Expanding the landscape of extreme transients

Andrew Levan

+ in Nijmegen, **Peter Jonker**, Joyce van Dalen, Agnes van Hoof, Danielle Pieterse, Johnathaon Quirola-Vasquez, Javi Sanchez, Nicola Gaspari

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WARWICK
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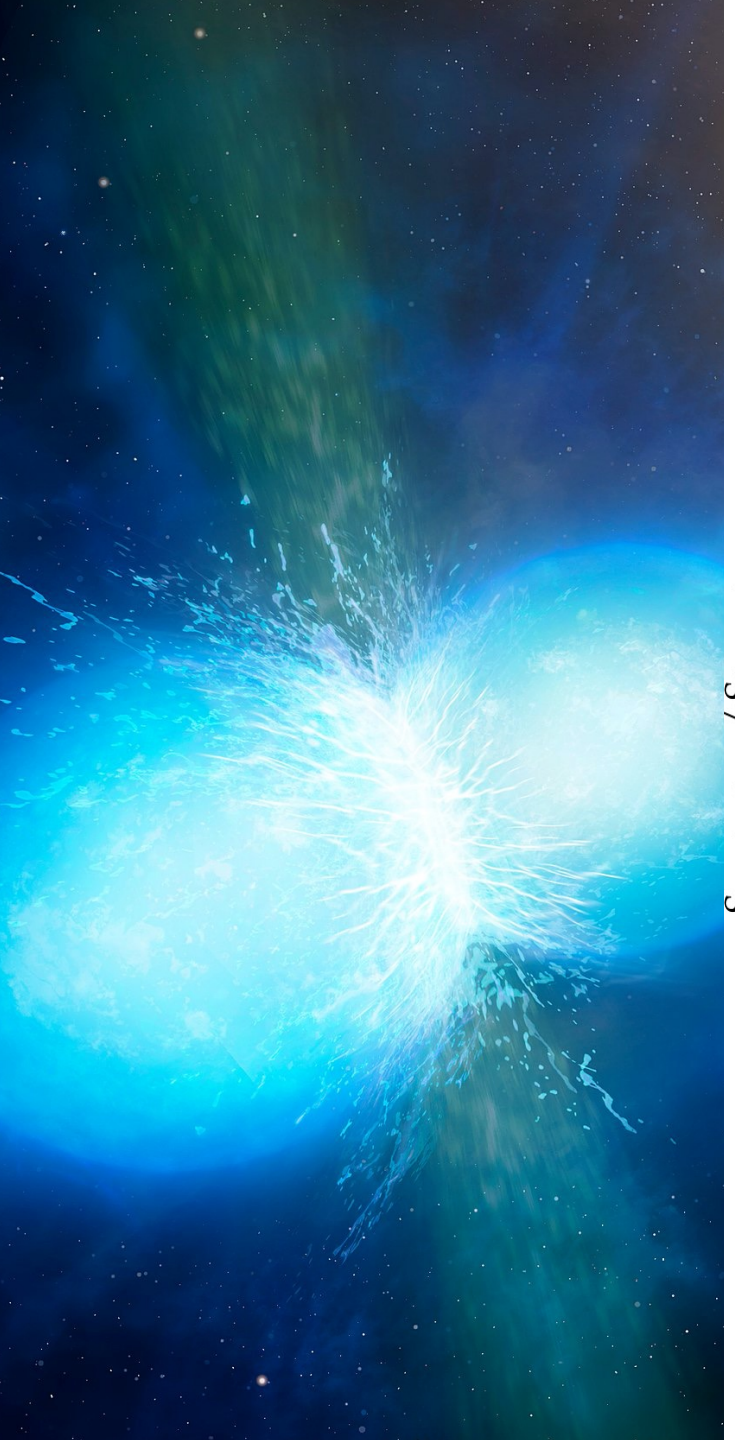
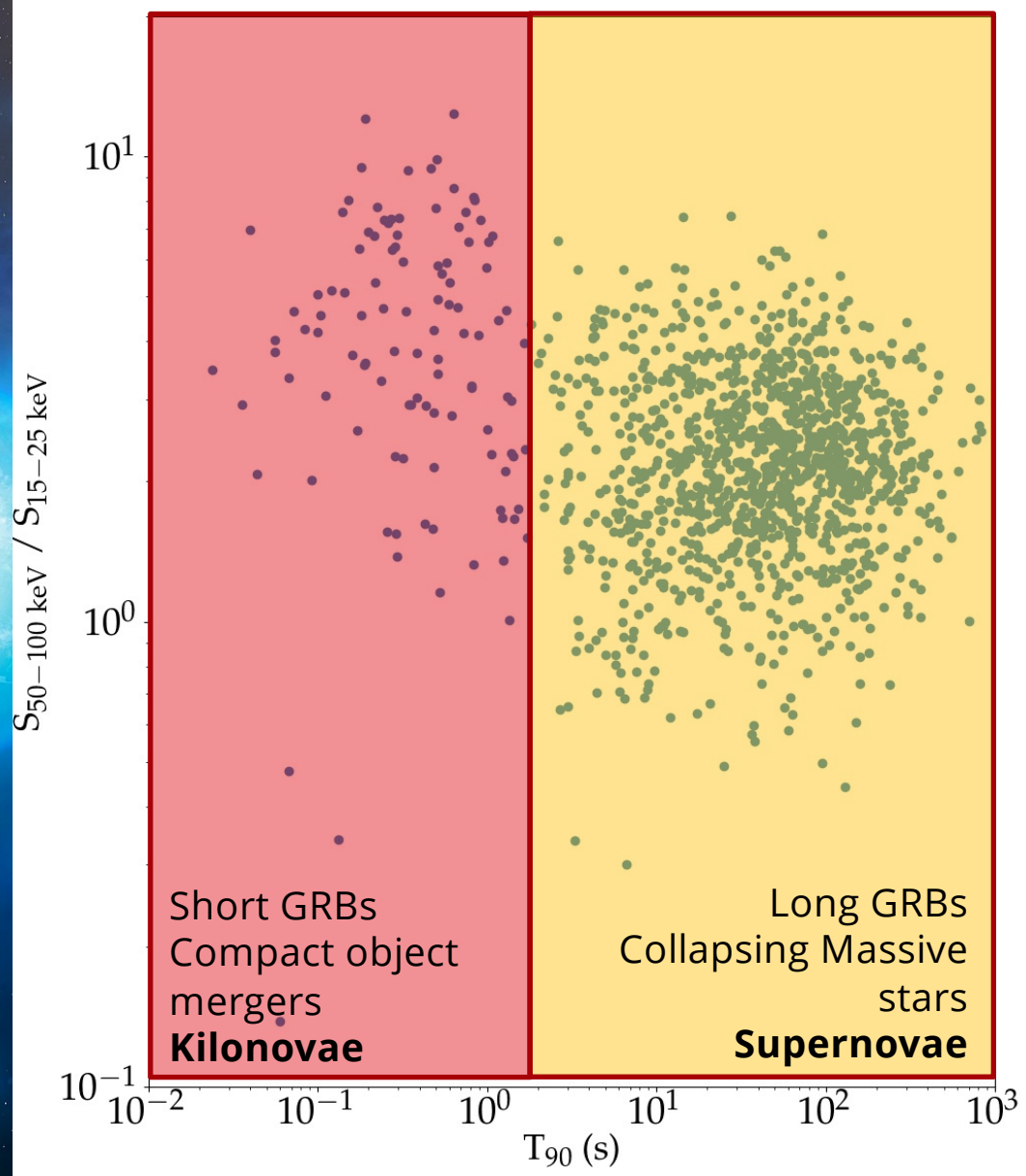
GRBs, accepted picture c. 2021





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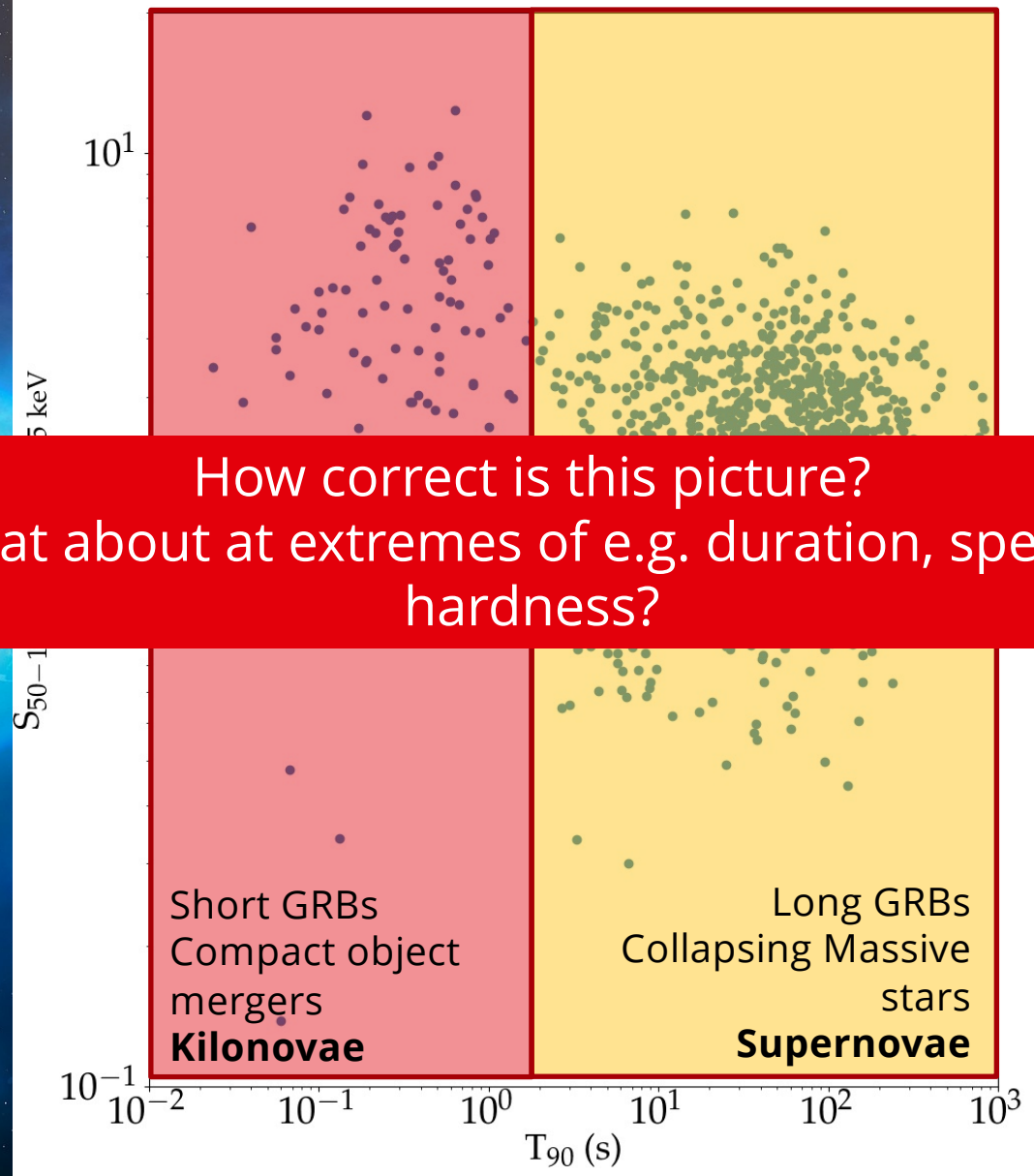
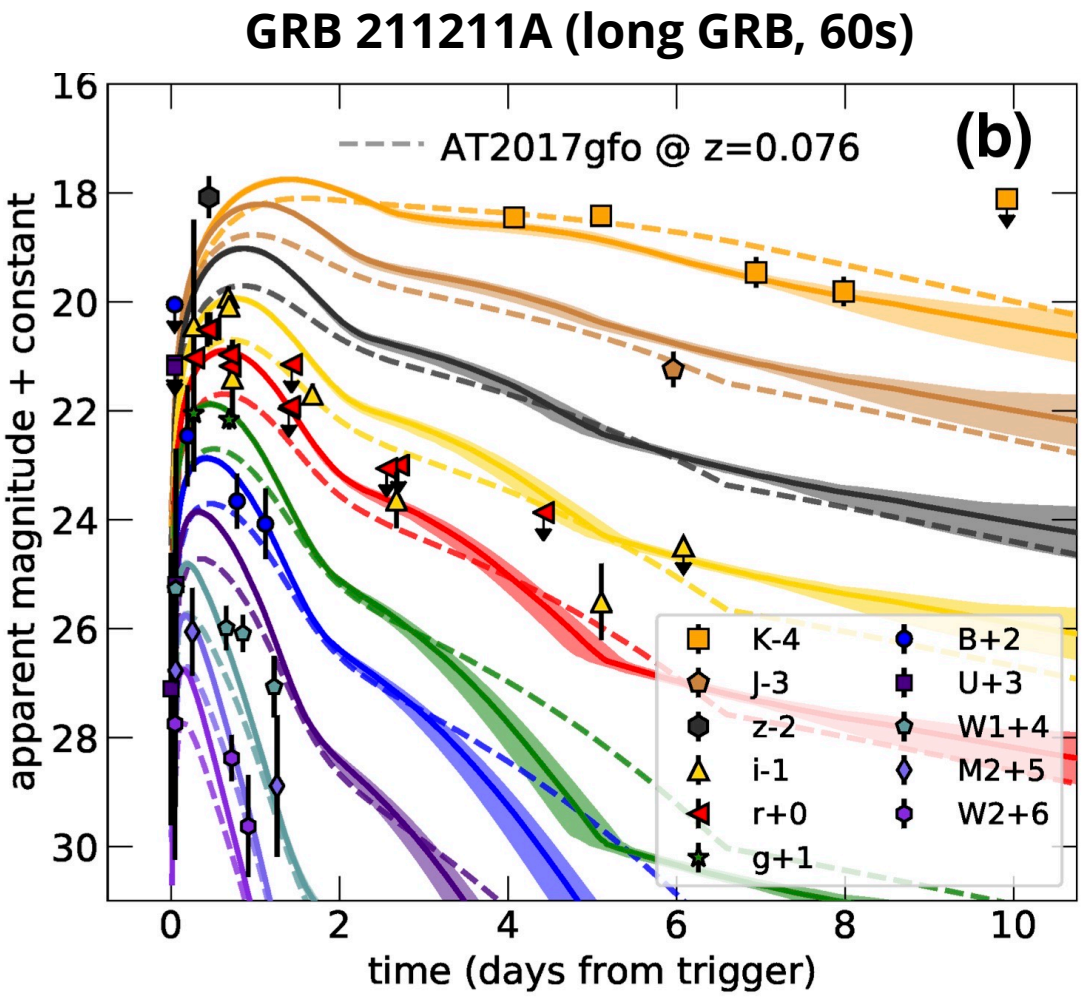
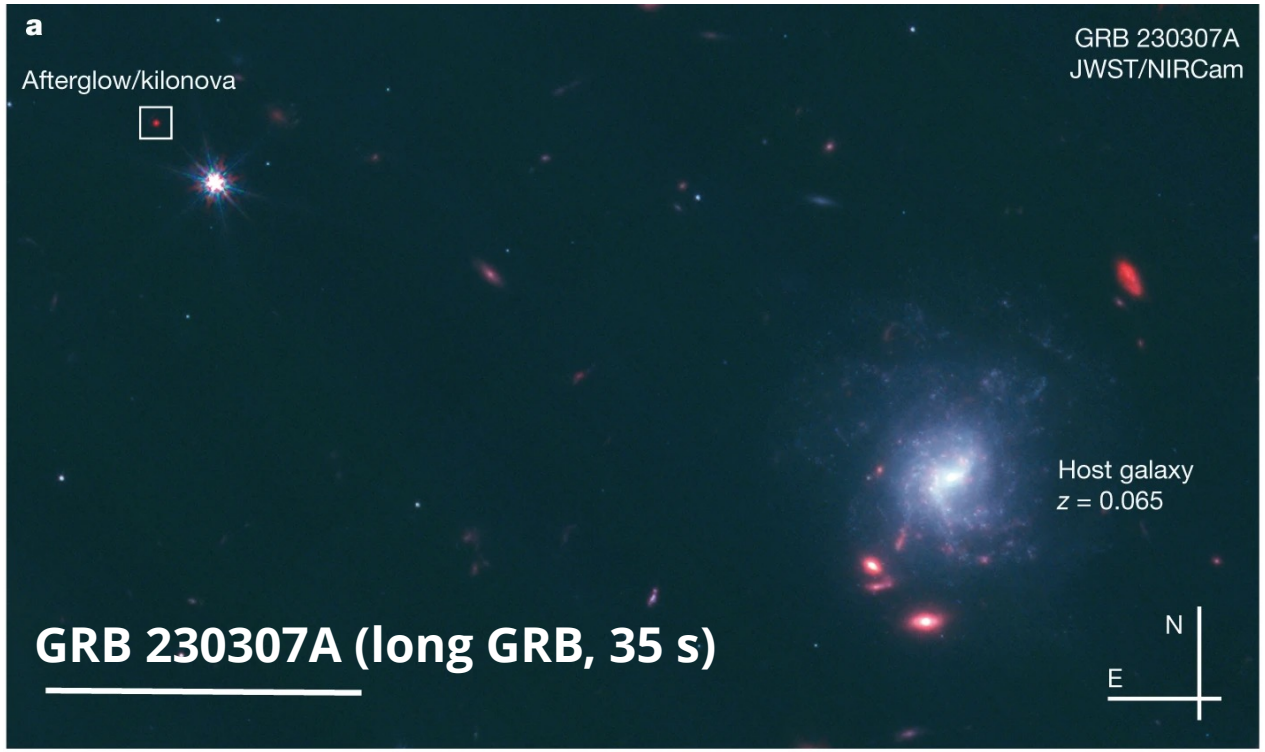


How correct is this picture?
What about at extremes of e.g. duration, spectral hardness?

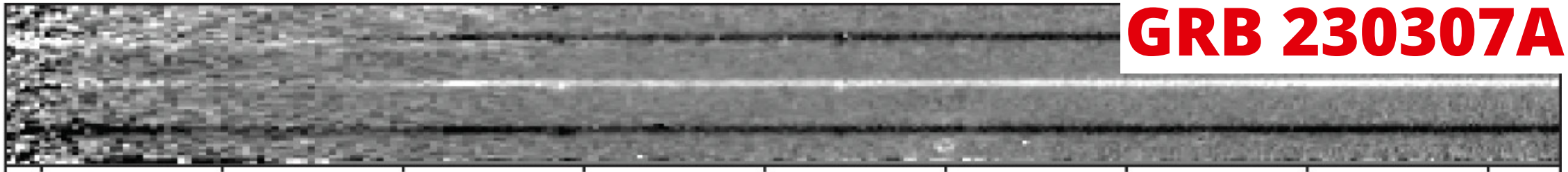
Some long GRBs have kilonovae → compact object mergers

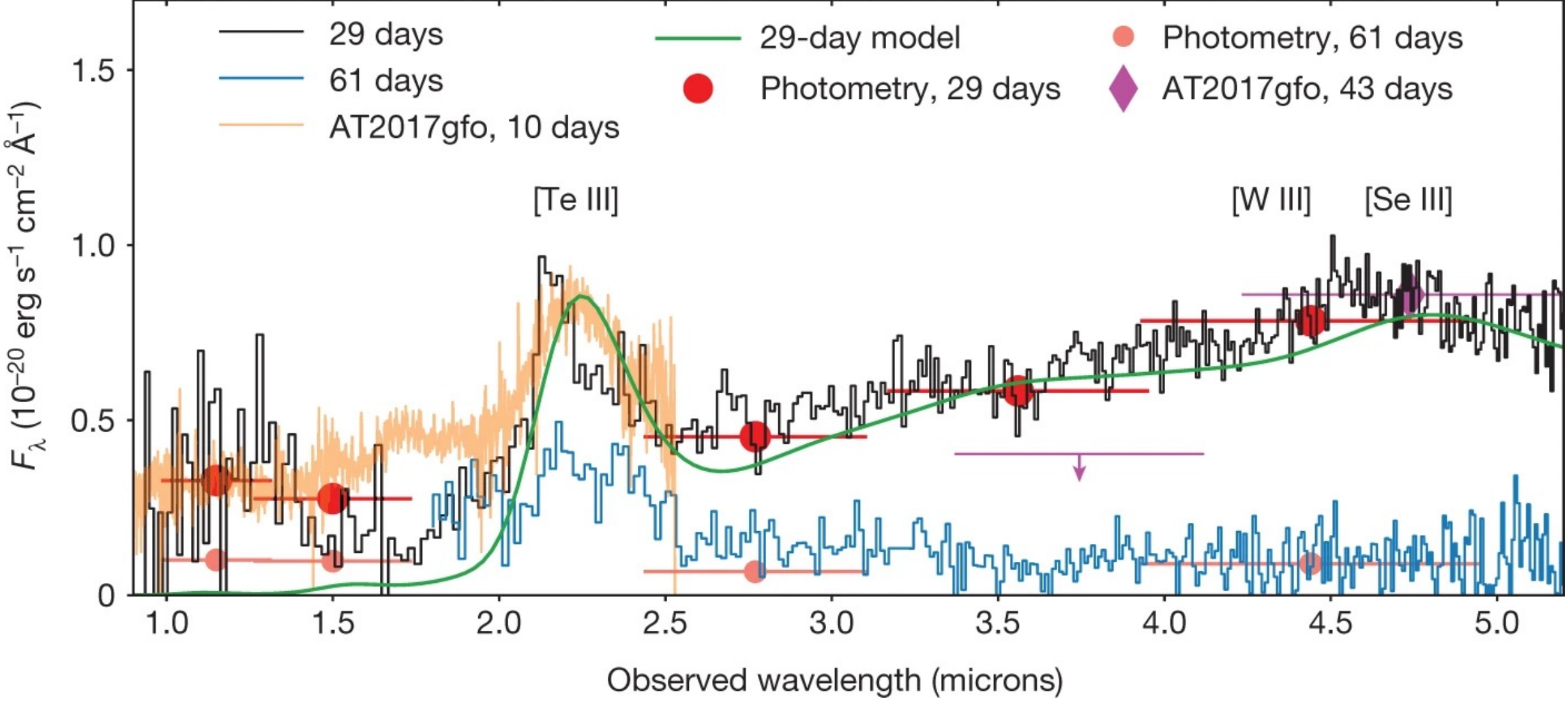




Rastinejad et al. 2022; Troja et al. 2022; Yang et al. 2022;Levan et al. 2024; Yang et al. 2024

GRB 230307A





Levan et al. 2024 Nature 626 737

Going soft – the Fast X-ray Transients

Visible to z~5 (and beyond?)

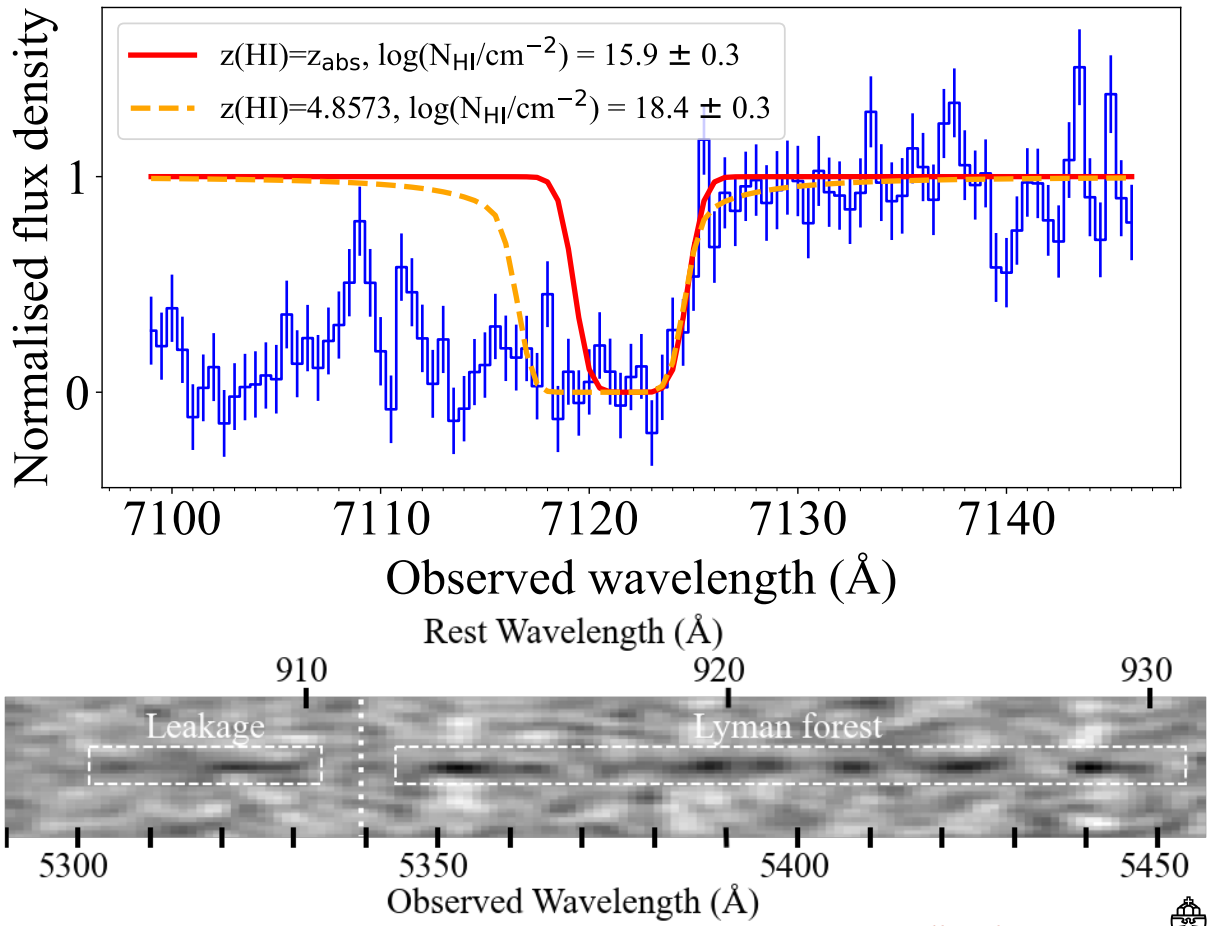
EP 240315a (z=4.85)

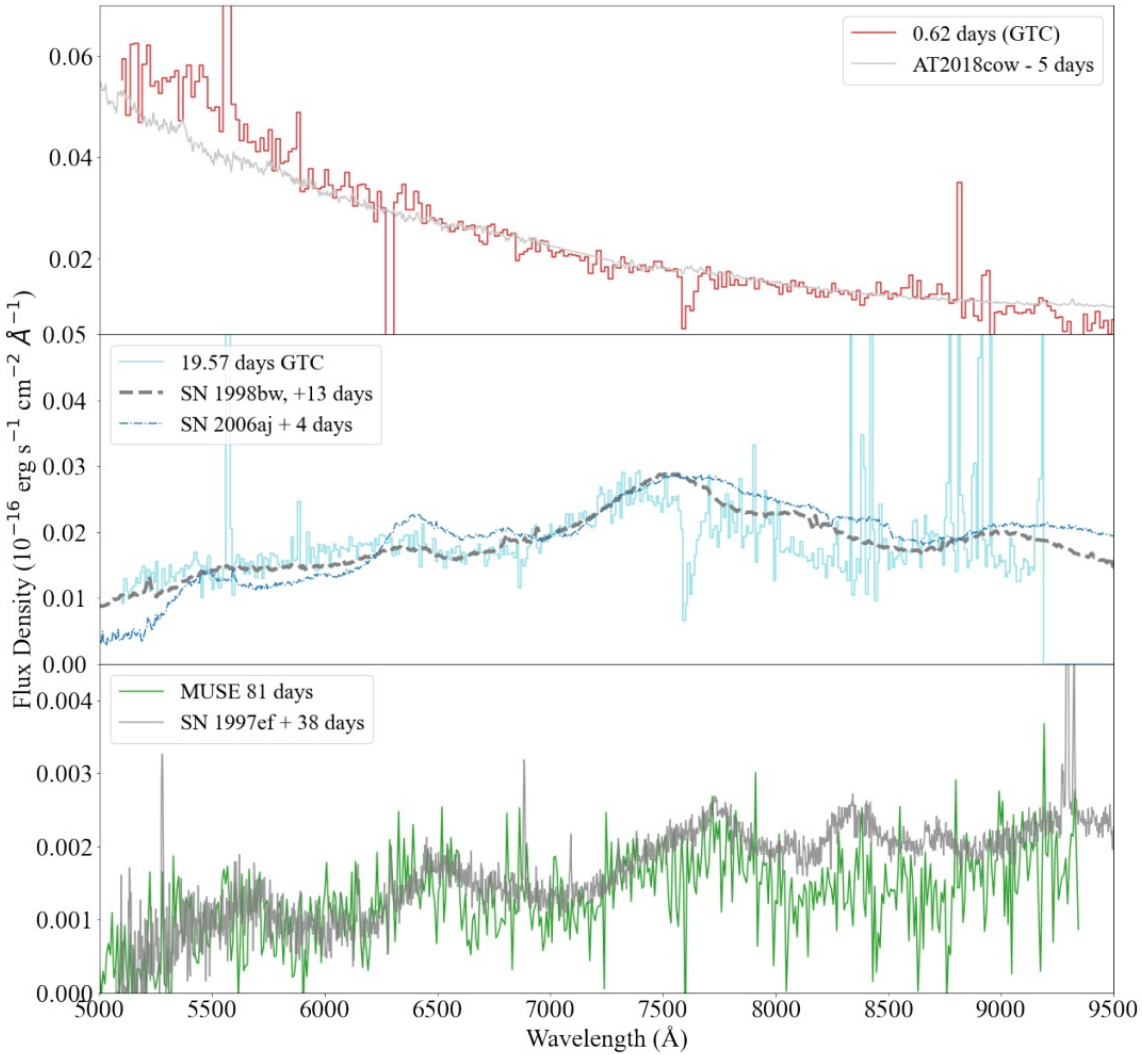
Levan, Jonker et al. 2025 Nature Astronomy, in press

Associated with broad lined SN Ic

van Dalen, Levan, Jonker et al. 2025 ApJ 982 47

Rastinejad, Levan, Jonker et al. 2025 988 13





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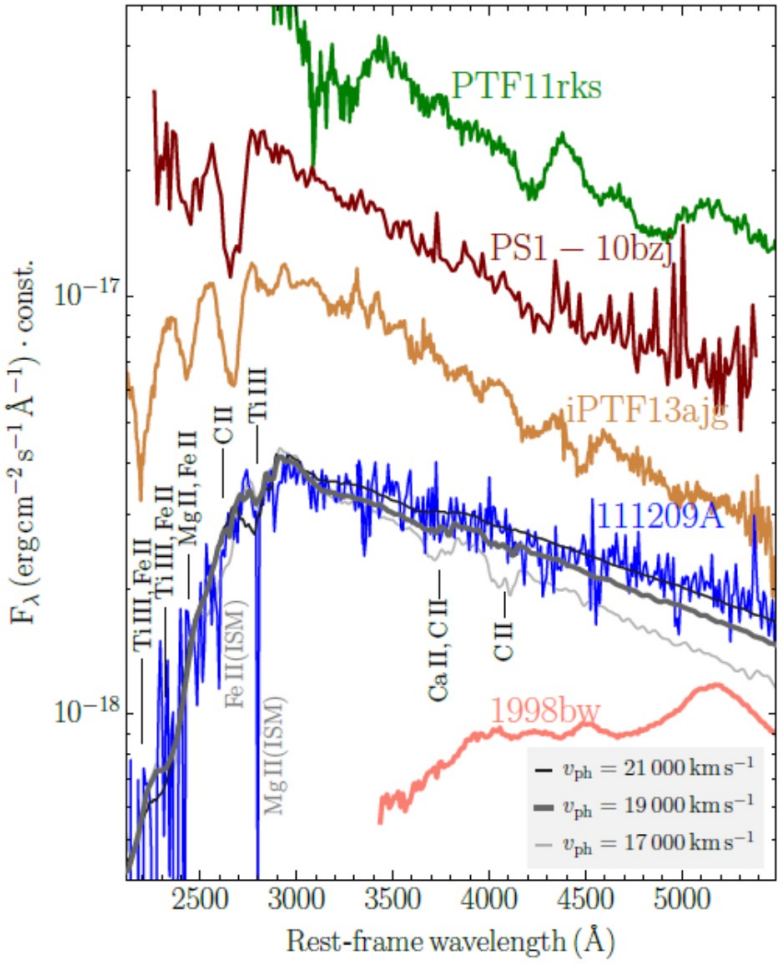
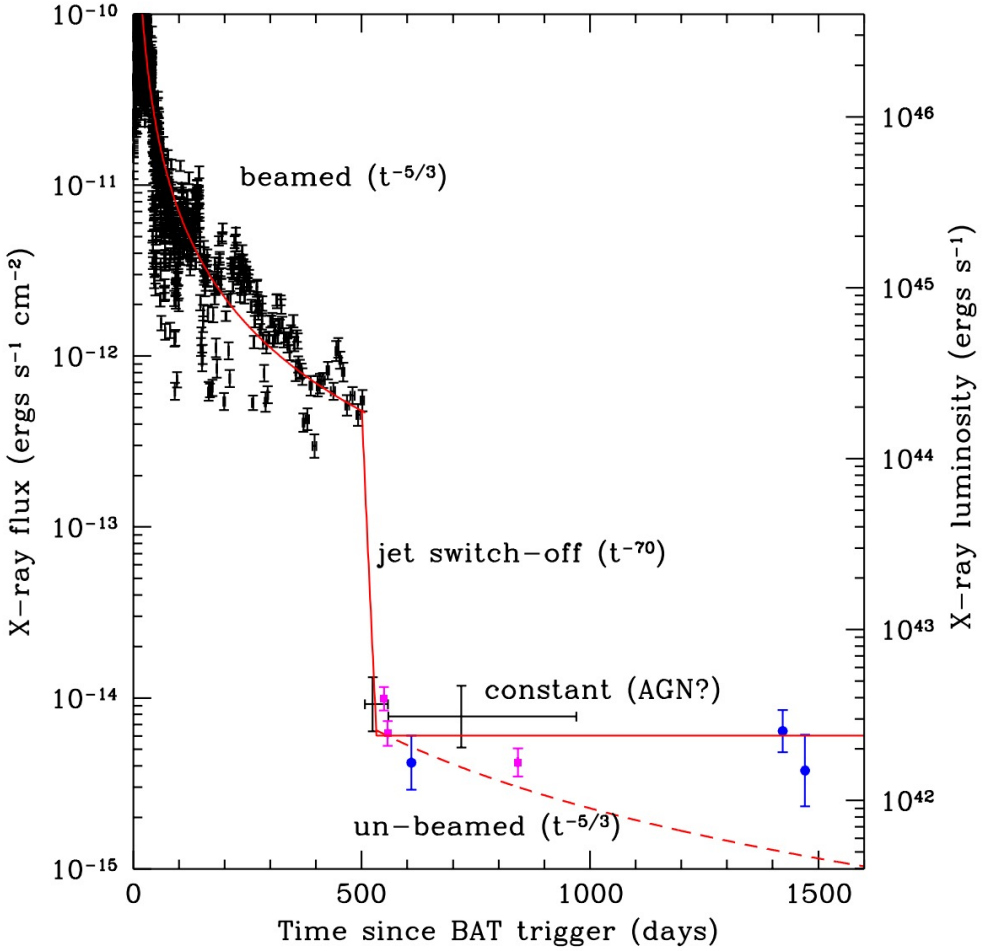
Going long – the nature of the longest duration transients

Ultra-long GRBs, some FXTs, relativistic TDEs



Some ultra-long GRBs apparently have luminous supernovae (Greiner et al. 2015), though others do not (Levan et al. 2014).

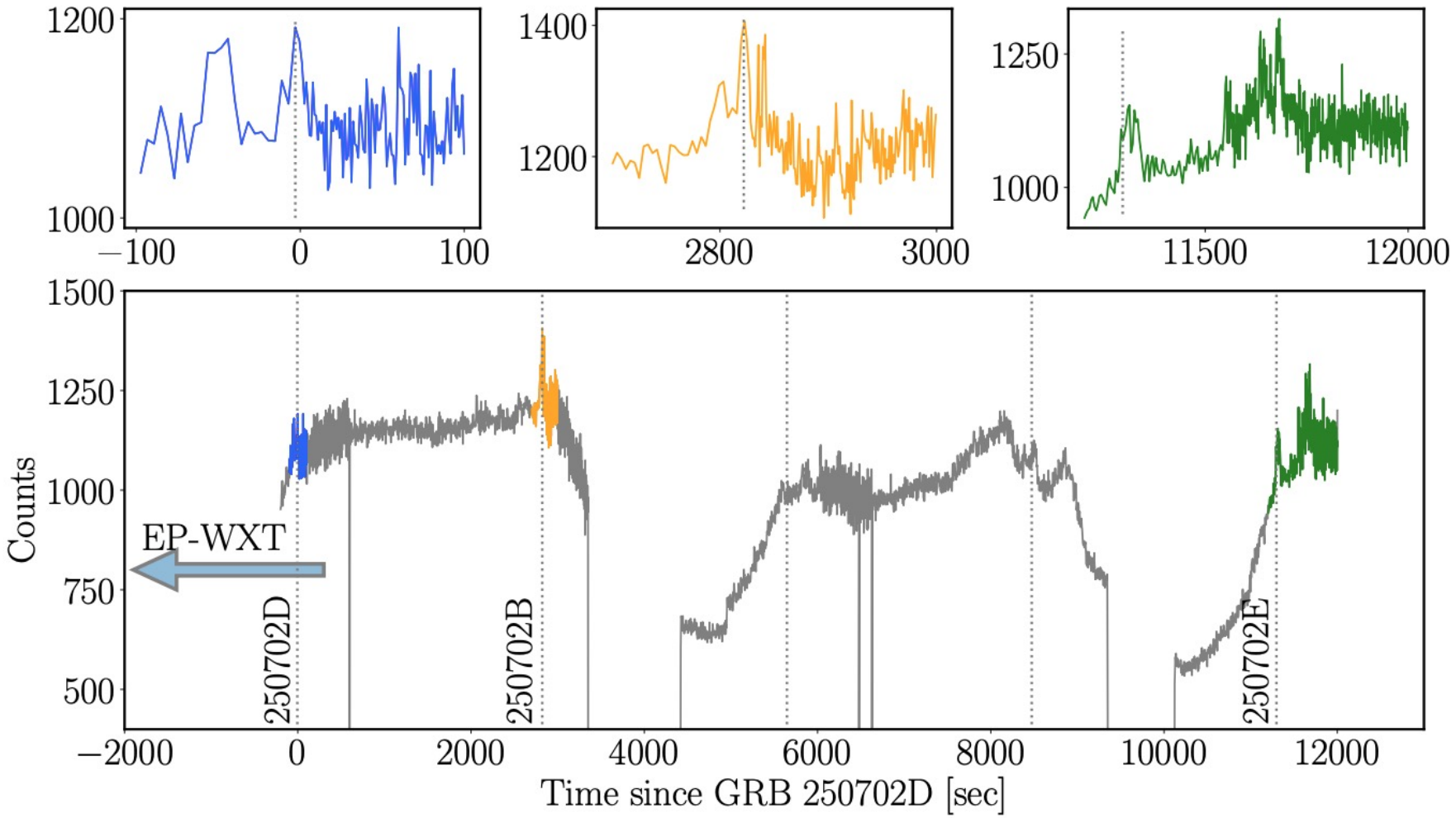
Apparent relativistic TDEs can last for hundreds of days and are nuclear in their hosts to HST resolution



Bloom et al. 2011, Levan et al. 2011, Zaudereer et al. 2011; Cenko et al. 2012, Pasham et al. 2015, Brown et al. 2015, Levan et al. 2016

Going long – the nature of the longest duration transients

The apparently unique GRB 250702B(DE)



>1 day long, multiple GRB triggers, possibly periodic

Levan et al. 2025 ApJ 990 28

Going long – the nature of the longest duration transients

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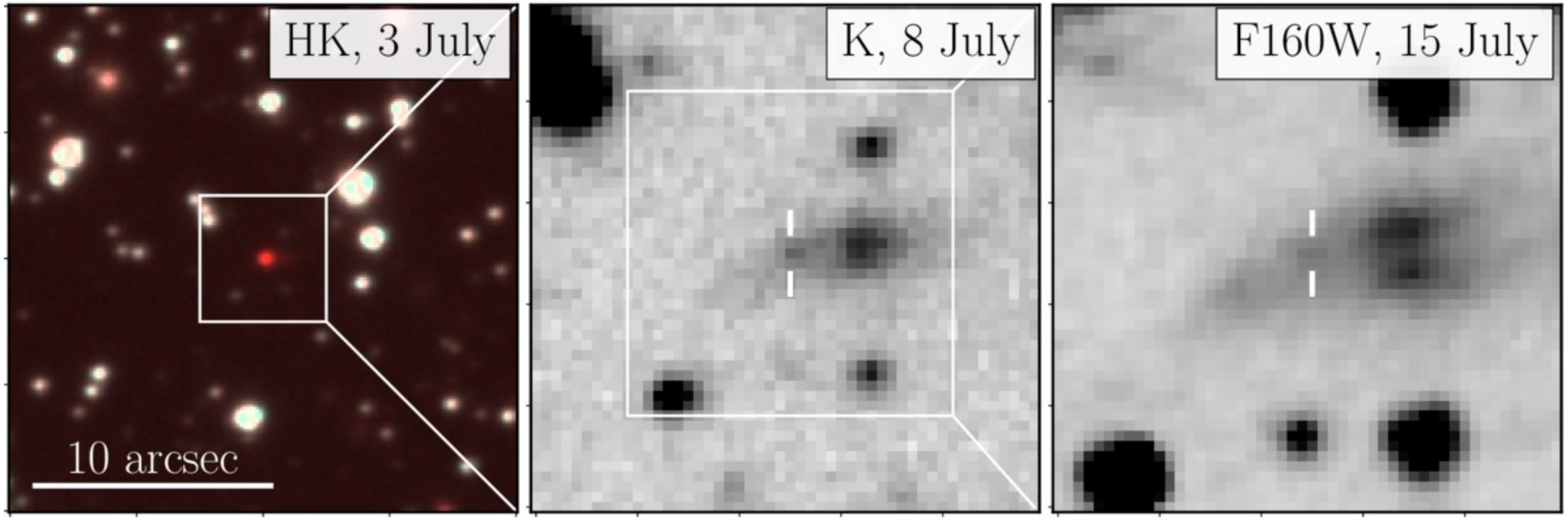


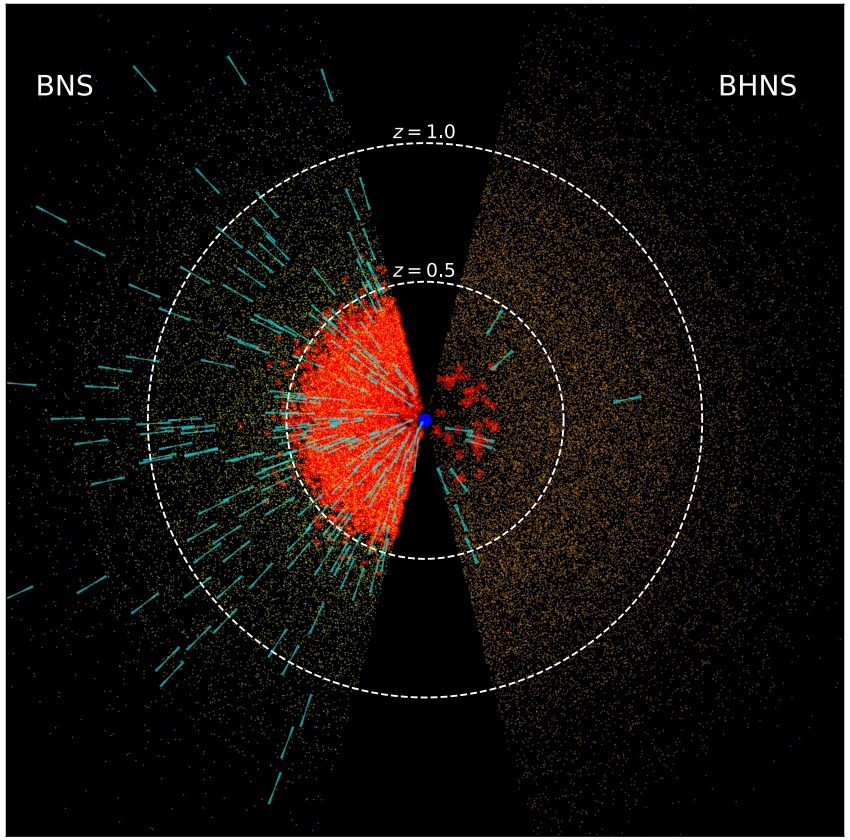
Host galaxy, extragalactic explosion!
Exceptionally long duration collapsing star?
White dwarf – IMBH tidal disruption?

>1 day long, multiple GRB triggers, possibly periodic

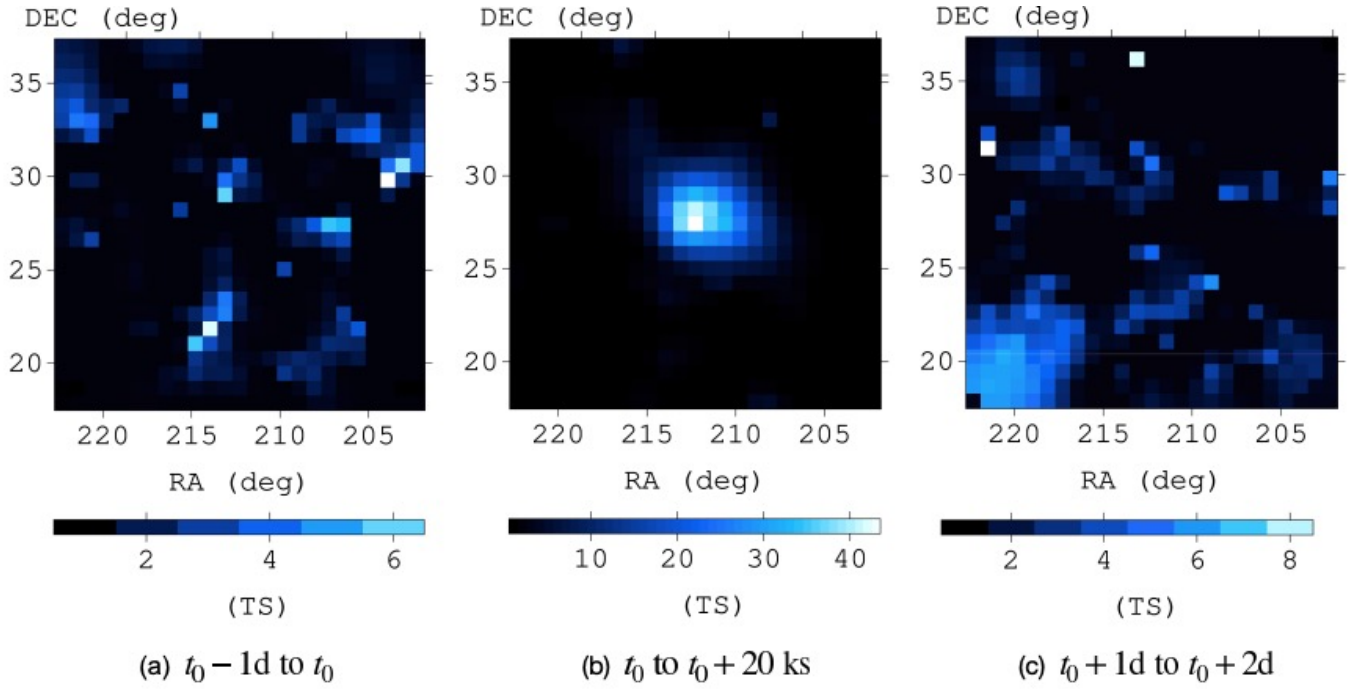
Levan et al. 2025 ApJ 990 28

High energy transients for the next generation of facilities

3G gravitational waves (Einstein Telescope)



Einstein Telescope, Blue Book, Division 4
(co-ordinators: G. Ghirlanda, A. Levan, S. Vergani

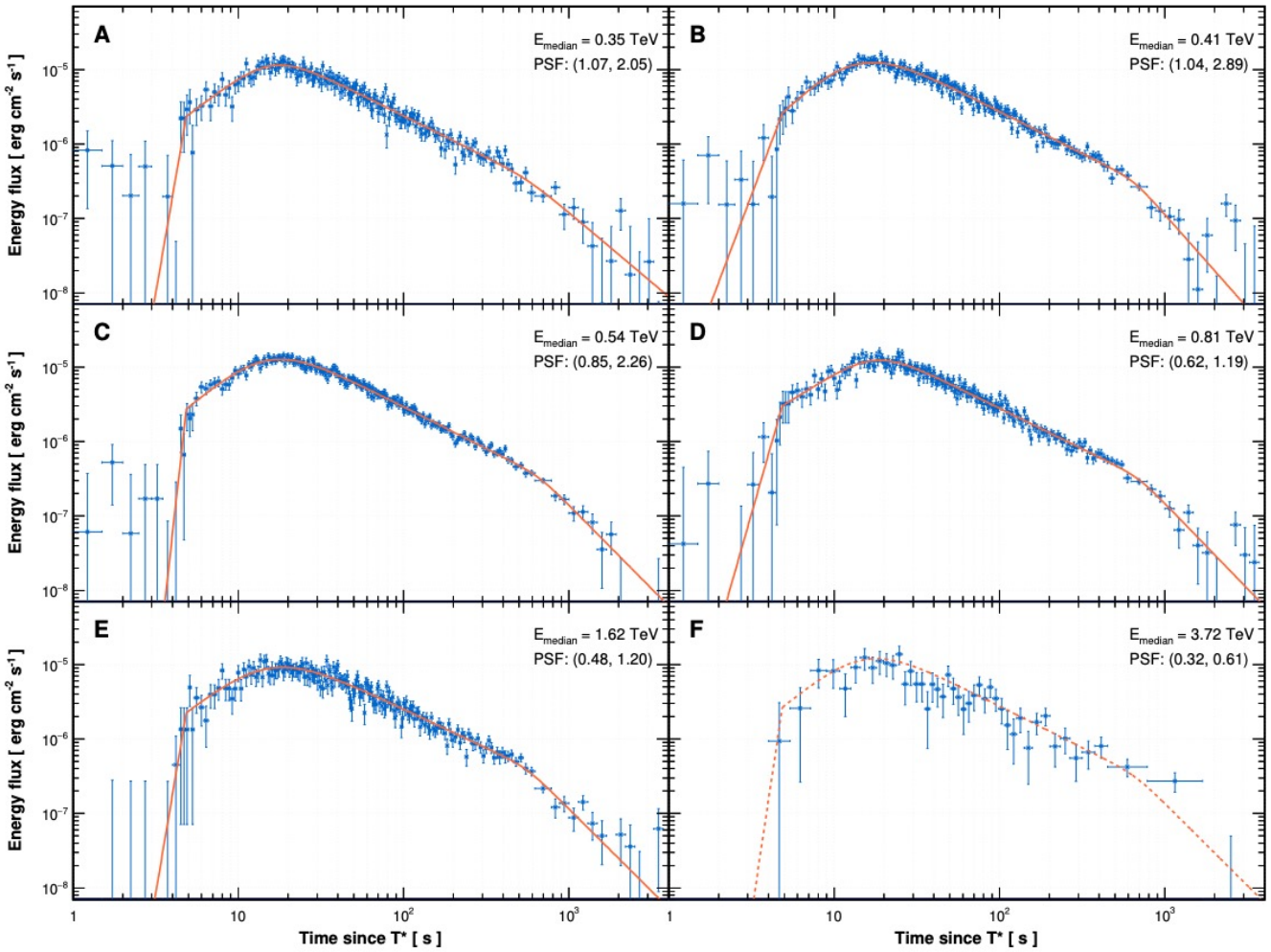


Delayed GeV emission from a compact object merger,
Mei et al. 2022 Nature 612 236

CTA observations could be a powerful route to identifying GW-EM counterparts in LVK 05 and 3G (e.g. Green et al. 2024).

High energy transients for the next generation of facilities

VHE gamma-rays



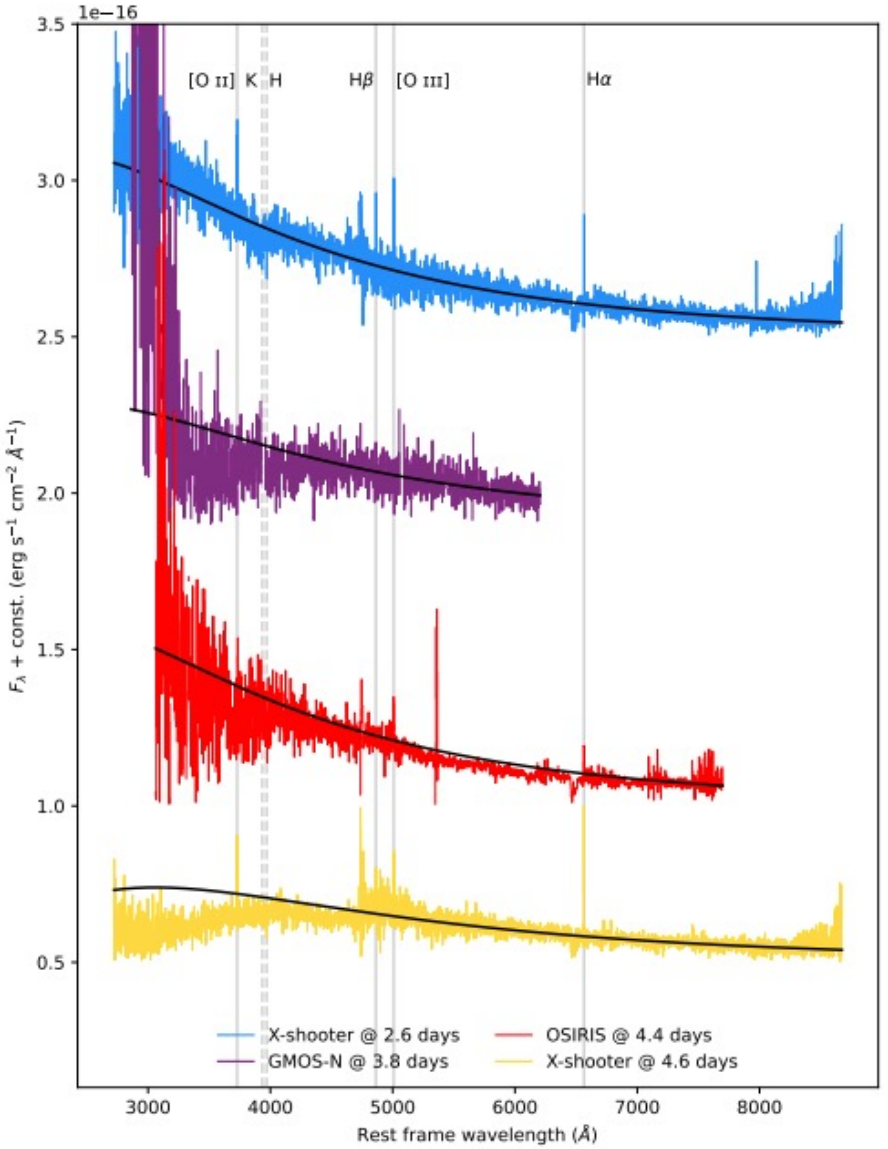
GRB 221009A

Brightest of All Time
(Burns et al. 2023, Malesani, Levan et al. 2023)

Many TeV photons, lightcurves, spectra etc (LHAASO collaboration 2024). Route to probing models for the Extragalactic Background Light (EBL).

High energy transients for the next generation of facilities

Neutrinos

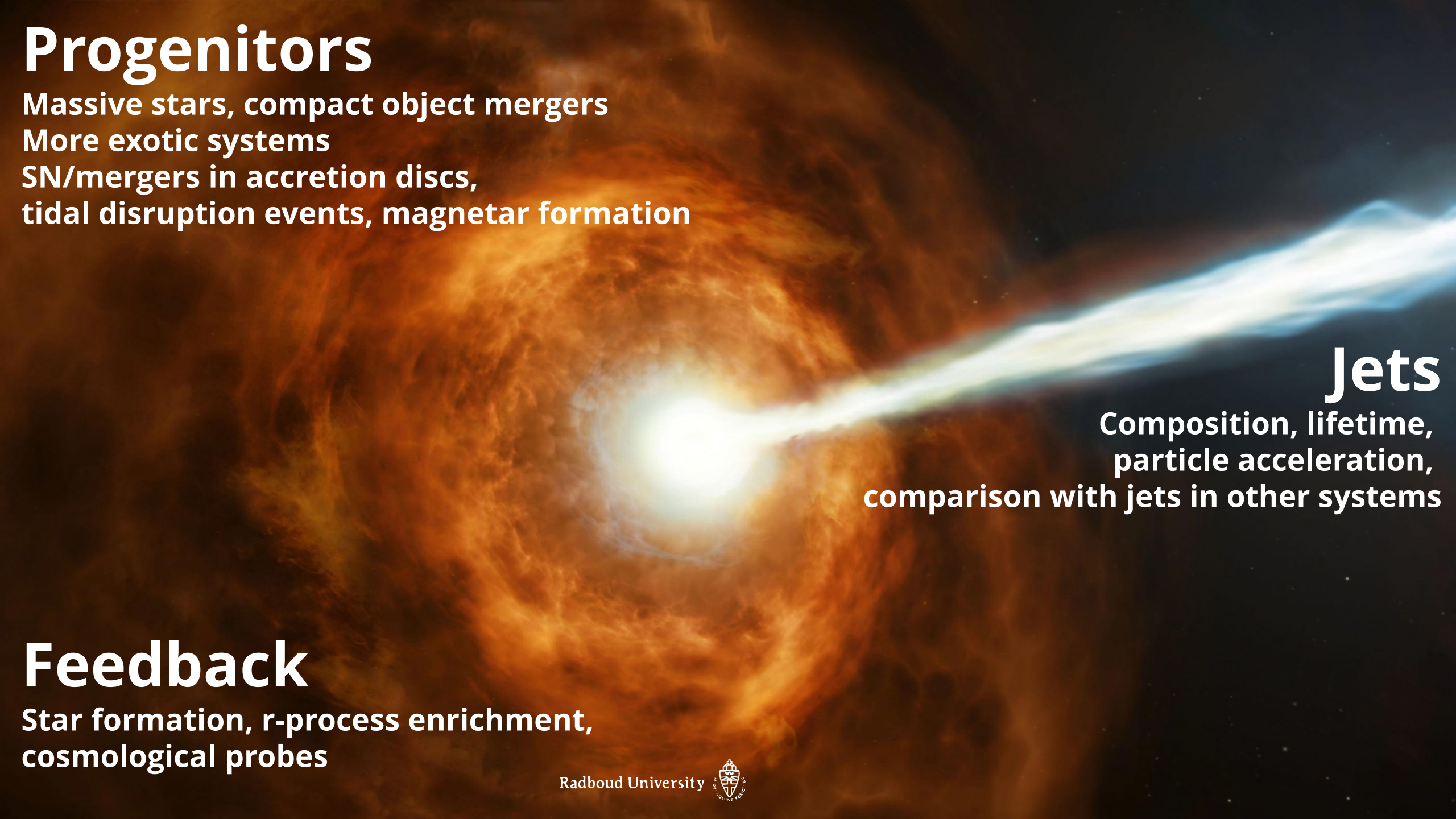


The Einstein Probe is now discovering the postulated, but so far unseen population of low-luminosity GRB/XRF events at low redshift.

Many of these are powered by cocoon-like emission and may also include choked fireballs.

These are prime sites for neutrino production, though distances (z>~0.1) still large to detect associated neutrinos.

Eyles-Ferris, Jonker, Levan et al. 2025, ApJ 988 14
Rastinejad, Levan, Jonker et al. 2025, ApJ, 988, 13



Progenitors

Massive stars, compact object mergers
More exotic systems
SN/mergers in accretion discs,
tidal disruption events, magnetar formation

Jets

Composition, lifetime,
particle acceleration,
comparison with jets in other systems

Feedback

Star formation, r-process enrichment,
cosmological probes

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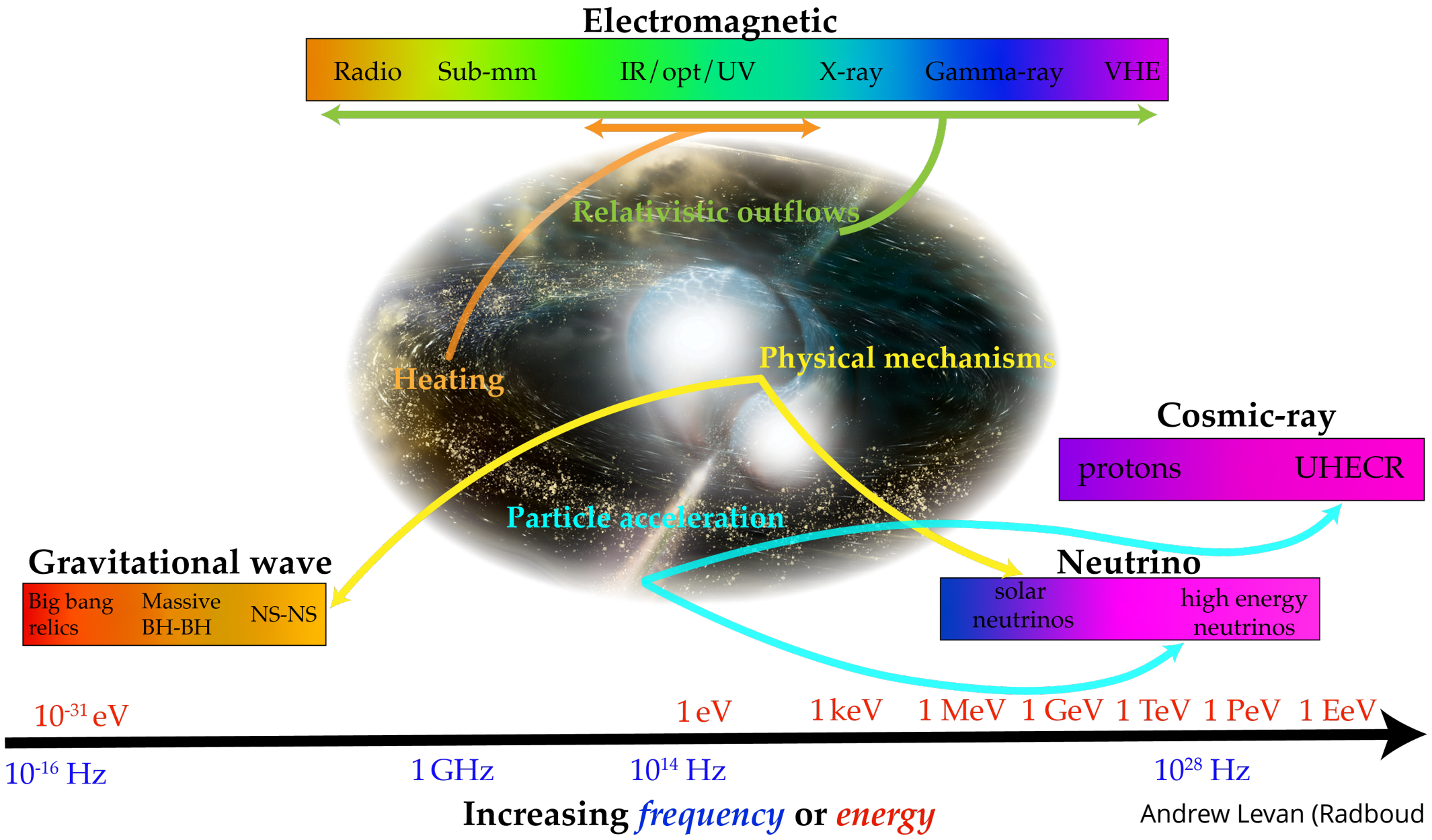

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GRB progenitors are one of the few physical systems where multiple messengers may be detected in the next decade. We should make sure we are position for this.