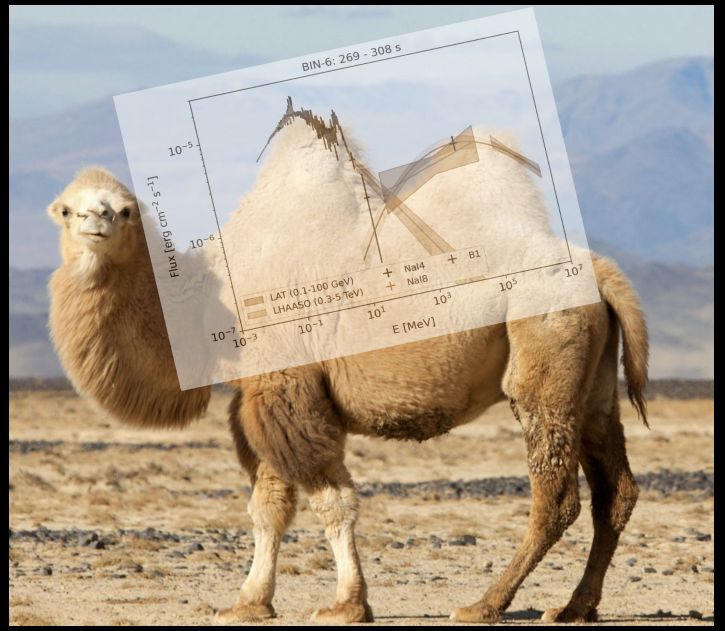
Observation of a second spectral component in GRB 221009A

- **Biswajit Banerjee**

Based on:

- ***BB***, *Macera, .. Oganesyan et al. 2024; arXiv: 2405.15855*
- *Macera,* ***BB,*** *Mei, Oganesyan* ***.. et al. in preparation***

Gamma-2024, Milan



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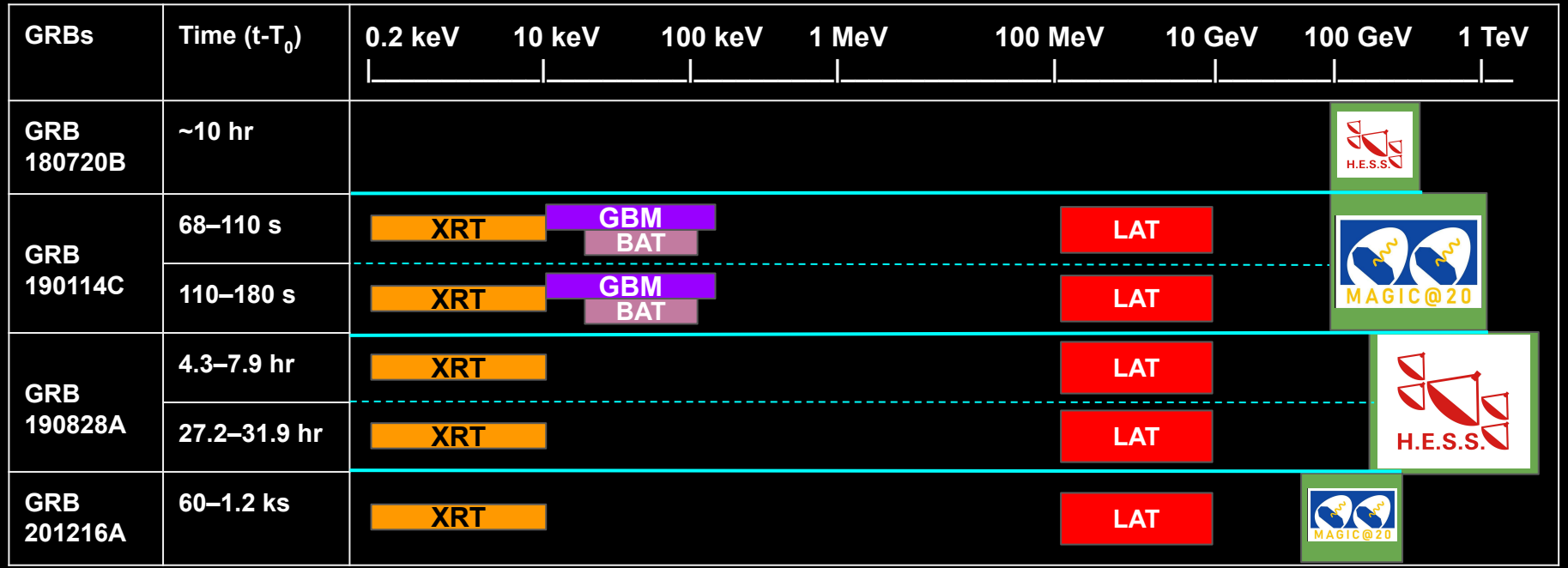
TeV GRBs

L. Nava's plenary talk



XRT | BAT | GBM | LAT | IACTs

MAGIC Collaboration:
Nature v. 575, p. 455–458 (2019) and
Nature v. 575, p. 459–463 (2019)
H.E.S.S. collaboration, Nature, 2019
H.E.S.S. collaboration, Science, 2021
MAGIC Collaboration, MNRAS, 2024

TeV GRBs

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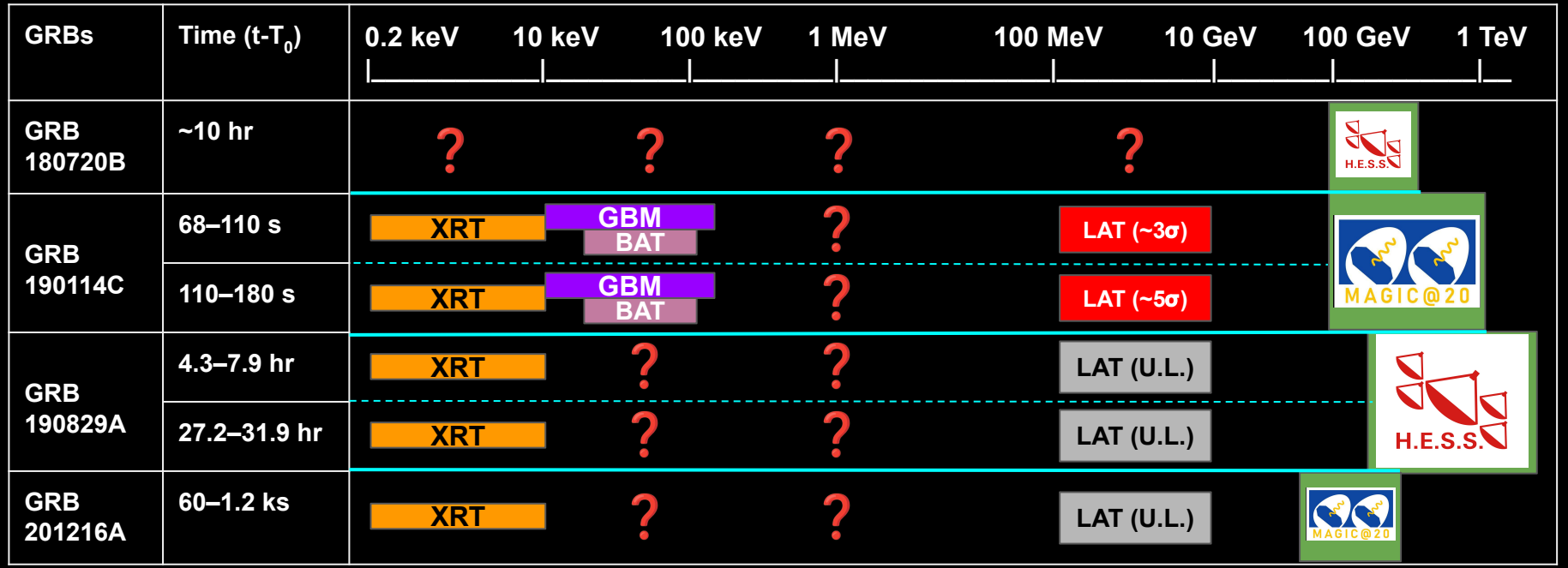

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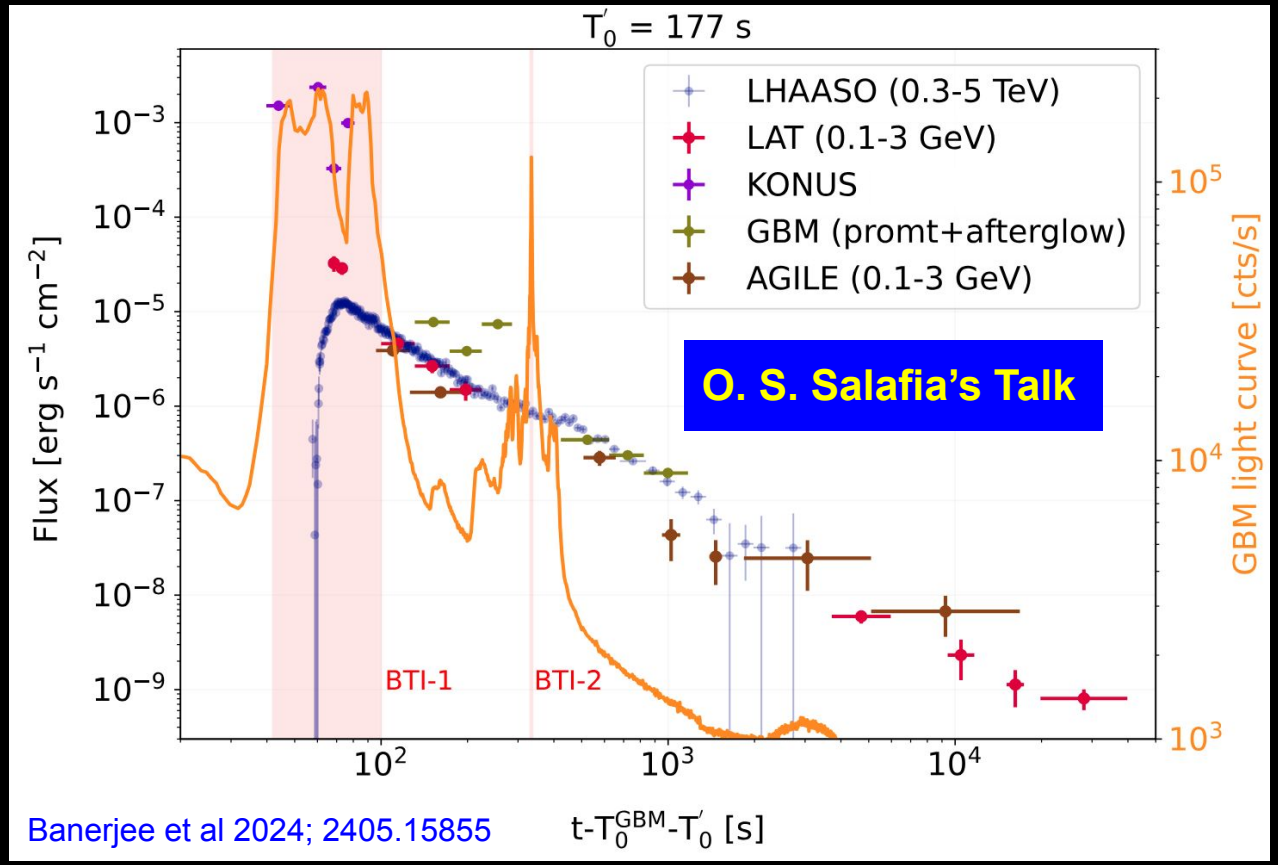
H.E.S.S. collaboration, Nature, 2019
H.E.S.S. collaboration, Science, 2021
MAGIC Collaboration, MNRAS, 2024

GRB 221009A; BOAT (Brightest Of All Time*)



z~ 0.15

LHAASO Collaboration, Science (2023)

Tavani et al 2023 ApJL 956 L23, 2023

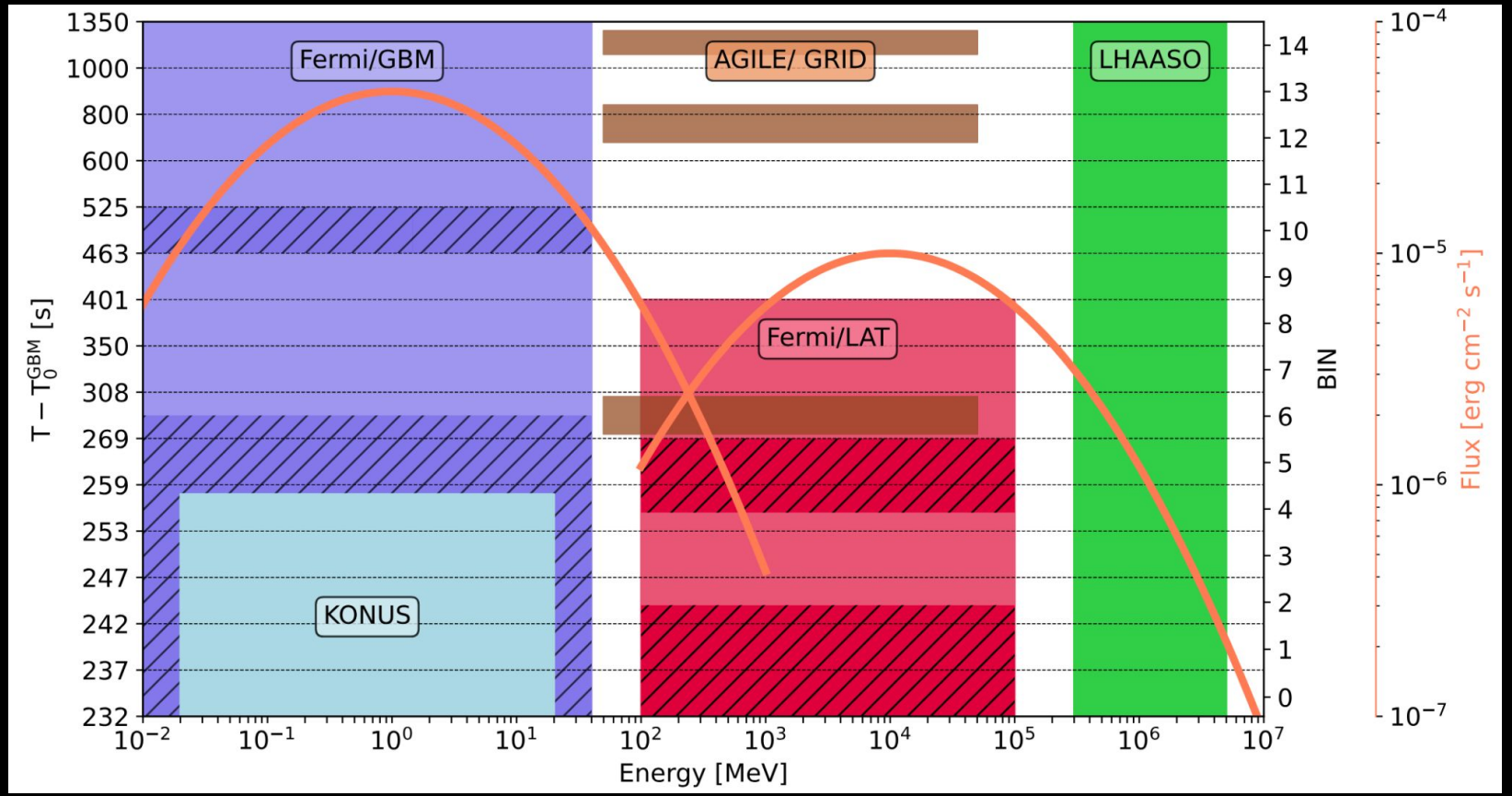
Bissaldi et al 2023: https://pos.sissa.it/444/847/

Frederiks et al 2023 ApJL, 949, L7 (2023)

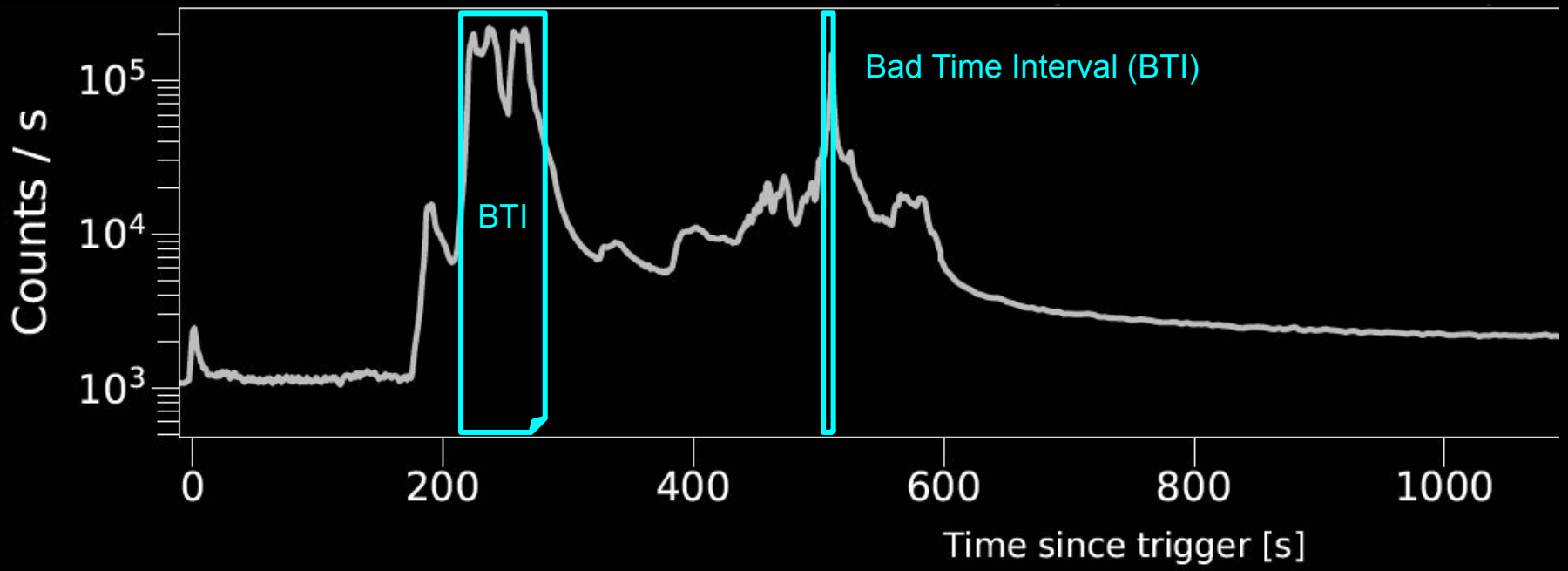
Lesage et al 2023, ApJL 952 L42

*Burns et al 2023, ApJL 946 L31

GRB 221009A; MWL data

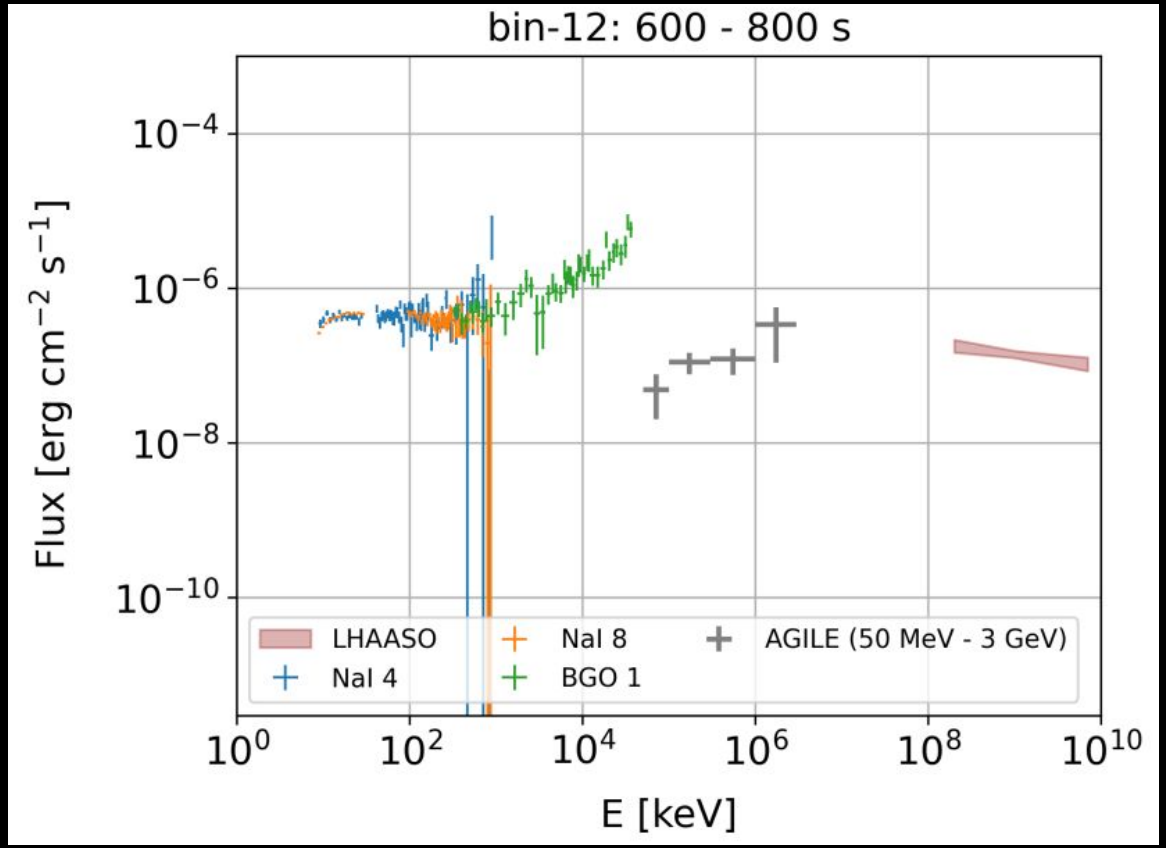


GRB 221009A: GBM light curve



Lesage et al 2023, ApJL 952 L42
Burns et al 2023 ApJL 946 L31
Ravasio et al 2023, Science

MWL spectrum; 600-800 s (after $T_{0,\,GBM}$)



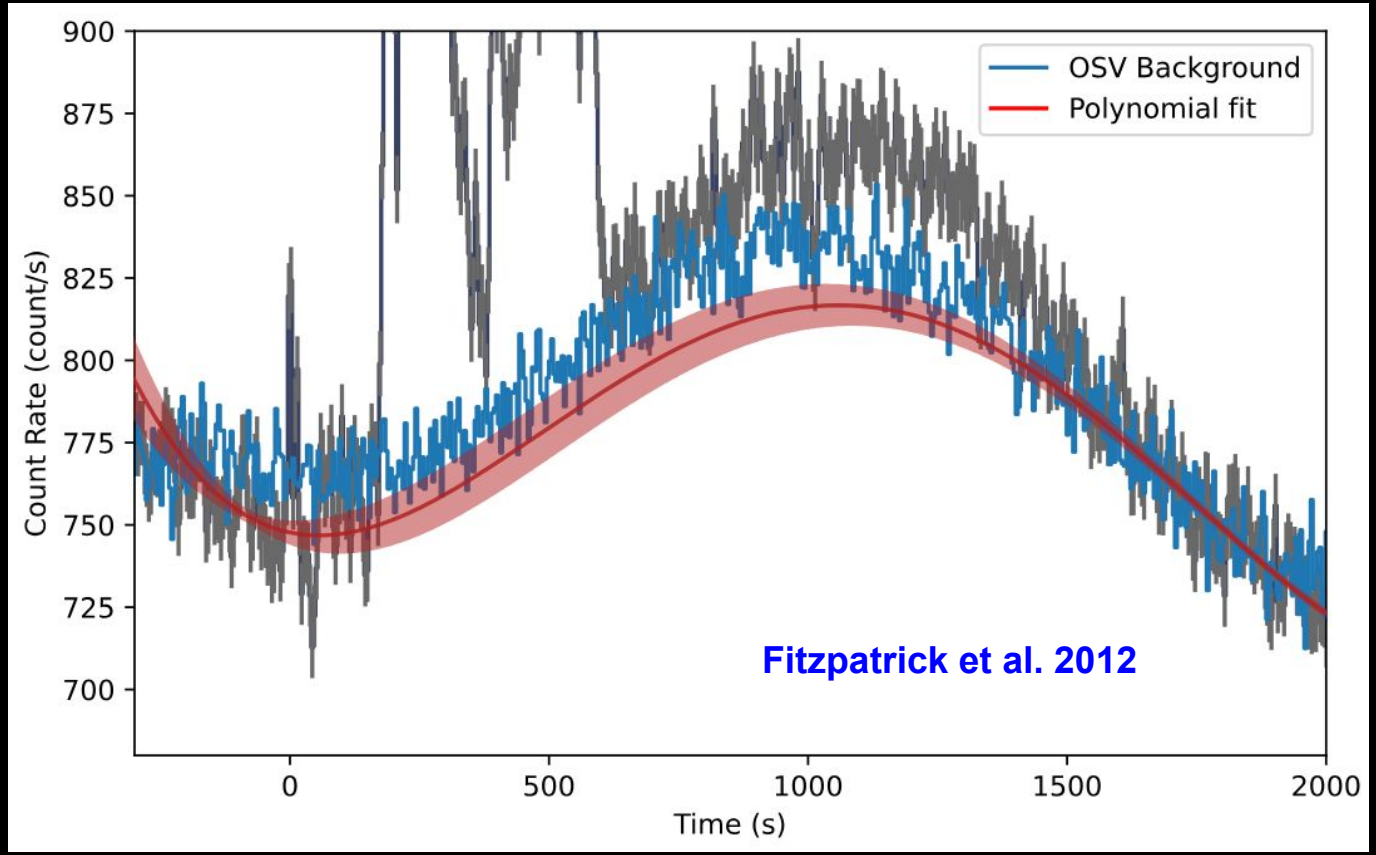
LHAASO Collaboration, Science (2023)

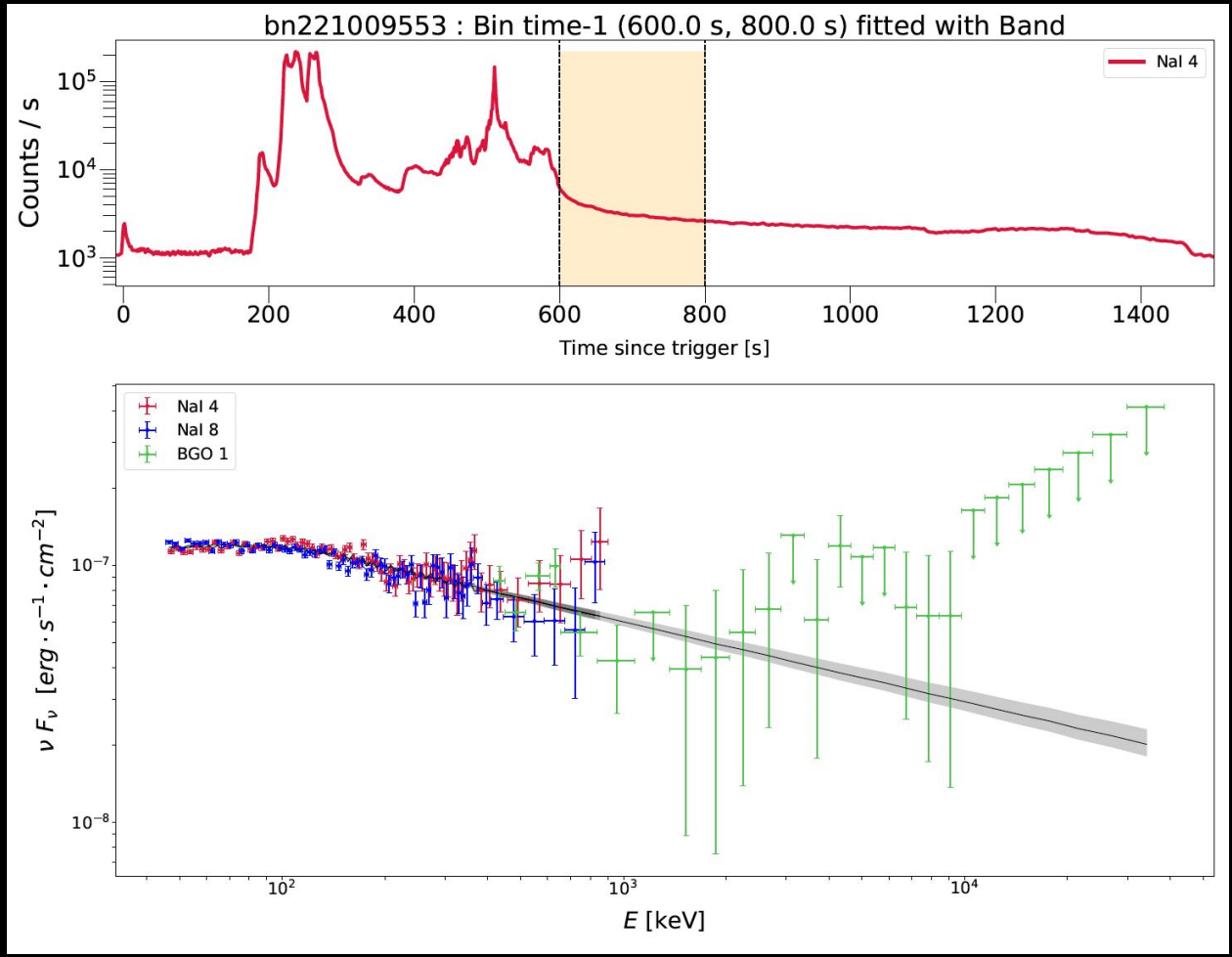
Tavani et al 2023 ApJL 956 L23, 2023

Lesage et al 2023, ApJL 952 L42

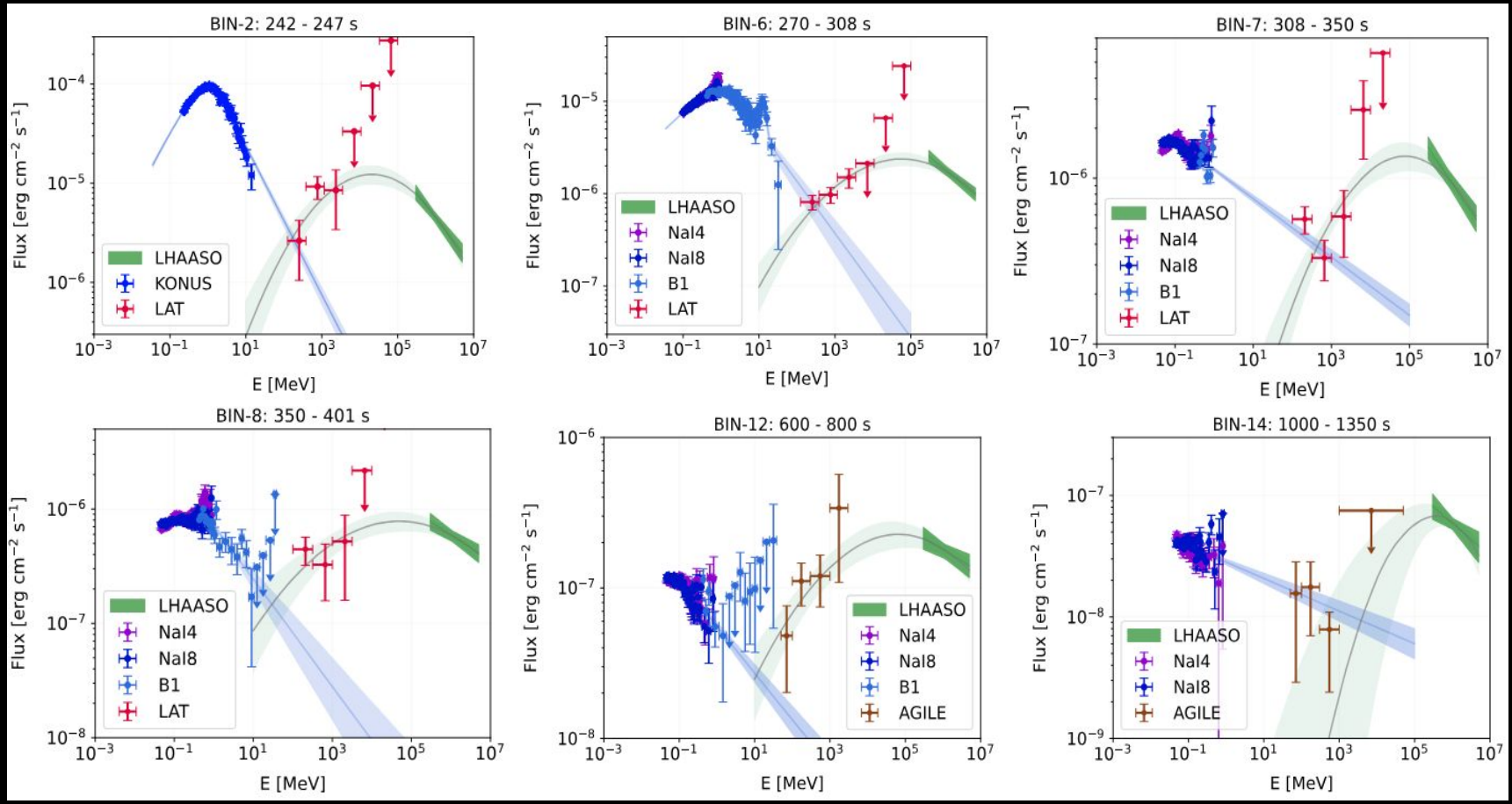
Burns et al 2023 ApJL 946 L31

Non standard GBM analysis:



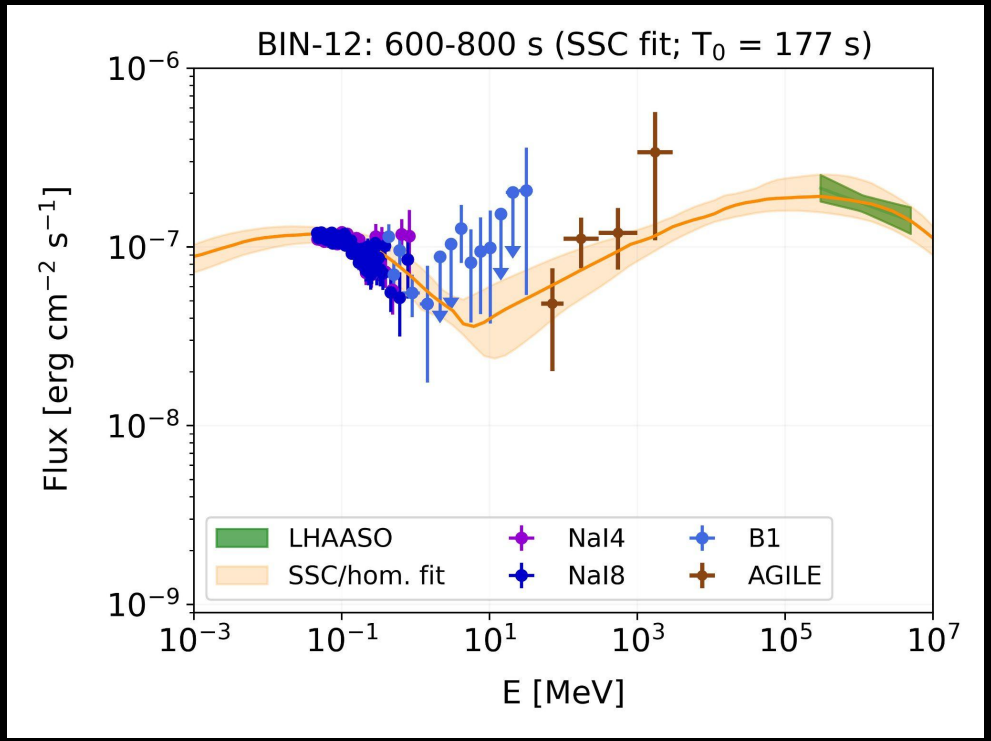

bn221009553 : Bin time-1 (600.0 s, 800.0 s) fitted with Band
Nal 4
Counts / s
10^5
10^4
10^3
0
200
400
600
800
1000
1200
1400
Time since trigger [s]
Nal 4
Nal 8
BGO 1
νF_ν [$erg \cdot s^{-1} \cdot cm^{-2}$]
10^{-7}
10^{-8}
10^2
10^3
10^4
E [keV]

Time resolved spectra of GRB 221009A



Homogeneous medium

SSC: LeHaMoC; Stathopoulos et al 2023



Miceli and Nava 2022 (+references therein)

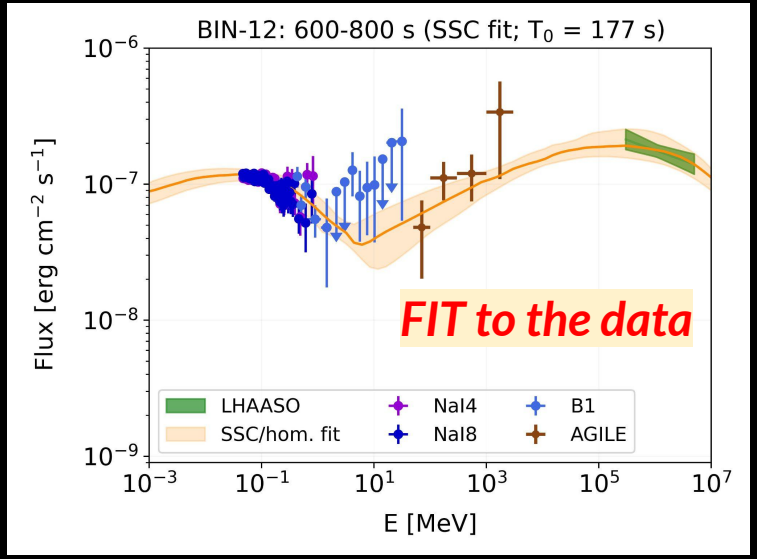
Parameters	Priors	Posteriors
$\log_{10}$(B) [G]	(-5; 2)	$-1.3^{+0.8}_{-0.4}$
$\log_{10}(\gamma_m)$	(0; 5)	$1.5^{+0.9}_{-1.0}$
$\log_{10}(\gamma_{max})$	(4; 8)	$6.3^{0.1}_{-0.2}$
$\log_{10}$l$_e$	(-7; -1)	$-2.8^{+0.6}_{-0.4}$
p	(2; 3)	$2.6^{+0.1}_{-0.4}$
$\log_{10}$D	(1; 4)	$2.5^{+0.1}_{-0.3}$

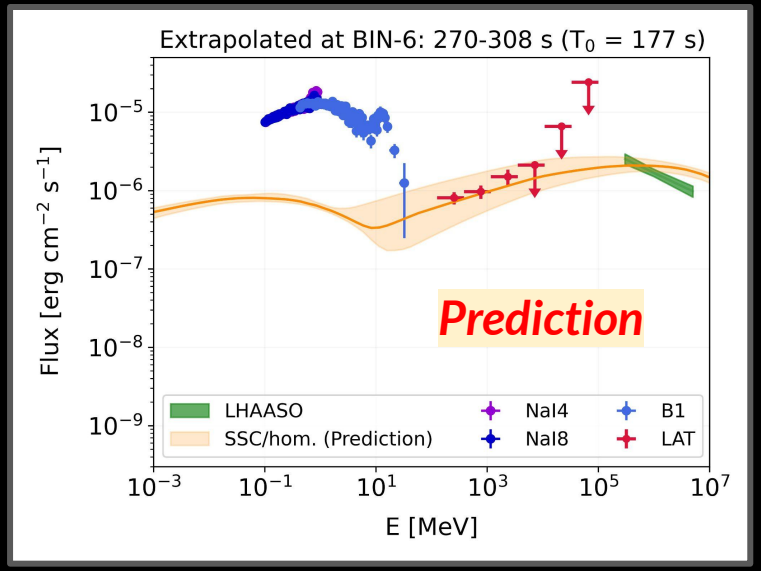
Extract microphysical parameters from bin 12

Homogeneous medium

Miceli and Nava 2022 (+references therein)

SSC: LeHaMoC
Stathopoulos et al 2023





Extract microphysical parameters from bin 12

Homogeneous medium

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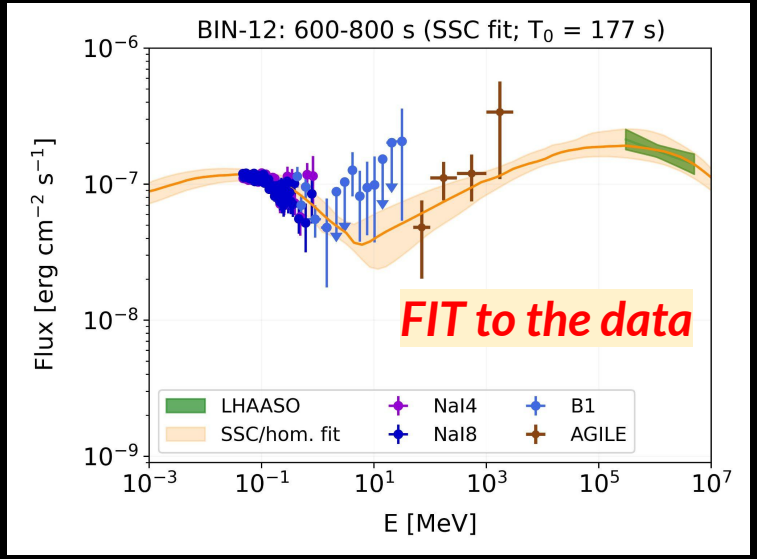
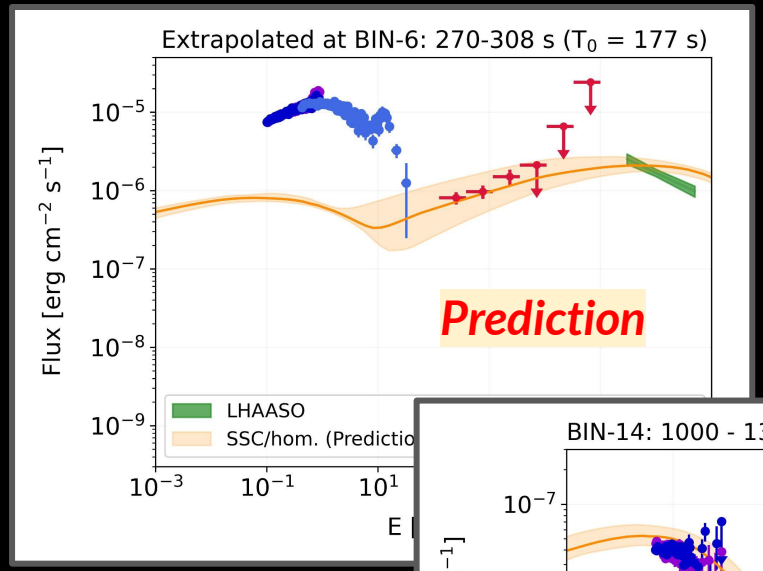
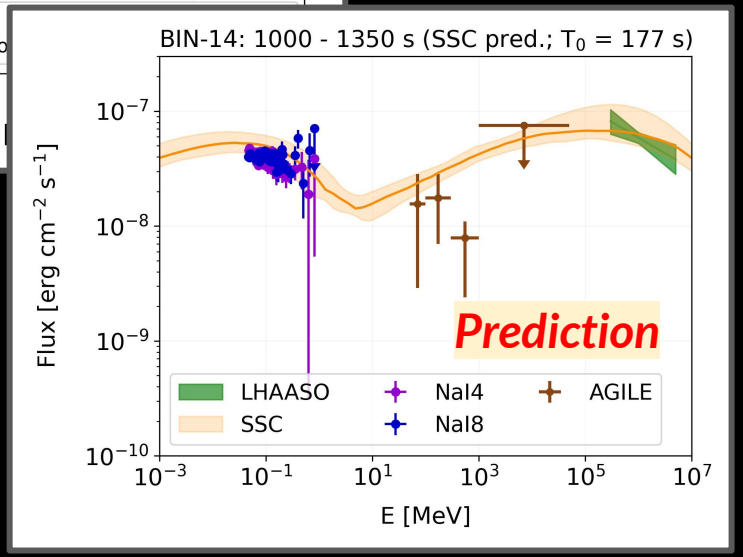


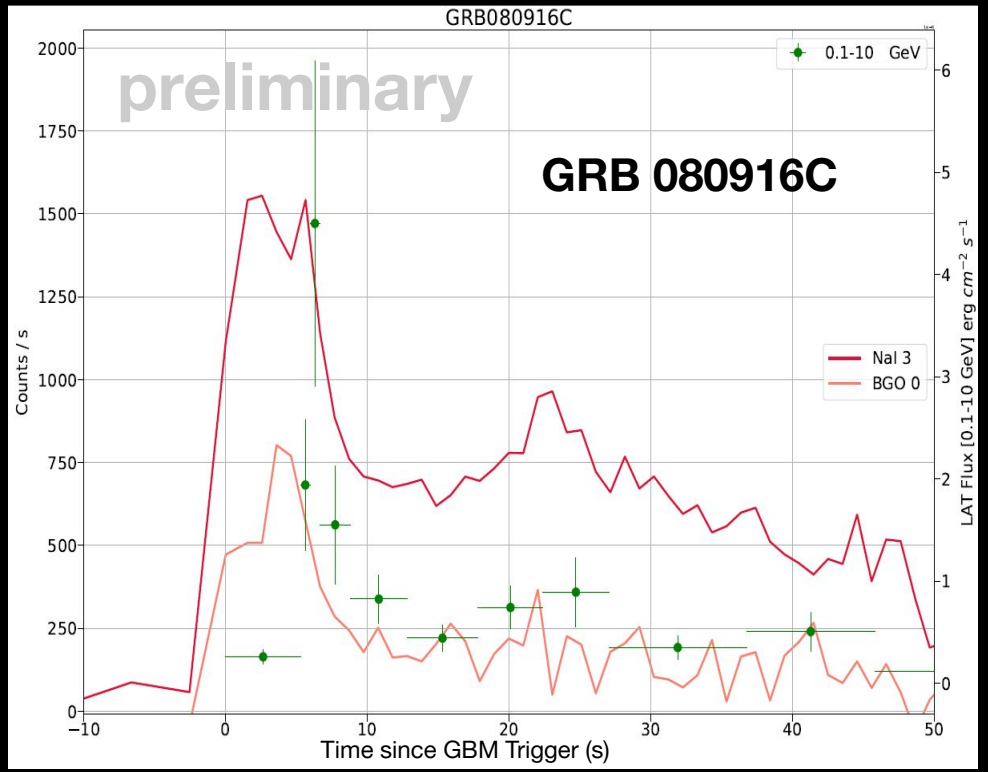




Extract microphysical parameters from bin 12

Nature of the early GeV emission

Macera, BB et al, in preparation



- For some GRBs early GeV emission follows variability of prompt
  [Zhang et al. 2011]
- Early Afterglow or Prompt origin?
  Ghisellini et al. 2009, Kumar & Barniol Duran, 2009
  Maxham et al. 2011
- What is the contribution of the keV-MeV prompt?
- Prompt second component?

For a complete review see: **Nava, 2018** and the references therein

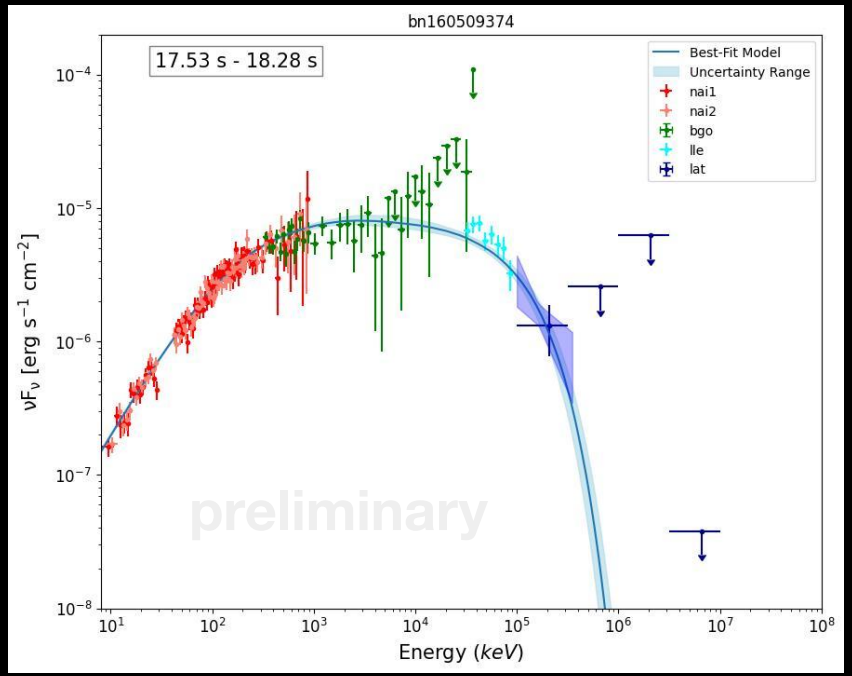
Results of the time-resolved spectral analysis

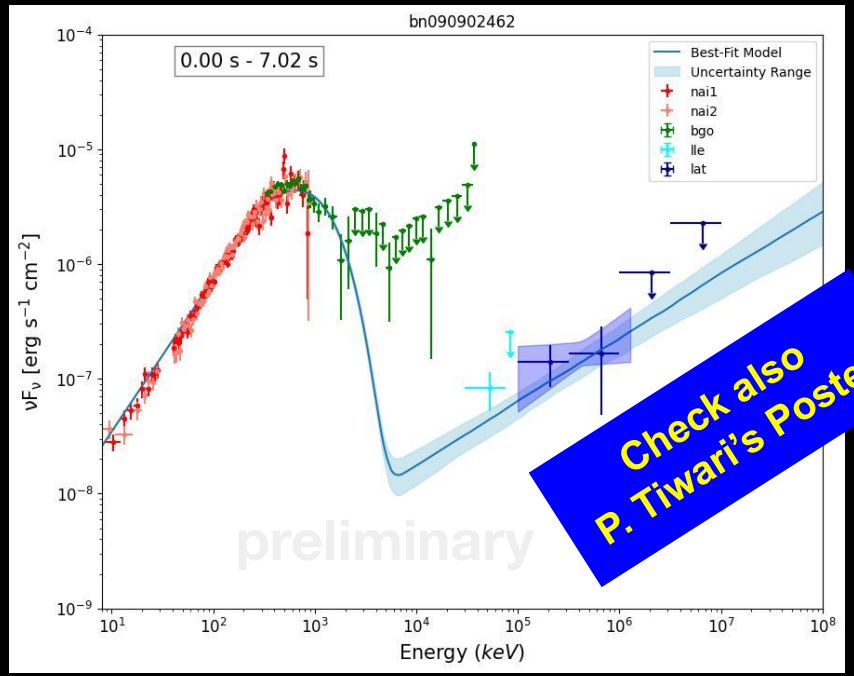
Sample divided in two groups

1 High-Energy emission dominated by synchrotron

2 High-Energy emission dominated by power law

See also Ravasio et al 2023



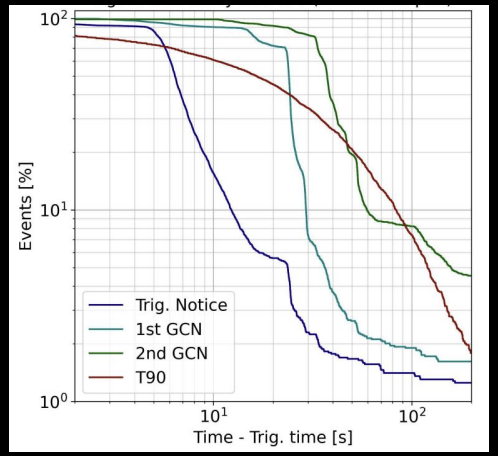


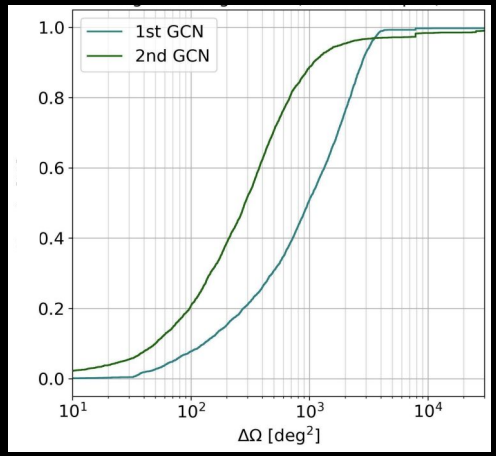
Observation proposal to MAGIC

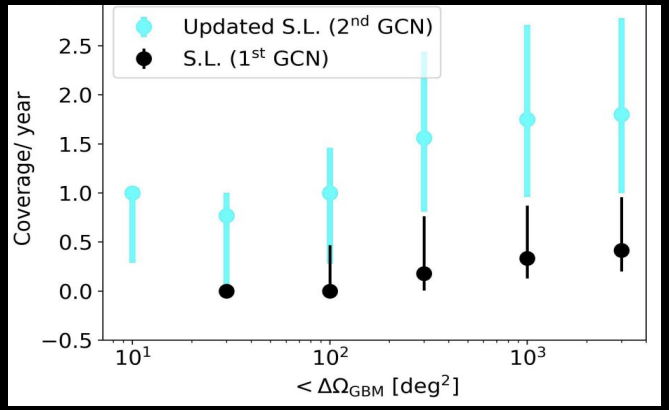
Catch me if you can- Hunt for the early TeV emission with MAGIC and Fermi GBM

Abstract

The prompt or early emission of gamma-ray bursts in the VHE regime remains largely unexplored due to challenges, such as short GRB durations and delays between triggers and notices. This study proposes an innovative approach: rapidly following Fermi Gamma-ray Burst Monitor (GBM) triggers to scan the sky-localization with a short exposure of 10 seconds. In addition, consider the follow-up GCN notice to obtain improved sky-localization. Anticipate about 30 follow-ups per year with the duty cycle of MAGIC as 10 percent, simulations indicate a coverage rate of about 0.1 - 0.8 GRB per year following the first Gamma-ray Coordinates Network (GCN) circular, increasing to about 1.0 - 2.8 GRB coverages per year with improved sky-localization from the second GCN circular.







Principal investigator

Banerjee, Biswajit

institute: Gran Sasso Science Institute

Principal investigator (Theory)

Oganesyan, Gor

institute: GSSI, Italy

Backup responsible

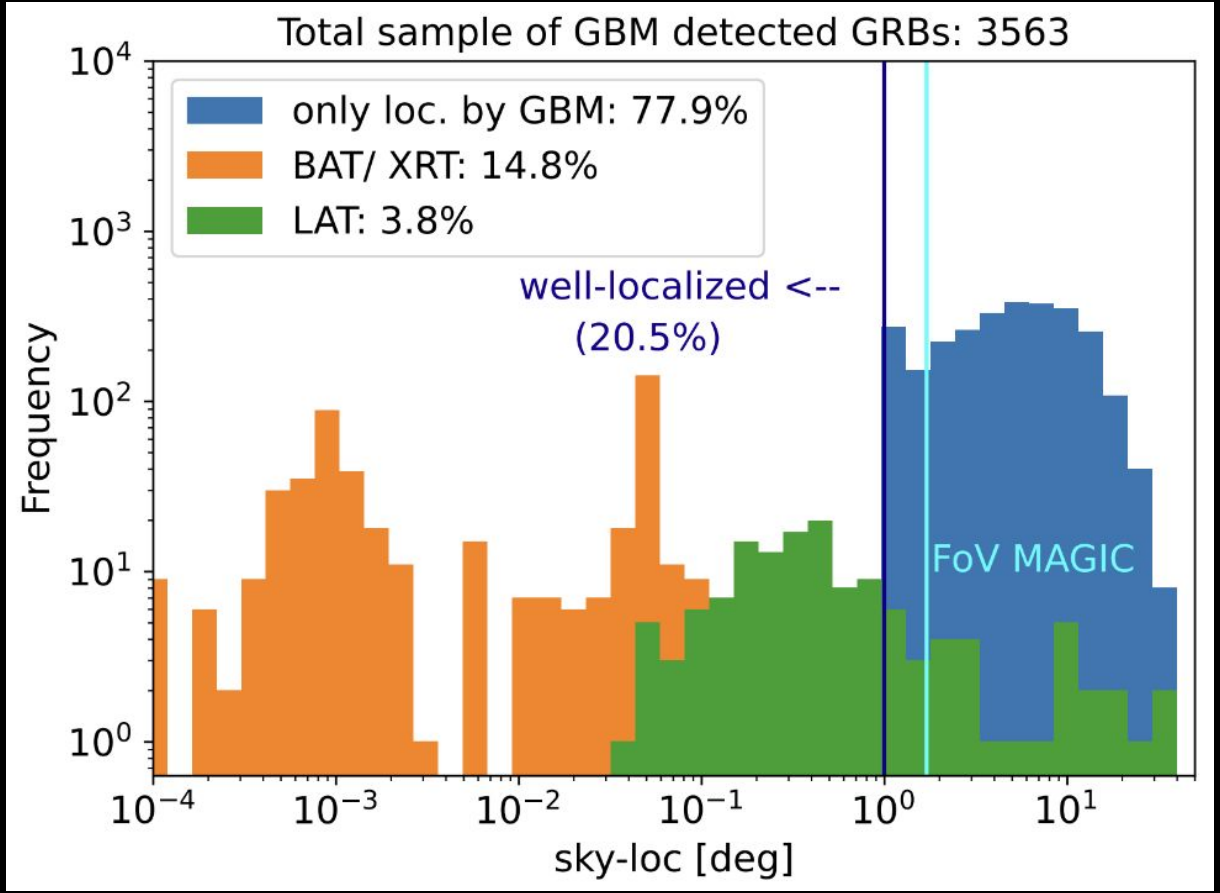
Stamerra, Antonio

institute: INAF, Roma

Summary:

- GRB 221009A is a special case with clear double hump.
- The available MWL data makes it possible to put constraints on the micro-physical parameters.
- GeV detections (LAT and AGILE) were crucial to establish the presence of the second component.
- The nature of the previous MWL data with GBM/LAT is important
- Observational proposals are in place to detect early VHE emission in the future.

More!


Total sample of GBM detected GRBs: 3563
only loc. by GBM: 77.9%
BAT/ XRT: 14.8%
LAT: 3.8%
well-localized <--
(20.5%)
FoV MAGIC
Frequency
sky-loc [deg]

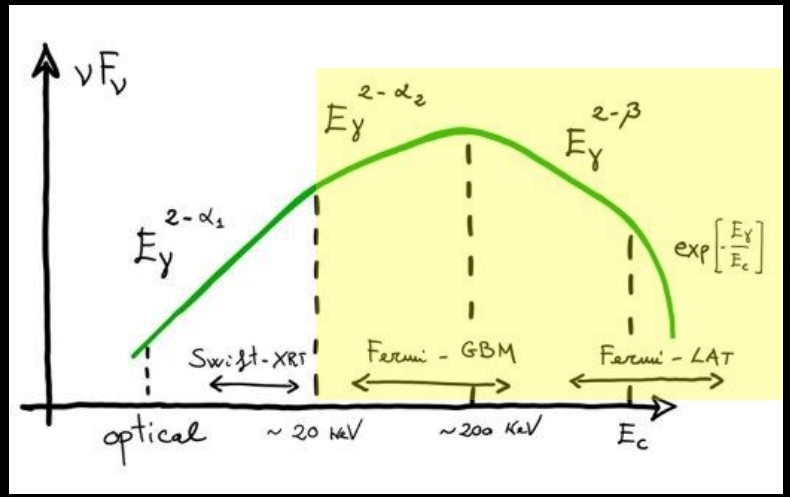
Early GeV emission and physics of prompt

- Extend energy band to Fermi-LAT energy range

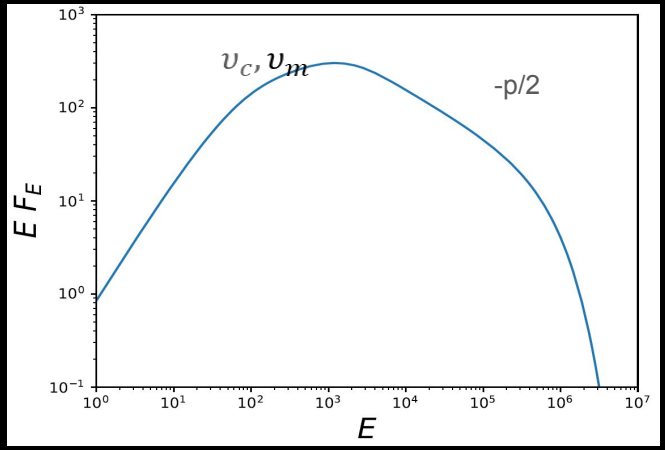
  → <u>total energy range covered: 8 keV - 10 GeV</u>

- Use a physical model for the prompt emission

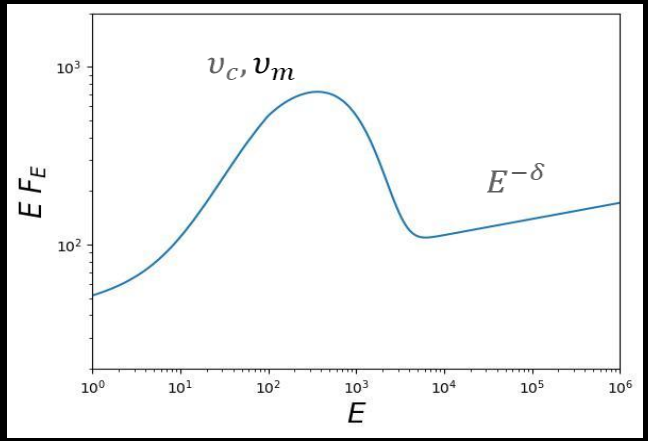
  → <u>adopt physical models based on synchrotron</u>



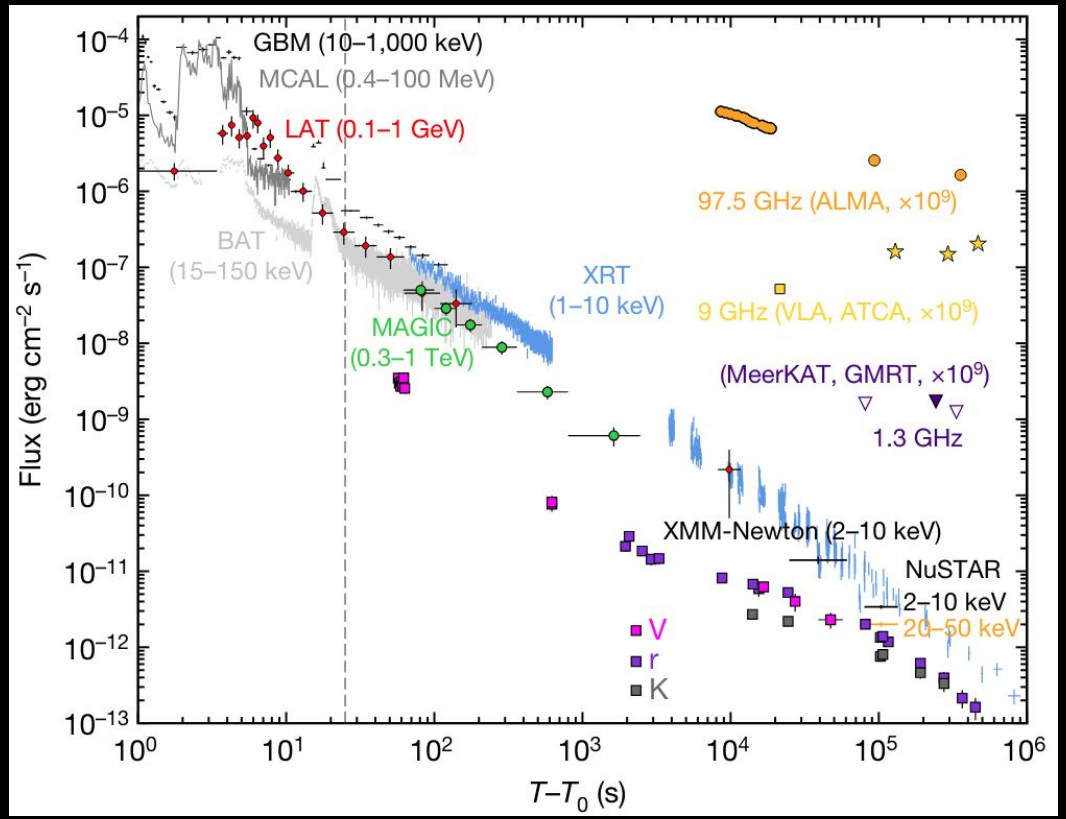
Synchrotron*HE cutoff



Synchrotron + Power Law



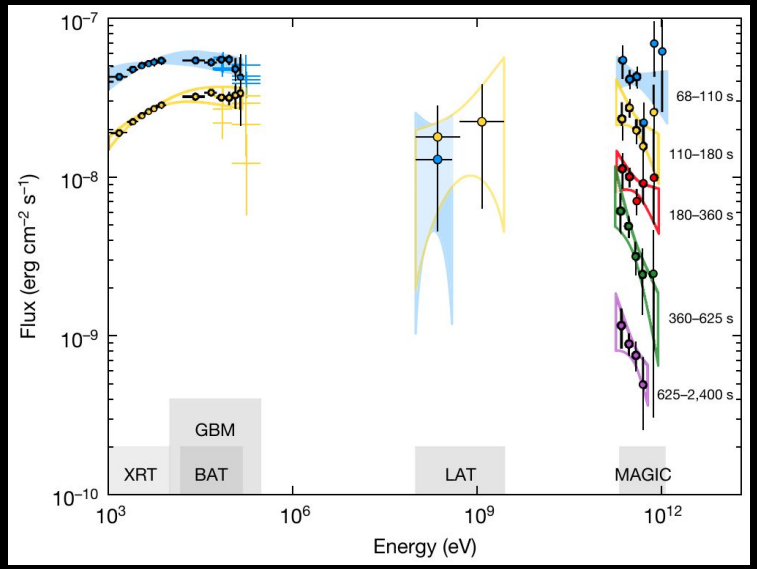
Why is it more informative?
GRB 190114C



MAGIC Collaboration:

Nature v. 575, p. 455–458 (2019) and
Nature v. 575, p. 459–463 (2019)

z~ 0.42



Sample selection

Macera, BB et al, in preparation

- At least three significant temporal bins (>5 σ detection) simultaneous with Fermi-GBM
- GRBs with and without redshift up to year 2023
- At least 20 photons within 10° of region of interest around the GRB location
- GBM + LLE (when possible) + LAT

Sample 1

Time resolved spectral analysis of 14 GRBs, 80 spectra

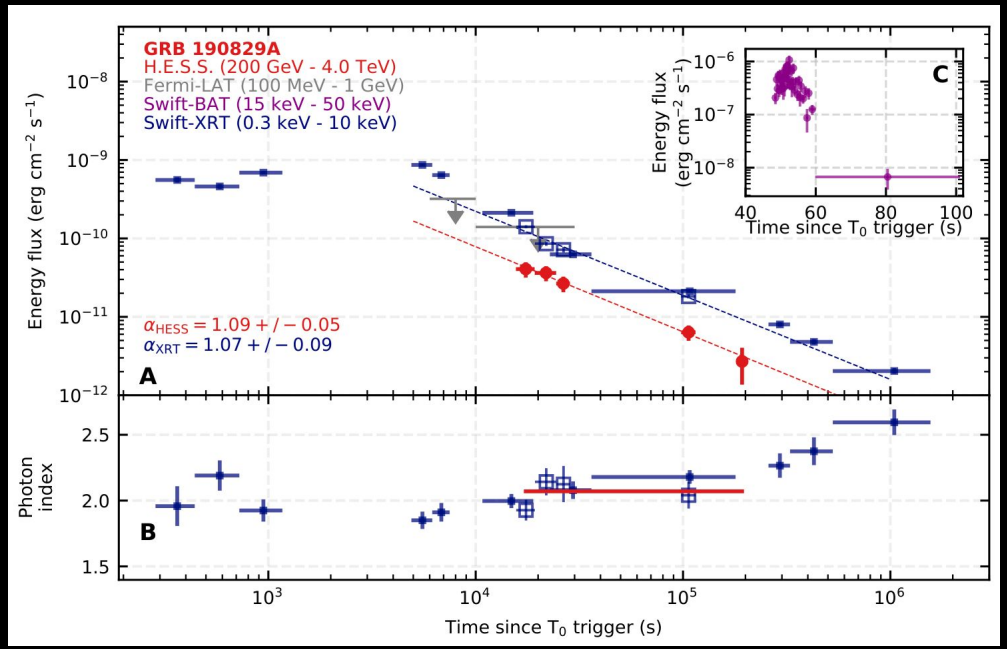
- One significant temporal bins (>5 σ detection) simultaneous with Fermi-GBM
- GRBs with and without redshift up to year 2023
- At least 20 photons within 10° of region of interest around the GRB location
- GBM + LLE (when possible) + LAT

Sample 2

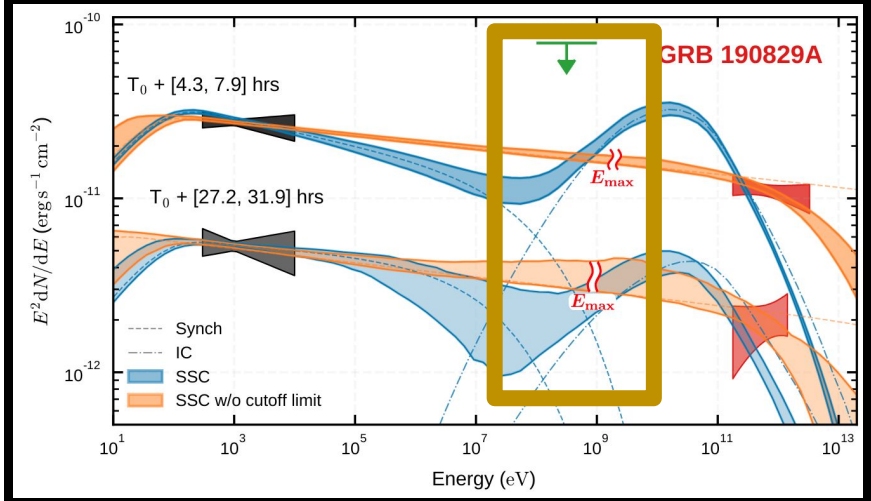
Spectral analysis of 66 GRBs

Total of 80 GRBs analysed in the energy range 8 keV - 10 GeV

Why is it more informative?
GRB 190829A



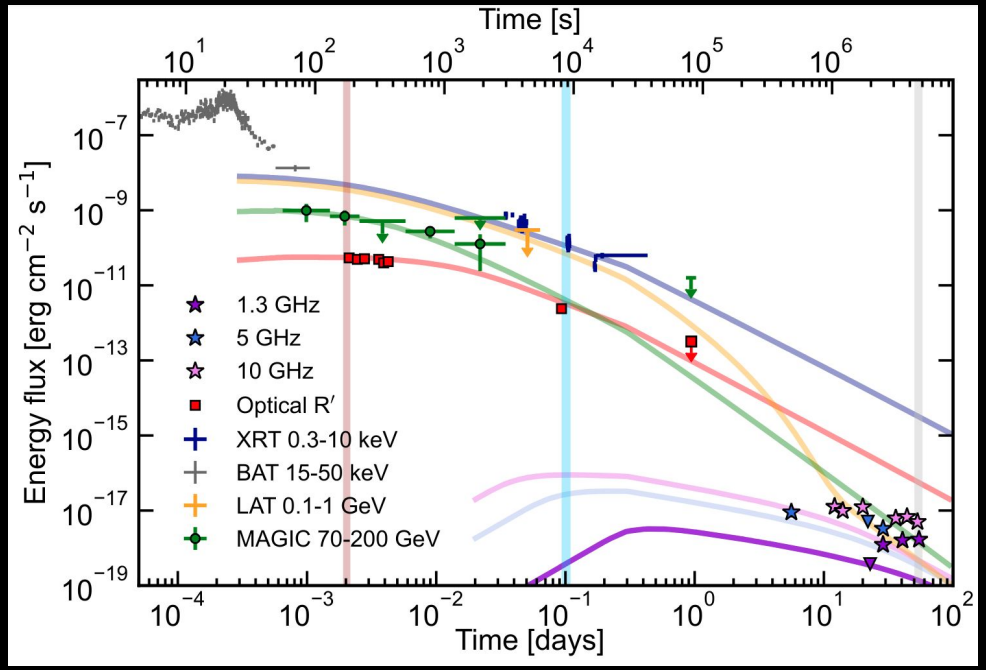
H.E.S.S. Collaboration 2021

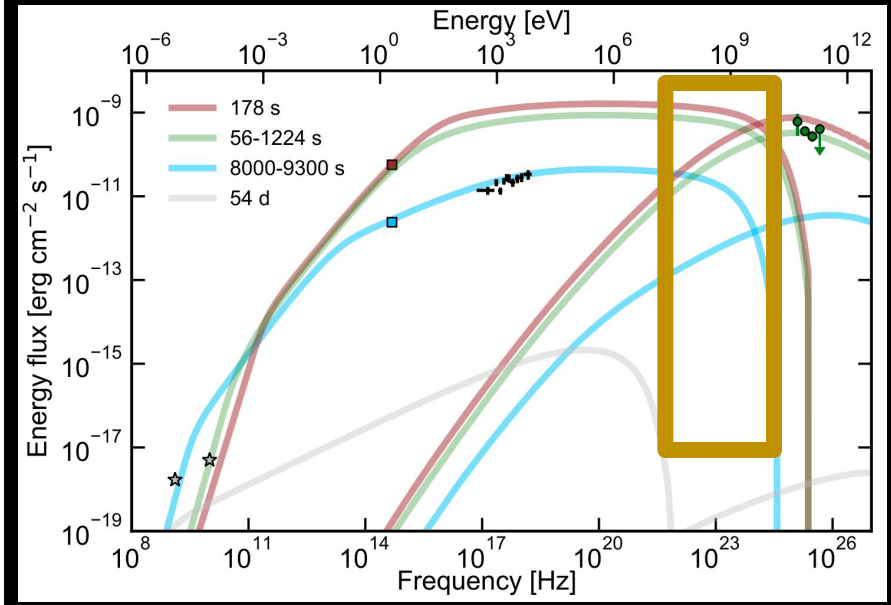


z~ 0.08

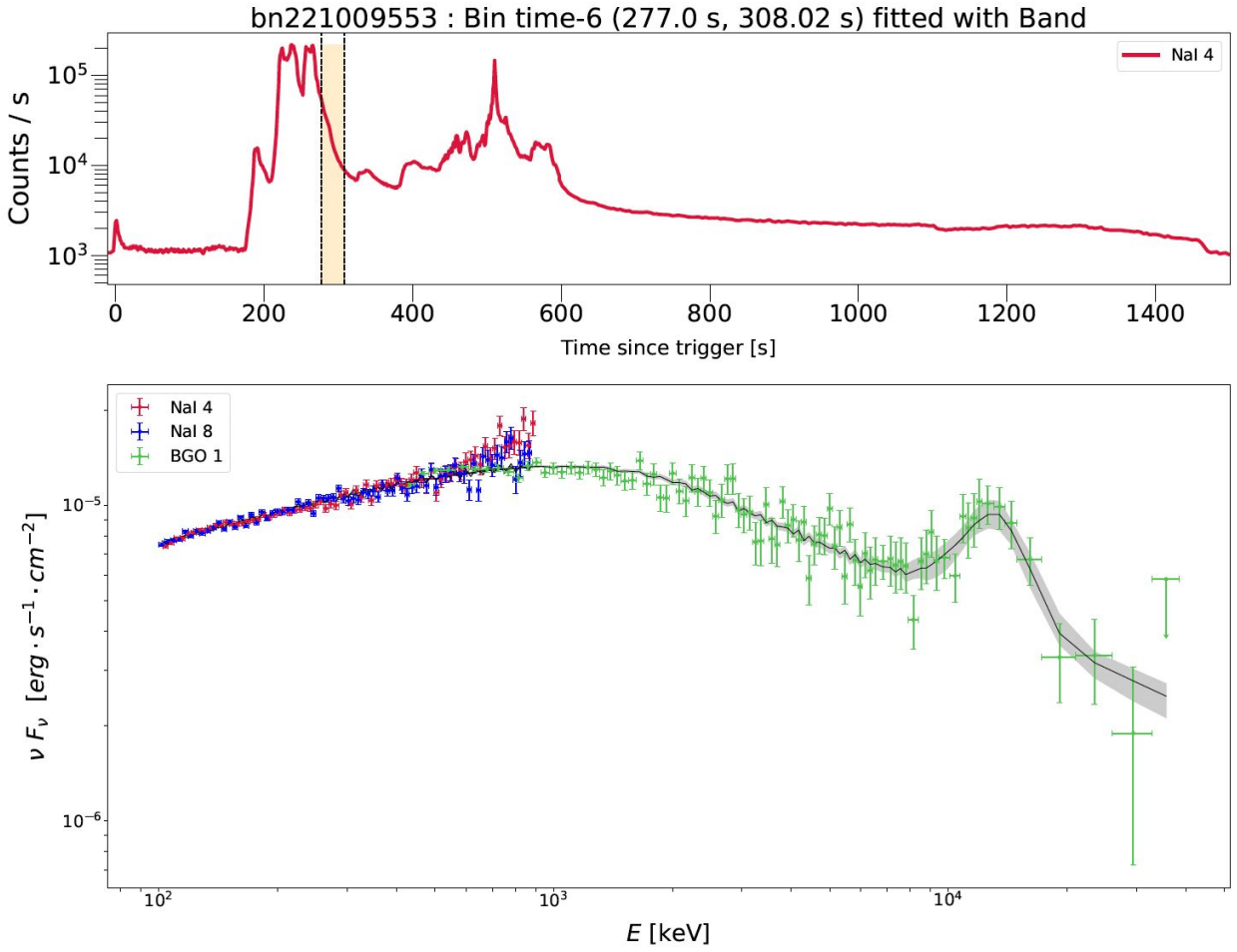
Why is it more informative?
GRB 201216C

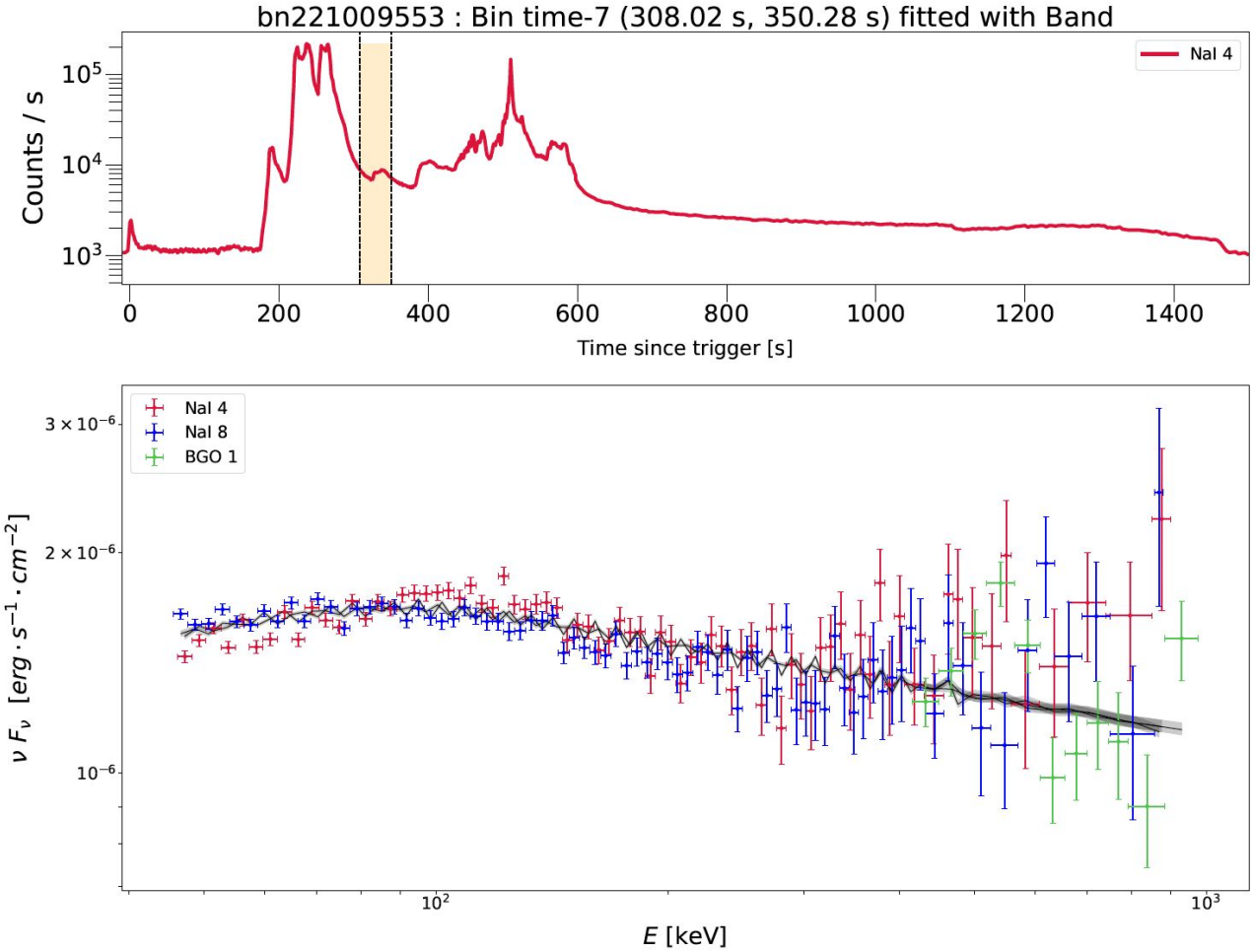
MAGIC Collaboration 2024

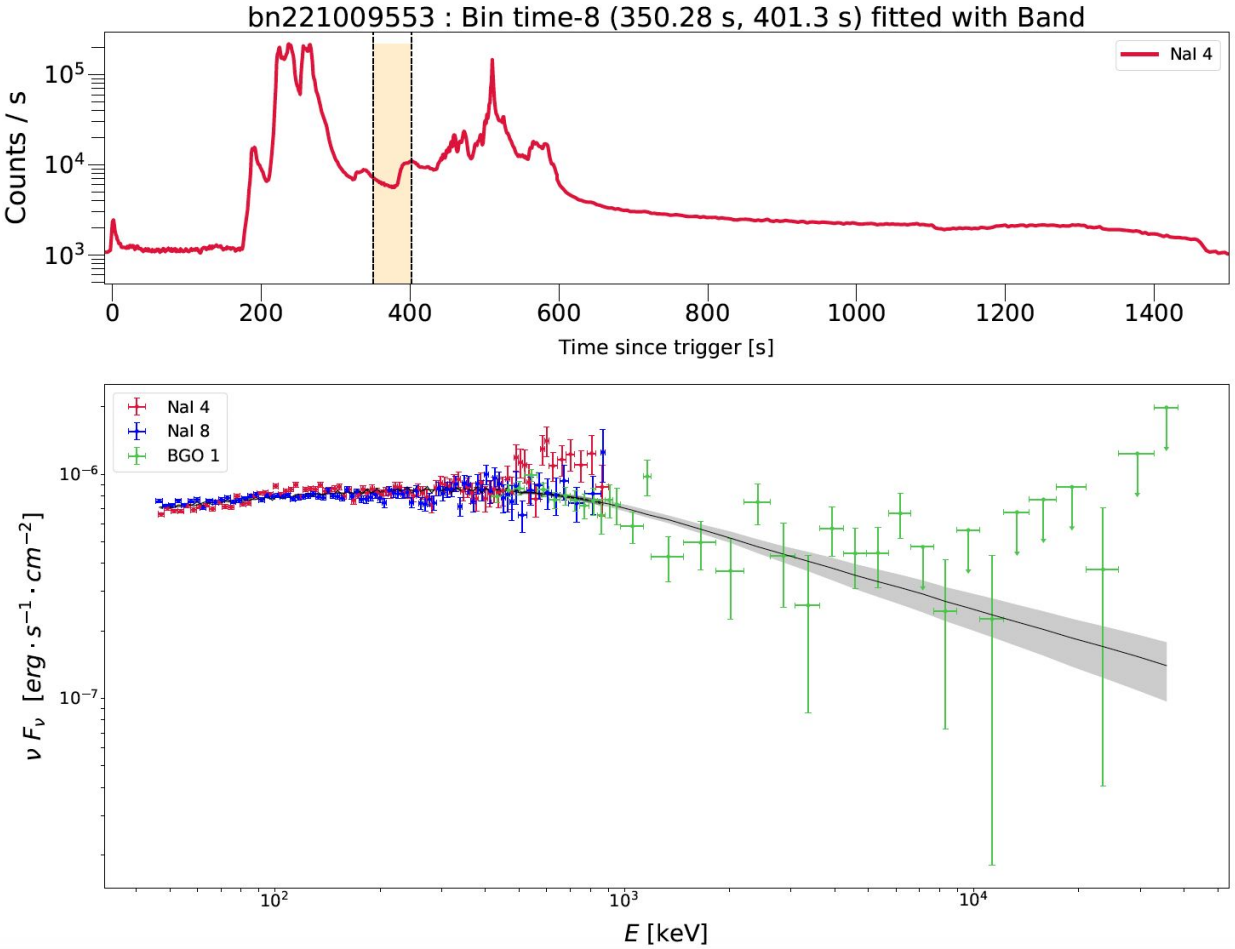




z~ 1.1


bn221009553 : Bin time-6 (277.0 s, 308.02 s) fitted with Band
Nal 4
Counts / s
10^5
10^4
10^3
0
200
400
600
800
1000
1200
1400
Time since trigger [s]
Nal 4
Nal 8
BGO 1
νF_ν [$erg \cdot s^{-1} \cdot cm^{-2}$]
10^{-5}
10^{-6}
10^2
10^3
10^4
E [keV]


bn221009553 : Bin time-7 (308.02 s, 350.28 s) fitted with Band
Nal 4
Counts / s
10^5
10^4
10^3
0
200
400
600
800
1000
1200
1400
Time since trigger [s]
Nal 4
Nal 8
BGO 1
3×10^{-6}
2×10^{-6}
10^{-6}
νF_ν [$erg \cdot s^{-1} \cdot cm^{-2}$]
10^2
10^3
E [keV]


bn221009553 : Bin time-8 (350.28 s, 401.3 s) fitted with Band
Nal 4
Counts / s
10^5
10^4
10^3
0
200
400
600
800
1000
1200
1400
Time since trigger [s]
Nal 4
Nal 8
BGO 1
10^{-6}
10^{-7}
νF_ν [$erg \cdot s^{-1} \cdot cm^{-2}$]
10^2
10^3
10^4
E [keV]