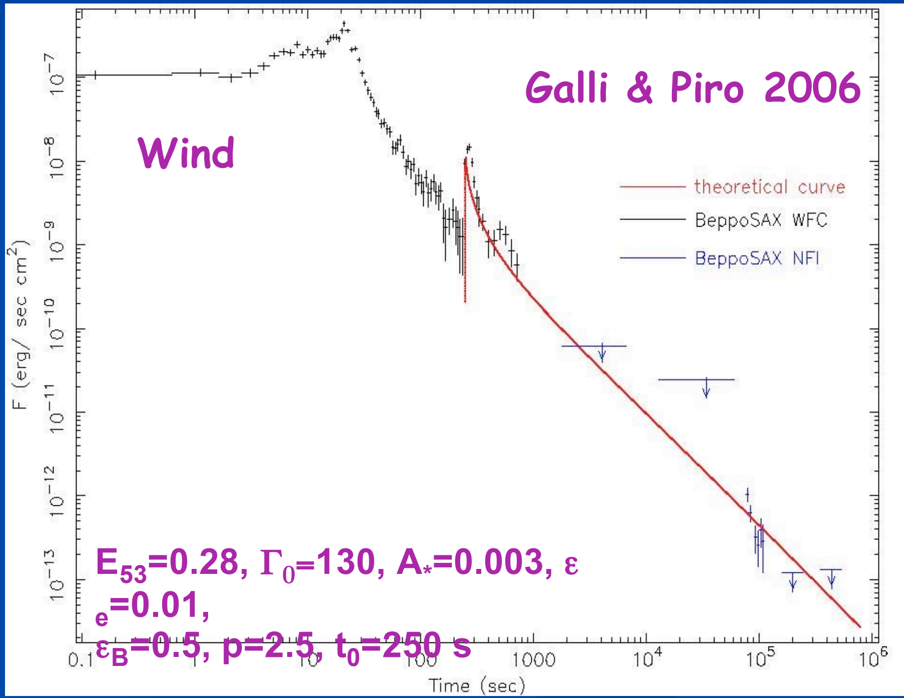


Application of the External Shock Model: GRB 011121

Flare spectrum softer than the main pulse and consistent with the afterglow spectrum at 1 day.

The light curve from the decay part of the flare is nicely reproduced by a power law if the origin of the time is shifted to the time of the flare.





This suggests that the flare is the beginning of the afterglow emission

GeV flares in association with X-ray flares

X-ray flares overlap with the afterglow emission, thus X-ray flares photons can be Inverse Compton scattered in the GeV-TeV band by afterglow electrons.

External Shock model-Thick shell fireballs

X-ray flares ⇒ synchrotron

GeV flares ⇒ self-IC emission of flare photons scattered by afterglow electrons

Late Internal Shock model

Two possible mechanisms (Wang et al. 2006, Fan & Piran 2006):

✓ X-ray flares ⇒ synchrotron
GeV flares ⇒ self IC emission

✓ X-ray flares ⇒ IC emission
GeV flares ⇒ 2° order IC on the afterglow electrons

-Internal Shock:

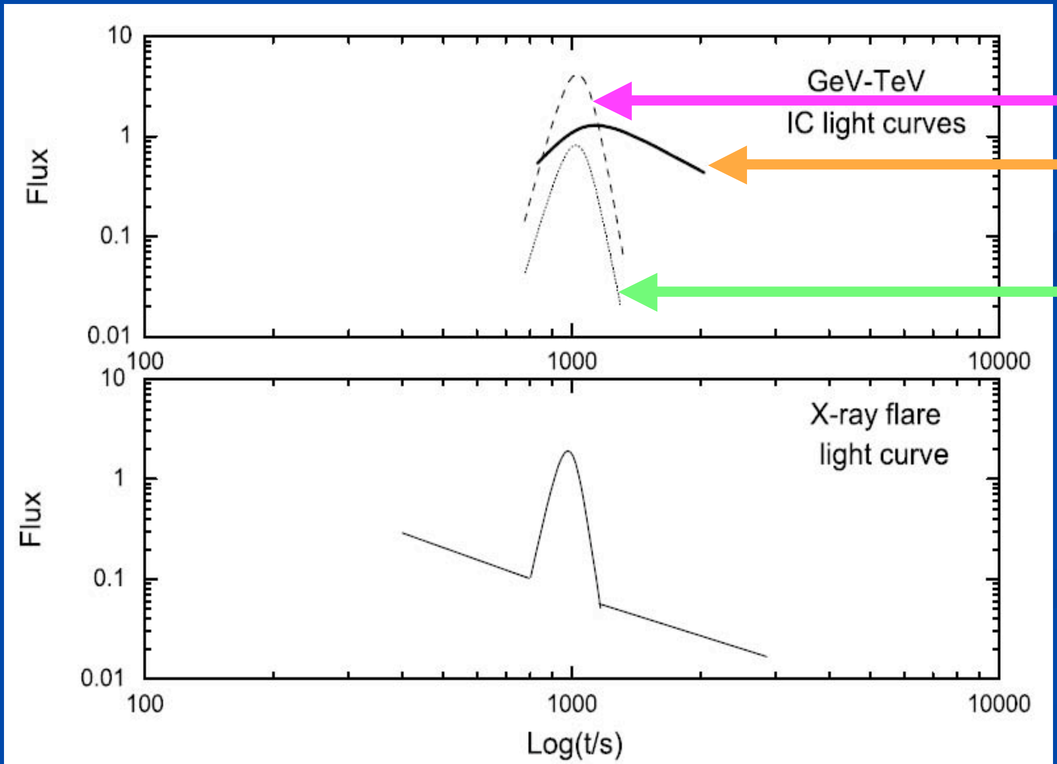
Low Lorentz factor, low Thompson cross section ⇒ no bright high energy flares

Different emitting regions ⇒ temporal dilatation

-External Shock:

Higher Lorentz factor ⇒ brighter high energy flares

Same region and electrons population ⇒ similar temporal profiles



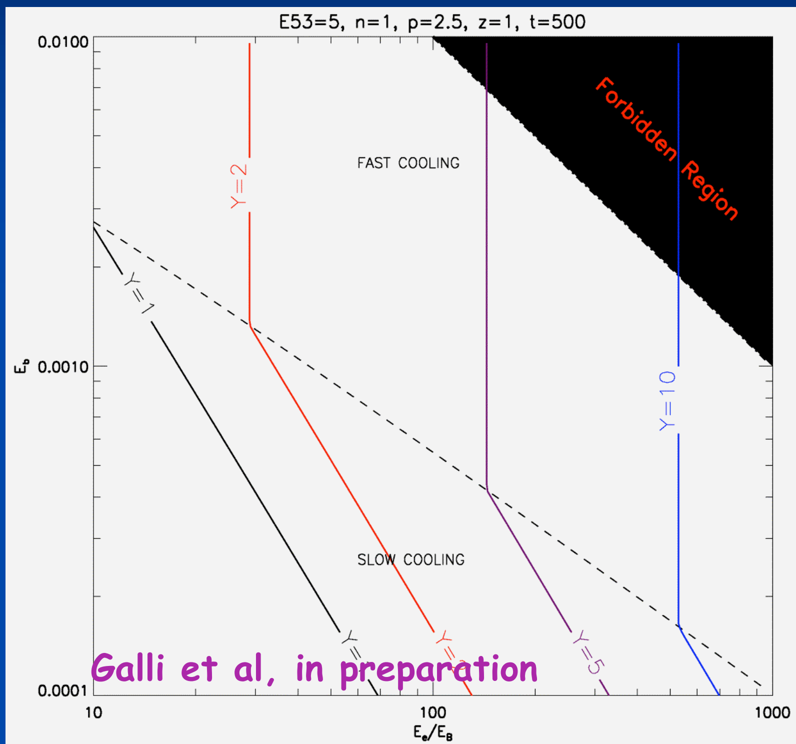
External Shock

Internal Shock 2:
IC + 2nd order IC

Internal Shock 1:
Synchr + self IC

External Shock: Inverse Compton vs Synchrotron

Thin shell, deceleration phase



$Y=L_{IC}/L_{syn}$

FAST COOLING:

$\eta=1,\ Y\propto(\epsilon_e/\epsilon_B)^{1/2}$

SLOW COOLING:

$\eta<1,\ Y\propto(\eta\epsilon_e/\epsilon_B)^{1/2}$

$\epsilon_B=8\cdot10^{-2}\,(E_{53}\,n)^{-1/4}\,[1+(\varepsilon_e/\varepsilon_B)^{1/2}]^{-1/2}\cdot\cdot(\epsilon_e/\epsilon_B)^{-1/2}\,T_d^{1/4}\,(1+z)^{-1/4}$

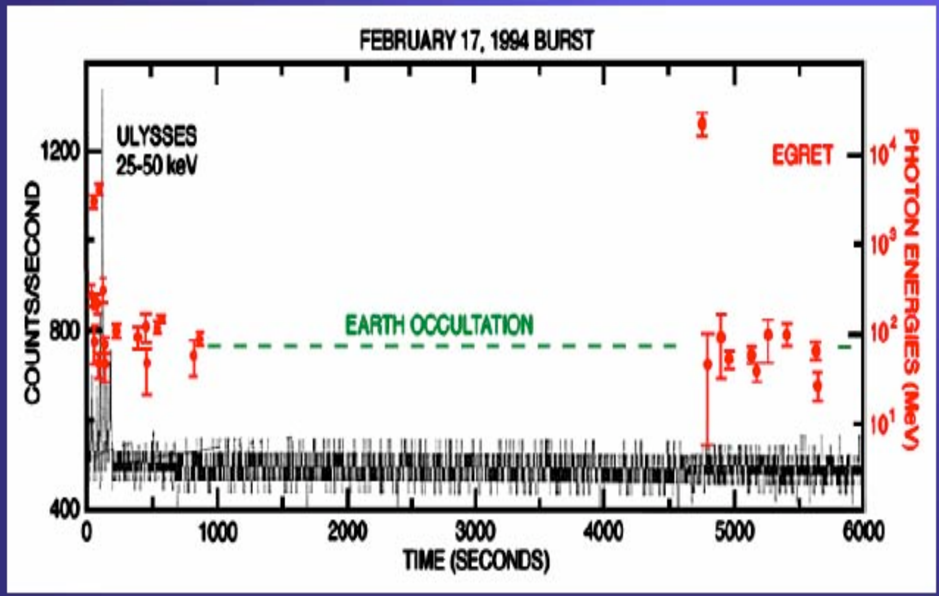
Relative importance of IC and synchrotron emission greater in fast cooling than in slow cooling

The importance of IC increases with E_{53} and n

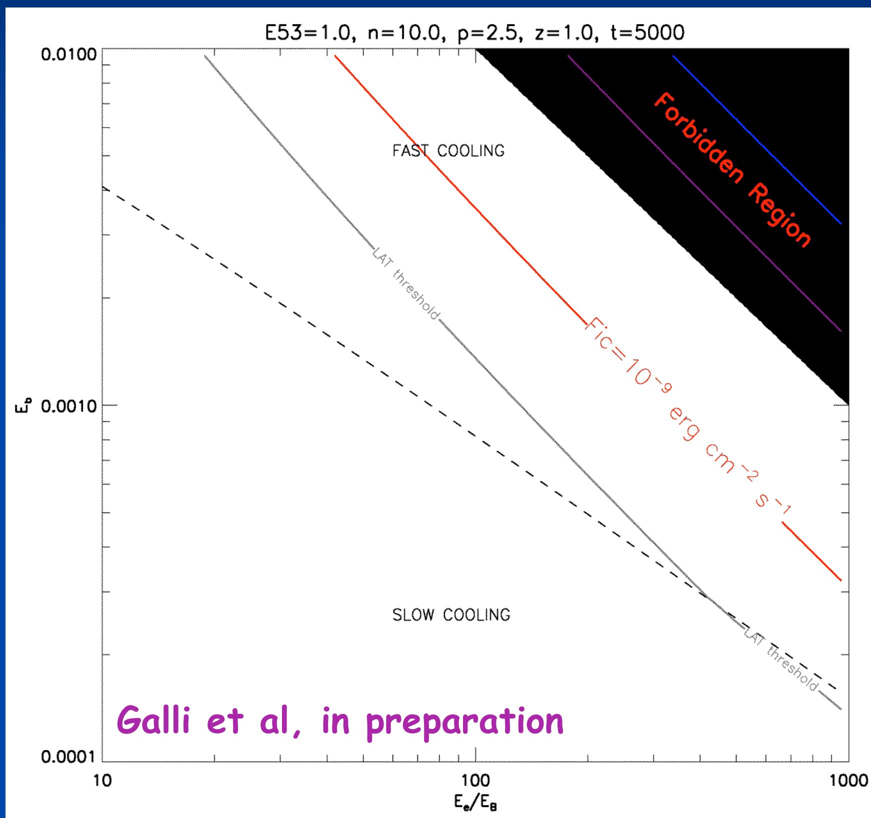
Very High Energy emission: GRB 940217

GRB 940217: indication of GeV emission thousands of s after the GRB onset (Hurley et al. 1994)

At high energies the spectrum becomes harder: additional emission process, such as Inverse Compton is required.



Inverse Compton emission from afterglow: application to GRB 940217



Duration of about 5000 seconds

Delayed emission spectrum, 30MeV-30GeV (Hurley et al. 1994):

-best fit power law, γ=2.83±0.64
-best fit fluence, S~$7\cdot10^{-6}$ erg cm^{-2}
-best fit mean flux, F ~10^{-9} erg cm^{-2} s^{-1}

Thin shell fireball

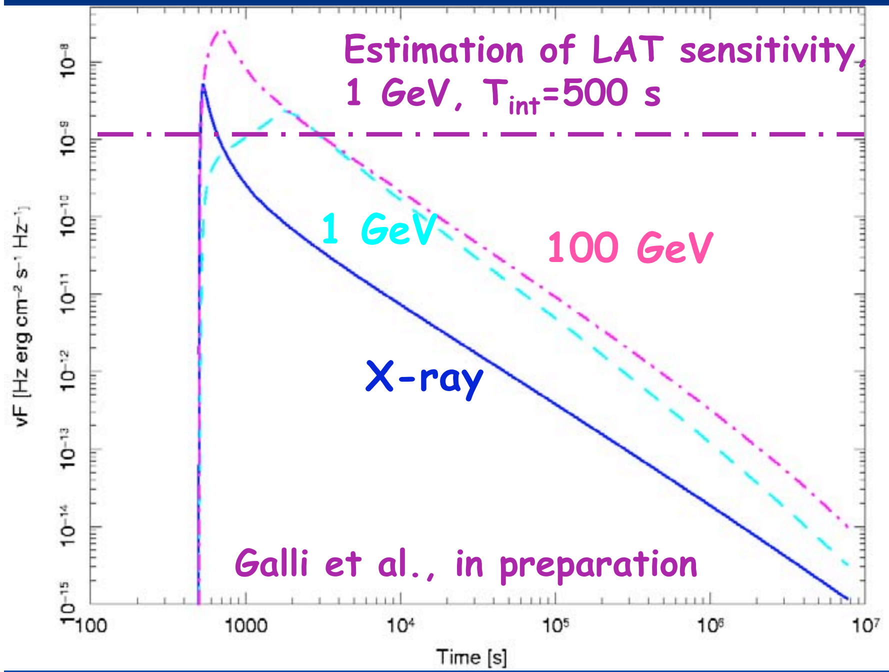
$\nu_{c,IC} < \nu_{i,IC} < \nu_{obs}$ $\quad \gamma=(p+2)/2$

p=2.5 $\Rightarrow$ β=2.25

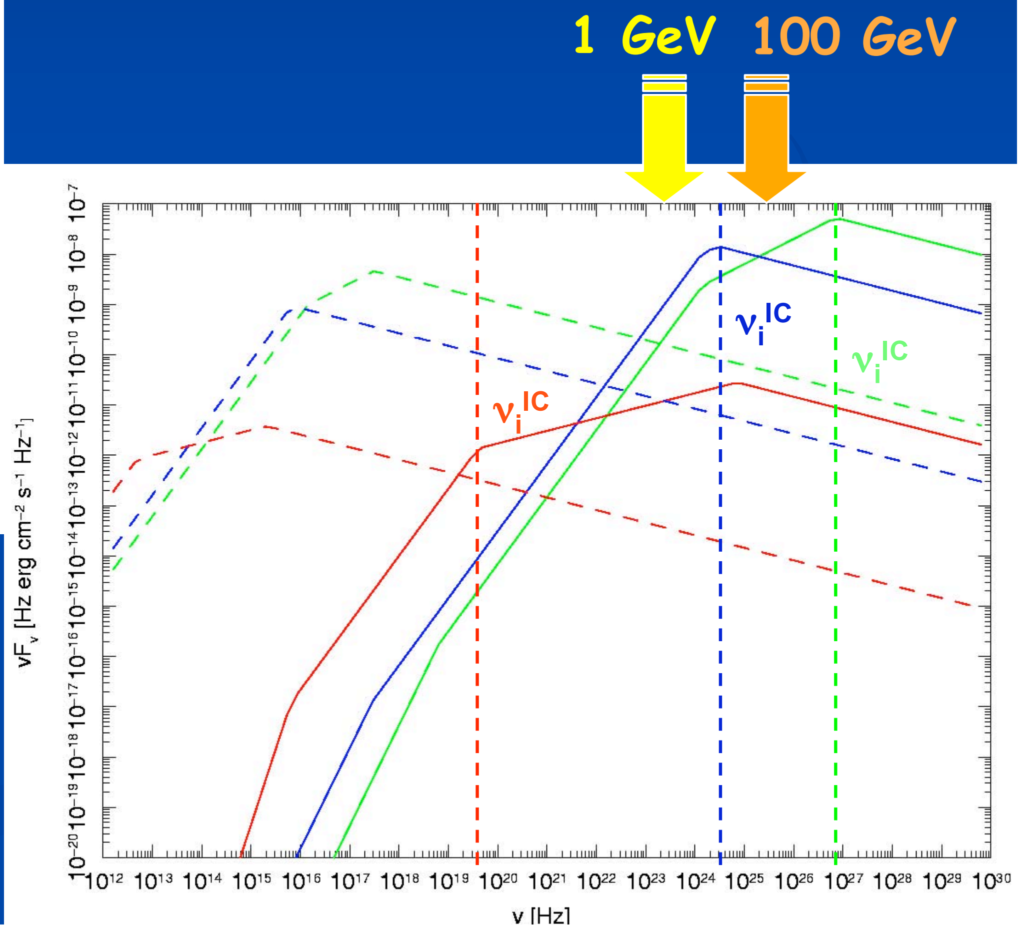
ϵ_e/ϵ_B =100, ϵ_B~ $3\cdot10^{-3}$, n=10

IC emission from a thick shell fireball

ISM-Fast Cooling



E_{53}=5, Γ_0=300, n=1, ε_e=0.1, ε_B=10^{-4}, p=2.5, z=1, t_0=500 s



A. Galli- Stanford, 7 February 2007

Conclusion

- ✓ Both in the framework of the internal shocks scenario and in that of the external shocks late X-ray flares are related to a long lasting central engine activity;

- ✓ X-ray flares can be attended by GeV flares produced by IC, that could be detected by GLAST;

- ✓ IC emission from afterglow can explain also the delayed high energy emission detected by EGRET in GRB 940217;

- ✓ In the framework of the external shock we expect similar temporal profiles for X-ray and high energy flares. This is a strong prediction that will permit to discriminate between different models;

- ✓ Broad band data (radio to X-ray) permit to determine External Shock model parameters, and thus to give Predictions for high energy emission