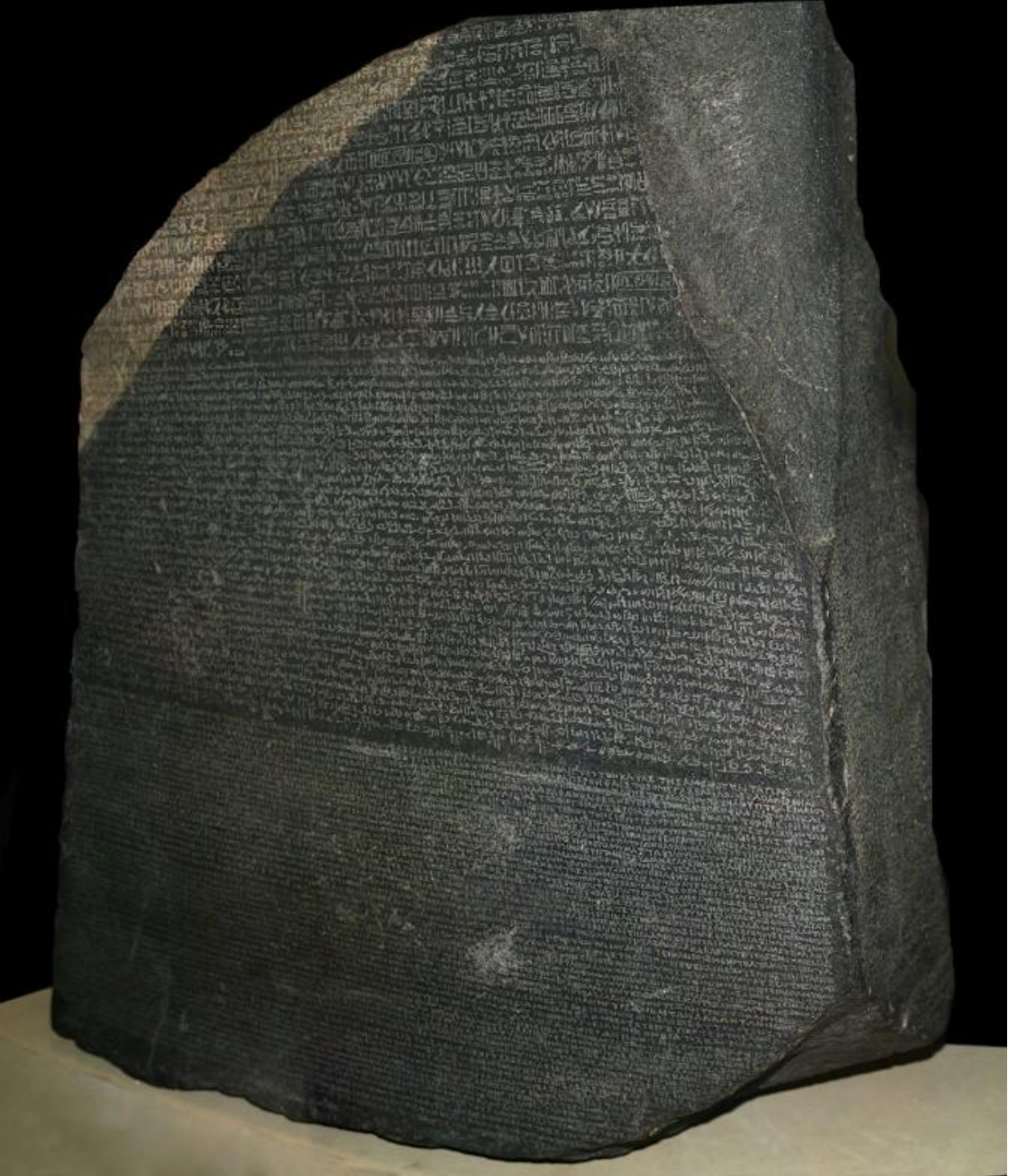
GRB 211211A: The attesoR Acid GRB

David Alexander Kann (IAA-CSIC)

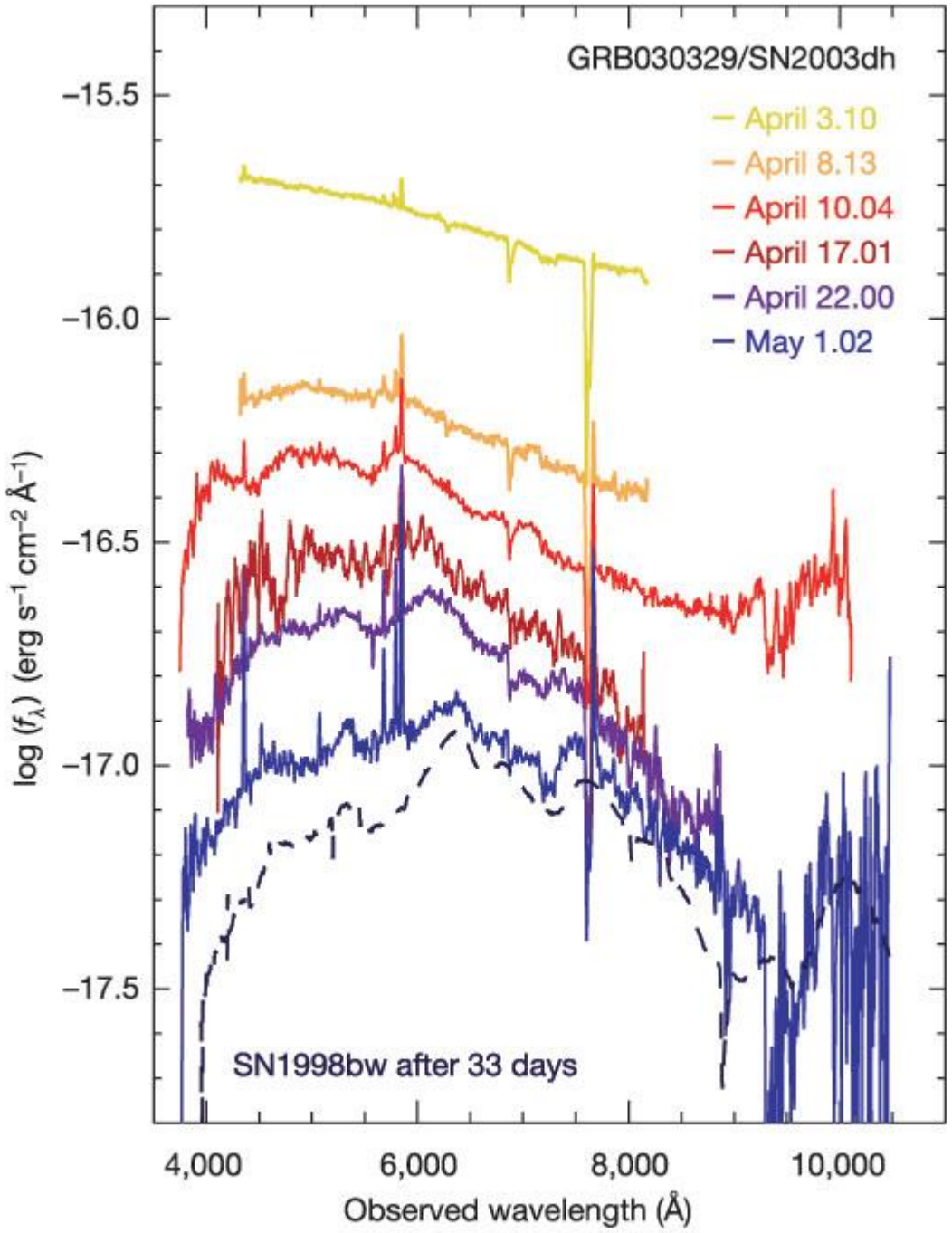
Multi-messenger astronomy with GWs and Neutrinos, GRANDMA Workshop, Nice, France, 220531.5000



Rosetta Stone

Literally: A stele containing the same decree in three languages, two in (unknown) Egyptian hieroglyphics, one in well-known ancient Greek, allowing Jean-François Champollion to begin the work of understanding hieroglyphics.

Figuratively: An object or event made up in part by something that is well-understood, and something that is unknown, allowing deductions to be made about the unknown aspect. Even more generally, an „essential clue to a new field of knowledge.“



A GRB Rosetta Stone: GRB 030329/SN 2003dh

GRB 980425/SN 1998bw: Strong clue to the GRB/SN connection but GRB 980425 was a peculiar, extremely subluminous GRB – exception, not the rule?

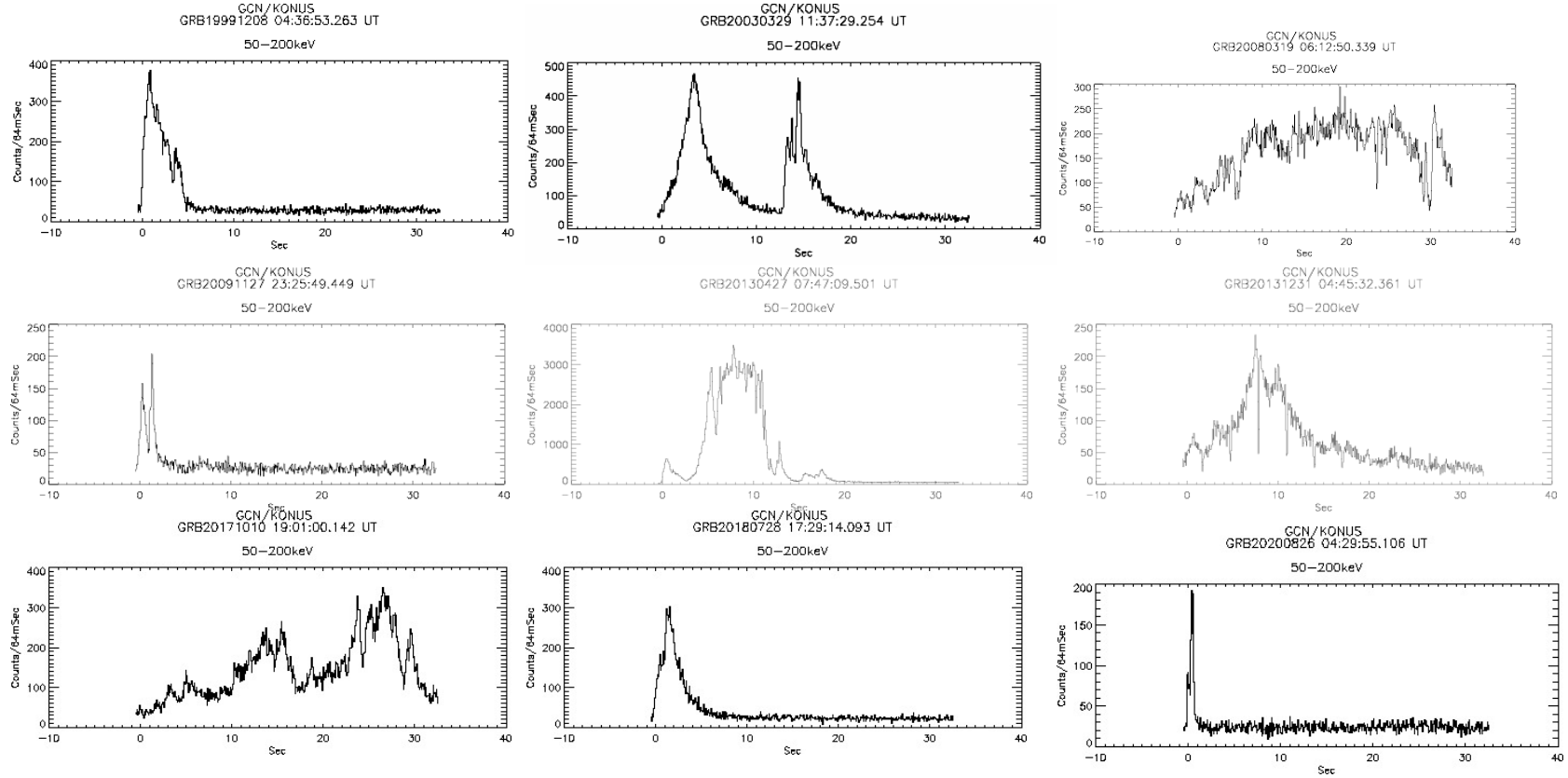
GRB 030329: Luminous „cosmological“ GRB clearly associated with a broad-lined Type Ic SN (2003dh), establishing the link between (long) GRBs and energetic stripped-envelope SNe.

attesoR Acid

The exact opposite of a Rosetta Stone: An event combining multiple aspects that had been thought to be well-understood, in a way that raises far more questions than it (initially) provides answers, dissolving accepted norms.

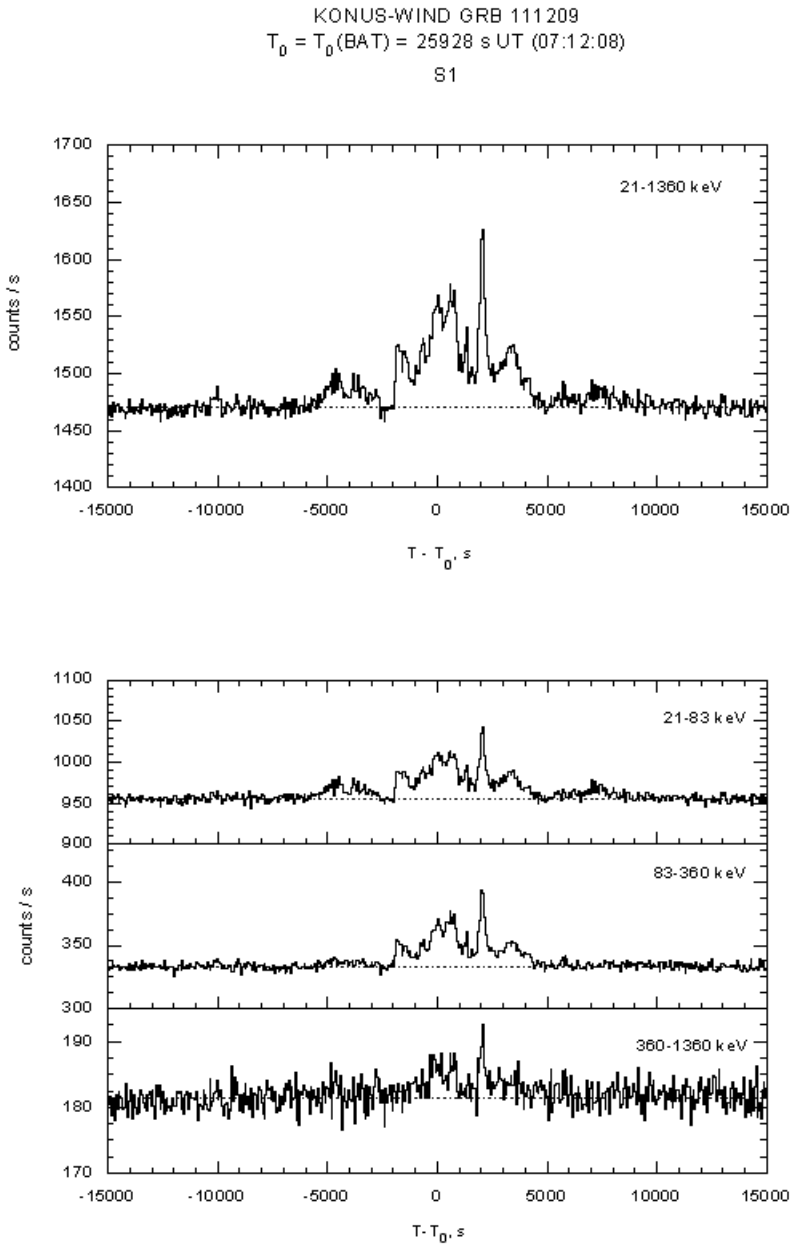
Bibliography (with arXiv numbers) (Submitted to Nature, Nature Astronomy):
2204.10864: J. Rastinejad et al: A Kilonova Following a Long-Duration Gamma-Ray Burst at 350 Mpc
2204.12771: J. Jang et al: A peculiar, long-duration gamma-ray burst from a neutron star-white dwarf merger
2205.02186: S. Xiao et al: The quasi-periodically oscillating precursor of a long gamma-ray burst from a binary neutron star merger
2205.05008: B. Gompertz et al: A minute-long merger-driven gamma-ray burst from fast-cooling synchrotron emission
2205.05031: H. Gao et al: GRB 211211A: prolonged central engine under strong magnetic field environment
2205.08566: A. Mei et al: GeV emission from a compact binary merger
2205.09675: H.-M. Zhang et al: Fermi-LAT detection of a GeV afterglow from a compact stellar merger

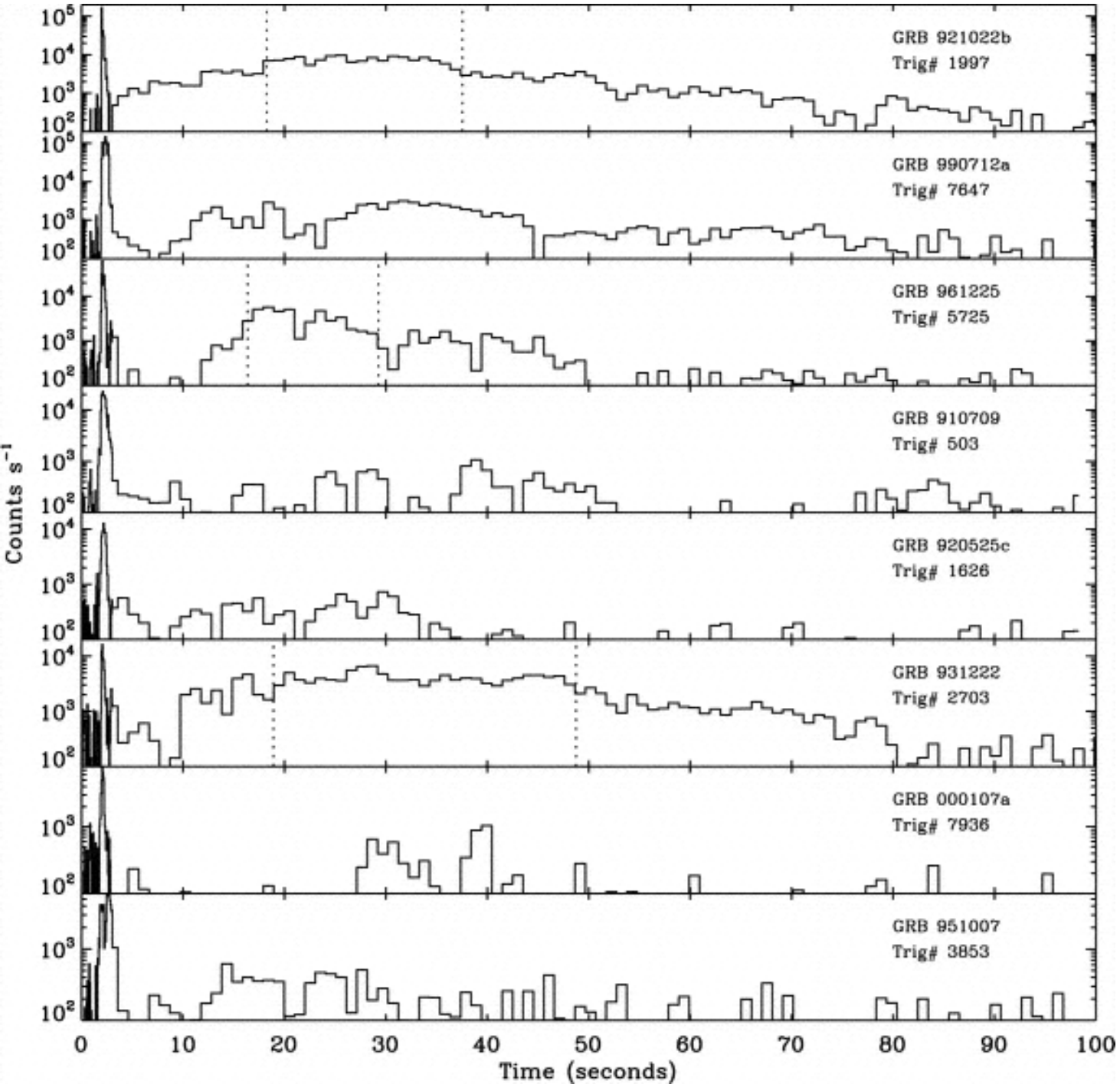
A Rogue‘s Gallery of SN-associated long GRBs



GRBs 991208 030329 080319B
091127 130427A 131231A
171010A 180728A 200826A („short“)

111209A (ultra-long)





Short GRBs with Extended Emission:

Norris & Bonnell (2006):

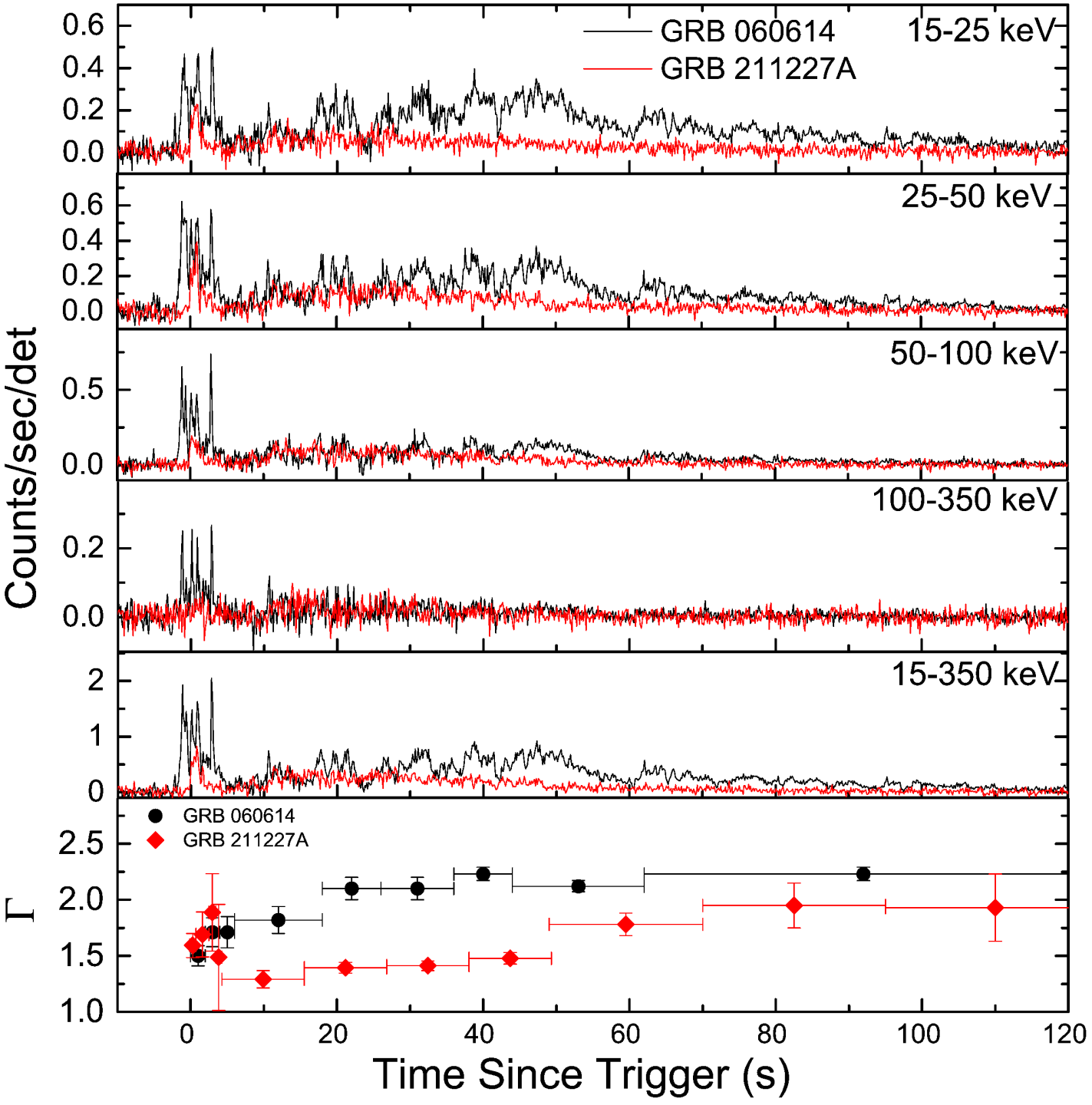
Found SGRBs in the BATSE sample accompanied by long-lasting (~100 s) softer, emission, can imply T_90 >> 2 s.

Combination of Initial Pulse Complex (IPC) and Extended Emission (EE).

IPC looks just like a normal SGRB, T_90 < 2 s.

IPC harder, brighter, more energetic than EE.

Multiple further examples known from *Swift* sample.



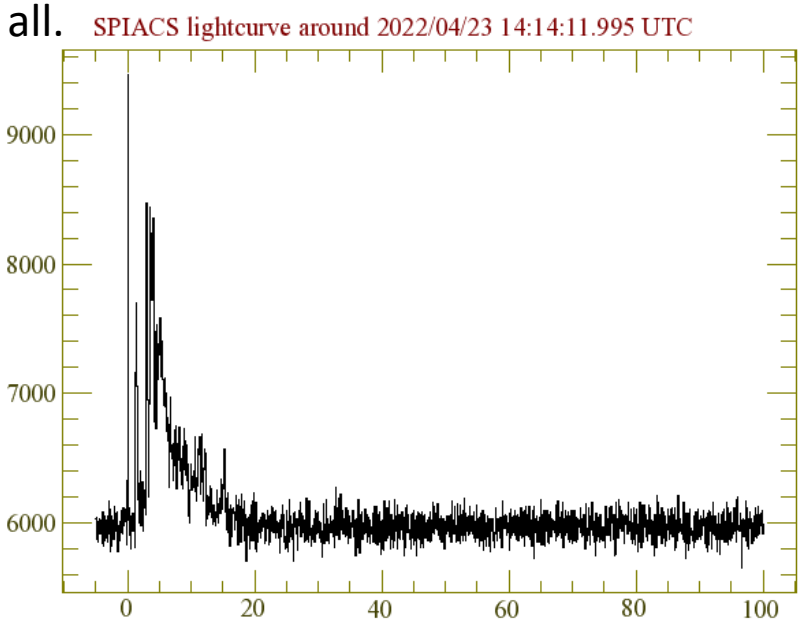
GRB 060614:

Some attesoR Acid: IPC is ca. 5 s long, not a traditional SGRB+EE: Long GRB? Short GRB?

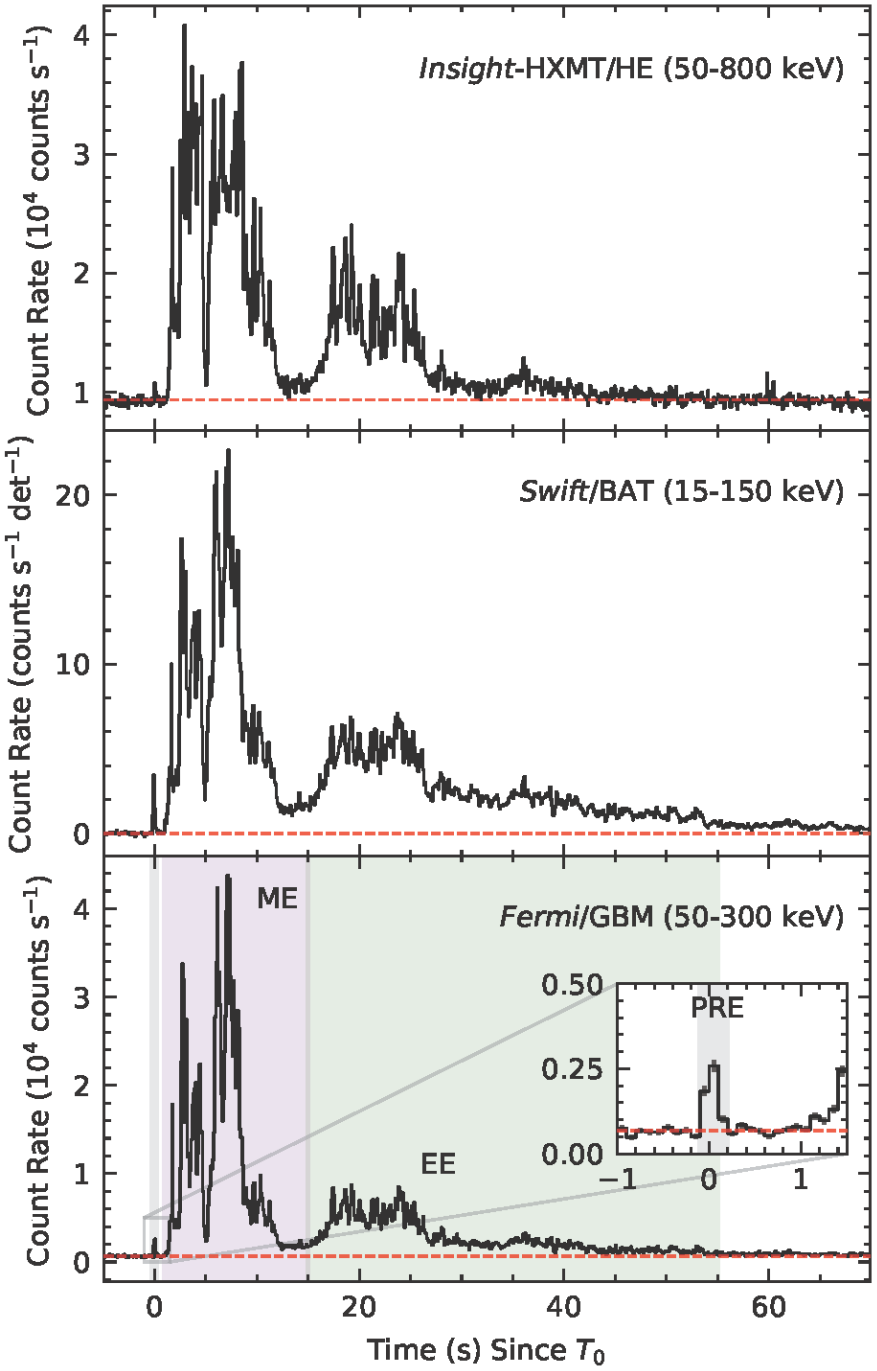
Yang et al.: 2015: Evidence for a KN in the late afterglow ➔ very likely a merger event!

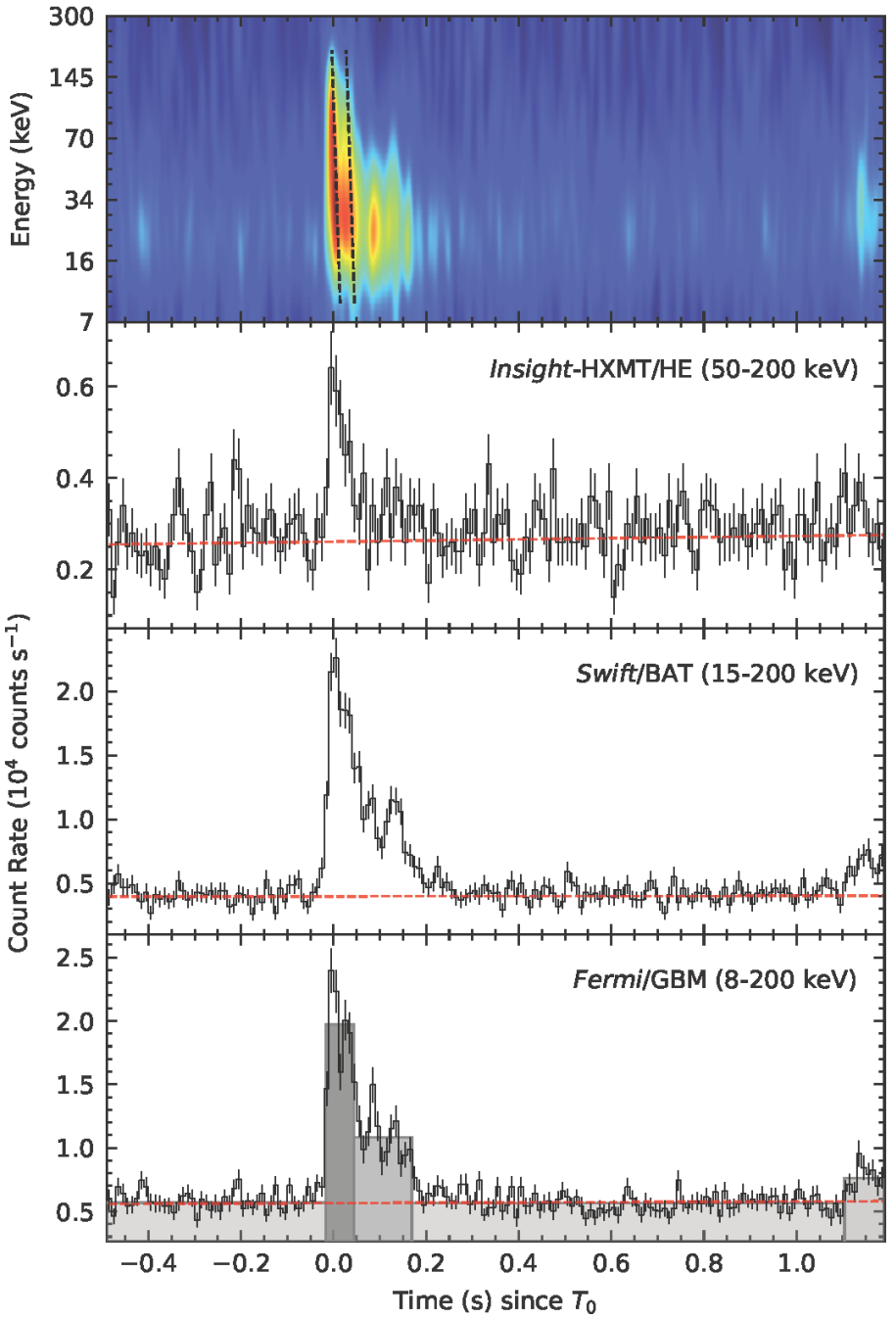
GRB 211227A at $z = 0.228$ looks very similar to 060614, no evidence for afterglow or KN at all (extinction?).

GRB 220423A: Potentially another one, but no localization at all.



Lü et al. 2022





GRB 211211A:

Ultrabright *Swift*/*Fermi* GRB, very hard, highly variable, T_90 ~ 60 s

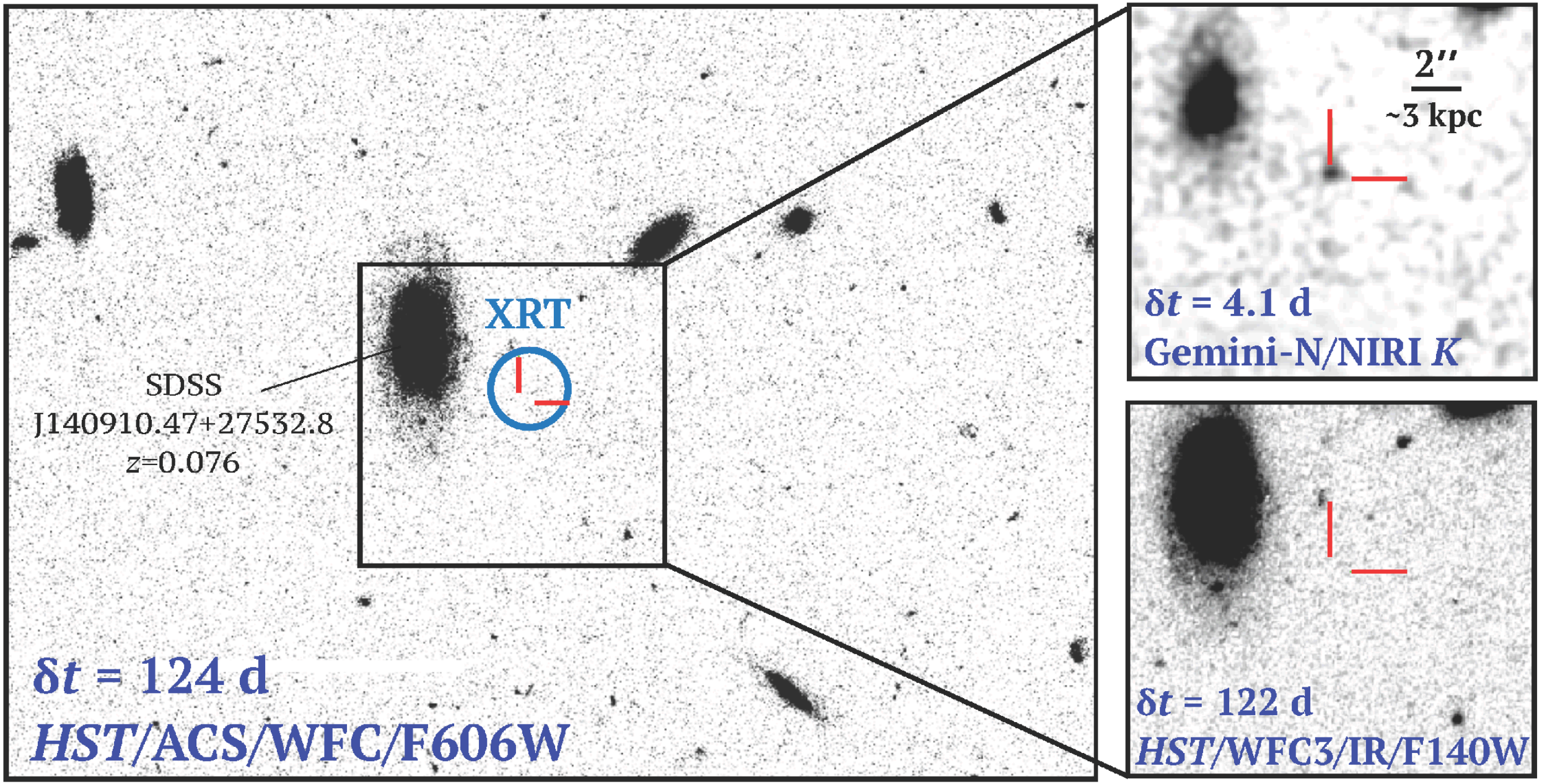
So bright it caused *Swift* telemetry to initially fail, brightest ever in raw counts (300 kcounts/s)

Precursor, main emission, extended emission

Does NOT look like 060614, „IPC“ is > 2 x as long, EE hard and very variable.

Initial impression: Luminous long GRB at likely moderate redshift (*z* ~ 1), not dissimilar to 991216 or 110918A

Association with a z = 0.076 galaxy? No lines in afterglow spectrum, no host directly under transient.



The UV/optical/NIR transient:

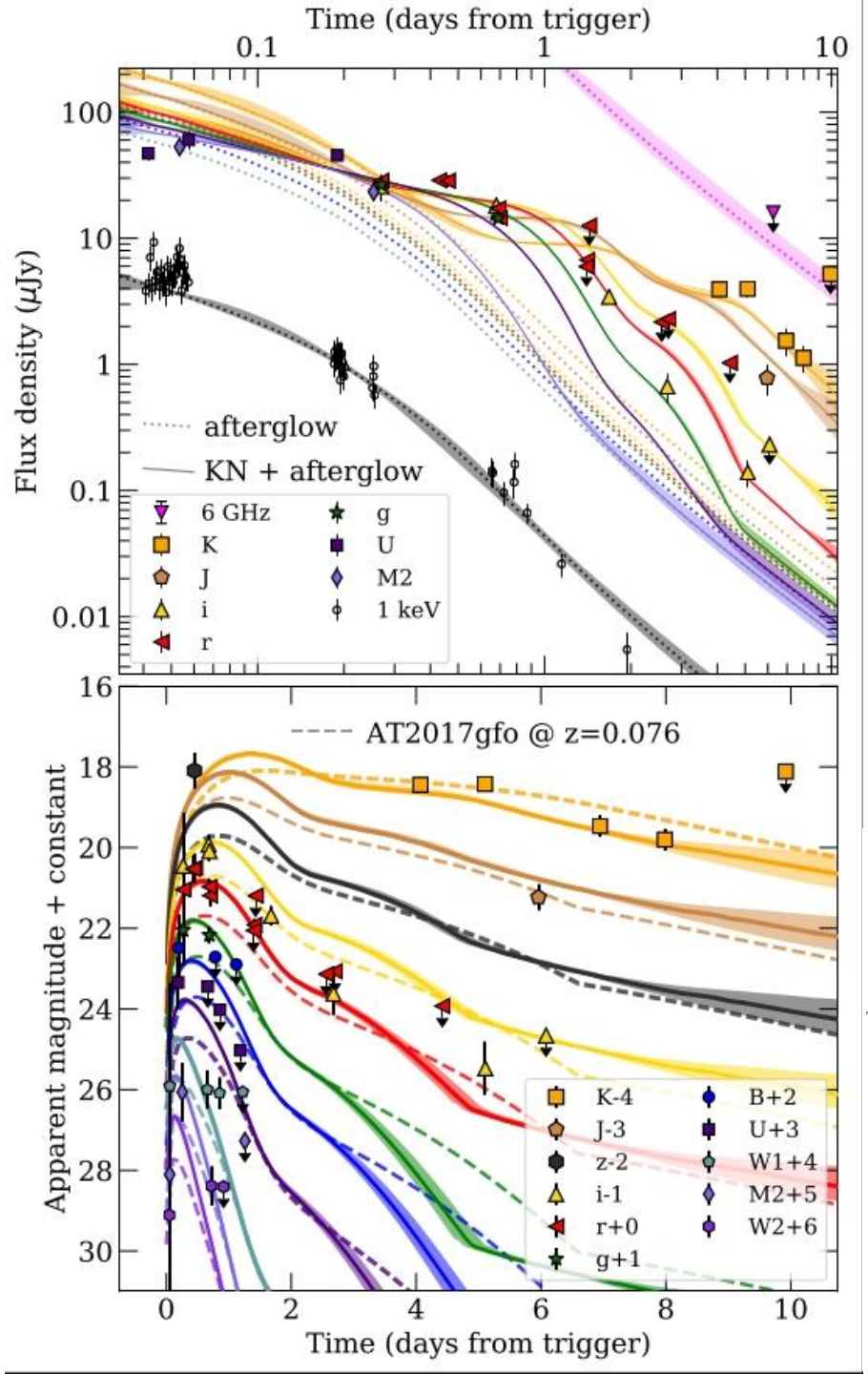
No bright afterglow, as expected, but a faint, nearly constant one!

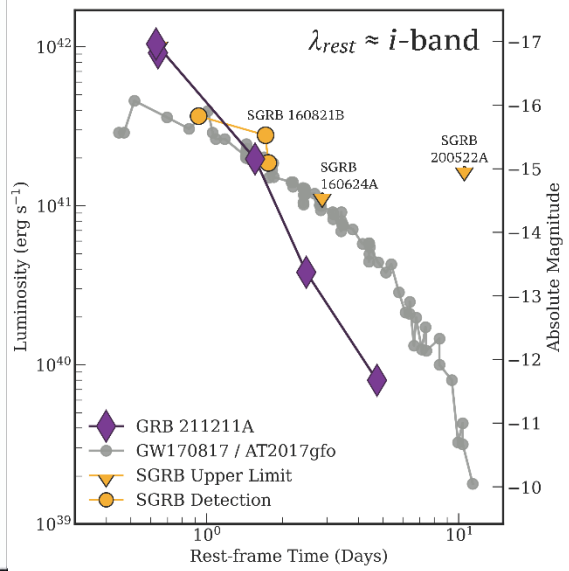
Bright initial UV detections: Little dust, low redshift.

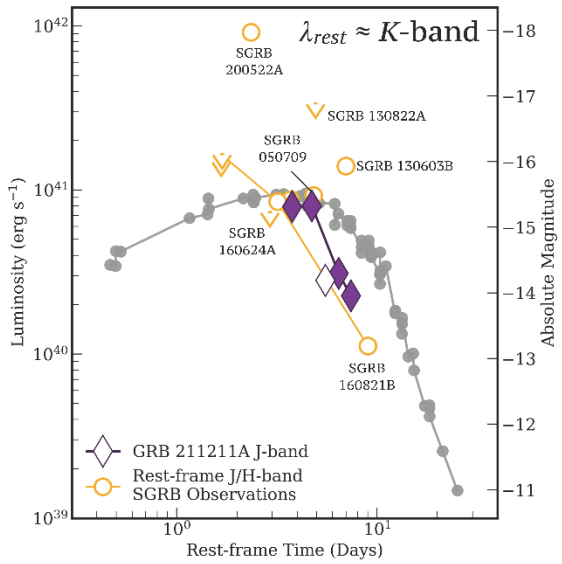
Multi-epoch *i*'-band follow-up by de Ugarte Postigo et al. with 2.2m CAHA/CAFOS discovers break and very steep decay ➔ not typical for a standard afterglow!

Further NIR follow-up reveals very strong color evolution to the red combined with deep upper limits on a classical SN ➔ this is a kilonova!!!

Independent of the prompt emission, **THIS IS A MERGER!!!**

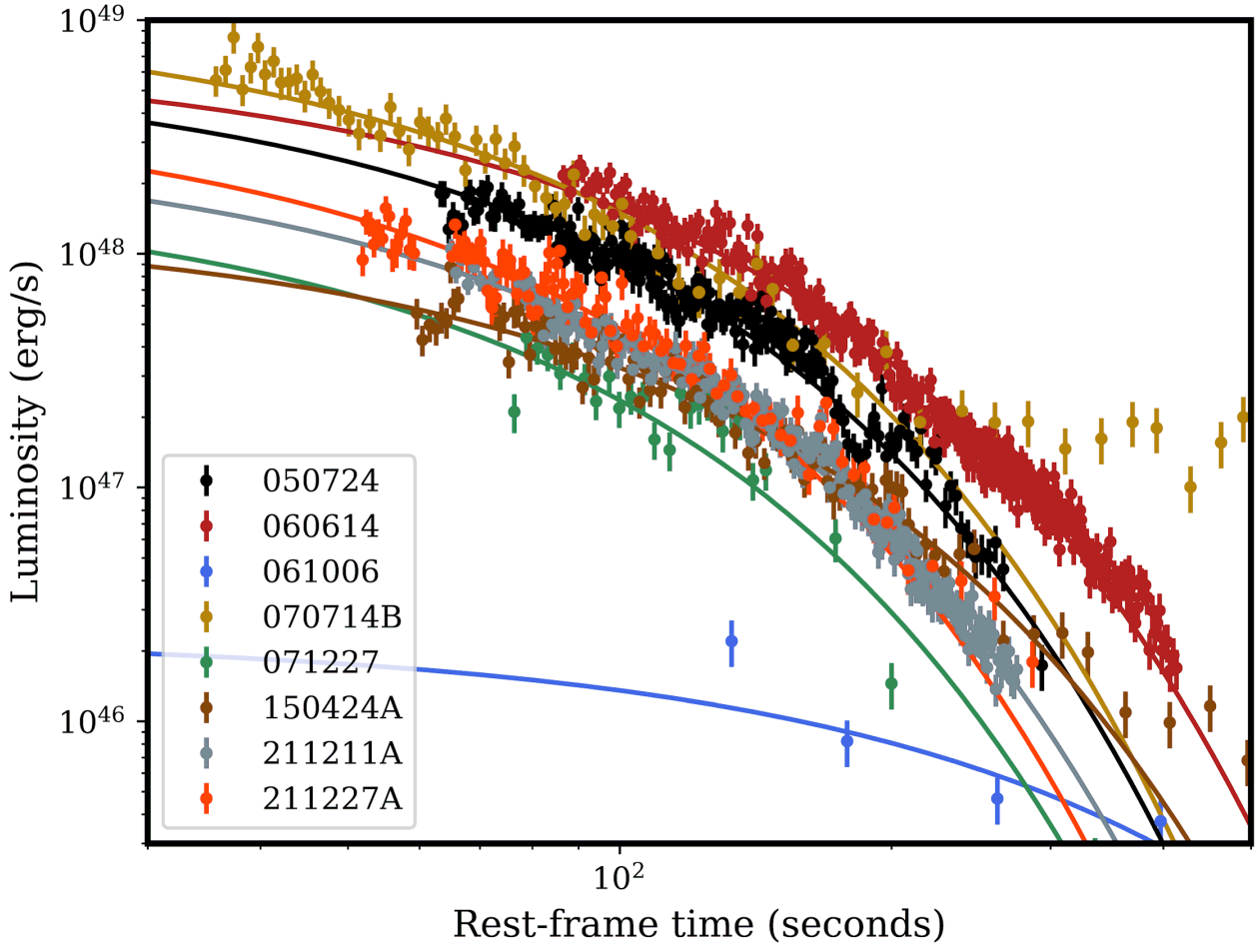






Maintenant nous avons la salade

Pro-merger and Counter-merger



Pro:

Early X-ray light curve looks a lot like other SGRB+EE

IPC agrees with SGRB Amati relation

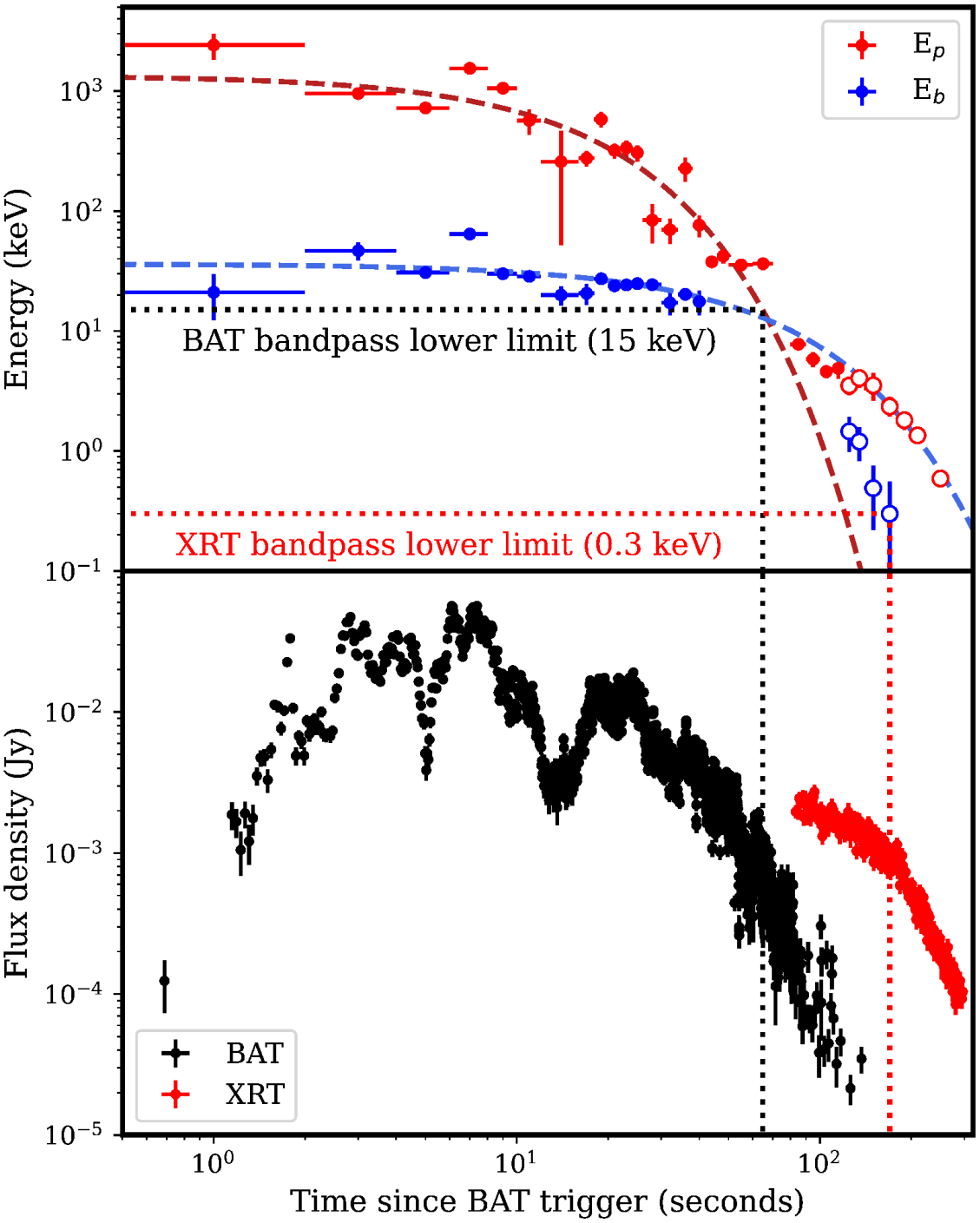
Variability time scale more similar to SGRBs

Con:

Of course duration of IPC

„Amplitude parameter“ agrees fully with long GRBs

➔ Rapid classification methods fail! Have similar, fainter cases been missed before?



Further interesting aspects:

Detailed spectral analysis of prompt reveals a double-broken power-law is needed

➔ Evolution of cooling break seen in the prompt emission, never before for a merger event, and transition from fast cooling to slow cooling, NEVER seen before in any GRB!

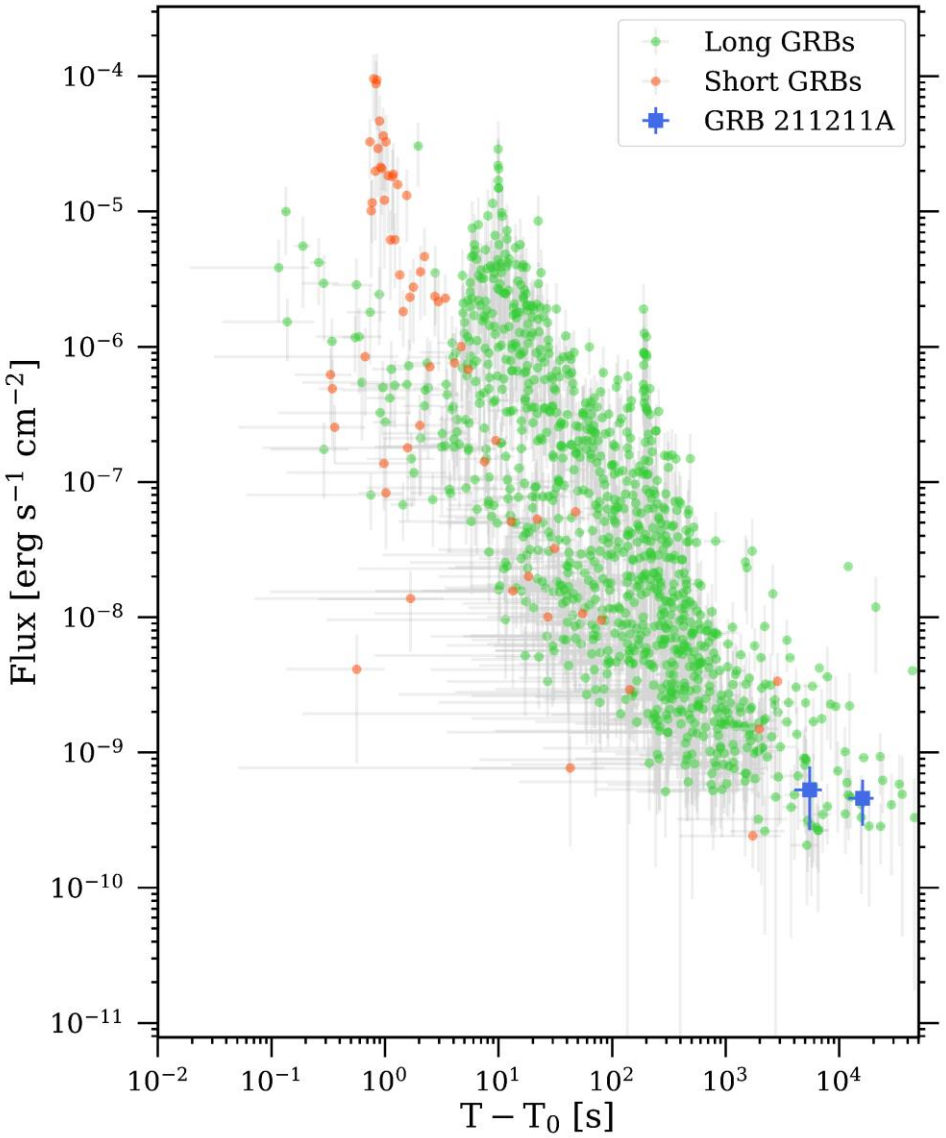
Claim of 22 Hz QPO in precursor (but? Eric Burns, priv. comm.)

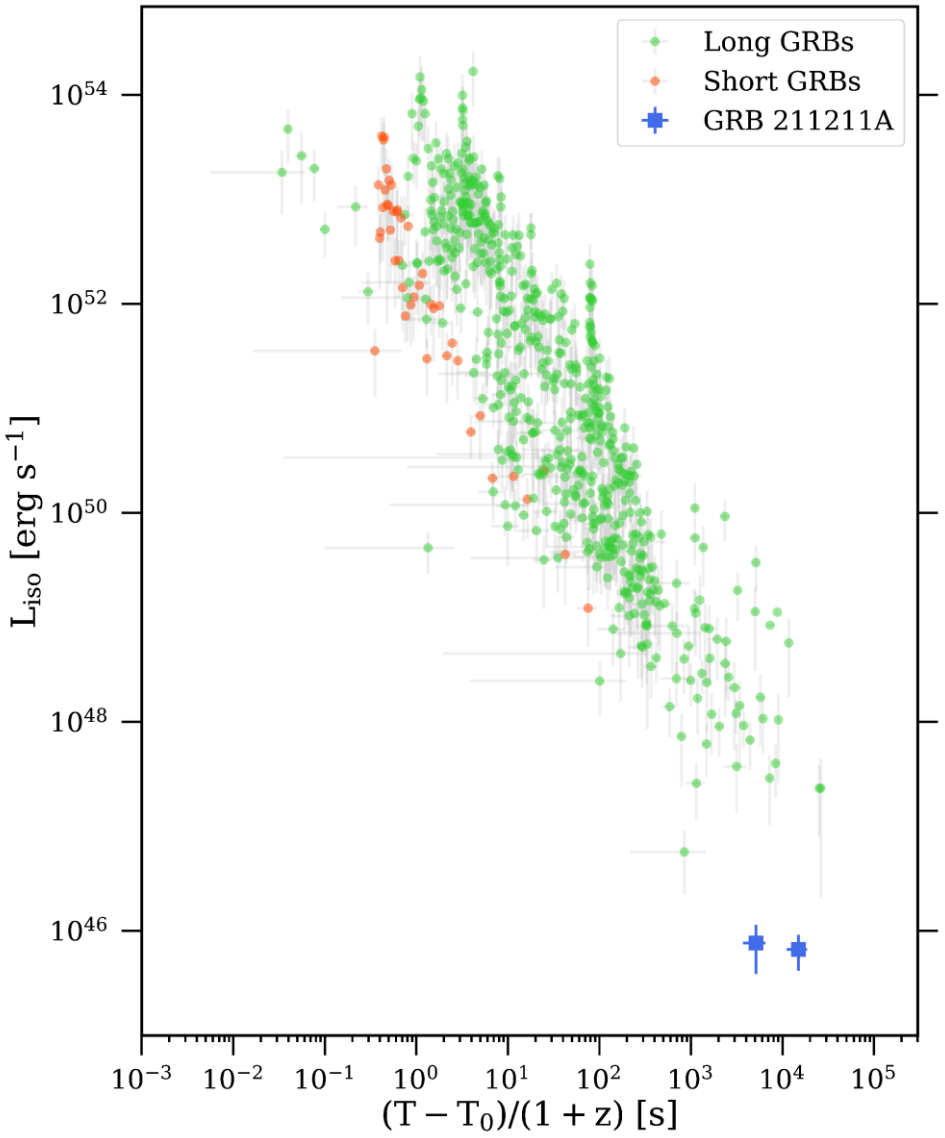
Interpretation: Crustal torsional oscillations lead to hyperflare a few orbits before final merger ➔ one of the compact objects must be a magnetar!

BUT: Magnetars are young objects associated with recent star-formation, NONE is seen at the GRB site! Also potentially long inspiral time, extremely low circumburst density (which can explain faint afterglow)

Further interesting aspects: Discovery of late-time high-energy emission with *Fermi* LAT, never seen before for a merger event.

Interpretation: Late afterglow synchrotron? Late jet upscattering KN photosphere photons?





You can‘t tell a book by its cover anymore...

Main problem: Prompt emission looks strongly like a long GRB, fainter cases might not lead to intense follow-up

Explanation?

- Neutron star-white dwarf merger?

- Magnetar would lead to magnetic barrier outside the ISCO, throttling accretion, preventing neutrino creation and extending prompt emission? BUT again arguments against a magnetar...

And FINAL Note:

This event, despite being an ultra-bright GRB, lies, at 350 Mpc, outside the detector horizon of GW observatories!!!