High-energy radiation from Gamma-Ray Bursts: origin and future prospects

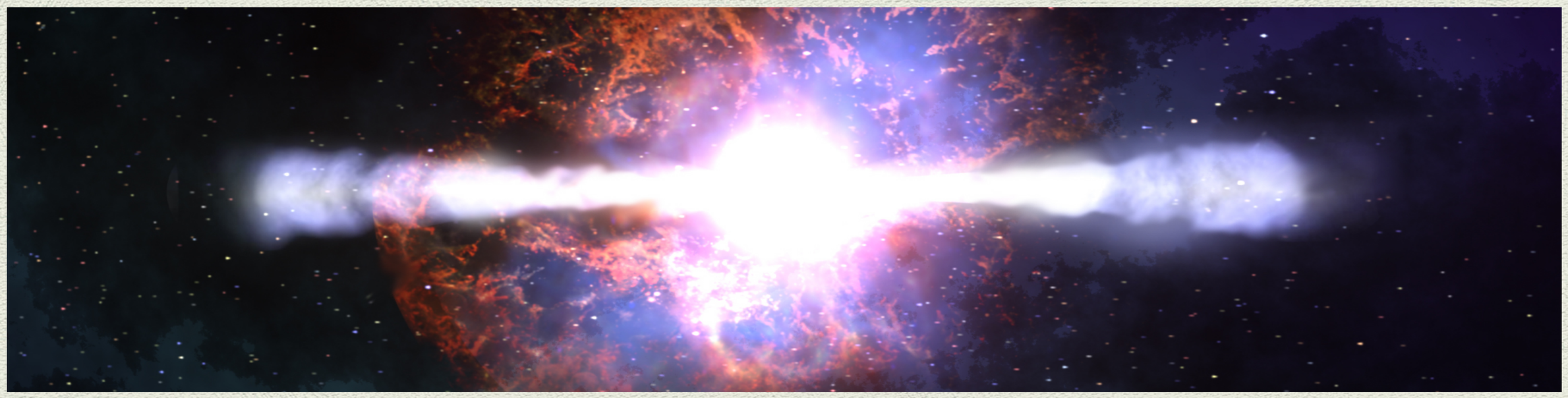
Lara Nava

Marie Skłodowska-Curie Fellow

INAF

Osservatorio Astronomico di Brera - Osservatorio Astronomico di Trieste

GRBs: powerful explosions at cosmological distances



PROMPT emission

internal shocks or reconnection

Particle acceleration: non-thermal

Radiative process: synchrotron??

Duration: seconds

Energy range: 10 keV - 10 MeV

AFTERGLOW emission

external shocks

Particle acceleration: non-thermal

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Duration: weeks-months

Energy range: radio to soft X-rays

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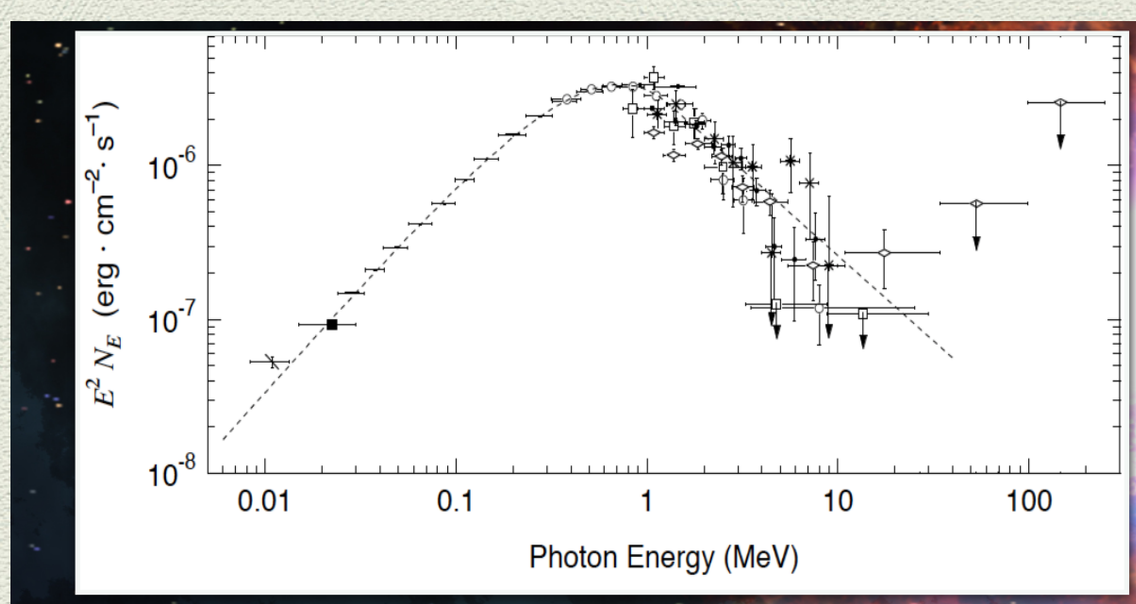

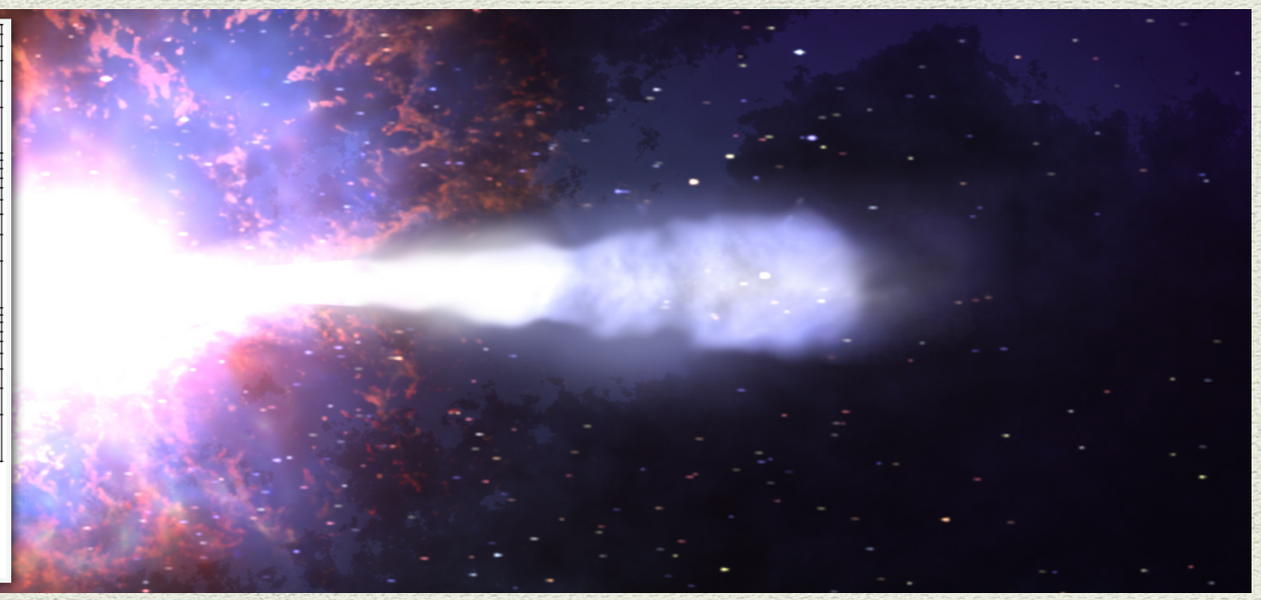

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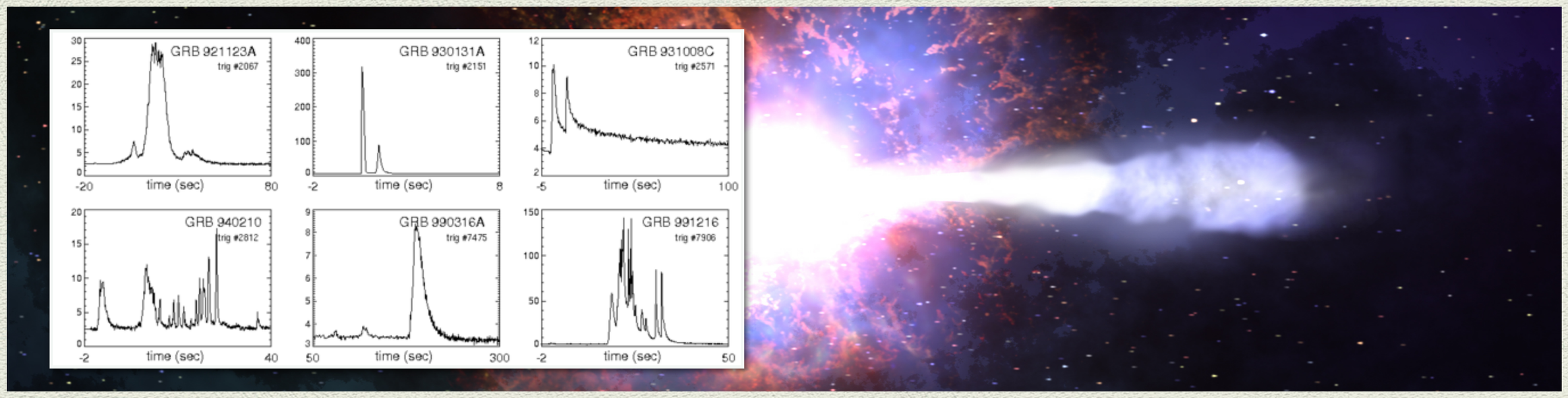

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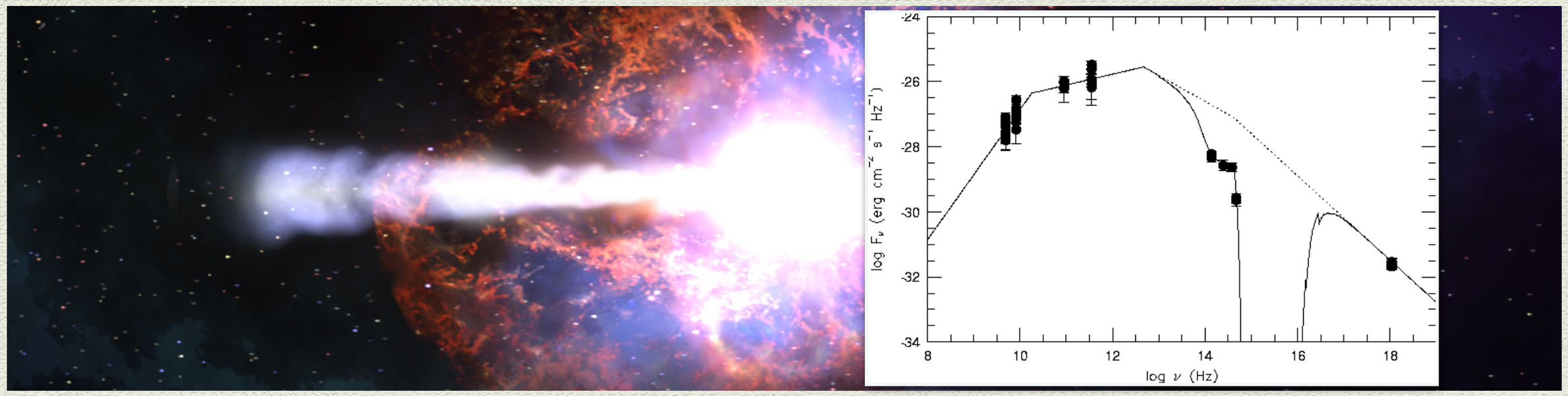

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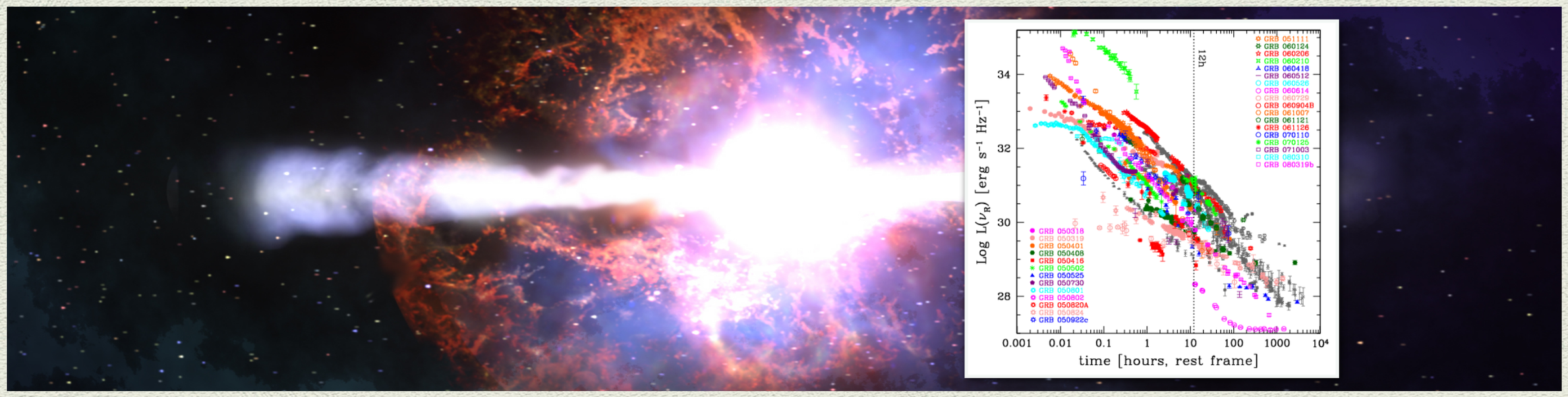

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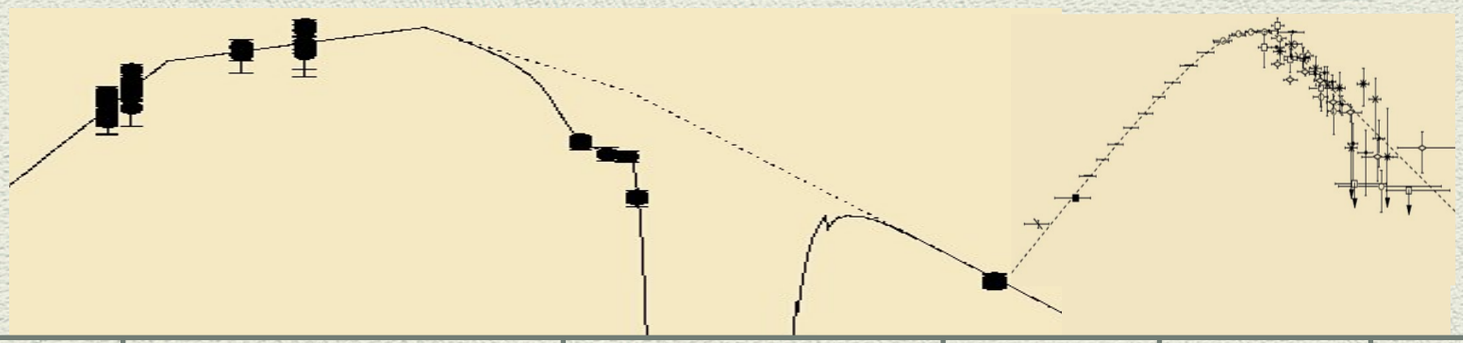
The GRB electromagnetic spectrum

AFTERGLOW

PROMPT

HIGH ENERGY

VERY-HIGH ENERGY



10^{10} Hz

10^{14} Hz

1 keV

10^{2} keV

10 MeV

1GeV

10^{2}GeV

10TeV

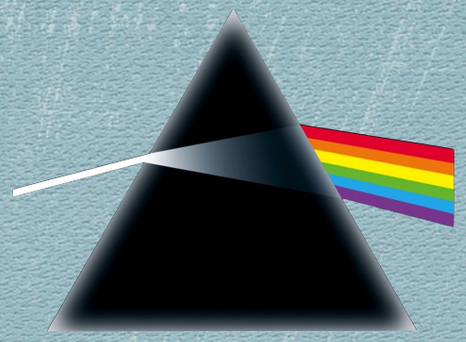
radio

optical

soft X-rays

hard X-rays

gamma-rays ⟶



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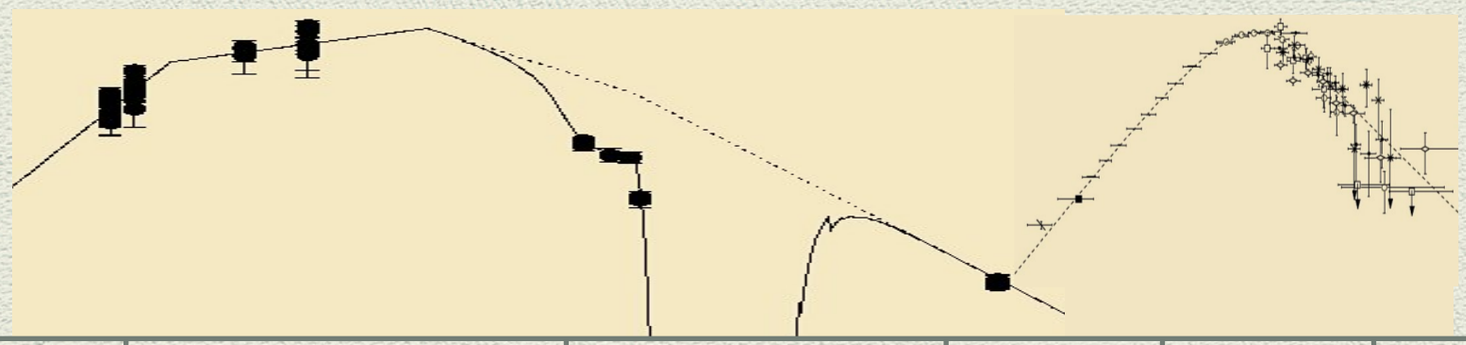


- continuation of prompt/aft spectra
- Inverse Compton scattered component

10^{10} Hz — radio

10^{14} Hz — optical

1 keV — soft X-rays

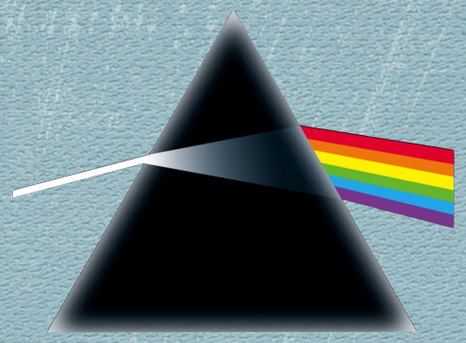
10^{2} keV — hard X-rays

10 MeV — gamma-rays →

1GeV

10^{2}GeV

10TeV



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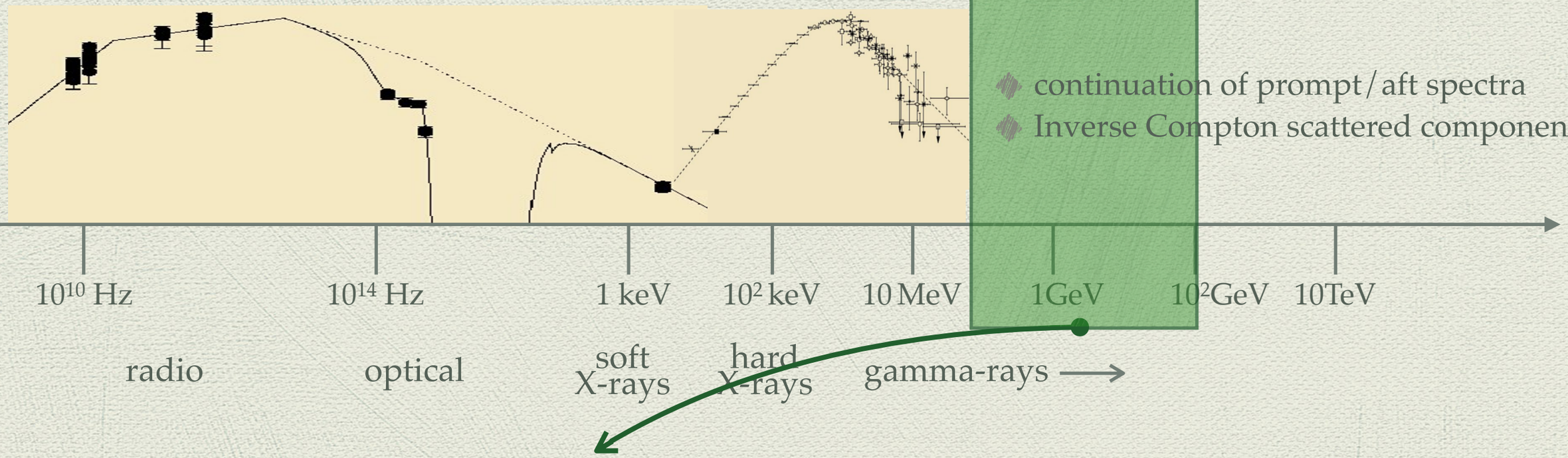
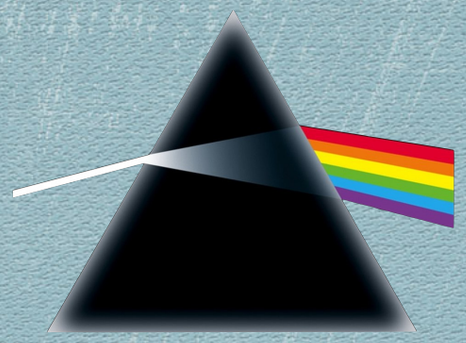


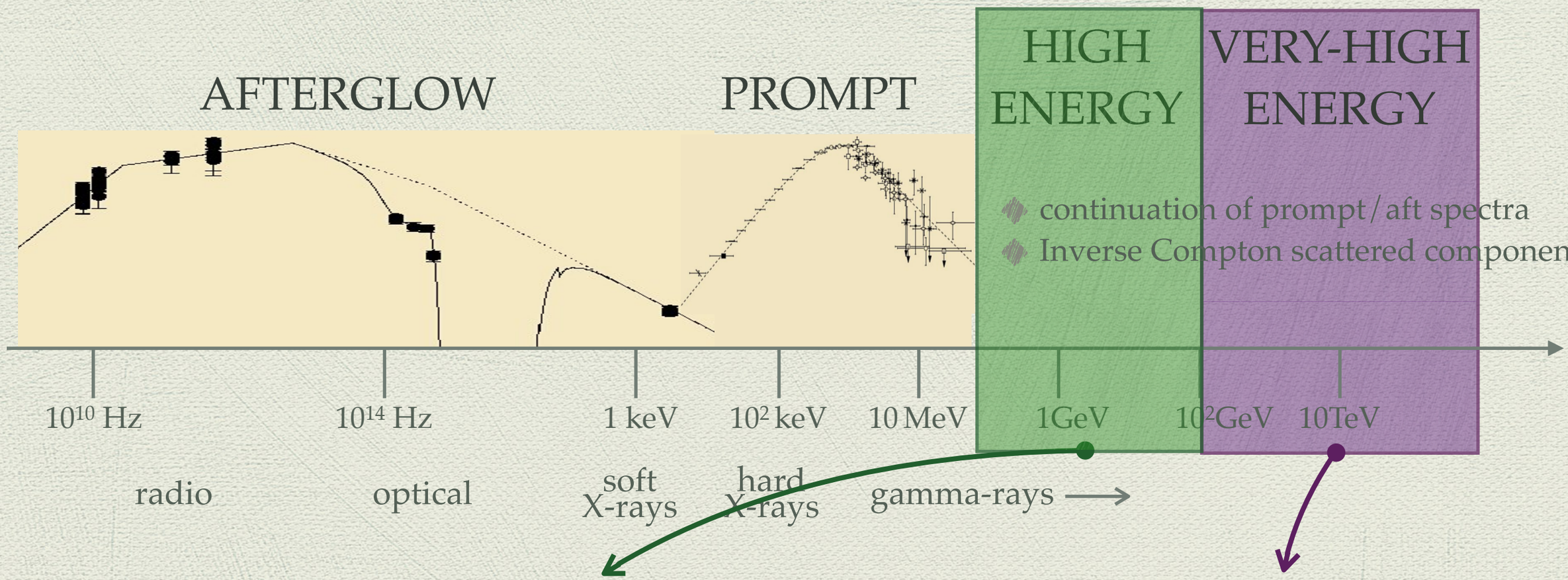
EGRET, AGILE, Fermi-LAT

20 MeV - 300 GeV

130 GRBs detected in 9yr

The GRB electromagnetic spectrum





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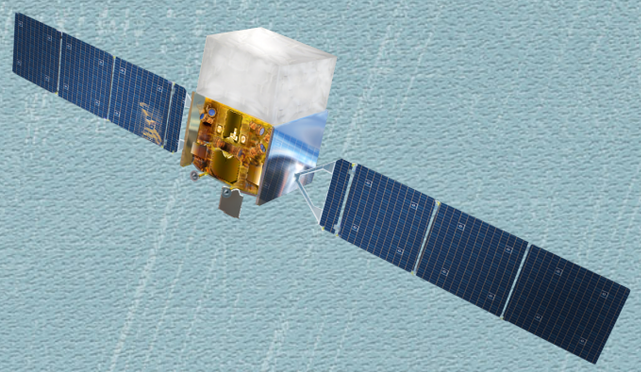
MAGIC, HESS, VERITAS

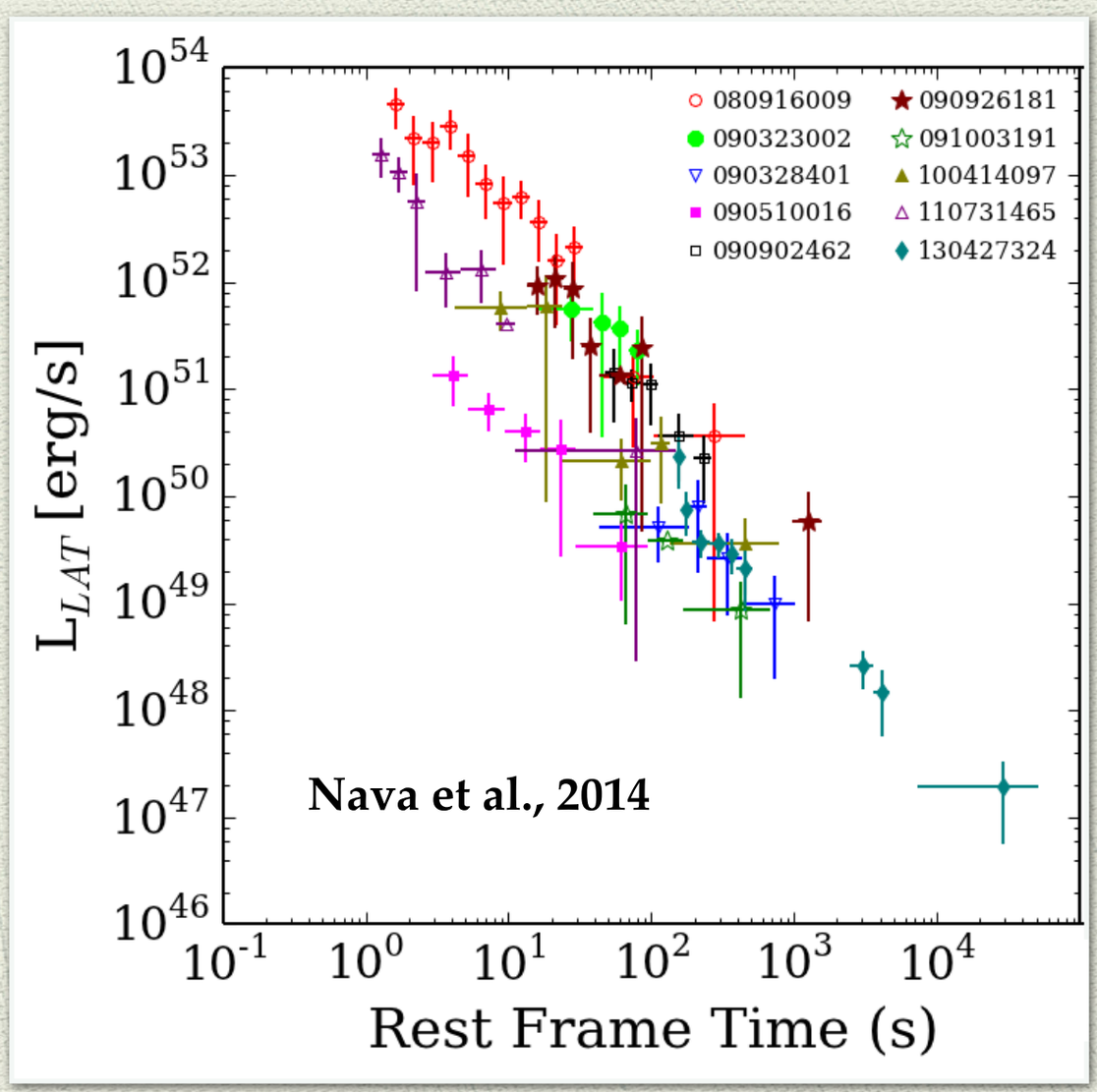
50-100 GeV — 100 TeV

no detections!

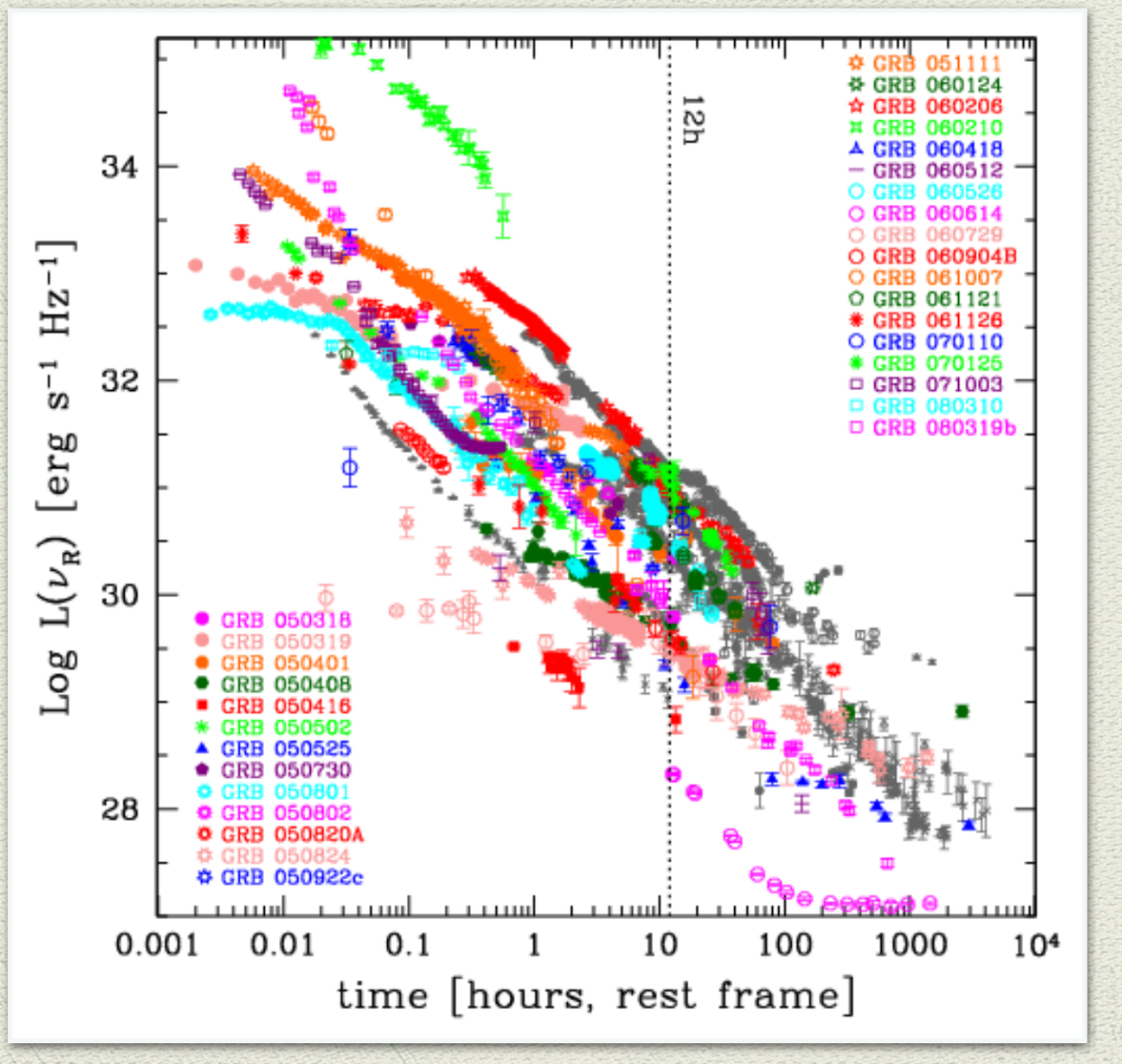


High-energy emission: Fermi-LAT observations

High-energy LAT lightcurves for 10 GRBs, 0.1-10 GeV



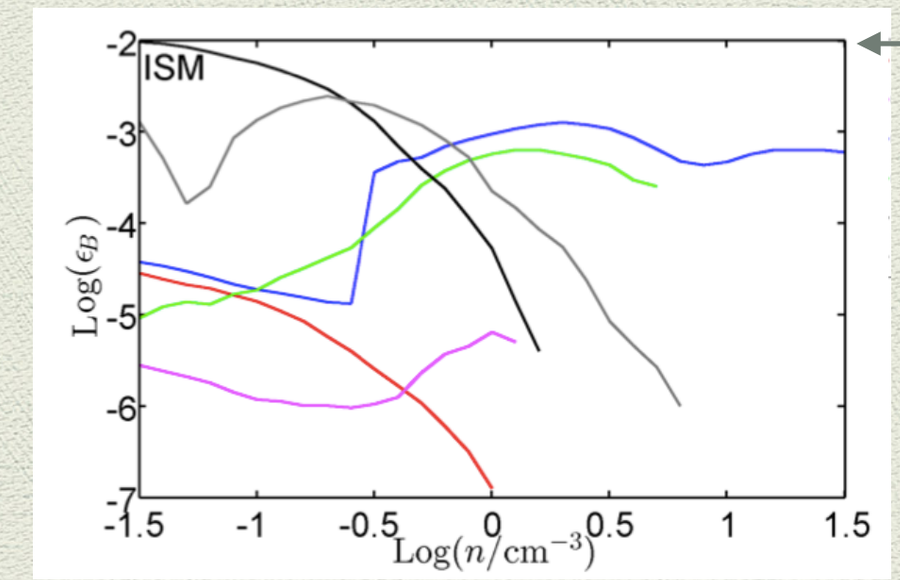
Optical lightcurves



Beniamini, LN, Barniol-Duran & Piran 2015

High-energy emission: modelling and interpretation

upper limits to ε_B



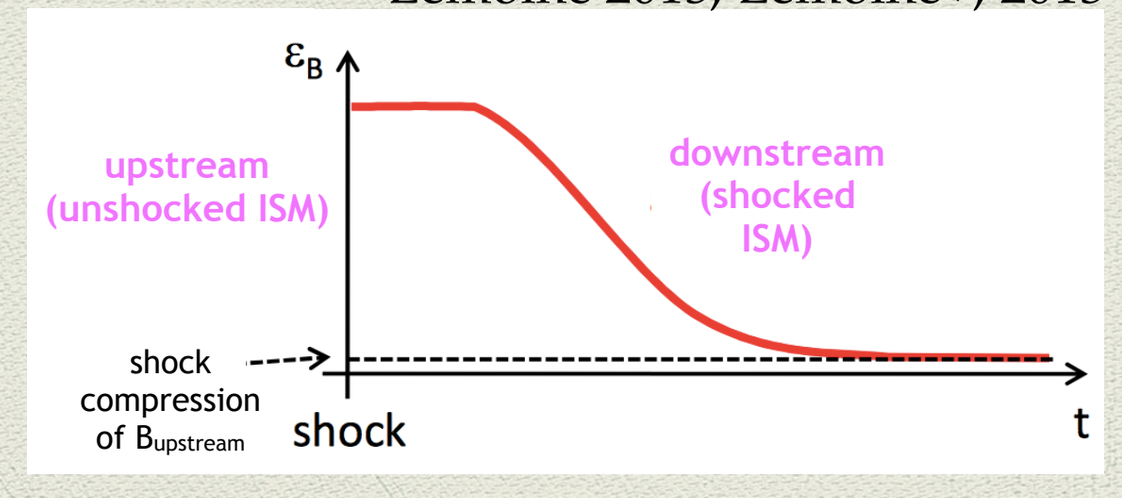
Density

← traditionally assumed values $> 10^{-2}$

similar results found by:
Kumar & Barniol Duran 2009
Lemoine 2013a/b
Santana et al., 2014

Possible explanation for such small values of the magnetic field →

Lemoine 2013, Lemoine+, 2013



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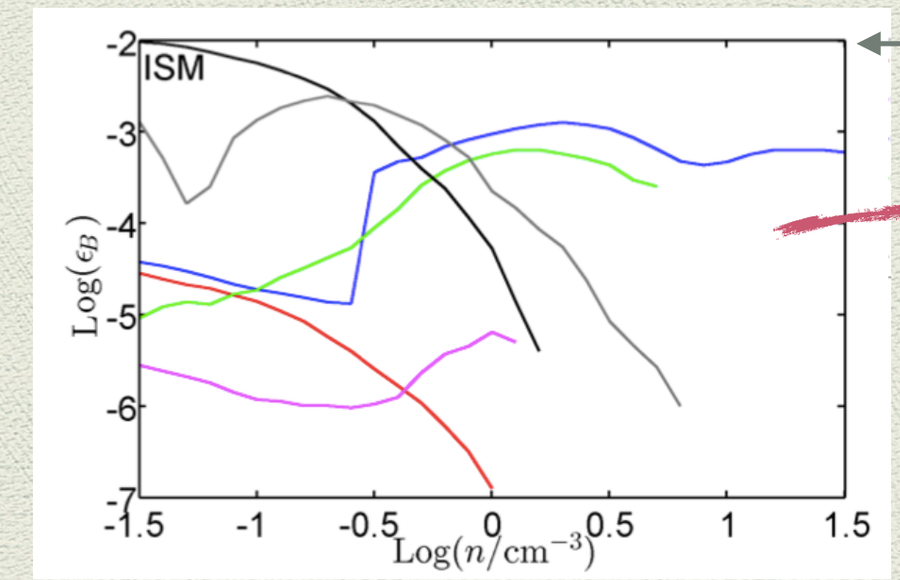

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SSC ???
(synchrotron
self-Compton)

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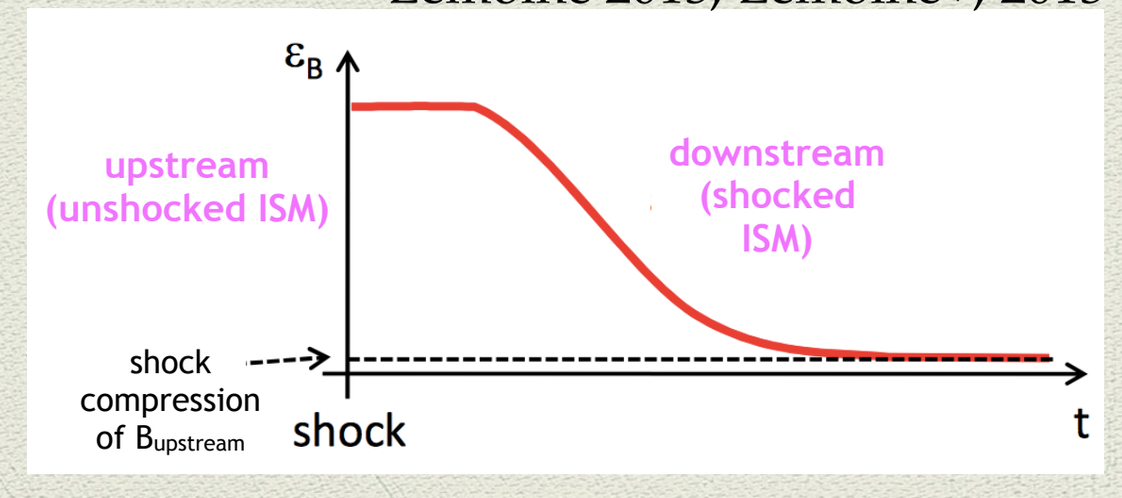


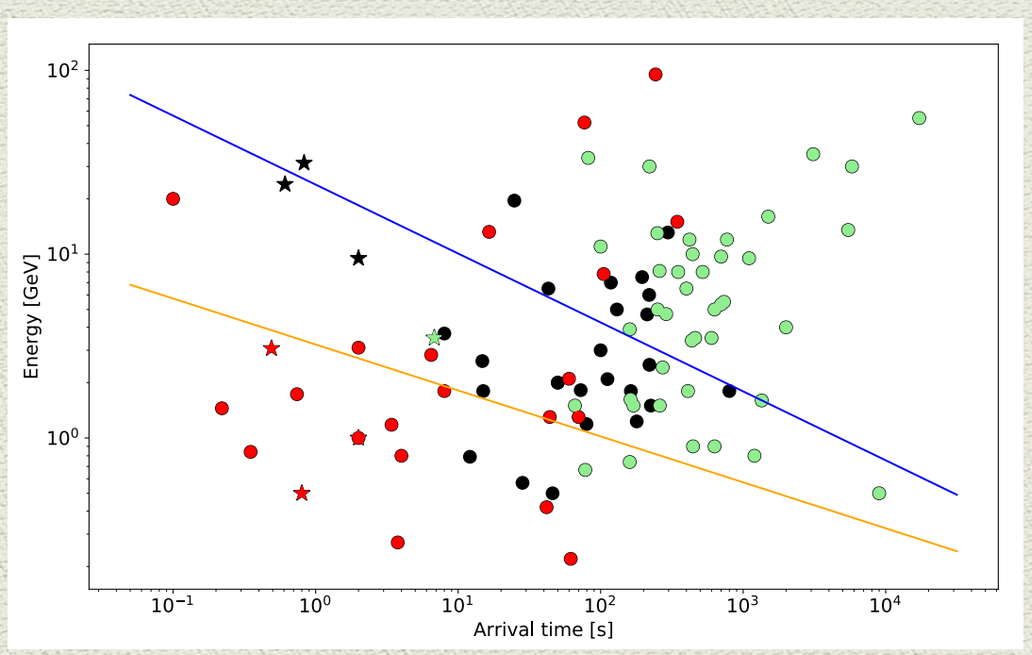
High-energy emission: modelling and interpretation

Issue with a external shock- synchrotron interpretation of the GeV emission

Electrons are accelerated up to some maximum energy γ_{max} → Synchrotron photons are emitted up to a maximum energy $E_{syn,max}$

$$E_{syn,max} \propto \gamma_{max}^2 B \, \mathbf{\Gamma}$$

$$\simeq 50 \text{ MeV x } \mathbf{\Gamma}$$



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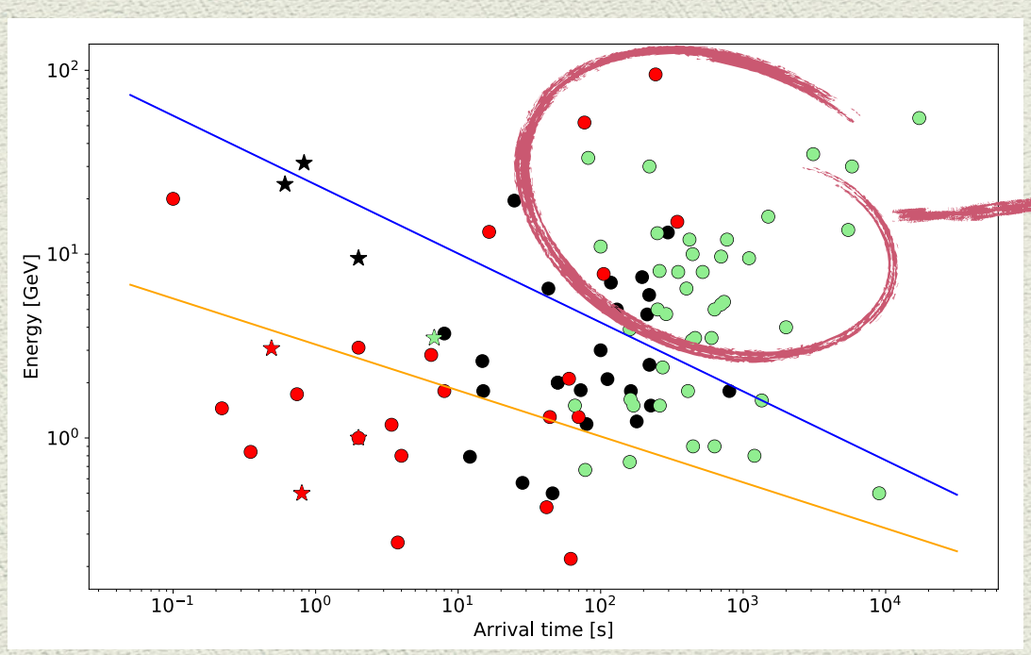
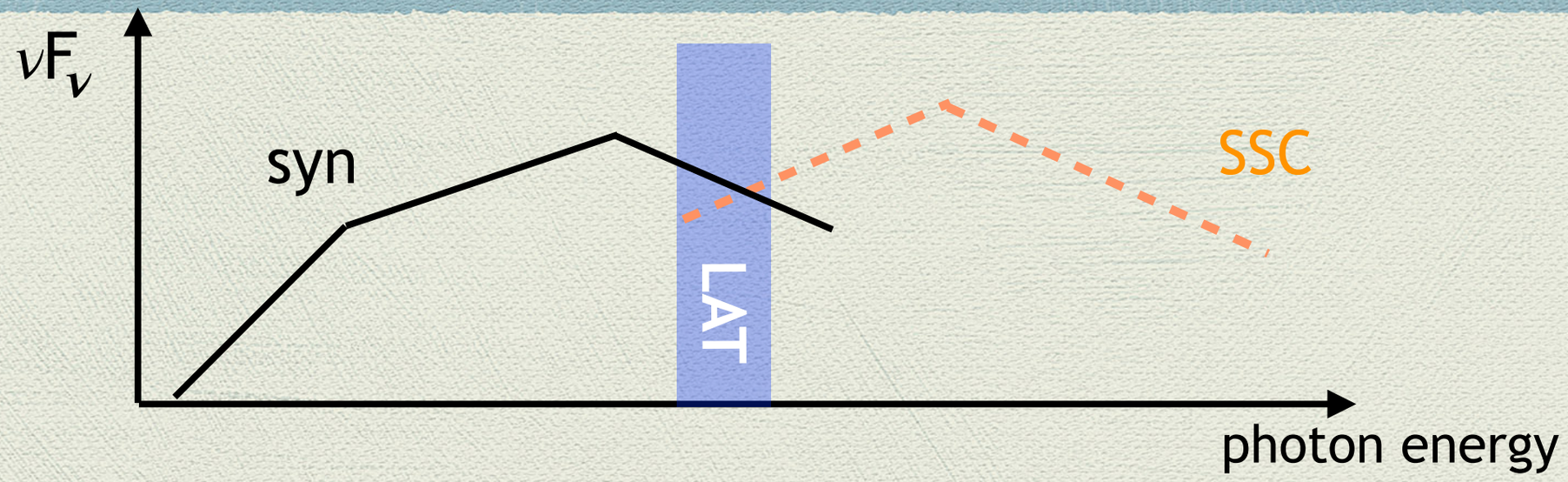
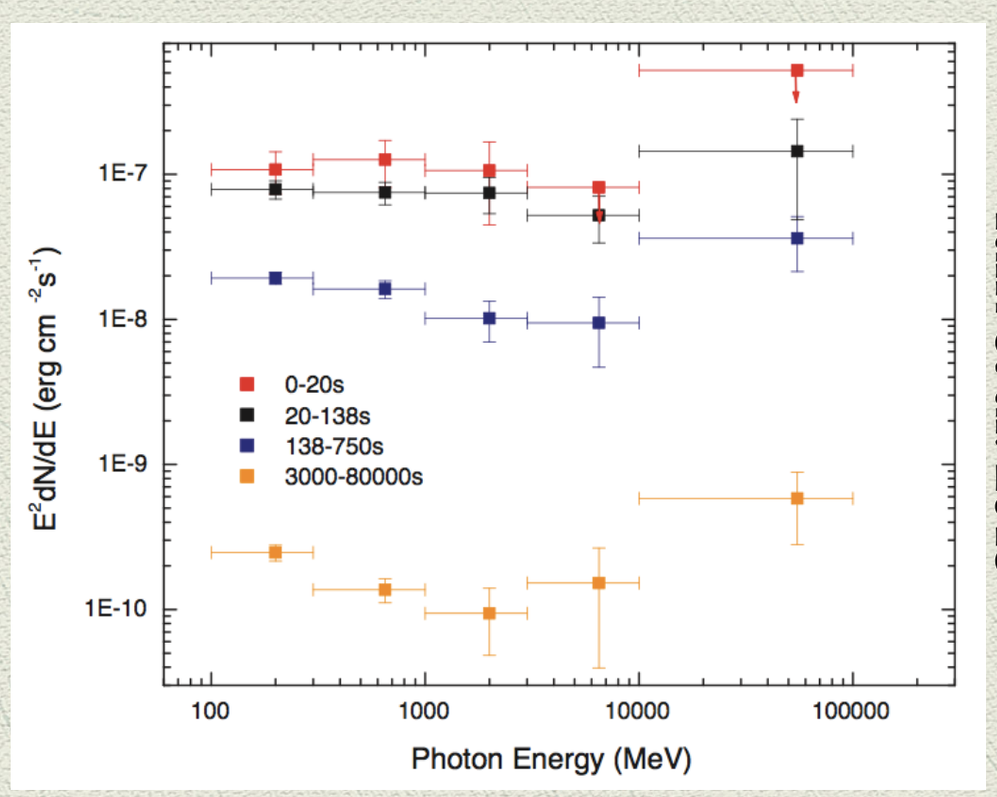


SSC ??? (synchrotron self-Compton)

Inverse Compton component?





Tam et al. 2013

Why should we care about what happens at high energies?

- nature of radiative processes
- energetics and efficiencies
- magnetic fields
- particle acceleration
- EBL (extragal. background light)
- quantum gravity

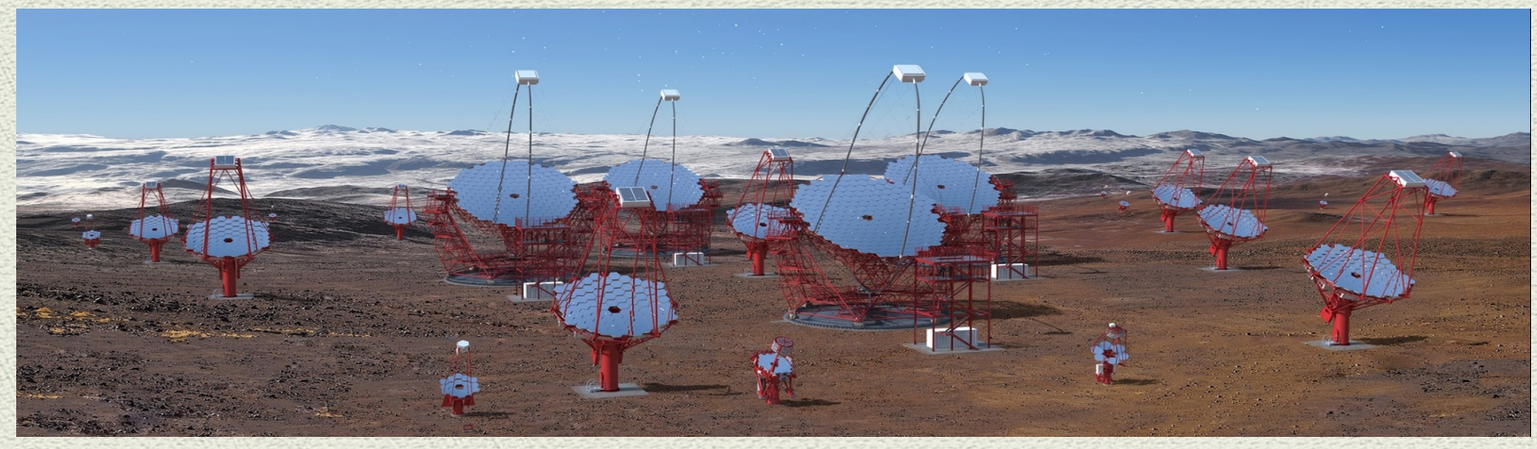
GRB physics

more general relevance

Why should we care about what happens at high energies?

CTA

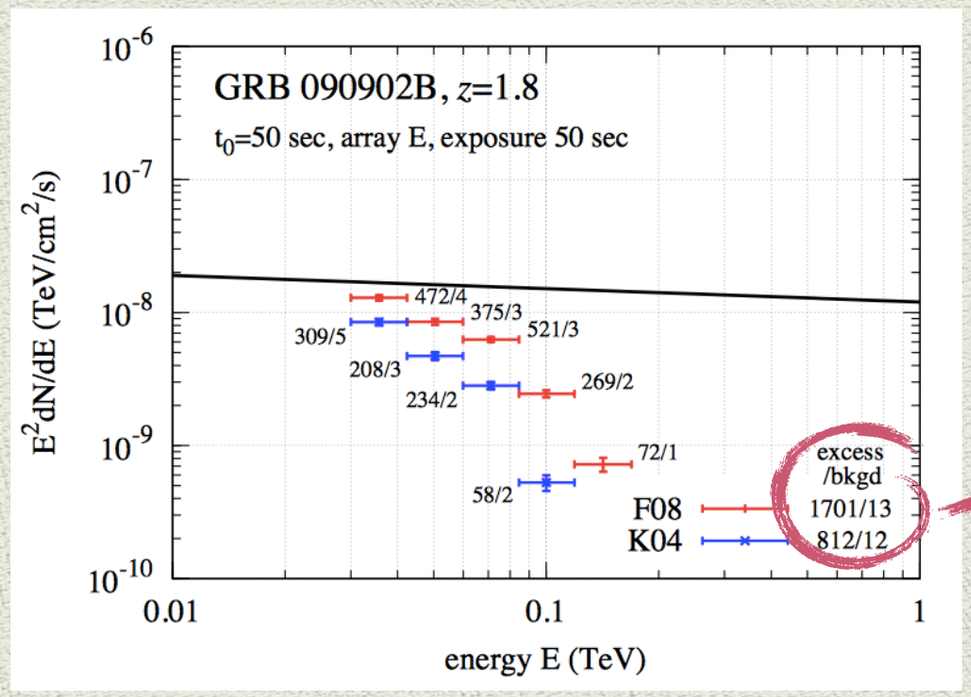
Cherenkov Telescope Array



Large-Sized Telescopes (LST)
30 - 200 GeV

Simulation GRB spectrum

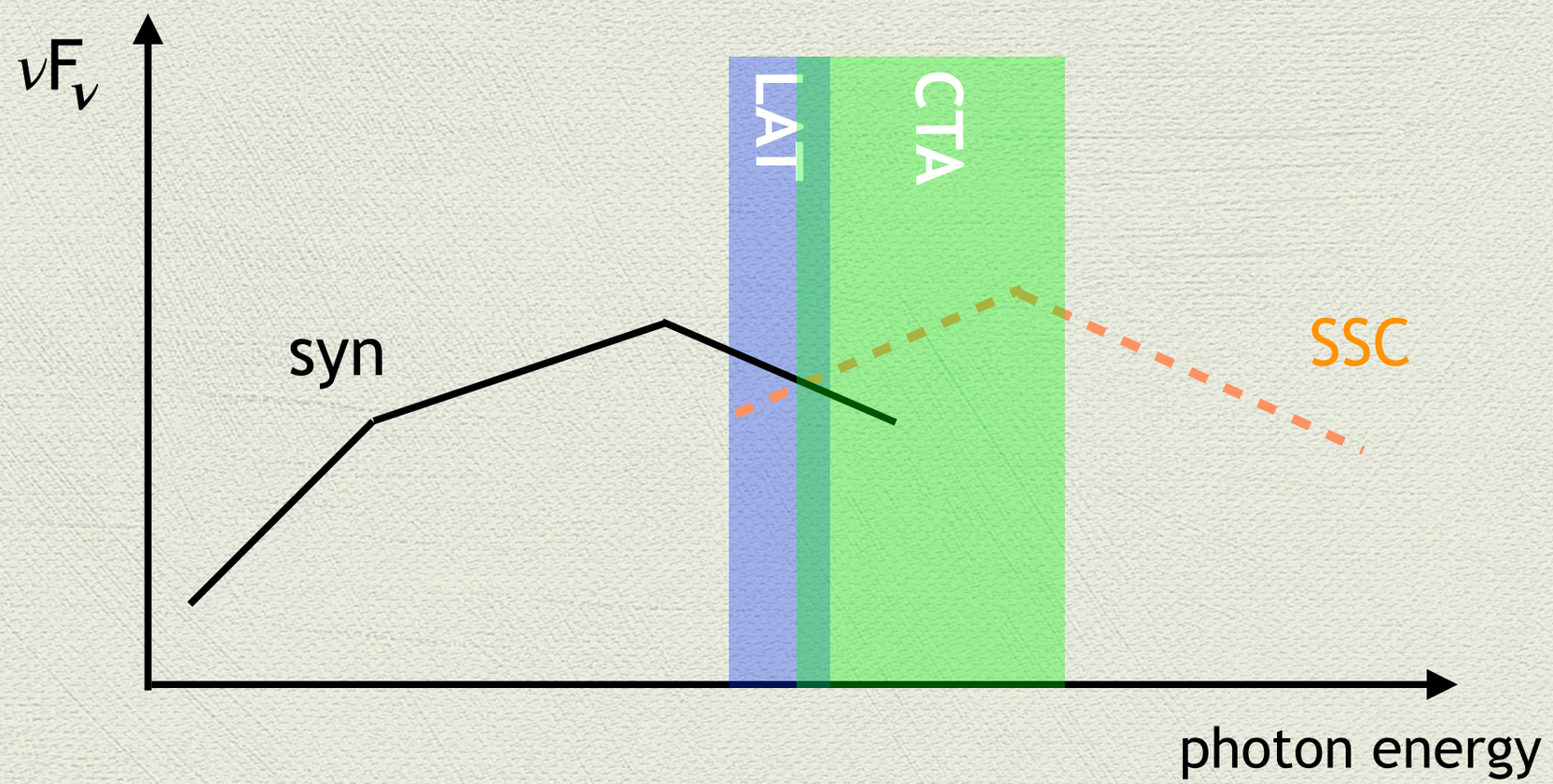
Inoue et al. 2013



huge number of events!

...but small detection rate:
0.1 - 1 per year

Inverse Compton component?



Prospects for GRB detection with the CTA

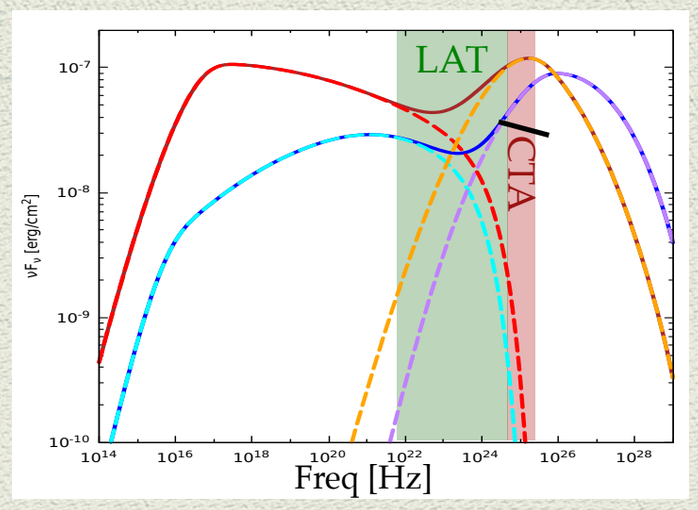
…work in progress…

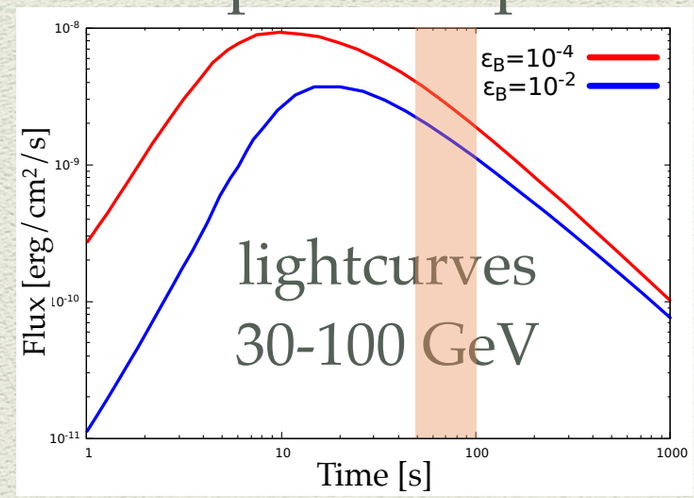
Future prospects

In collaboration with Francesco Longo, Enrico Peretti, Michele Palatiello,…

- Development of a code for modeling afterglow emission describing synchrotron and SCC emission, Klein-Nishina, pair production. Solution of two coupled equations for evolution of particle and photon spectra

Two examples of syn+SSC spectra and lightcurves from the code





- Application to Fermi-LAT GRBs: can high-energy photons be explained by SSC radiation?
- CTA GRB detection rate