

8th Heidelberg International Symposium on High-Energy Gamma-Ray Astronomy

A bright and narrow line at mega-electronvolt photon energies in the prompt emission of GRB221009A

Om Sharan Salafia

INAF – Osservatorio Astronomico di Brera

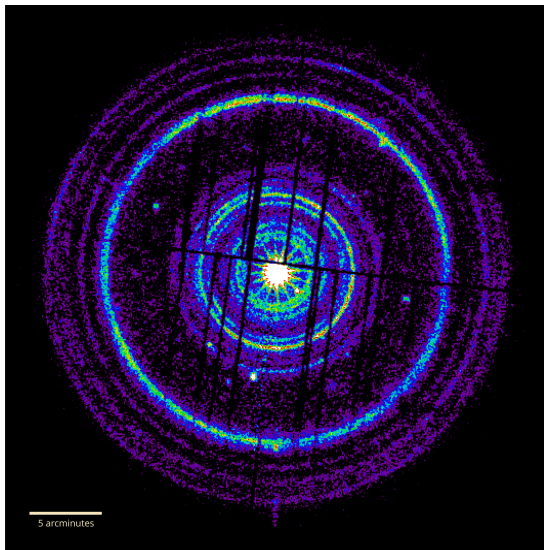
INFN – Sezione di Milano-Bicocca

Milan, Italy



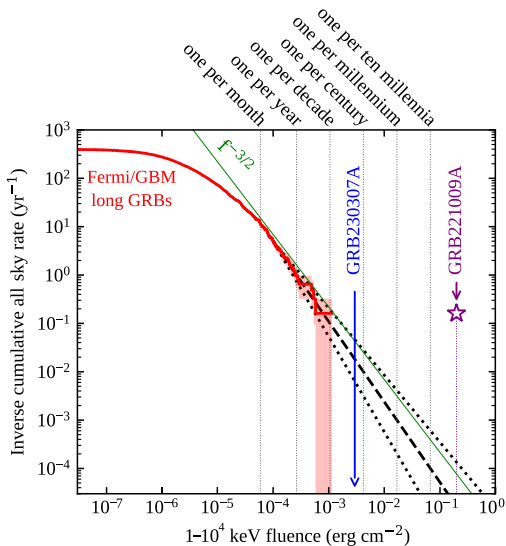
[Image credits: NASA's Goddard Space Flight Center Conceptual Image Lab]

GRB 221009A - The B.O.A.T.



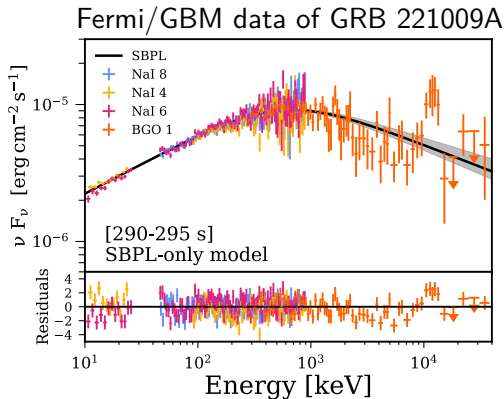
[ESA/XMM-Newton/M. Rigoselli (INAF)]

The B.O.A.T. in context



[Adapted from Malesani et al. 2023, see also Burns et al. 2022; Finke & Razzaque 2024]

Mery Ravasio's discovery

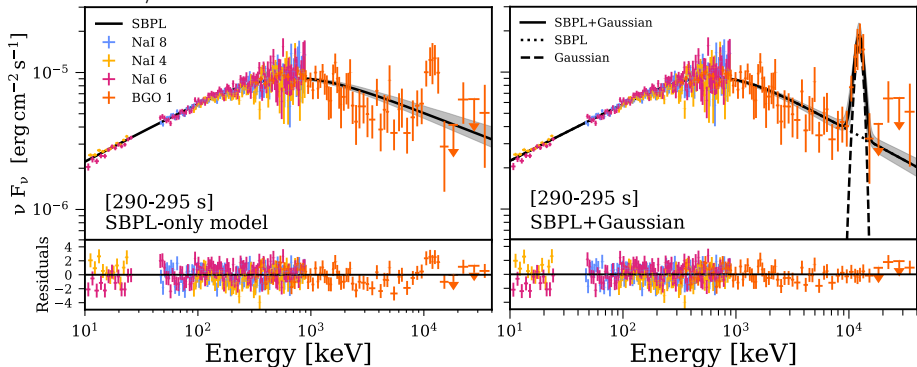


[Adapted from Ravasio, OS, et al. 2024]

Mery Ravasio's discovery



Fermi/GBM data of GRB 221009A



[Adapted from Ravasio, OS, et al. 2024]

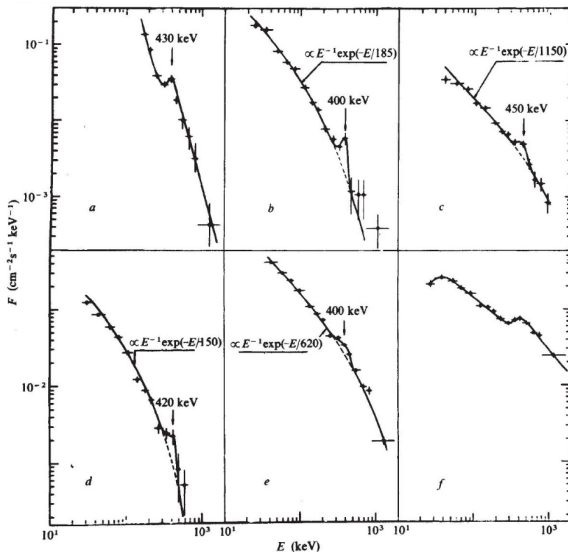
Is it real?



*Ad patrios fines dum sumptis Icarus alis | Subuolat ad Solem propius, mox cera liquefcit,
Aërias carpit cum genitore vias. Inque necaturas precipitatur aquas.
Martini de Vestimenti.*

[P. Bruegel – “The fall of Icarus”]

Previous claims of lines in GRBs



[Mazets et al. 1981 – claimed lines in Venera GRB spectra]

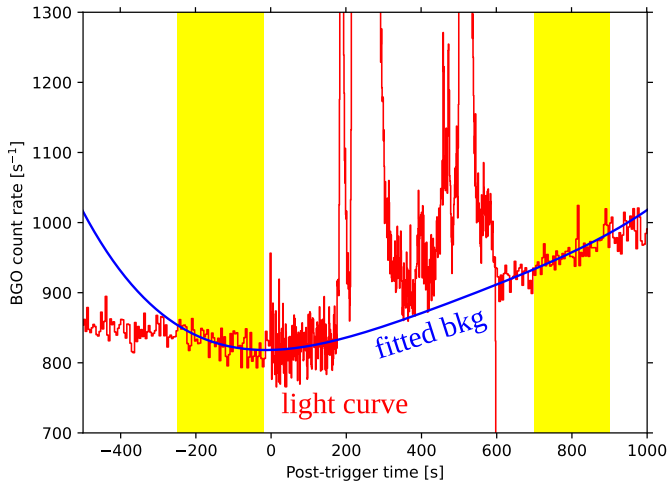
Are we pursuing heresy?



[The burning of Joan of Arc – Encyclopaedia Britannica]

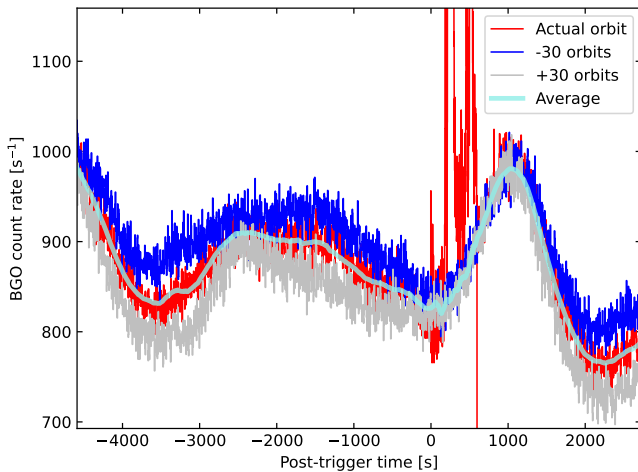
Assessing the background estimation

The usual method



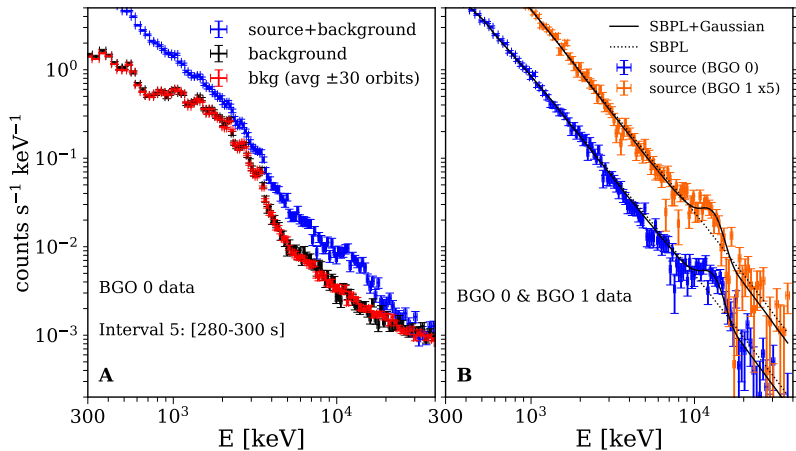
Assessing the background estimation

The 'orbital' method



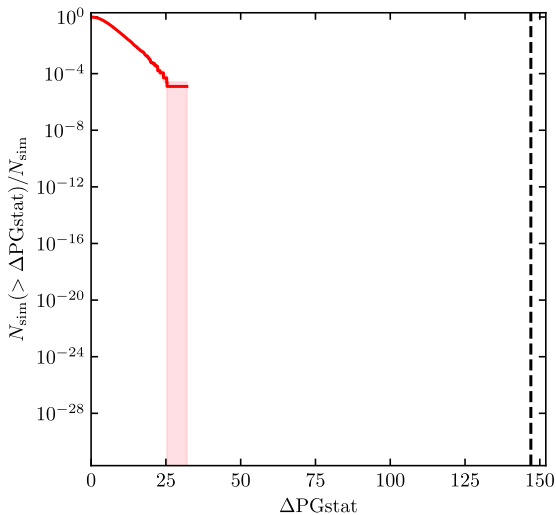
[See Fitzpatrick et al. 2011, Lesage et al. 2023]

Background estimate OK



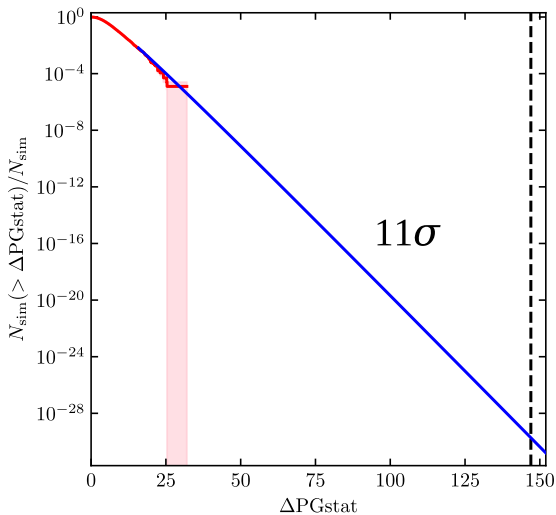
[Ravasio, OS, et al. 2024]

Significance



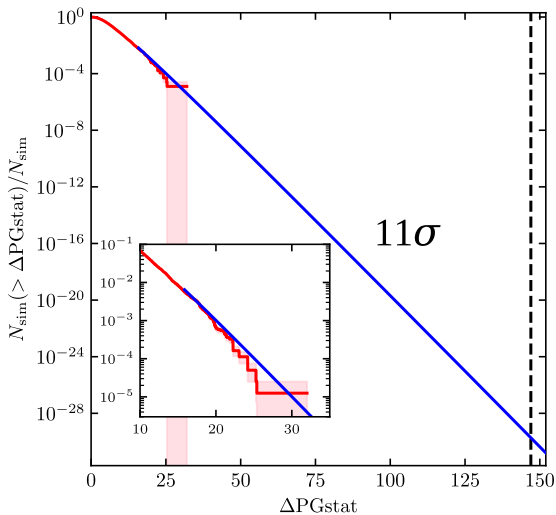
[Ravasio, OS, et al. 2024]

Significance



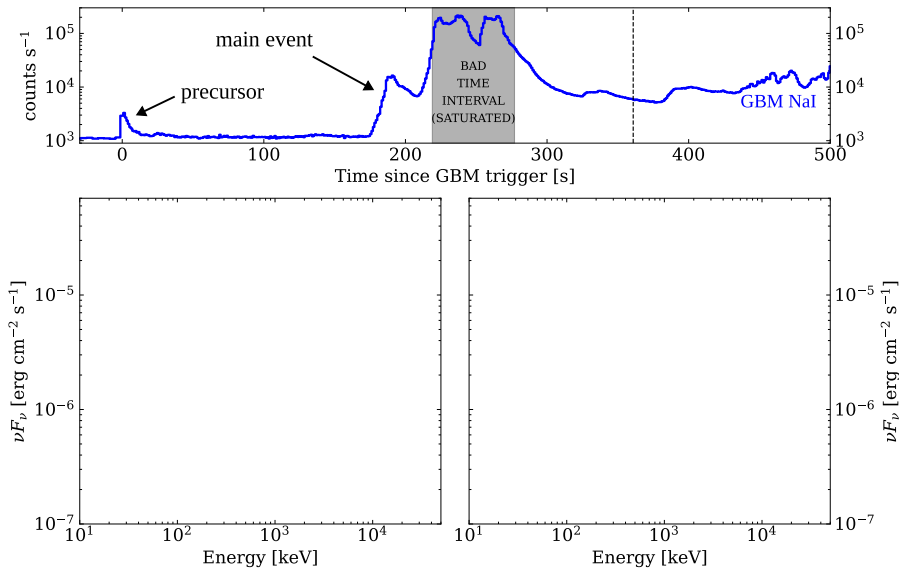
[Ravasio, OS, et al. 2024]

Significance



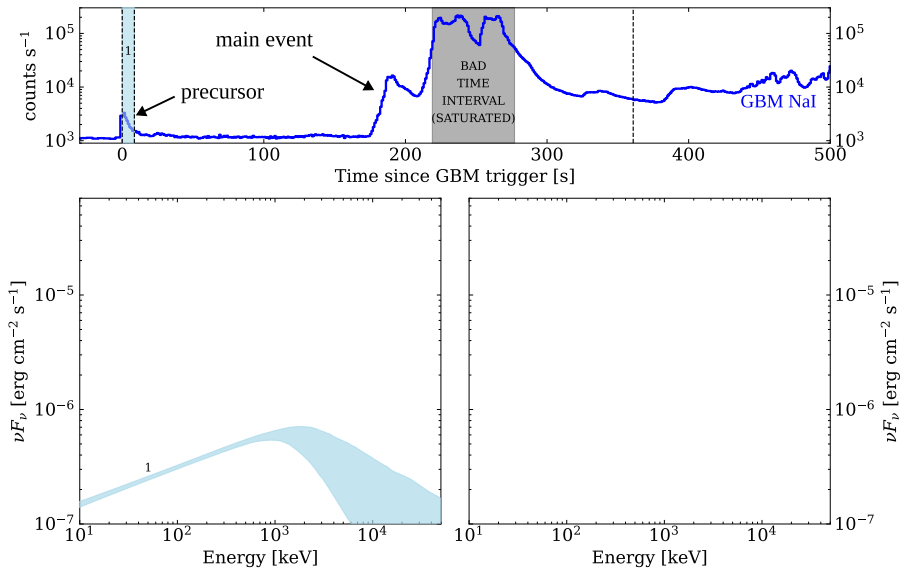
[Ravasio, OS, et al. 2024]

SED evolution



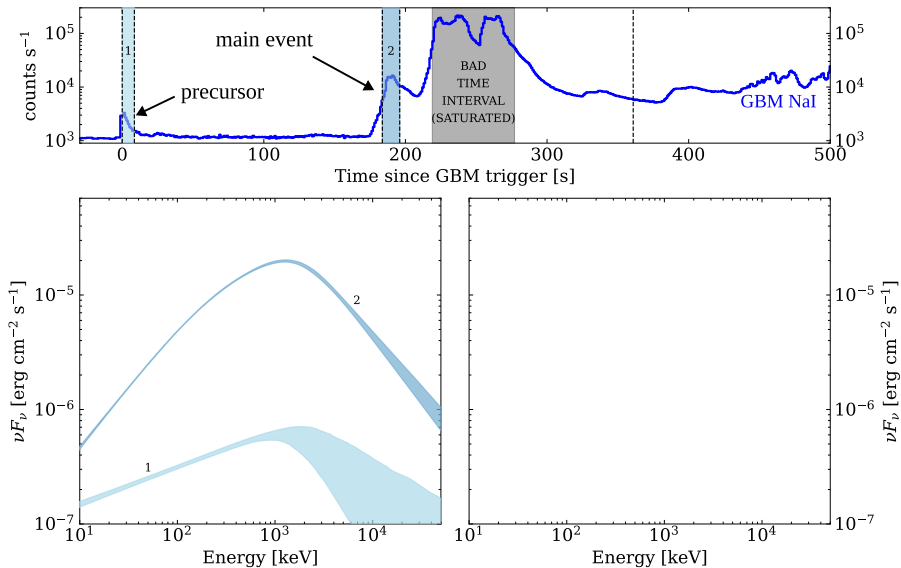
[Adapted from Ravasio, OS, et al. 2024]

SED evolution



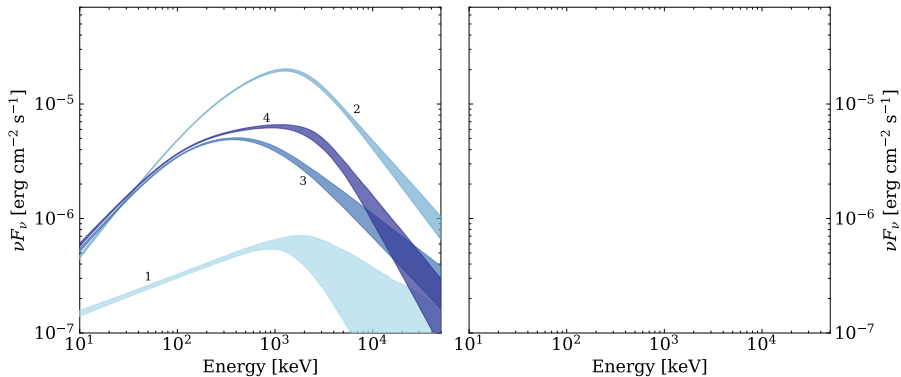
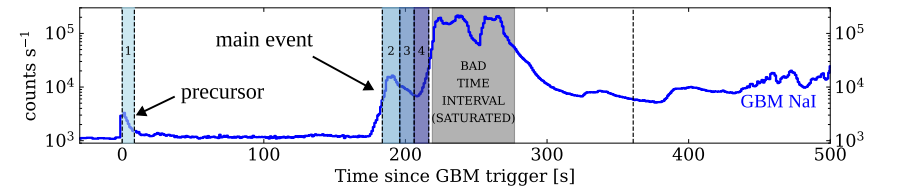
[Adapted from Ravasio, OS, et al. 2024]

SED evolution



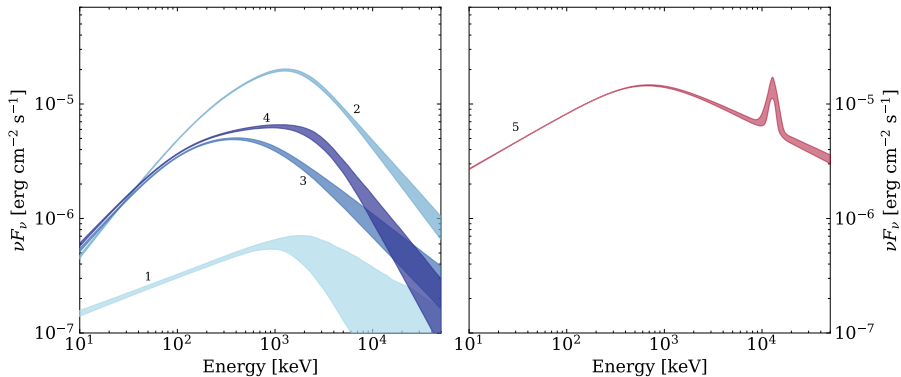
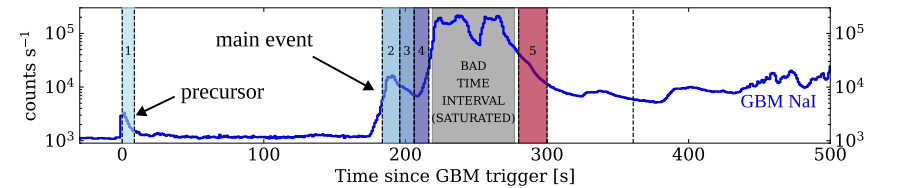
[Adapted from Ravasio, OS, et al. 2024]

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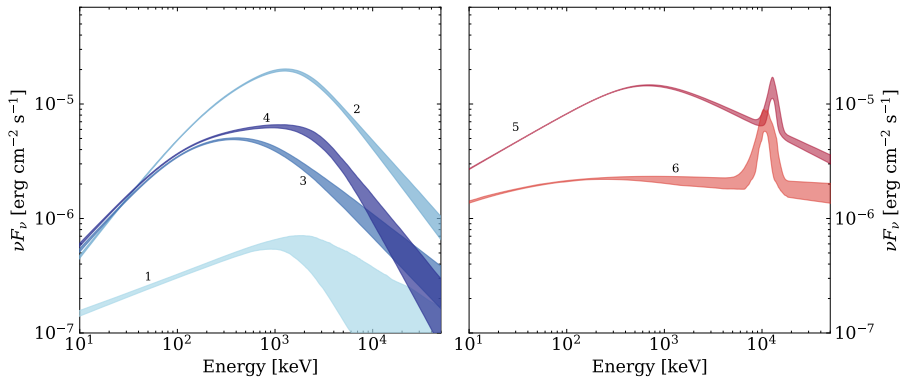
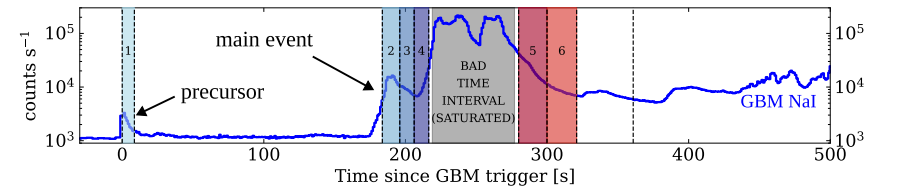
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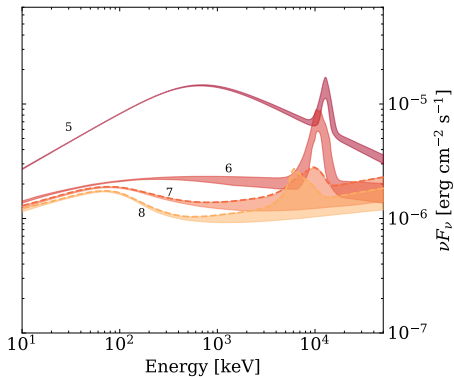
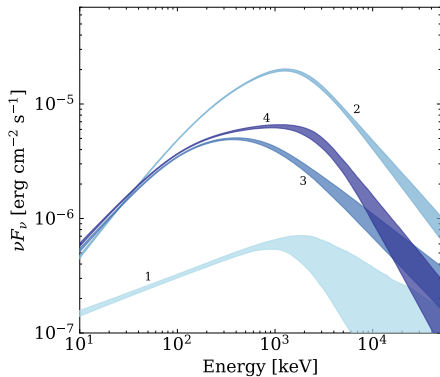
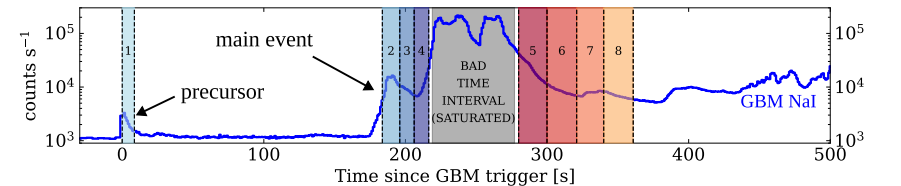
[Adapted from Ravasio, OS, et al. 2024]

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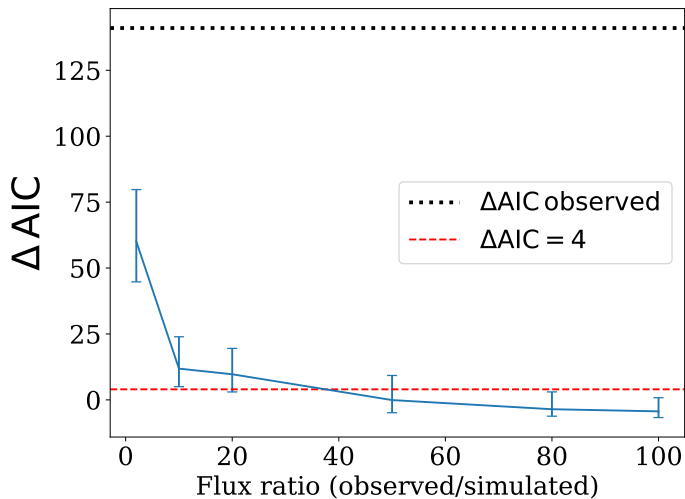
General properties

$t - t_0$ (s)	L_{line} ($10^{50} \text{ erg s}^{-1}$)	E_{line} (MeV)	$\sigma_{\text{line}}/E_{\text{line}}$
280 – 300	1.1 ± 0.2	12.6 ± 0.3	0.10 ± 0.03
300 – 320	1.1 ± 0.2	10.2 ± 0.3	0.17 ± 0.05
320 – 340	< 0.5	7.2 ± 1.7	0.30 ± 0.25
340 – 360	< 0.4	6.1 ± 0.7	0.25 ± 0.15

* More precise values in the paper

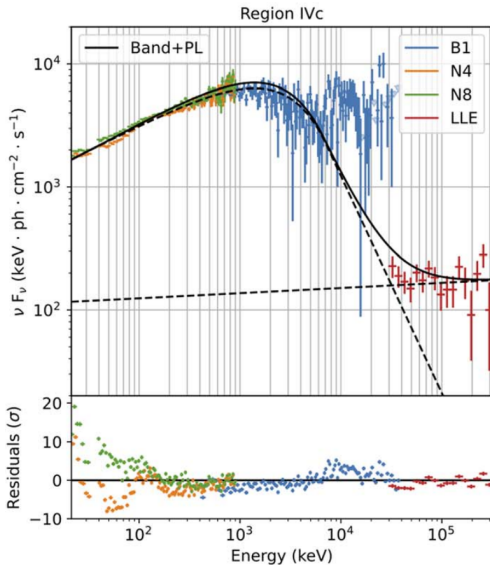
Why have we not seen this before

1. Emission needs be very bright



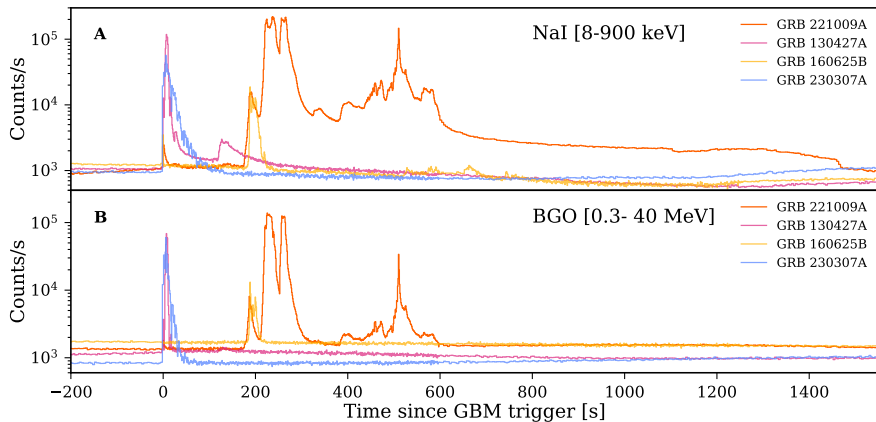
Why have we not seen this before

2. We usually do not look for this kind of feature



Fermi/GBM team analysis paper
[Lesage et al. 2023]

Search in other bright GRBs

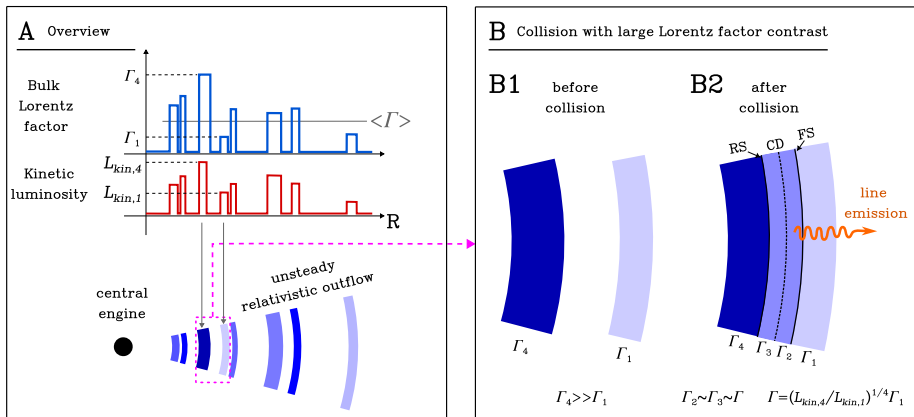


No clear features in three next brightest Fermi/GBM GRBs.
But **narrow** needle in a haystack.

Interpretation

How do you produce a narrow feature with $L \sim 10^{50}$ erg/s luminosity at $h\nu \sim 10$ MeV?

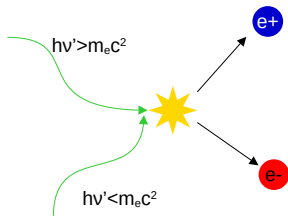
Blue-shifted e^-e^+ line from internal shock



[Ravasio, OS, et al. 2024]

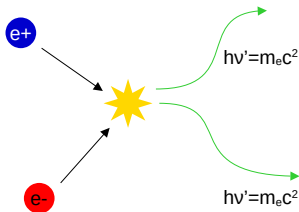
e^-e^+ creation, annihilation, and cooling

gamma-gamma pair production

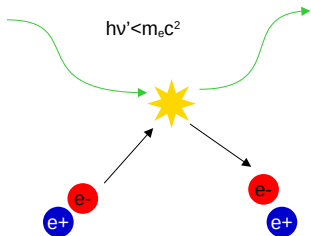


e^+e^- pair annihilation

equilibrium



Thomson scattering



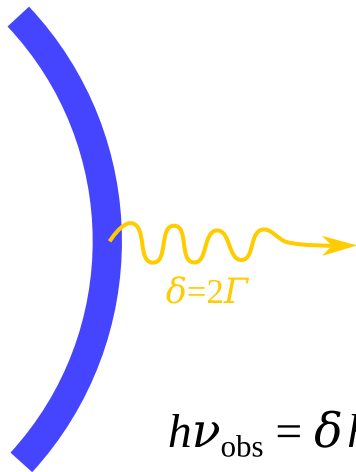
$t_{\text{cool}} \ll t_{\text{annihilation}}$

High-latitude emission?



[Kumar & Panaitescu 2000]

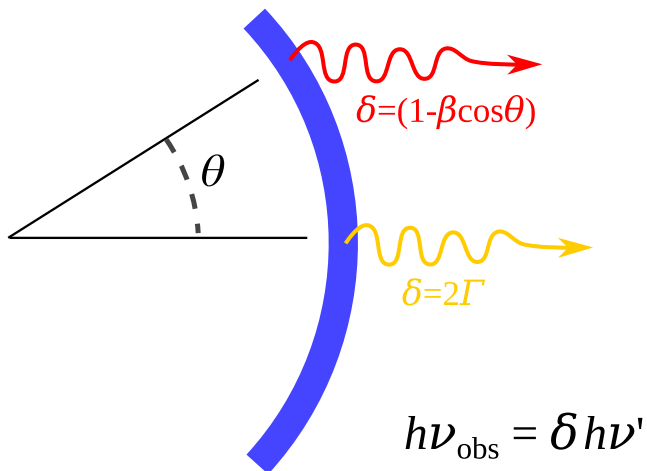
High-latitude emission?



$$h\nu_{\text{obs}} = \delta h\nu'$$

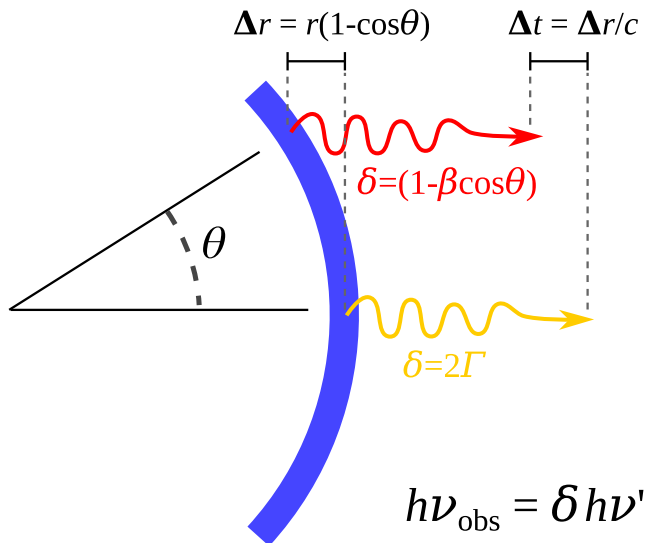
[Kumar & Panaitescu 2000]

High-latitude emission?



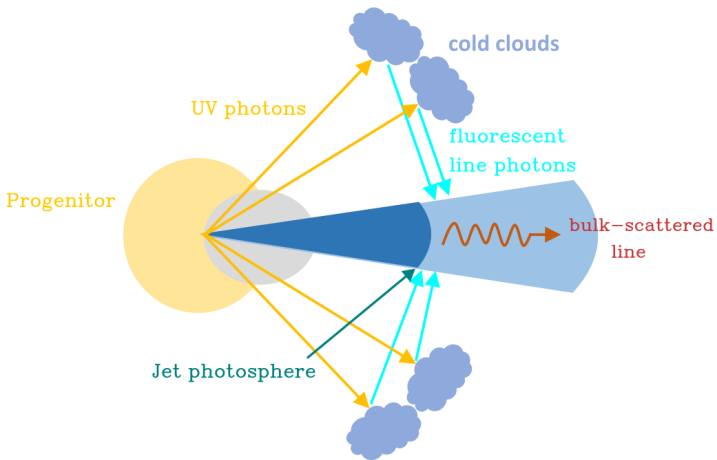
[Kumar & Panaitescu 2000]

High-latitude emission?



[Kumar & Panaitescu 2000]

Up-scattered fluorescence line?



[Adapted from Wei et al. 2024]

Summary

- **Narrow** ($\Delta\nu/\nu \lesssim 0.2$), **luminous** ($L \sim 10^{50}$ erg/s) emission line at $h\nu \sim 10$ MeV right after the bright emission peak of the BOAT GRB

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Thank you!