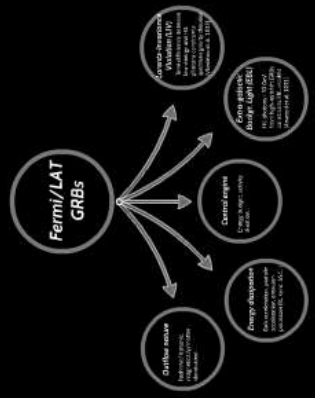

Fermi/LAT observations of Gamma-ray Bursts

G. Vianello
Stanford University (HEPL)
giacomov@stanford.edu

on behalf of the Fermi/LAT collaboration

Wonderful dataset challenges the current "standard" model for GRBs

All in all, the "standard" model works decently well, but:

- Internal shocks model for prompt emission not quite right
- LAT observations are especially hard to account for
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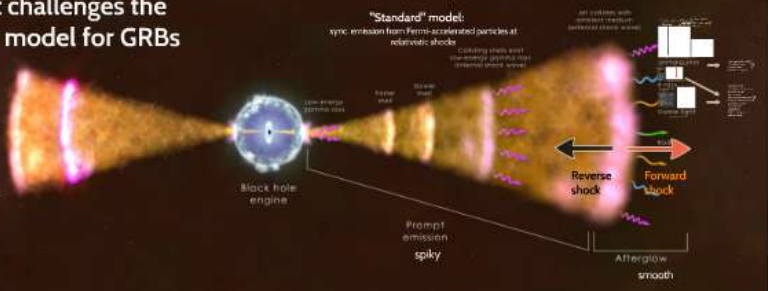

Fermi/LAT observations of Gamma-ray Bursts

The brightest GRB of the last 25 years:
GRB 130427A

G. Vianello
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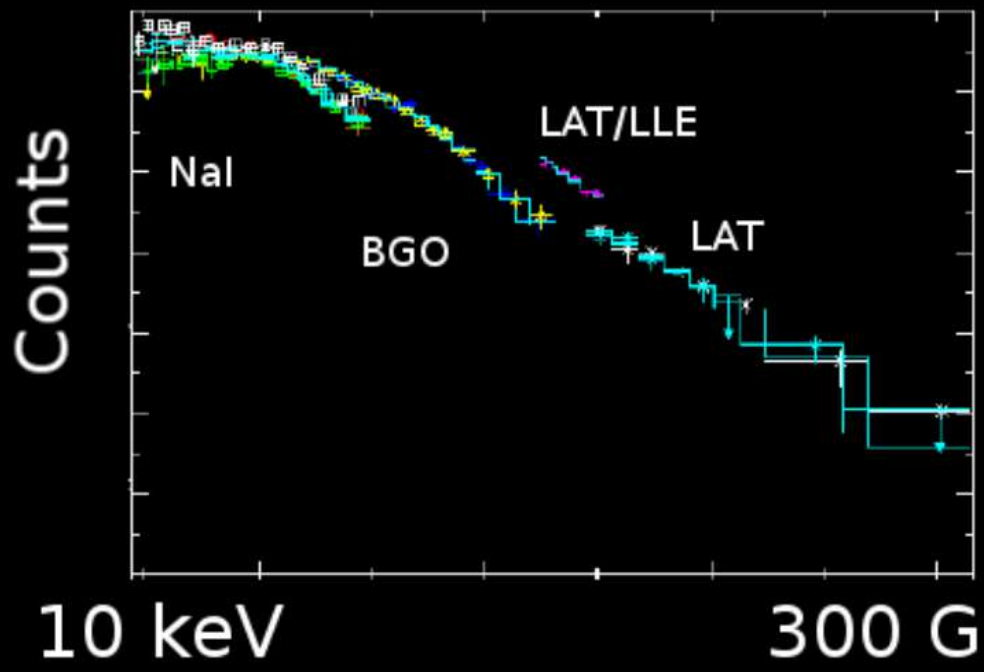
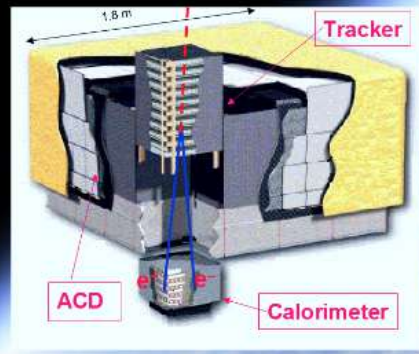


Energy range:
- 100 MeV - 300 GeV (standard analysis)
- 20 MeV - 1 GeV (LAT Low-Energy, LLE)

Field of view (FOV): ~2.4 sr

(details tomorrow, Carmelo talk)



› 7 orders of magnitude

The Large Area Telescope (LAT)

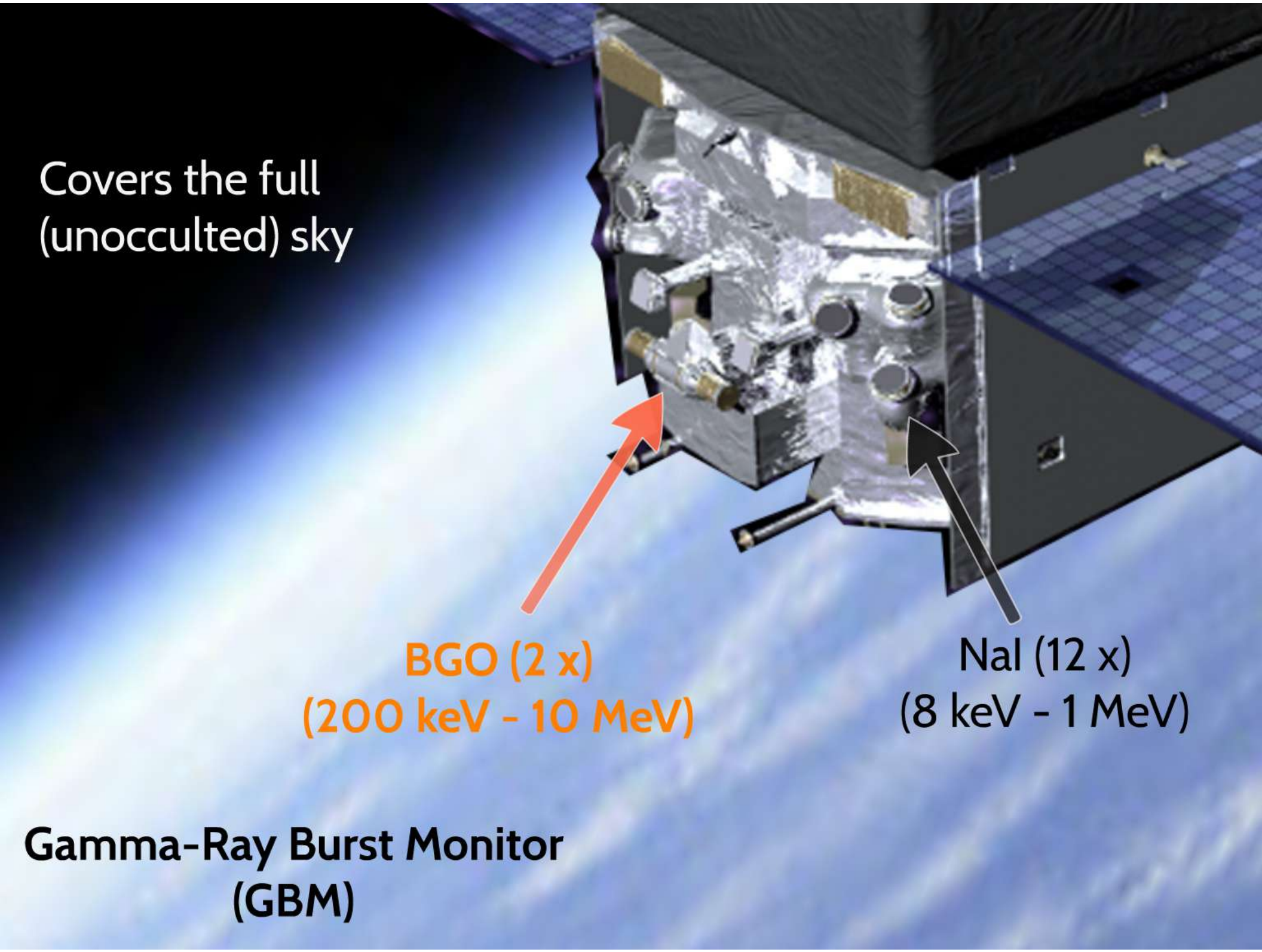
Covers the full (unocculted) sky

BGO (2 x) (200 keV - 10 MeV)

NaI (12 x) (8 keV - 1 MeV)

Gamma-Ray Burst Monitor (GBM)

The Fermi observatory (altitude: 560 km)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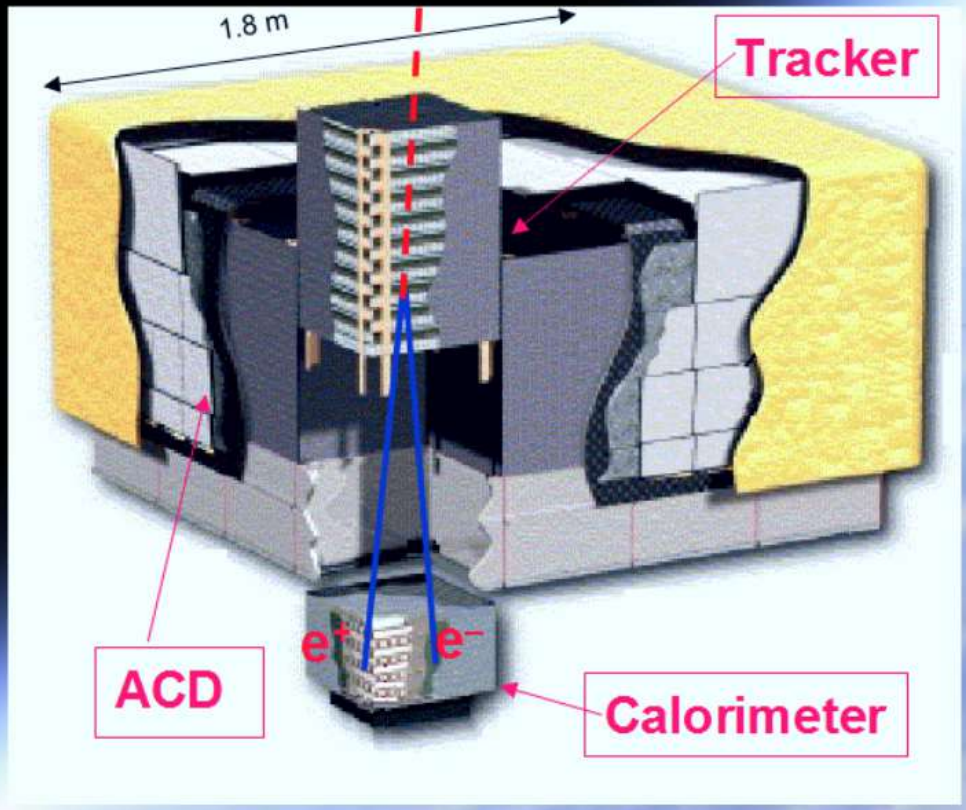

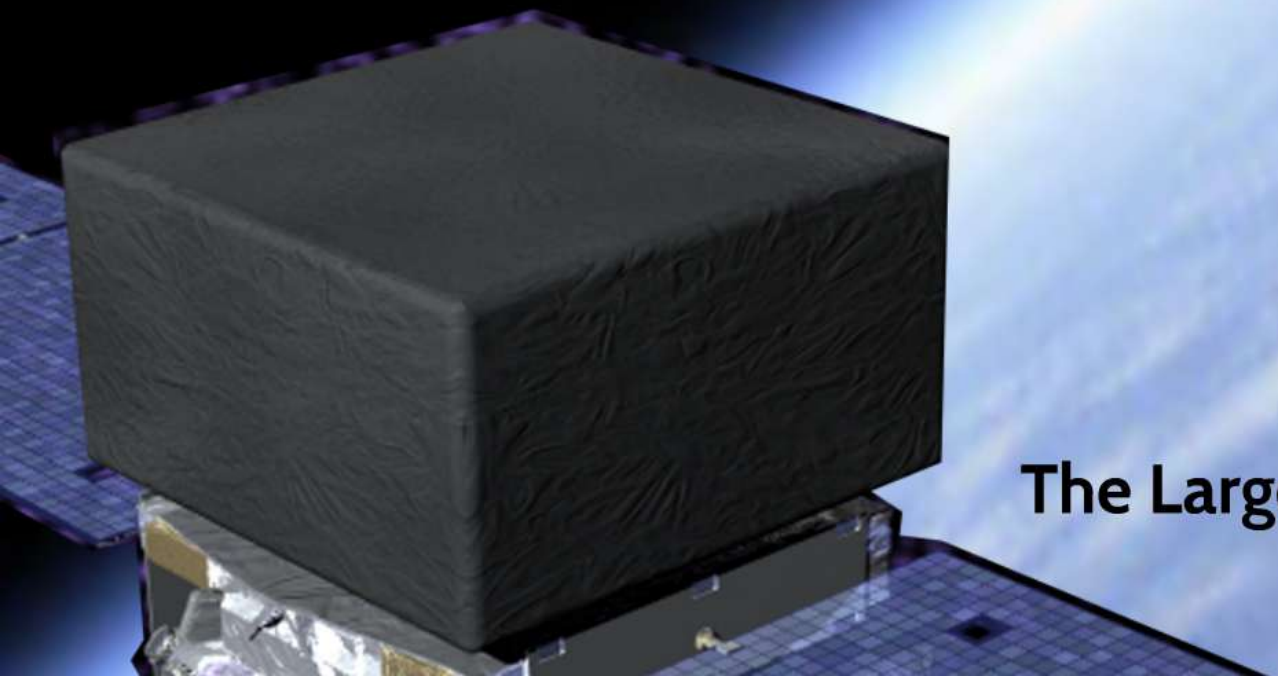

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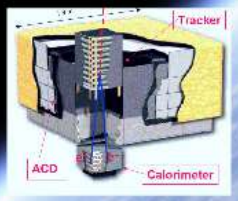
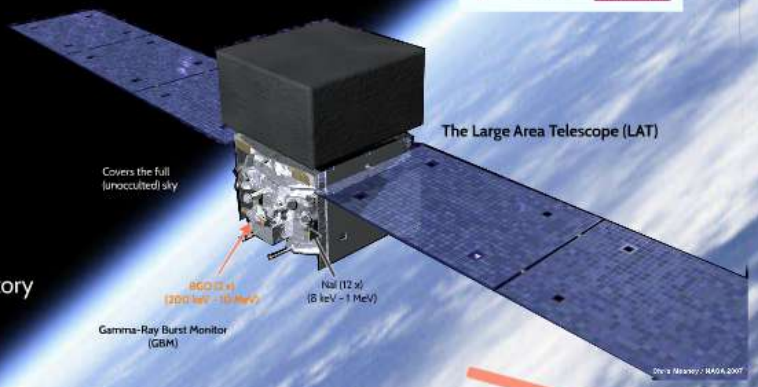




The Fermi observatory
(altitude: 560 km)

LAT downlink latency: L = 8-12 hours

Processing:
~1 hour

Swift ToO
(< L + 20 minutes)

Machine-readable GCN notice
(< L + 20 minutes)

GCN circular
(< L + 2 hours)

Expect further improvement with Pass 8 (2015):

- larger effective area, better PSF
- lower threshold for likelihood analysis, our most sensitive technique
- See the talk by Carmelo Sgro tomorrow

~ 15 GRB/year

~ 9.5 GRB/year

- Pass 7
- New algorithm

Cumulative number of announced GRBs

0 10 20 30 40 50 60 70 80 90

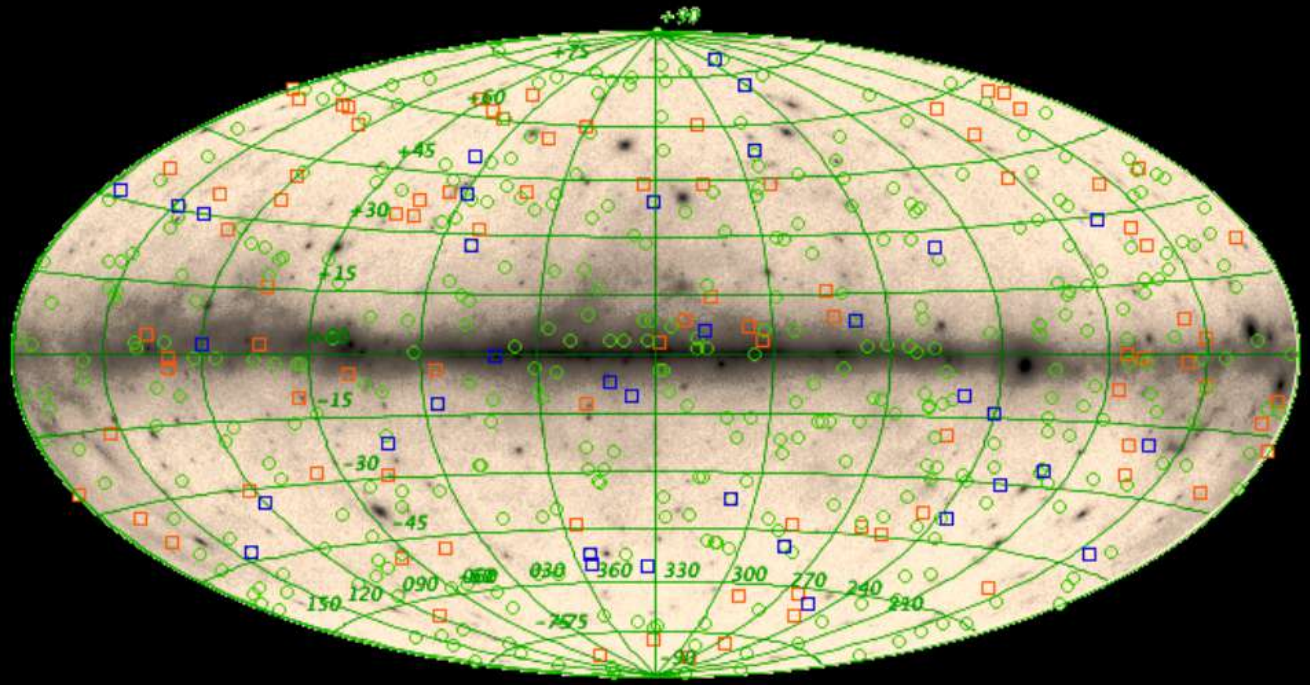
2009 2010 2011 2012 2013 2014

Date

Covers: launch (Aug 2008) to end of July 2011

Fermi/LAT detections

GBM short and long GRBs



- GBM: ~700 GRBs, ~300 in the LAT FoV
- 28 detections (~10 %, 5 shorts) + 7 LLE-only
- ~Half with follow-up
- 9 redshifts

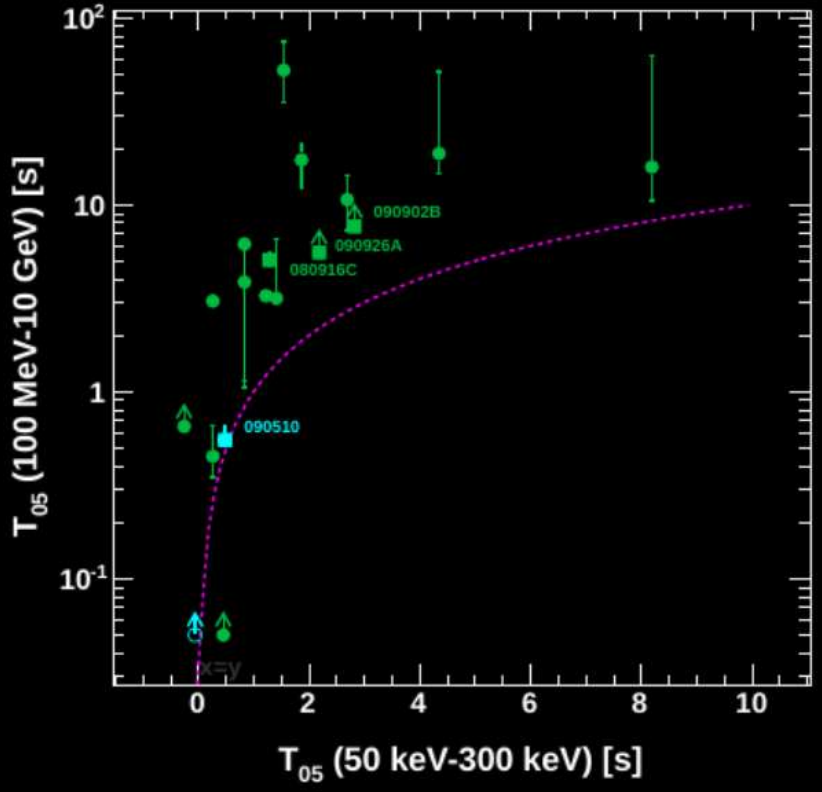
(Background is Fermi/LAT 3-years map in Galactic coordinates)

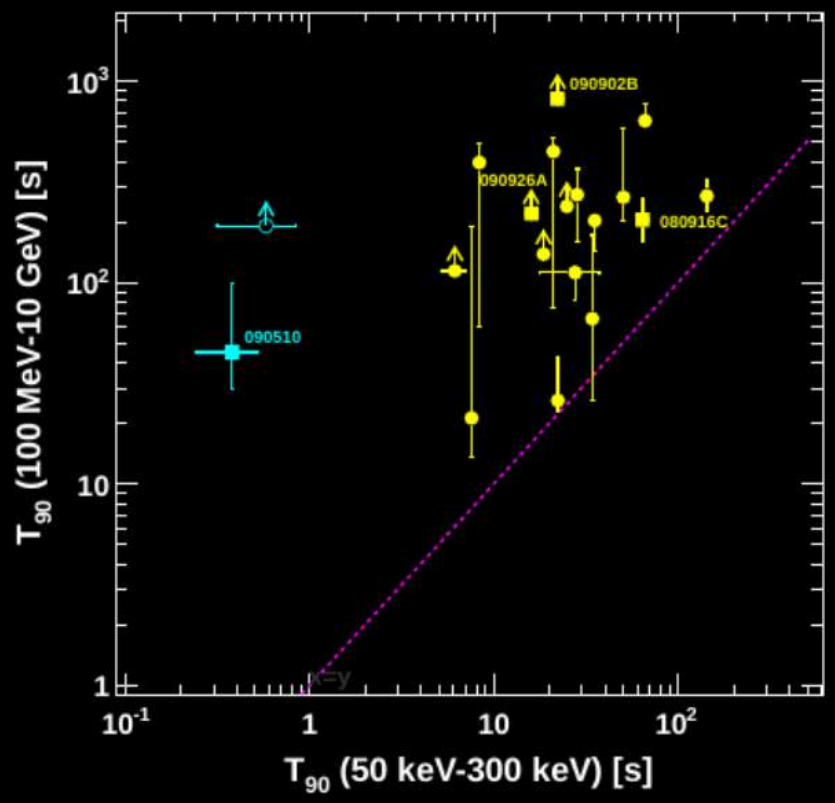
First LAT GRB Catalog (Ackermann et al. 2013)

- 9 redshifts

First LAT GRB Catalog (Ackermann et al. 2013)

Emission > 100 MeV is:

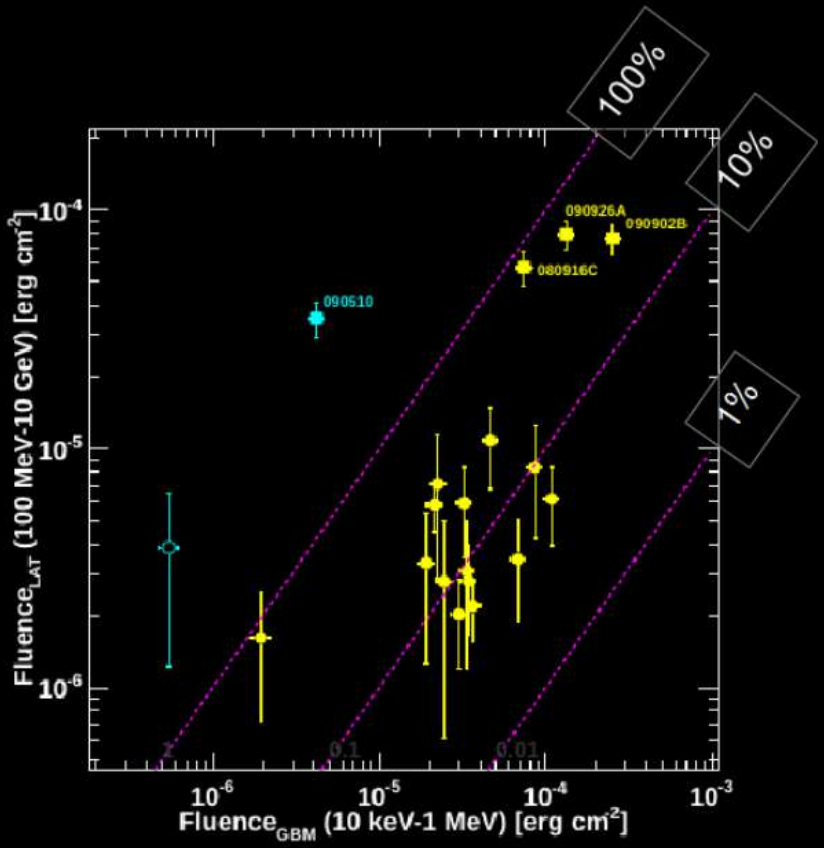




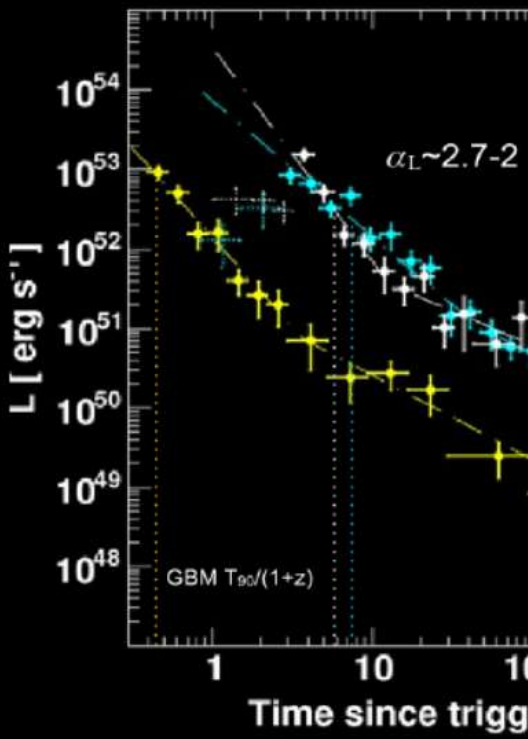
Delayed

Extended

Extended

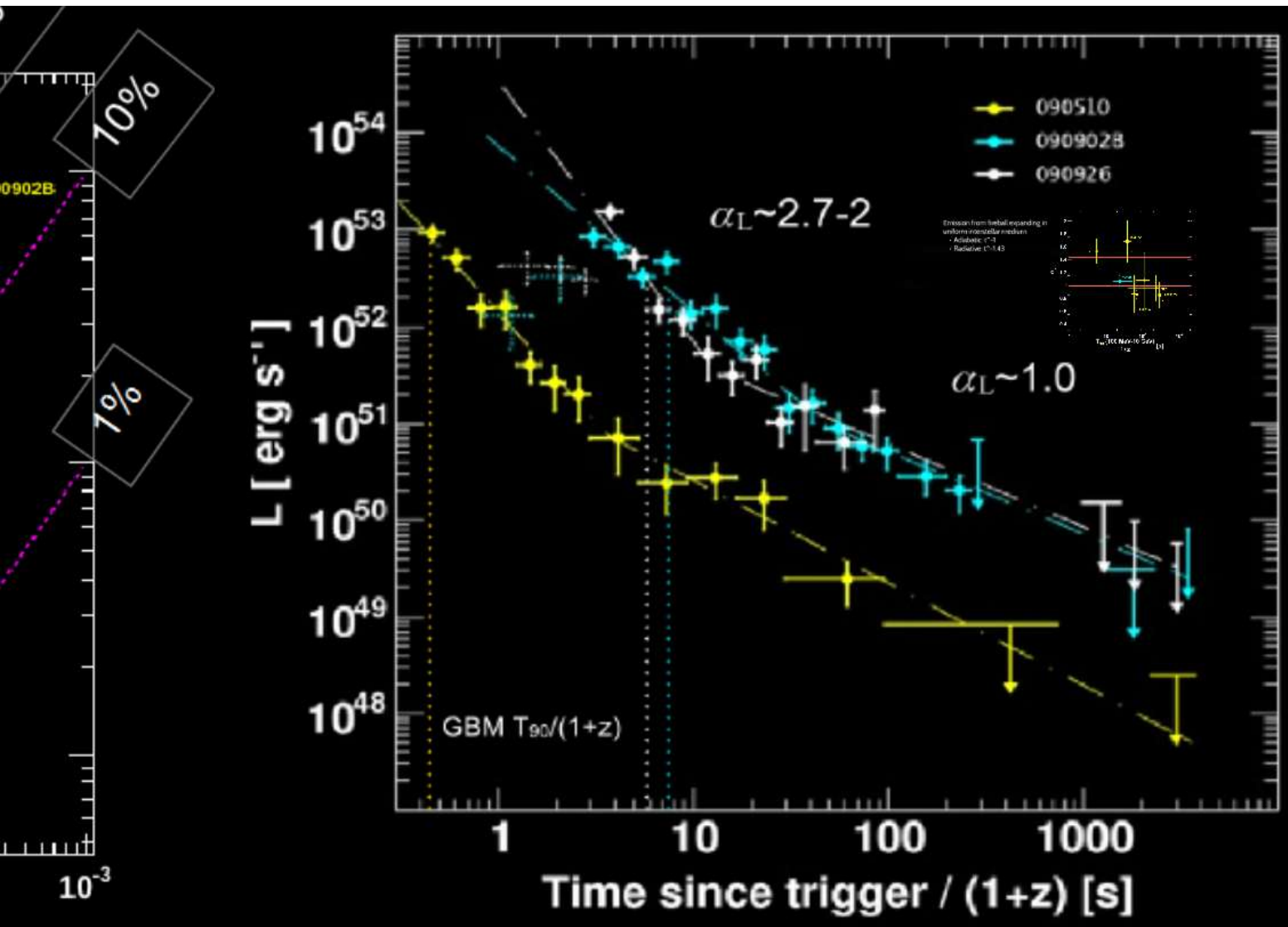


Energetic output > 100 MeV is not negligible with respect to the low-energy one



Break in 2 long and 1 short b

- IC transition? But no spe break
- Prompt-contaminated t



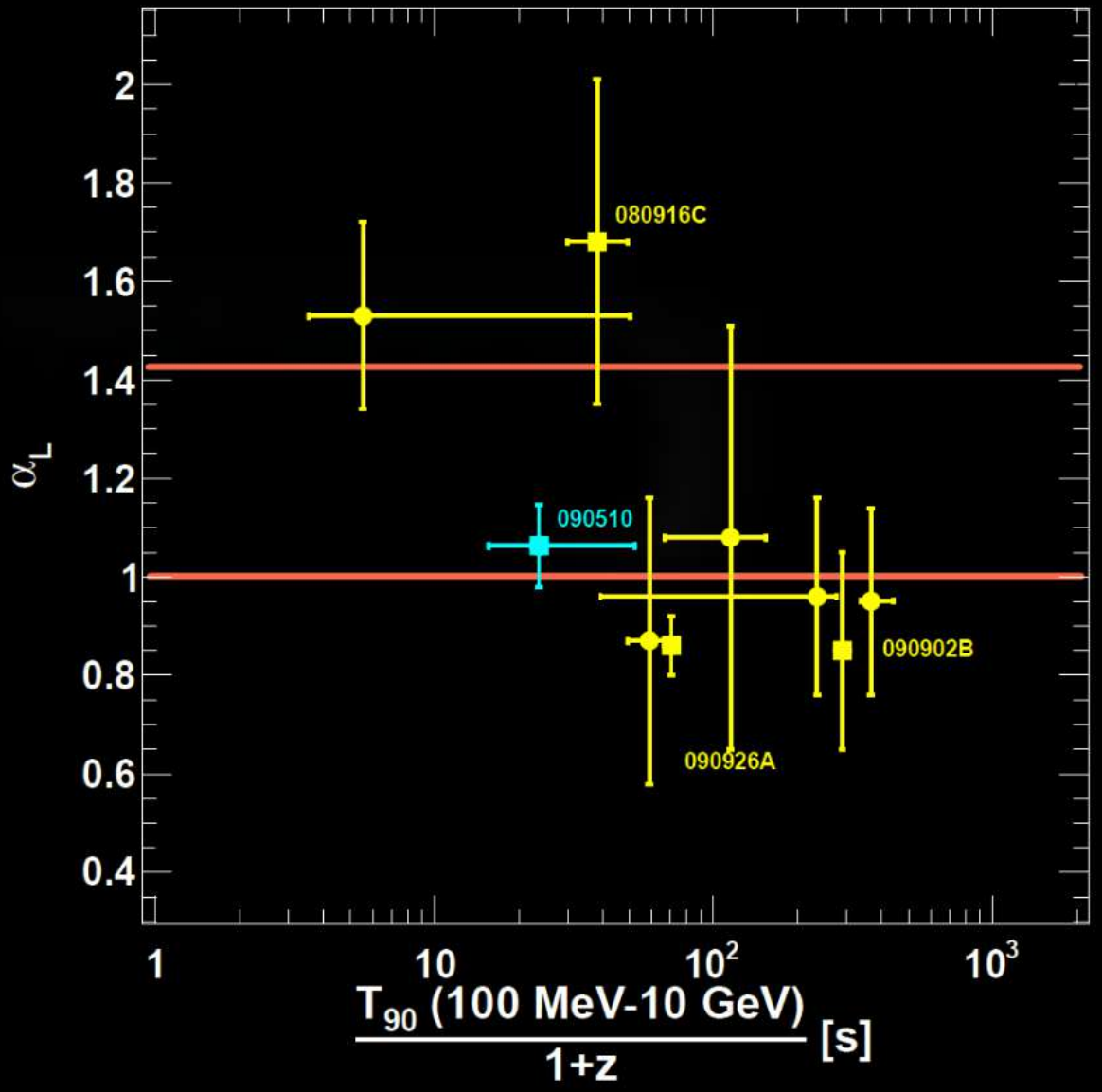
hot
w-

Break in 2 long and 1 short bright GRBs:

- IC transition? But no spectral evolution across the break
- Prompt-contaminated to pure afterglow phase?

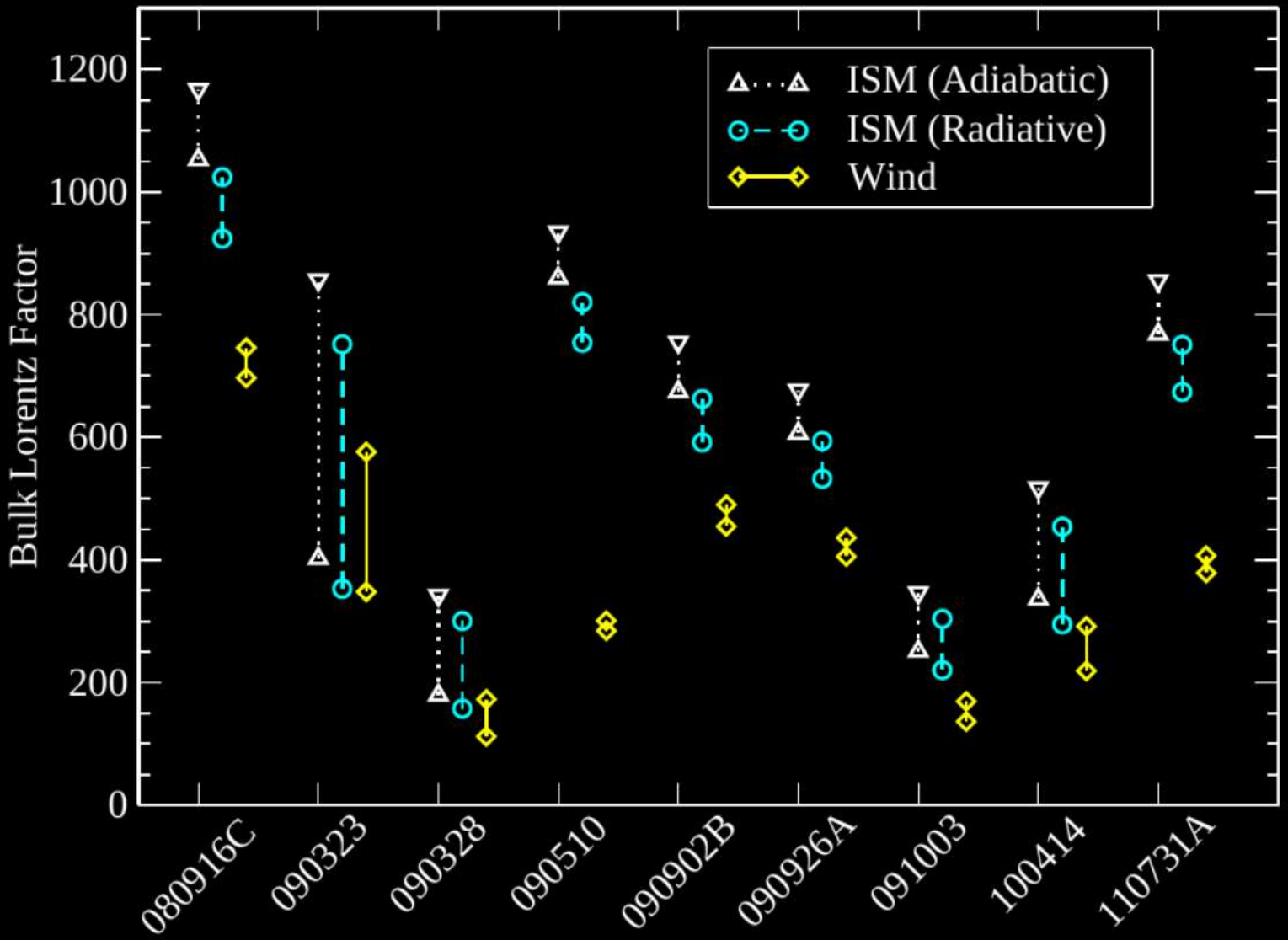
Emission from fireball expanding in uniform interstellar medium:

- Adiabatic: t^-1
- Radiative: t^-1.43



$\alpha_L \sim 1.0$

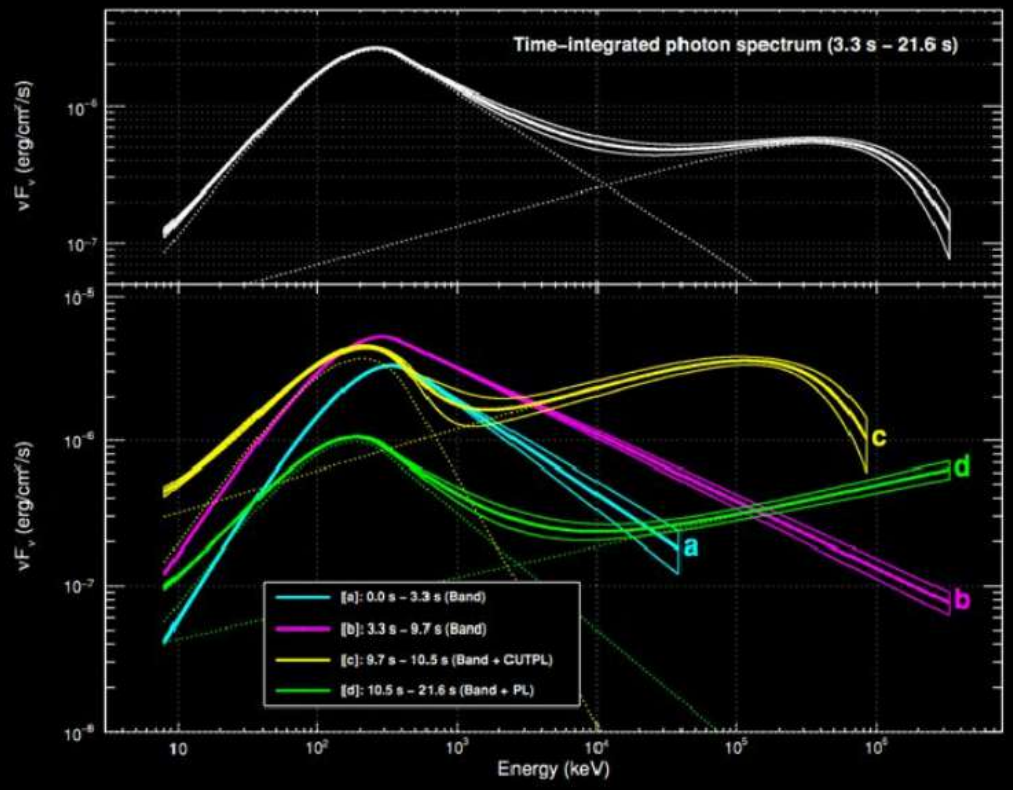
Interpreting the LAT emission as external shock emission, the peak time is a measure of the deceleration time (transition between coasting and self-similar phase), and can be used for a measure of the Lorentz factor:



Prompt phase: a Band model crisis

The Band model does not capture significant features in the spectrum of all GRBs with high statistic (bright, or observed on axis)

- the catalog deals only with integrated spectra
- papers on single GRBs deal also with time-resolved spectra (Ackermann et al. 2011, Guiriec 2010, Burgess 2013...)



Gamma-ray Bursts

The brightest GRB of the last 25 years: GRB 130427A

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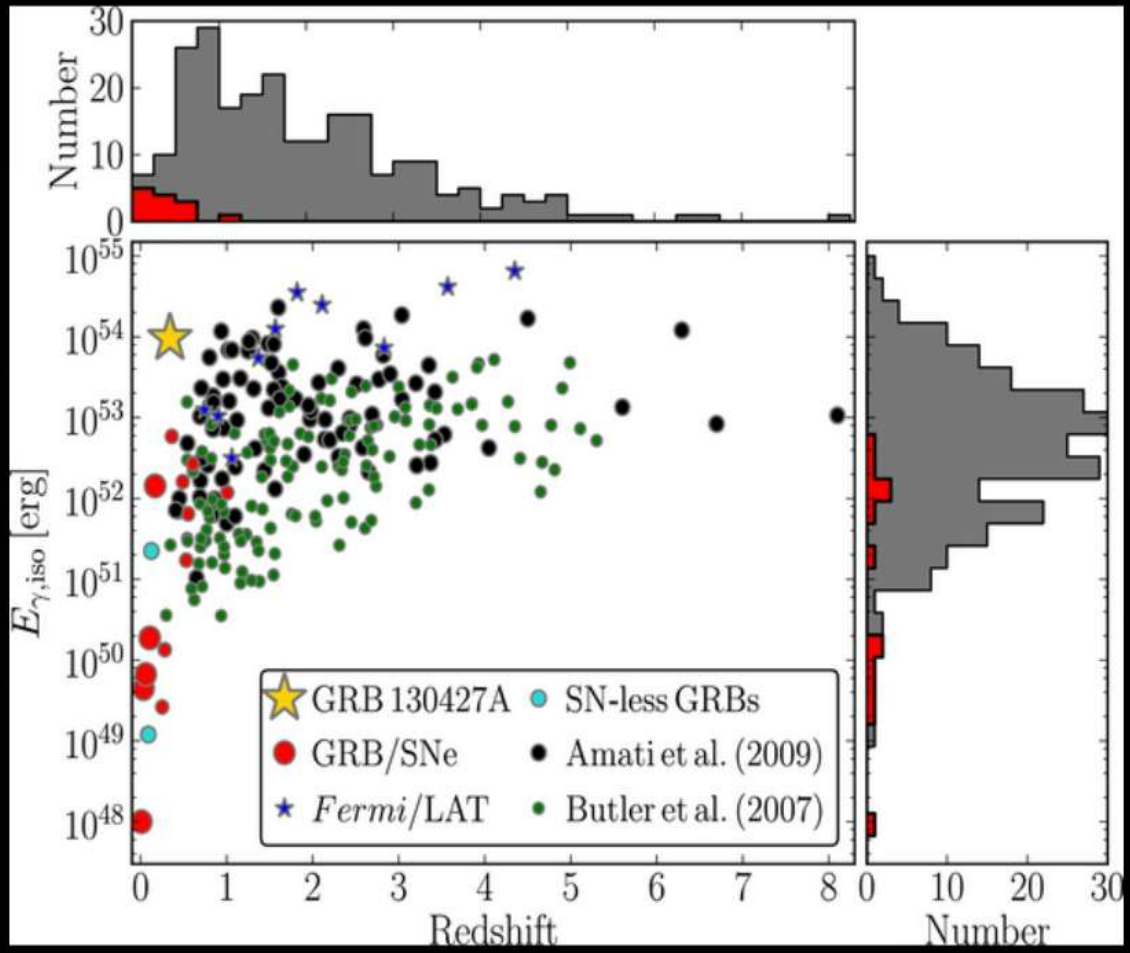
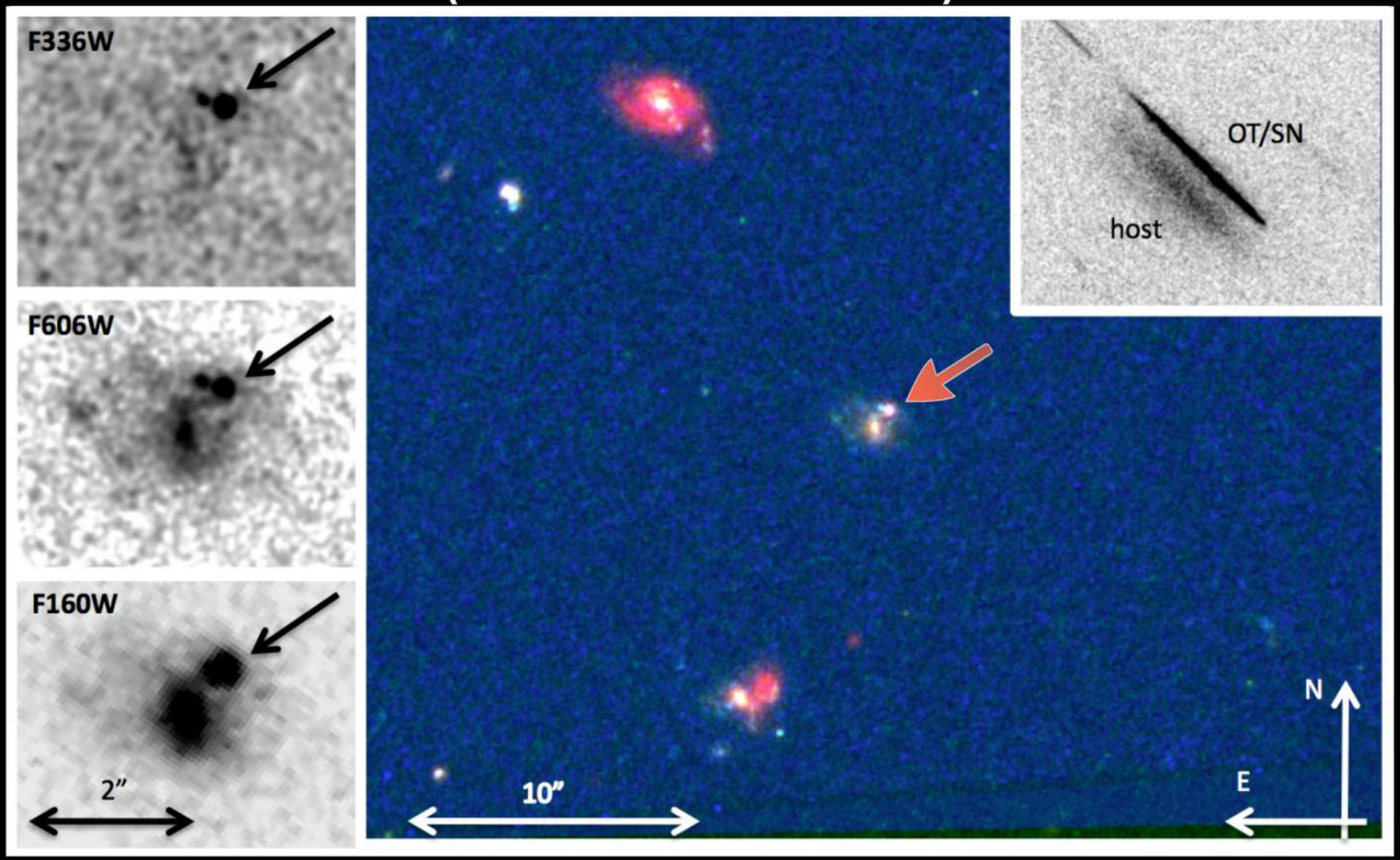
"A nearby ordinary monster"



(D. Xu et al. 2013 ApJ 776 98)

Supernova detected by HST (and other observatories)



(Levan et al. 2013, arXiv:1307.5338)

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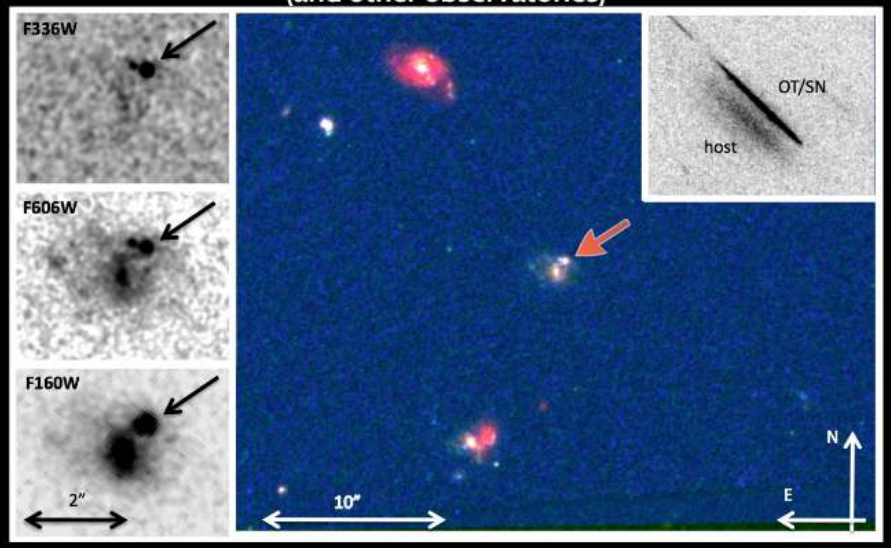

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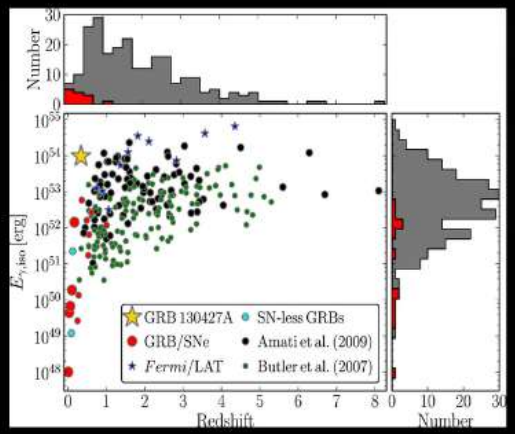

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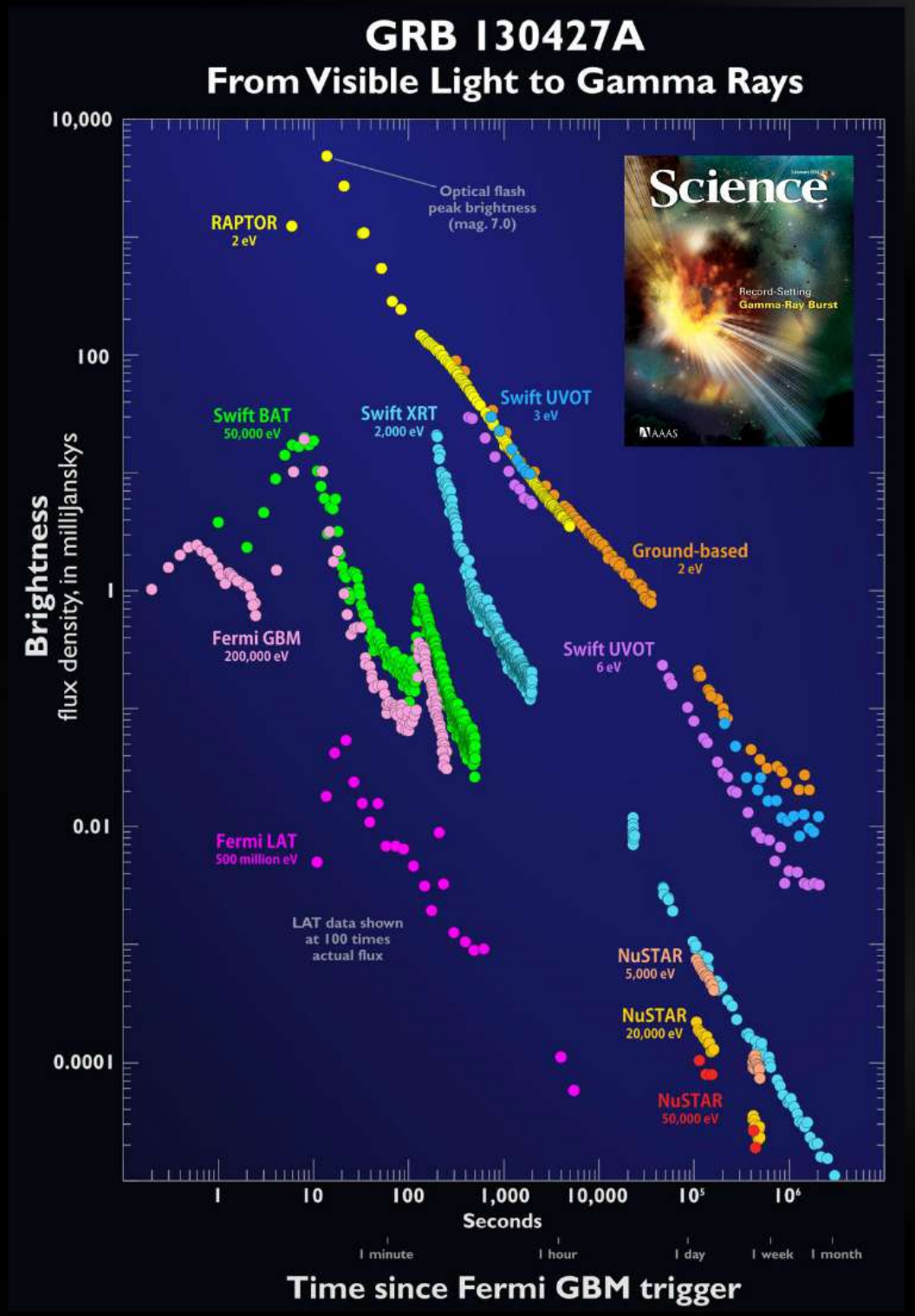
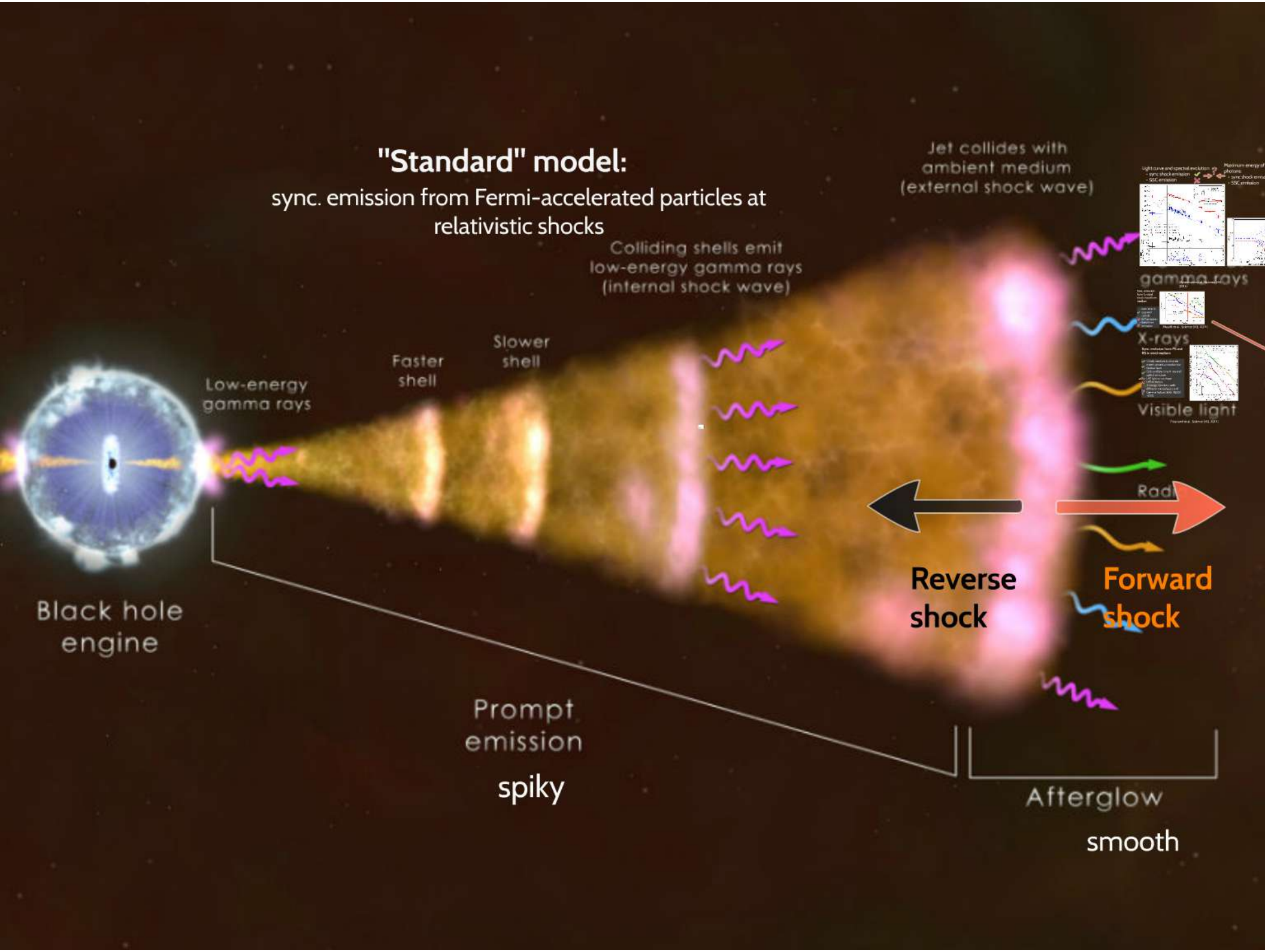
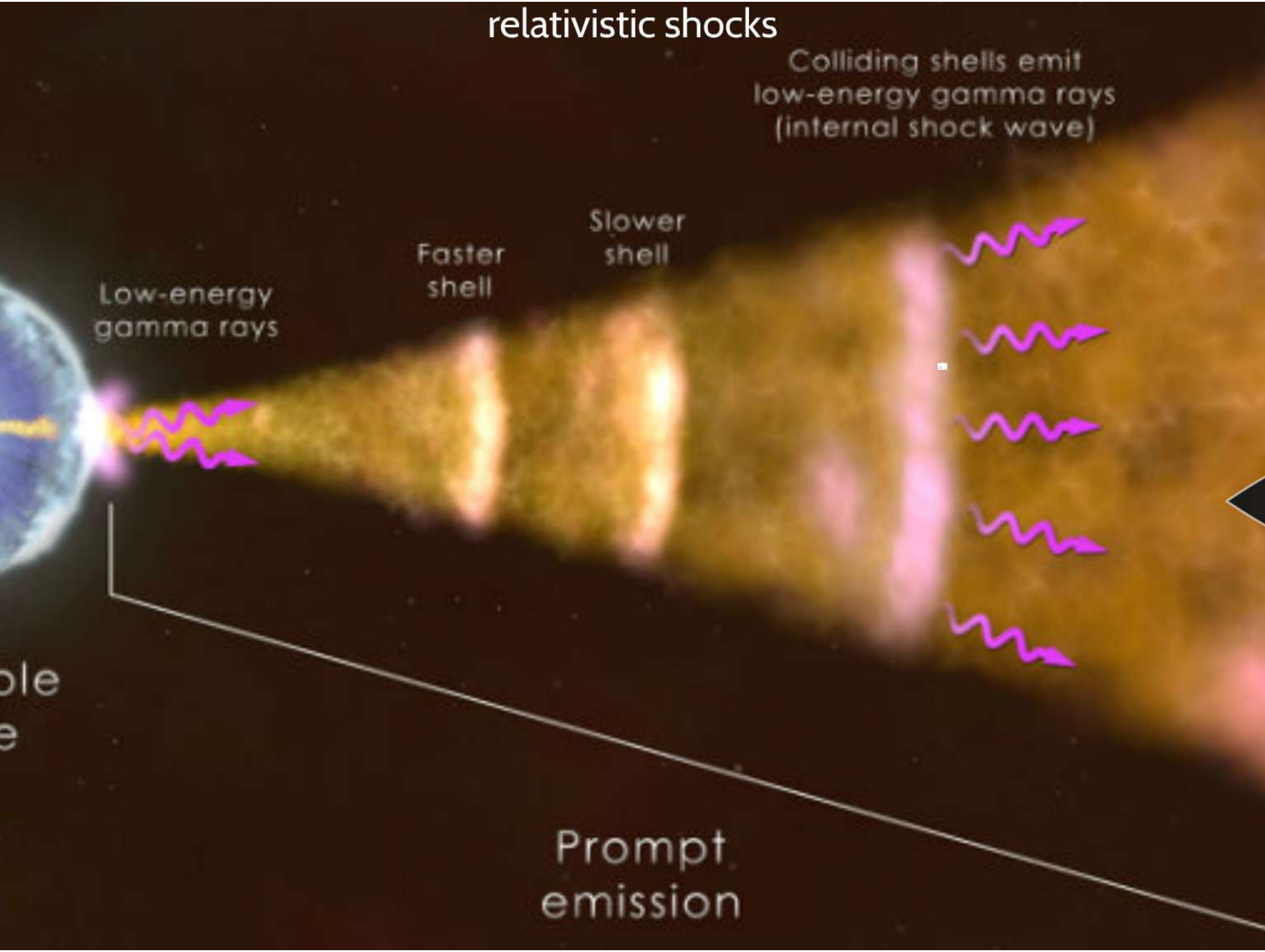


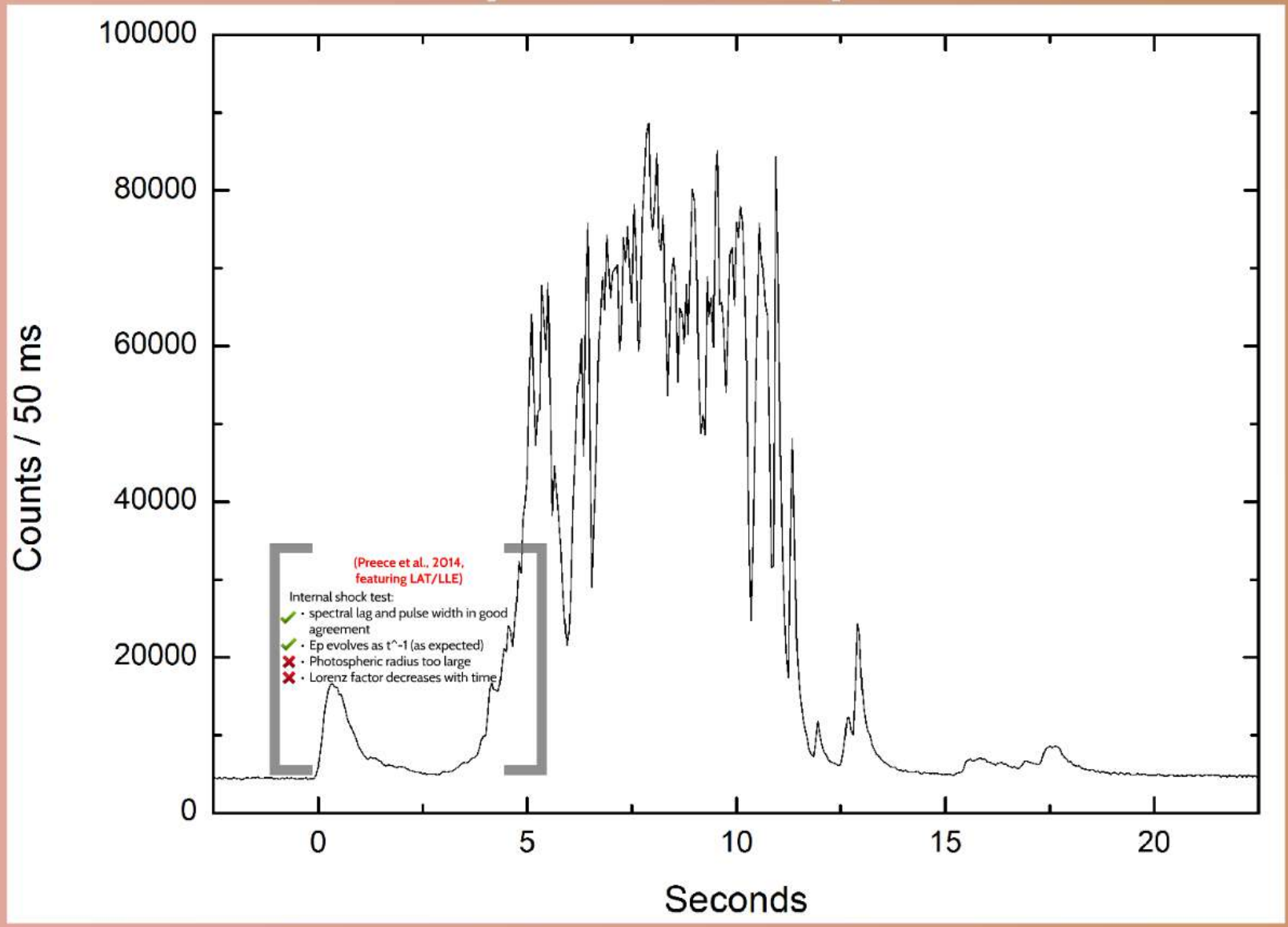

"Standard" model:
sync. emission from Fermi-accelerated particles at relativistic shocks
Jet collides with ambient medium (external shock wave)
Colliding shells emit low-energy gamma rays (internal shock wave)
Slower shell
Faster shell
Low-energy gamma rays
gamma rays
X-rays
Visible light
Rad
Reverse shock
Forward shock
Black hole engine
Prompt emission
spiky
Afterglow
smooth

relativistic shocks



Prompt emission:

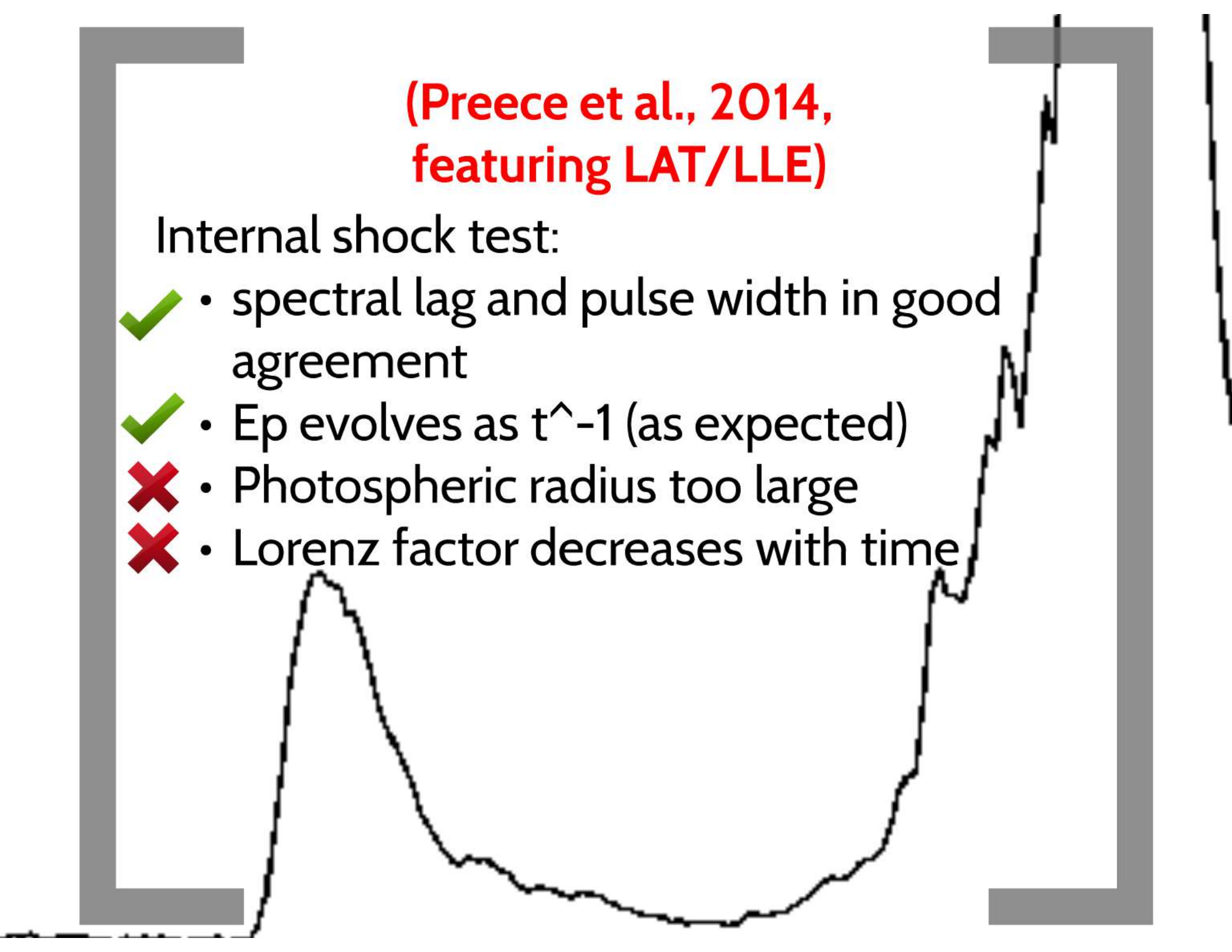
- fast variability
- pulse overlap

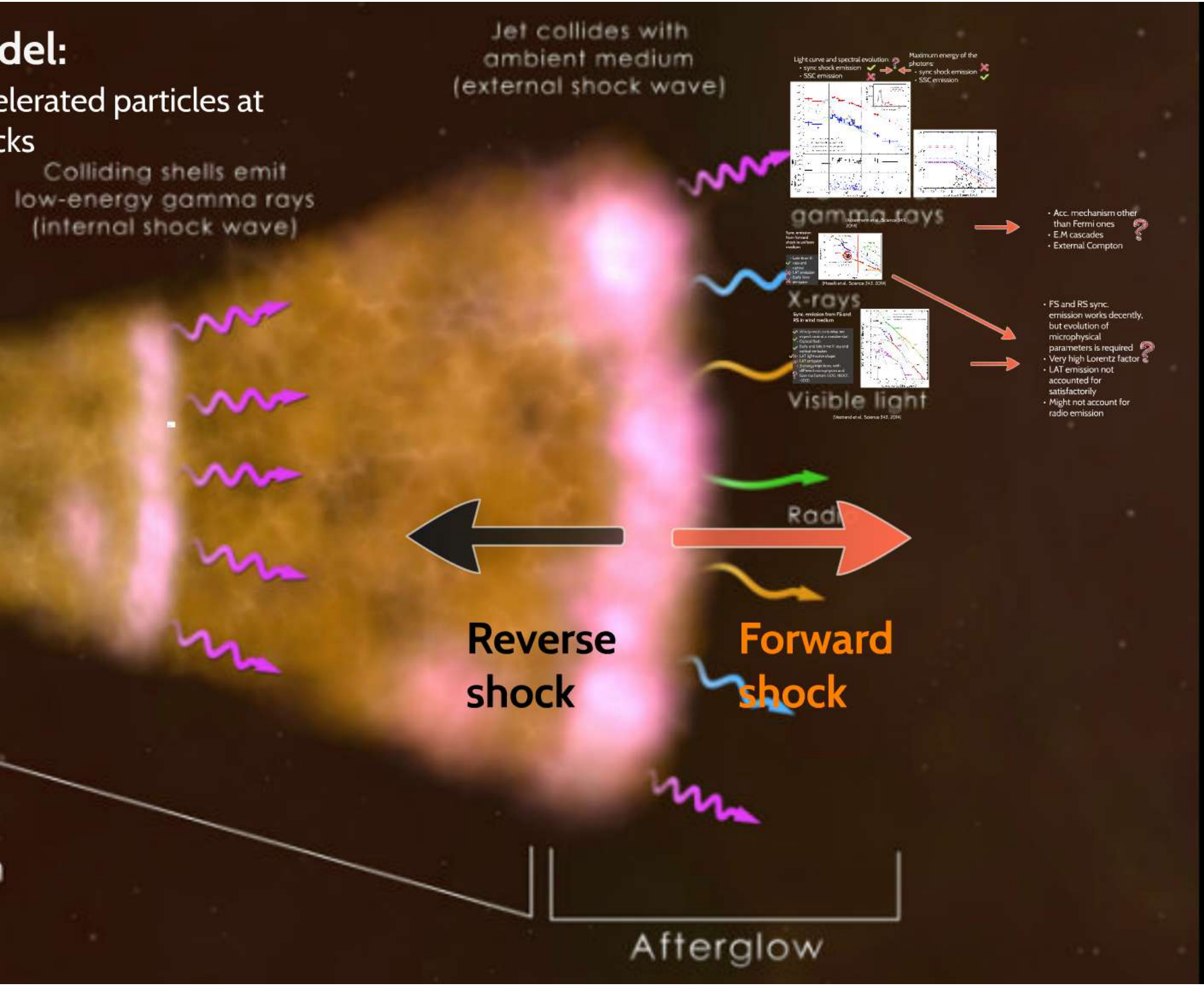


(Preece et al., 2014, featuring LAT/LLE)

Internal shock test:

- ✓ spectral lag and pulse width in good agreement
- ✓ Ep evolves as t^-1 (as expected)
- ✗ Photospheric radius too large
- ✗ Lorenz factor decreases with time




del:
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cks
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(internal shock wave)
Jet collides with
ambient medium
(external shock wave)
Light curve and spectral evolution:
• sync shock emission
• SSC emission
Maximum energy of the photons:
• sync shock emission
• SSC emission
gamma rays
• Acc. mechanism other than Fermi ones
• E.M cascades
• External Compton
X-rays
• FS and RS sync. emission works decently, but evolution of microphysical parameters is required
• Very high Lorentz factor
• LAT emission not accounted for satisfactorily
• Might not account for radio emission
Visible light
Radi
Reverse
shock
Forward
shock
Afterglow

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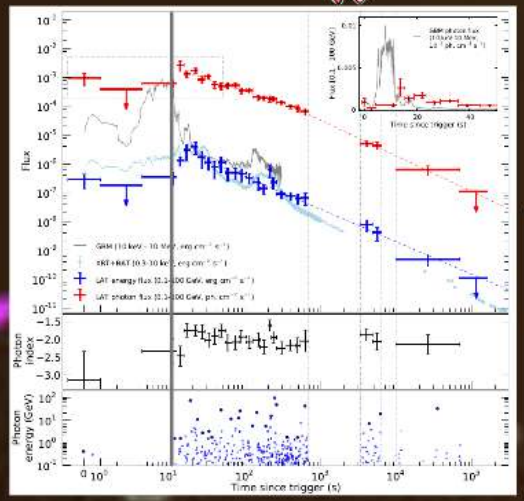
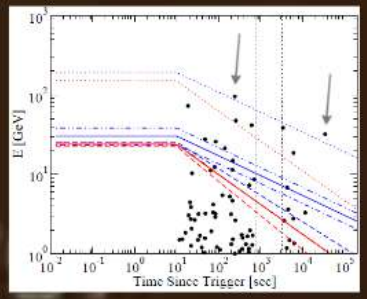




gamma rays

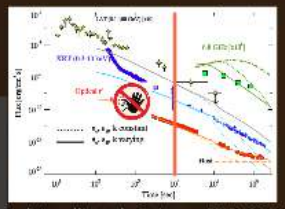
(Ackermann et al., Science 343, 2014)

- Acc. mechanism other than Fermi ones
- E.M cascades
- External Compton

?

Sync. emission from forward shock in uniform medium

- Late time X-rays and optical ✓
- LAT emission ✗
- Early time emission ✗

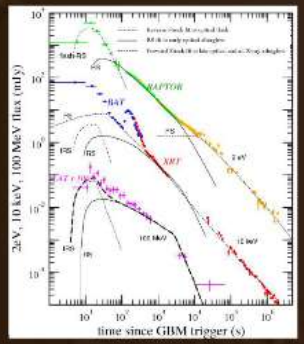


(Maselli et al., Science 343, 2014)

X-rays

Sync. emission from FS and RS in wind medium

- Windy medium is what we expect around a massive star ✓
- Optical flash ✓
- Early and late time X-ray and optical emission ✓
- LAT light curve shape ✓✗
- LAT emission ✗
- 3 energy injections, with different microphysics and Gamma factors (500, 1800!, >100) ?



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?

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- Might not account for radio emission

Visible light

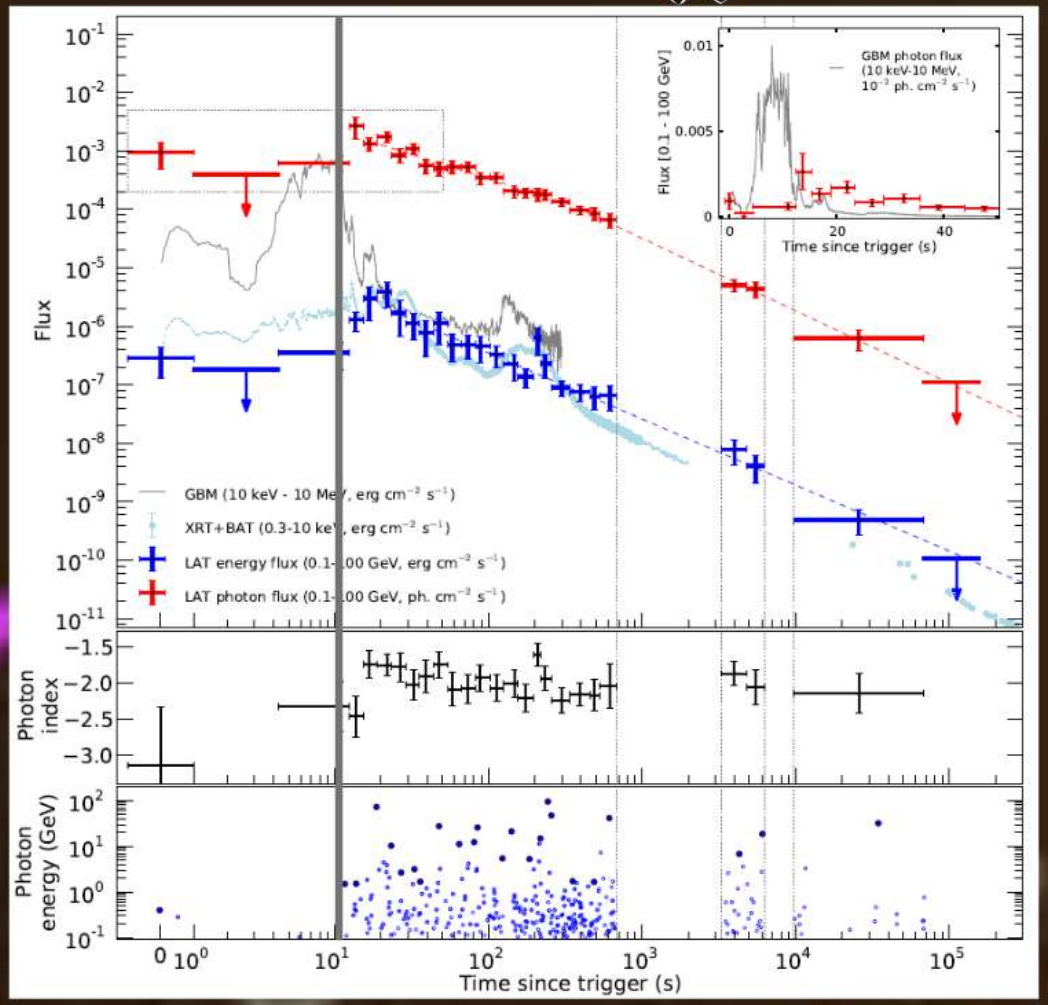
(Vestrand et al., Science 343, 2014)

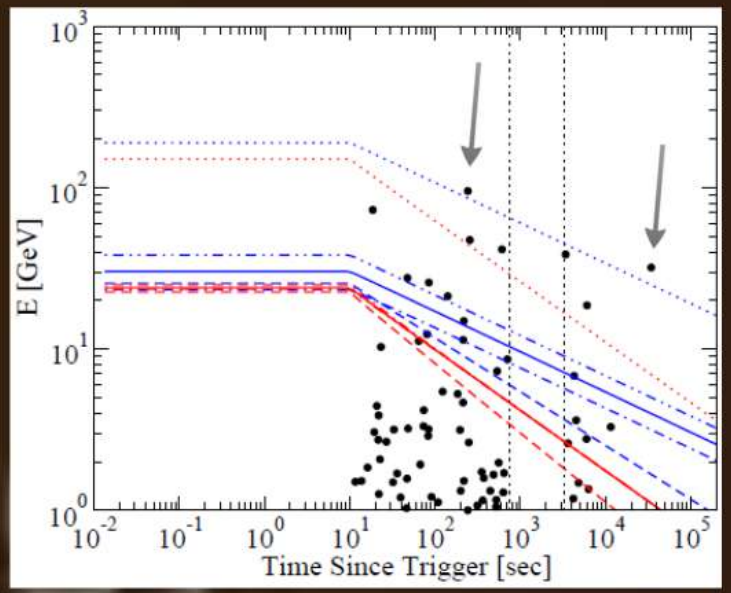
Light curve and spectral evolution:

- sync shock emission
- SSC emission

Maximum energy of the photons:

- sync shock emission
- SSC emission





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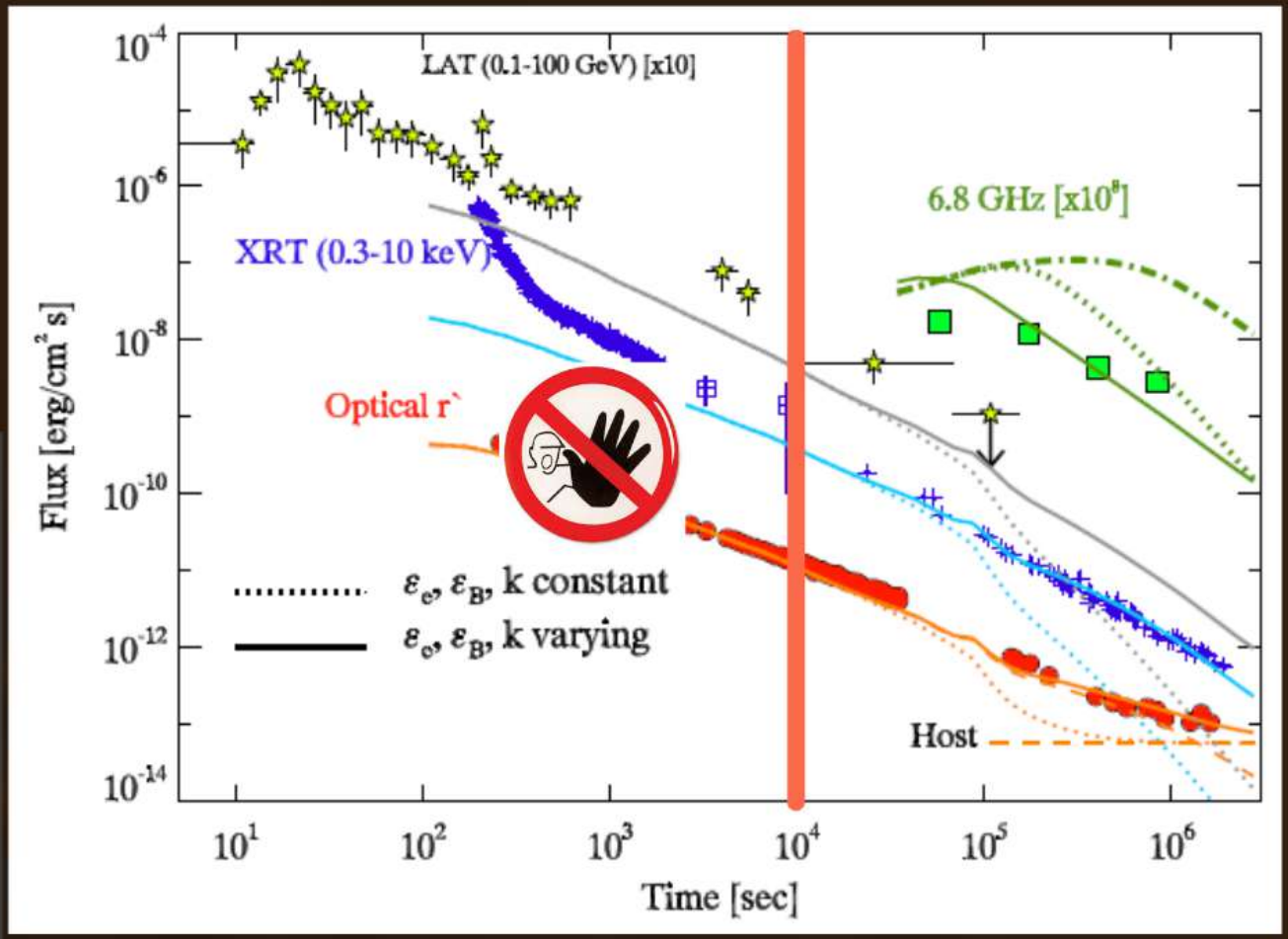

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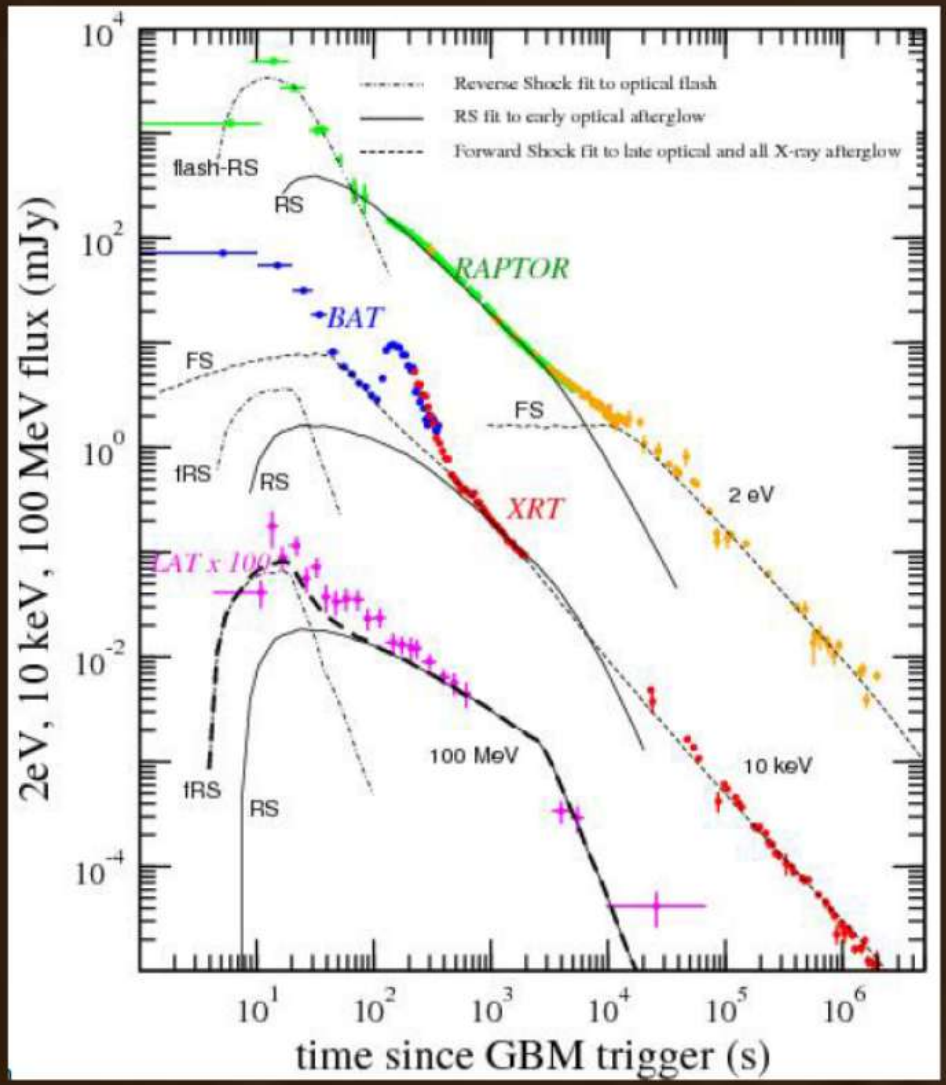

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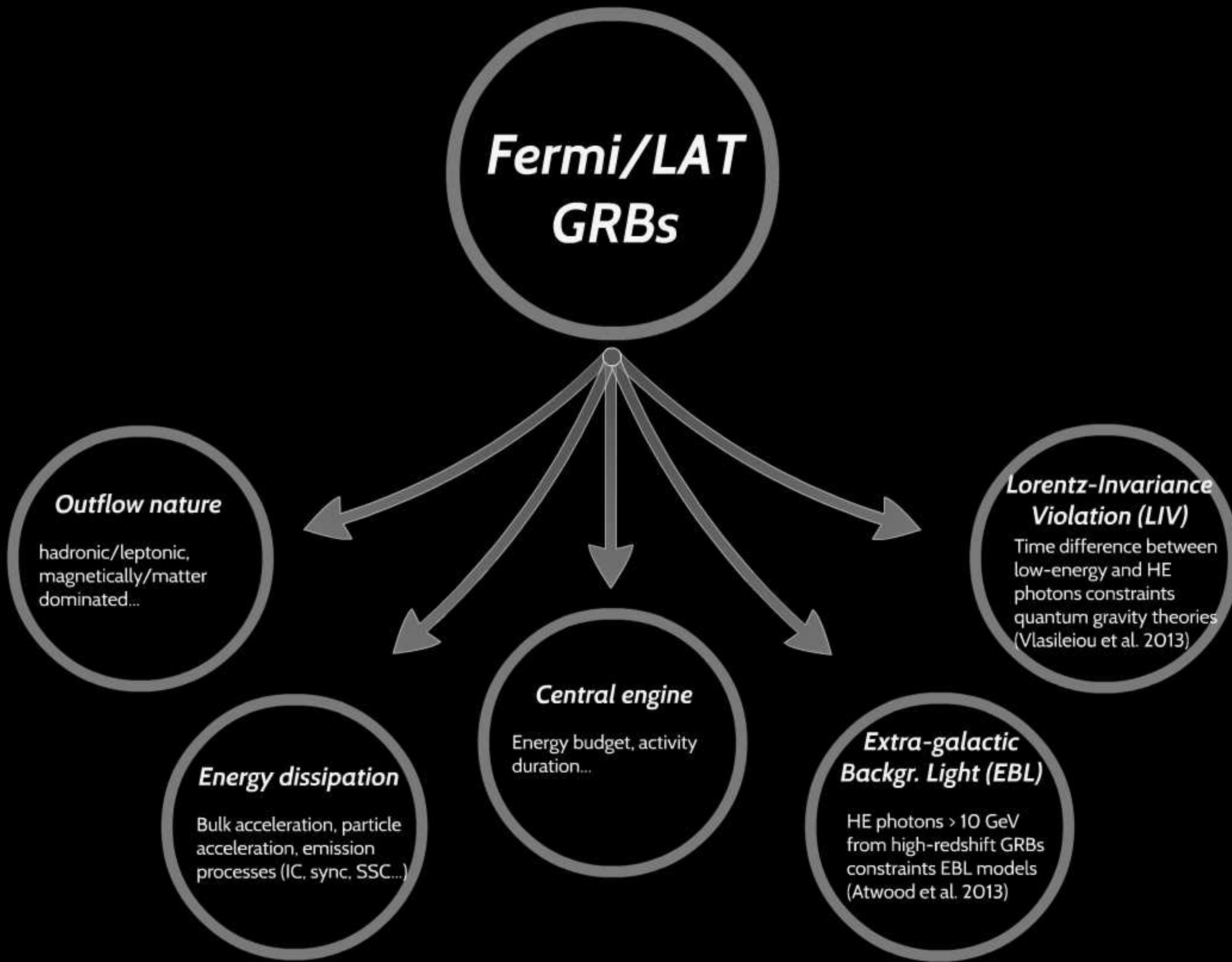

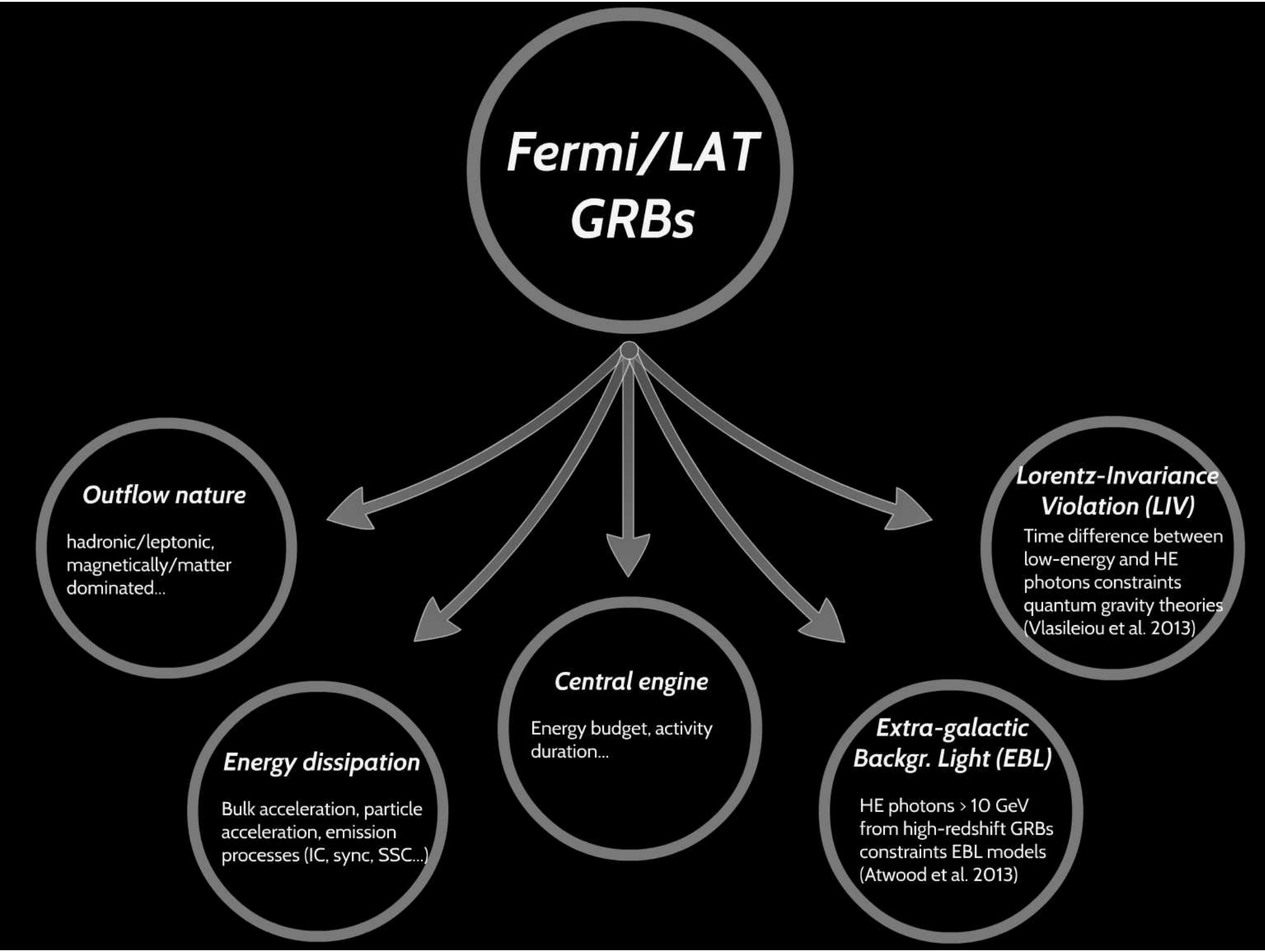
Fermi/LAT GRBs
Outflow nature
hadronic/leptonic, magnetically/matter dominated...
Lorentz-Invariance Violation (LIV)
Time difference between low-energy and HE photons constraints quantum gravity theories (Vlasileiou et al. 2013)
Central engine
Energy budget, activity duration...
Energy dissipation
Bulk acceleration, particle acceleration, emission processes (IC, sync, SSC...)
Extra-galactic Backgr. Light (EBL)
HE photons > 10 GeV from high-redshift GRBs constraints EBL models (Atwood et al. 2013)

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