GRB 221009A: The BOAT

Antonio de Ugarte Postigo (CNRS - Observatoire de la Côte d'Azur)

7 September 2023

GRB 221009A: The Brightest Of All Time

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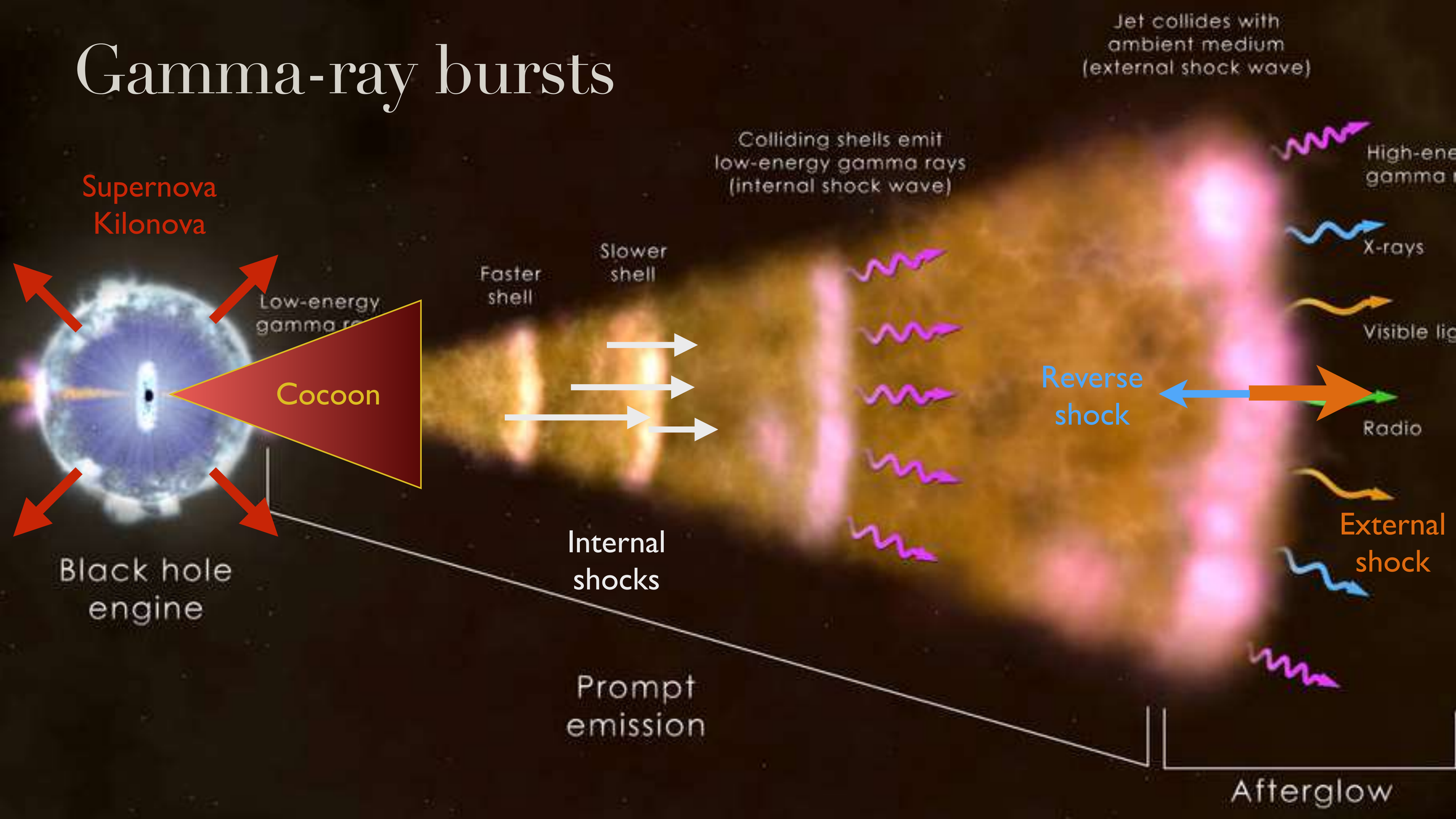
Gamma-ray bursts

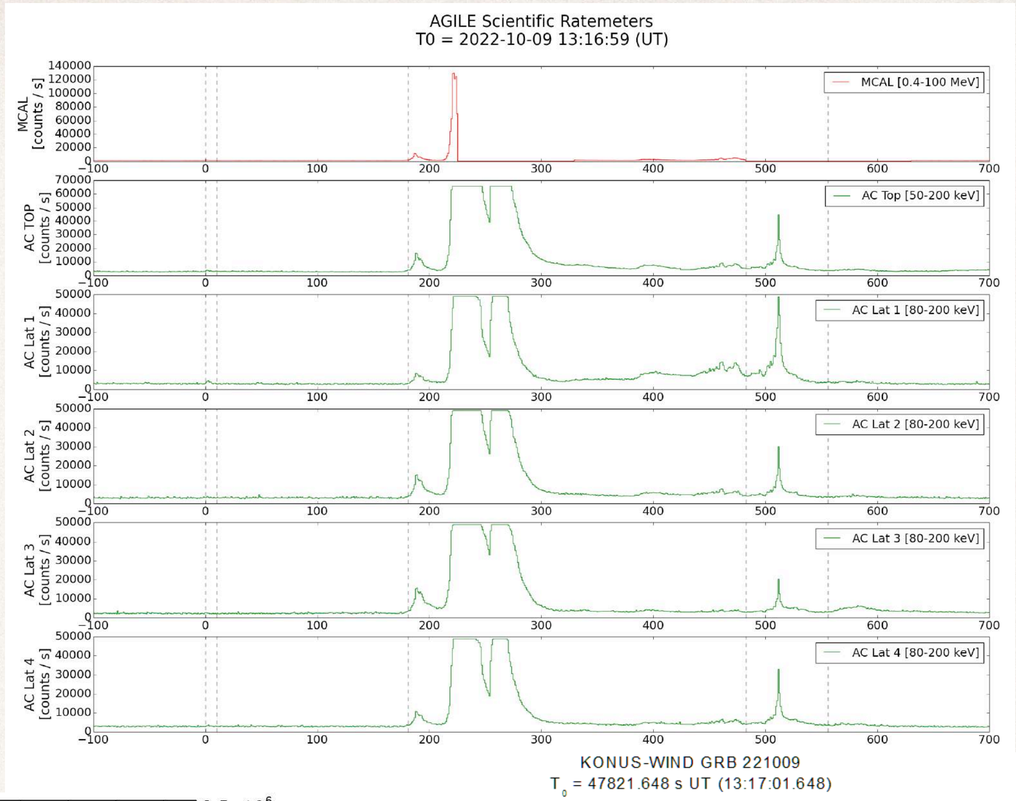


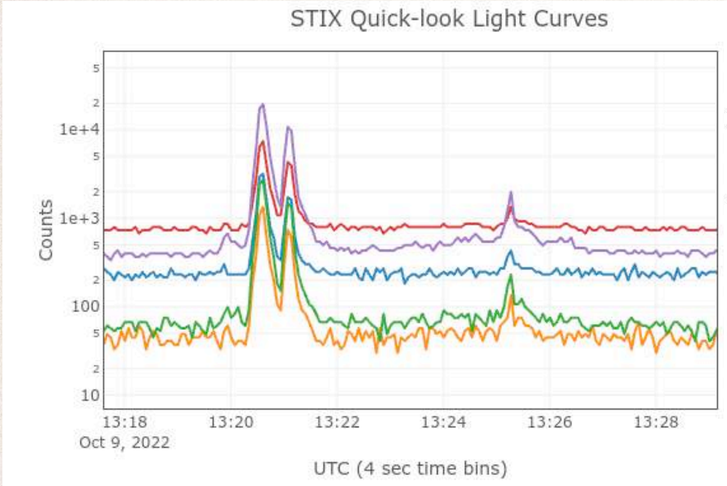
Discovery of GRB 221009A

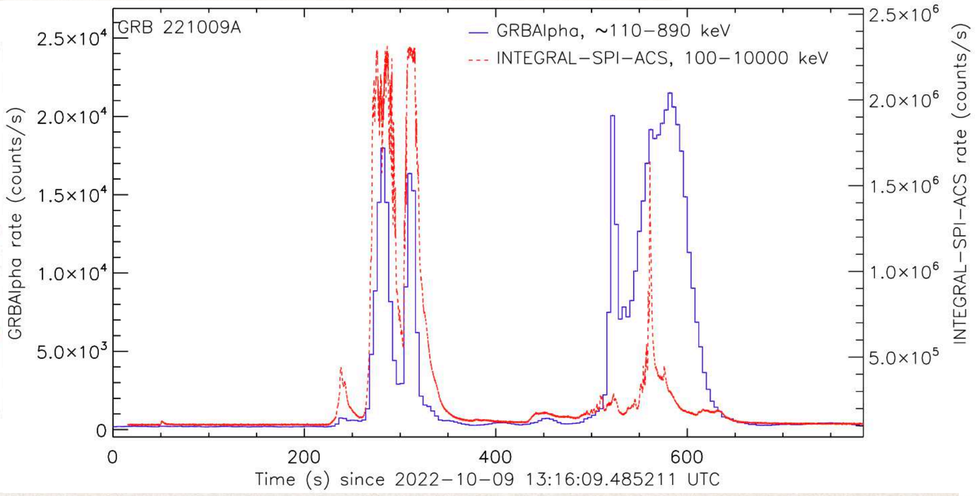
- Initially identified by *Swift* as a Galactic source Swift J1913.1+1946
  - Was in the galactic plane
  - Slow evolution
  - Triggered on the afterglow
- *Fermi*/GBM reported it as an extremely bright GRB almost an hour before *Swift*

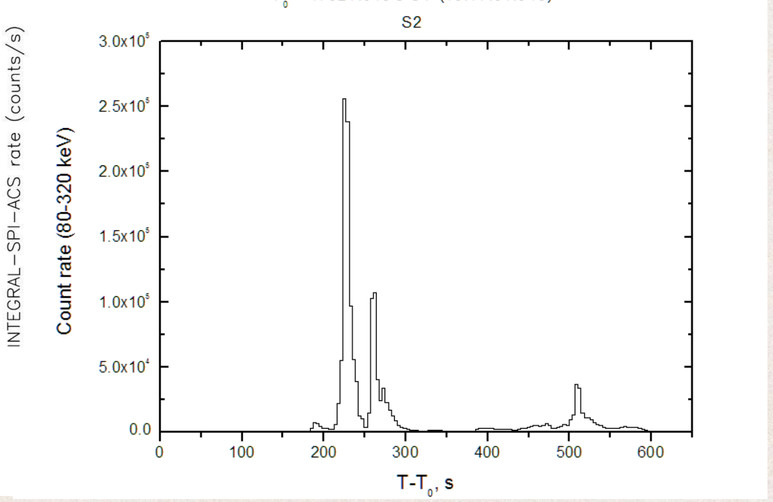
An extremely bright event

- Detected by: *Fermi* (GBM & LAT), *Swift*, *MAXI*, *INTEGRAL*, *Insight*-HXMT/HE, *Konus*-Wind, *IPN*, *AGILE*, *STIX*, *ART*-XC, *GRBAlpha*, *SIRI-2*, *HEBS*, …
- Saturated many of the detectors



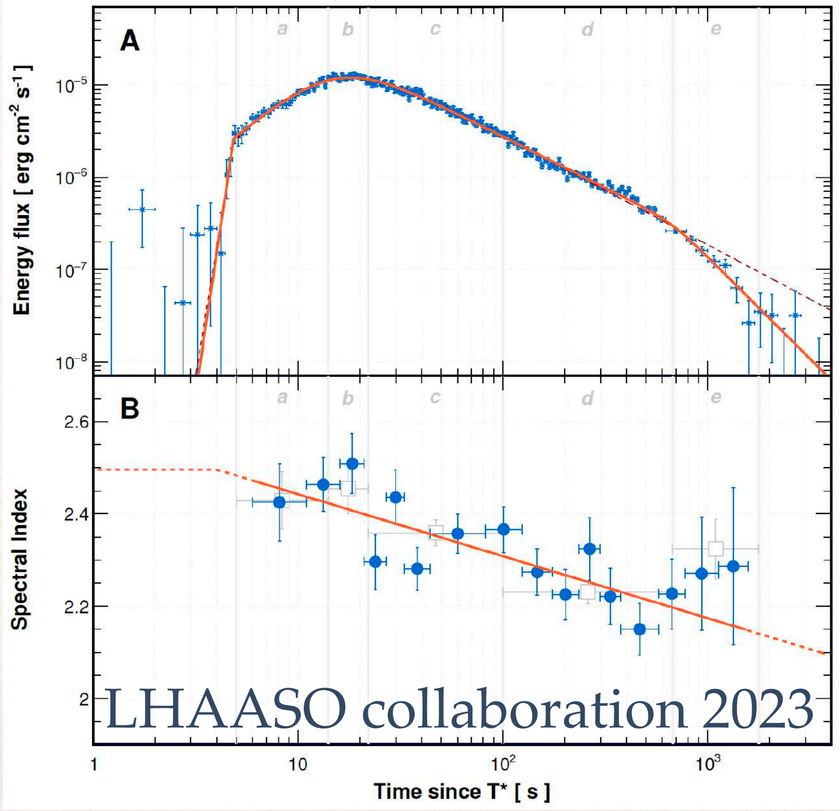






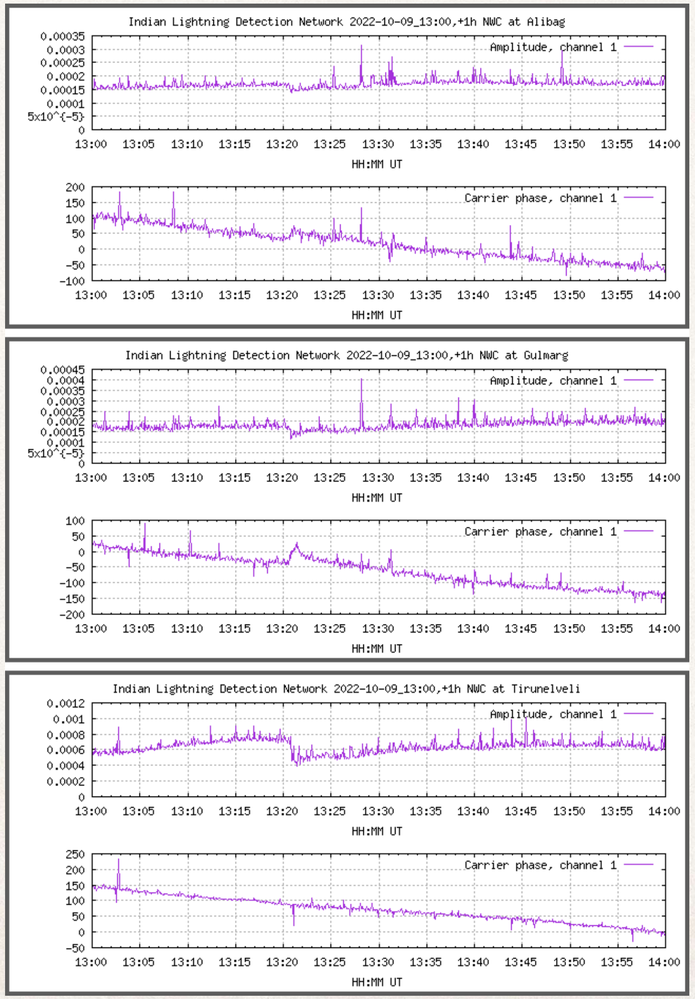
LHAASO detection at 18TeV

- Large High Altitude Air Shower Observatory (LHAASO)
- Sensitive to 10^{11} and 10^{15} eV
- Located in Tibet
- More than 64 000 photons above 0.2 TeV
- Starting minutes after the GRB



Disturbances in the Earth's ionosphere

- Detected by radio transmitters at < 100 kHz
- Schnoor et al. GCN 32744, Guha et al. GCN 32745



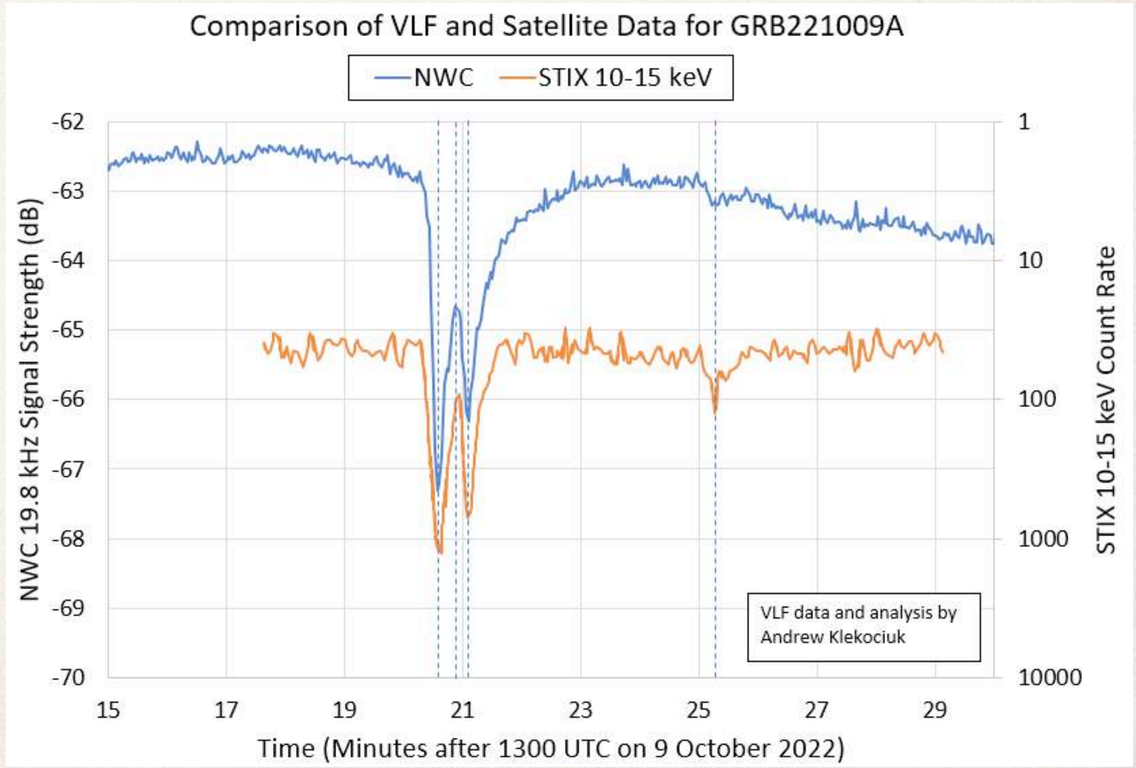
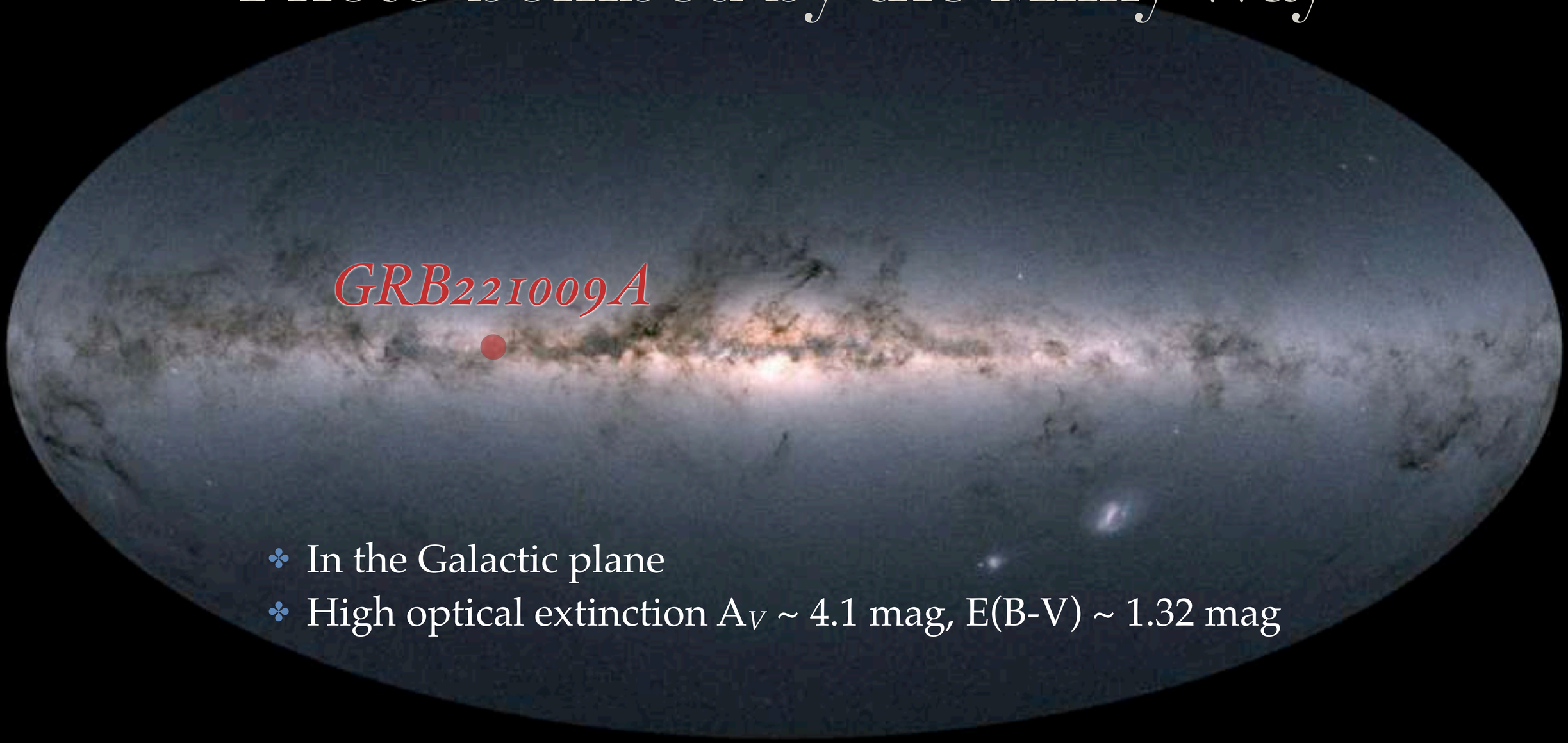
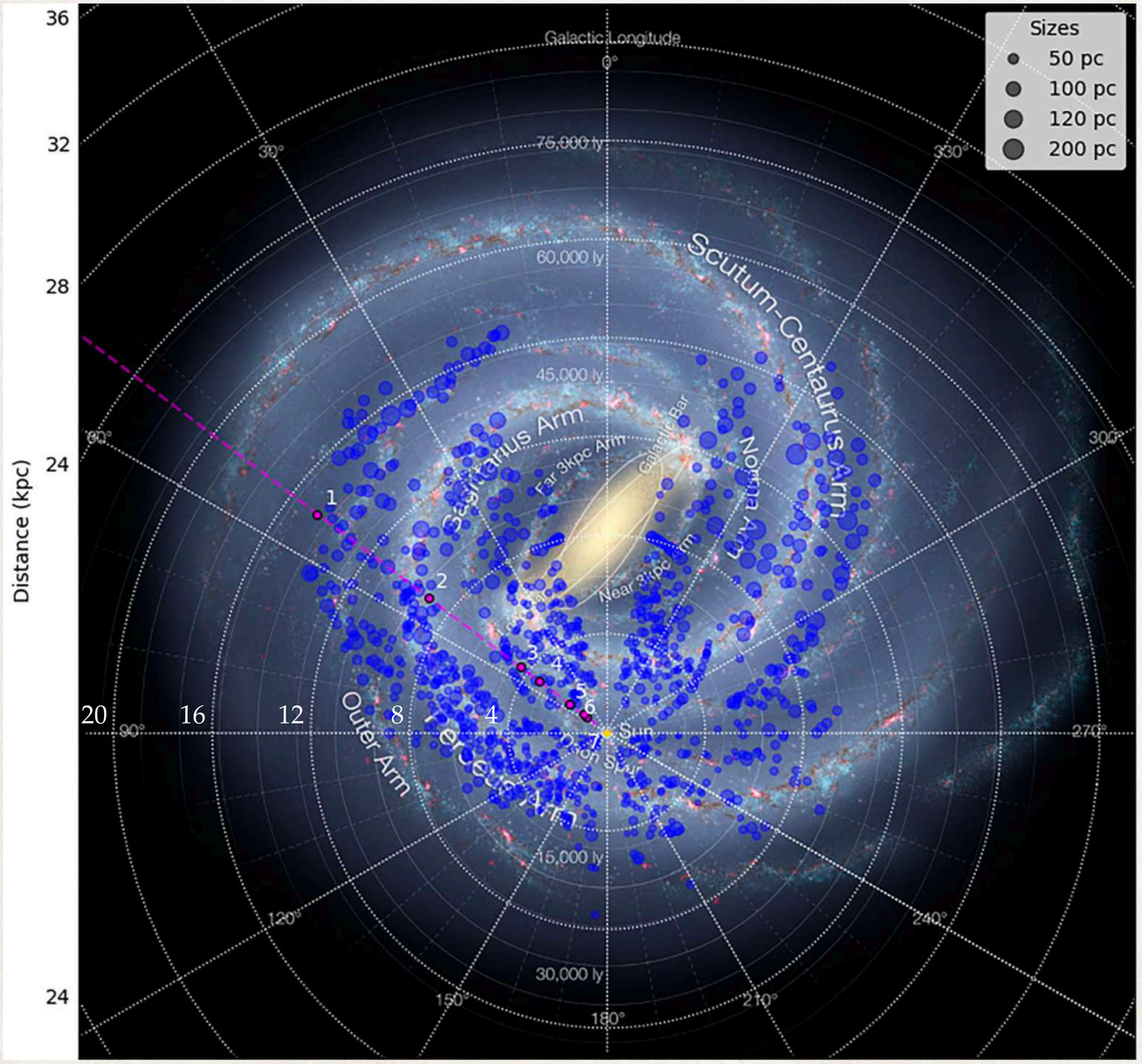


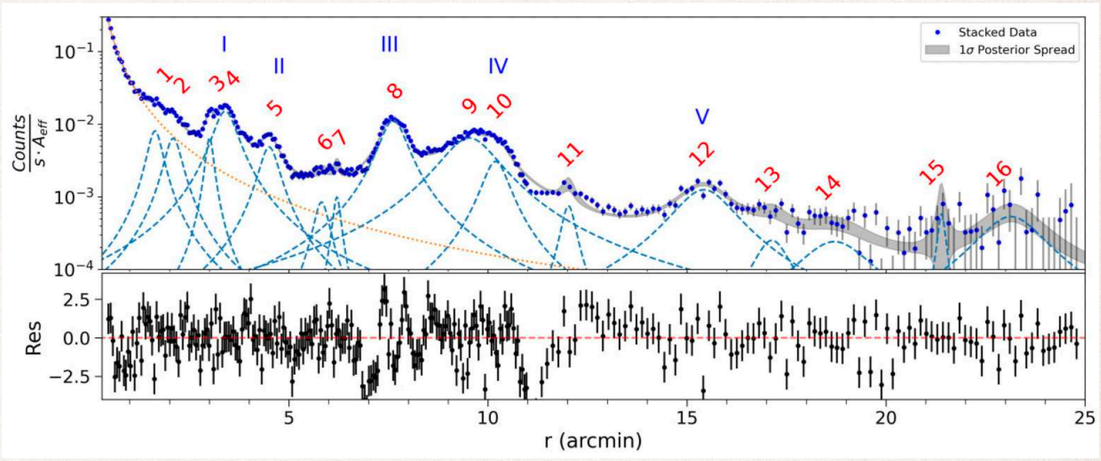
Photo-bombed by the Milky Way

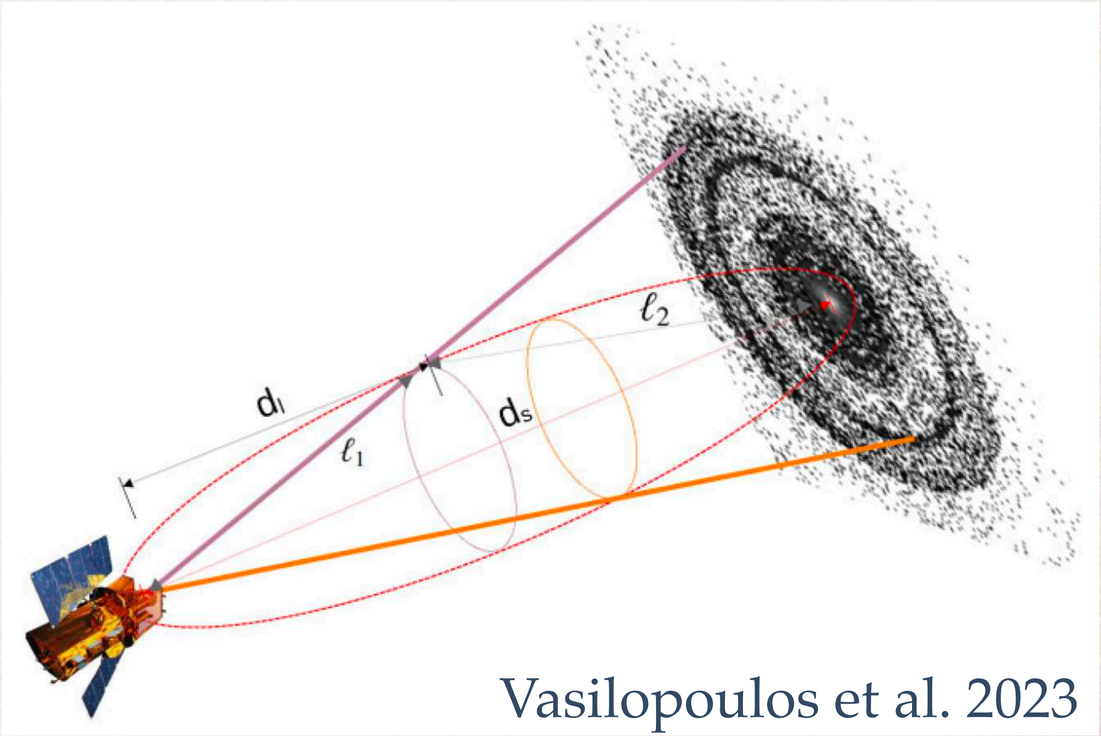


- In the Galactic plane
- High optical extinction A_V ~ 4.1 mag, E(B-V) ~ 1.32 mag

Dust scattering of X-rays







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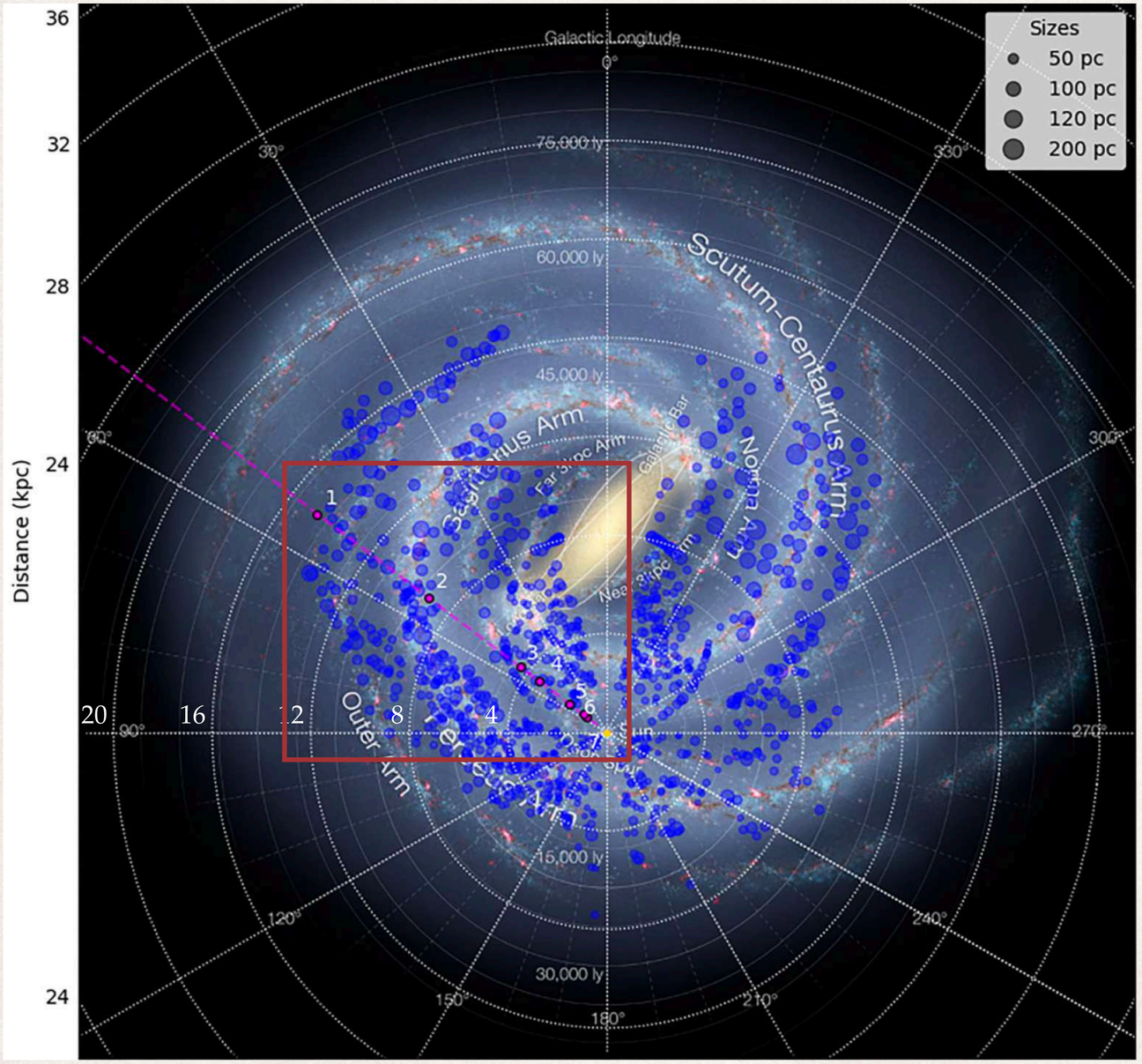

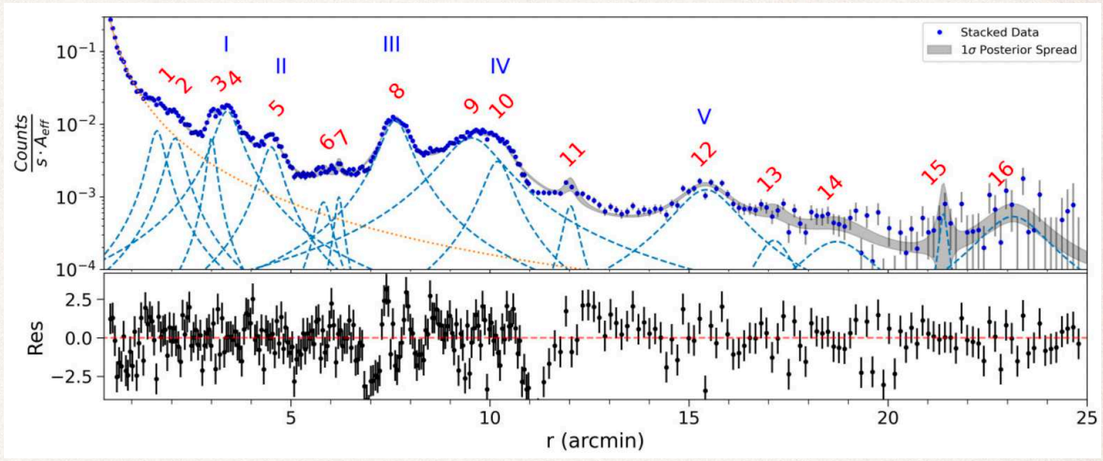

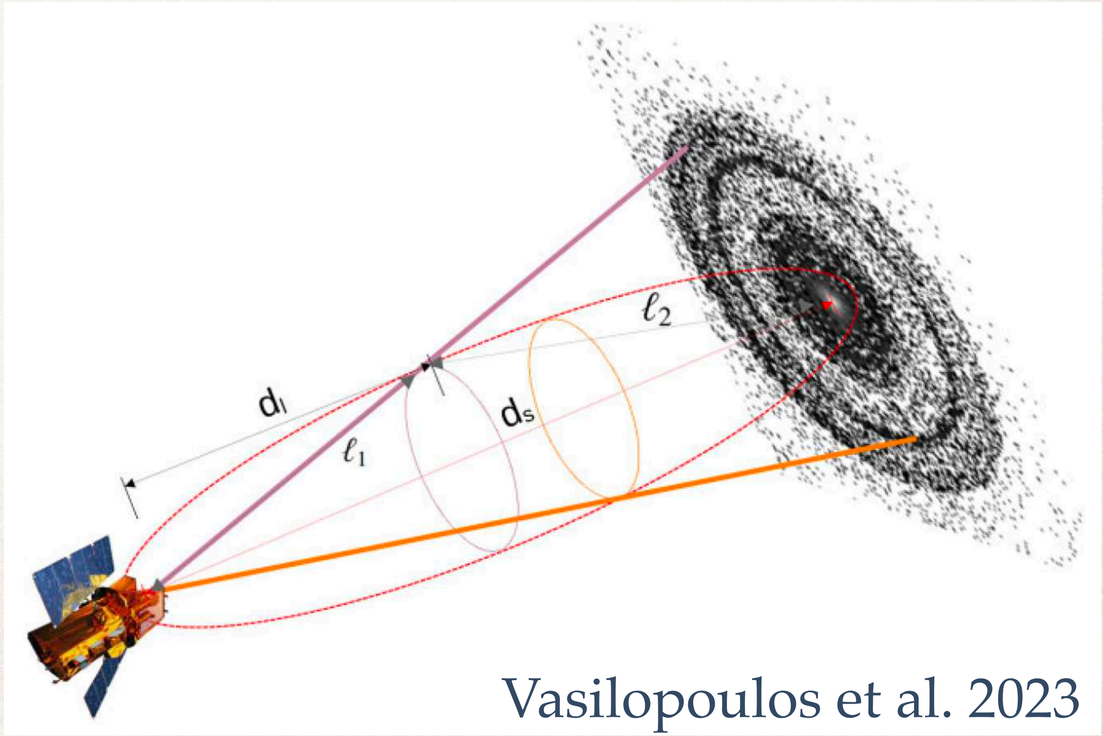

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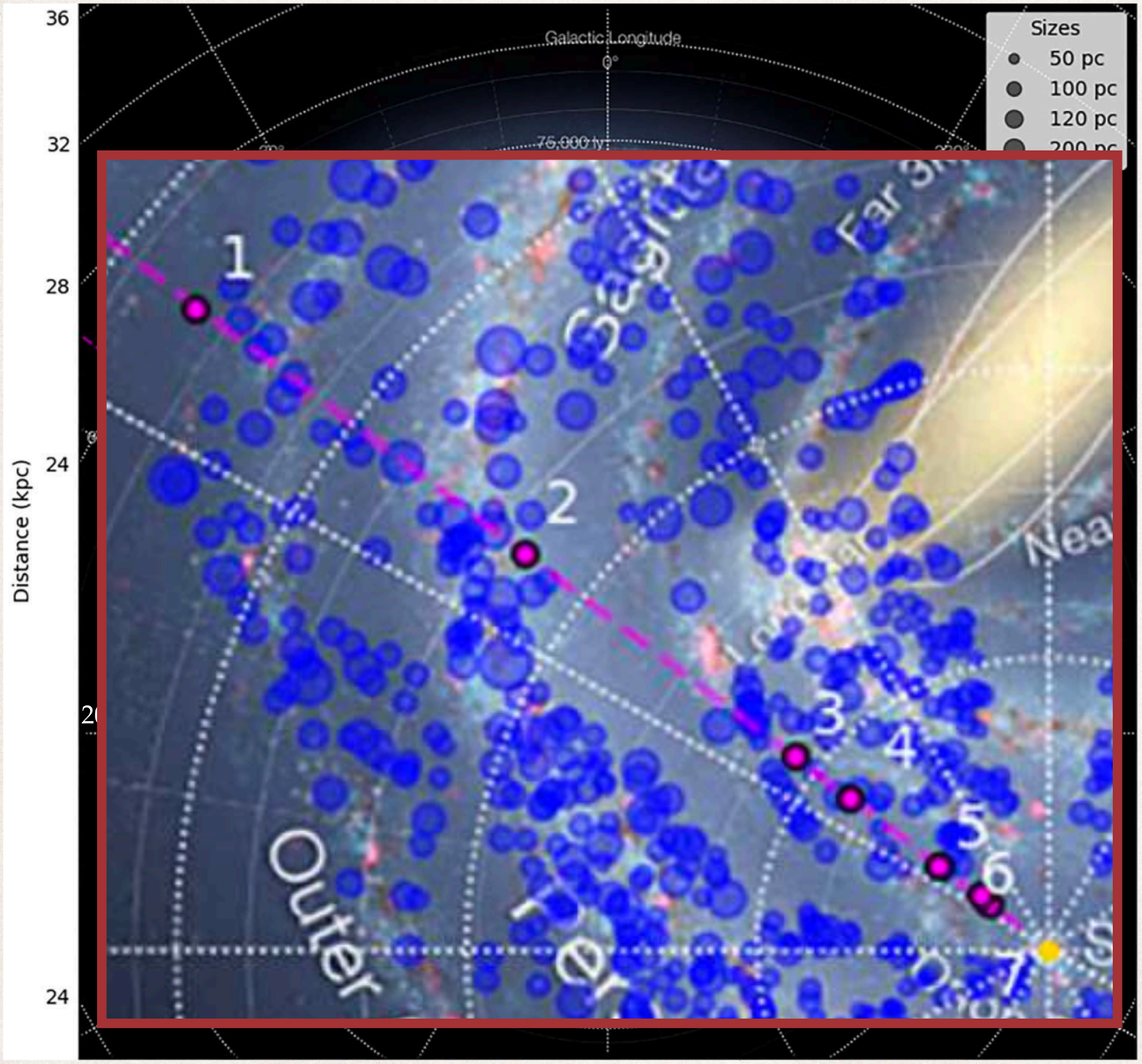
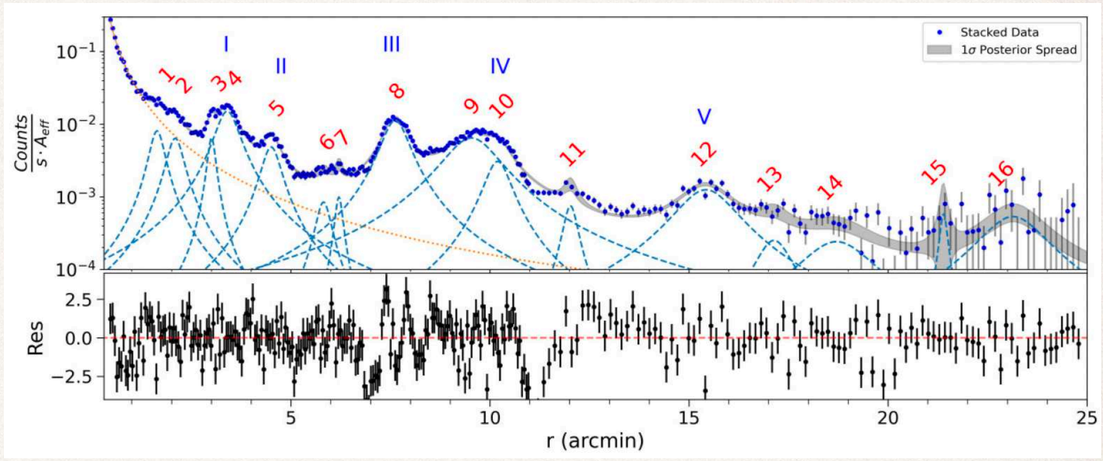
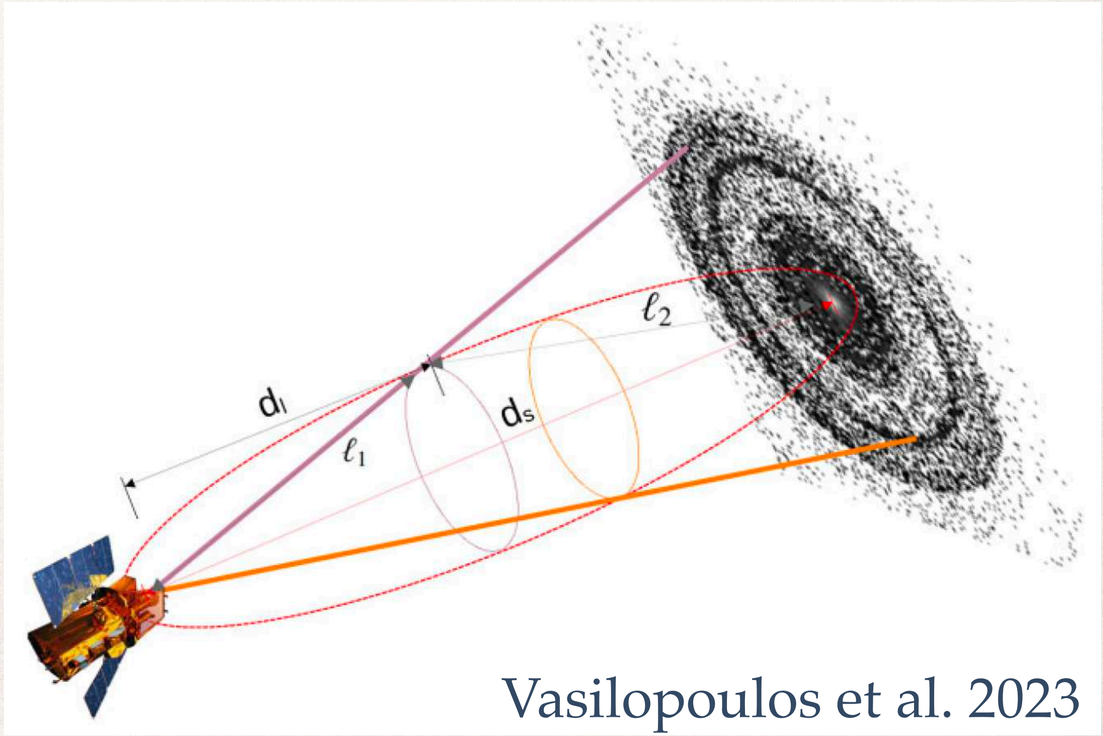


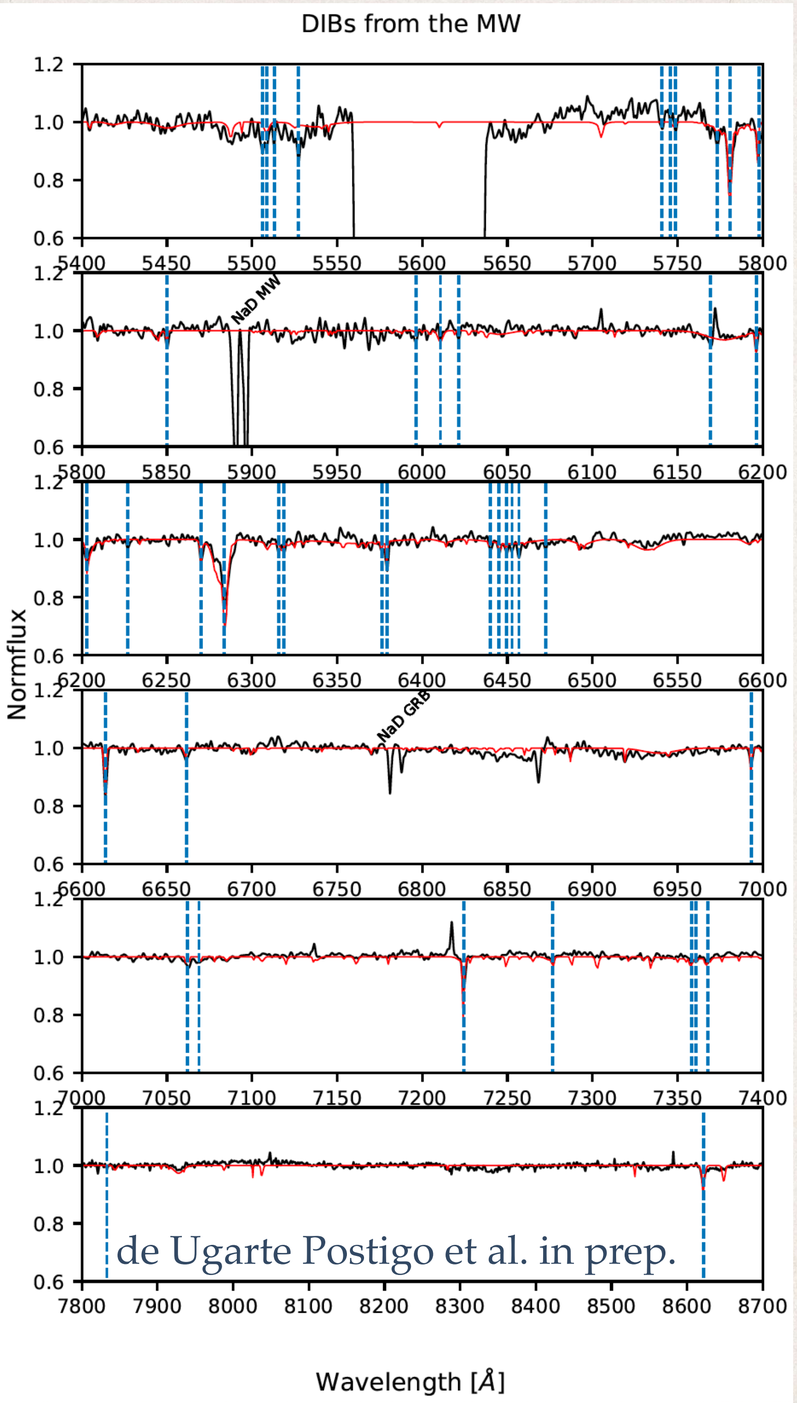




Vasilopoulos et al. 2023

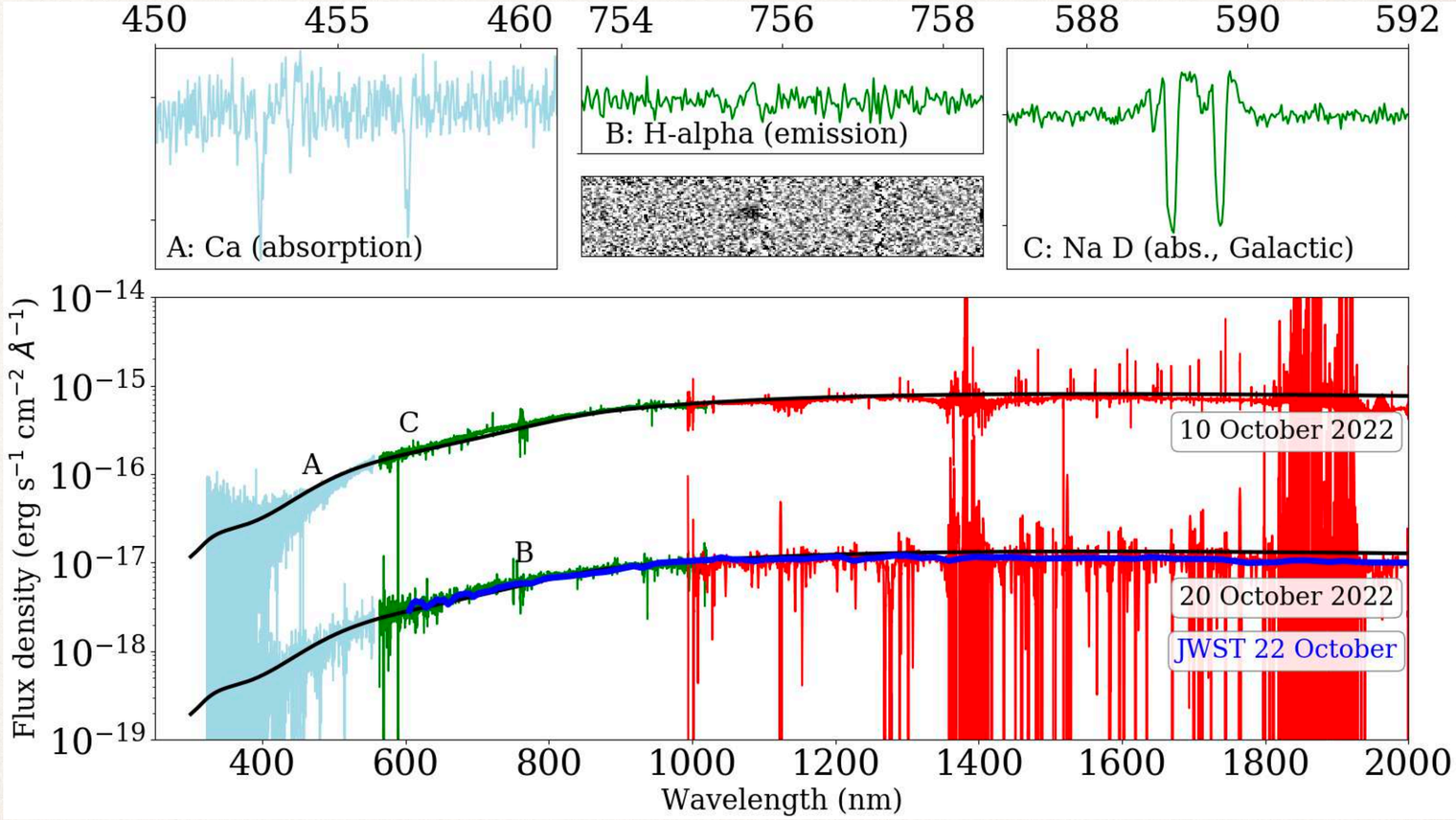
Diffuse interstellar bands

- Imprints of interstellar material in high-density Galactic sight lines
- Most carriers still unknown
- Related to extinction (Friedman et al. 2011):
  - E(B-V) [5780.50] = 1.46+/- 0.04
  - E(B-V) [6283.80] = 1.33+/- 0.04
  - E(B-V) [6204.50] = 1.72+/- 0.12
  - E(B-V) [6196.00] = 2.69+/- 0.21
  - E(B-V) [6613.60] = 1.50+/-0.05
  - E(B-V) [5797.10] = 2.38+/- 0.12
- And a weighted mean of <E(B-V)> = 1.48+/- 0.02



Distance and energetics

- $z = 0.151$ (1.9 Gly) from X-shooter
  (de Ugarte Postigo et al. GCN 32648; Malesani et al. 2023)
- Absorption and emission features
- Very energetic in gamma-rays
  $E_{iso} \gtrsim 1\text{-}1.5 \cdot 10^{55}$ erg
  (Kann & Agüí-Fernández 2022; Frederiks et al. 2023; S. Lesage et al. 2023)
- Follow-up with VLT, NOEMA, GRANDMA, GTC, HST, JWST, …



Once in a life time?

- Atteia GCN 32793:
  - one in 130-520 years 2023 (energetics)
- Malesani et al. 2023:
  - One in > 68 years (count rate)
  - One in > 112 years (fluence)
  - Up to one in a millennia
- Burns et al. 2023:
  - One in 10 000 years (energetics)
- Kann et al. 2023:

  It is unlikely that a chance like this will come again in the coming decades or even centuries, making this an event to be remembered through the ages.

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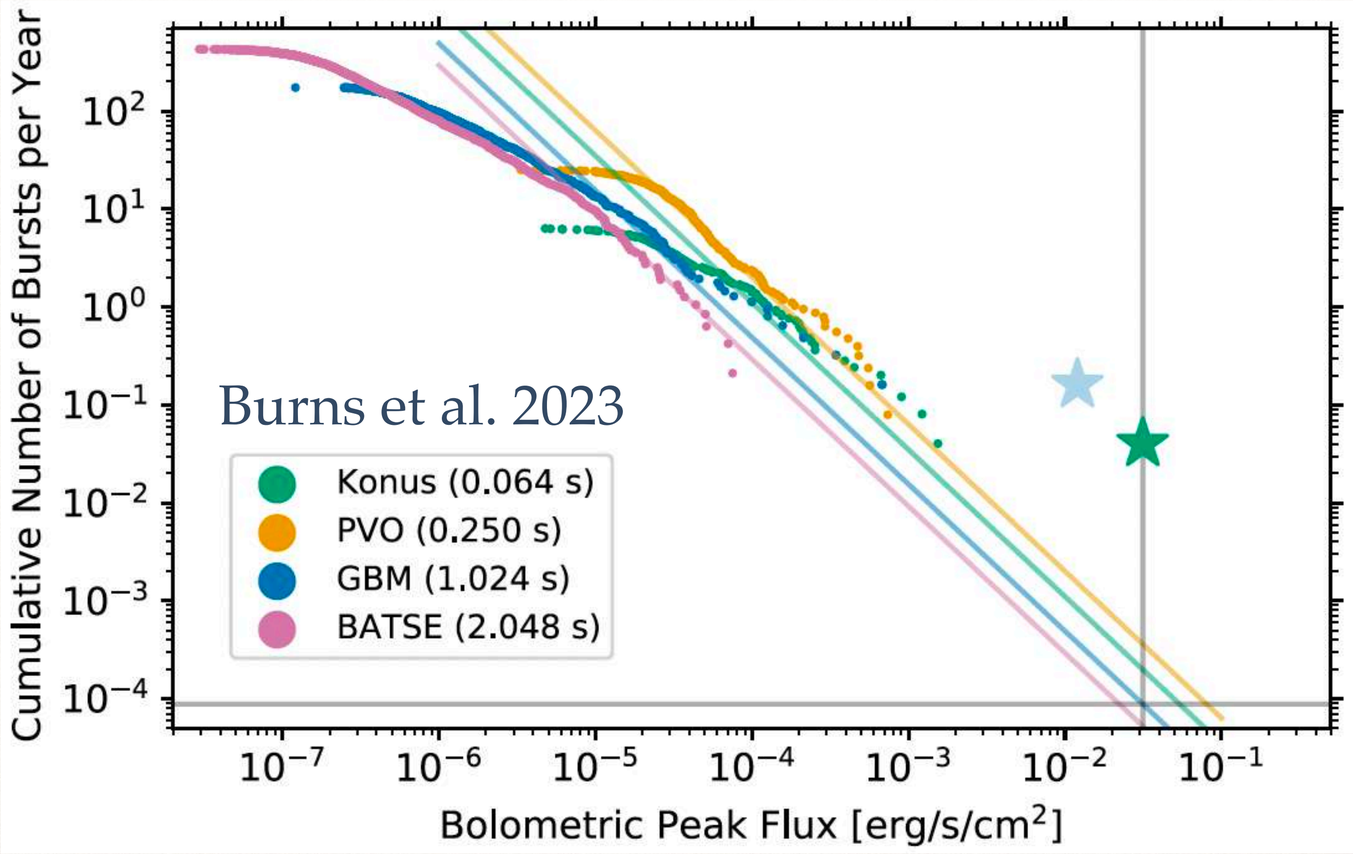
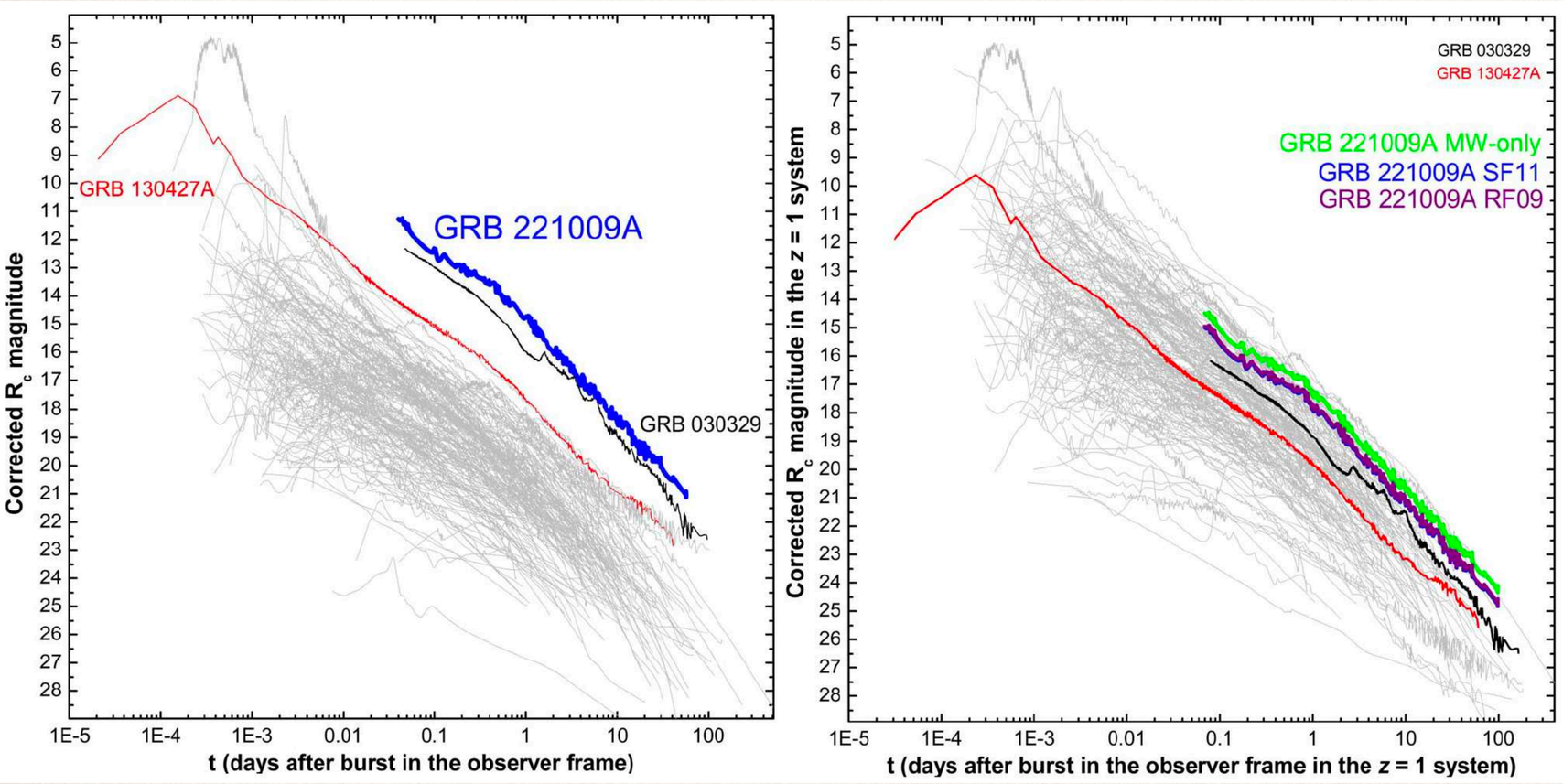
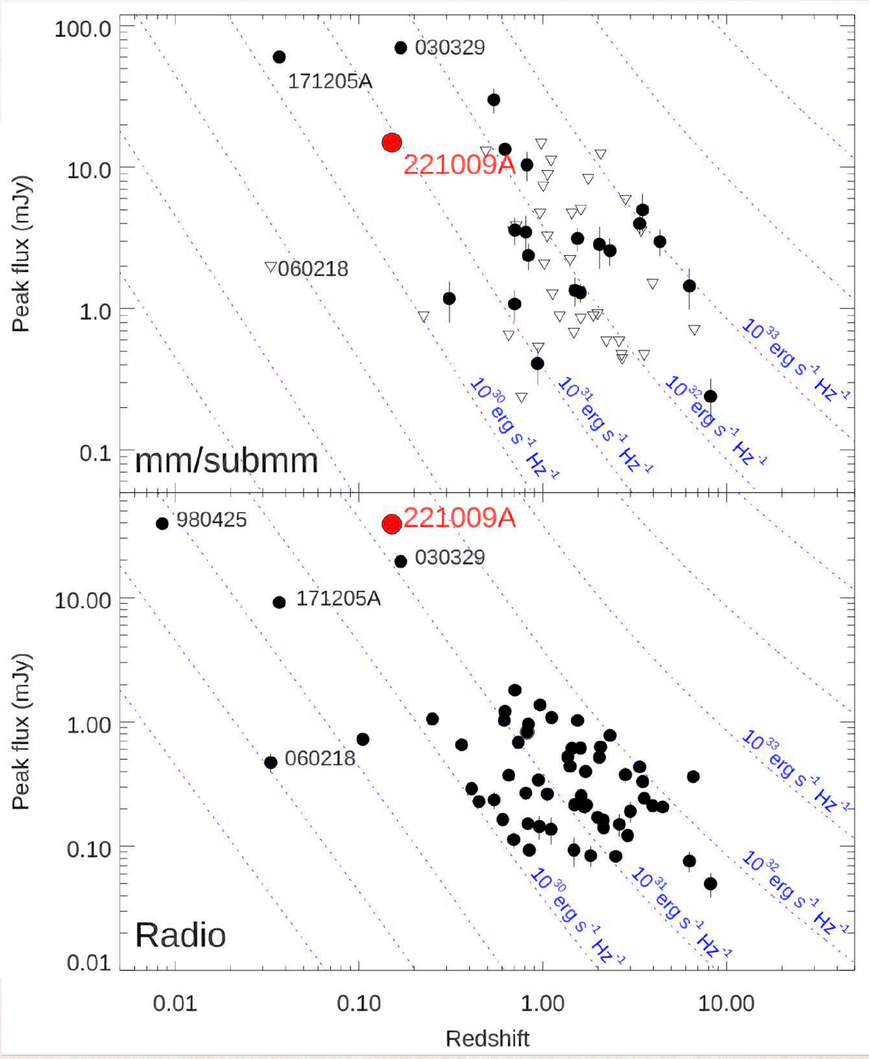


Afterglow luminosity



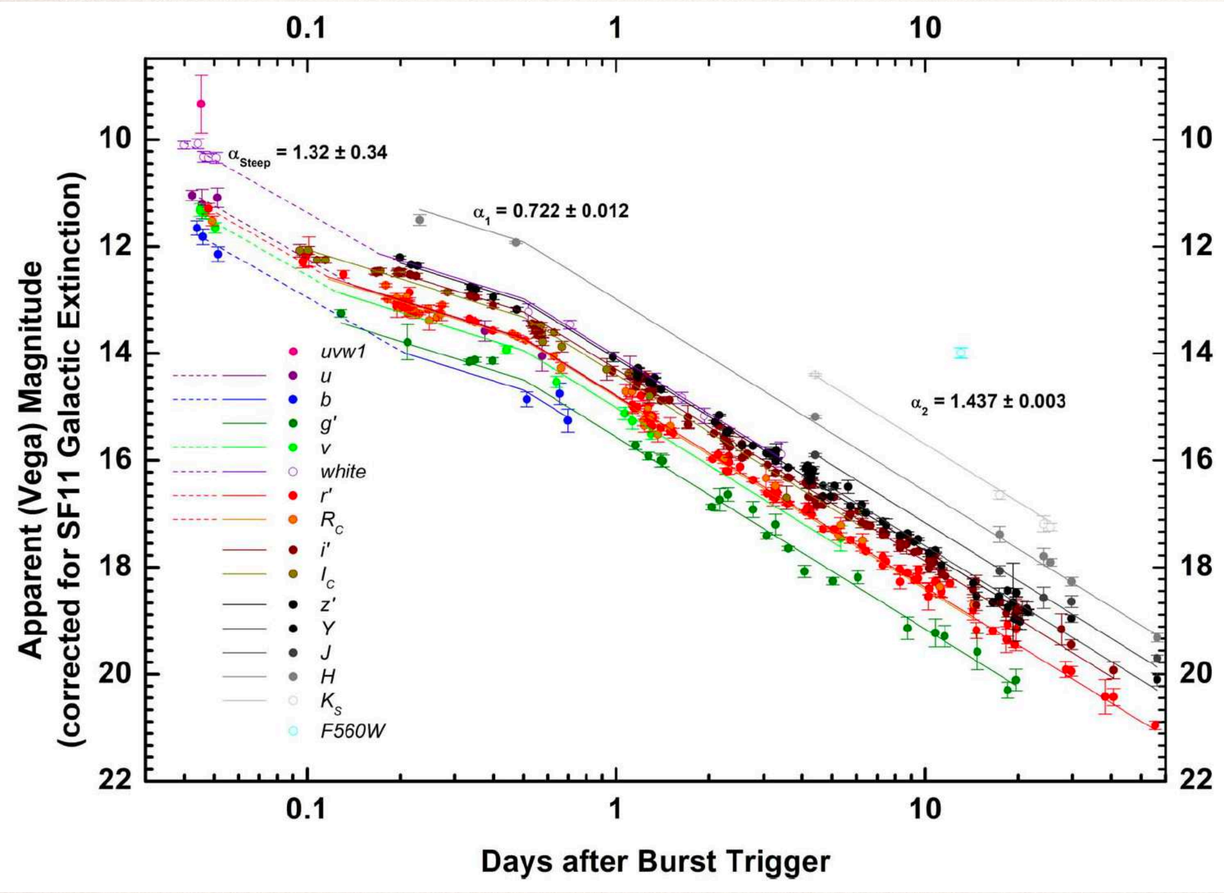
Kann et al. 2023

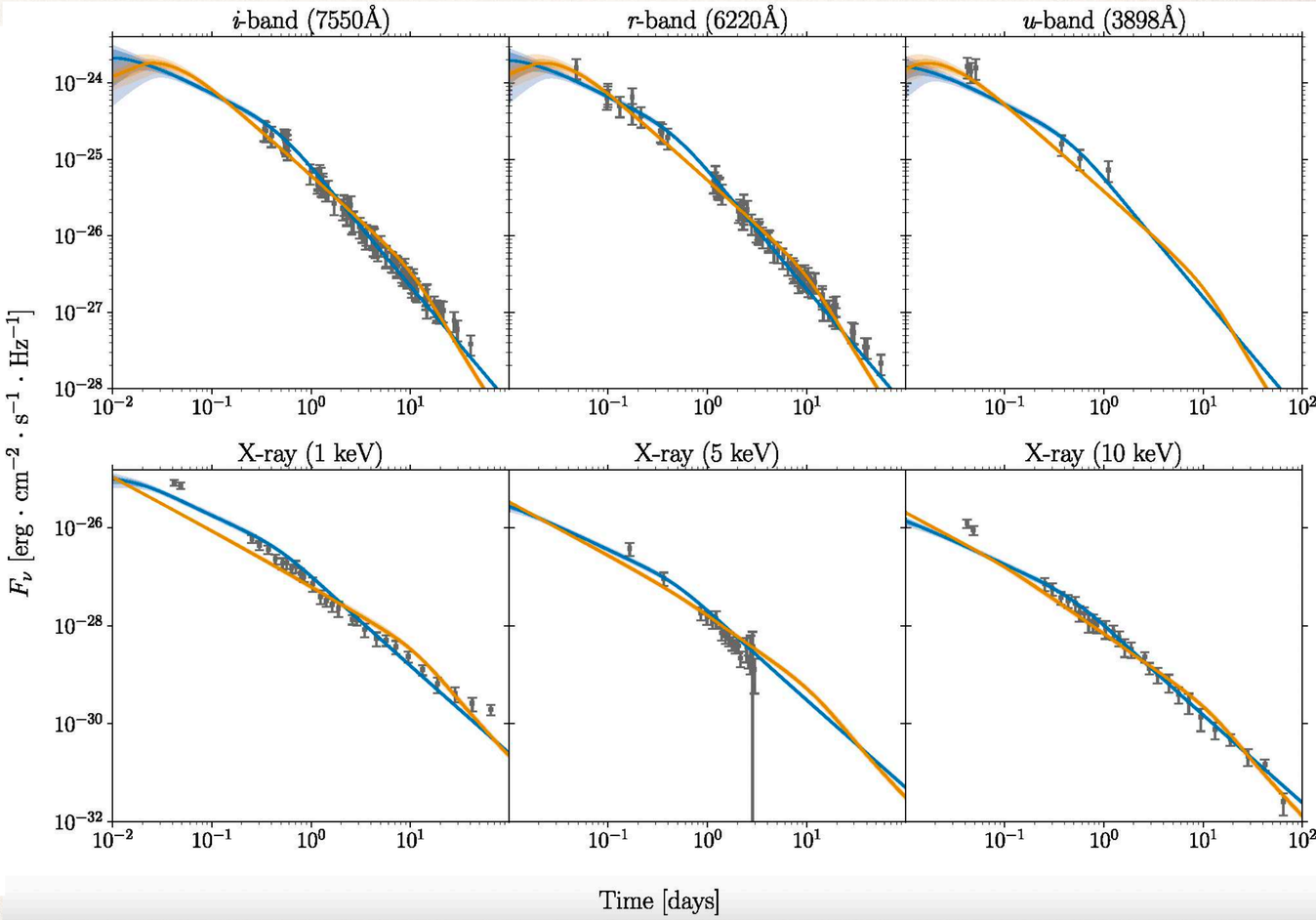


de Ugarte Postigo et al. in prep.

GRANDMA follow-up

- Over 300 observations from:
  - 15 GRANDMA telescopes
  - 19 amateur telescopes

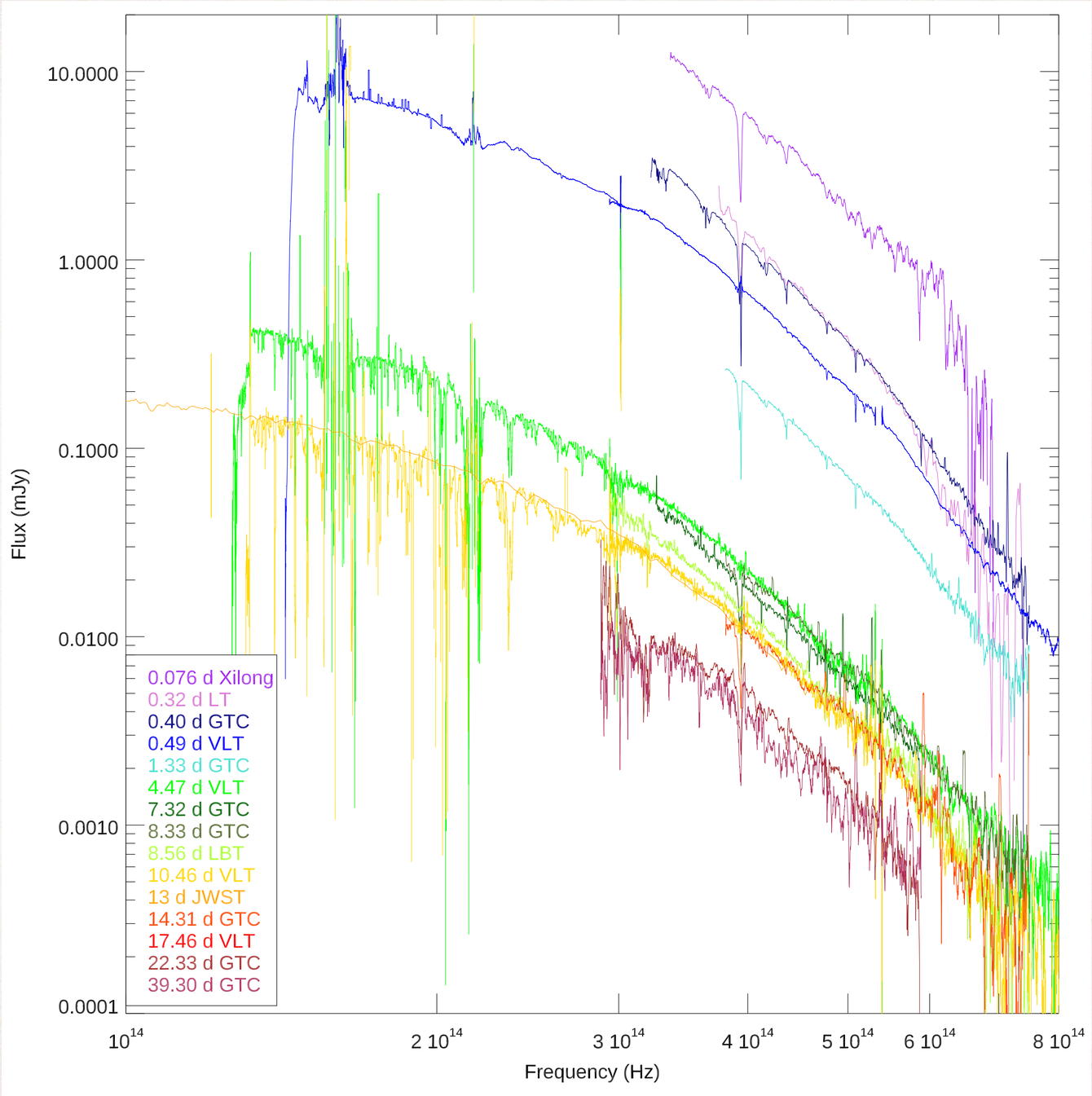




Kann et al. 2023

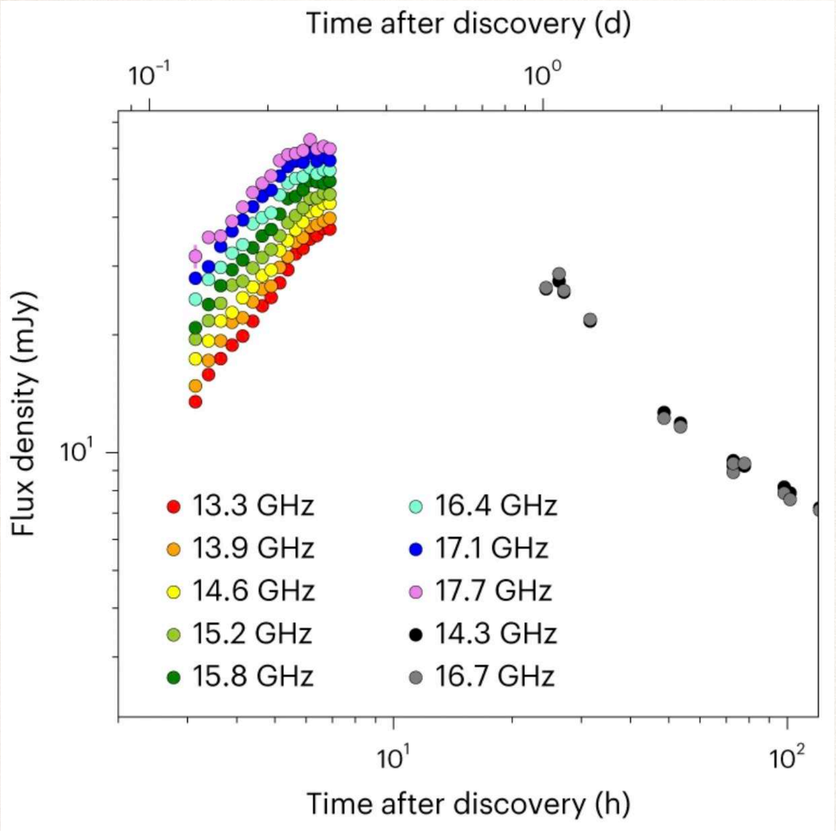
Spectral evolution

- 15 spectral epochs from GTC, VLT, JWST, LT and Xilong
- From 1.8 hrs to 39 days
- Extreme extinction complicates disentangling afterglow and supernova component

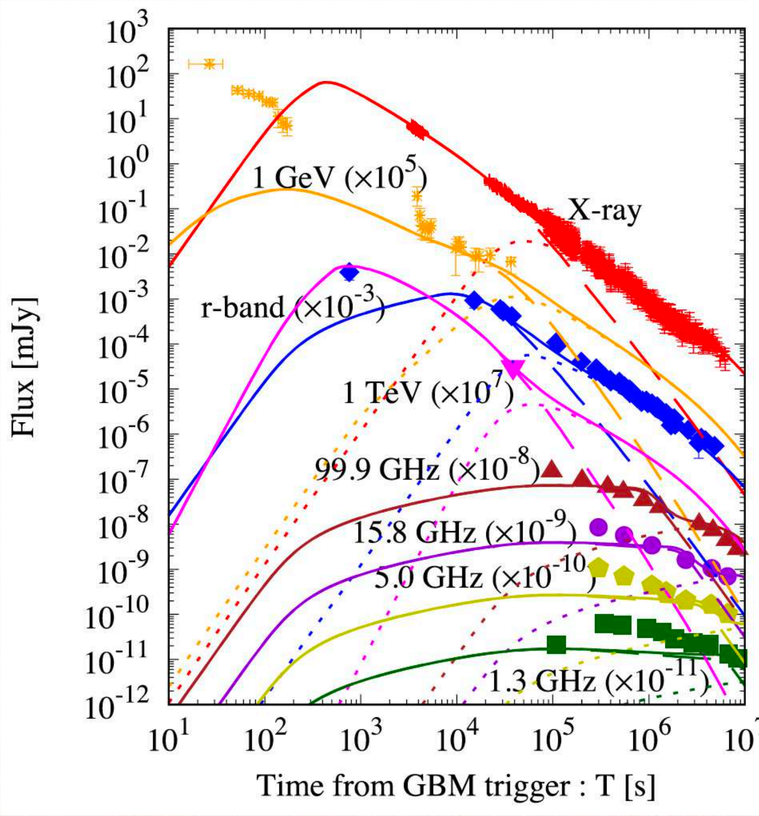


de Ugarte Postigo et al. in prep.

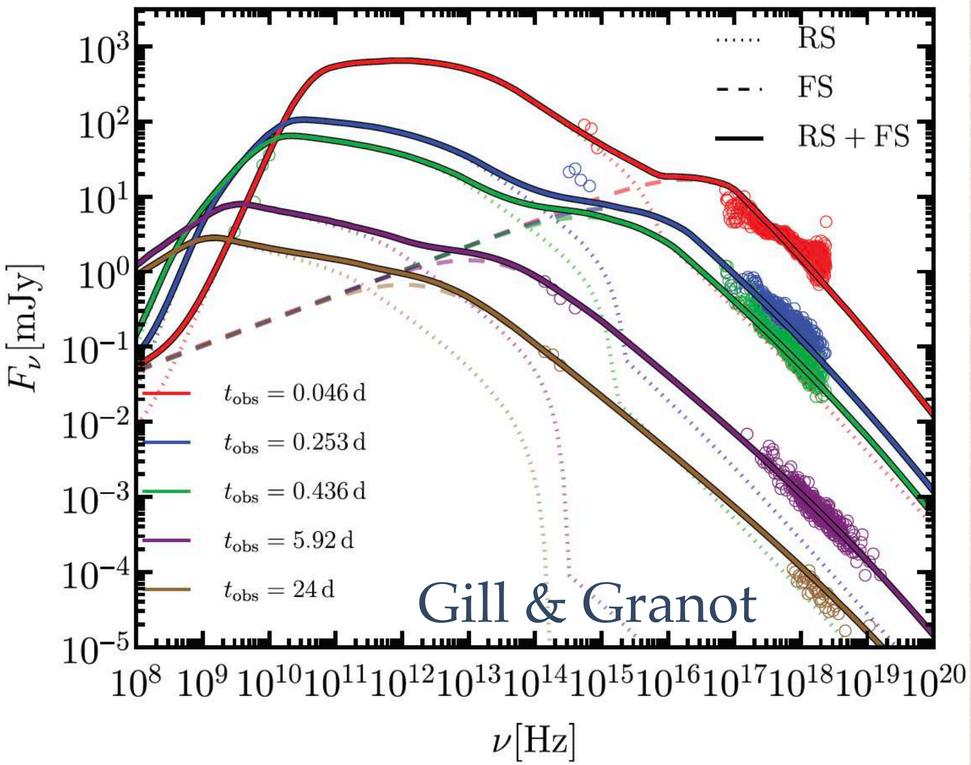
Broad-band emission

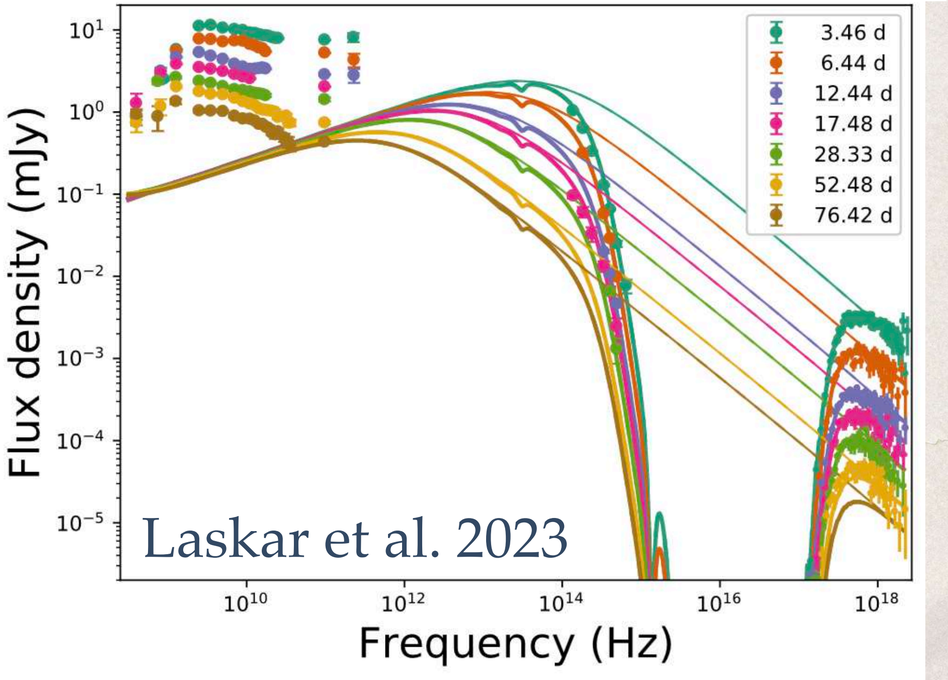


Bright et al. 2023



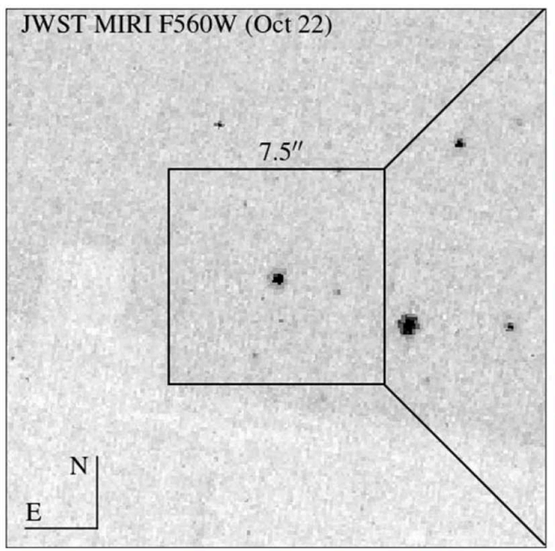
Sato et al. 2023

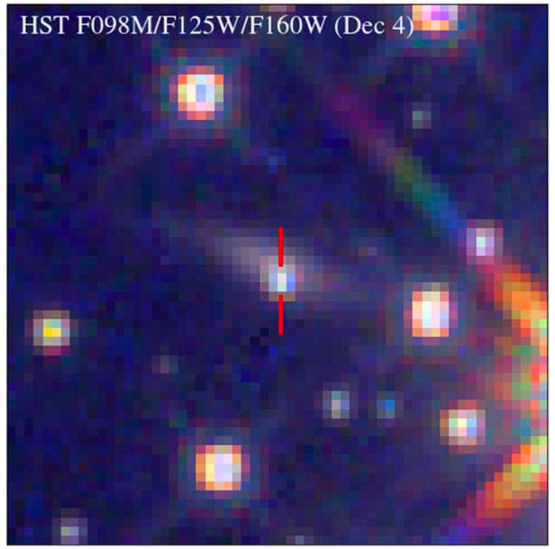


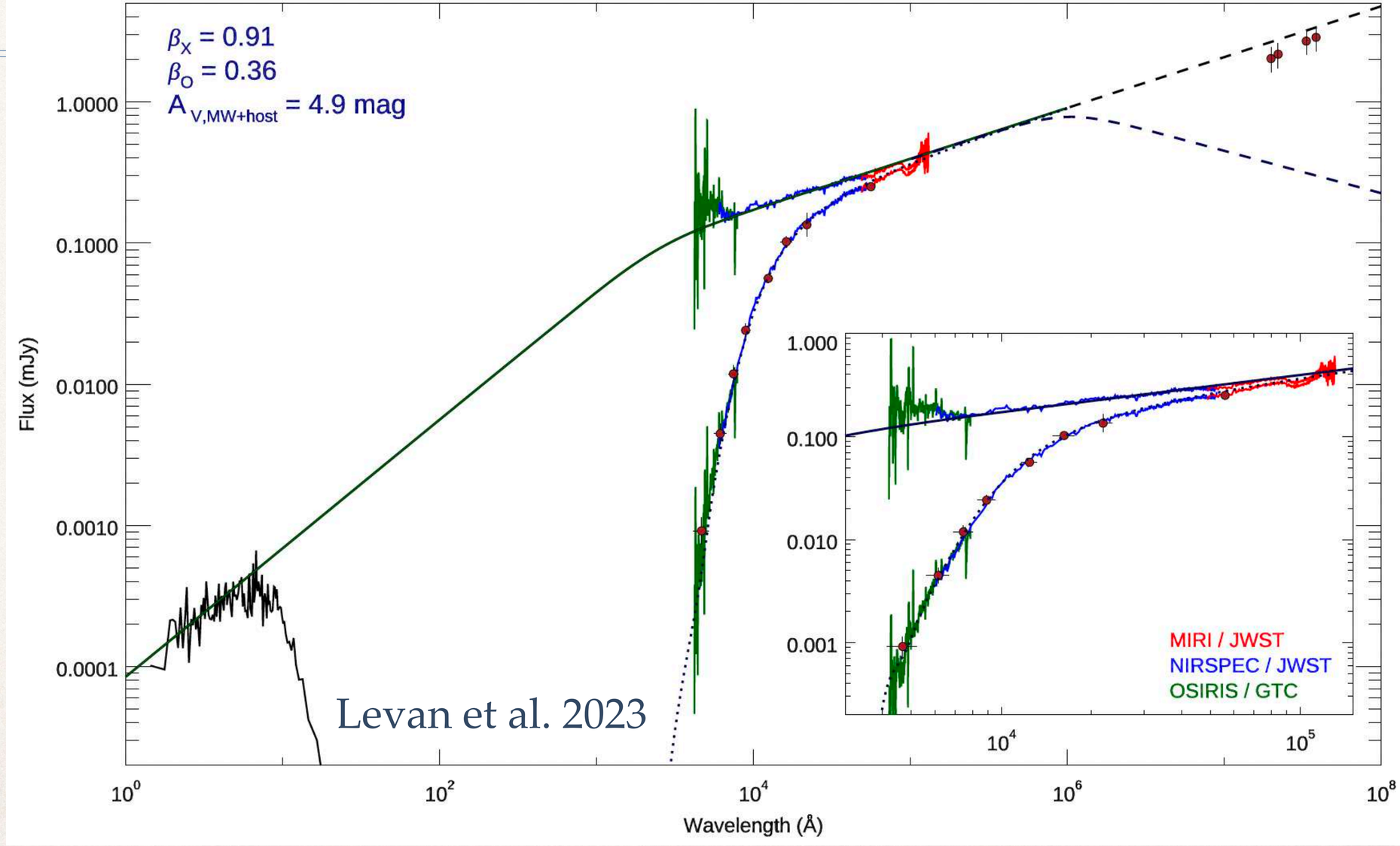


JWST & HST

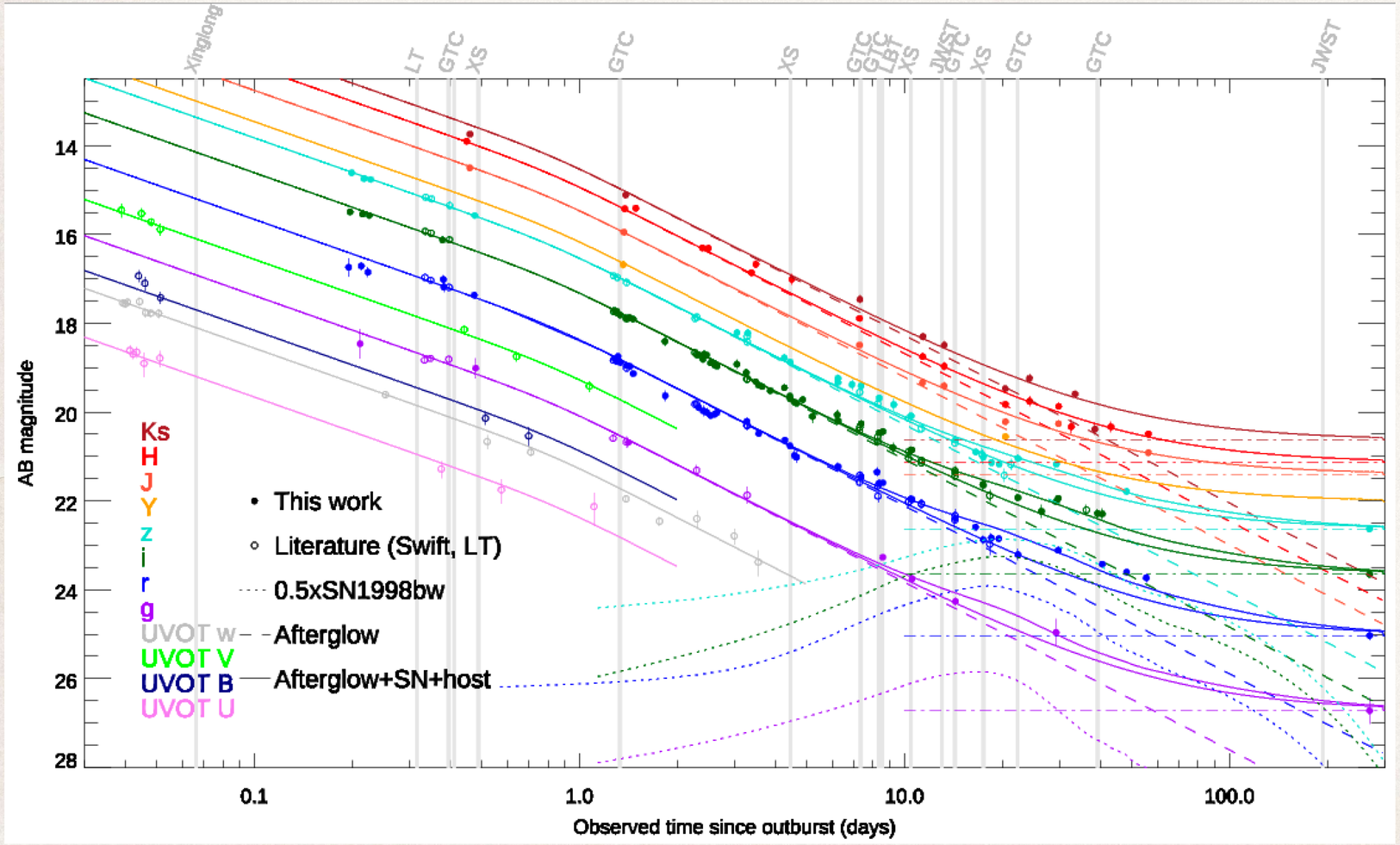
- First JWST observation of a GRB
- Hint of a faint SN

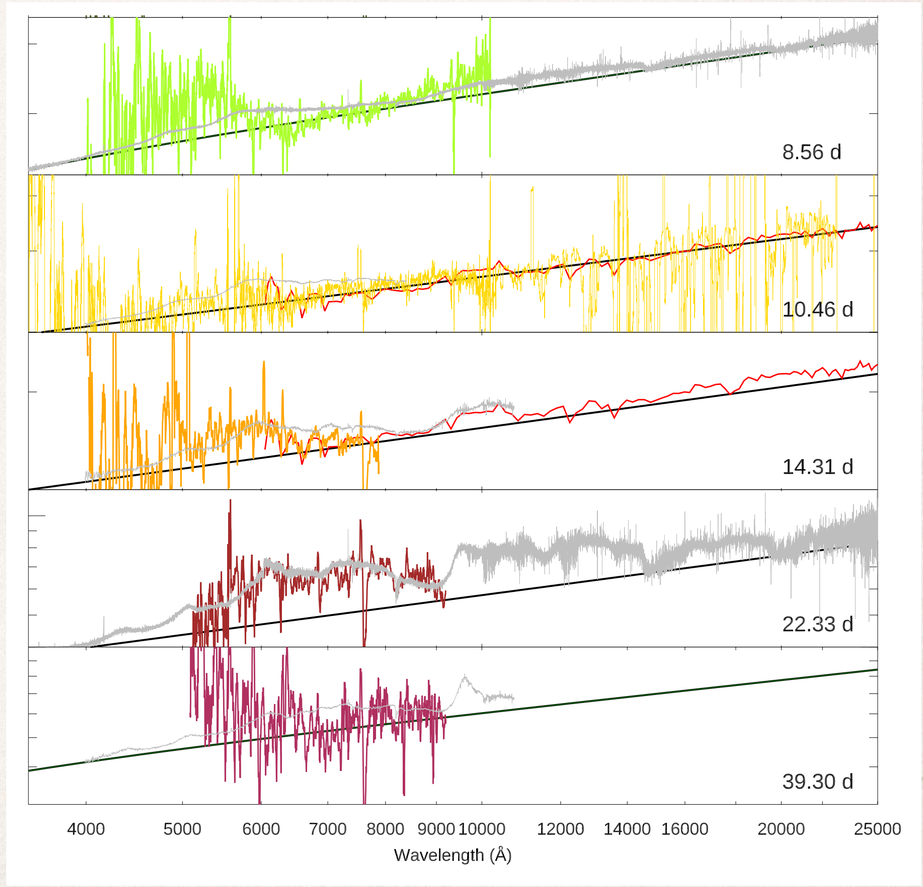






Supernova component





de Ugarte Postigo et al. in prep.

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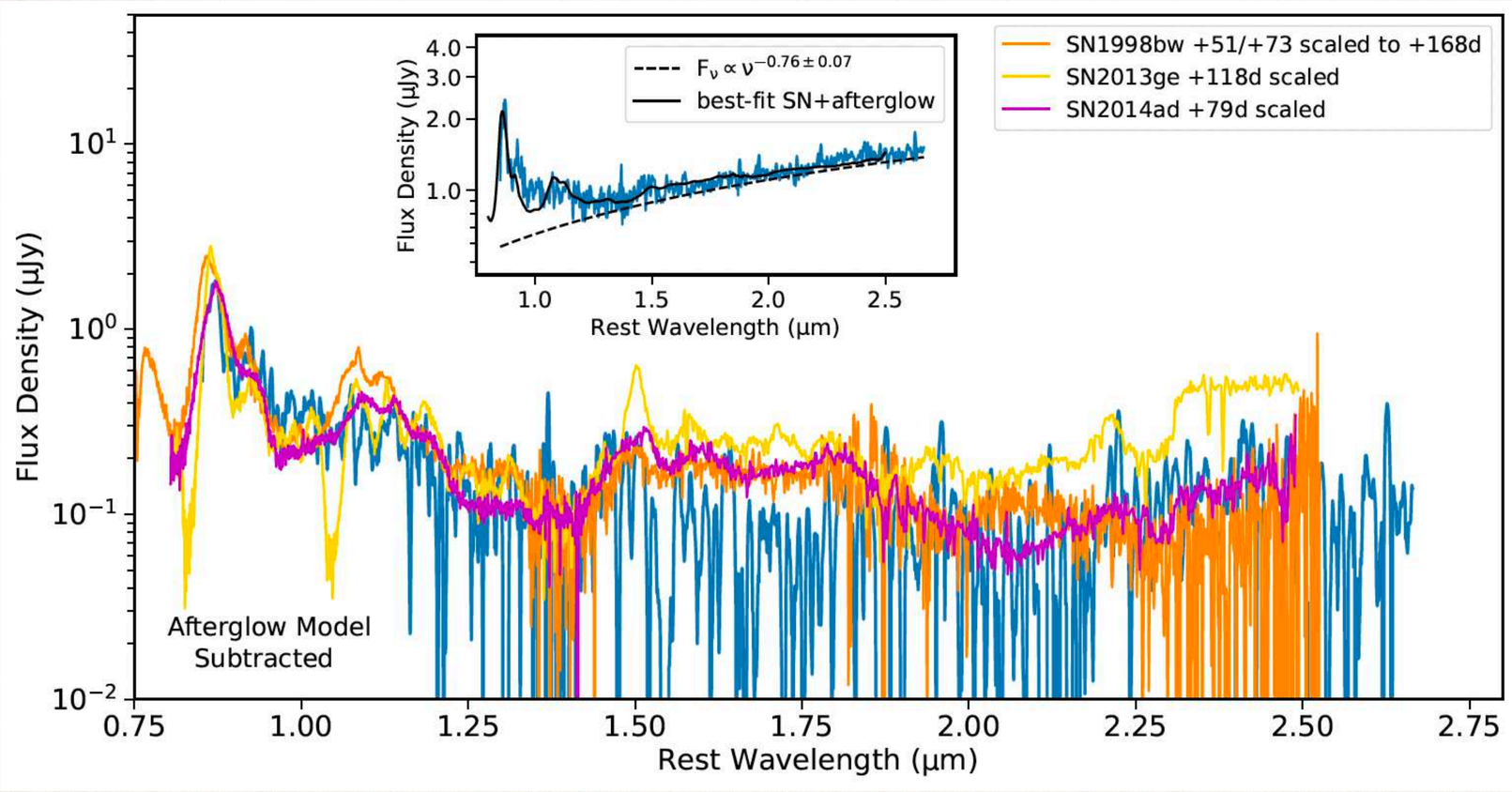
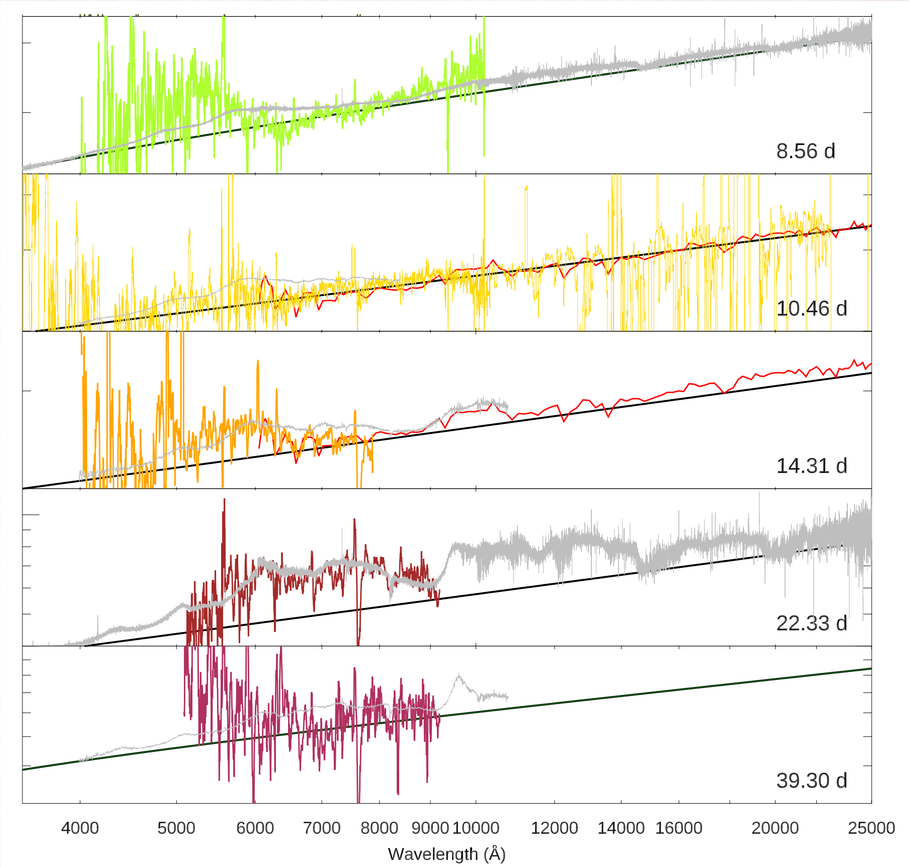


Blanchard et al. 2023



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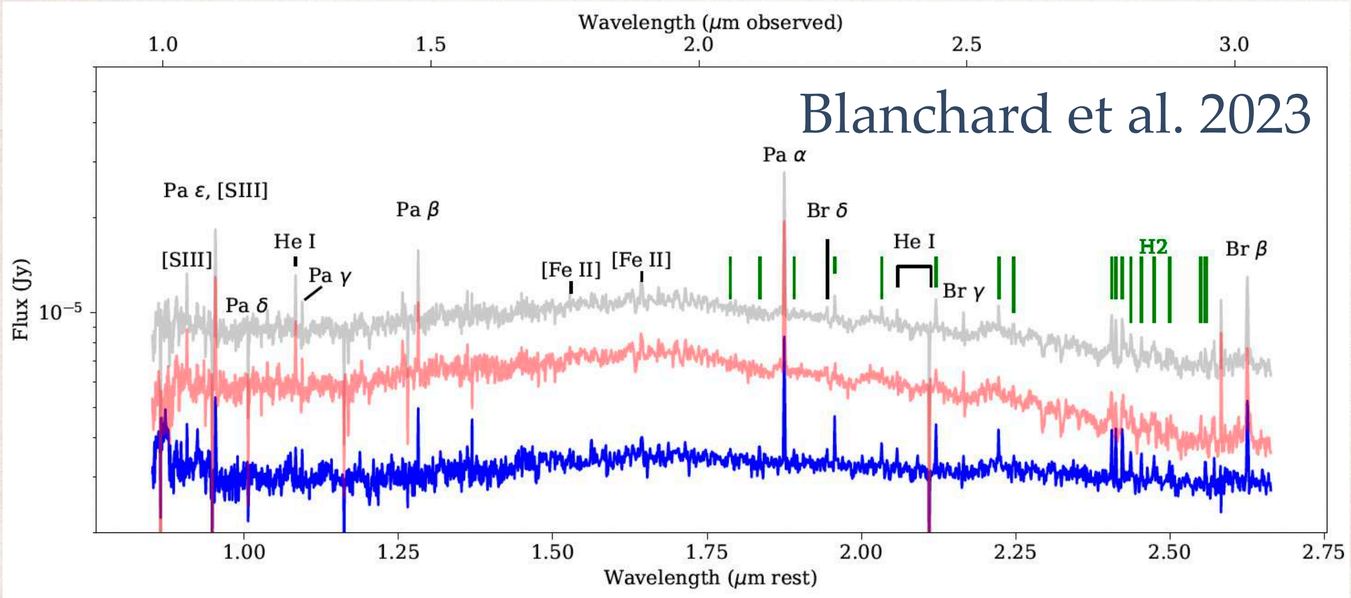
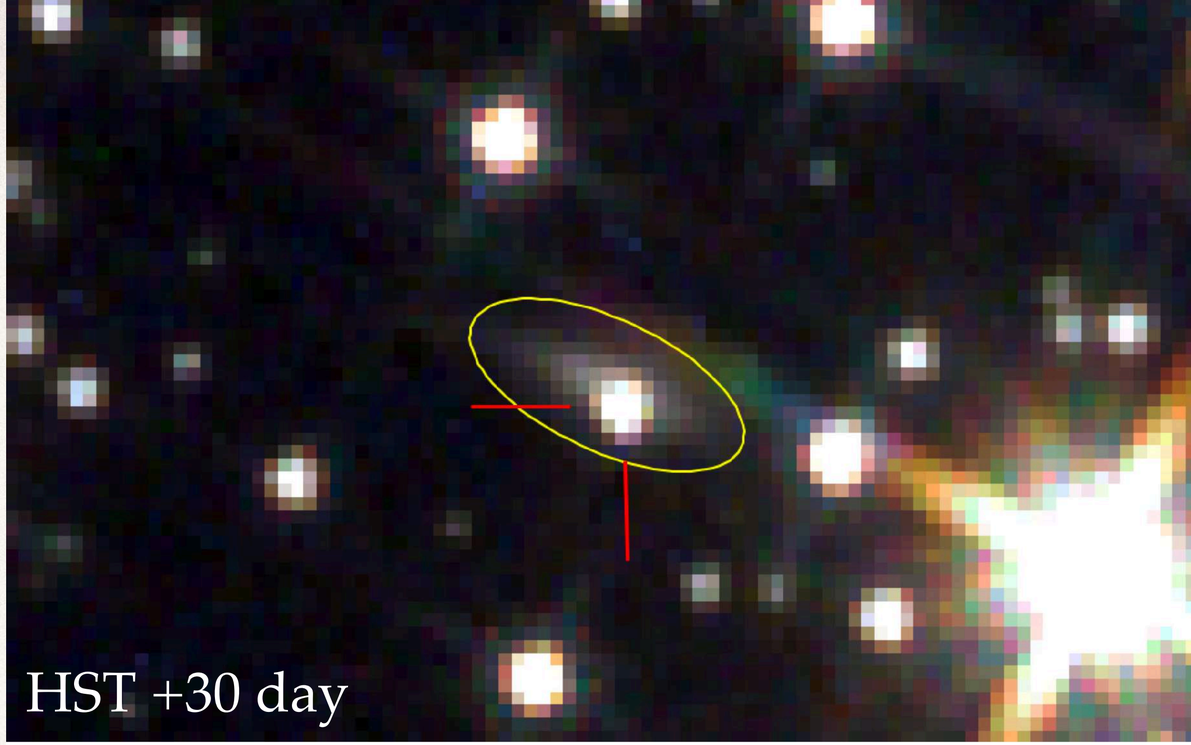
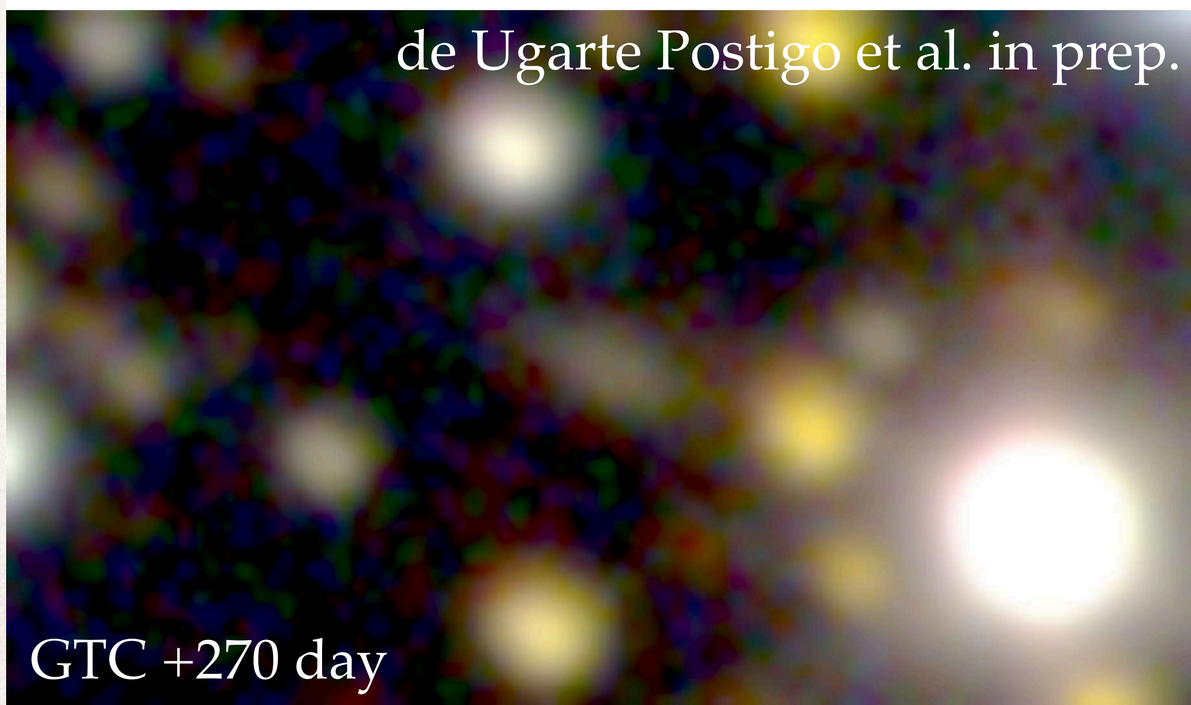
Host galaxy

- Near edge-on galaxy
- Star forming SFR = 0.17 Msol/yr
- Low metallicity log Z/Zsol = - 0.9
- The GRB location shows H_2 emission







In memory of
Alex

Conclusions

- The Brightest Of All Time
- Probably the most energetic in gamma-rays ($E_{iso} \sim 10^{55}$ erg)
- Nearby, $z = 0.151$
- Luminous but not extreme optical afterglow
- Hidden behind strong Galactic exitction
- Associated with a supernova
- In a low-metallicity galaxy