Early X-ray emission of short GRBs

Insights into physics and multi-messenger prospects

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TeV Particle Astrophysics
Valencia, 4 November 2025

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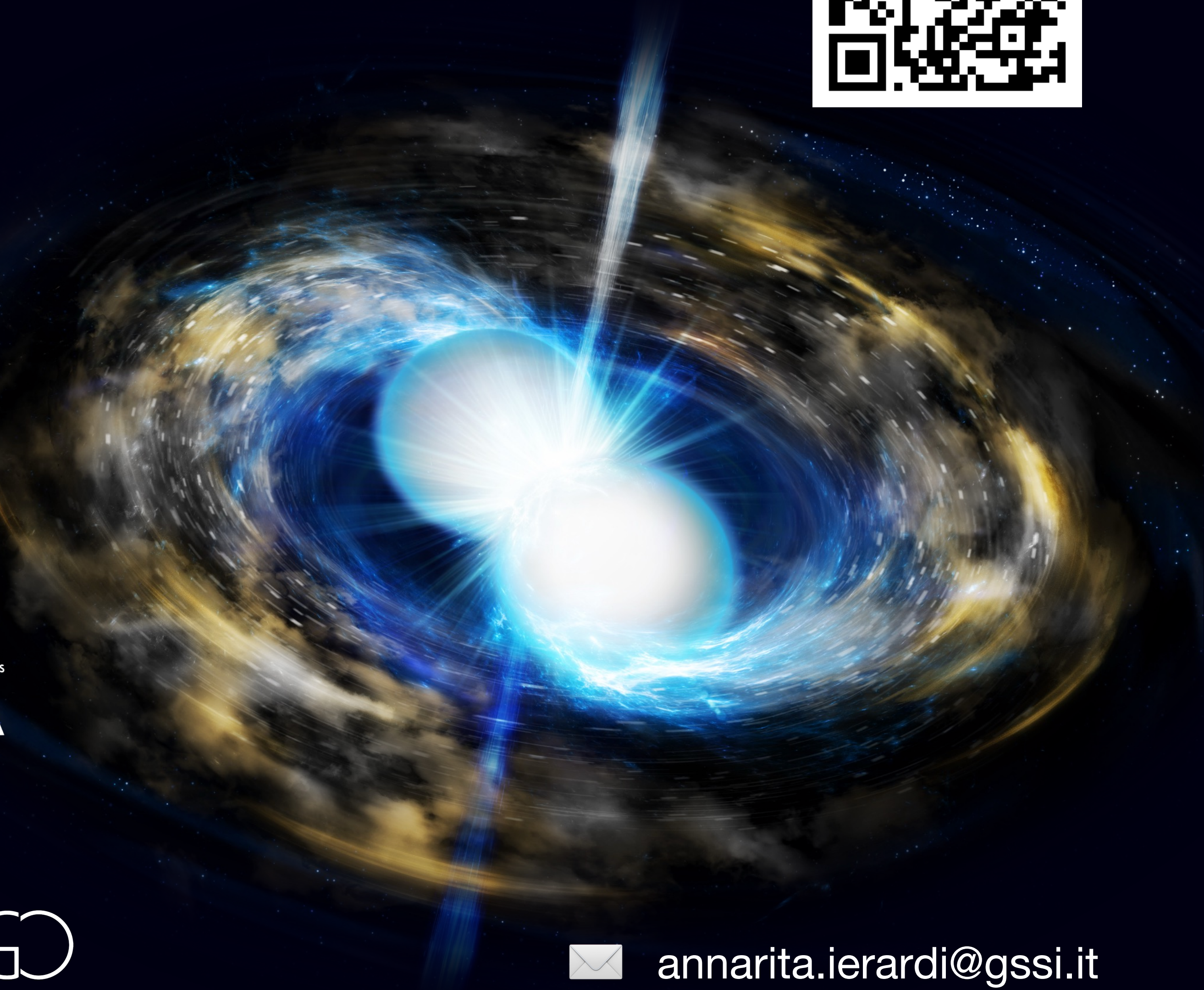

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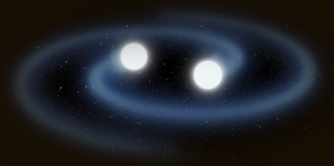
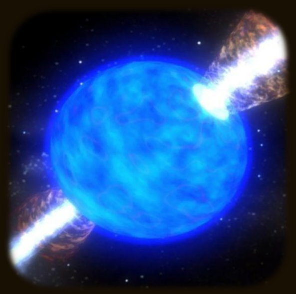
Gamma-Ray Bursts

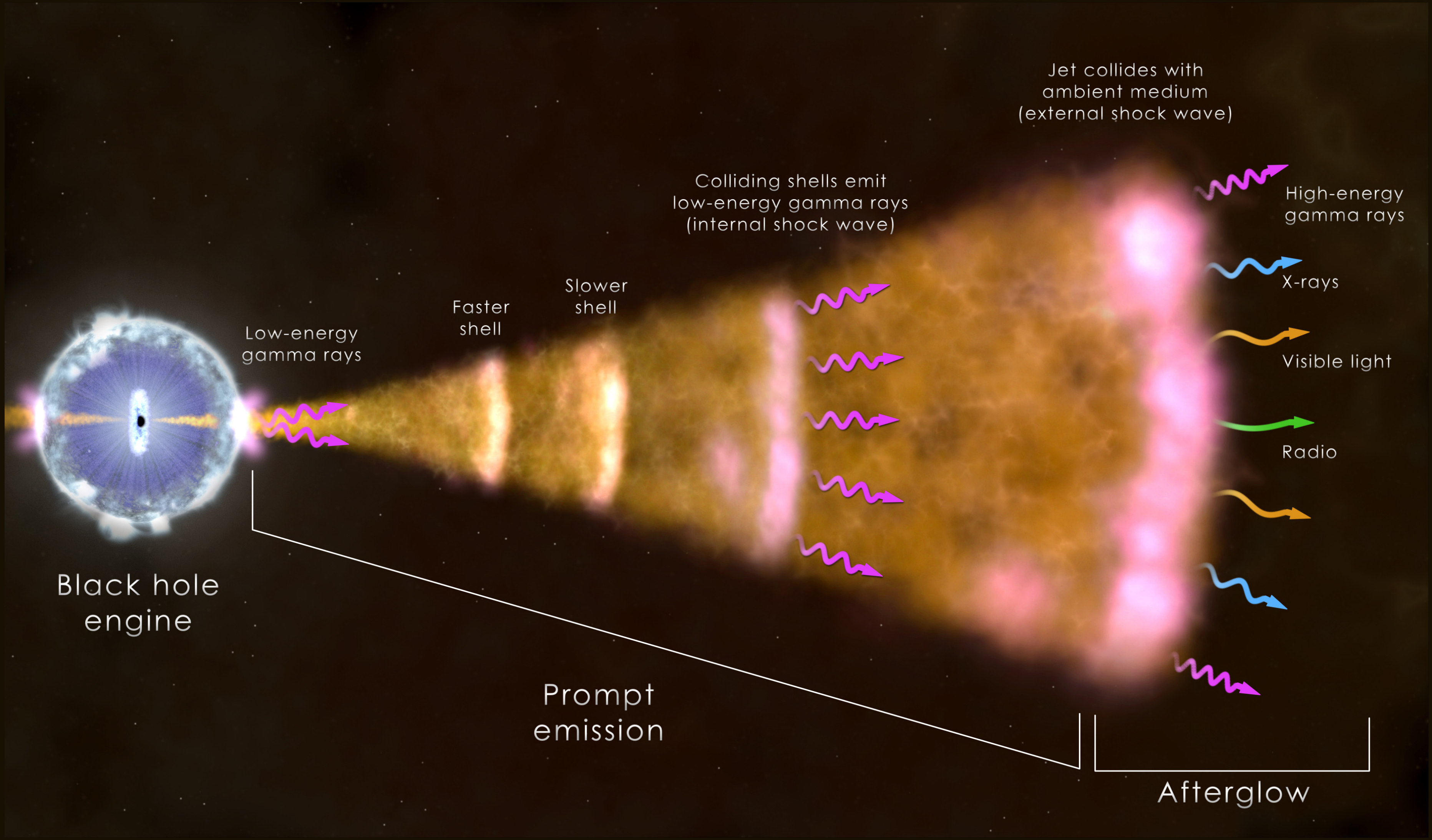
Credit: NASA

Binary Neutron Star Merger

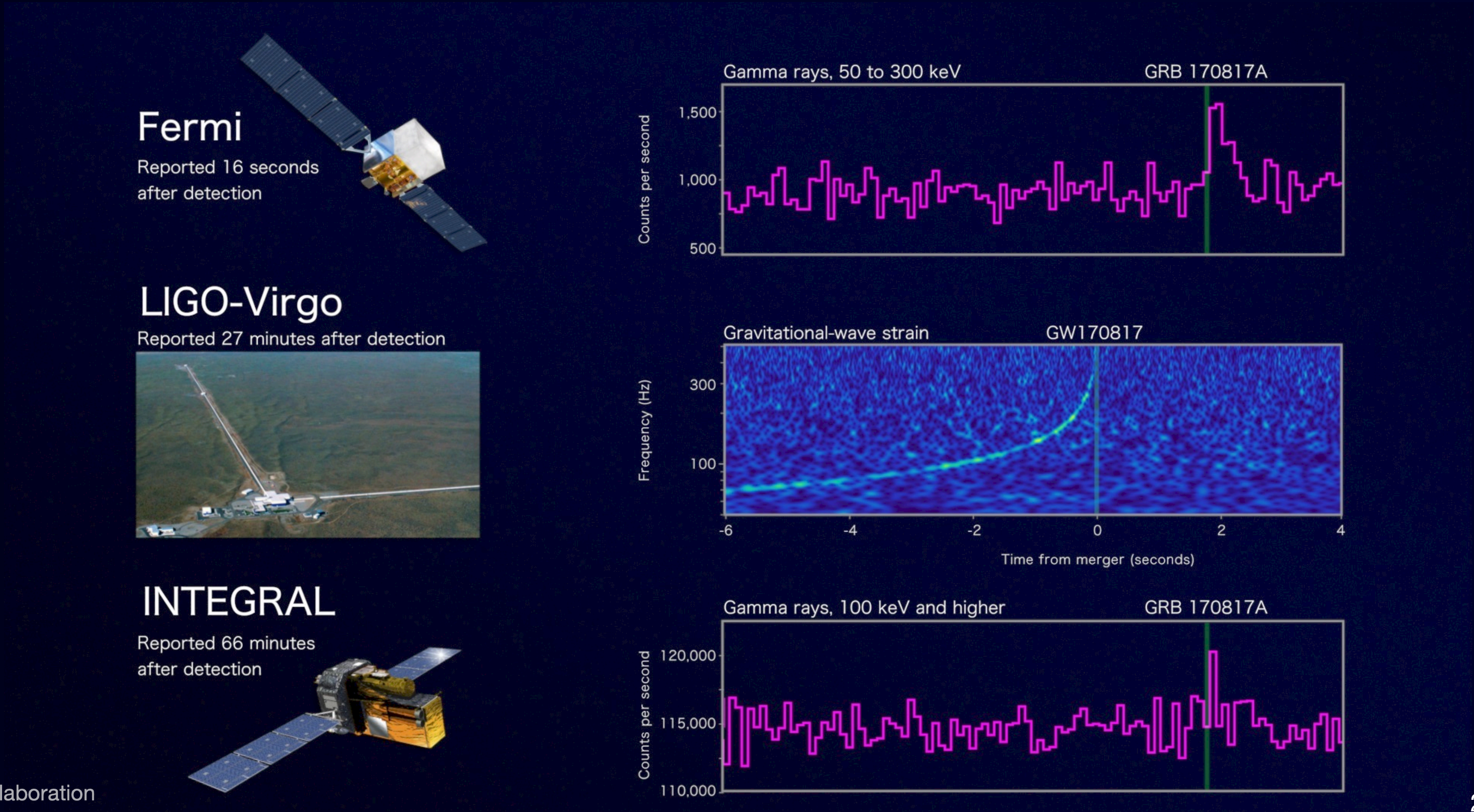




Collapsar



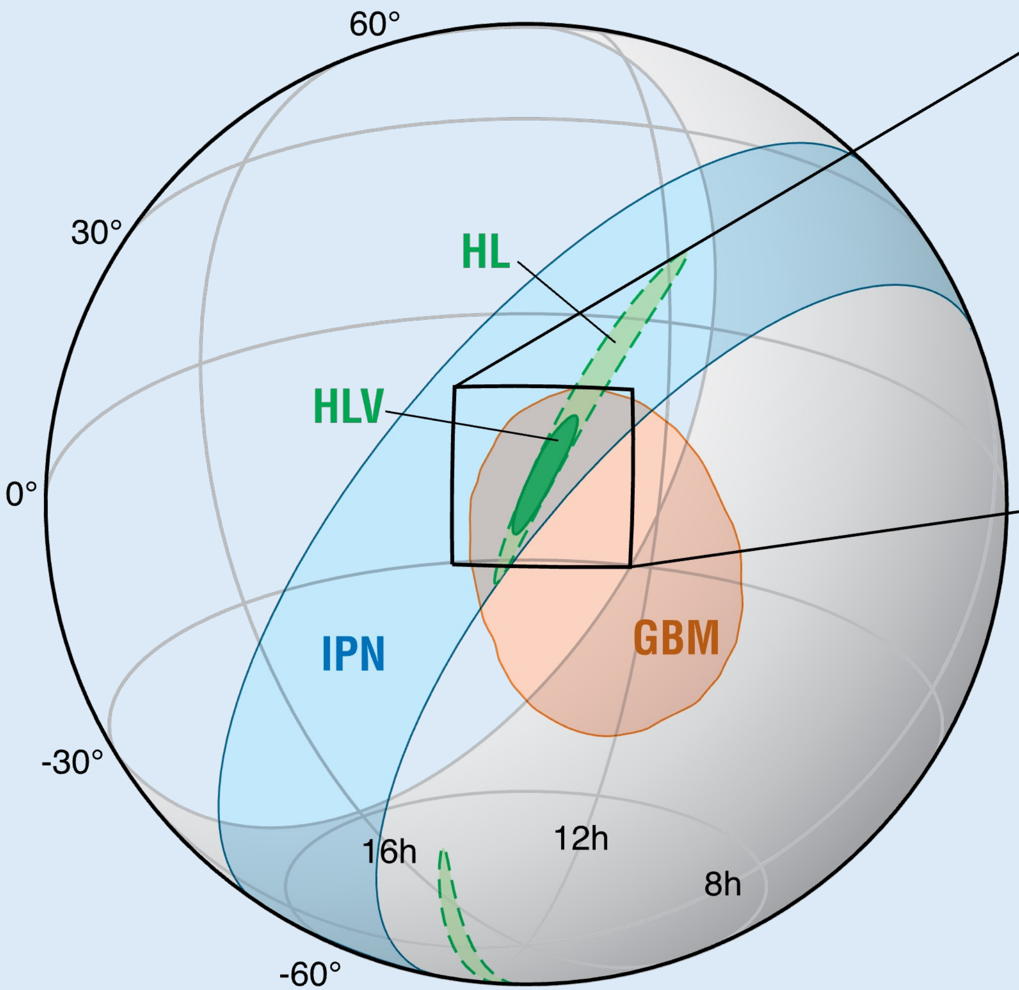
Multimessenger astronomy with GWs

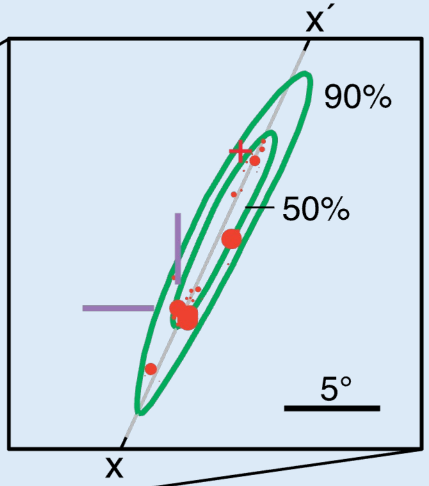


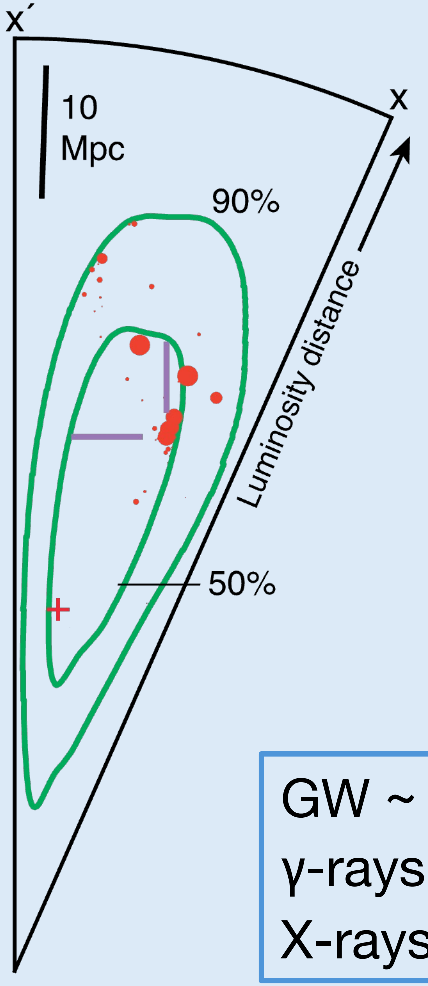
Credit:
Fermi collaboration

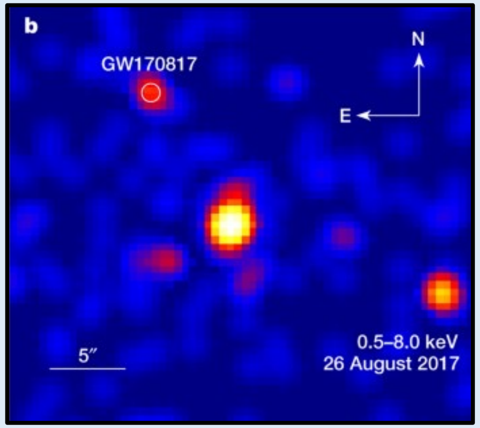
Sky localization

Adapted from: M. M. Kasliwal et al. 2017









E. Troja et al. 2017

GW ~ 100 deg^2
γ-rays ~ 10 - 100 deg^2
X-rays ~ arcmin

Swift

BAT [15-150 keV]

wide-field (1.4 sr) and sensitive coded-mask instrument with a ~4 arcmin localisation

XRT [0.3-10 keV]

Wolter-I telescope with higher angular resolution (~5 arcsec) and higher sensitivity for follow-up

Einstein Probe

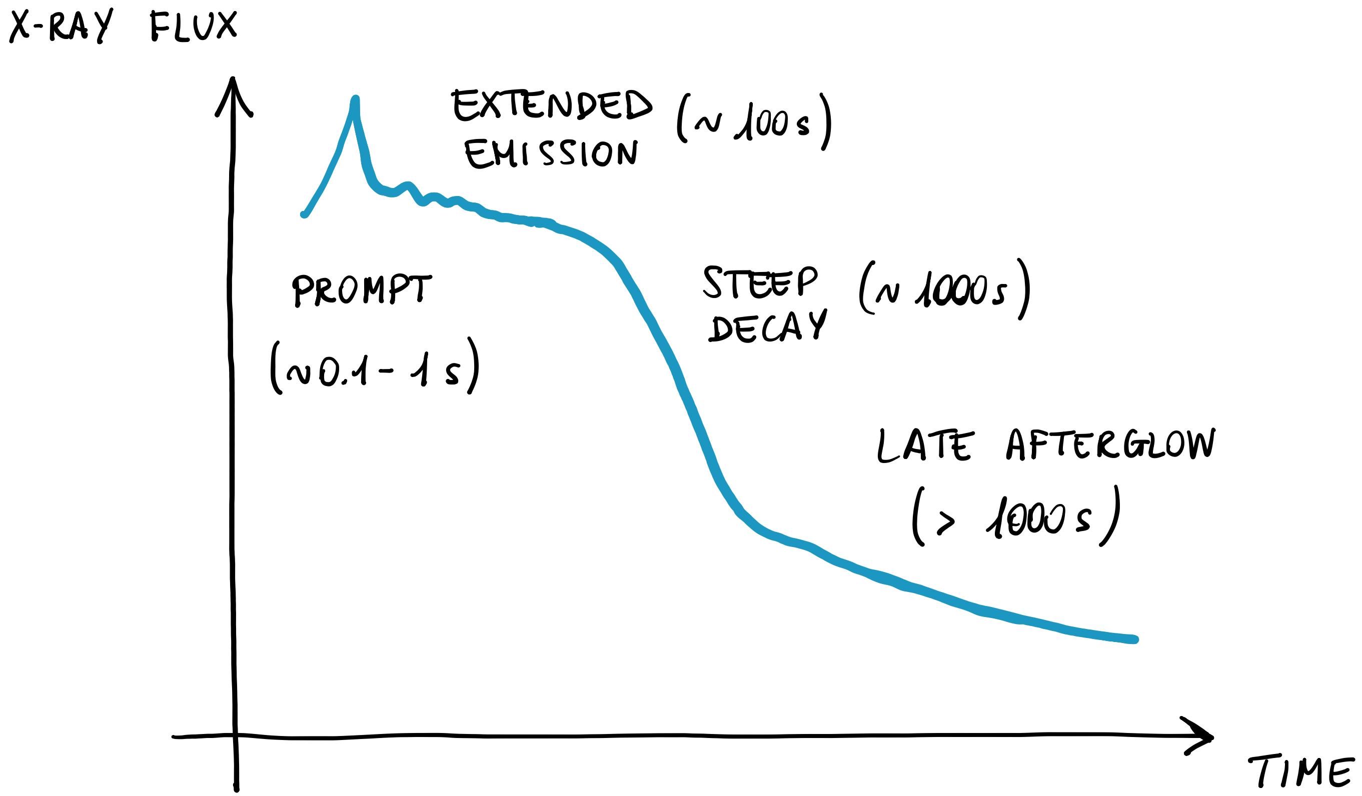
WXT [0.5-4 keV]

lobster-eye optics to combine a large FoV (3600 sq. deg.) with a ~5 arcmin localisation

FXT [0.3-10 keV]

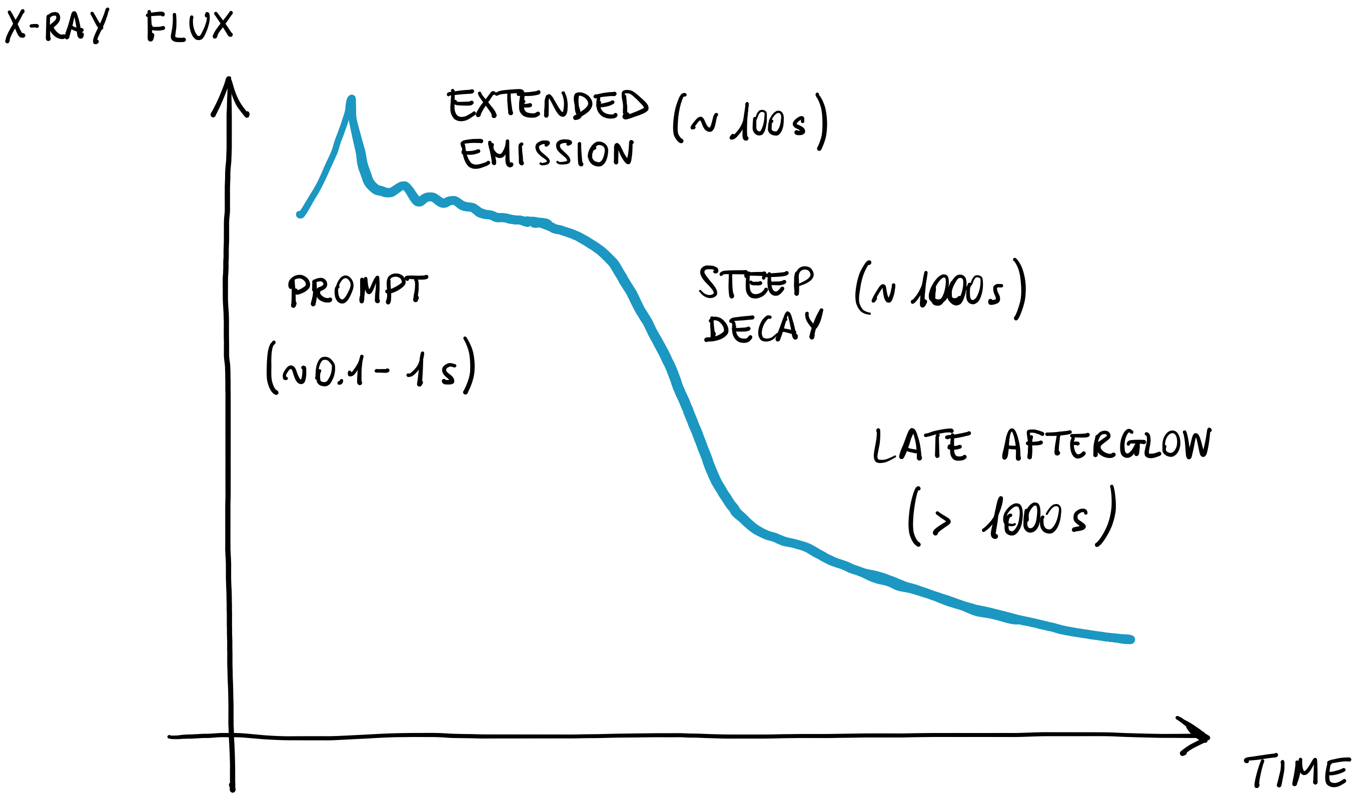
Wolter-I telescope with higher angular resolution (~5 arcsec) and higher sensitivity for follow-up

Short GRBs in soft X-rays



- Late-time afterglow of short GRBs has been well characterized (W. Fong et al. 2015, 2022)
- Early X-ray radiation is a probe of GRB jet physics and emission mechanisms
- It can be detected and localized by wide-field X-ray monitors

Short GRBs in soft X-rays



Ierardi+, arXiv:2510.16108

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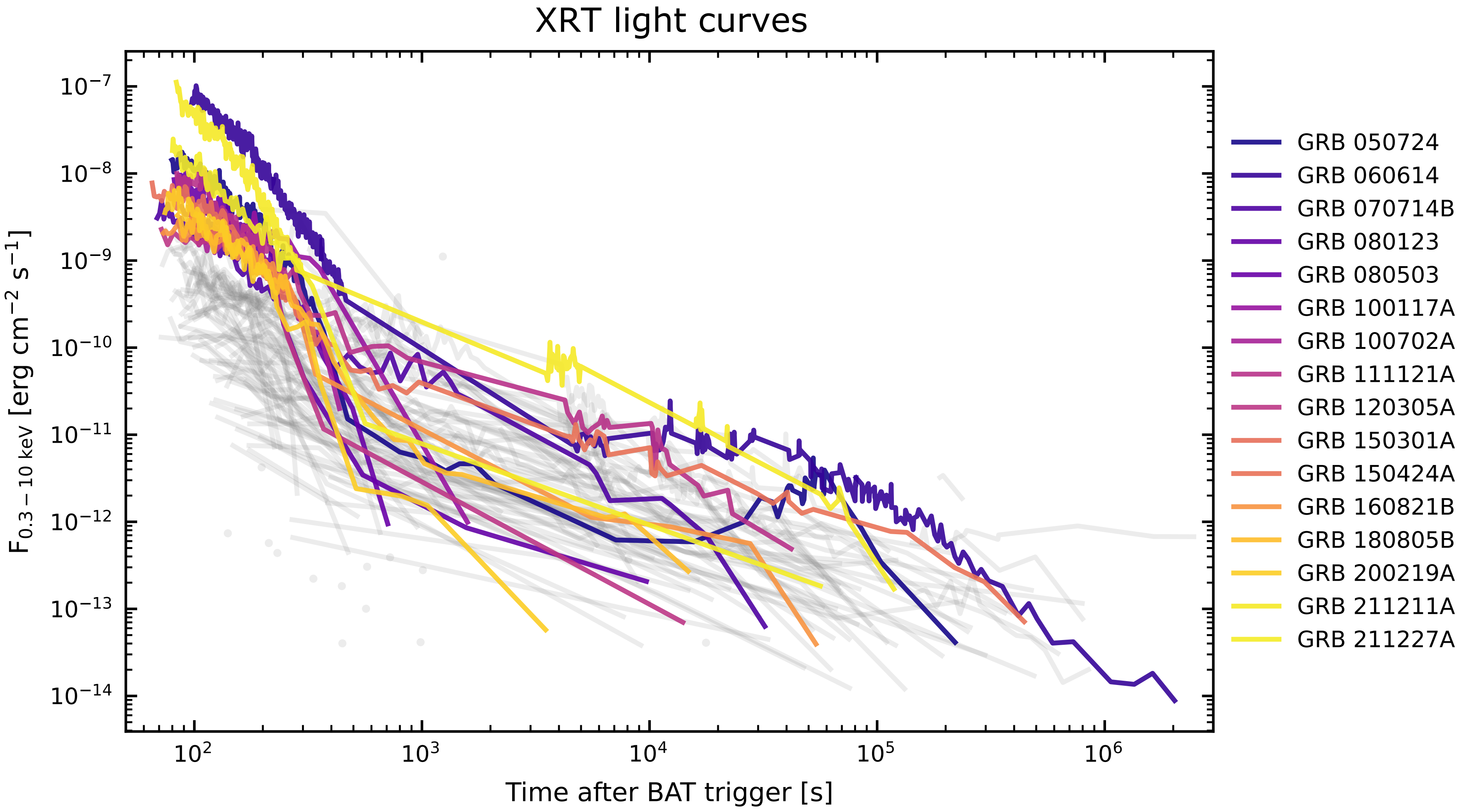
We systematically analyzed temporal and spectral evolution of early X-ray emission in short GRBs

Sample selection



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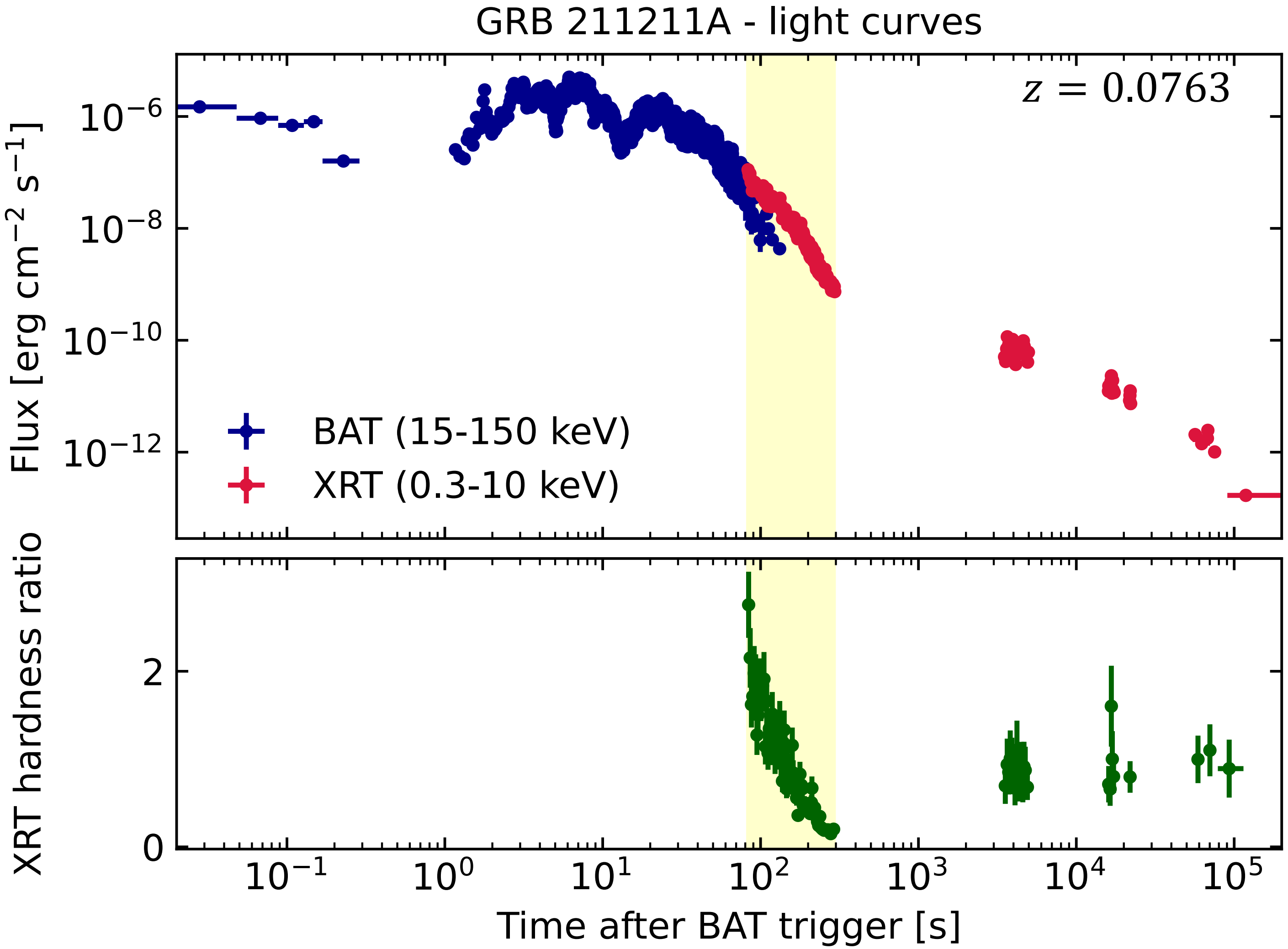
Spectral analysis



- Spectral evolution of the X-ray emission identified from the XRT hardness ratio
- Time-resolved spectral analysis of XRT and BAT data in the [0.3-150] keV energy range

Ierardi+, arXiv:2510.16108

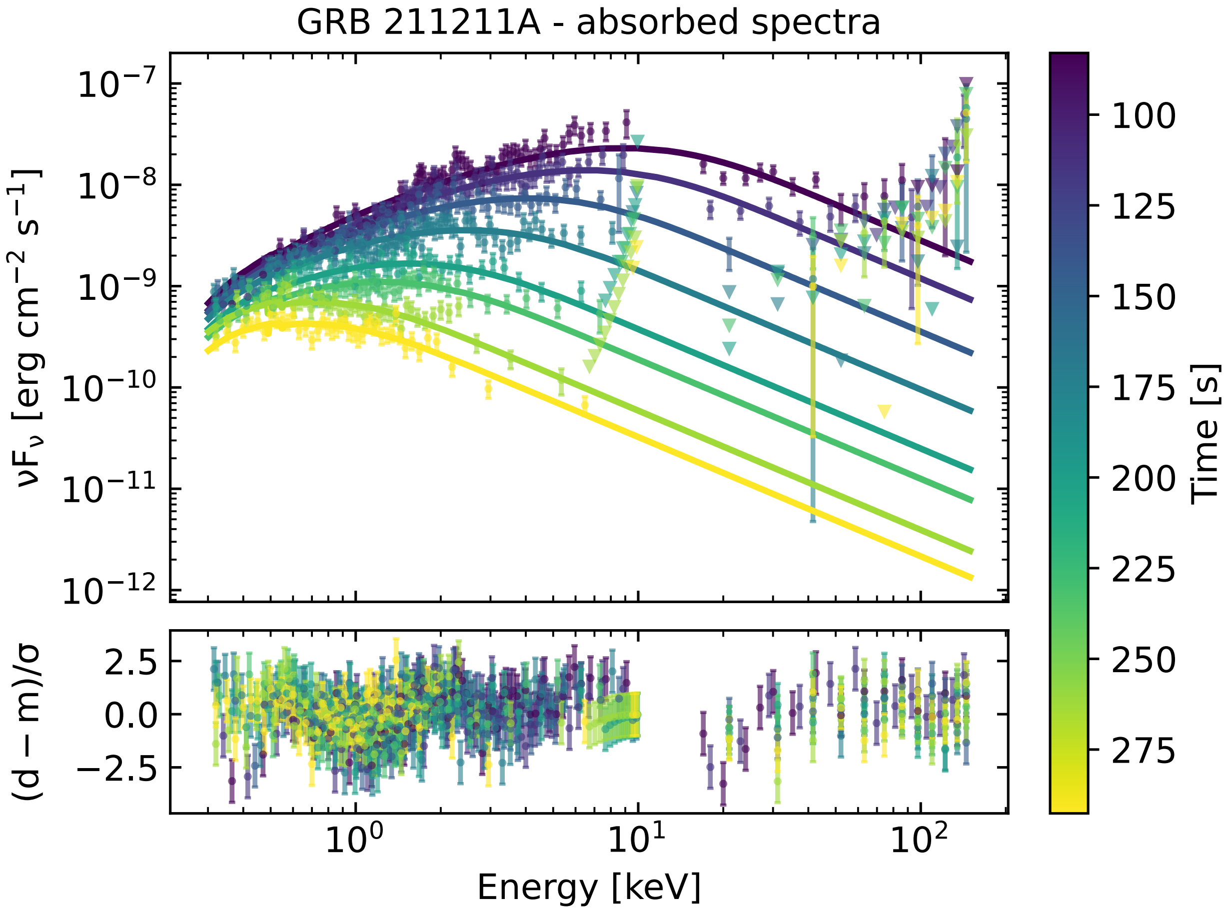
Model

- Empirical modelling of early X-ray flux and spectral evolution

- Cooling of a non-thermal spectrum, whose peak is transiting across the instruments band

- Tested spectral models: synchrotron and sBPL

- We accounted for neutral Hydrogen absorption in the Milky-Way and in the host galaxy



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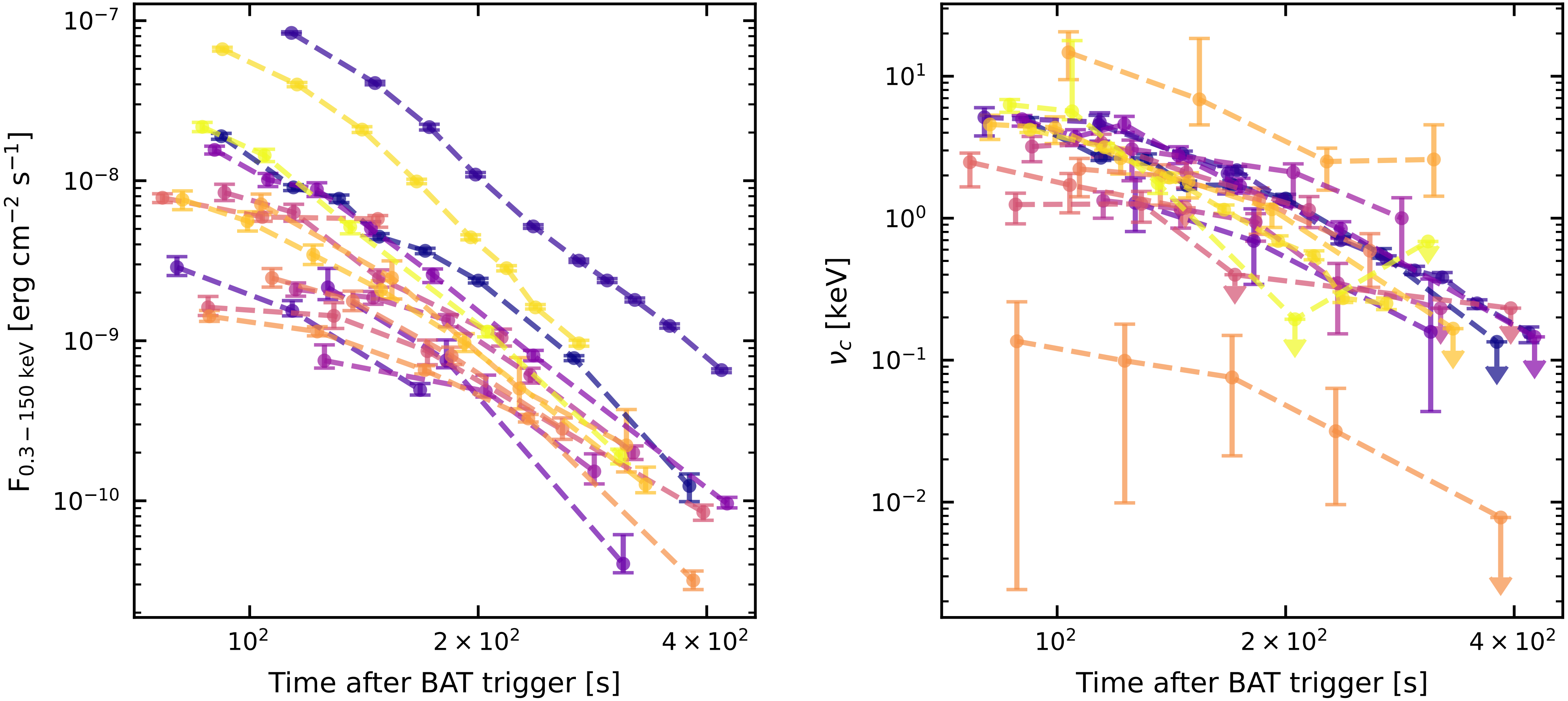
Results



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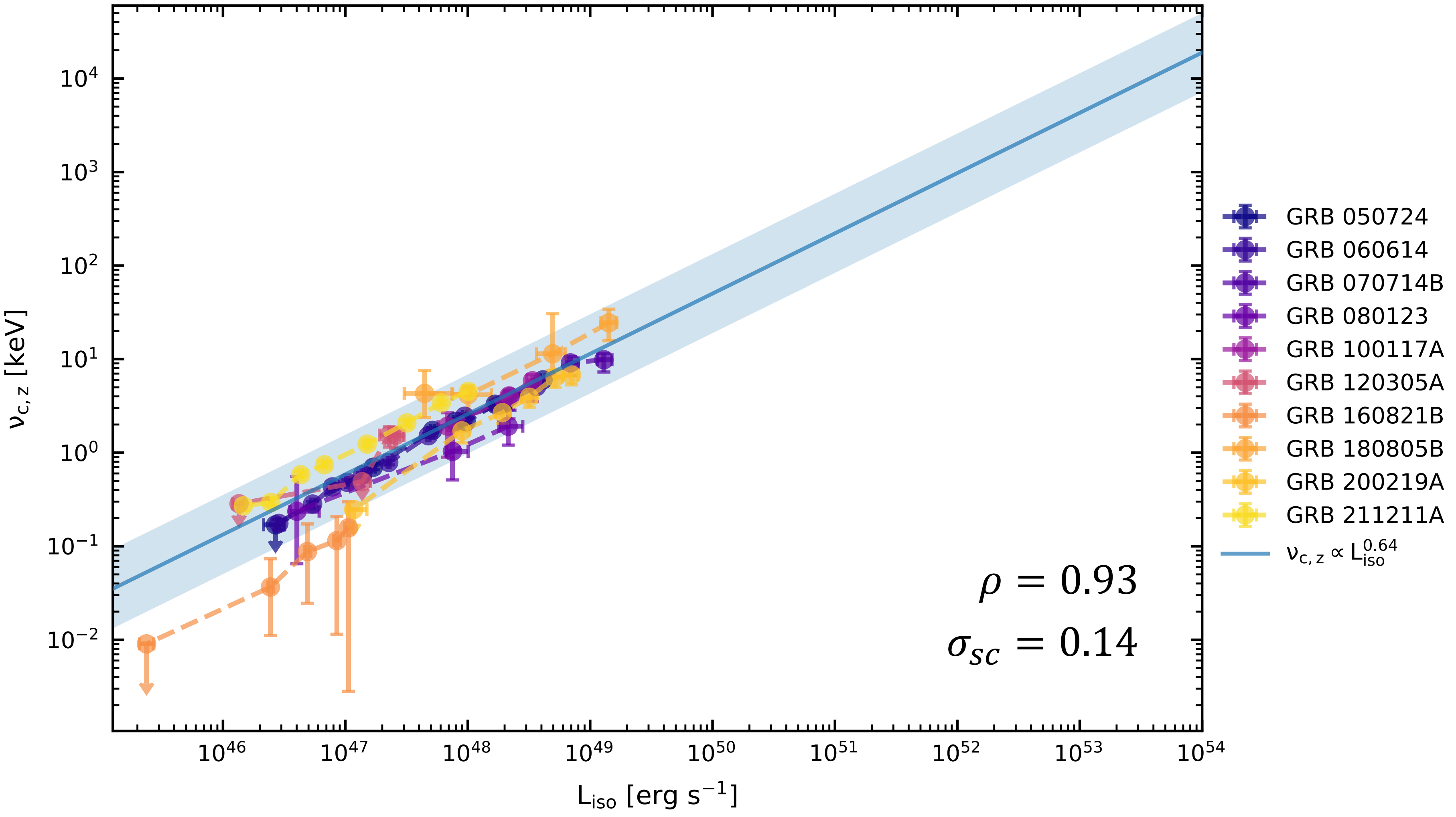
$\nu_{c,z} - L_{iso}$ relation (synchrotron model)



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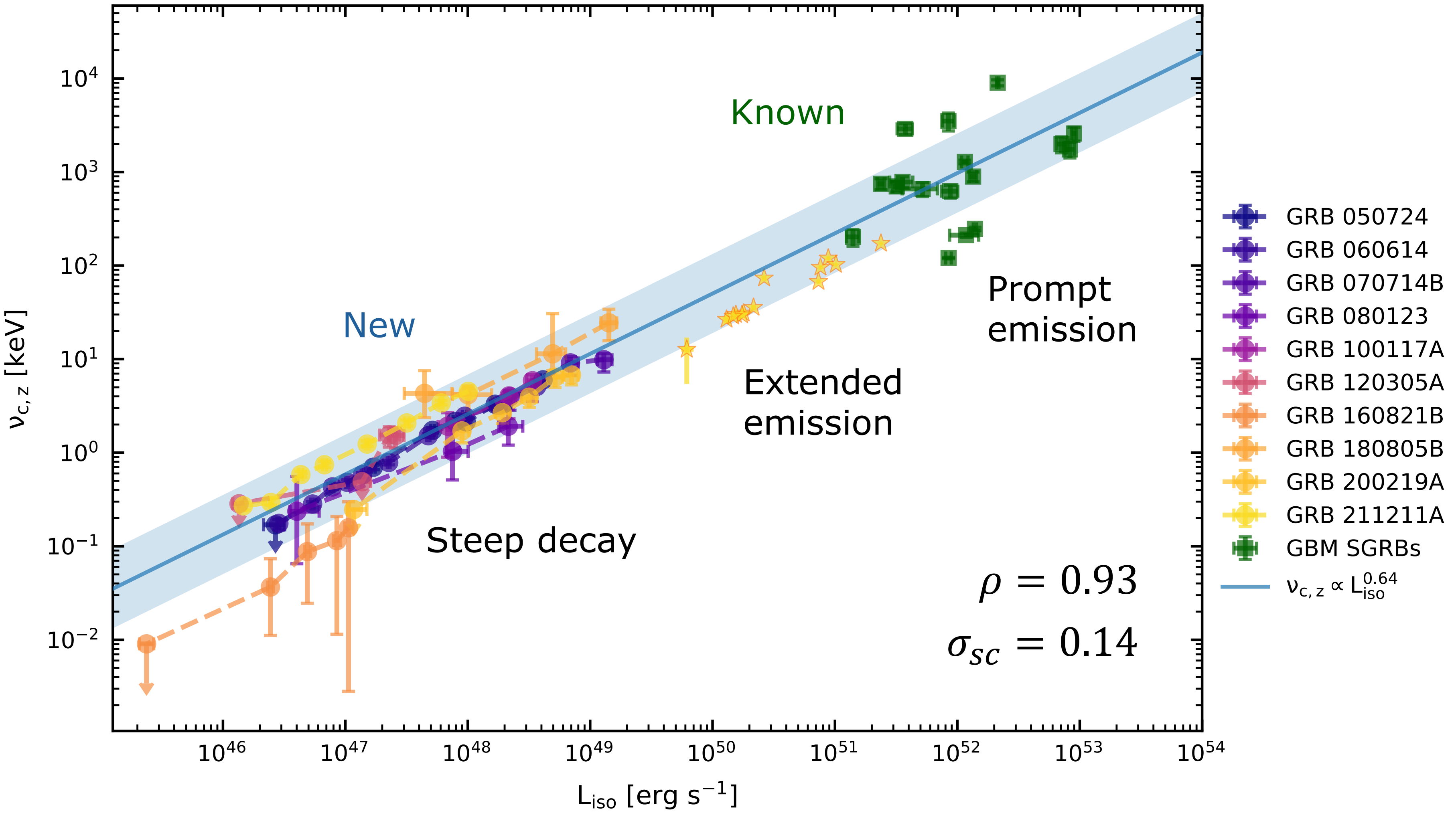

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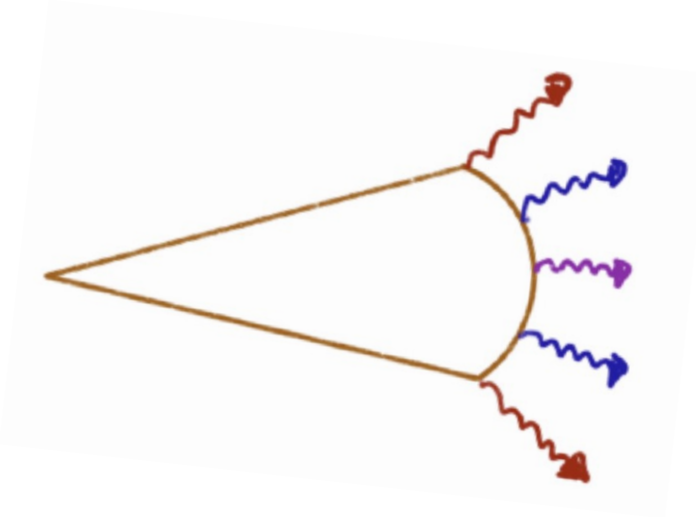
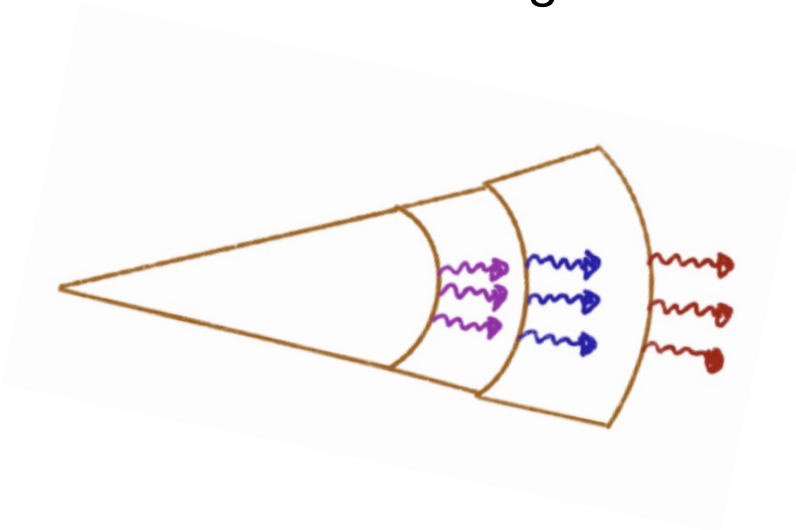
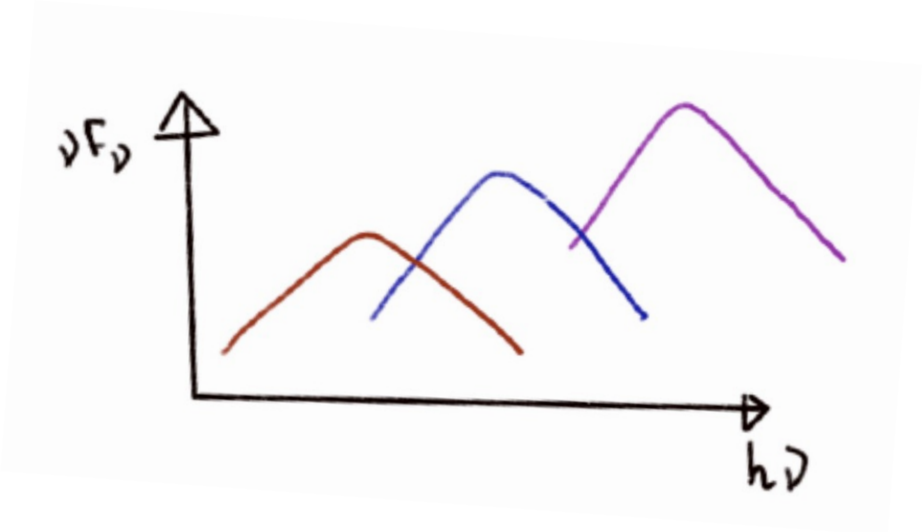
Physical interpretation

High latitude emission ✗

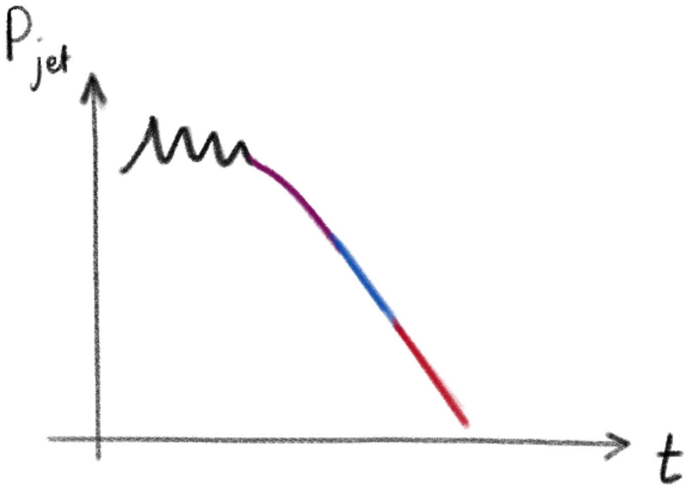


Adiabatic cooling ✓



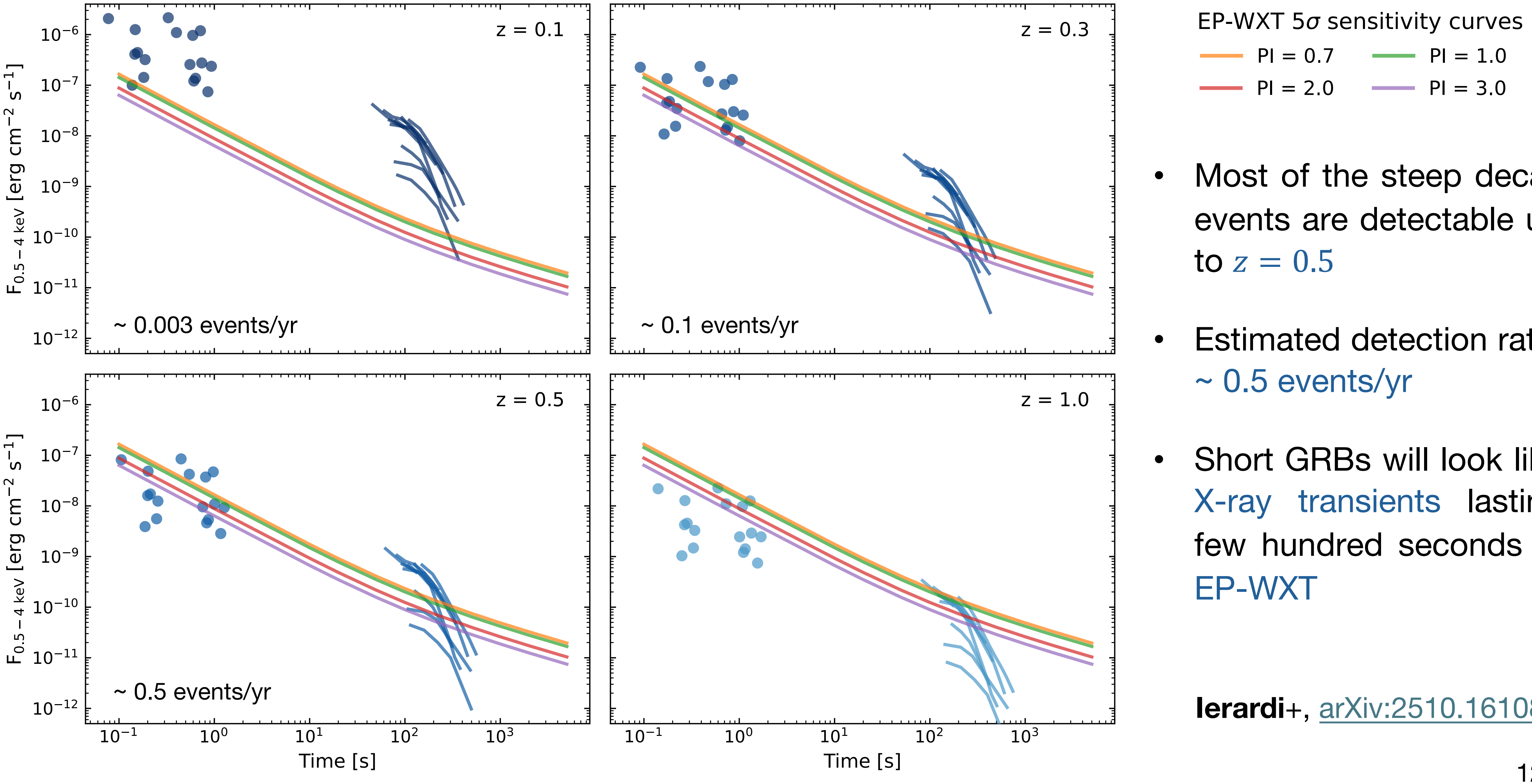


Jet power decline ✓



Credit: G. Oganesyan

Detectability with EP-WXT



- Most of the steep decay events are detectable up to $z = 0.5$
- Estimated detection rate: ~ 0.5 events/yr
- Short GRBs will look like X-ray transients lasting few hundred seconds in EP-WXT

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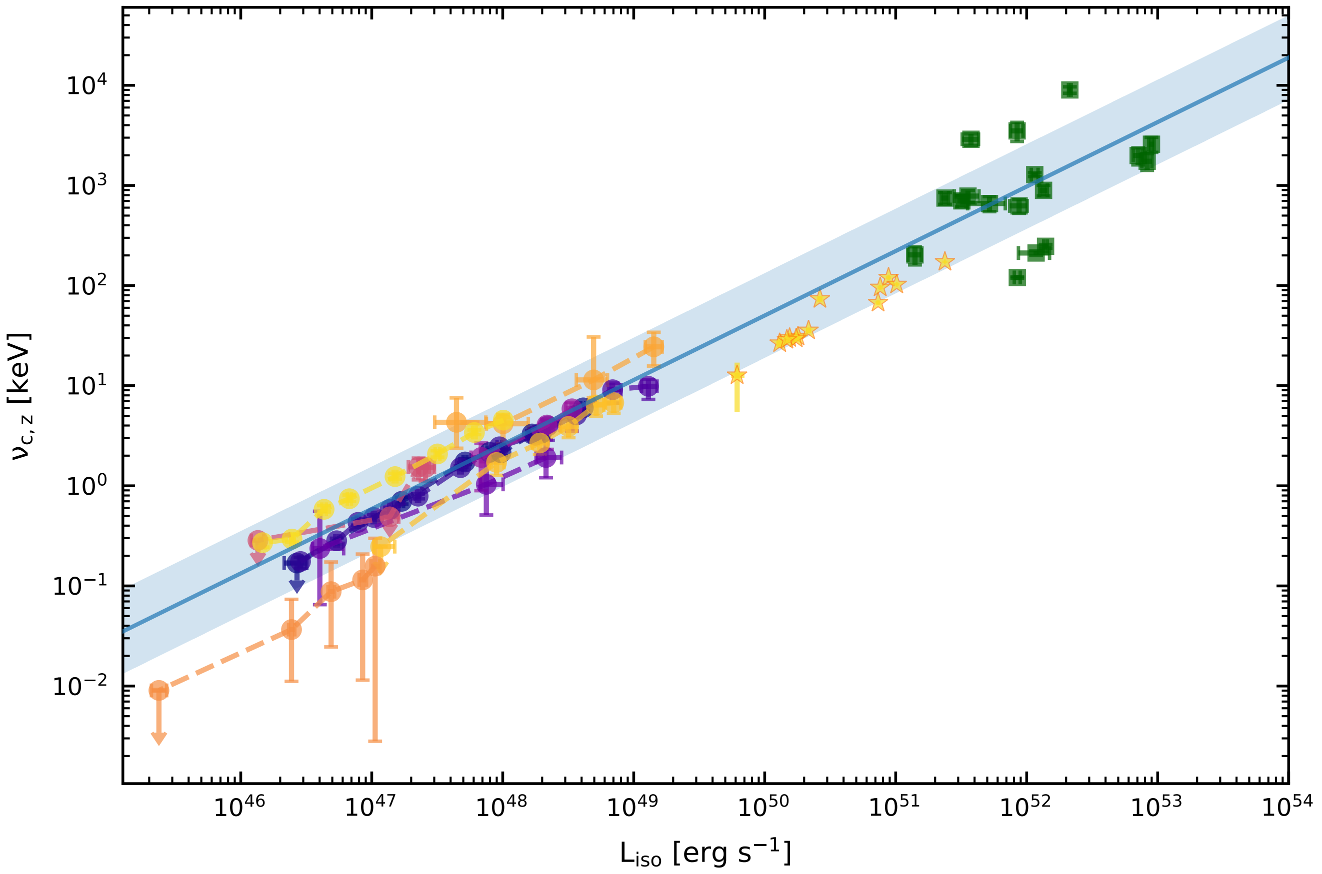
Summary

TeV Particle Astrophysics TeVPA Valencia 2025

- We characterized the temporal and spectral evolution of the early X-ray emission of merger-driven GRB candidates
- We discovered a new peak energy-luminosity relation at low energies
- Short GRBs will look like X-ray transients lasting few hundred seconds in EP-WXT



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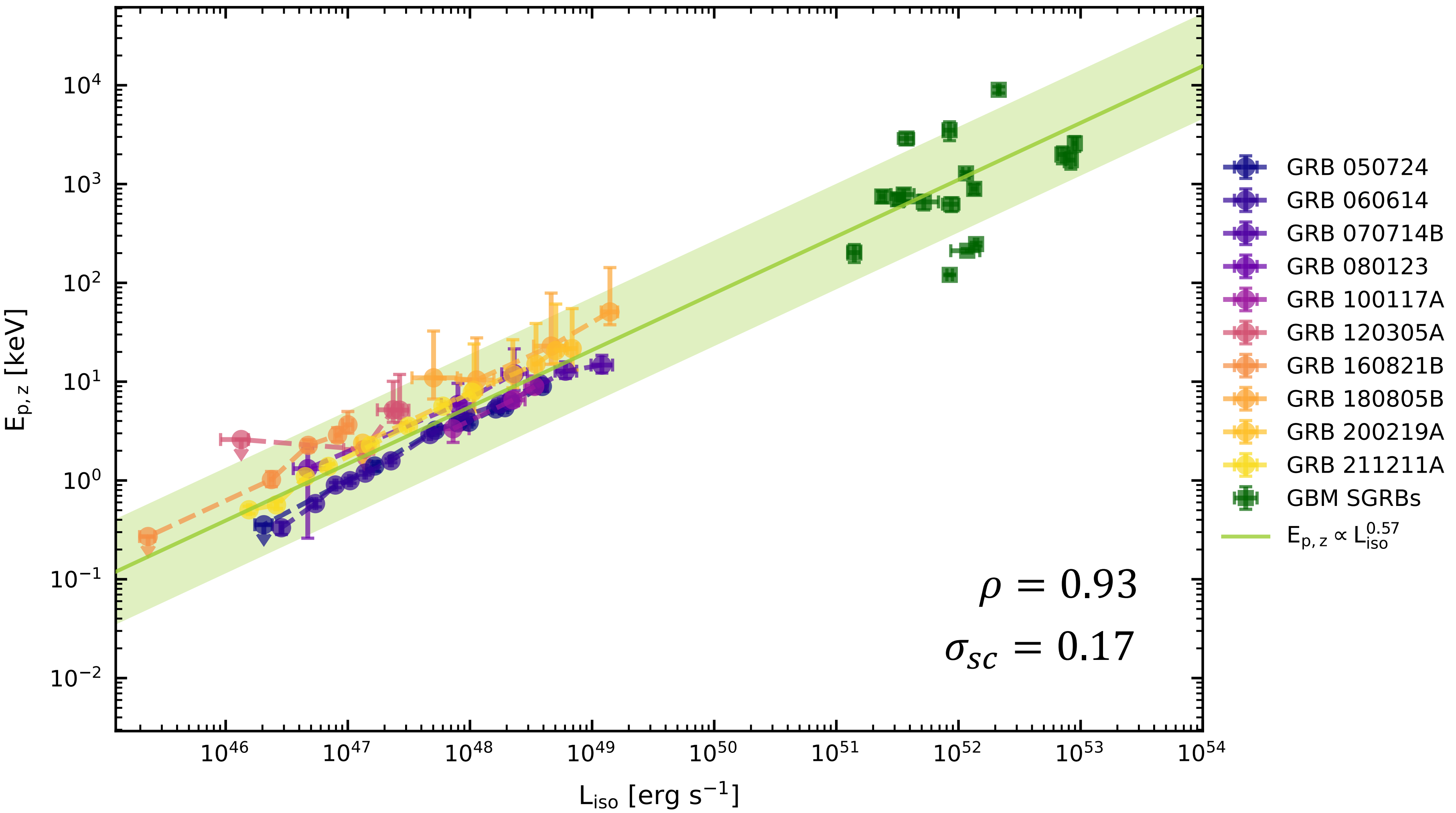
Backup

$E_{p,z} - L_{iso}$ relation (sBPL model)



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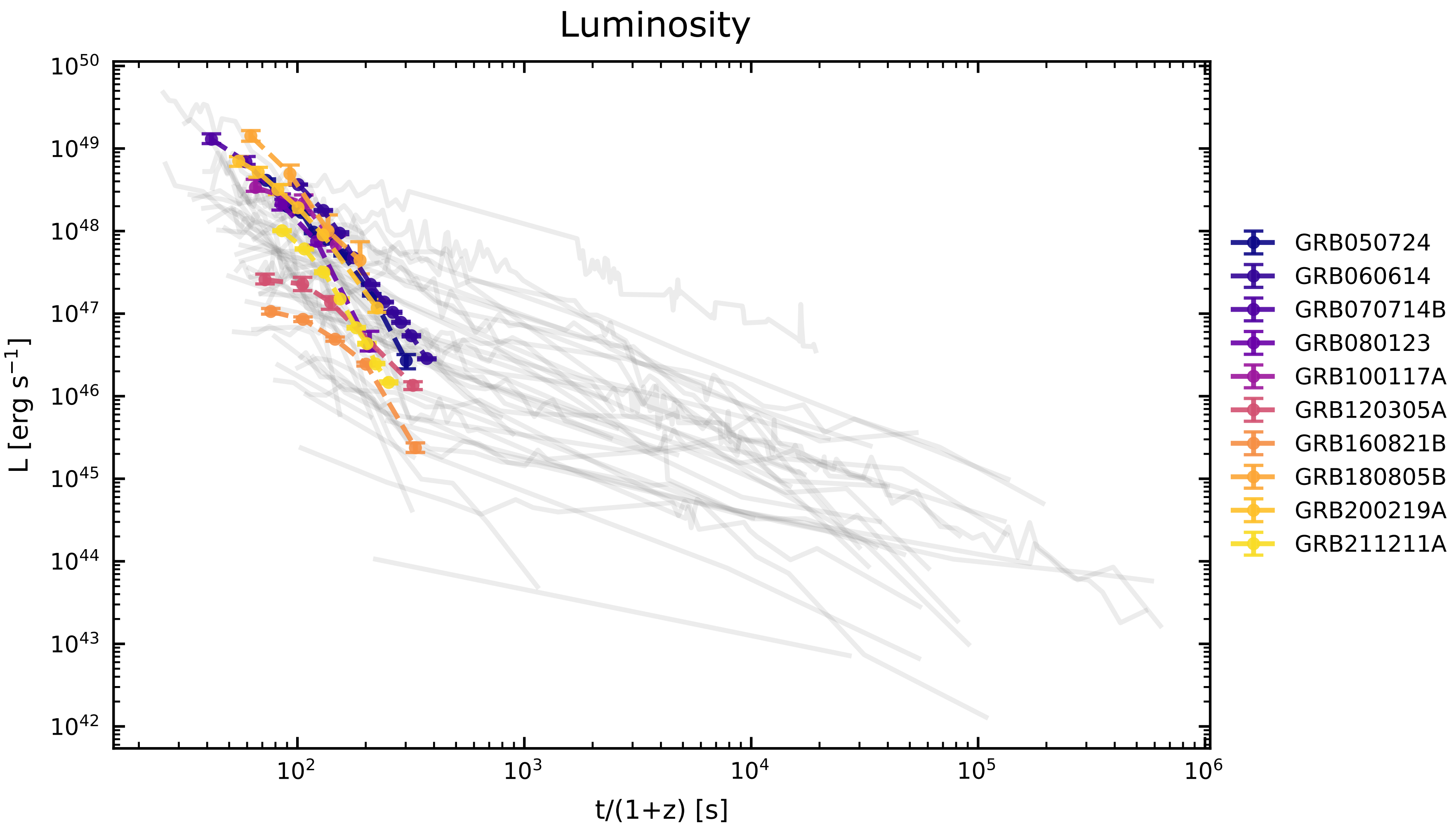
Detectability with EP-WXT

- Our sample is representative of all the XRT-detected short GRB population

- We can assess the detectability of short GRBs with EP-WXT



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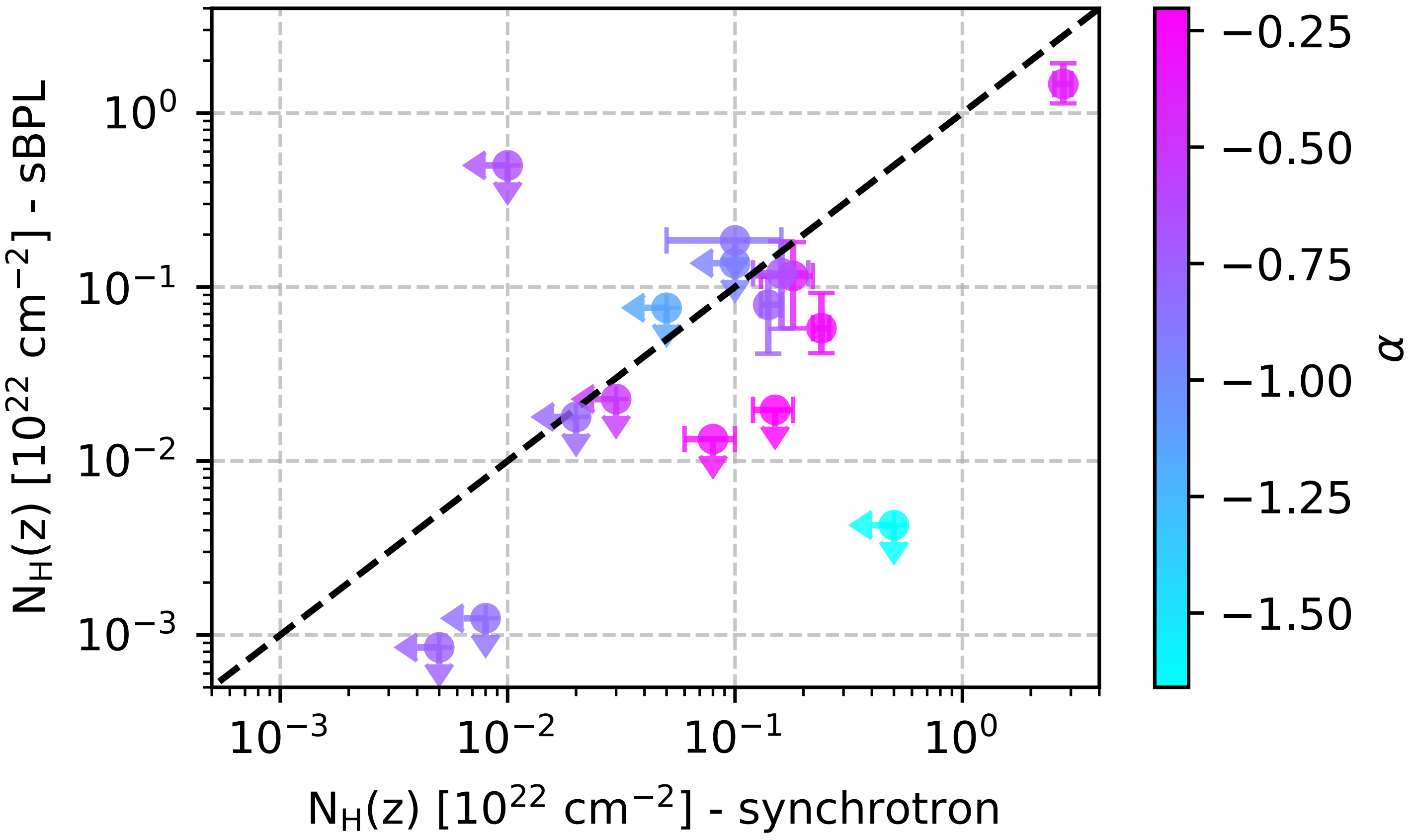
Neutral hydrogen absorption

- Fitted $N_H(z)$ values generally consistent with the ones expected from host galaxies of merger-driven GRBs



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Detectability with EP-WXT

Assuming that all short GRBs originate from BNS

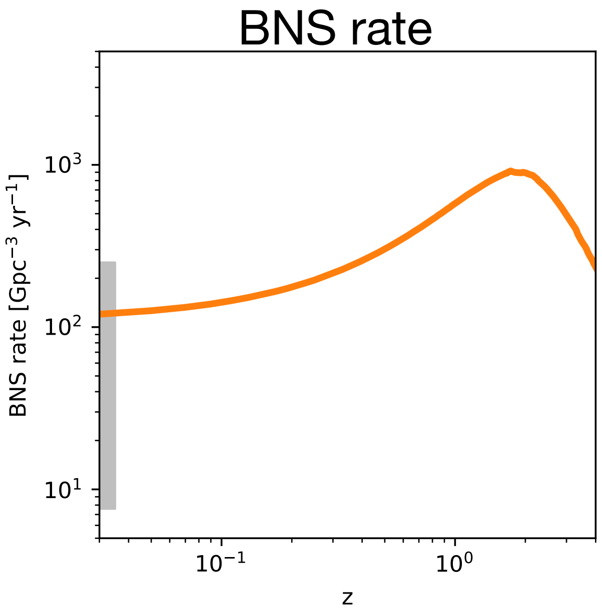
Detection rate →

$$\frac{dN}{dt} = \int_0^{z_{max}} dz\, R_{BNS}(z)\, \frac{dV}{dz}\, f_\theta\, f_j\, f_\Omega$$

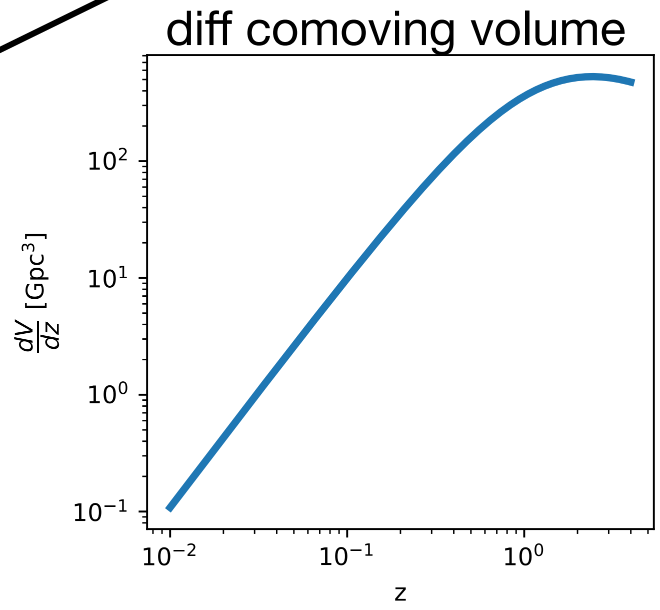
fraction of successful jets

sky coverage

fraction of on-axis jets



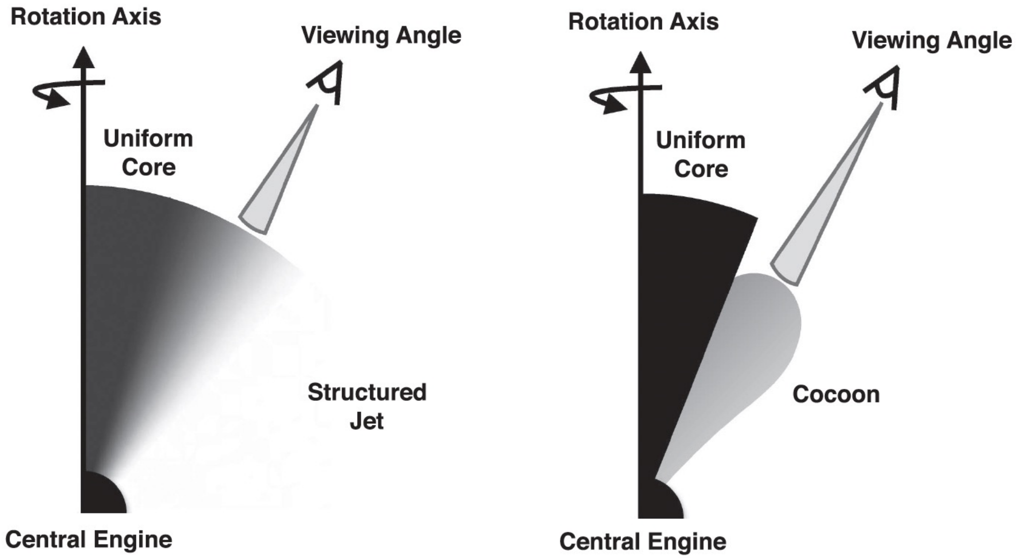
Iorio et al. 2023

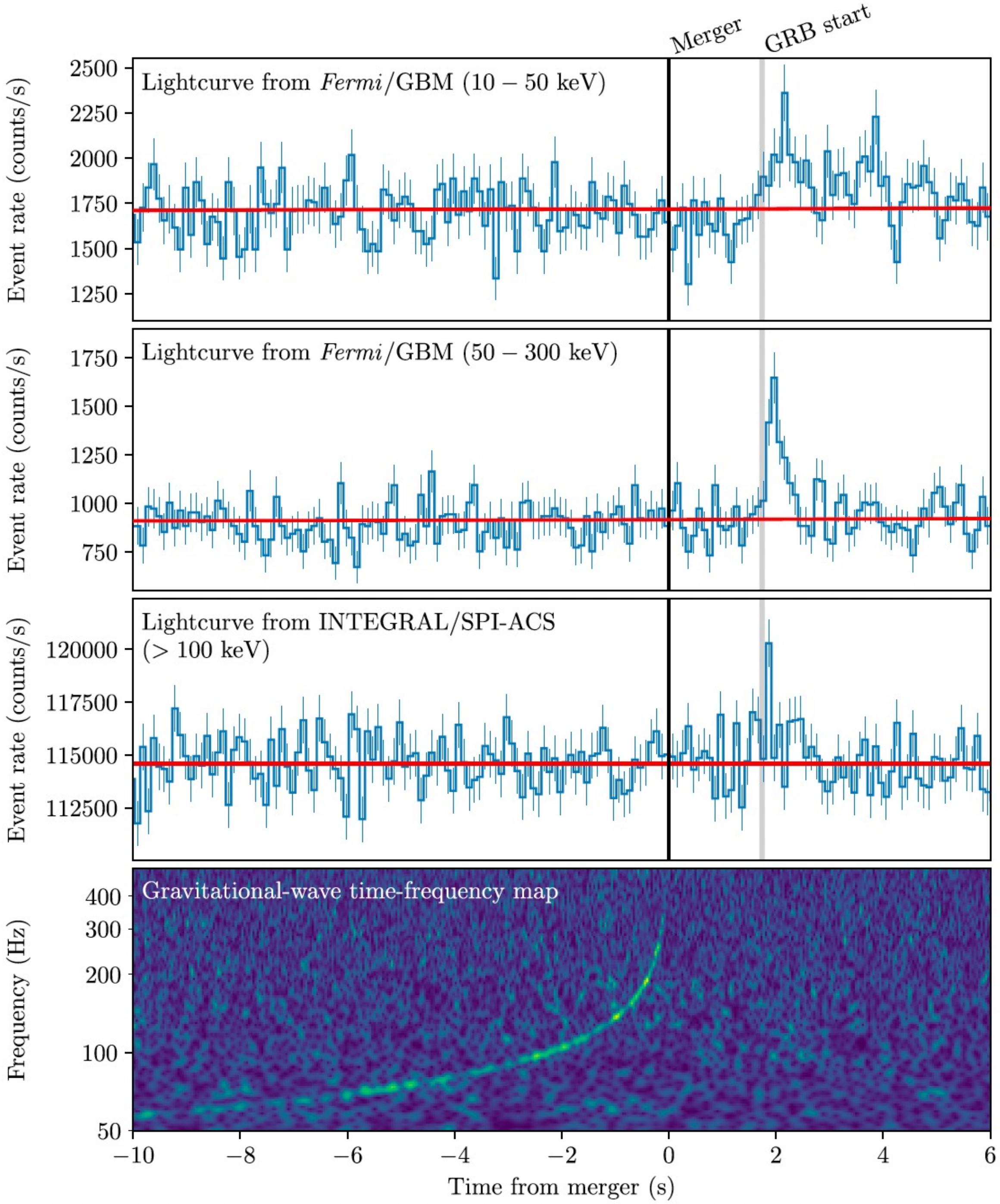


- Detection rate independent of the value chosen for the local BNS rate
- f_j optimized to reproduce the detection rate of short GRBs by Fermi-GBM

(De Santis et al. 2025, in preparation)

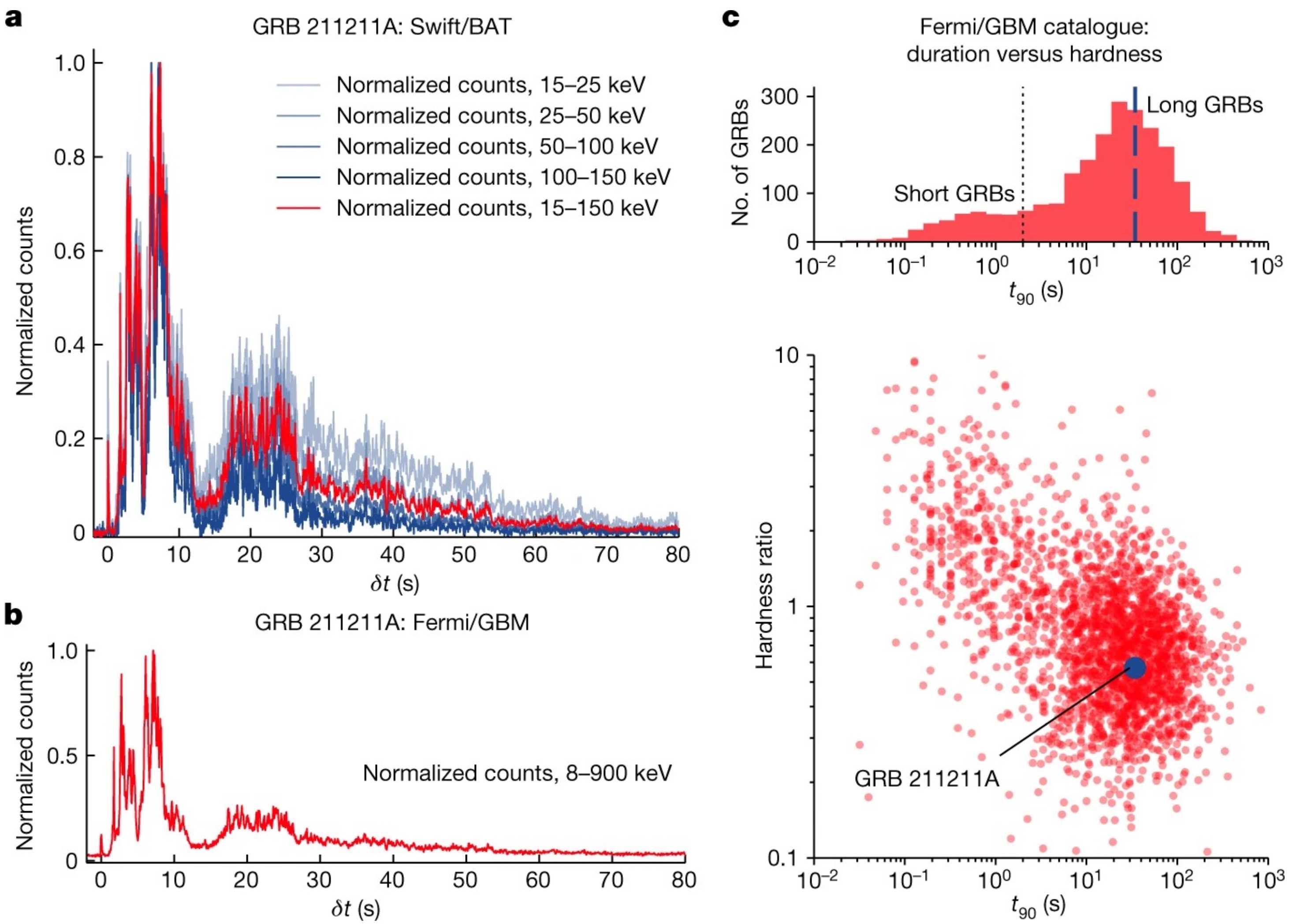
What is it?

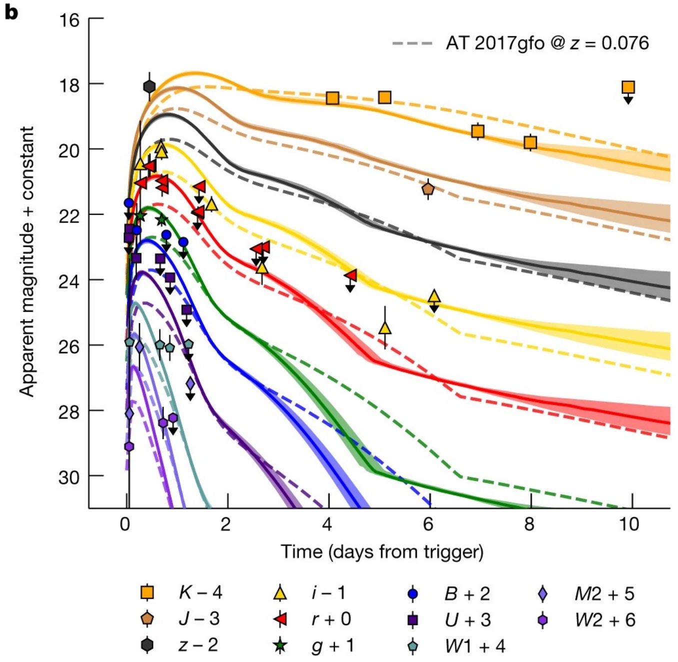




Abbott et al. 2017

Oddballs





See also:

GRB 060614 (N. Gehrels et al. 2006)

GRB 230307A (A. Levan et al. 2024)

J. Rastinejad et al. 2022