Rubakov Conference

Erevan 2023

# The Diversity of Gamma Ray Burtsts

## And

## Can we learn anything new from GRB 221009 A?

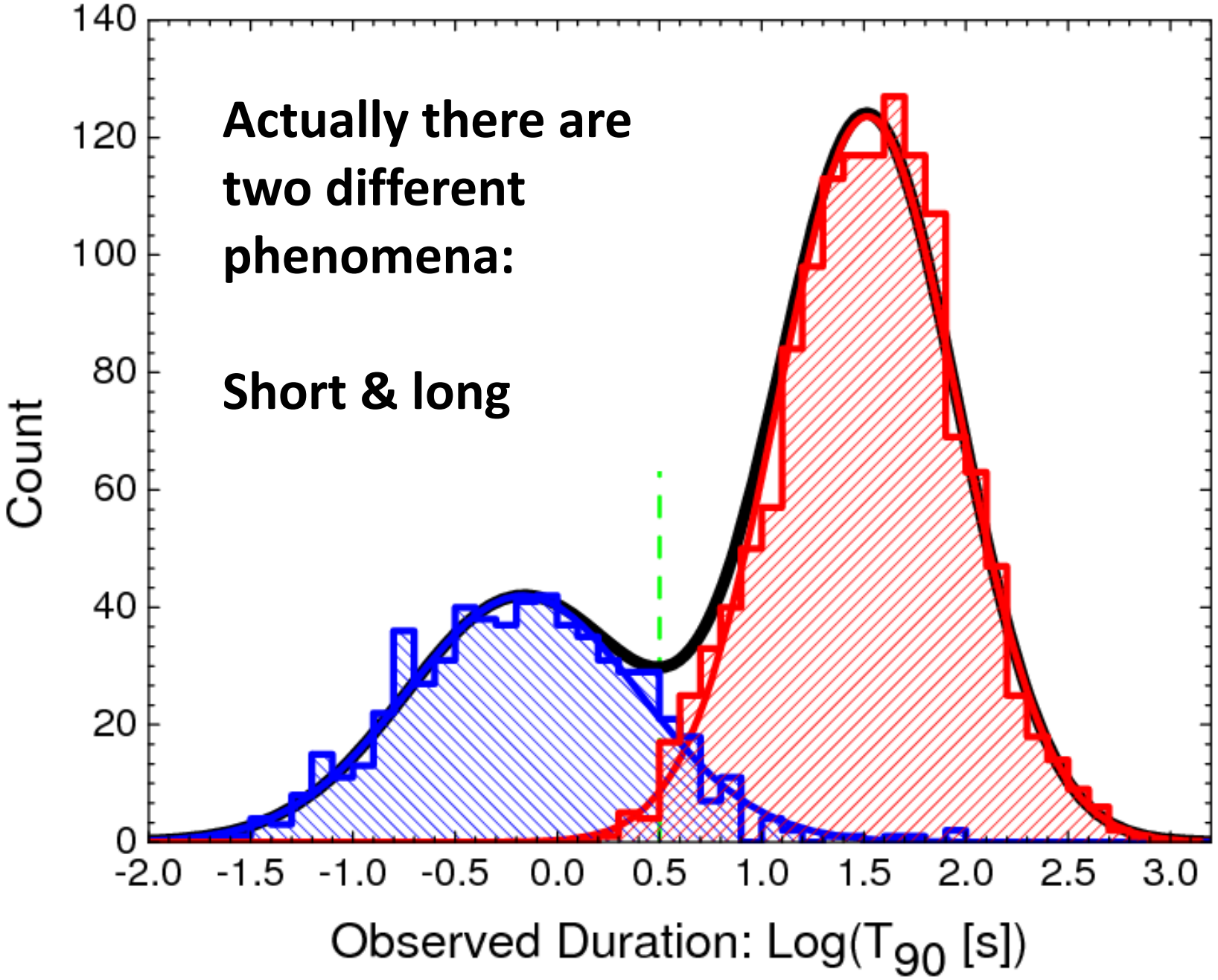
# The Outline

General scenario (prompt stage -> afterglow)

Phenomenology

- Spectra (implications)
- Time variability (implications)

GRB 221009 A

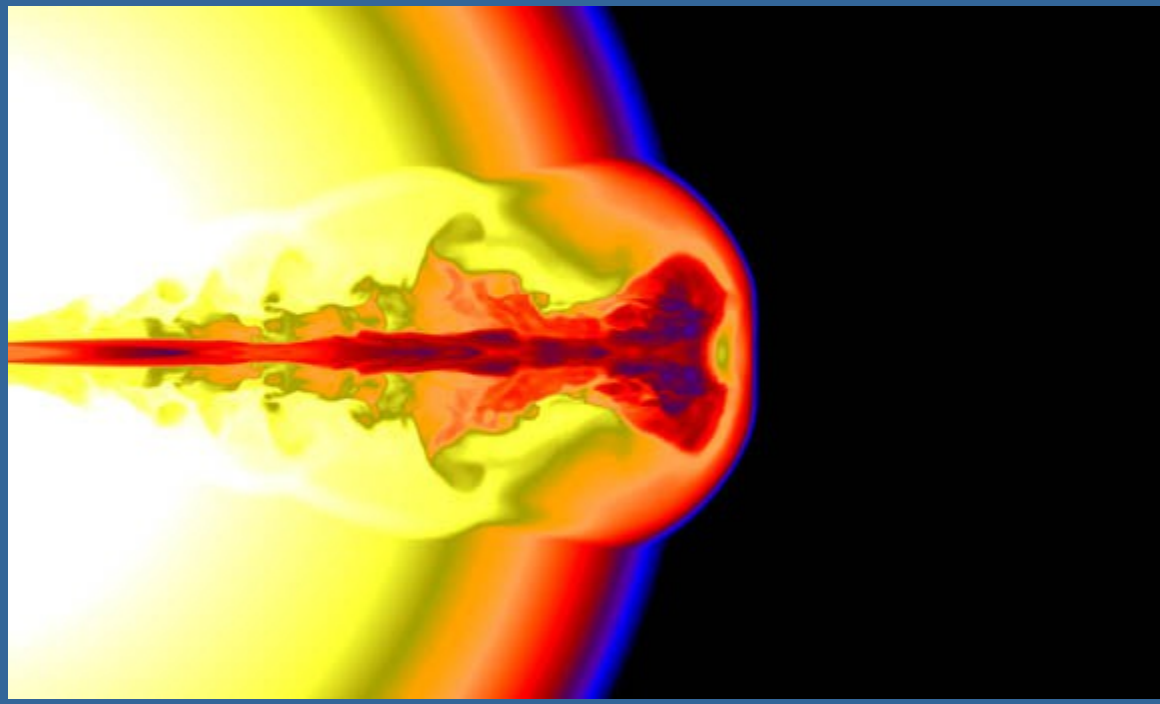

Actually there are two different phenomena:
Short & long
Count
140
120
100
80
60
40
20
0
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Observed Duration: Log(T90 [s])

# The long GRB paradigm:

Collapse of an evolved giant star (e.g. Wolf-Rayet - a bare carbon nuclear)

Formation of intermediate accretion disk which launches a jet

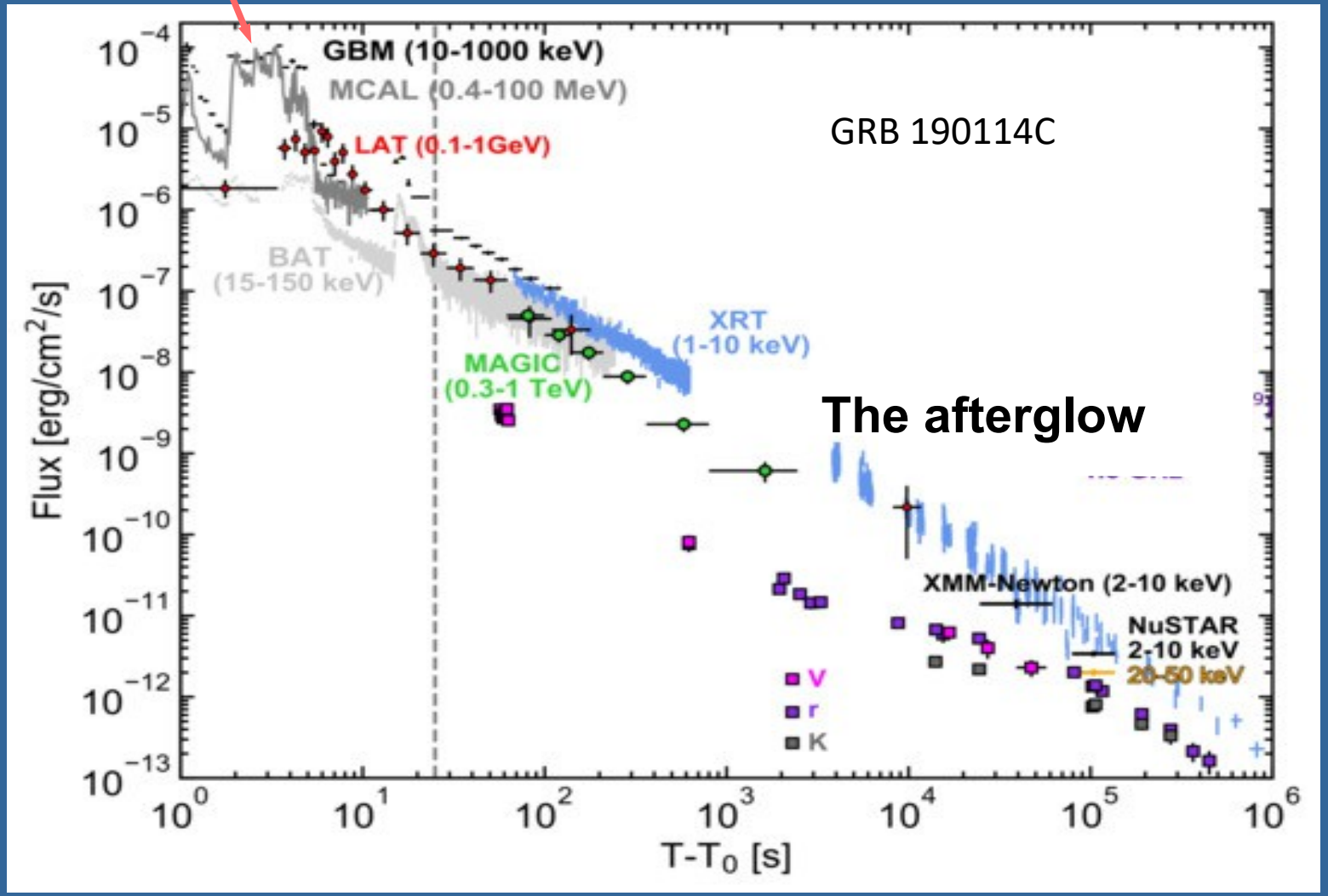
The jet breaks through the star and somehow radiates a beam towards the observer



# Two stages of a GRB

## GRB 190114C D.Miceli, L.Nava

**The prompt stage (GRB itself)**



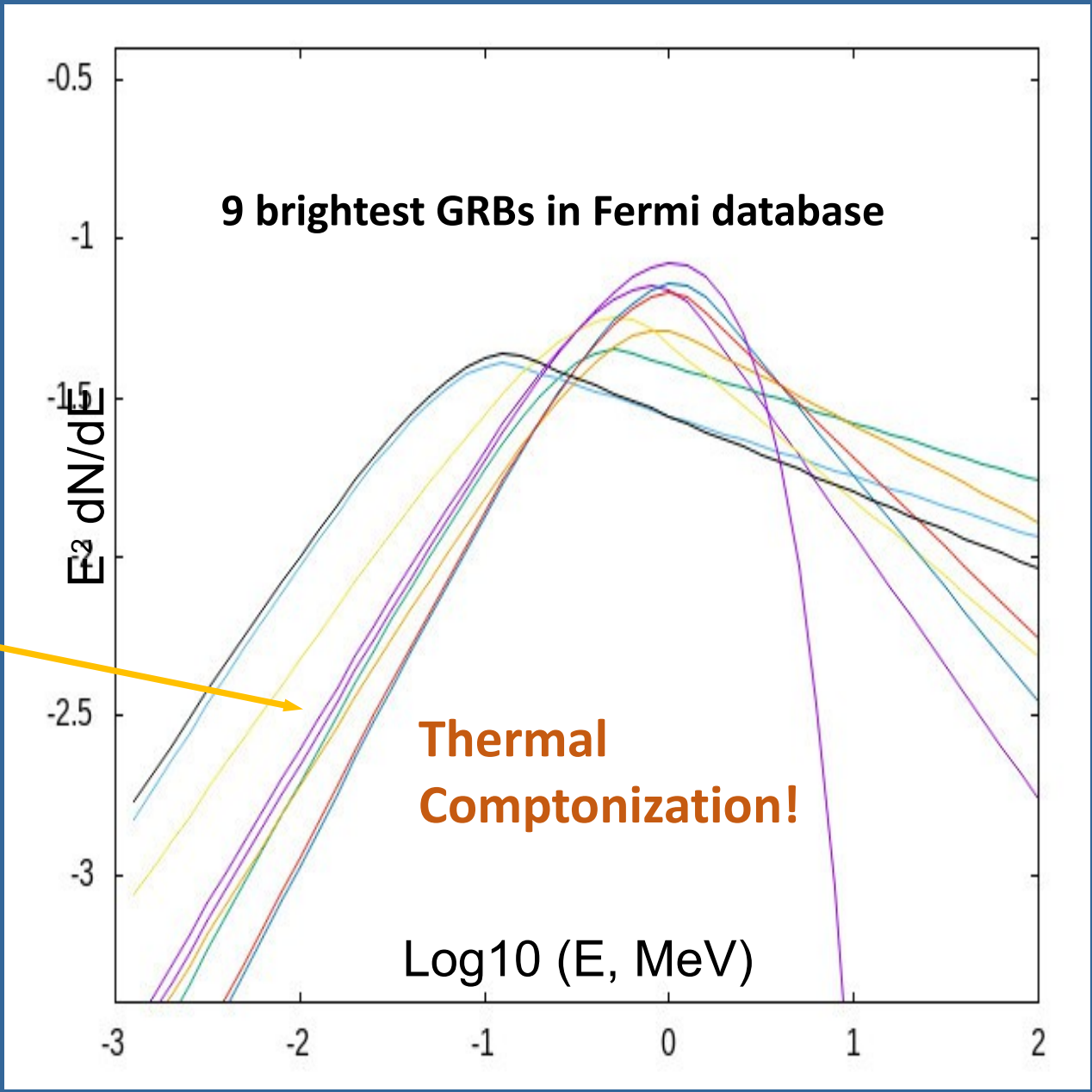
# The prompt stage, spectral energy distribution

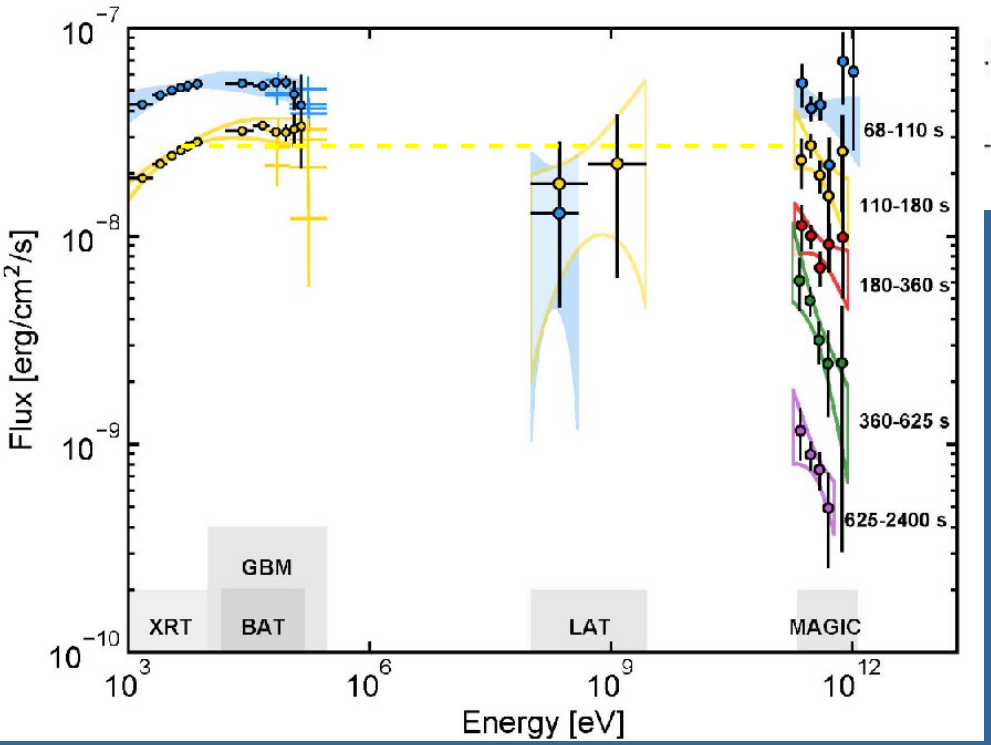
**Band Function:**

**Two power laws smoothly connected by an exponential**

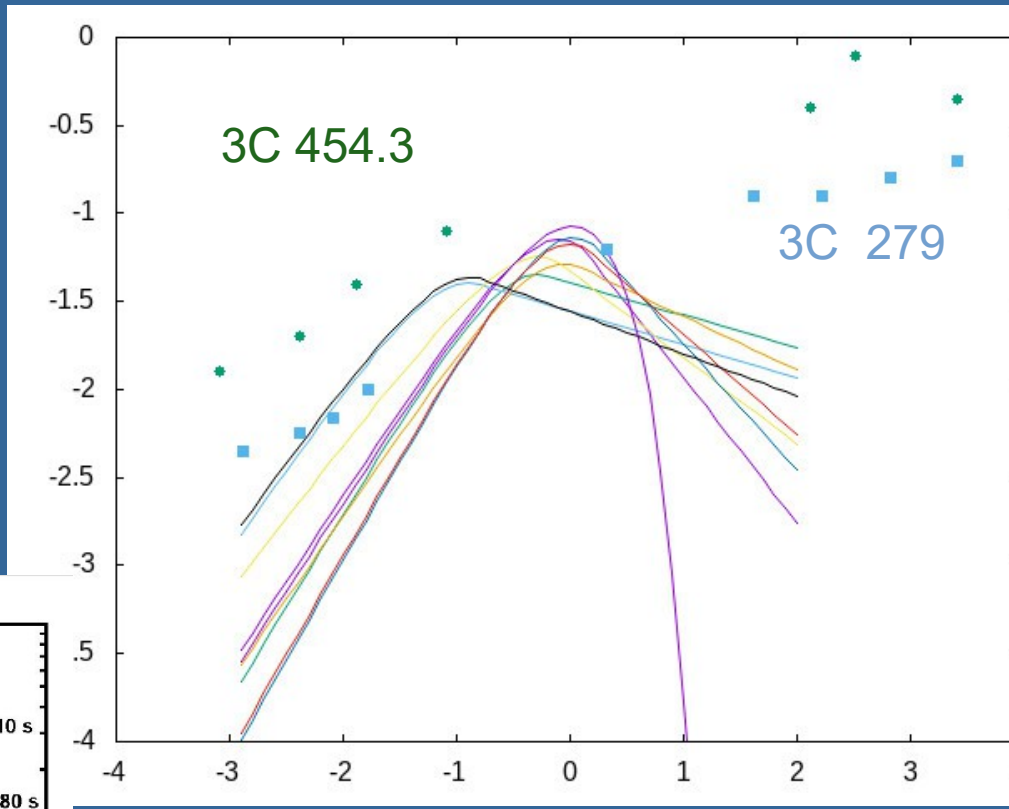
**Harder than the fast cooling spectrum**

**Harder than synchrotron from monochromatic electrons**






$E^2$ dN/dE




Log10 (E, MeV)

**GRB 190114C, afterglow**

**Mirzoyan, Wagner**

## Emission at the prompt stage:

A hint to an optically thick emitter (up to blackbody – Felix Ryde)

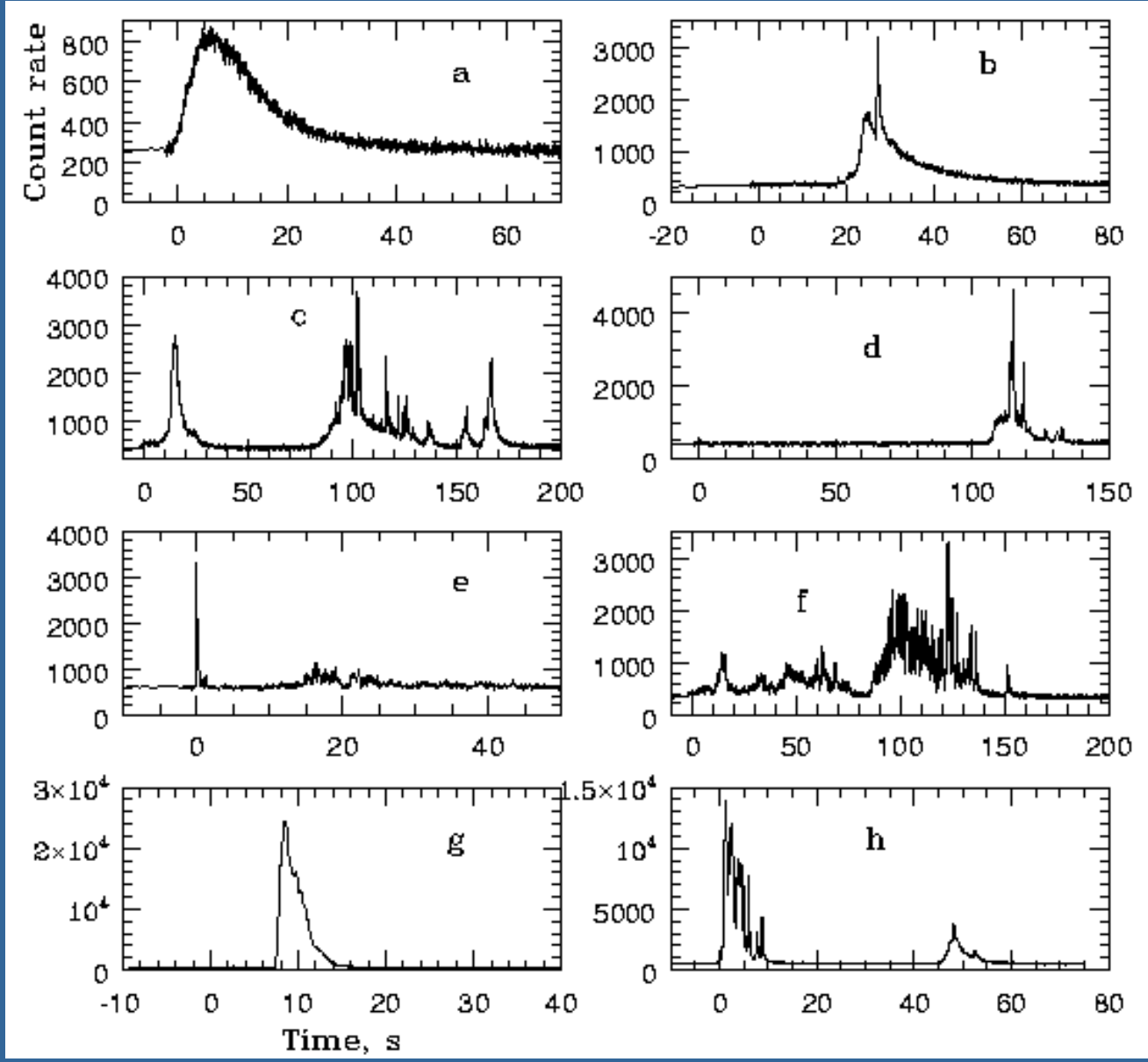
My guess: thermal Comptonization in equilibrium $e^+e^-$ plasma ($\tau$ ~ a few)

Lorentz factor ~ a few tens (not hundreds)

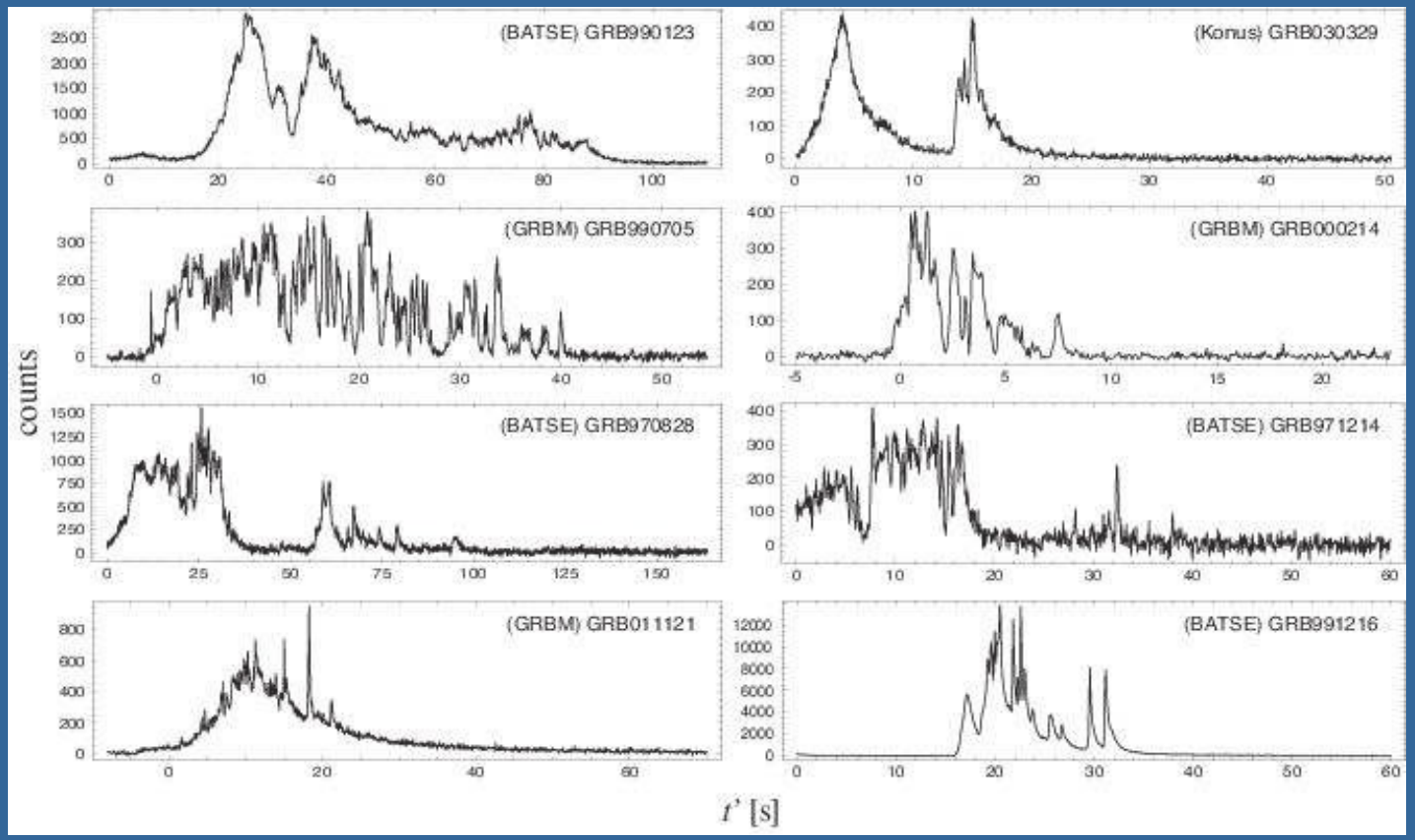
## The afterglow emission:

Optically thin medium + runaway acceleration of electrons & (possibly) protons (neutrinos from a GRB could come only from an afterglow)

B, d and g have a weak precursor which had triggered the detector

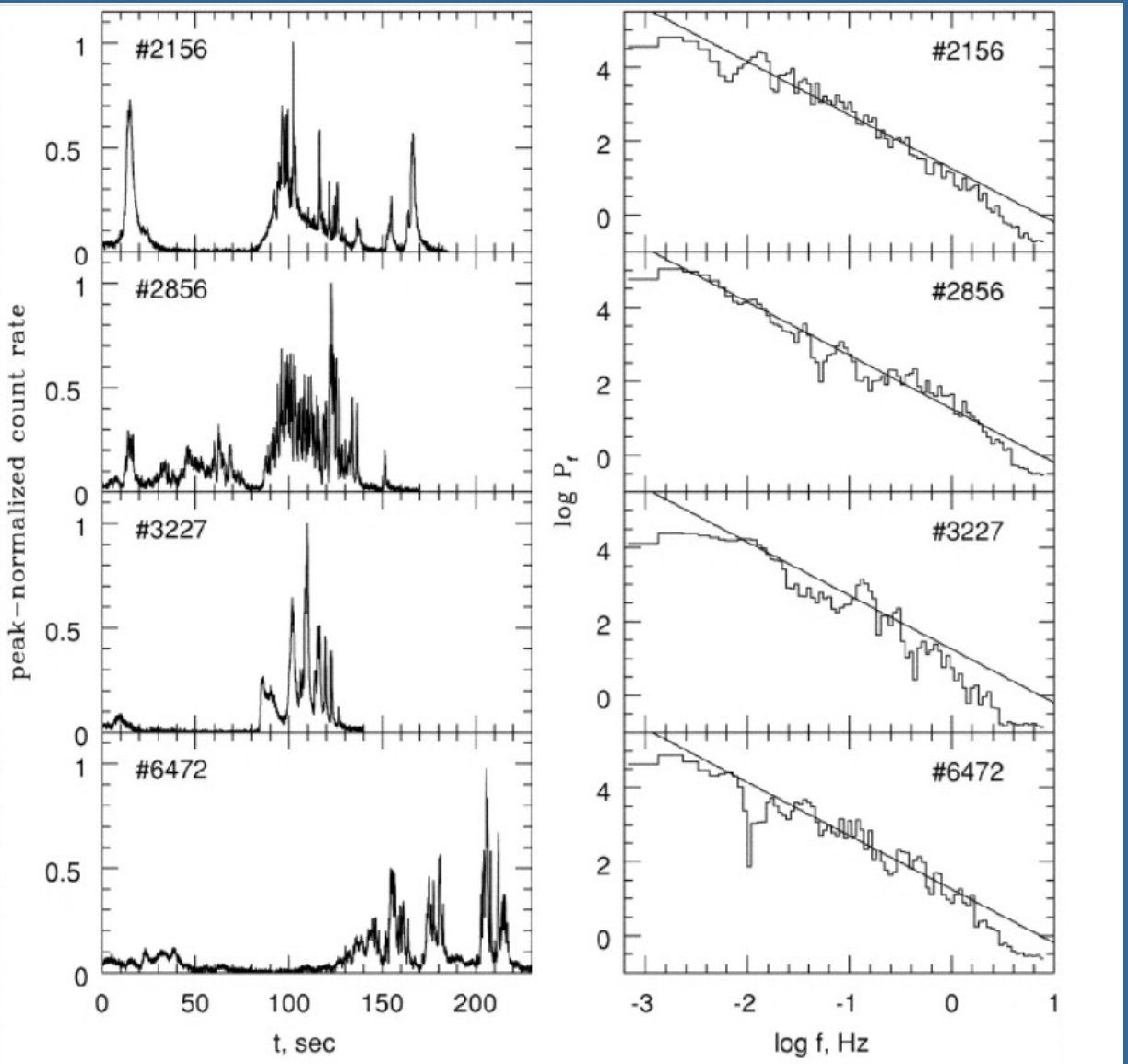


# Where this time variability comes from?



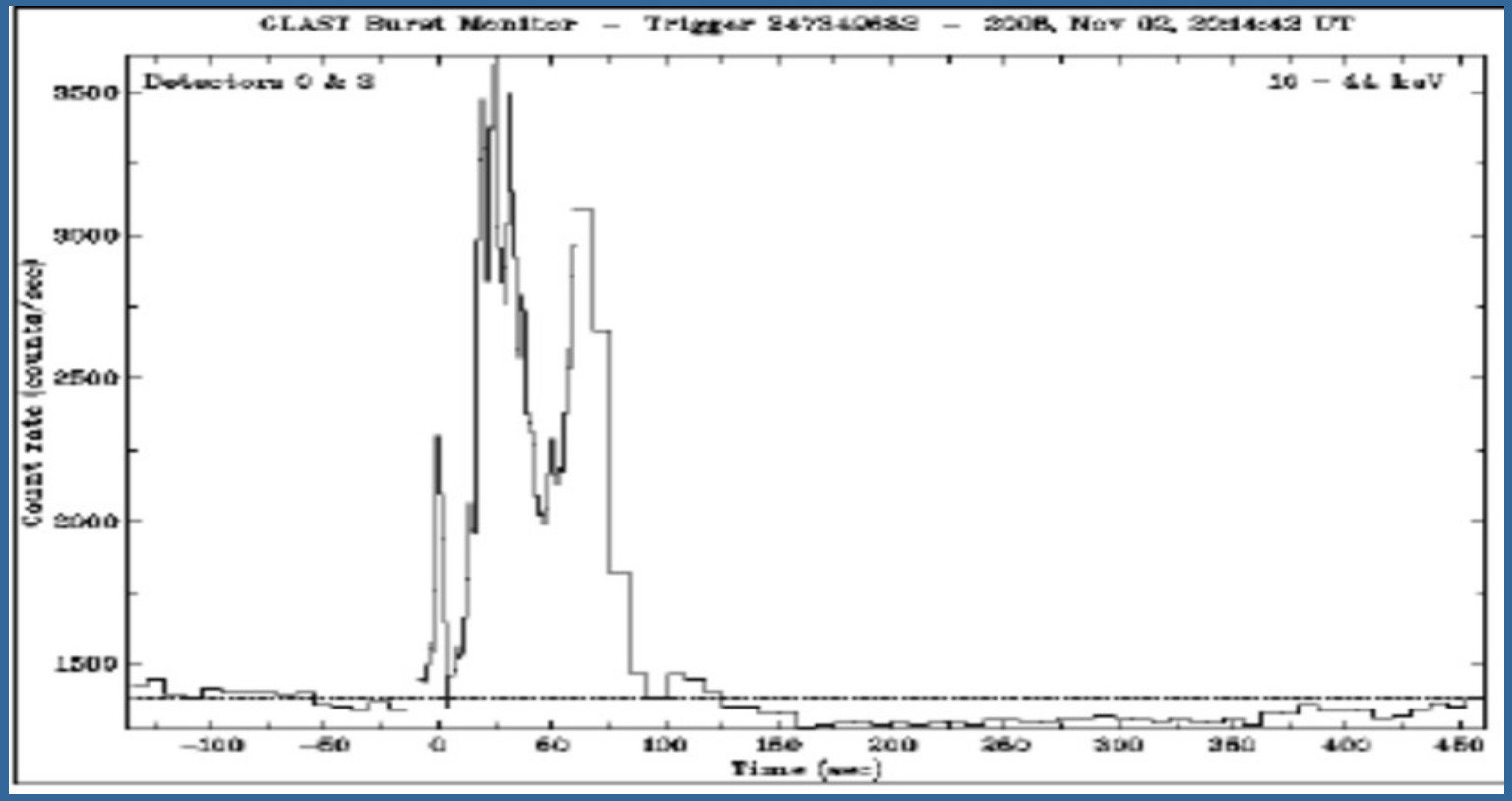

**There is no specific time scale!**

# Beloborodov, Stern & Svensson 2000




Power density
Fourier spectra

# Could it be magnetic reconnection?




Solar flares: magnetic reconnection certainly

**Conclusions from the time variability:**

**Some near-critical mechanism producing a striking diversity of light curves?**

**Looks like an instability in the jet.**

**MHD turbulence?**

## Apparently it all works at once:

- The central engine

- Internal shocks

- Magnetic reconnection

- External shock

- Synchrotron

- Comptonization (including quasithermal one)

- Pair loading and preacceleration of the external medium

Only the popular synchrotron-self Compton does not work

# 9 October 2022 .

## The strongest GRB in the history of observations

**Z = 0.151, 1.9 light years (this is nearby!)**

**The next one in Fermi catalog is 10 times weaker In energy fluence**

**The famous photons 18 and 250 GeV, as it seems, are not confirmed**

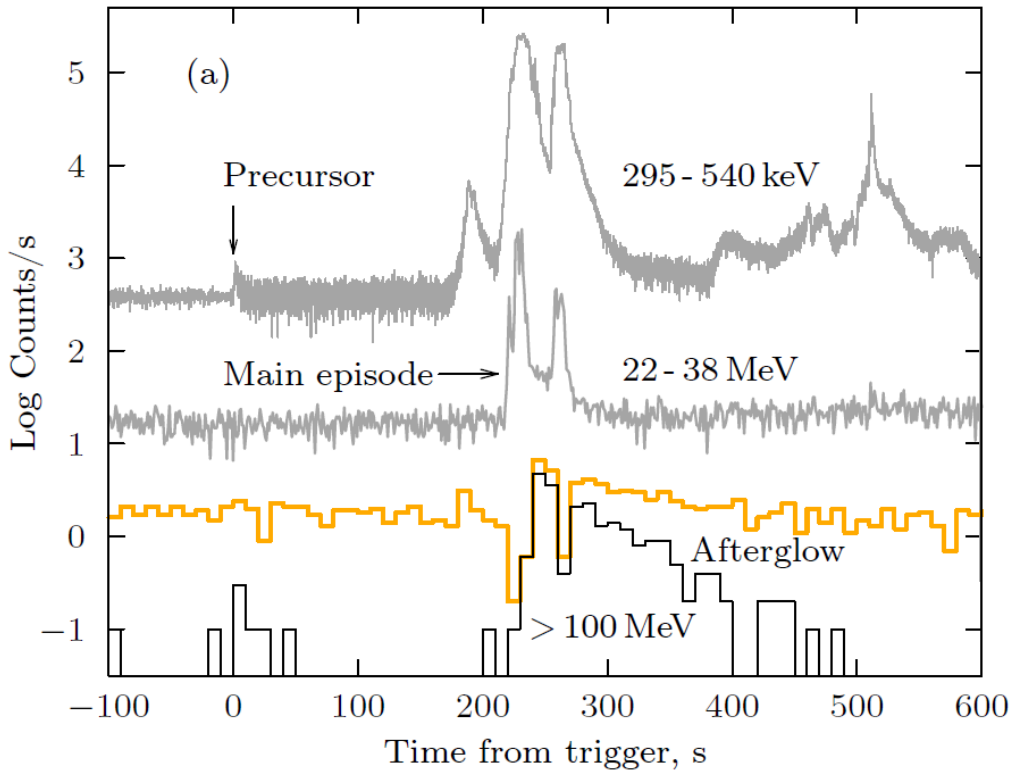
## B.Stern & I.Tkachev

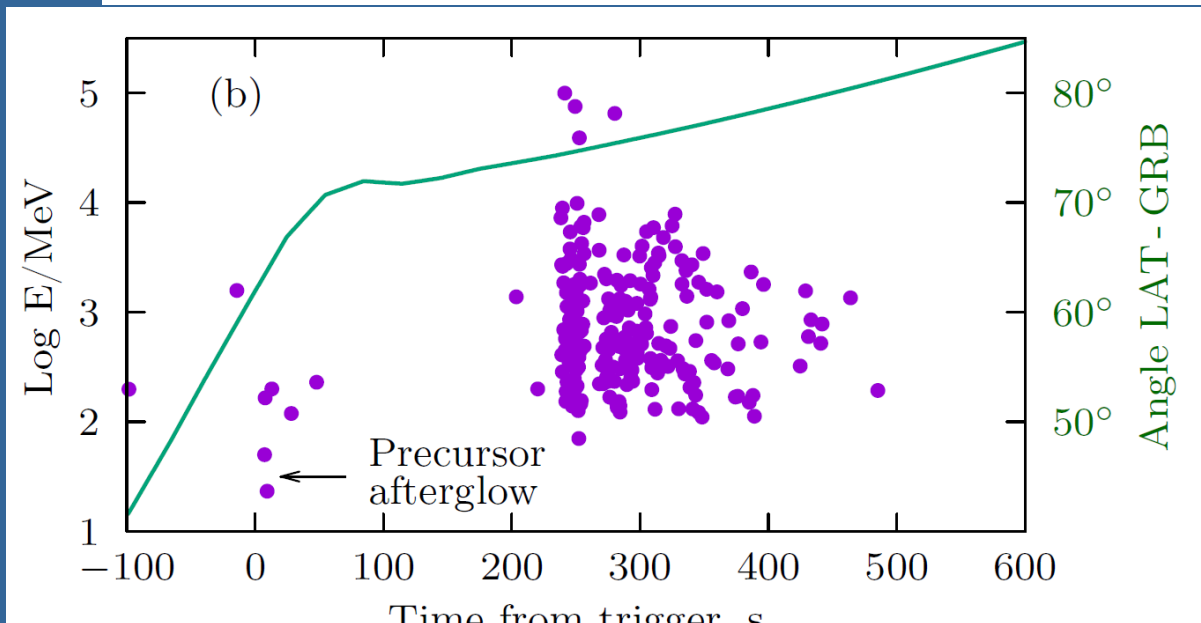
GRB 221099 and its two afterglows

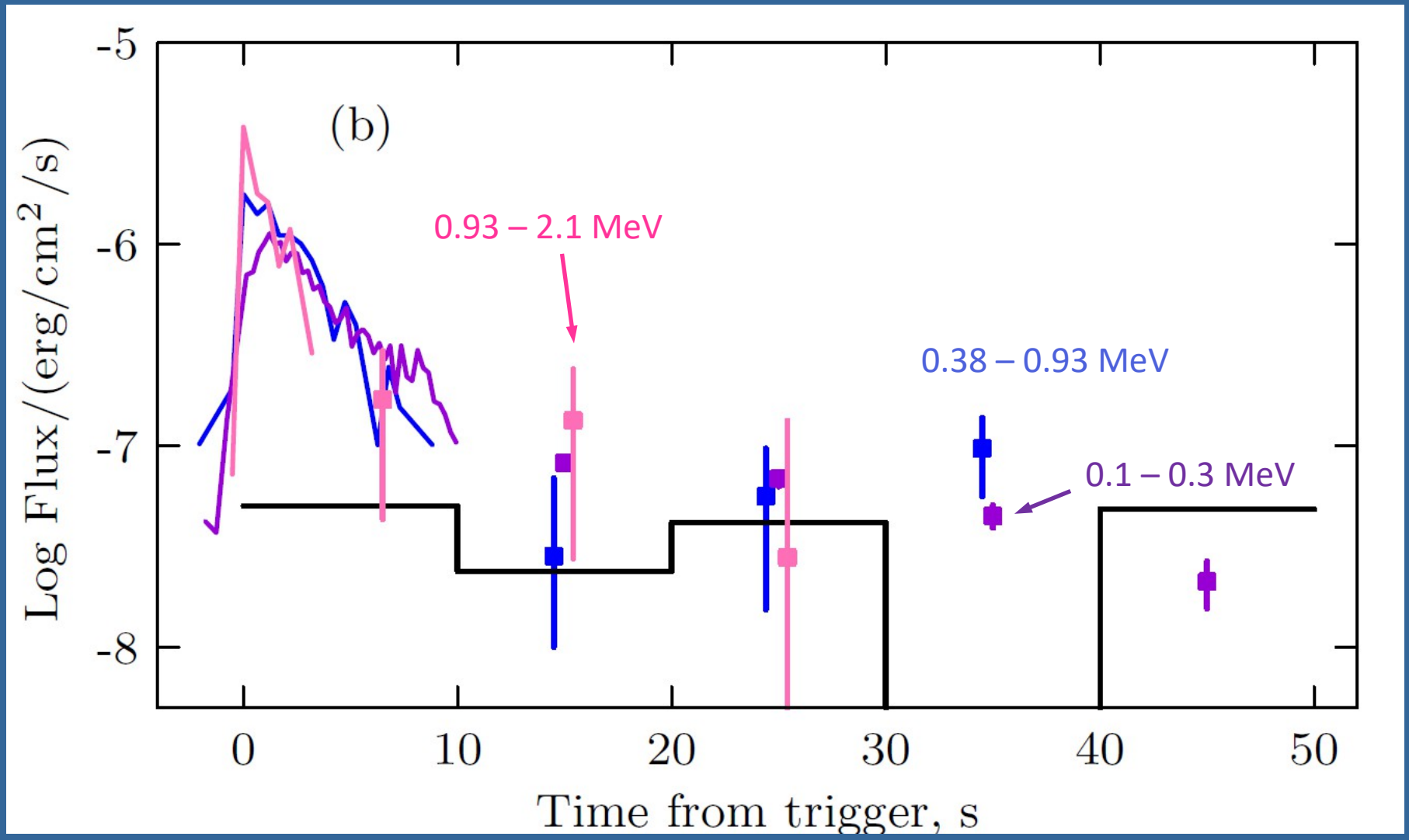
6 photons after the precursor

The background expectation 0.6

Significance = $10^{-4}$






**Consistent with a "flat" spectral energy distribution**

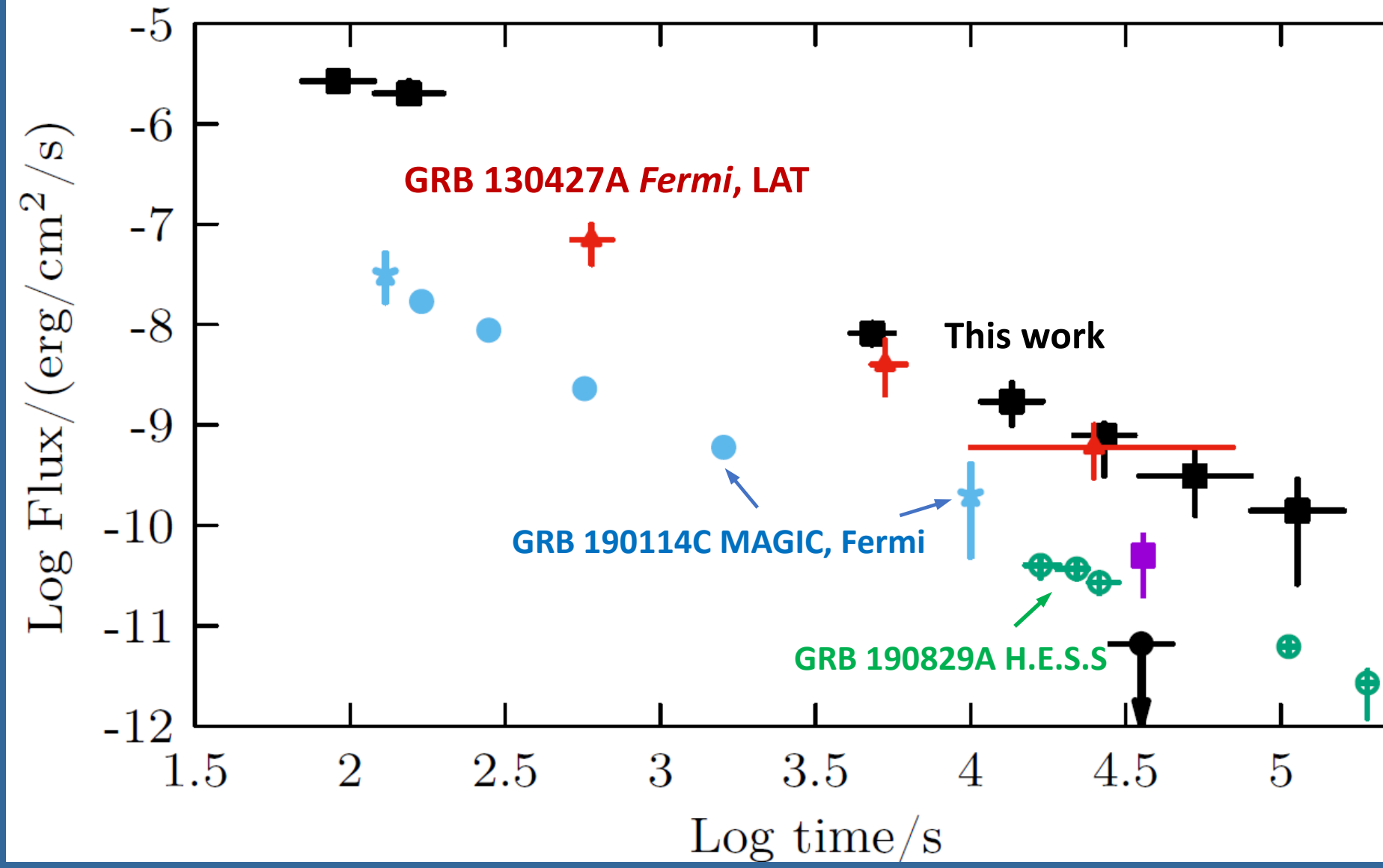
The emission after ~ 10 s has typical feature of GRB afterglow:

- Flat wide spectral energy distribution
- Smooth time behavior

If our interpretation is correct, there were two independent jets separated by 3 minutes.

This rules out precursor models associated with a single jet, e.g. photospheric emission

The prompt emission overlaps with the early afterglow


GRB 130427A *Fermi*, LAT
This work
GRB 190114C MAGIC, Fermi
GRB 190829A H.E.S.S
Log Flux/(erg/cm$^2$/s)
Log time/s
-5
-6
-7
-8
-9
-10
-11
-12
1.5
2
2.5
3
3.5
4
4.5
5

# Concluding remarks (general)

- The GRB business is in a deep stagnation: like search under a streetlight.

- Simplest models like the synchrotron – self-Compton emission or star wind environment are not realistic. Everything is much-much more complicated (pair loading, preacceleration of the external environment)

We need a massive MHD simulation together with nonlinear Monte-Carlo of high energy interacting particles.

**GRB 221009 A: a really new fact is afterglow of the precursor, Nevertheless strong GRBs can be used to study the intergalactic environment**