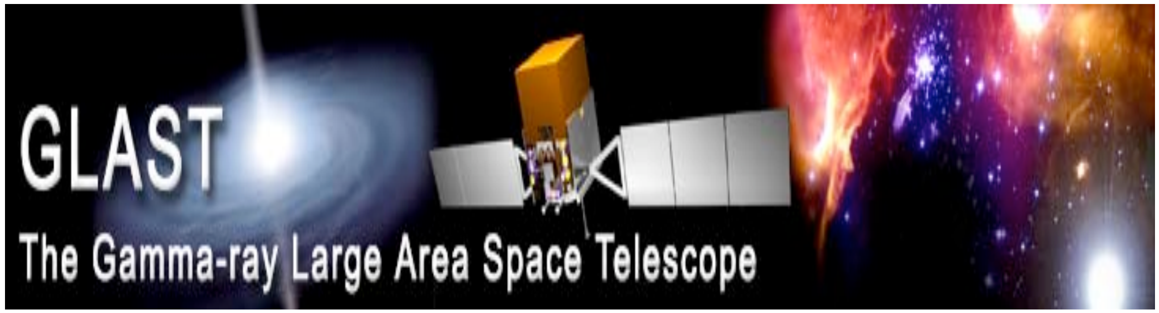
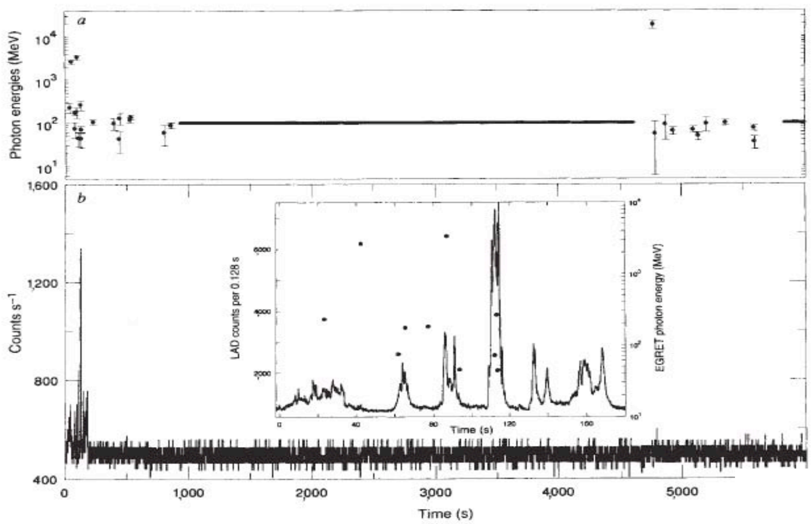
GRBs with GLAST



Tsvi Piran
Racah Inst. of Jerusalem, Israel

Yizhong Fan, Ramesh Narayan D. M. Wei
Maria Rodriguez Martinez; Yonathan Oren; Uri Jacob

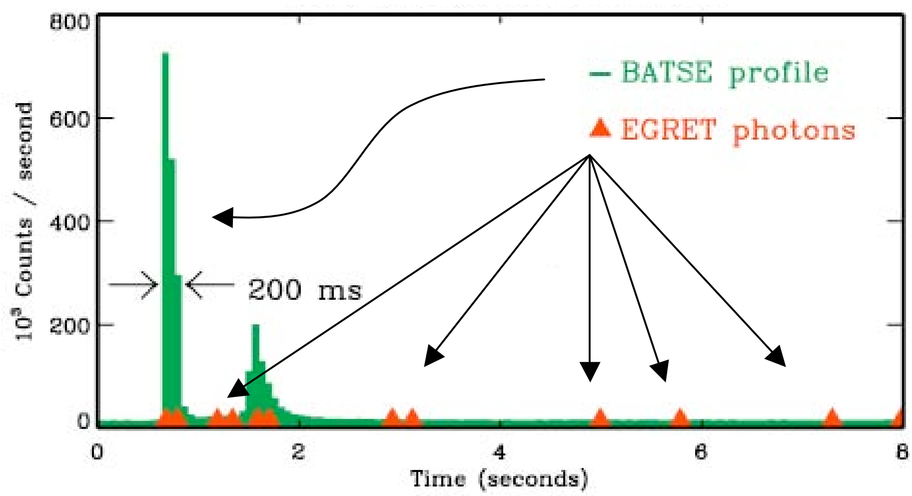
Observations (EAGRET)



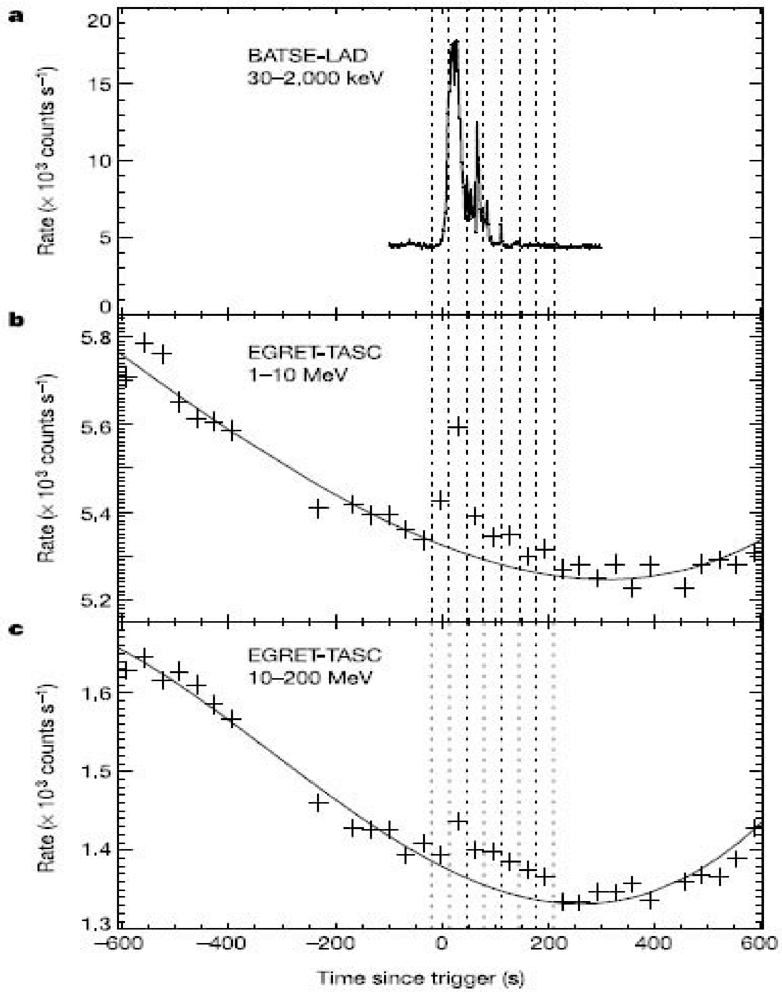
GRB 940217

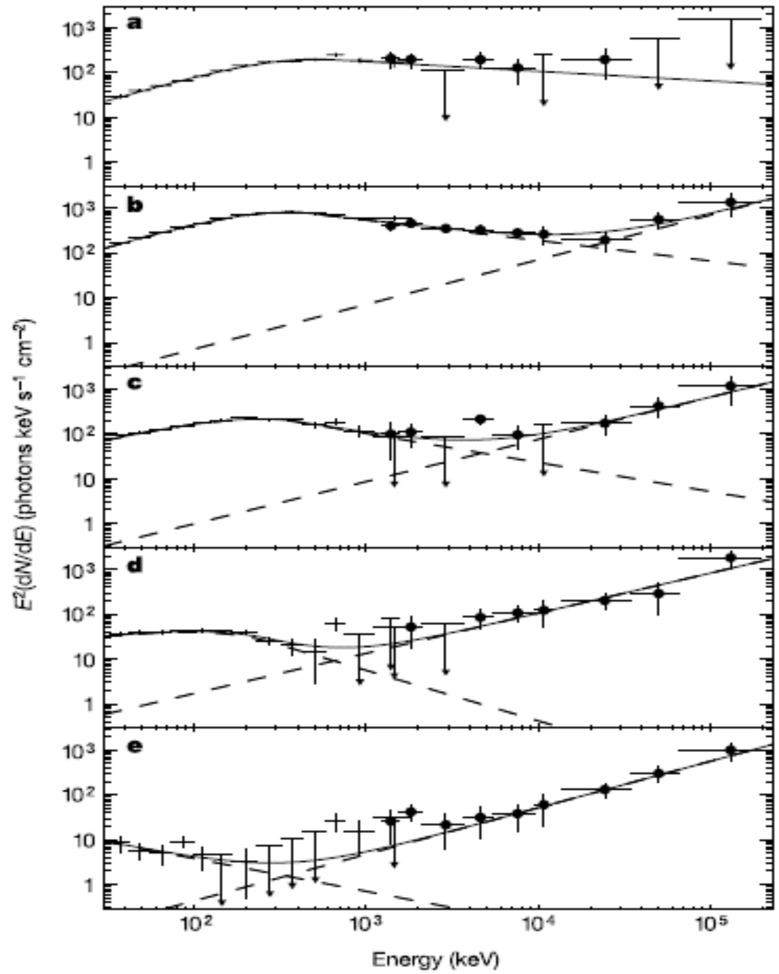
(Hurley et al. 1994)

GRB 930131 (Superball Burst)

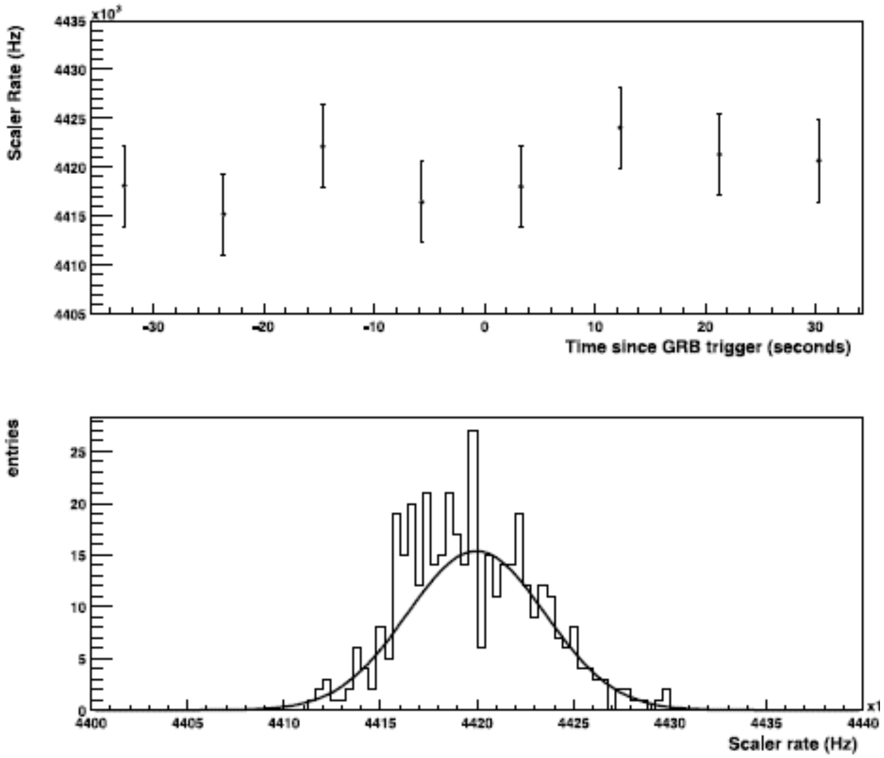


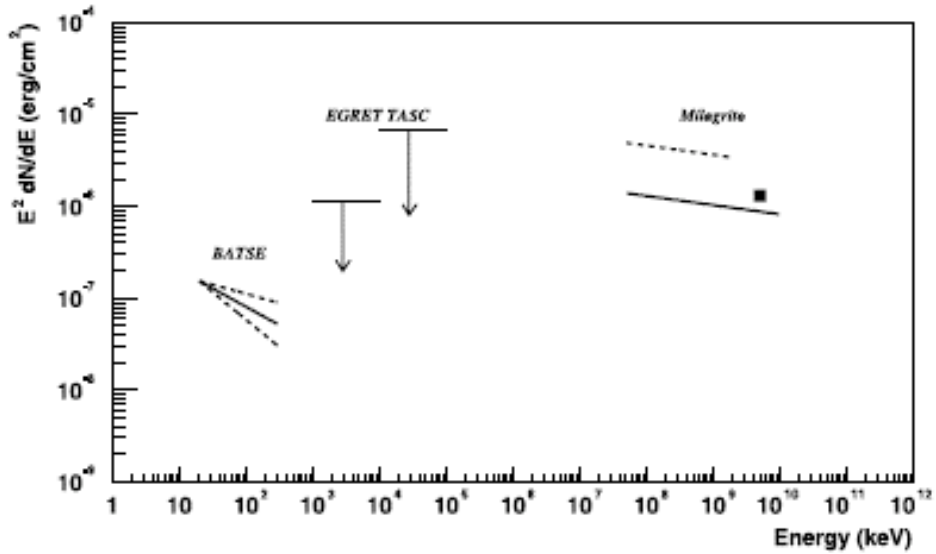
Observations (EAGRET):
GRB 941017: Gonzalez et al. 2003





Observations (MILAGRITO): GRB 970417a: Atkins et al., 00,03





>3s detection

$E_{Tev} > 10\ E_g$

Additional Observations

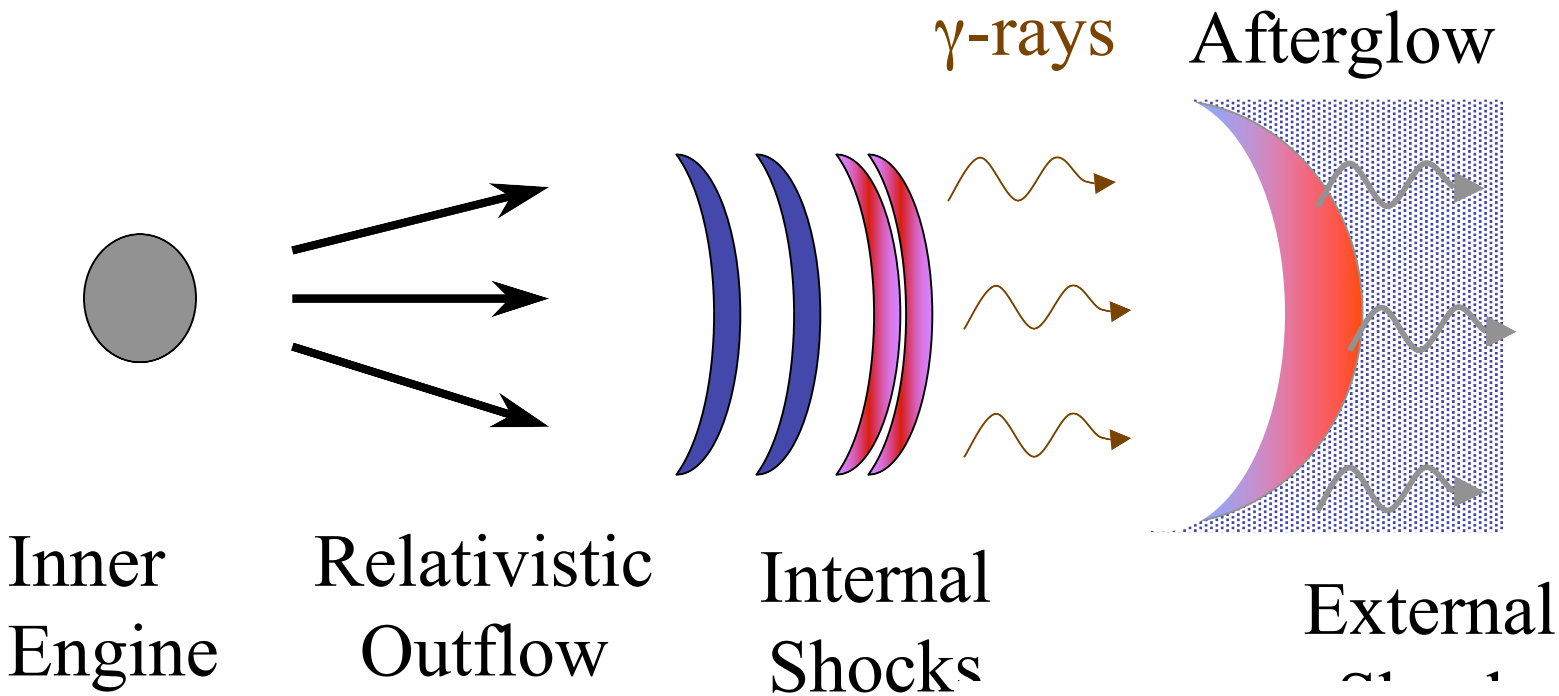
- **Upper limits from Magic for several Swift bursts** (Albert et al., 06, see also poster)
- **Claims of detection GRAND at 2.7 σ** (Poirier et al 03, but see Fragile etal 03)
- **Tibet array: 7σ coincidence ?** (Amenomori et al 01)
- **ARGO-YBJ array find only upper limits** (Di Sciascio, et al., 06)

High Energy Events

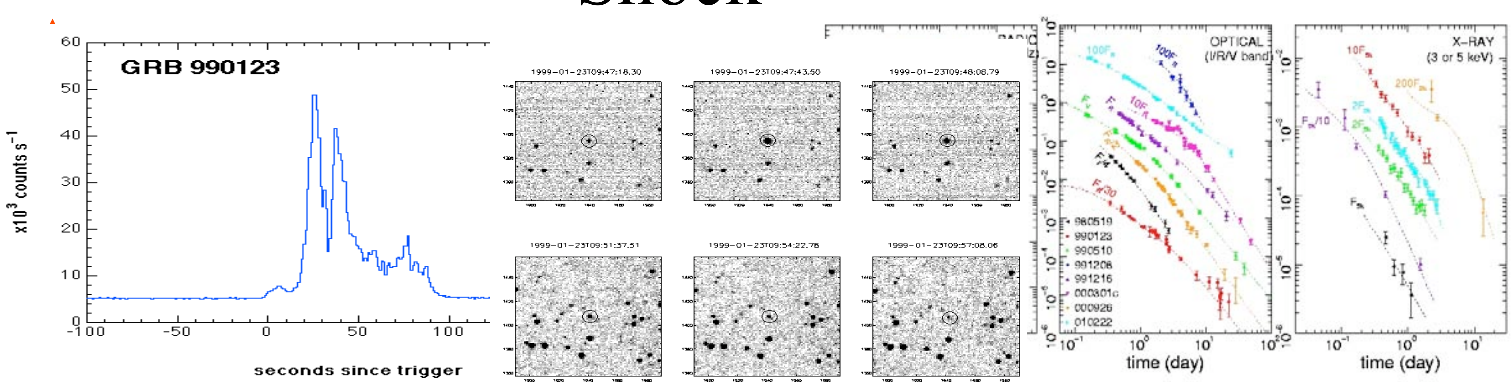
- 940217 – GeV EGRET.
- 941017 – 0.2 GeV – TASC on EGRET
- 970417 – TEV Milagrito

What is happening on the 17^{th}s ?

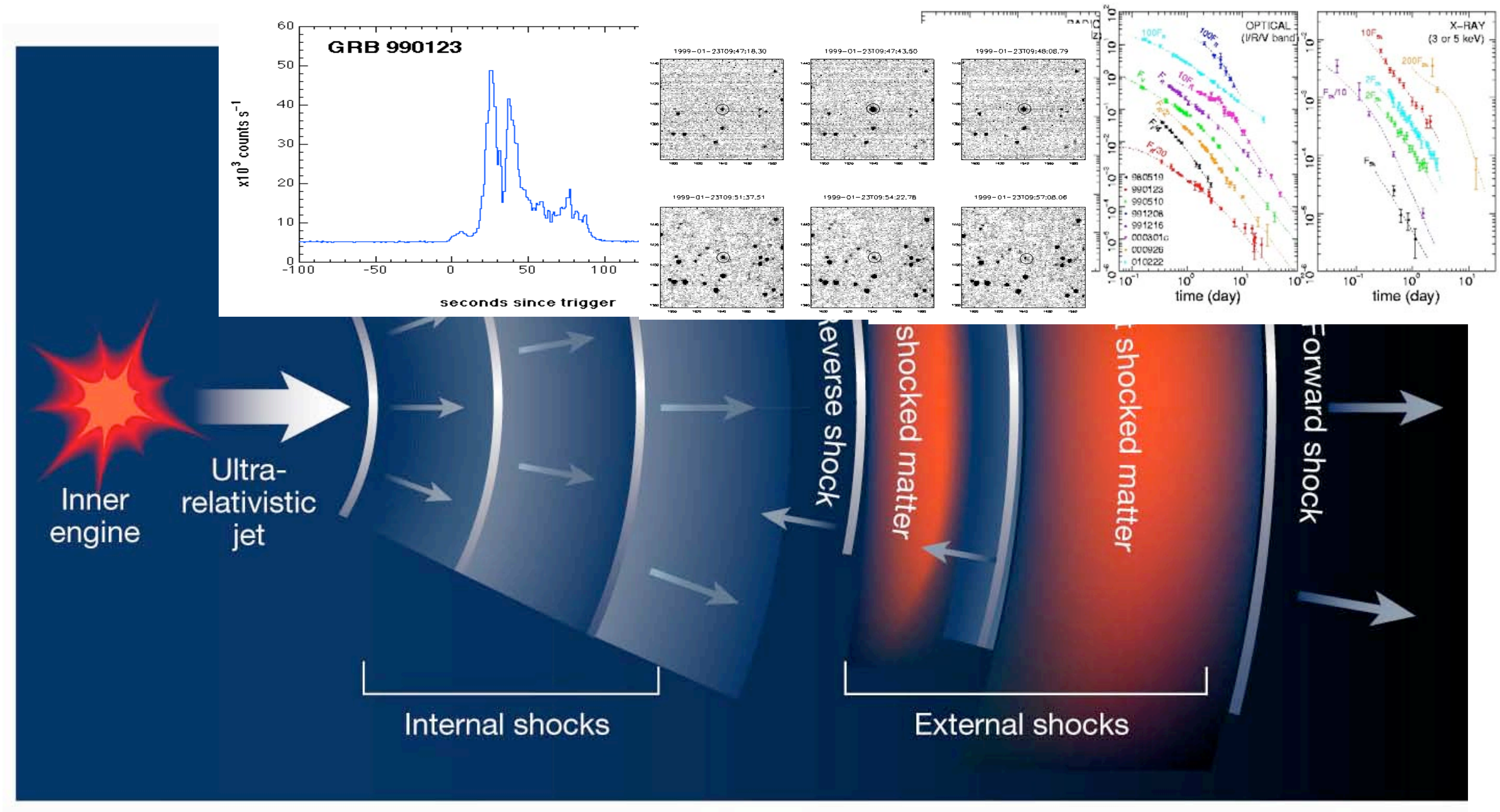
The Internal-External Fireball Model



1

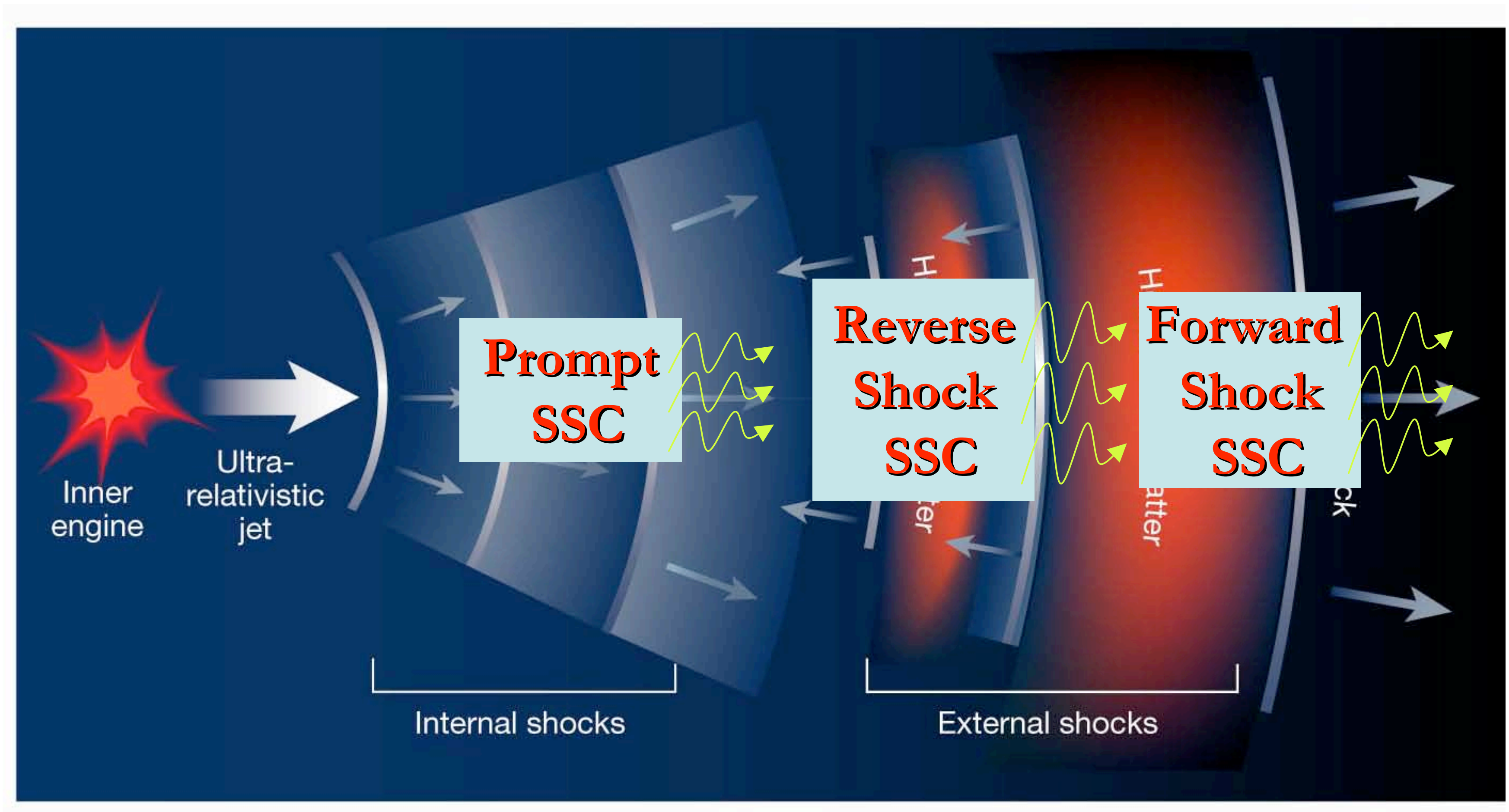


The Internal-External Shocks Model



$R \approx 10^{6}$ cm	$R \approx 10^{14}-10^{15}$ cm	$R \approx 10^{16}-10^{17}$ cm	$R \approx 10^{17-18}$ cm

SSC



$\gamma_e \approx 1000$

$\gamma_e \approx 1000$

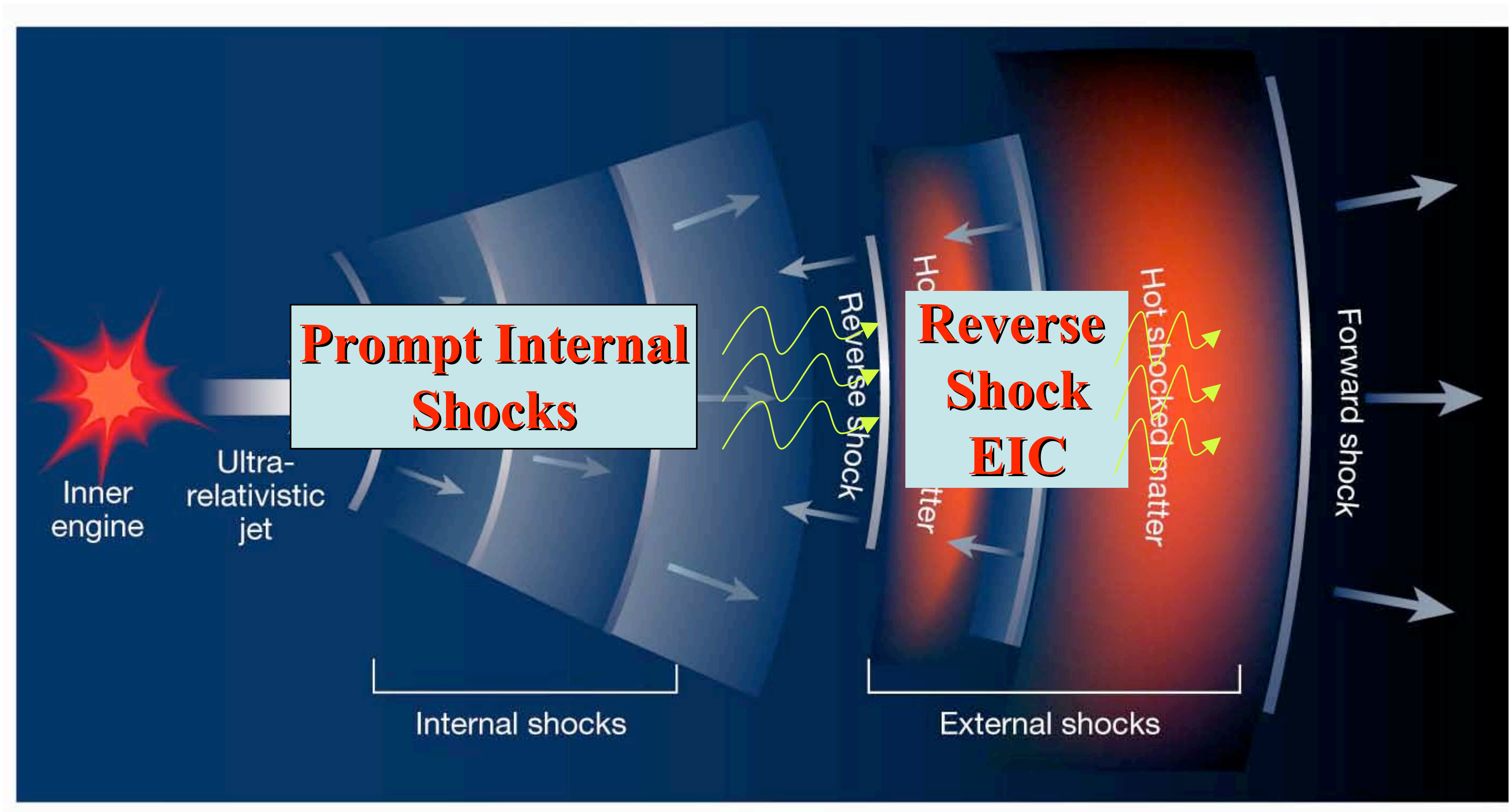
$\gamma_e \approx 10^5 - 10^3$

SSC

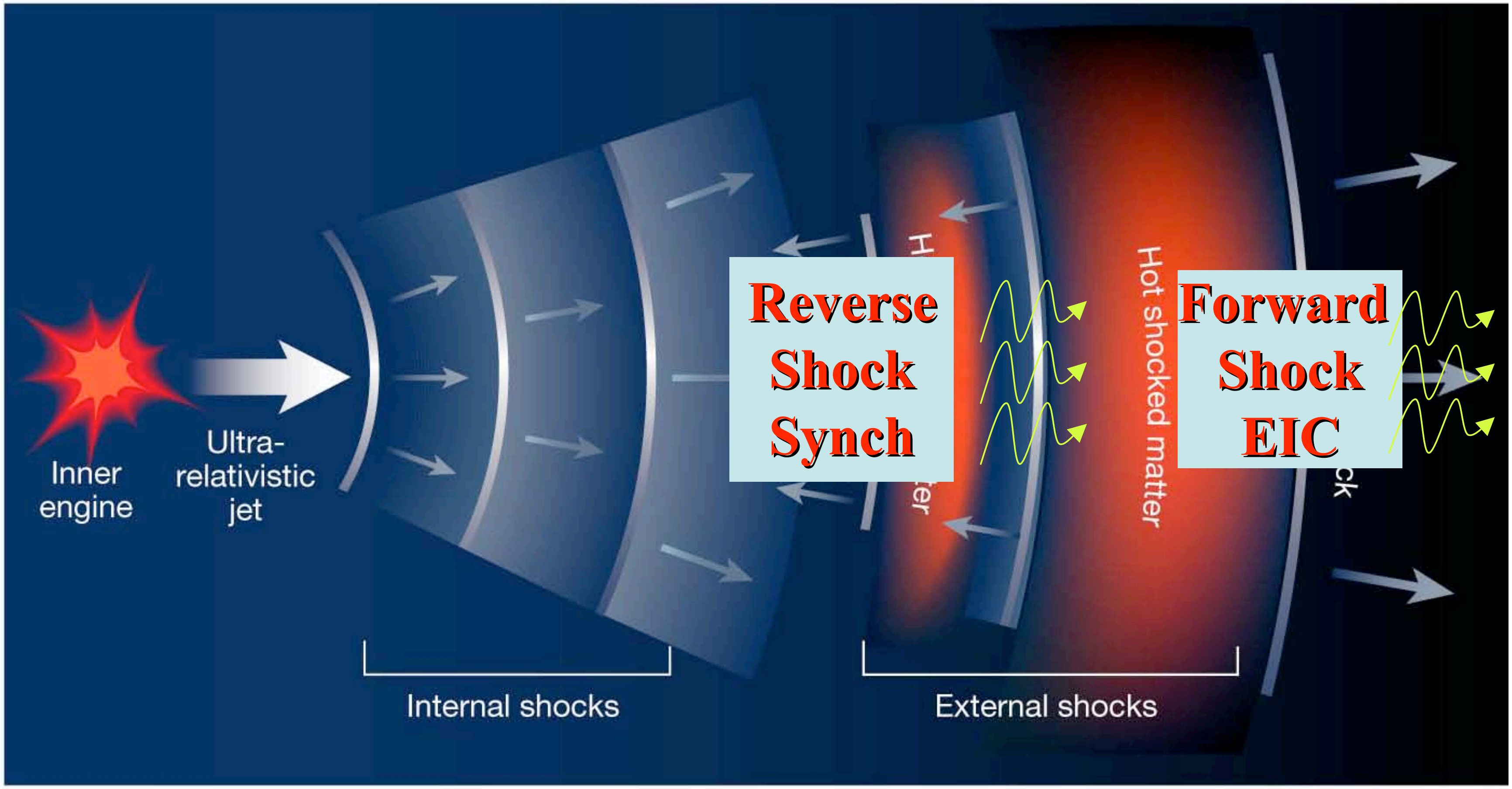
	Synch Energy	Electron's Lorentz Factor	SSC energy	Duration
Prompt	100 keV	1000	100GeV	Prompt
Reverse Shock	0.1 eV	1000	100MeV	Short
Forward Shock	10keV-1eV	10^5-10^3	100TeV-MeV	Long

M'esz'aros & Rees 94; Pilla & Leob 98; Waxman & Pe'er 04, Granot & Guetta 03; Kobayashi et al. 07; Dermer, Chiang & Mitman 00; Sari & Esin 01; Zhang & M´esz´aros 01)

External IC


Prompt Internal Shocks
Reverse Shock EIC
Inner engine
Ultra-relativistic jet
Reverse shock
Hot shocked matter
Forward shock
Internal shocks
External shocks

External IC


Reverse Shock Synch
Forward Shock EIC
Inner engine
Ultra-relativistic jet
Hot shocked matter
Internal shocks
External shocks

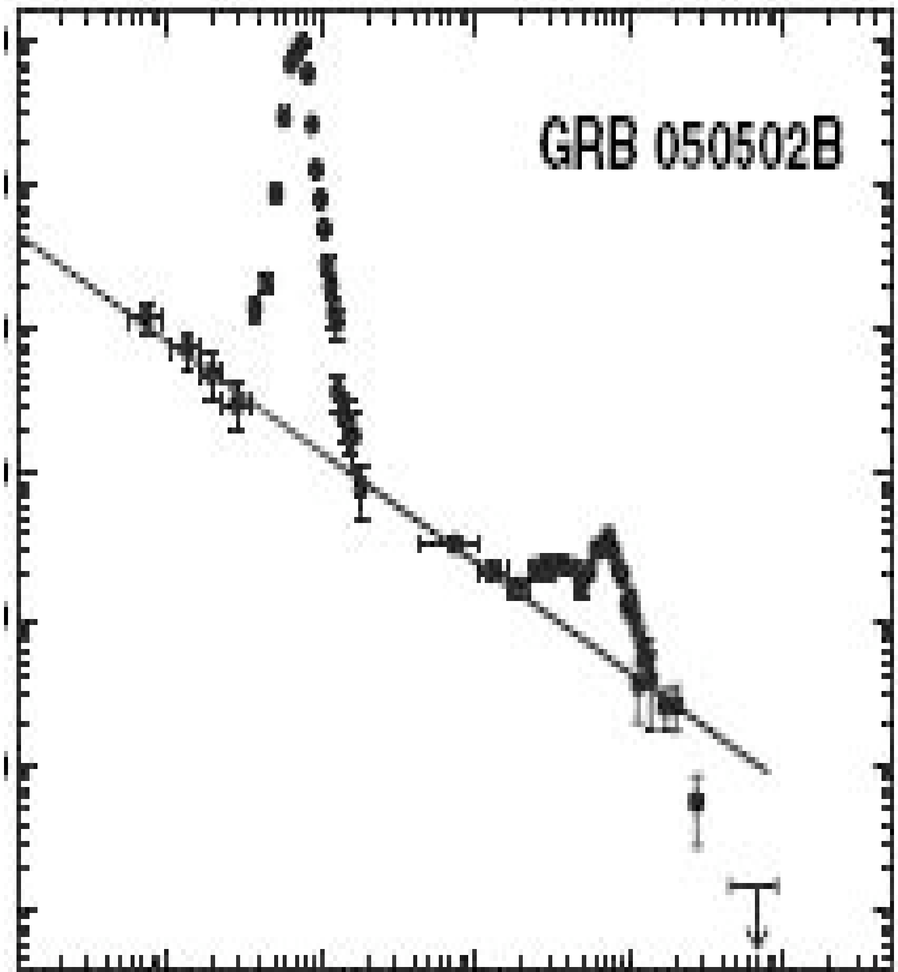
External IC

elns / Photons	Reverse Shock	Forward Shock
Internal shocks	100keV → 100GeV Short	0.1-10keV → Sub GeV - TeV Short
Reverse Shock	----	0.1eV → 100 MeV Short

Beloborodov 05; Fan, Zhang & Wei 05; Fan & Piran 06; Fan et al., 07)

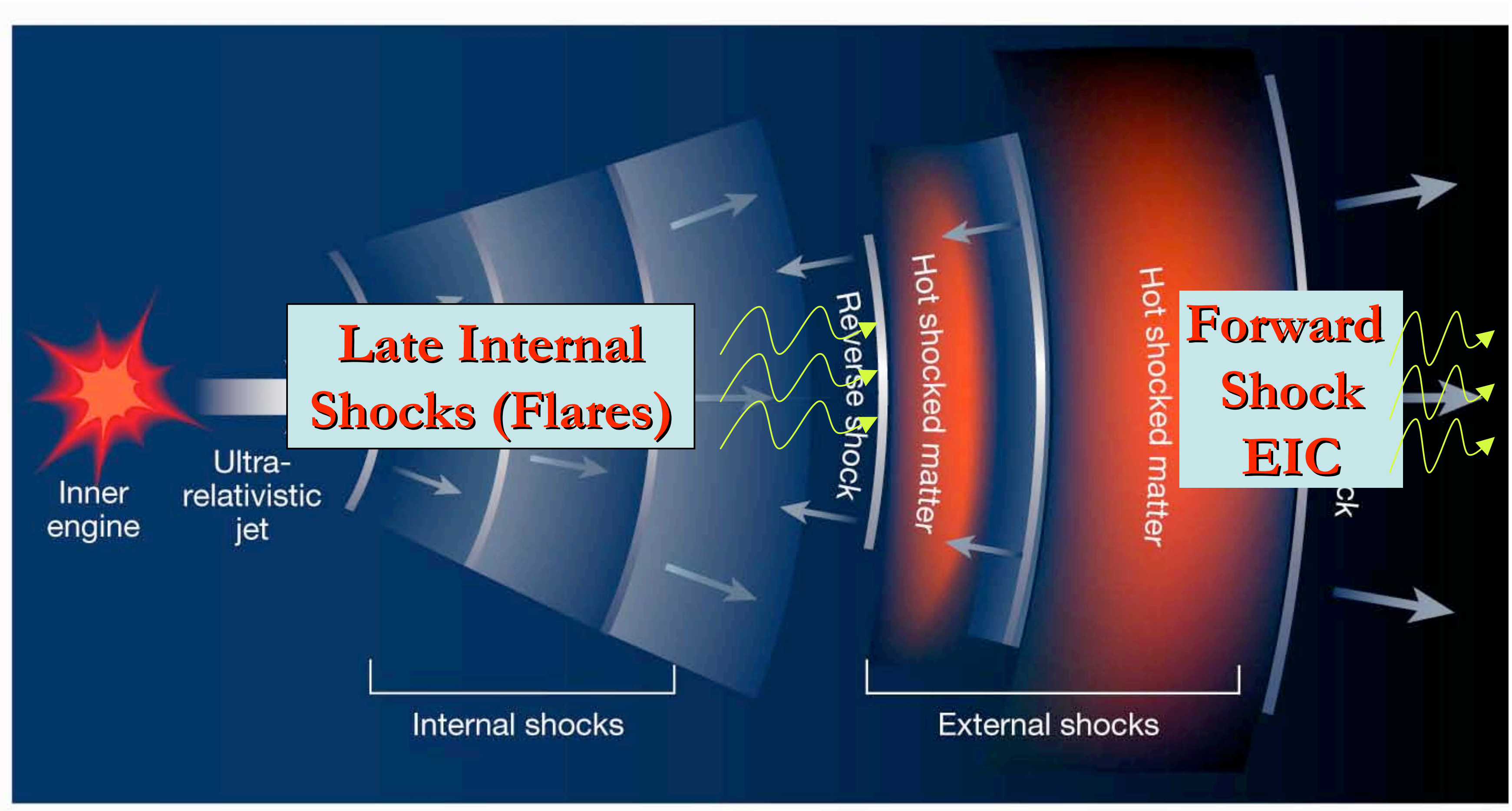
Flares

Long-activity of the central engine
(Fan & Wei 2005; Burrows et al. 2005; Zhang et al. 2006)
Or refreshed shocks (Piro et al., 2005)



GRB 050502b (Burrows et al. 2005)

GRB 050904 (Watson et al. 2006)



Late Internal Shocks (Flares)
Forward Shock EIC
Inner engine
Ultra-relativistic jet
Reverse shock
Hot shocked matter
Hot shocked matter
Internal shocks
External shocks

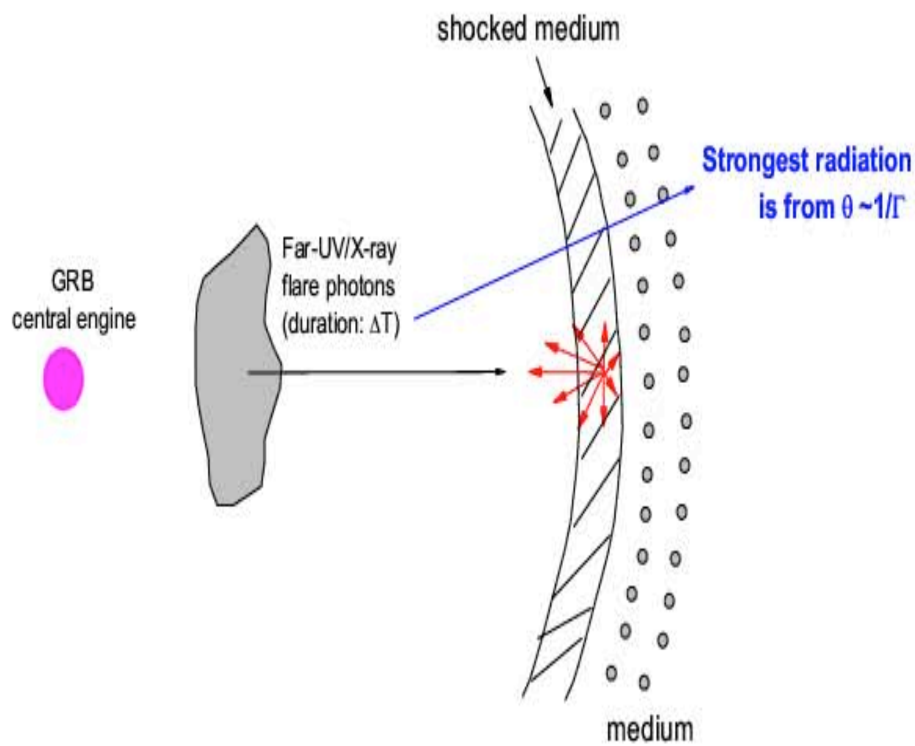
Flare IC

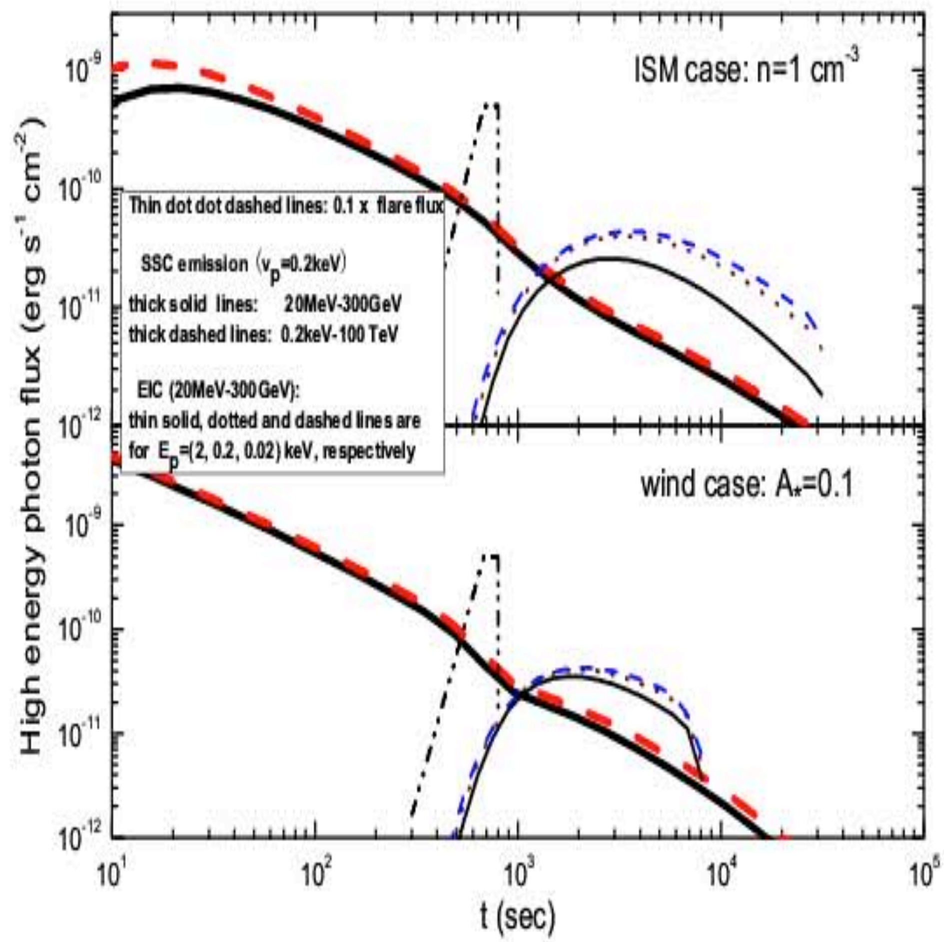
	Synch Energy	Electron's Lorentz Factor	IC energy
Internal Shocks Flare SSC Refreshed shocks SSC	1-10 keV	100	10-100 MeV (but GeV is possible)
Internal Shocks Flare EIC	.1-10 keV	1000	Sub GeV - TeV

Wei, Yan & Fan 06; Wang, Li & Meszaros 06; Galli, Piro et al 06 Fan, Piran, Narayan & Wei 07

Flare- shock Interaction

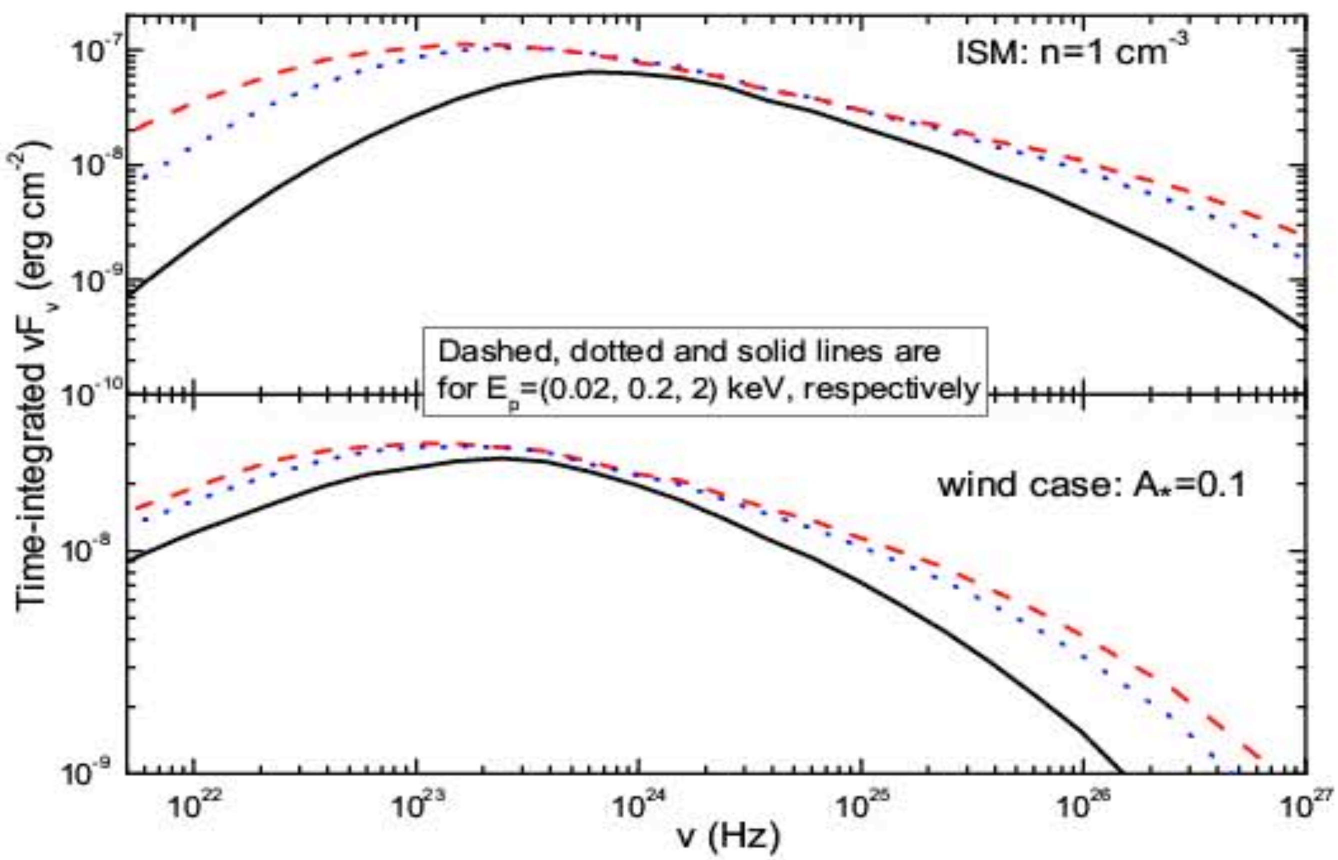
(Wang et al. 06 Fan & Piran 06; Fan et al. 007)





The high energy spectrum

(Fan & Piran 2006; Fan , Piran, Narayan & Wei 2007)



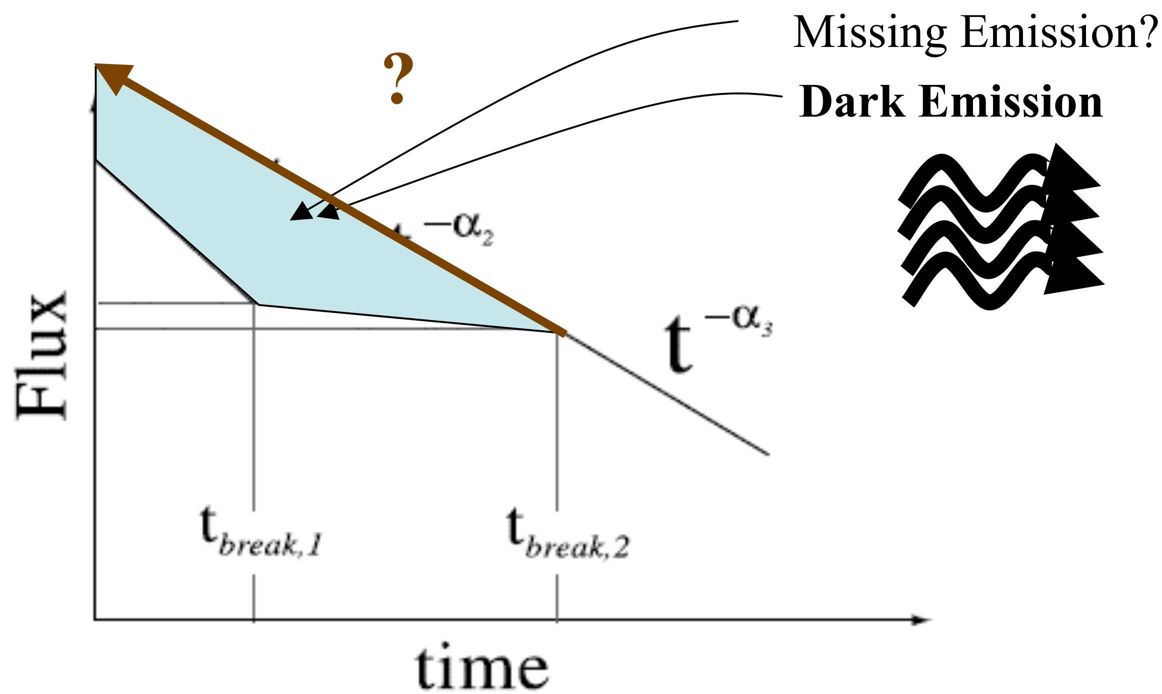
Long-lasting X-ray flattening

Possible interpretations

- **Energy injection**
- **Increasing e_e**
- **?**

GRB 060729 (astro-ph/0611240)

Swift early X-ray light curves

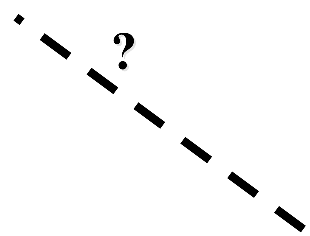


Constraining the physical processes

(Fan , Piran, Narayan & Wei 2007)

Energy injection vs. Variable efficeincy

A schematic high energy afterglow light curve (Fan , Piran, Narayan & Wei 2007)



Further complications are possible and even likely

- In some GRBs, the optical and X-ray afterglows break chromatically (Fan & Piran, 2006, Panaitescu et al. 2006).
- A drastic solution is that the two should be attributed to different physical processes from different regions (Fan & Wei 2005; Piran & Fan 2007)
- There are further indications supporting this possibility (e.g. GRB 060218, 070110)
- This will lead to additional EIC processes! A possibity that could be tested by GLAST.

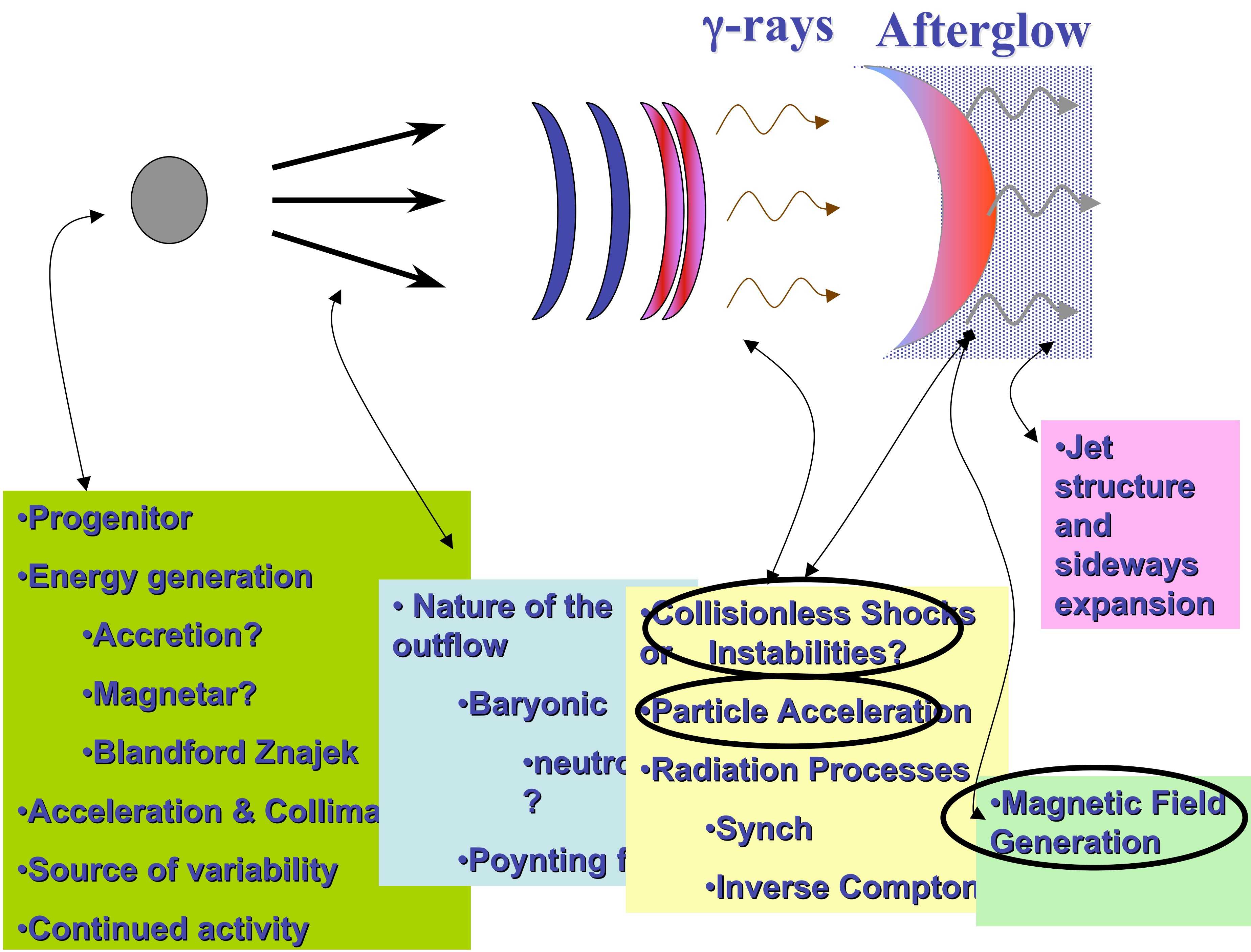
Additional Processes

- $pp \rightarrow \ldots + \pi$
  $\quad\quad\quad\quad\mapsto \ldots + \gamma$

  Katz 94, …

- $p\gamma$ EM cascade Boettcher & Dermer 98, Dermer, Atoyan 03, Dermer, Atoyan 04
- Neutronic Processes: $np \rightarrow .. + \pi$
  $\quad\quad\quad\quad\mapsto \ldots + \gamma$

  etc… Razzaque & Mészáros, 06


γ-rays
Afterglow
•Progenitor
•Energy generation
•Accretion?
•Magnetar?
•Blandford Znajek
•Acceleration & Collima
•Source of variability
•Continued activity
• Nature of the outflow
•Baryonic
•neutro
?
•Poynting f
•Collisionless Shocks or Instabilities?
•Particle Acceleration
•Radiation Processes
•Synch
•Inverse Compton
•Magnetic Field Generation
•Jet structure and sideways expansion

Conclusions I

- Very High Energy emission is expected from GRBs both from the prompt phase and from the afterglow phase.
- This emission is likely to be detected by GLAST (see several poster for estimates of rates of events).
- The emission would carry a wealth of information on the GRBs (in particular on the Baryonic content of the outflow).
- However, as there are so many options it might be difficult to figure out from non – detalied observations what was the radiation's origin.

GBM Spectroscopy

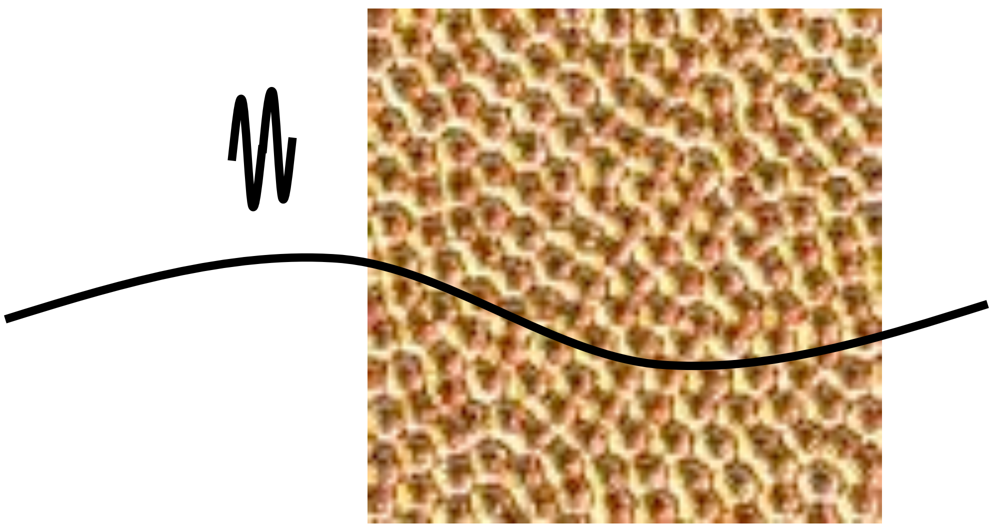
- The GBMs Spectral ability (8 keV – 20MeV) will provide information on the GRBs' high energy spectrum which could answer open questions like:
  - The Amati Relation?
  - The existence of a hard burst population?

Quantum Gravity with GRBs

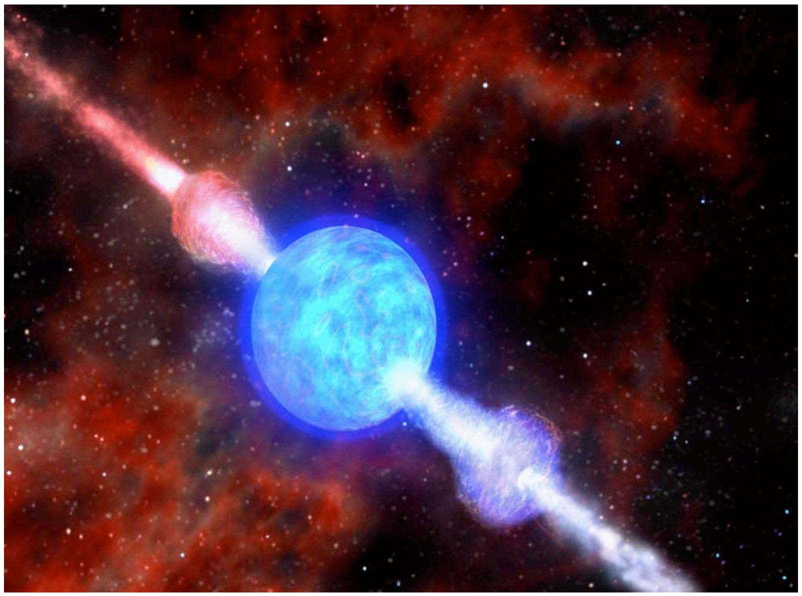
(Amelino-Camelia et al., 98, Norris et al., 99, Ellis et al., 00,06, Amelino-Camelia and Piran, 02, Boggs 04, Martinez-Rodriguez et la., 06)

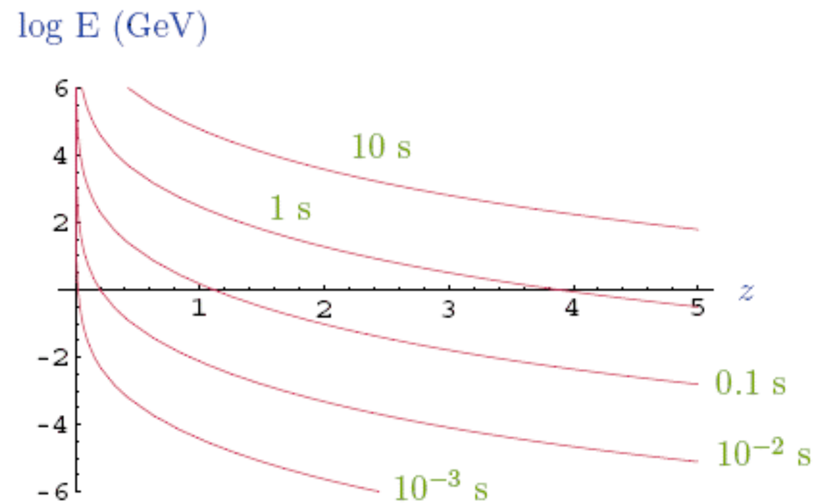
- Lorentz Violation (or deformation) appears in various Quantum Gravity Theories.

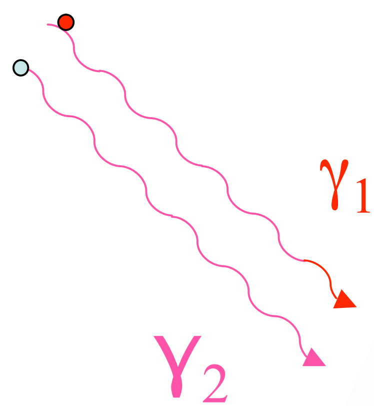
➢ Energy dependent dispersion and speed of light. Low energy approximation:

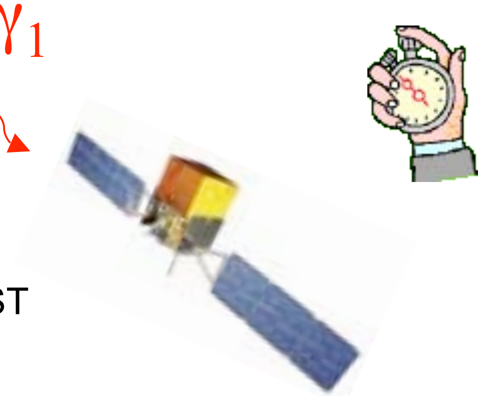


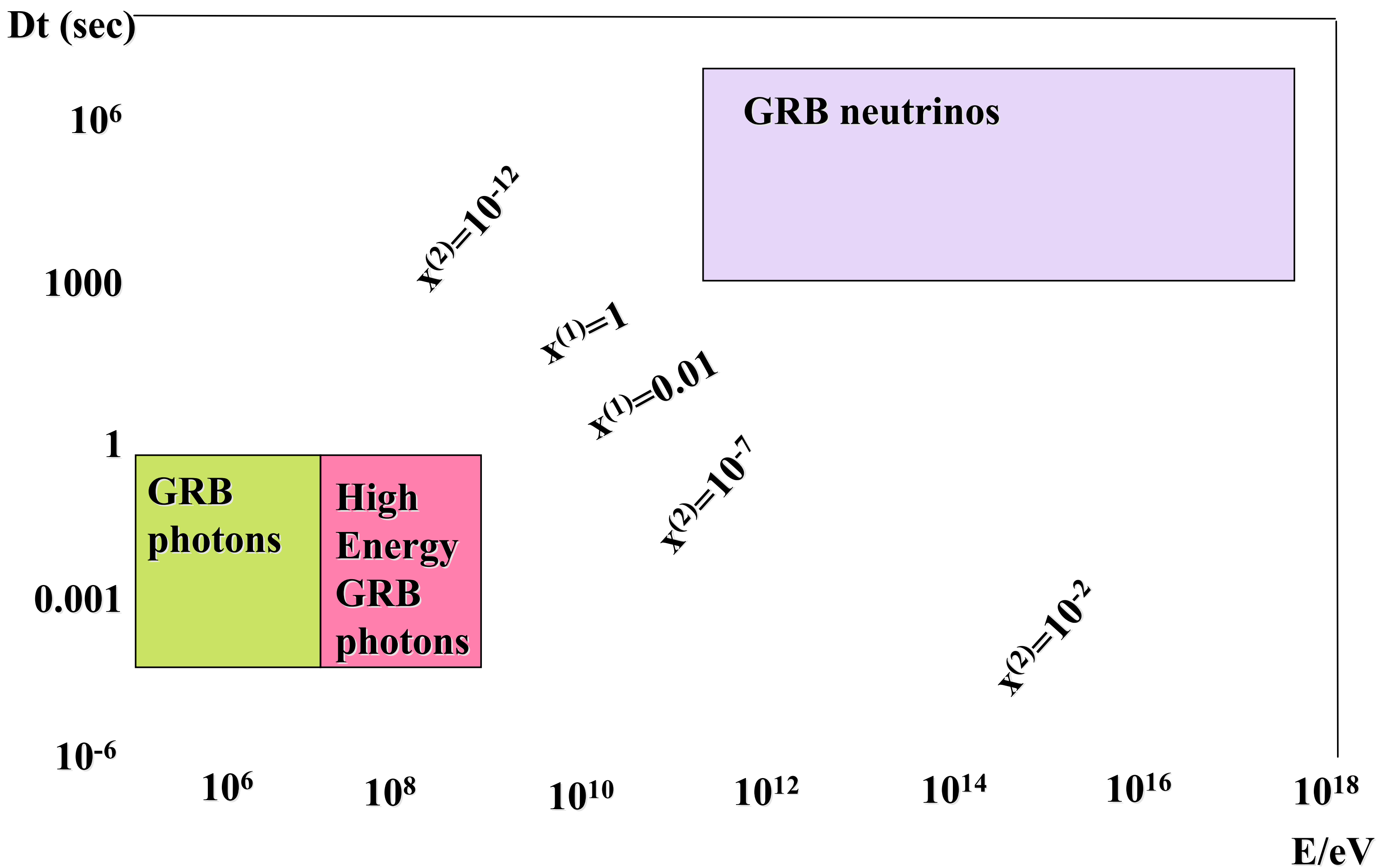
Energy dependent arrival time
(Amelino-Camelia et al., 1998)





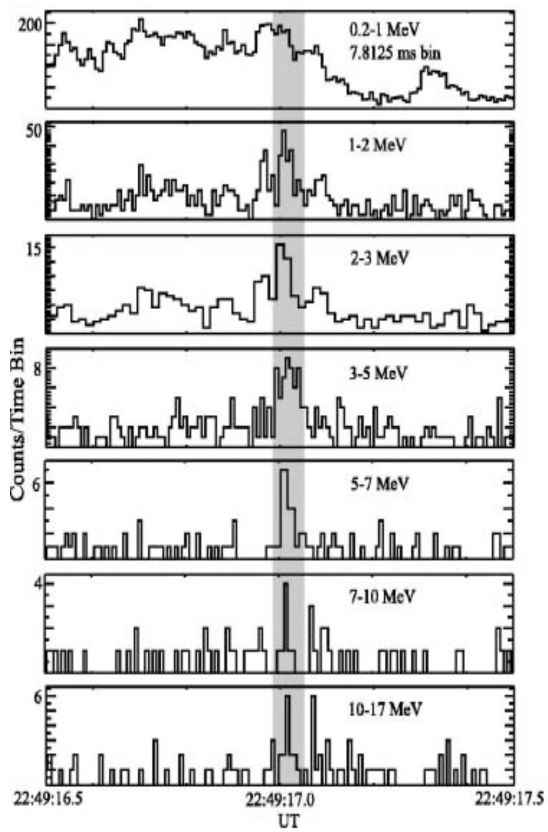






Dt (sec)
10^6
1000
1
0.001
10^-6
GRB neutrinos
x(2)=10^-12
x(1)=1
x(1)=0.01
x(2)=10^-7
x(2)=10^-2
GRB photons
High Energy GRB photons
10^6
10^8
10^10
10^12
10^14
10^16
10^18
E/eV

RHESSI observations of GRB021206



RHESSI light curves of GRB 021206

7.8 msec Bins

$\Delta t_{20keV-20MeV}$

< 7.8 msec

$\Rightarrow x^{(1)} > 0.018$

$E^{(1)}_{LV} > 1.8\ 10^{17}$ GeV

$\Rightarrow x^{(2)} > 4.5\ 10^{-12}$

$E^{(2)}_{LV} > 4.5\ 10^{7}$ GeV

(assuming z=0.3)

Swift and Konus-Wind observations of GRB051221A

$Dt_{16keV-300keV}$

< 2 msec

$\Rightarrow x^{(1)} > 0.0066$

$E^{(1)}_{LV} > 6.6\ 10^{16}$ GeV

Swift

$\Rightarrow x^{(2)} > 5\ 10^{-13}$

$E^{(2)}_{LV} > 5\ 10^{6}$ GeV

Konus-Wind

Z=0.5465

Conditions for Detection

Conclusions II

- Gamma Ray Observations could shed light on possible Quantum Gravity induced Lorentz violation (Energy dependent speed of light).
- Already now GRBs timing give the best limits on the scale of possible Lorentz violation: $E^{(1)}_{LV} > 10^{17}$ GeV
- Surprisingly distance and high energy do not work in favor of a better limit for n=1. GBM will have a major role here.
- High energy photons are important for n ≥ 2. LAT will provide the best limit on these models.

GRB photons & high energy neutrinos

One expects 10 neutrinos detected in a km^3 detector per 1000 GRBs