GRB study with GLAST

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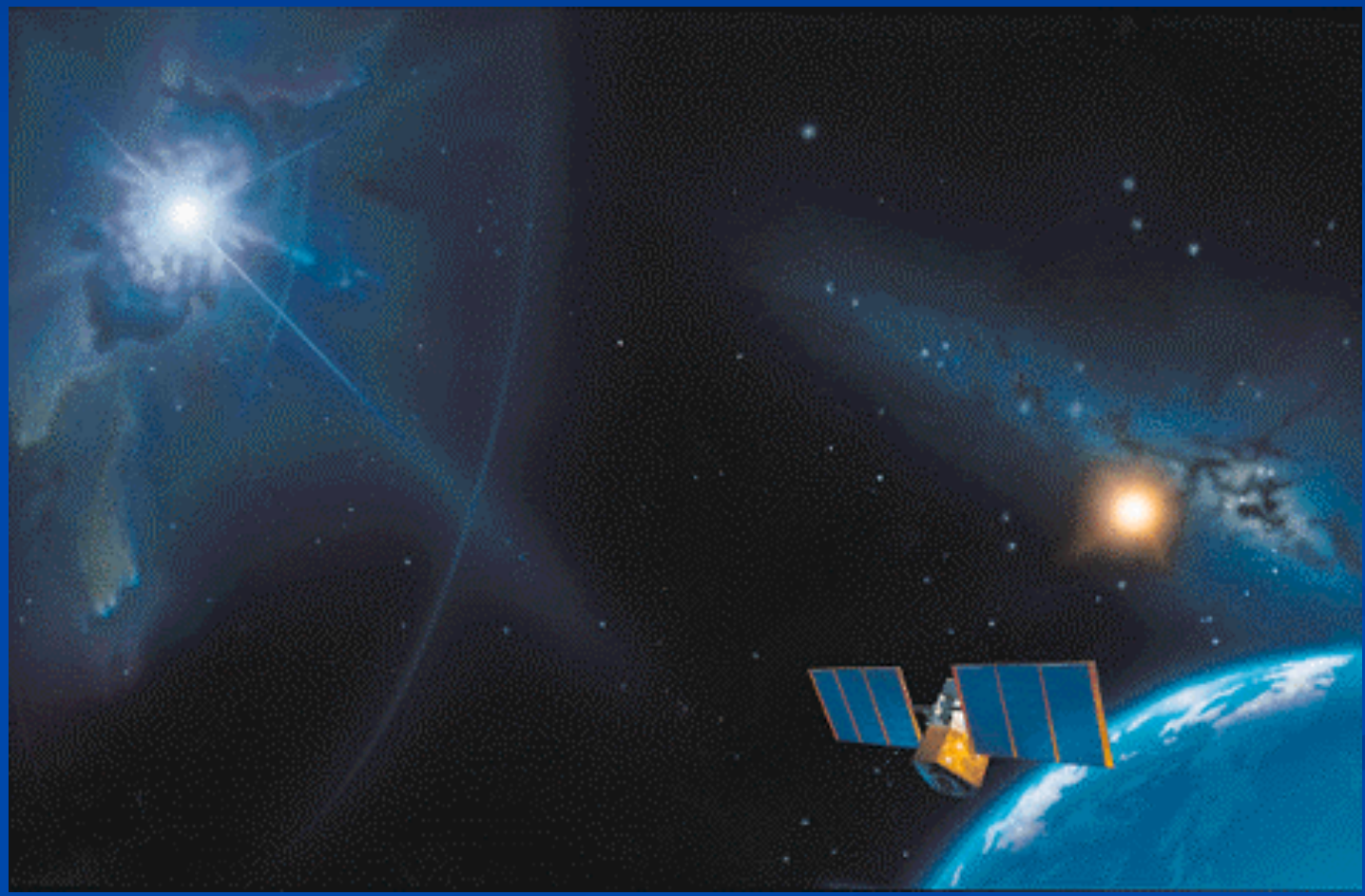
Gamma-ray bursts: the most violent explosions in the universe!



What do we expect in the GLAST era?

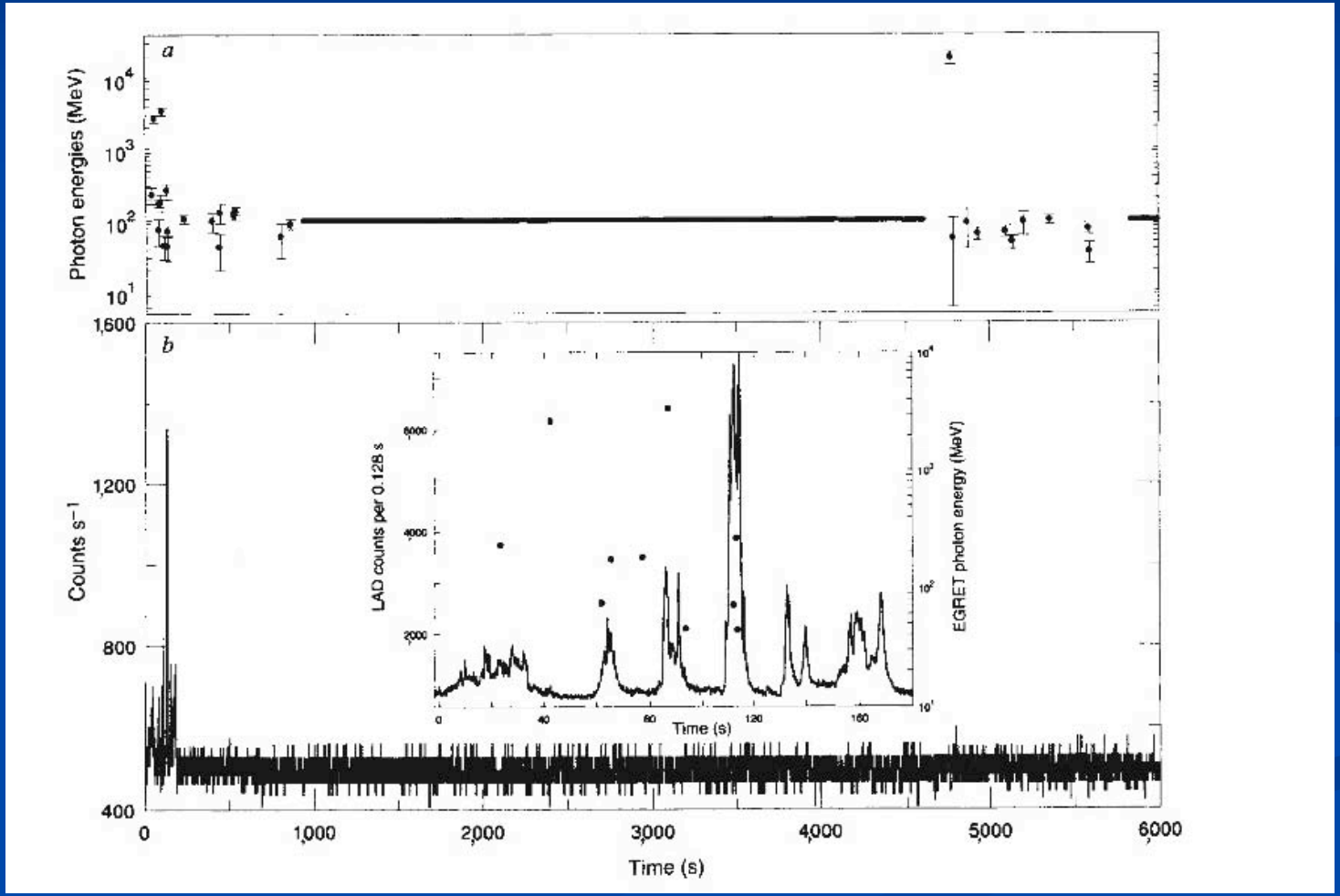
High Energy Photon Emission from GRBs

Extended High energy Emission - Previous Observational Evidence

- GRB 940217 (Hurley et al. 1994)
  - Lasted 90 minutes
  - Hard, including one 18 GeV photon
- GRB 941017 (Gonzalez et al. 2003)
  - A distinct multi-MeV spectral component
  - Decays more slowly than the low energy component
- Milagro and other ground-based observatory
  - GRB 970417 (Atkins et al)
  - Many upper limits (Saz Parkinson et al)

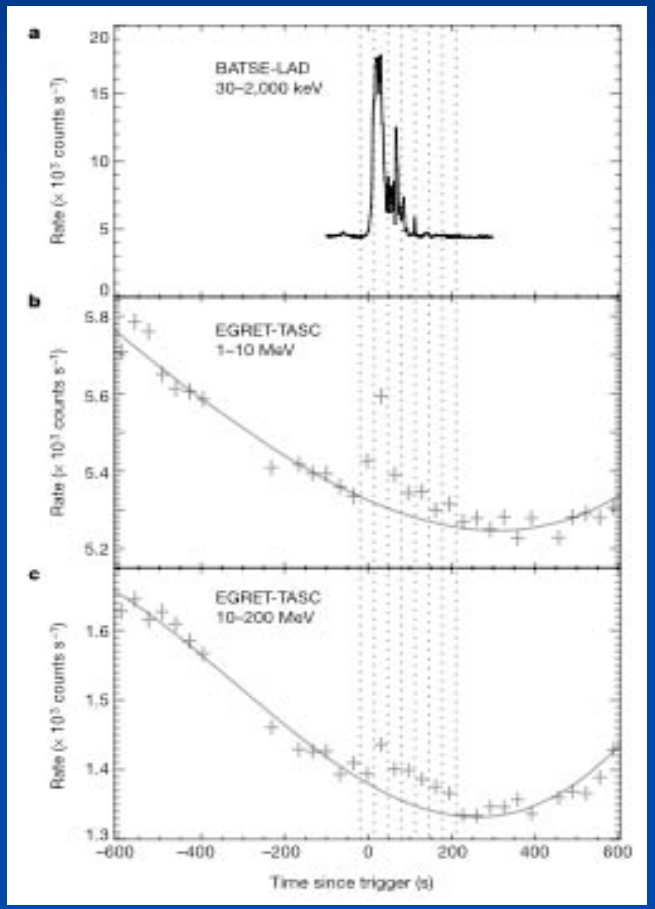
GRB 940217

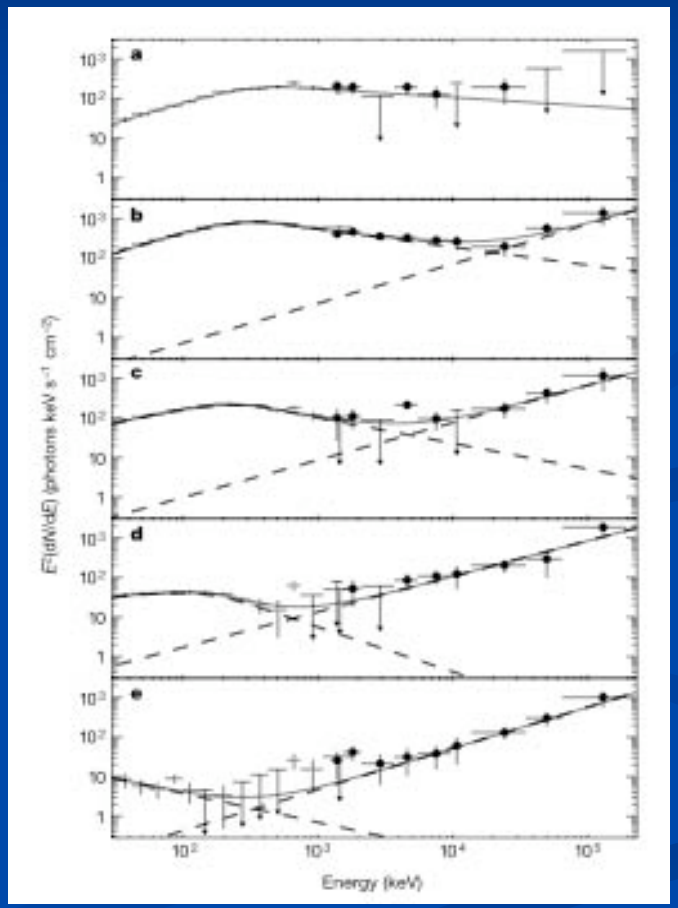
(Hurley et al. 1994)



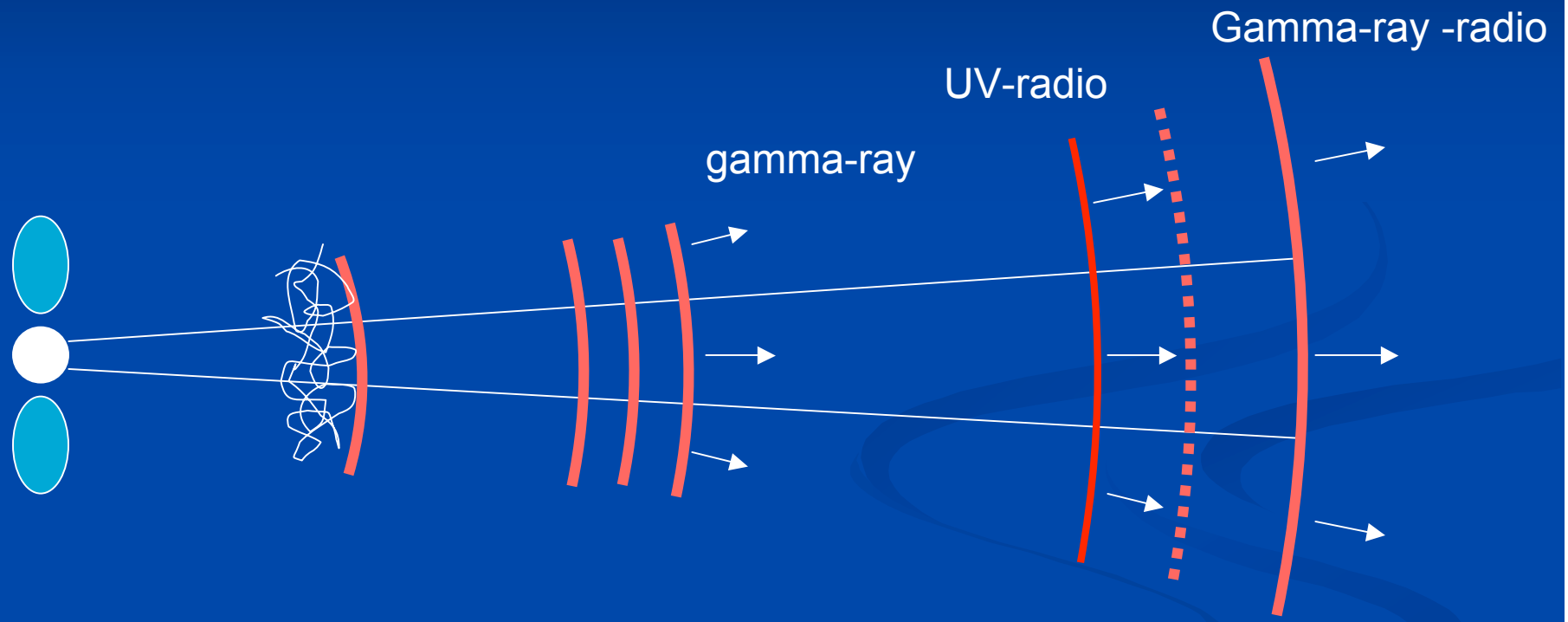
GRB 941017

(Gonzalez et al. 2003)

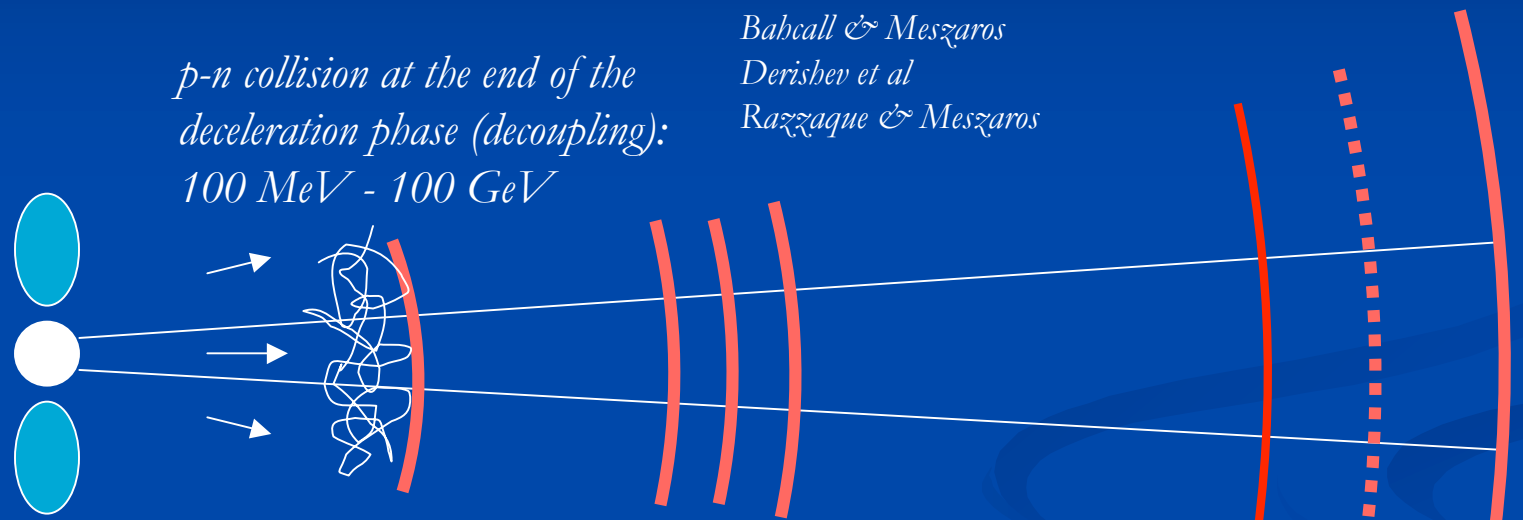




A generic GRB fireball



High energy emission from GRBs

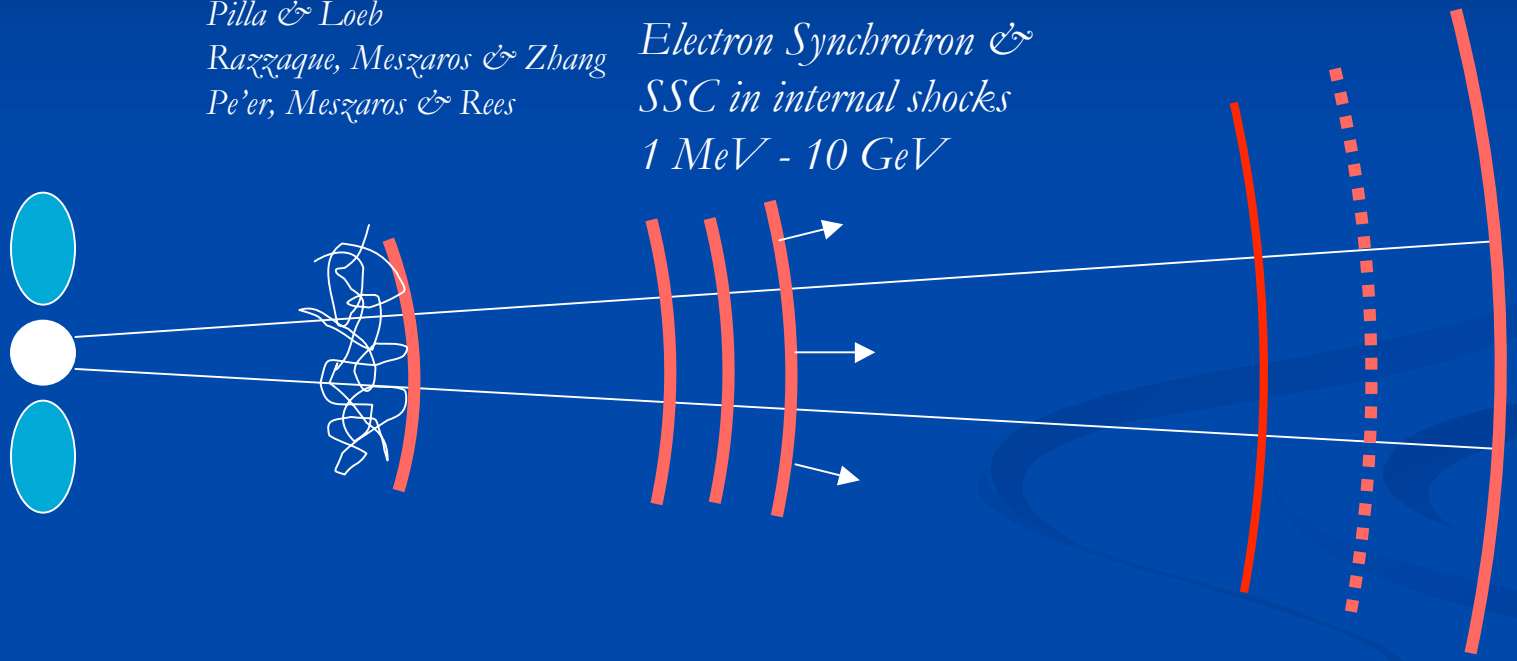


central engine **photosphere** **internal (shocks)** **external shocks (reverse)** **(forward)**

High energy emission from GRBs

Meszaros et al
Pilla & Loeb
Razzaque, Meszaros & Zhang
Pe'er, Meszaros & Rees

Electron Synchrotron & SSC in internal shocks
1 MeV - 10 GeV



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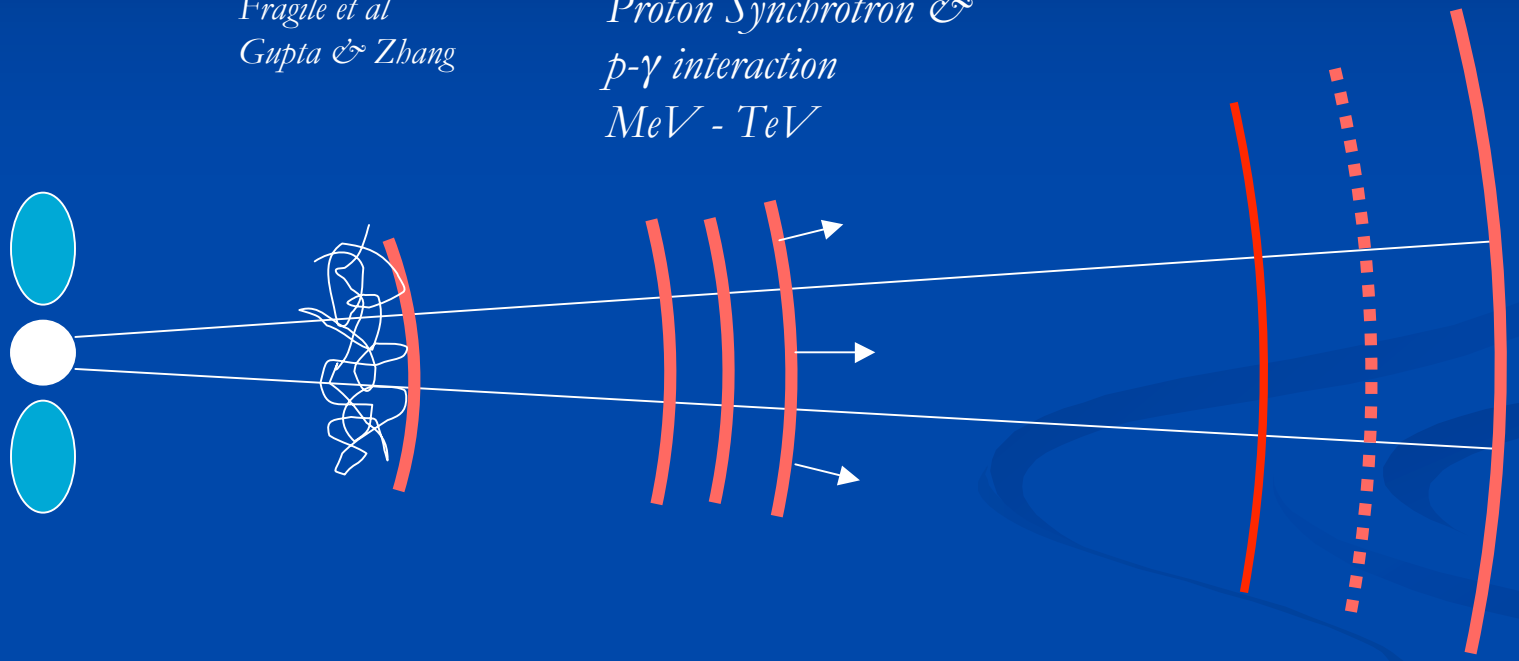
High energy emission from GRBs

Totani
Fragile et al
Gupta & Zhang

Proton Synchrotron &
p-γ interaction
MeV - TeV

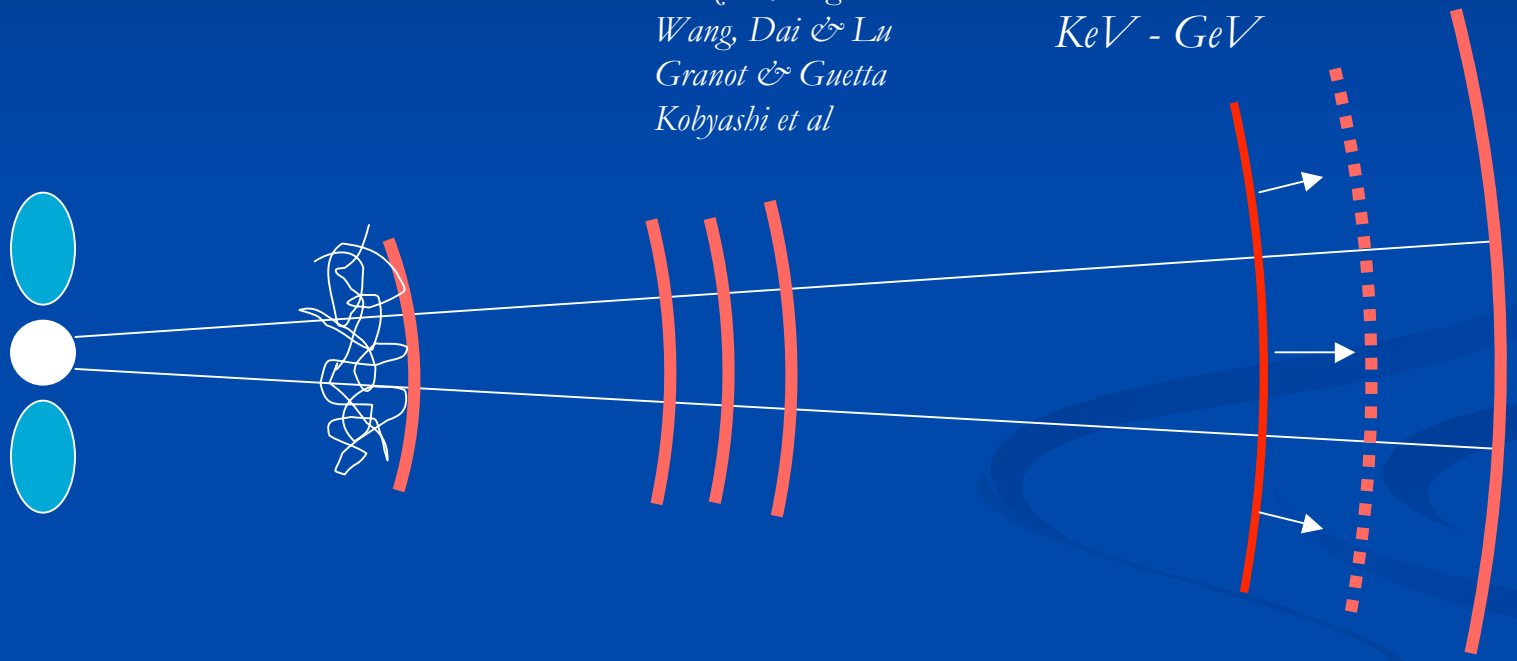


central engine **photosphere** **internal (shocks)** **external shocks (reverse)** **(forward)**

High energy emission from GRBs

Meszaros, Laguna & Rees
Wang, Dai & Lu
Granot & Guetta
Kobyashi et al

SSC in reverse shcok
KeV - GeV



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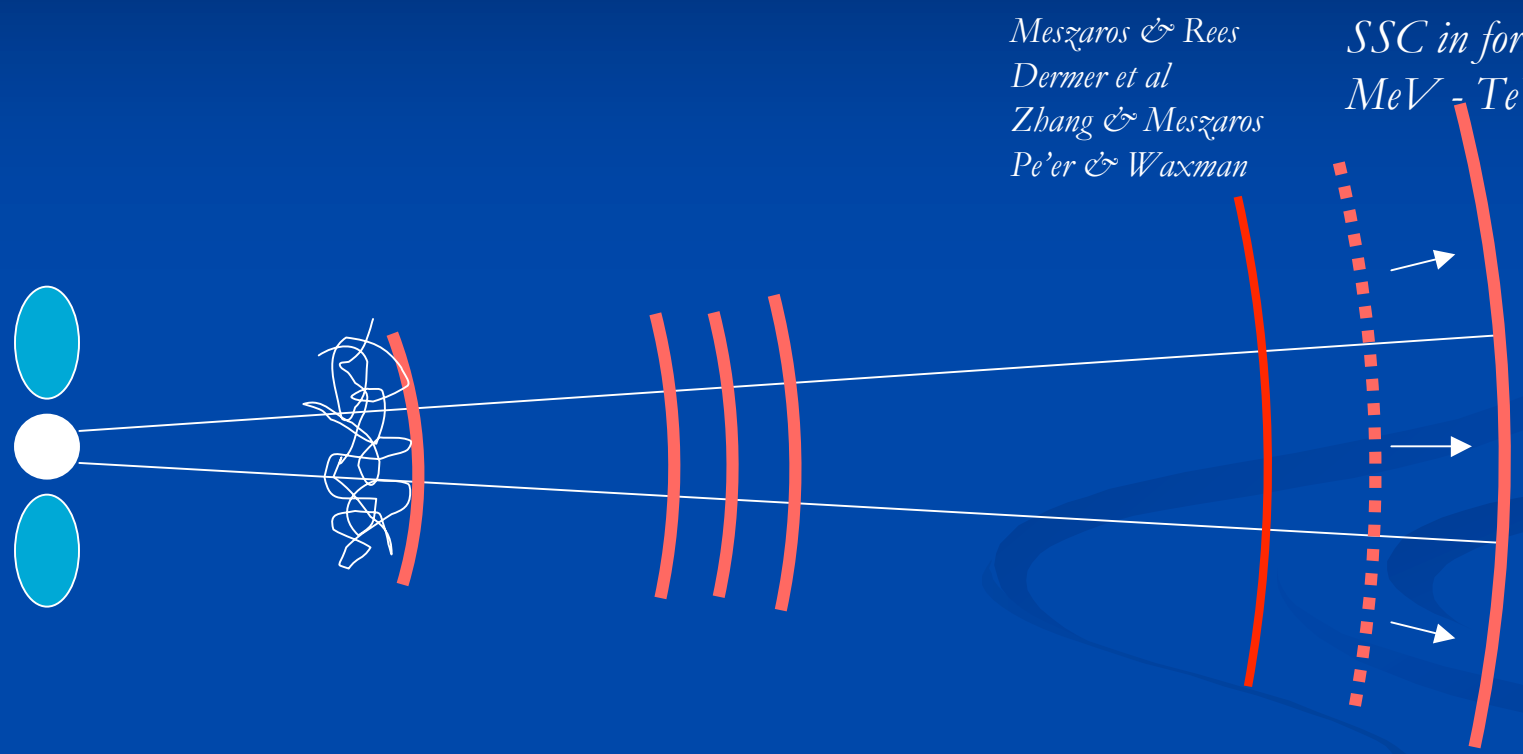
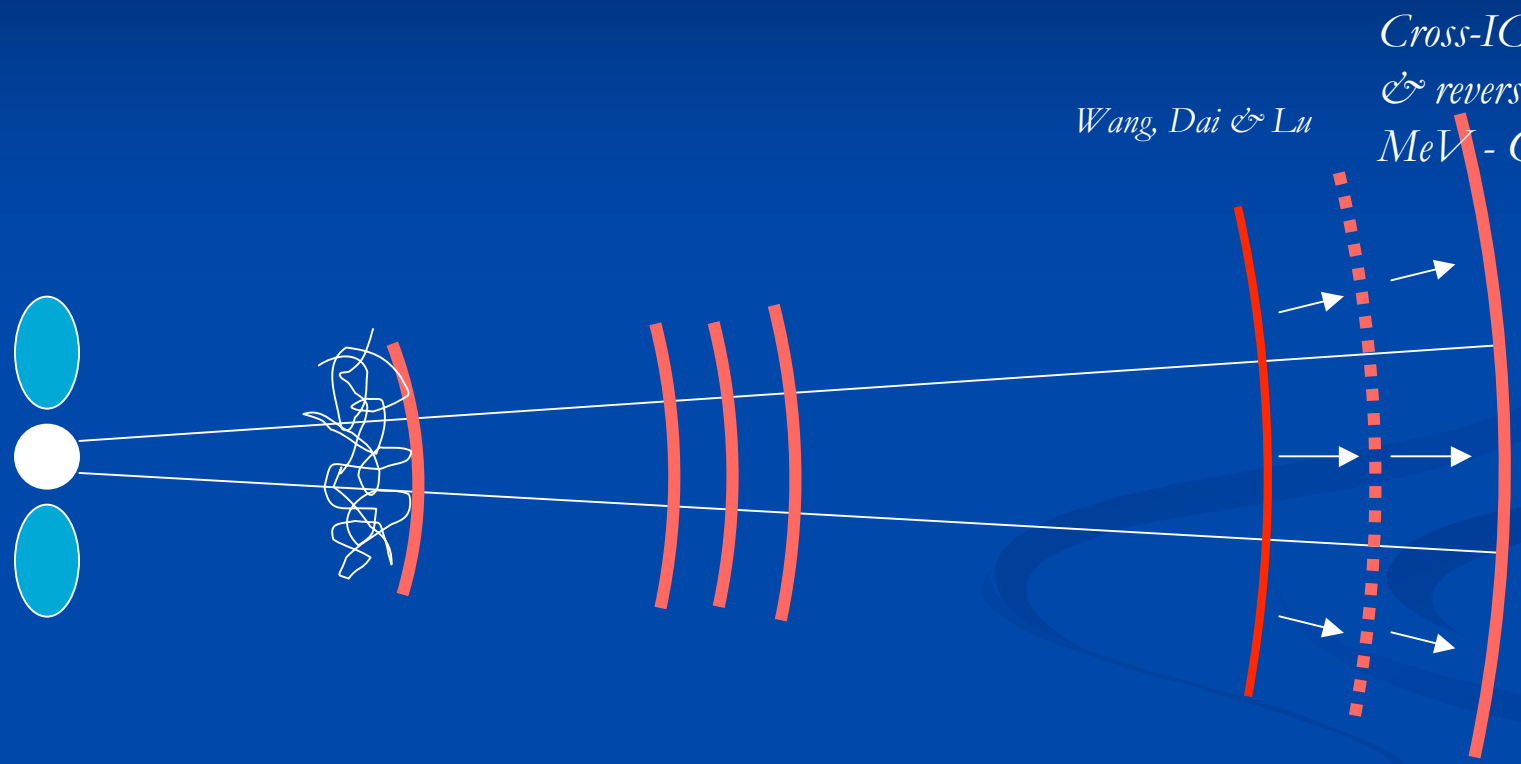
High energy emission from GRBs



central engine | photosphere | internal (shocks) | external shocks (reverse) (forward)

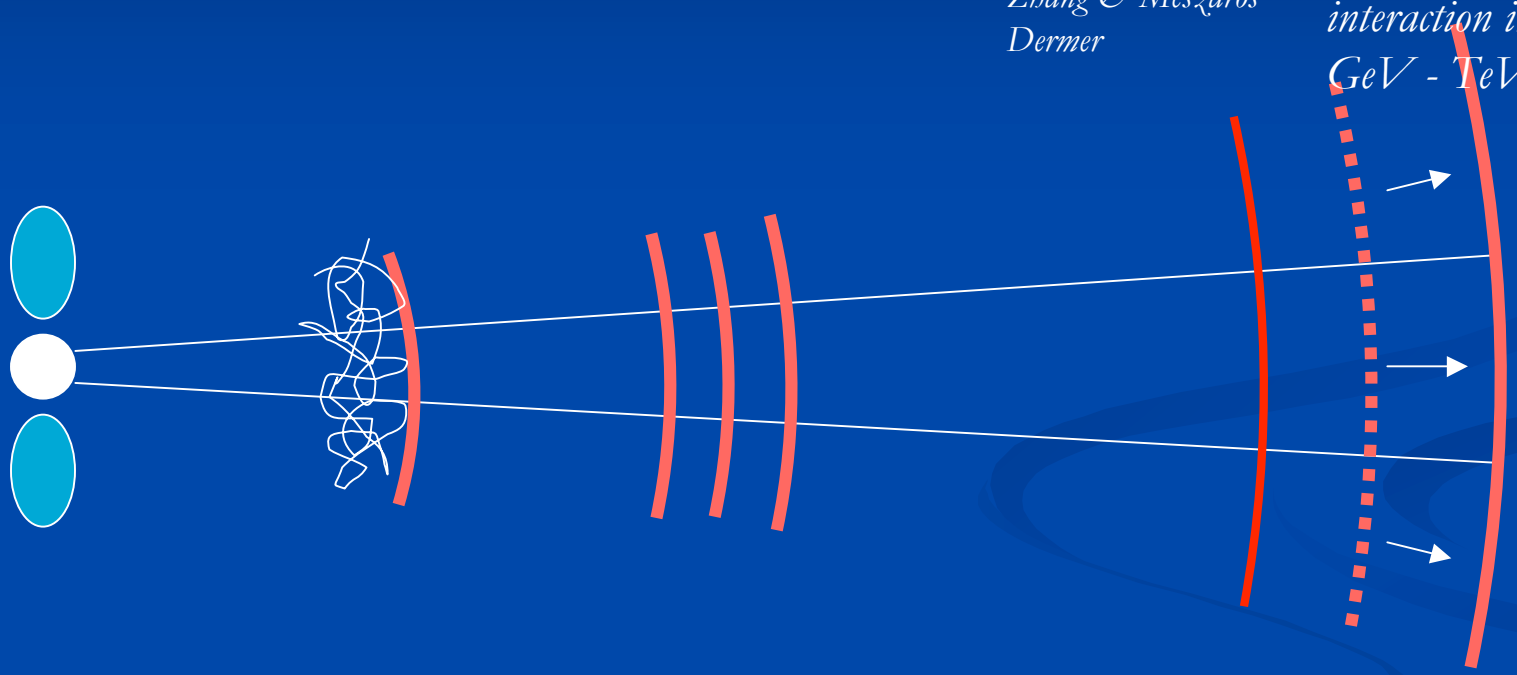
High energy emission from GRBs



High energy emission from GRBs

Boettcher & Dermer
Zhang & Meszaros
Dermer

Proton synchrotron, p-γ interaction in forward shcok
GeV - TeV



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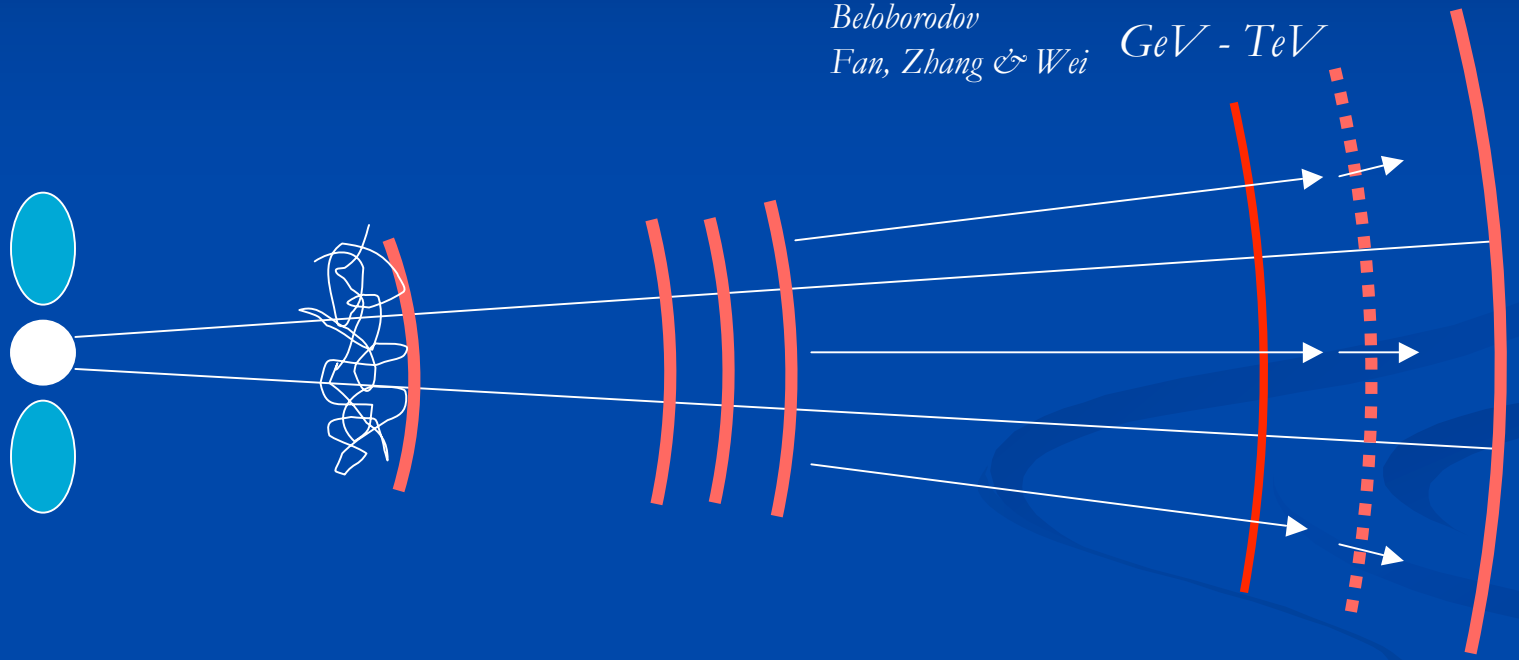
High energy emission from GRBs

"Overlapping IC" of prompt emission in external shock GeV - TeV

Beloborodov
Fan, Zhang & Wei



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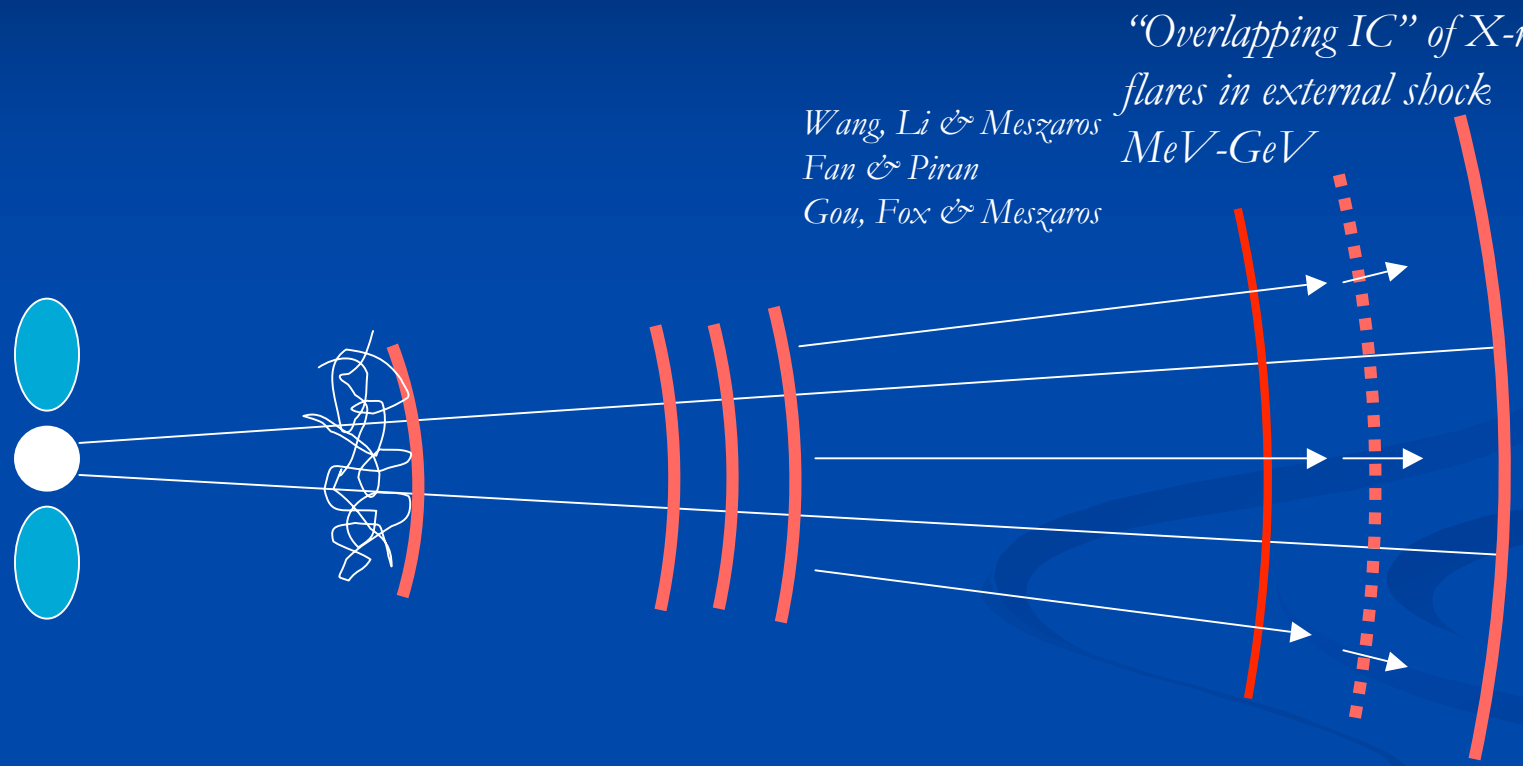
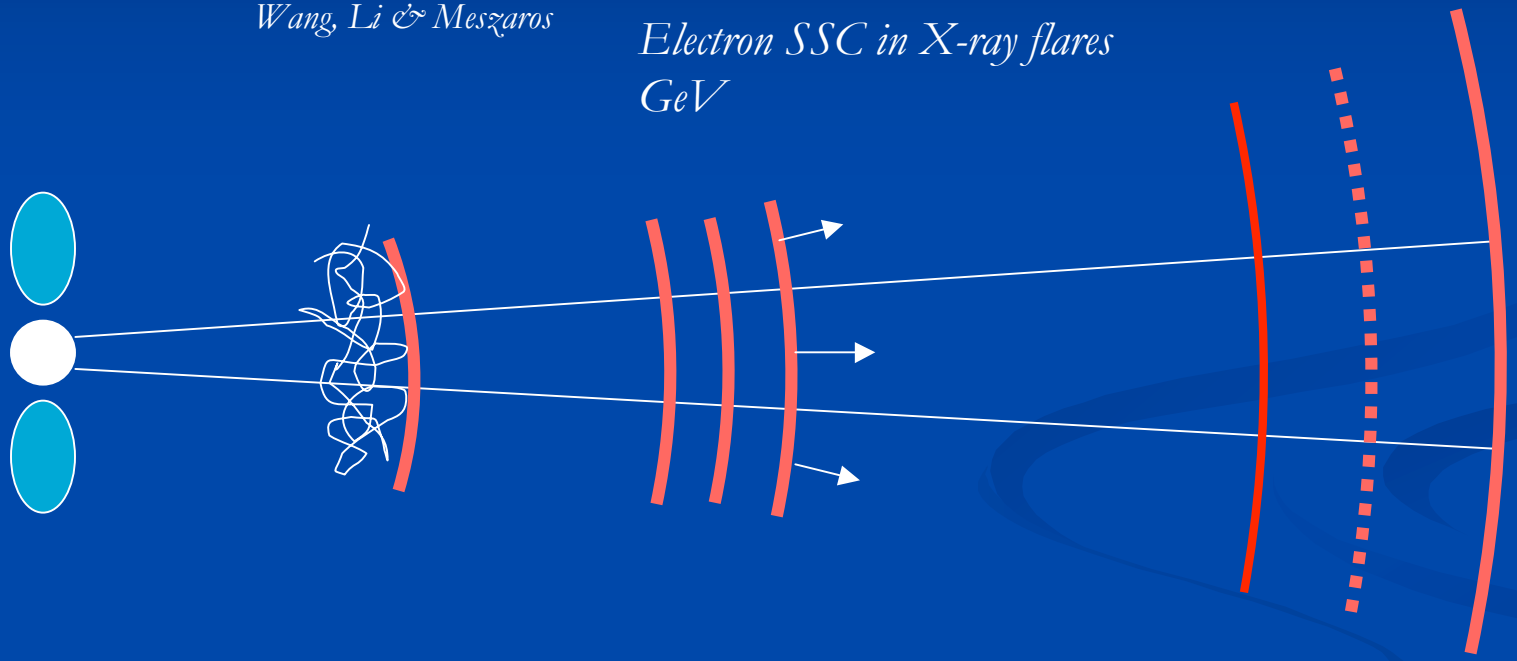
High energy emission from GRBs



High energy emission from GRBs

Wang, Li & Meszaros

Electron SSC in X-ray flares
GeV



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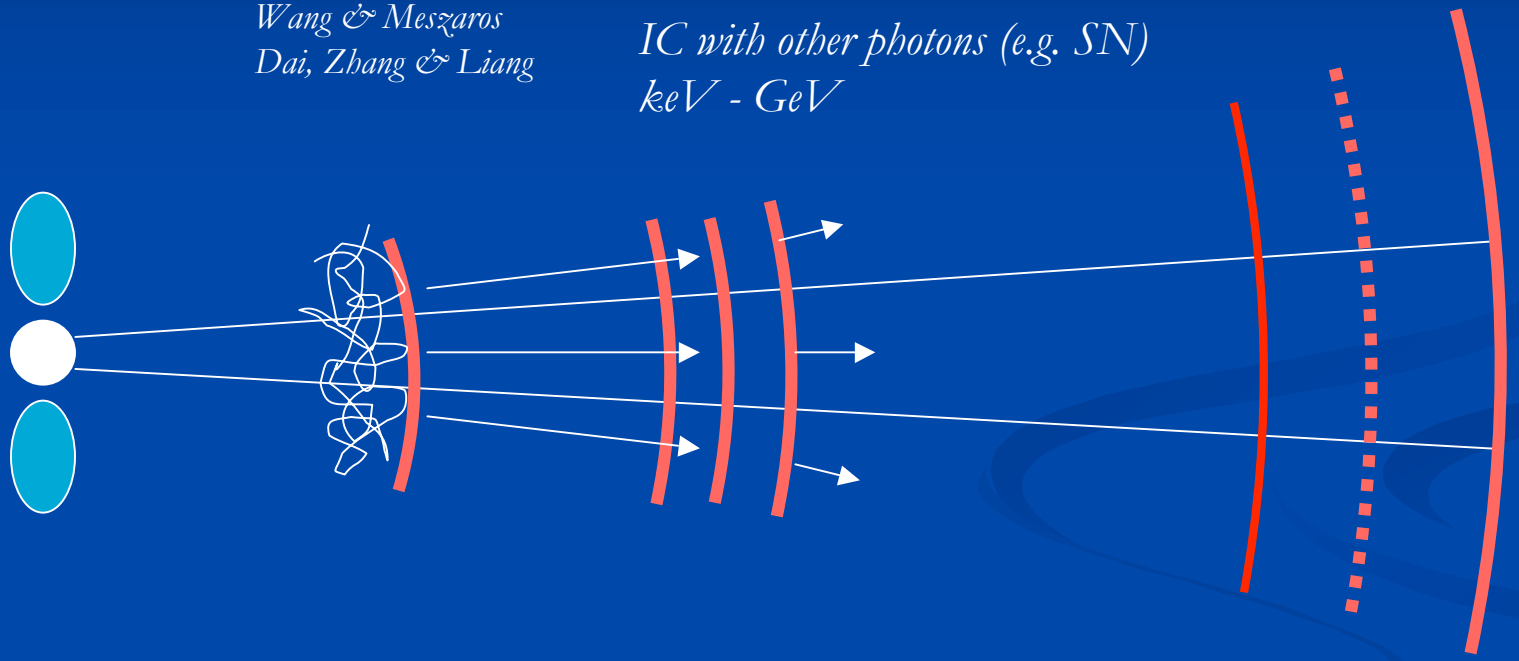
High energy emission from GRBs

Wang & Meszaros
Dai, Zhang & Liang

IC with other photons (e.g. SN)
keV - GeV



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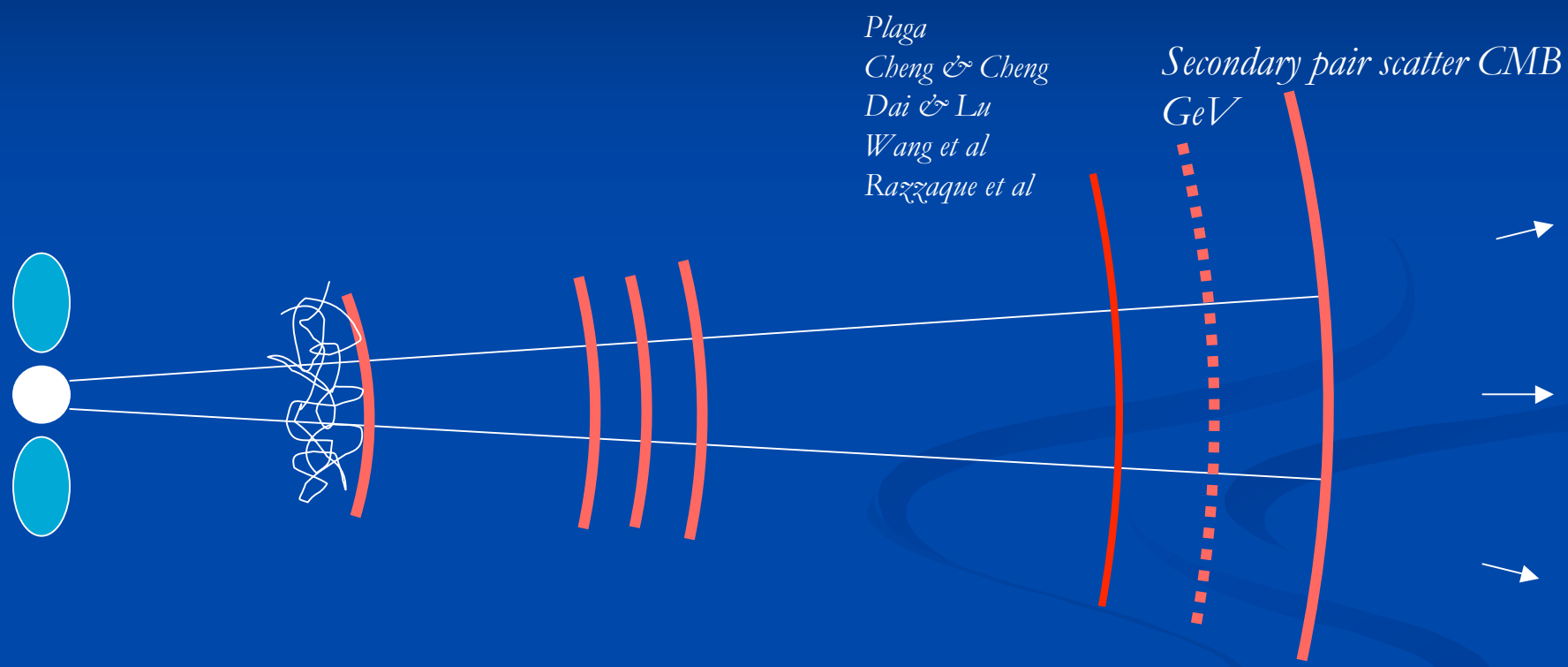
High energy emission from GRBs



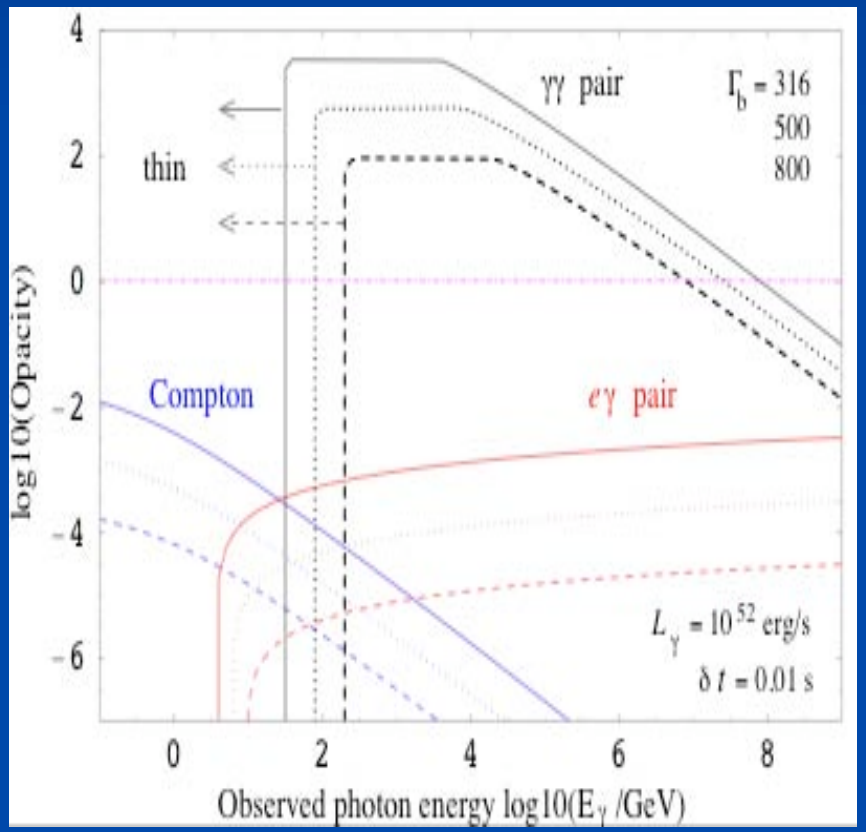
Expected high-energy (GeV-TeV) emission from GRBs (A non-exhaustive list)

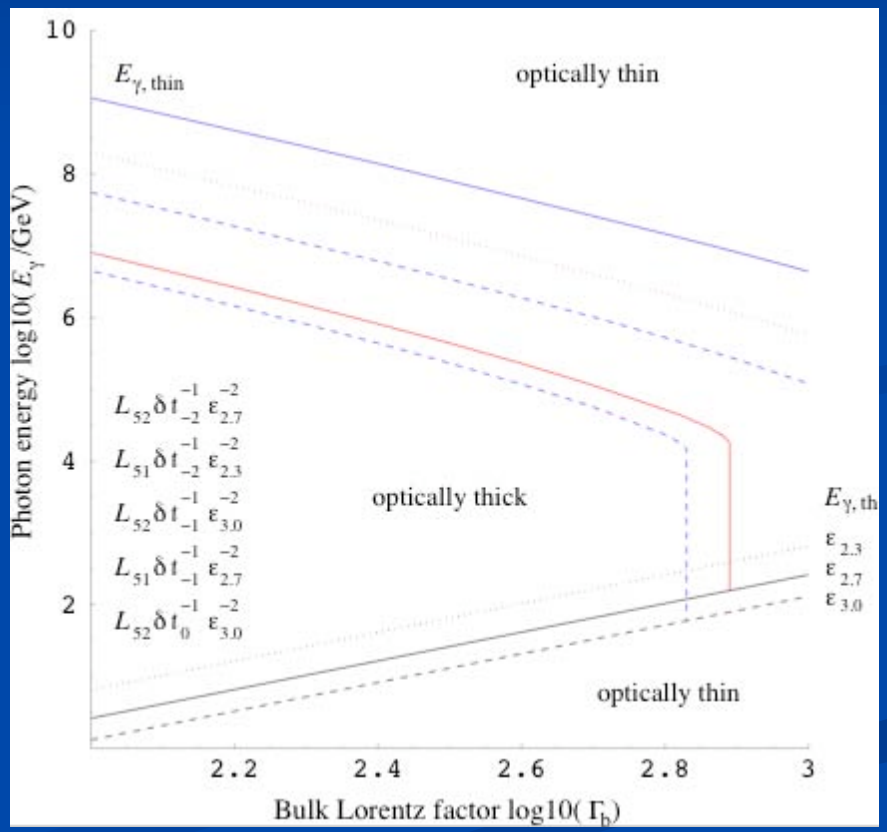
- Prompt phase
  - Internal leptonic: electron synchrotron & SSC
  - Internal hadronic: proton synchrotron & p-γ interaction
- Early afterglow phase
  - External leptonic: forward, reverse and cross shock SSC
  - External hadronic: proton synchrotron & p-γ interaction
  - Overlapping IC (prompt emission and X-ray flares)
  - SSC from X-ray flares
- Extended emission
  - Photon-pair interaction in the fireball and IC with CMB

What is the relative importance of each component?

Prompt GeV-TeV emission: internal optical depth

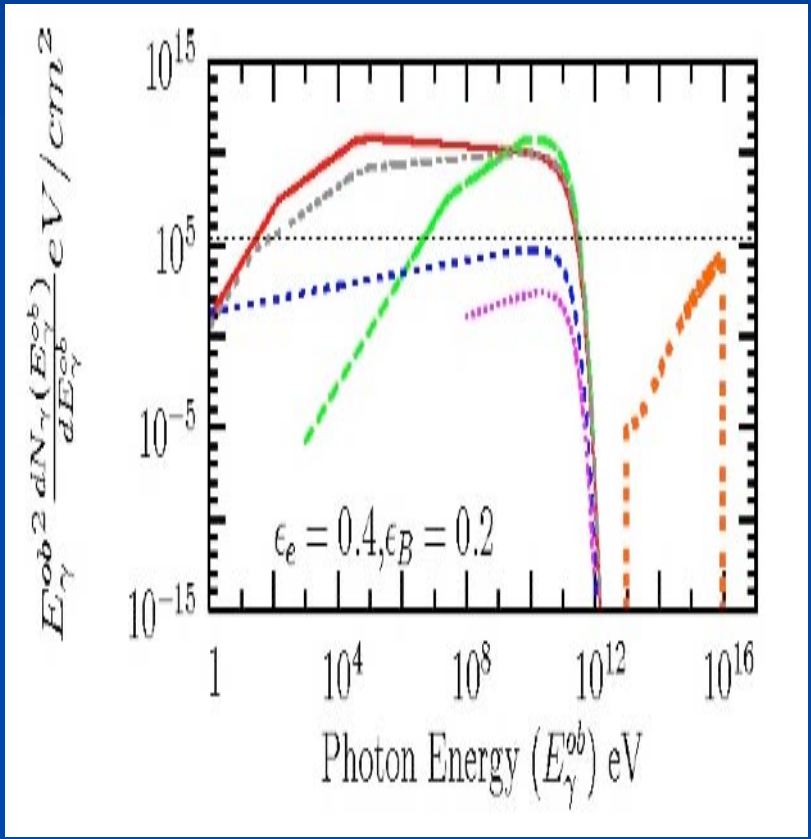
(Razzaque, Meszaros & Zhang 2004)

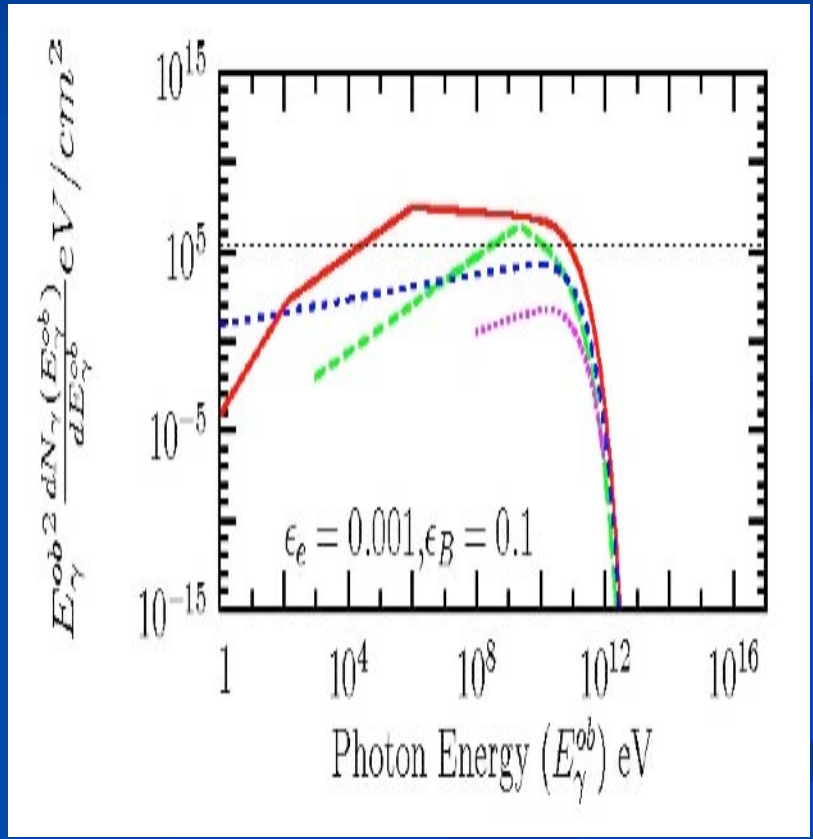




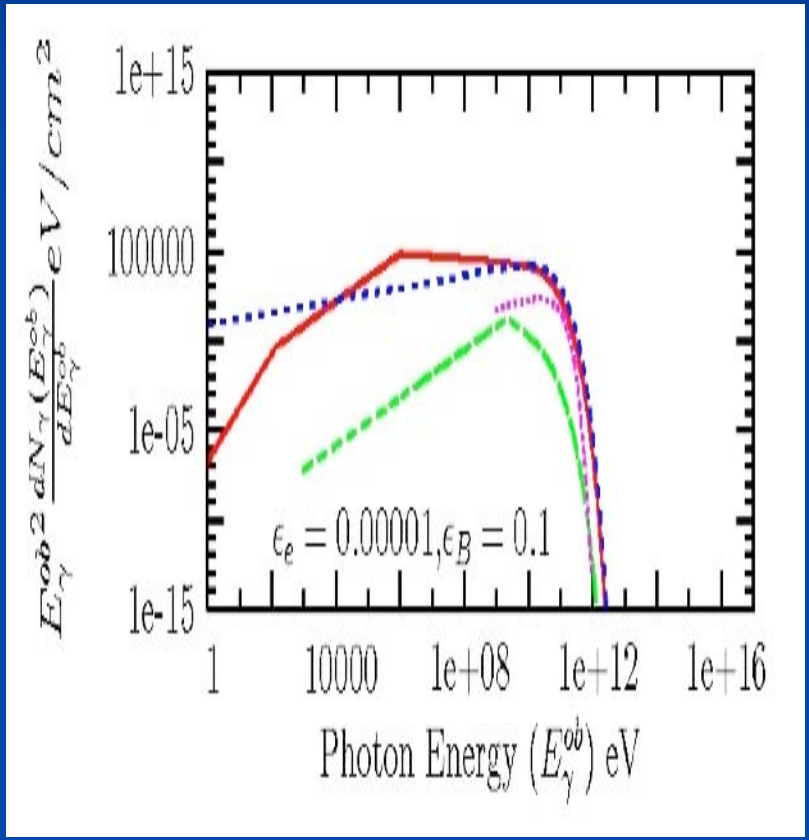
Become opaque above 10-100 GeV, transparent again above several PeV
Depends on the Lorentz factor of the fireball.

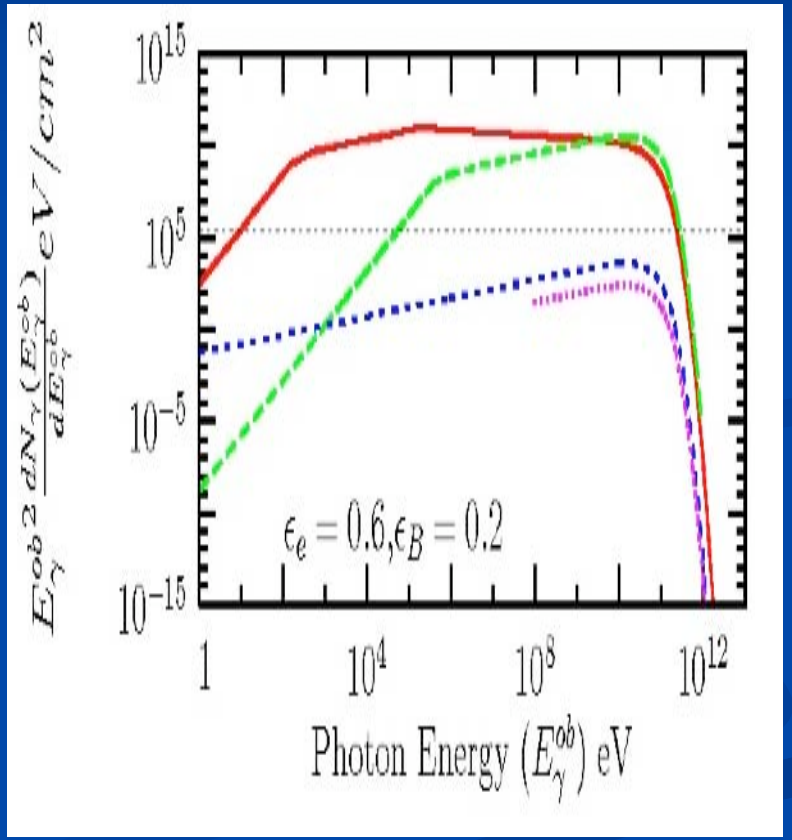
Prompt emission
(Gupta & Zhang 2007)



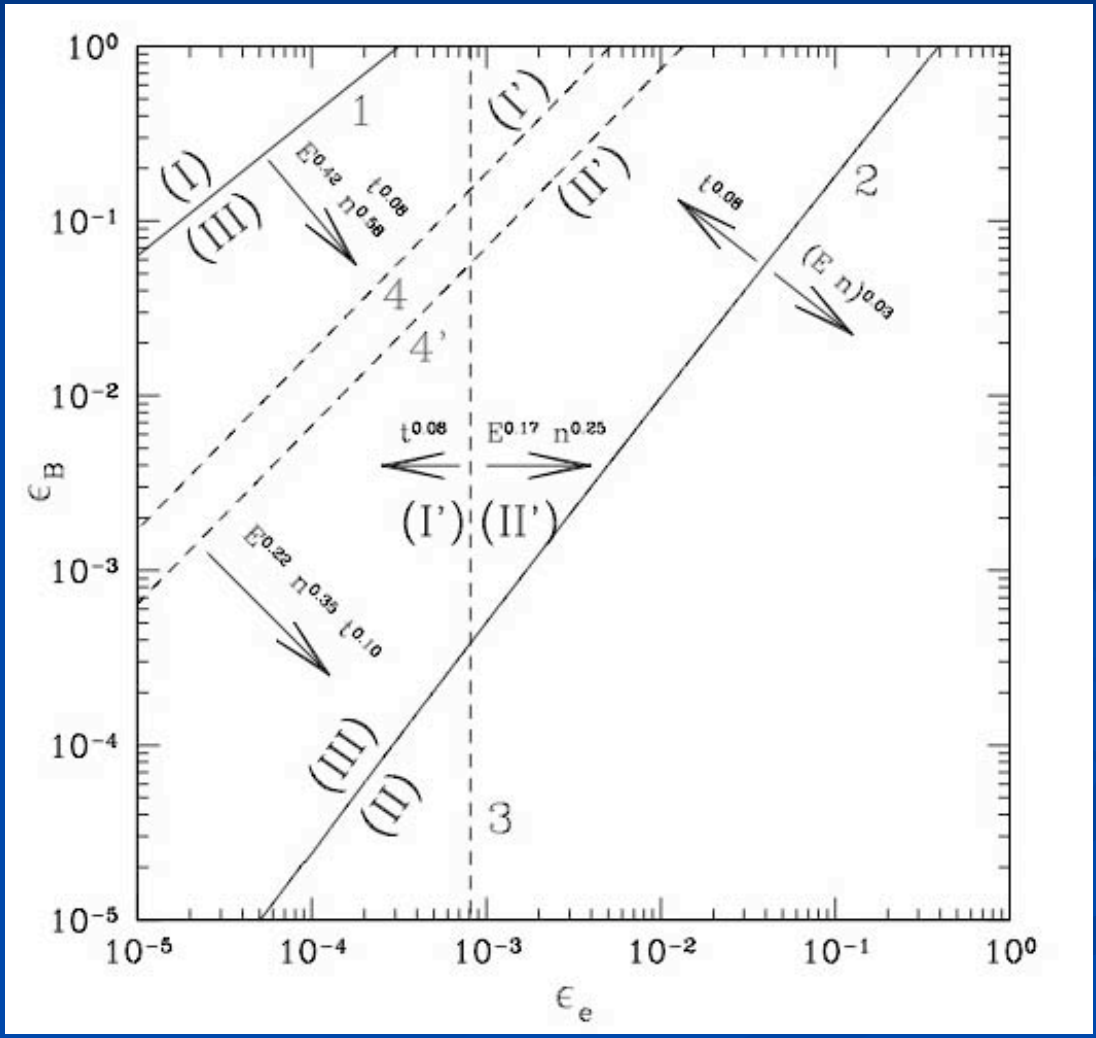


Prompt emission
(Gupta & Zhang 2007)

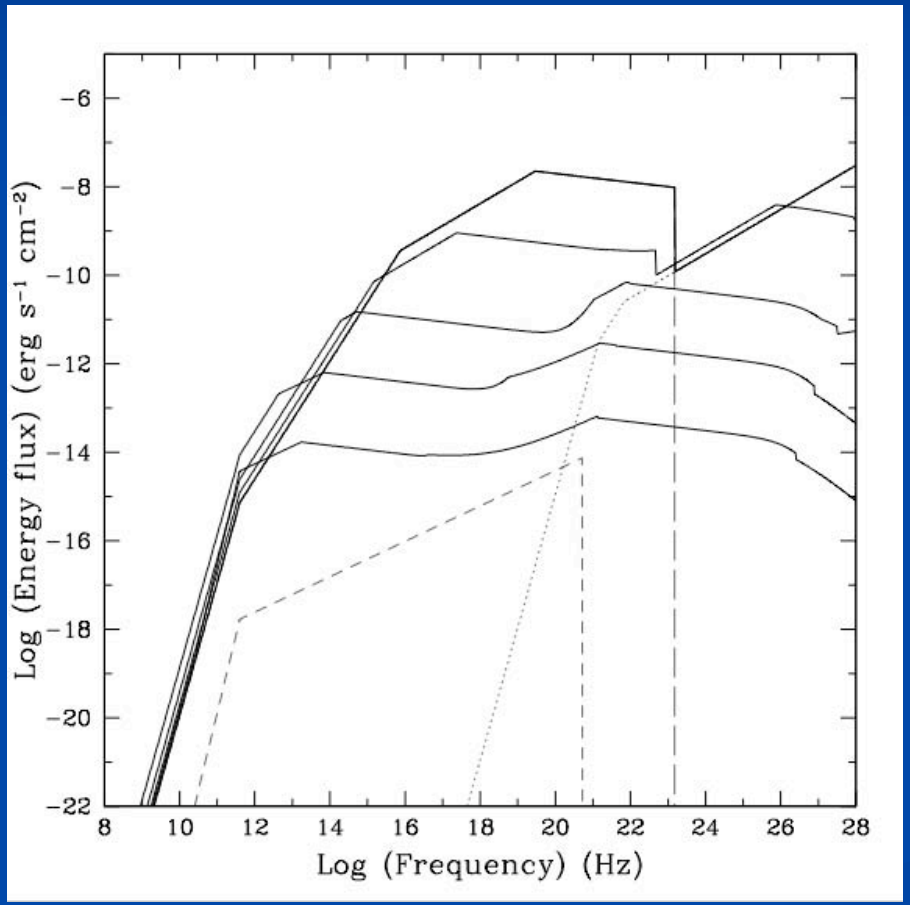


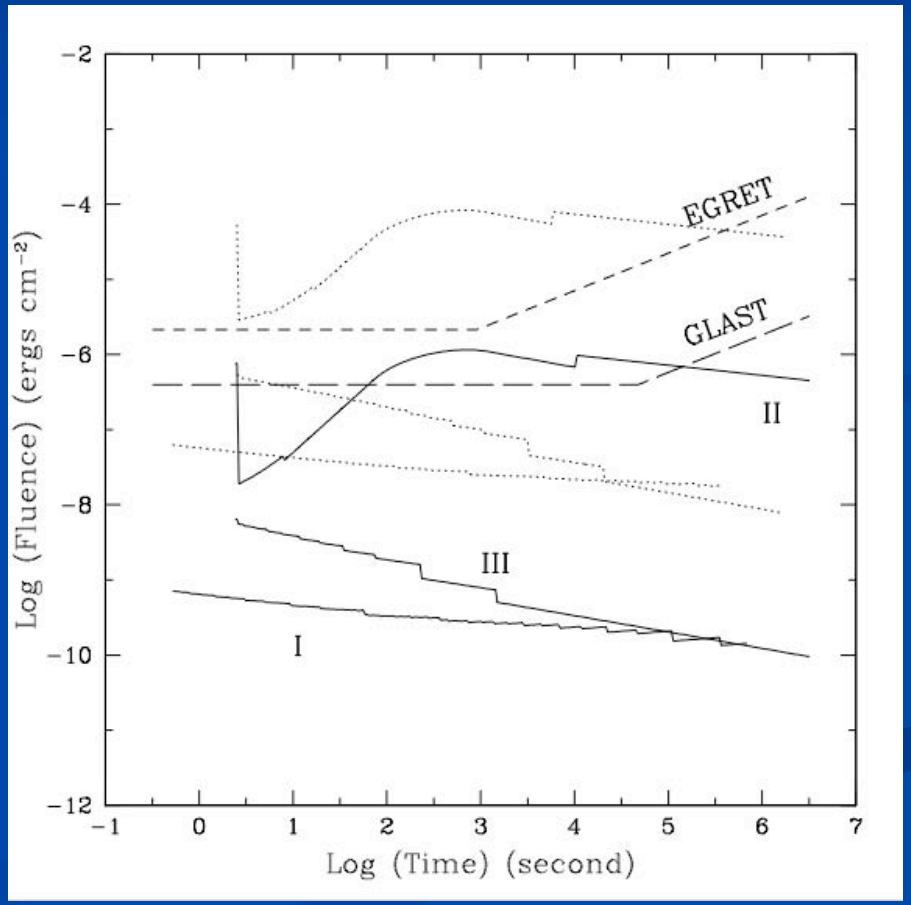


Afterglow
(Zhang & Meszaros 2001)



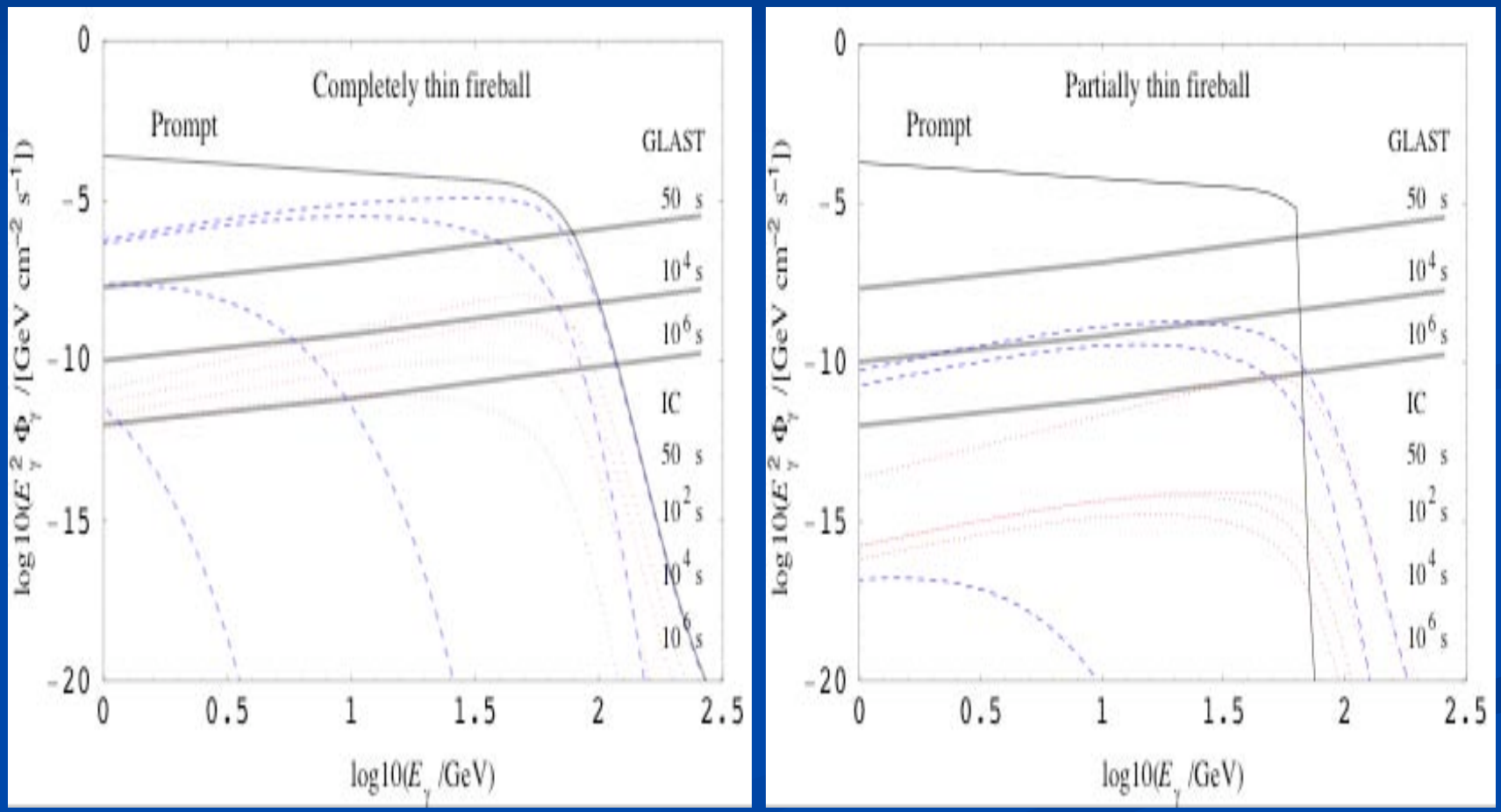
High Energy Afterglow
(Zhang & Meszaros 2001)



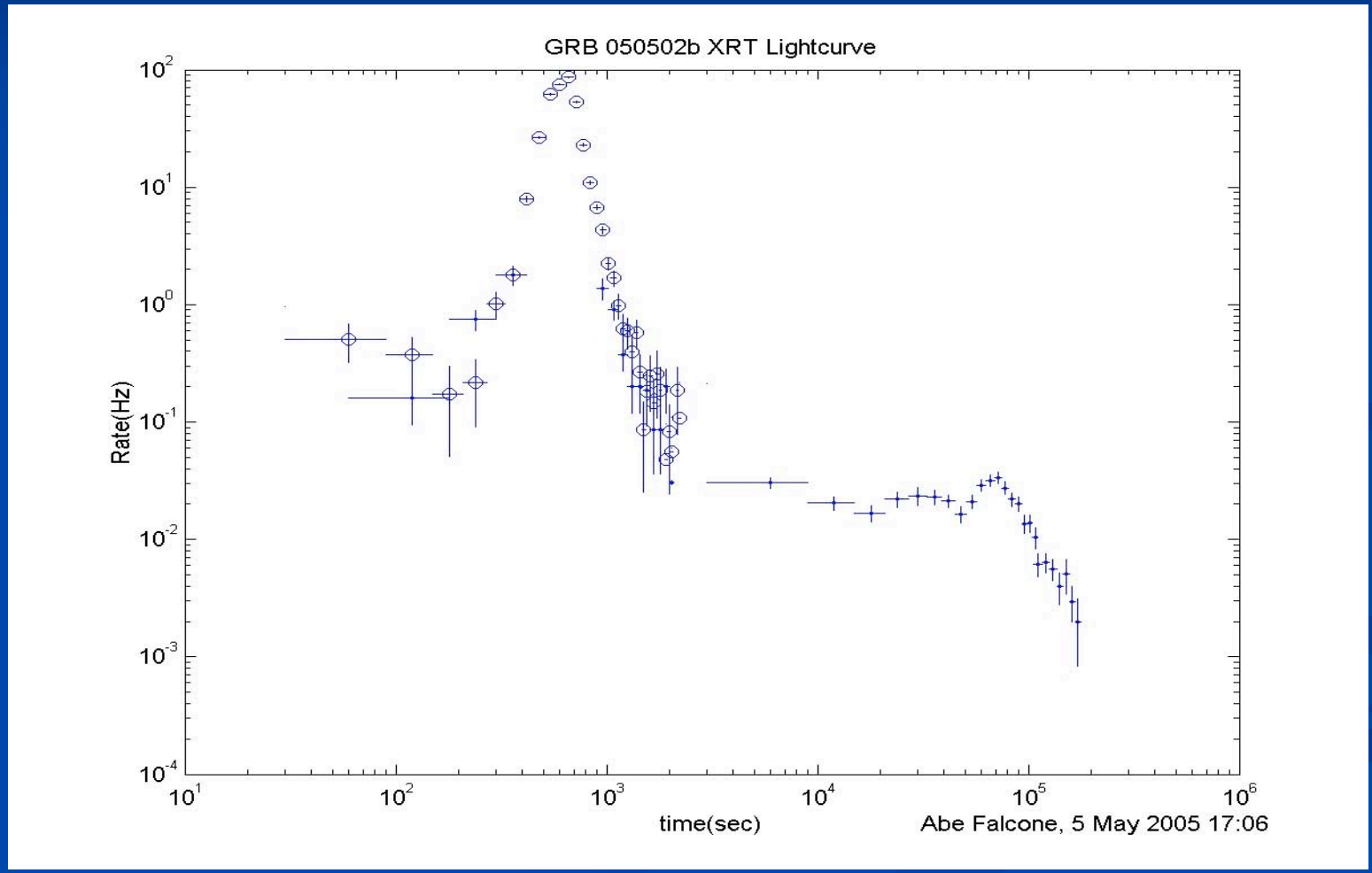


Photon-Pair Interaction

(Razzaque, Meszaros & Zhang 2004)

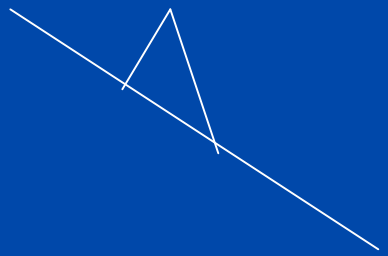


GeV flares - like X-ray flares?



GeV flares
- possible but harder to identify

- Overlapping IC of X-ray flare photons
- SSC in X-ray flares
- Caveats:
  - IC process tends to smear the sharp signature of X-ray flares
  - The background (forward shock) component fades slowly - even rises initially

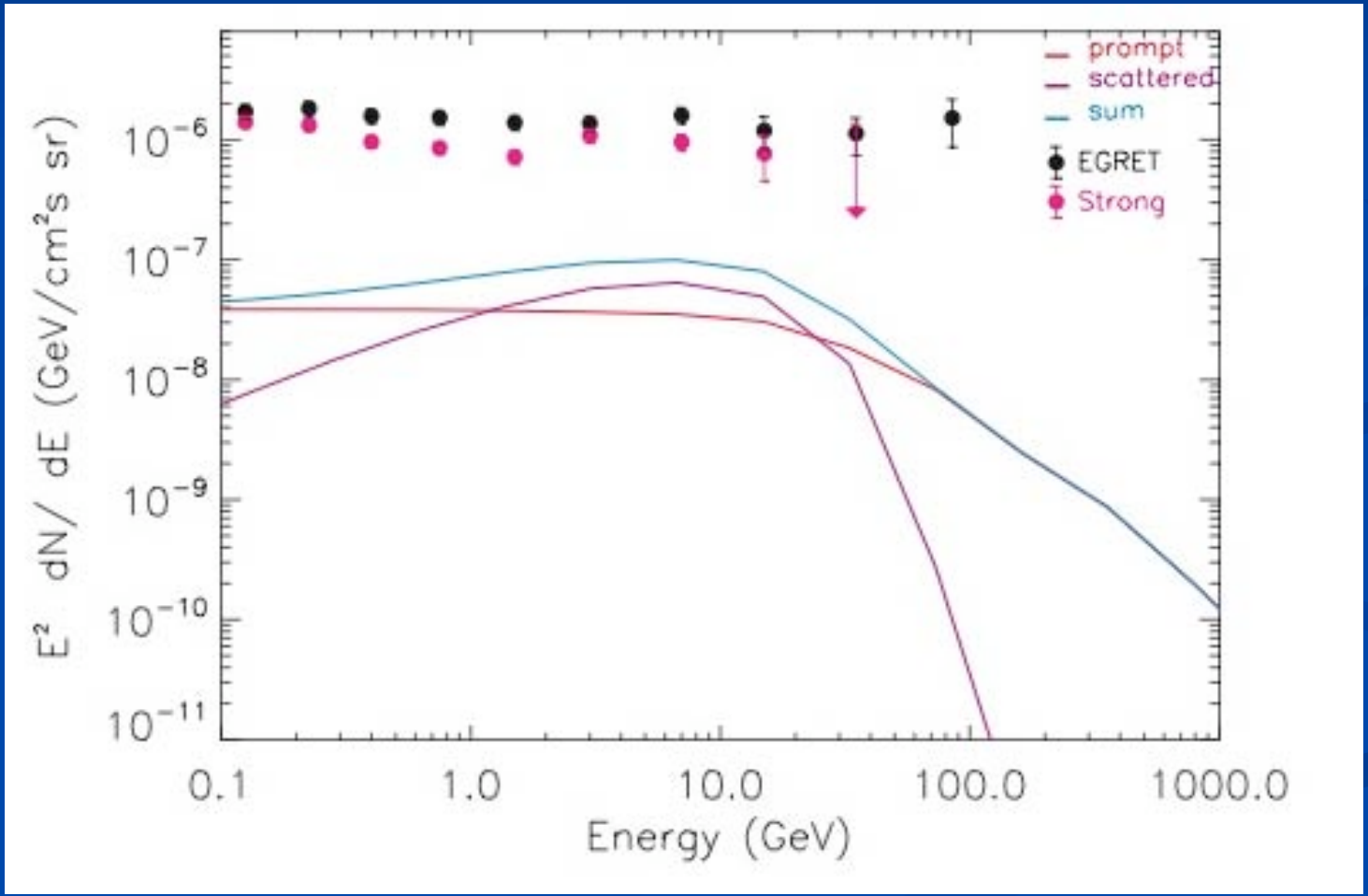


X-ray flares

GeV flares

Gamma-ray background

(Casanova, Dingus & Zhang 2007)



Bold predictions for GLAST

- GLAST is almost guaranteed to detect GeV emission from GRBs. Cutoff energy - bulk Lorentz factor and emission radius
  - Long GRBs lower cut off?
  - Short GRBs higher cut off?
  - X-ray flashes: less GeV emission
- High energy emission lasts longer than the MeV emission
  - External shock emission
  - Overlapping IC emission
  - Secondary pair emission (IC off CMB)
- Pulse width: narrower with energy initially, but wider when the IC component takes over
- GeV flares: likely, but
  - Broader
  - Smaller contrast

Conclusions