Mixing up the standard GRB classification

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Outline

New peculiar and surprising GRBs:

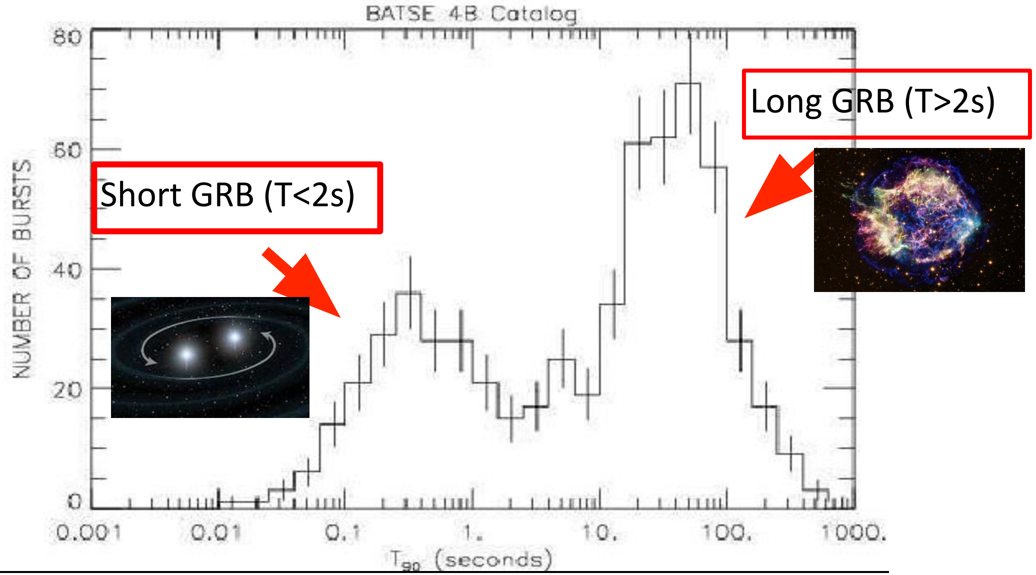
1. GRB 200826A was the shortest collapsar gamma-ray burst.

2. On the opposite side, GRB 211211A is the longest merger event.

3. GRB 210905A was a rare and extremely energetic event at very high redshift

Gamma ray bursts

The burst duration shows a bimodal distribution interpreted to be (indirect) evidence of two classes of progenitors



BATSE data *Kouveliotu et al. 1993*

Is the simple duration an indicator of the origin of a GRB?

The 2 distributions show overlap
(e.g., Horvath+02, Levesque+10)

Bromberg+11,12,13:

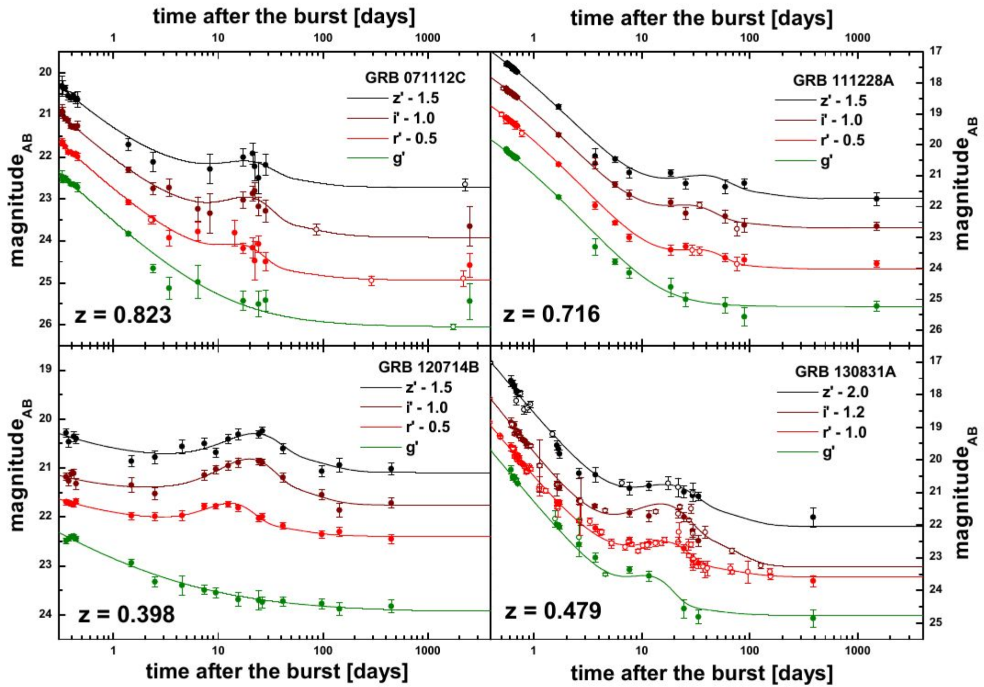
- The limit of 2s is valid for BATSE bursts.
  - 0.8s is more suitable for Swift BAT
  - 1.7s for FERMI GBM

- **Bursts with duration ~0.5 s may be collapsar**

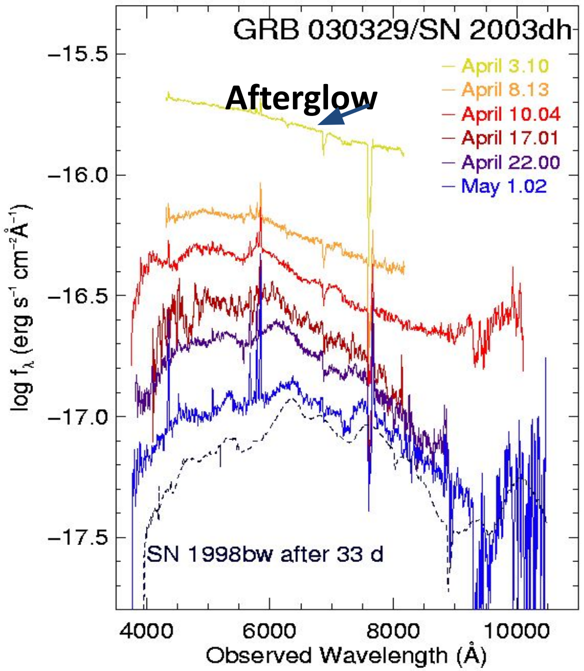
- The shortest known to date was GRB 040924 (T90,i~1s, HETE-2)

Unveil the progenitor: a massive star

Long GRB afterglow monitoring of nearby events (z<1) enables to detect the associated SNIb/c signatures → core-collapse star origin is confirmed!



Klose et al. 2019

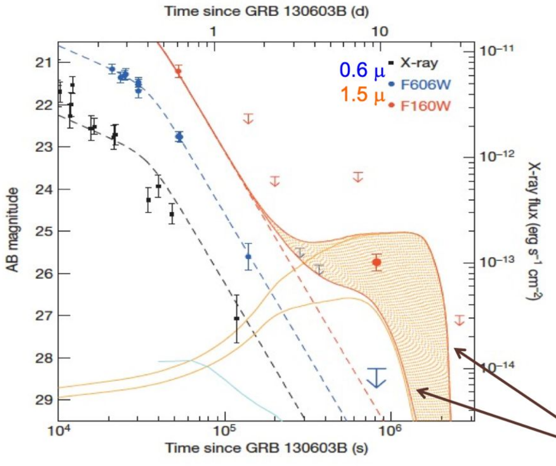


Hjorth et al. 2003

Unveil the progenitor: a merger

Short GRB afterglow monitoring enables to detect the thermal emission ("kilonova") powered by the radioactive decay of newly formed (r-process) heavy elements in NS-NS (and possibly also in NS-BH) mergers → in line with compact binary coalescences progenitor hypothesis

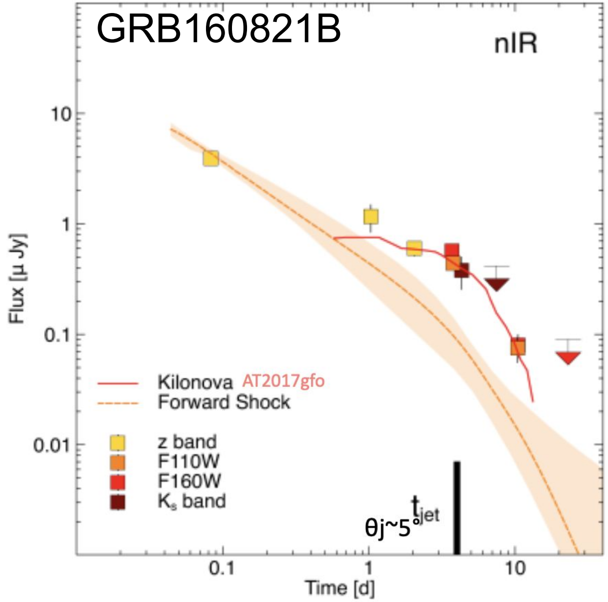
short GRB 130603B



Tanvir et al. Nature, 500, 547, 2013

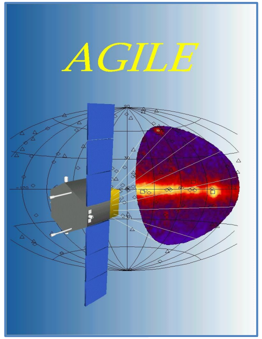
- short GRB 130603B a z=0.356 (Tanvir+2013)
- Possible evidence of kilonova 7 days after the burst as a significant deviation from expected afterglow flux

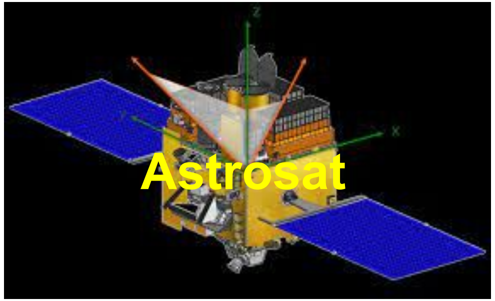
Ejected mass: 0.1 Mo
Ejected mass: 0.01 Mo

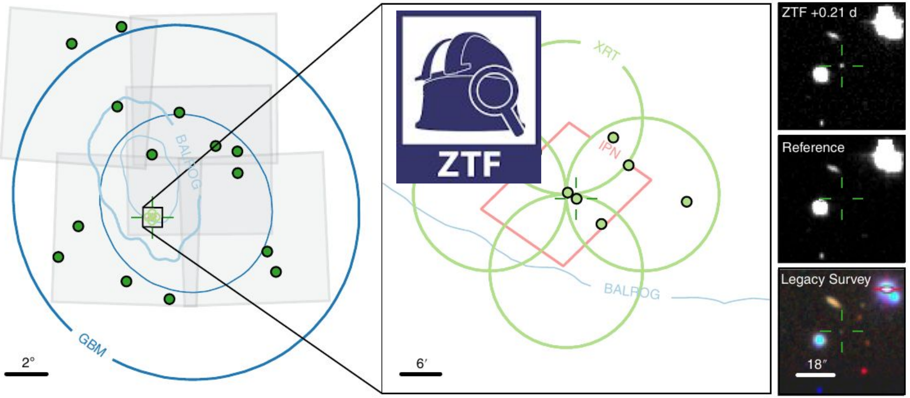


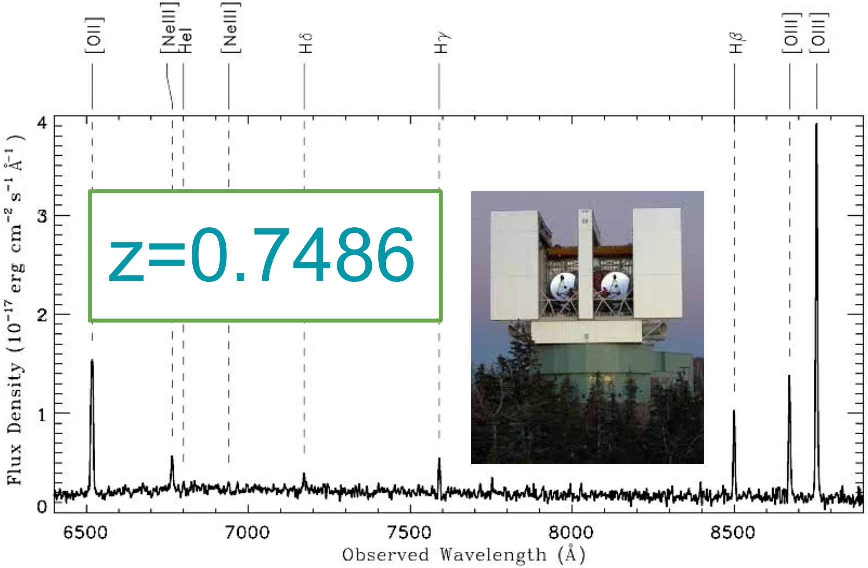
Troja et al. 2019

Discovery of GRB 200826A



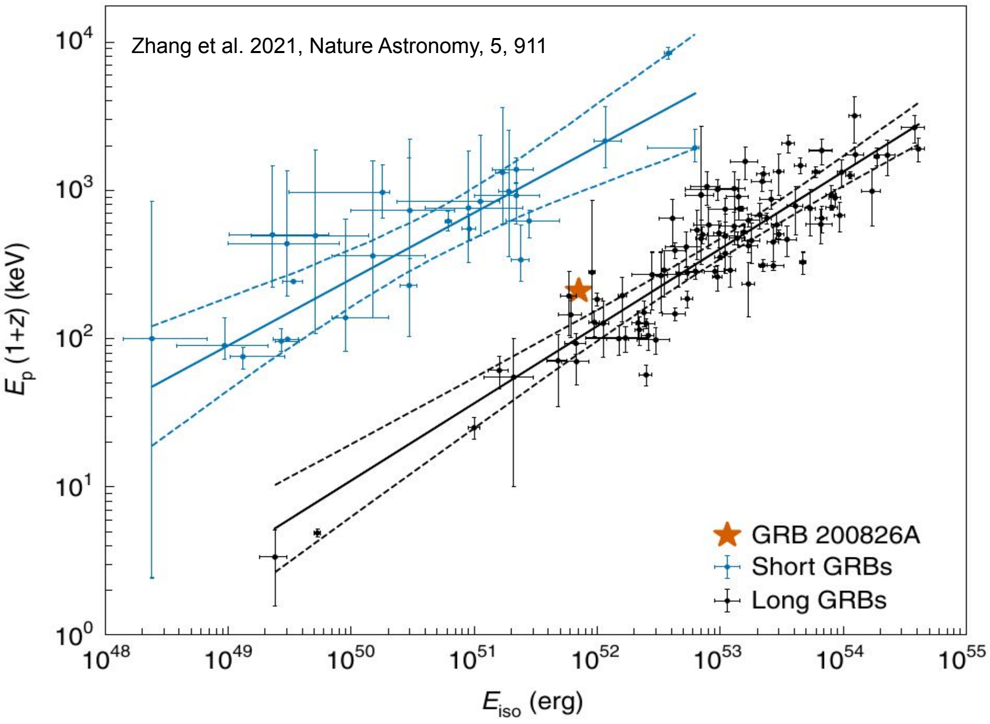


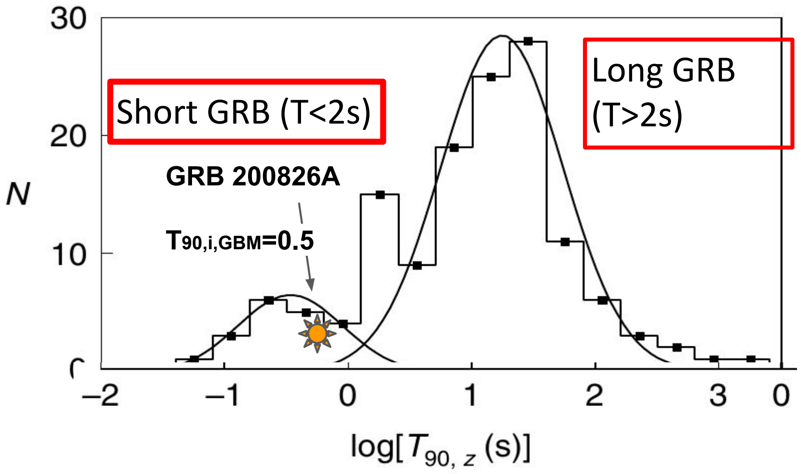




GRB 200826A prompt emission

Rest-frame energetics

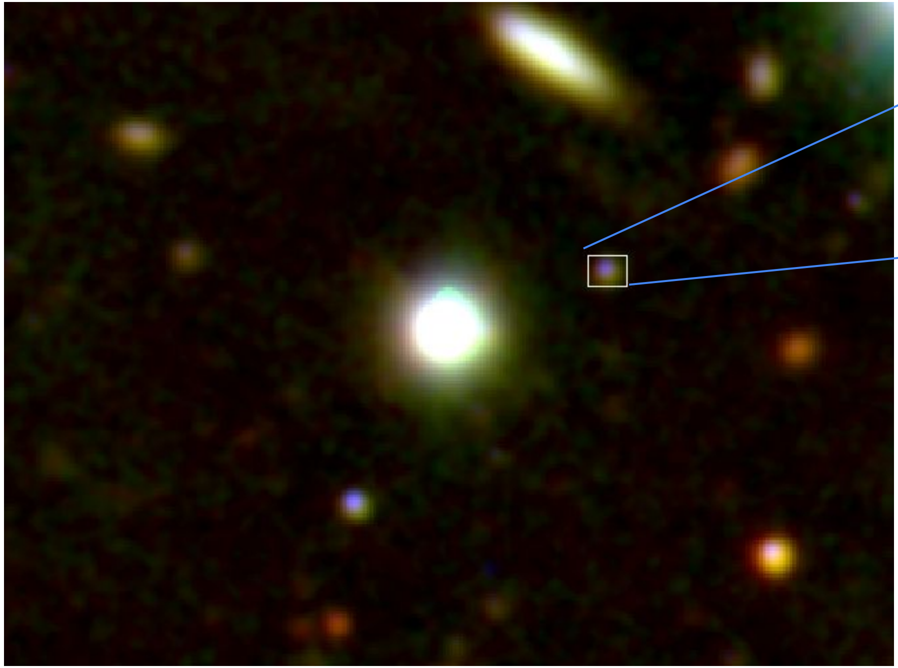


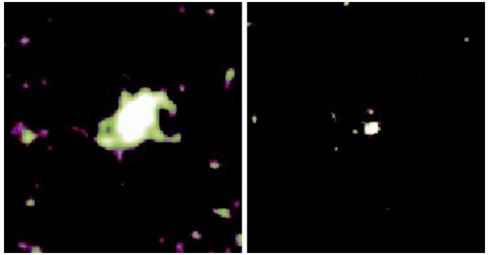


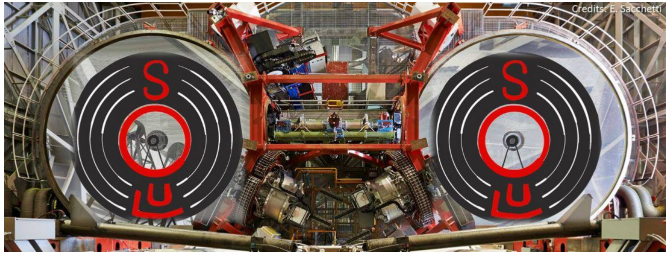
Rest-frame duration

The prompt properties do not allows us to clearly understand the progenitor of GRB 200826A

Deep NIR (rest-frame z-band) imaging in adaptive optics



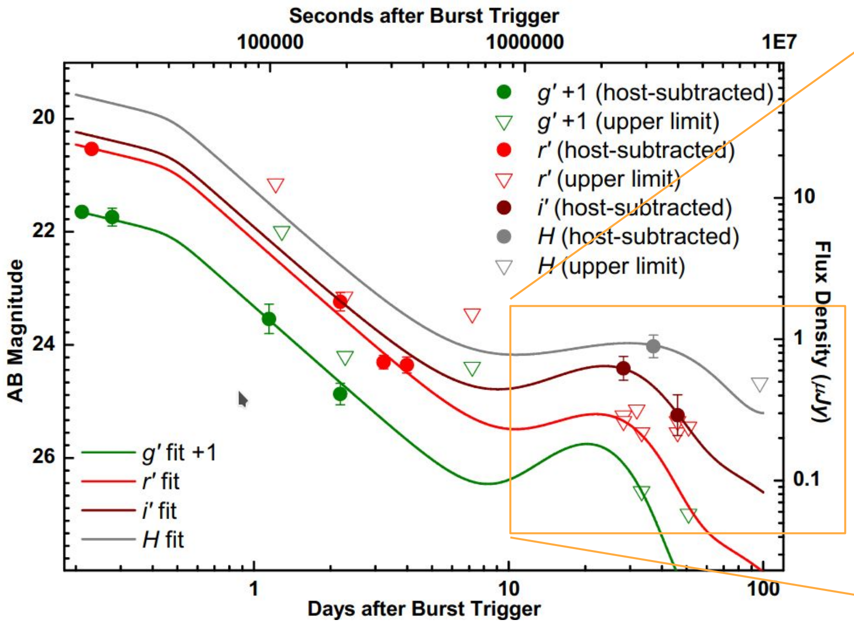


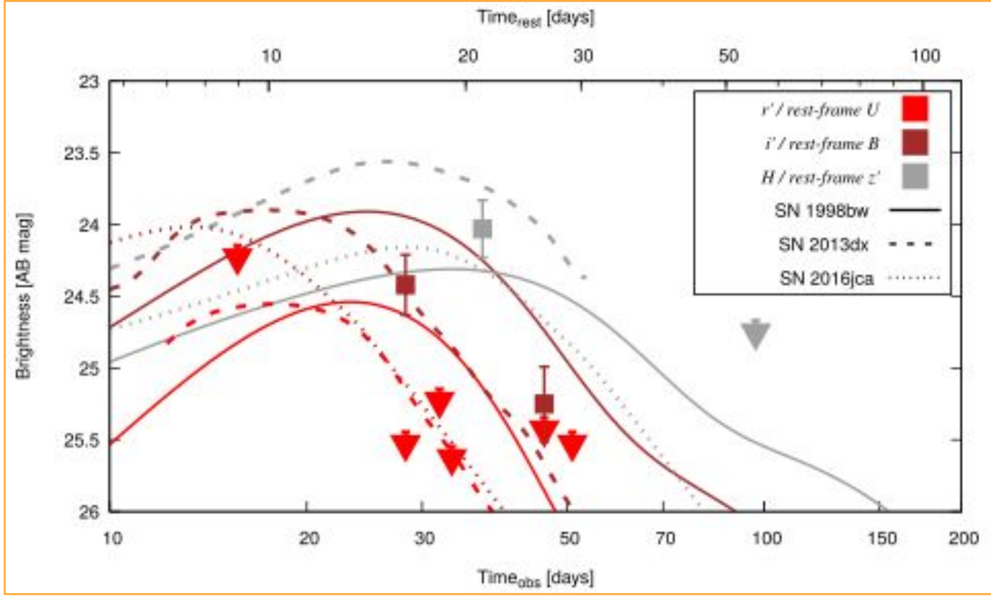


- LBT+ LUCI *H*-band +~37 days - ~+21days rest-frame
- Image subtraction with reference at ~160 days
- **Detection!**

Rossi et al., 2022, ApJ, 932, 1

The optical/NIR afterglow

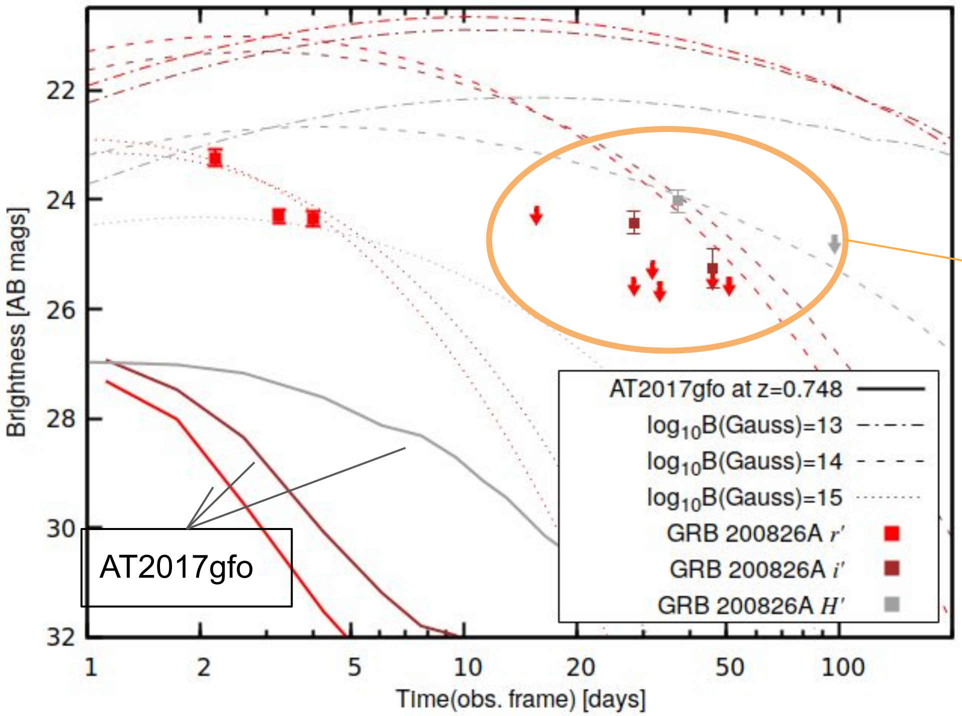




Rossi et al., 2022, ApJ, 932, 1

See also Zhang+21, Ahumada+21, Rhodes+21

The optical/NIR afterglow



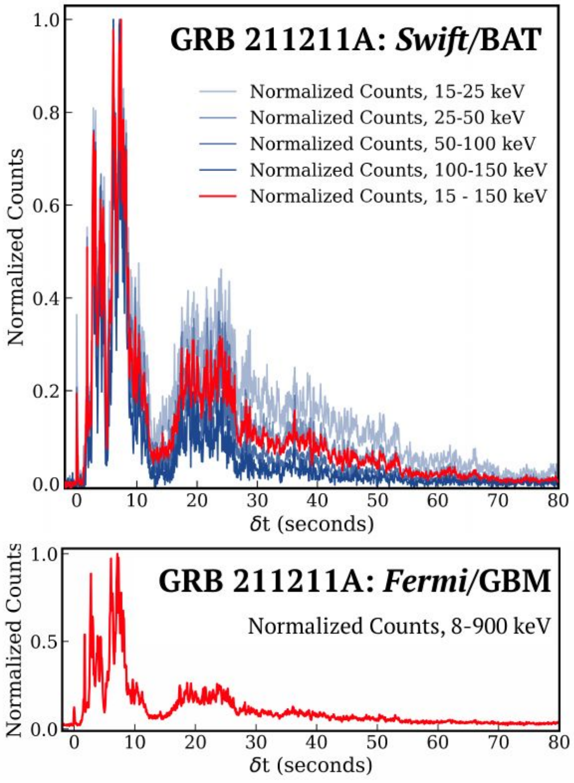
- **Observed bump is too bright for a kilonova like AT2017gfo**

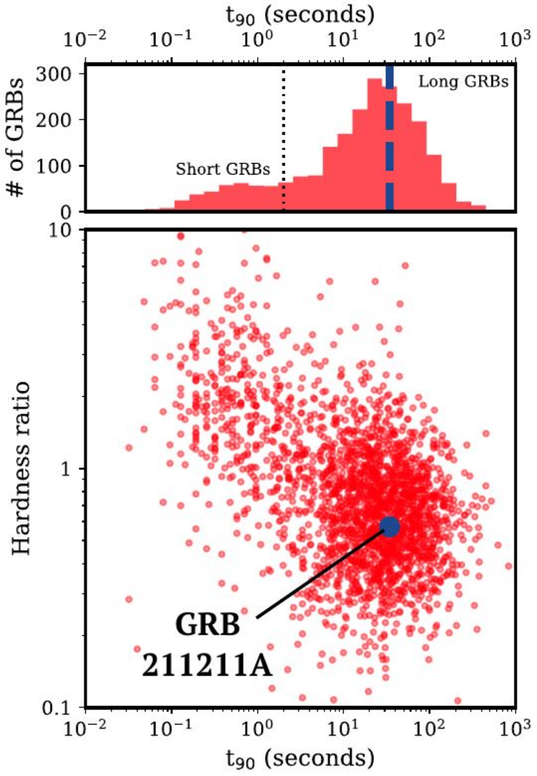
Rossi et al., 2022, ApJ, 932, 1

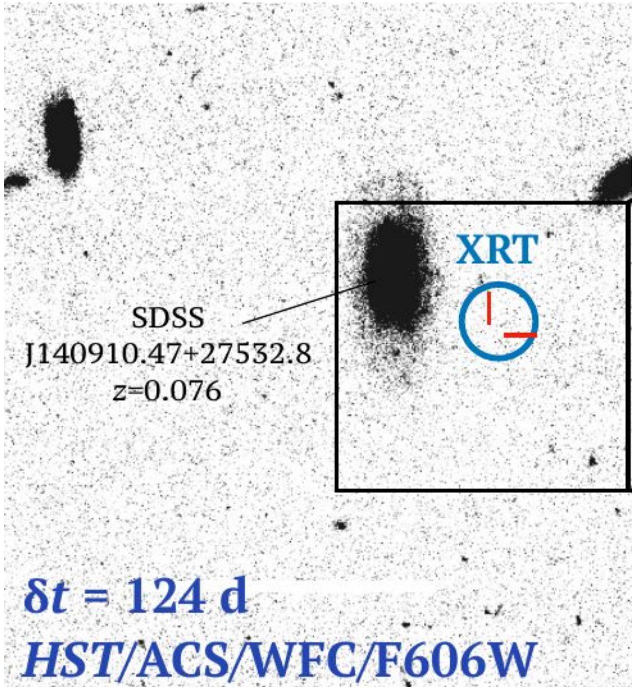
See also Zhang+21, Ahumada+21, Rhodes+21

Discovery of GRB 211211A

Rastinejad et al. *submitted to Nature*
https://arxiv.org/abs/2204.10864







see also e.g., Gomperz+2022, …

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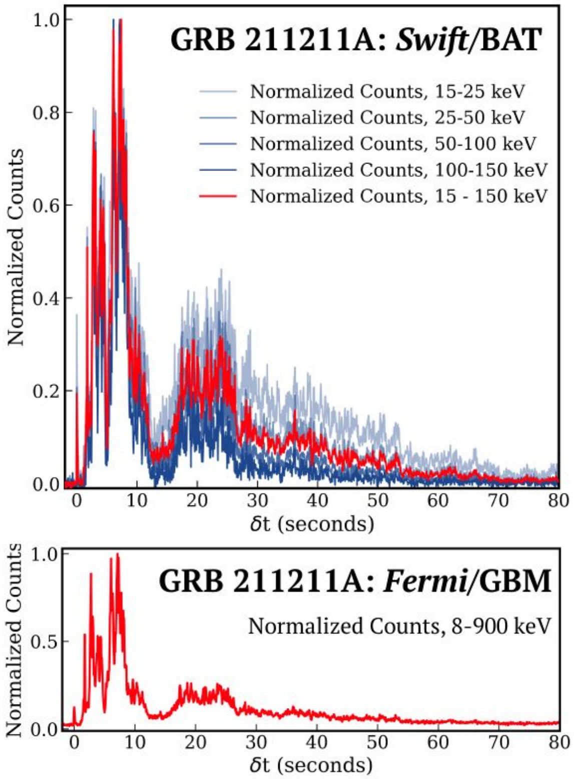

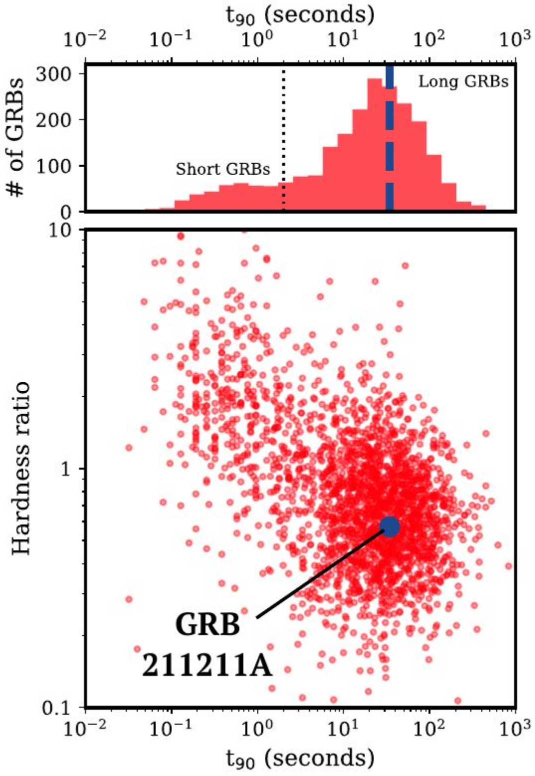

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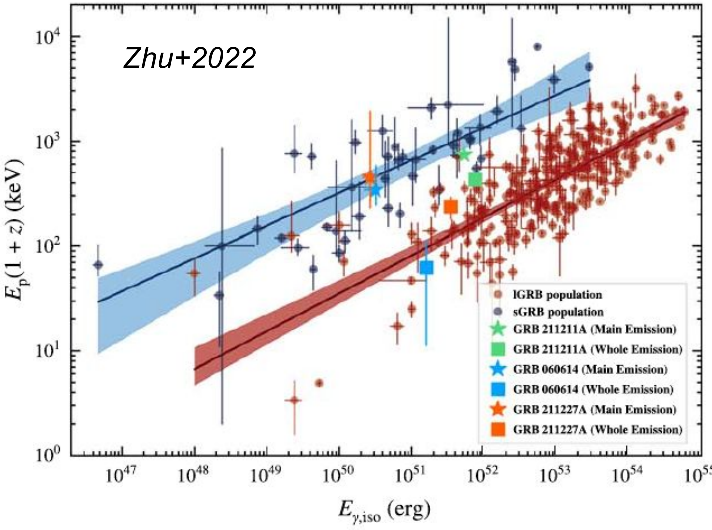
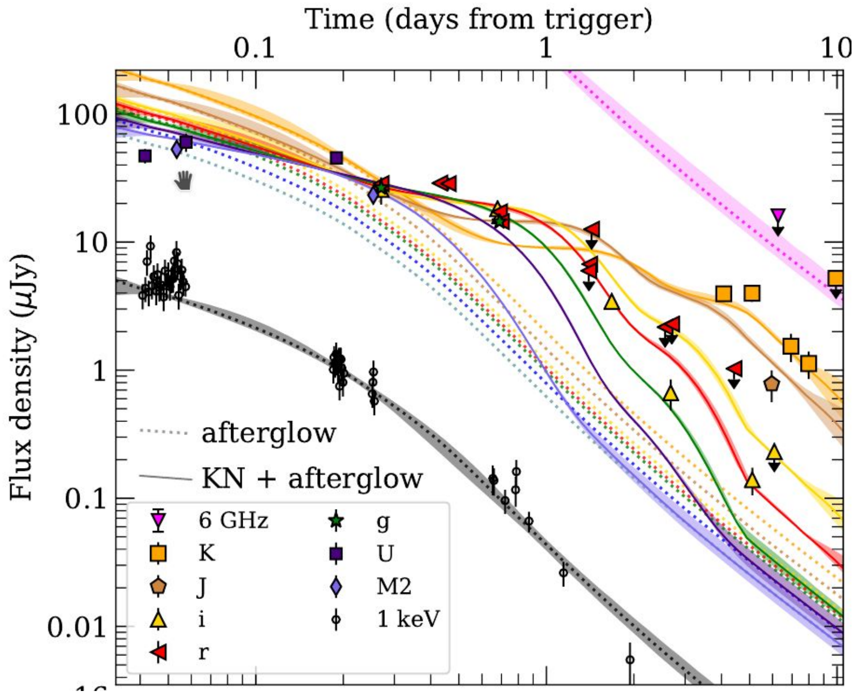
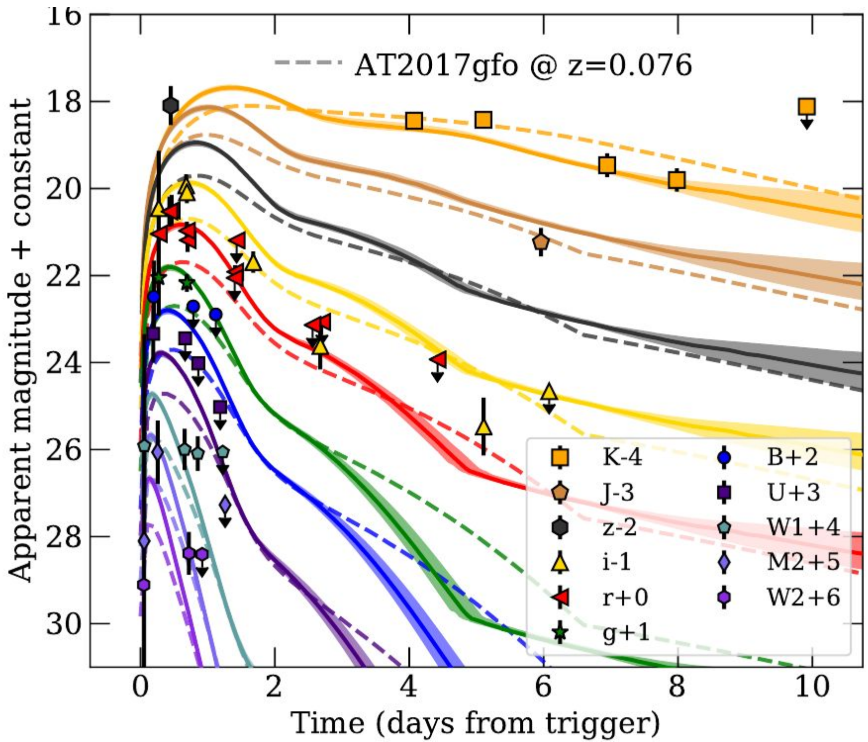


What is this?

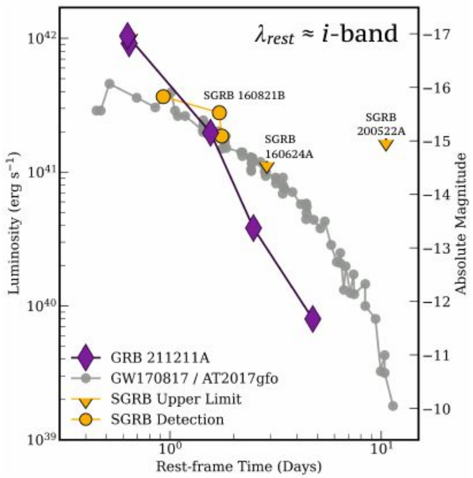
Afterglow and Kilonova models

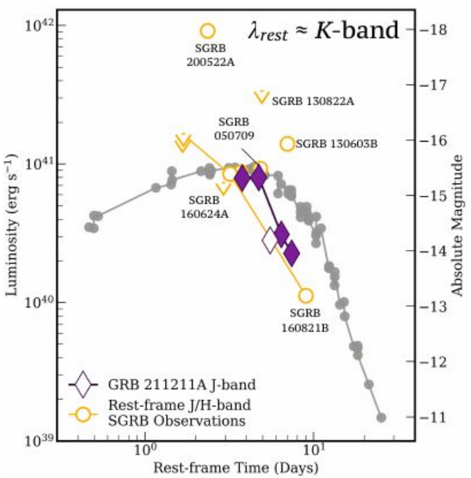


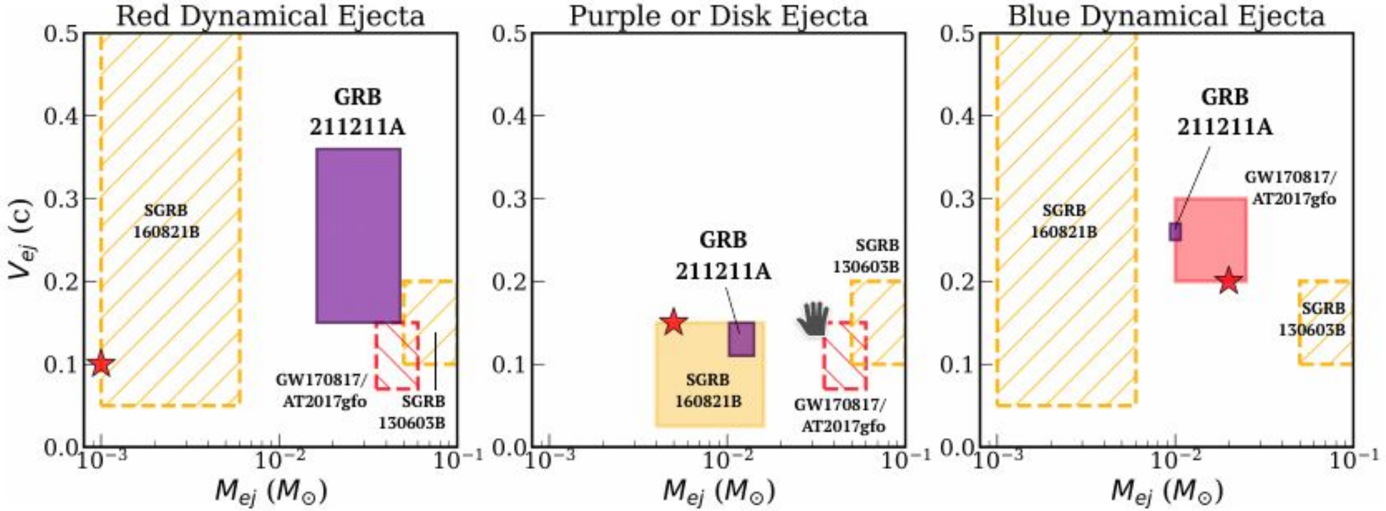


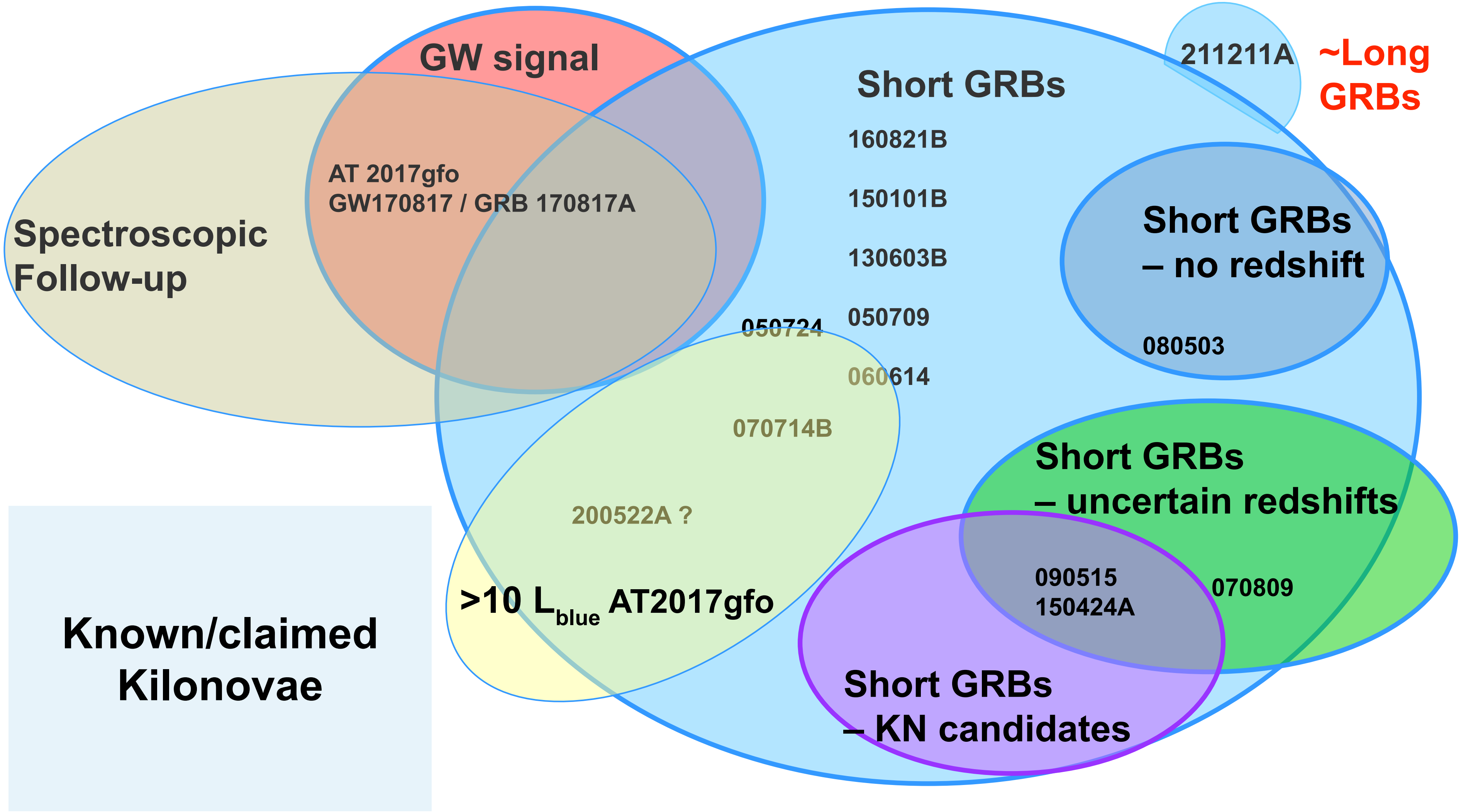
Rastinejad et al. +22

GRB 211211A: kilonova details

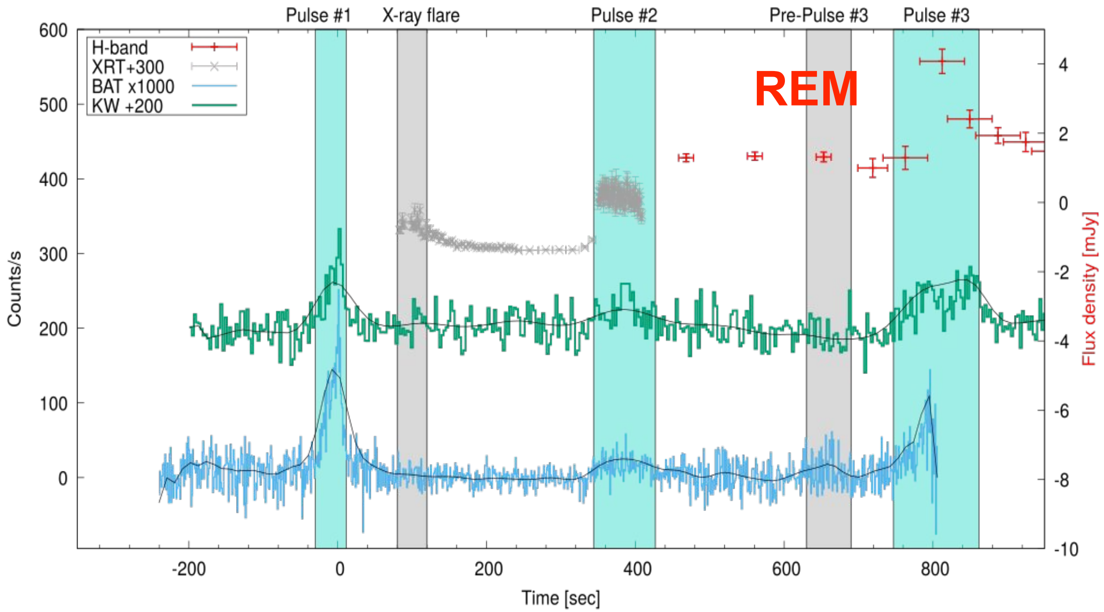




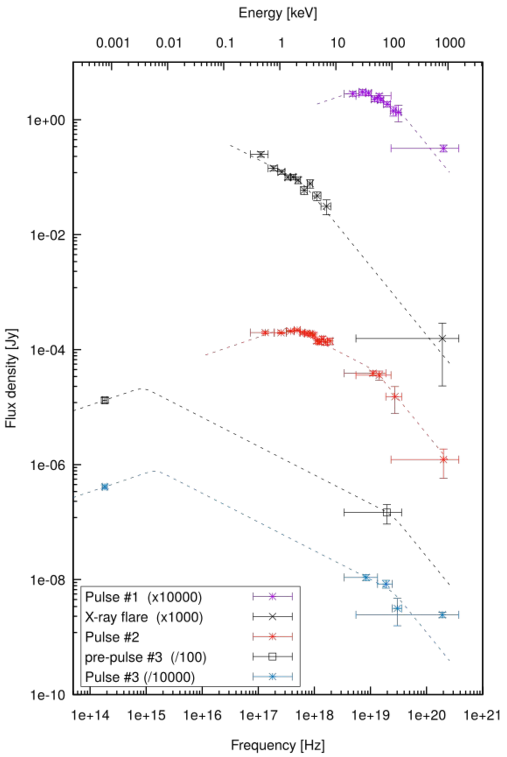



GW signal
Short GRBs
211211A
~Long GRBs
160821B
150101B
130603B
050709
060614
AT 2017gfo
GW170817 / GRB 170817A
Spectroscopic Follow-up
Short GRBs – no redshift
080503
050724
070714B
200522A ?
Short GRBs – uncertain redshifts
090515
150424A
070809
>10 L blue AT2017gfo
Short GRBs – KN candidates
Known/claimed Kilonovae

Follow-up of GRB 210905A at z=6.312



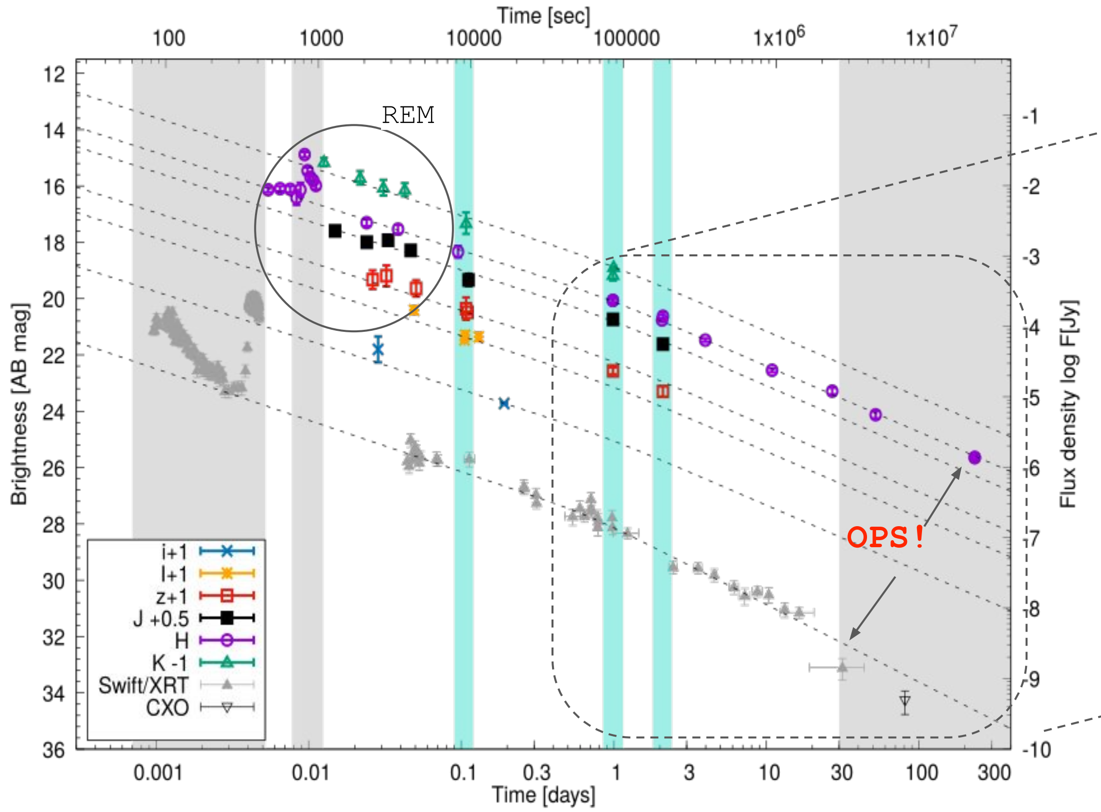
REM

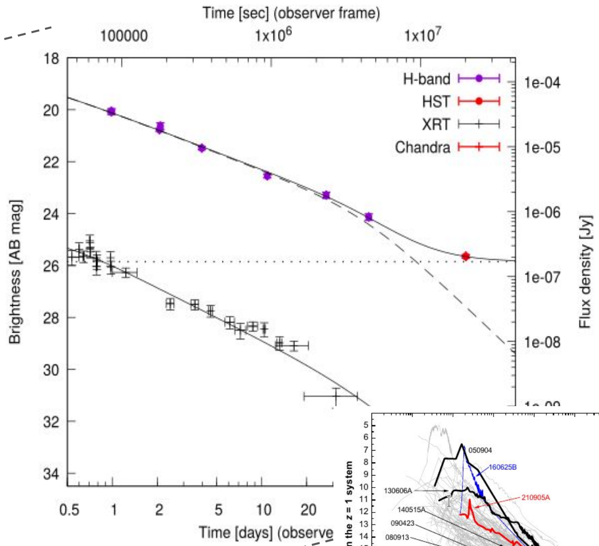


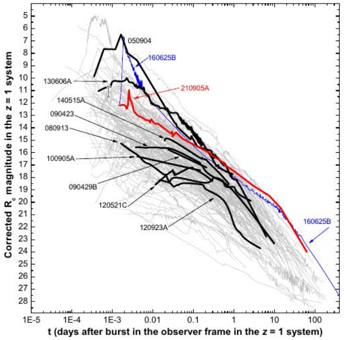
See Gor talk

Follow-up of GRB 210905A

Rossi et al., accepted in A&A
arXiv:2202.04544







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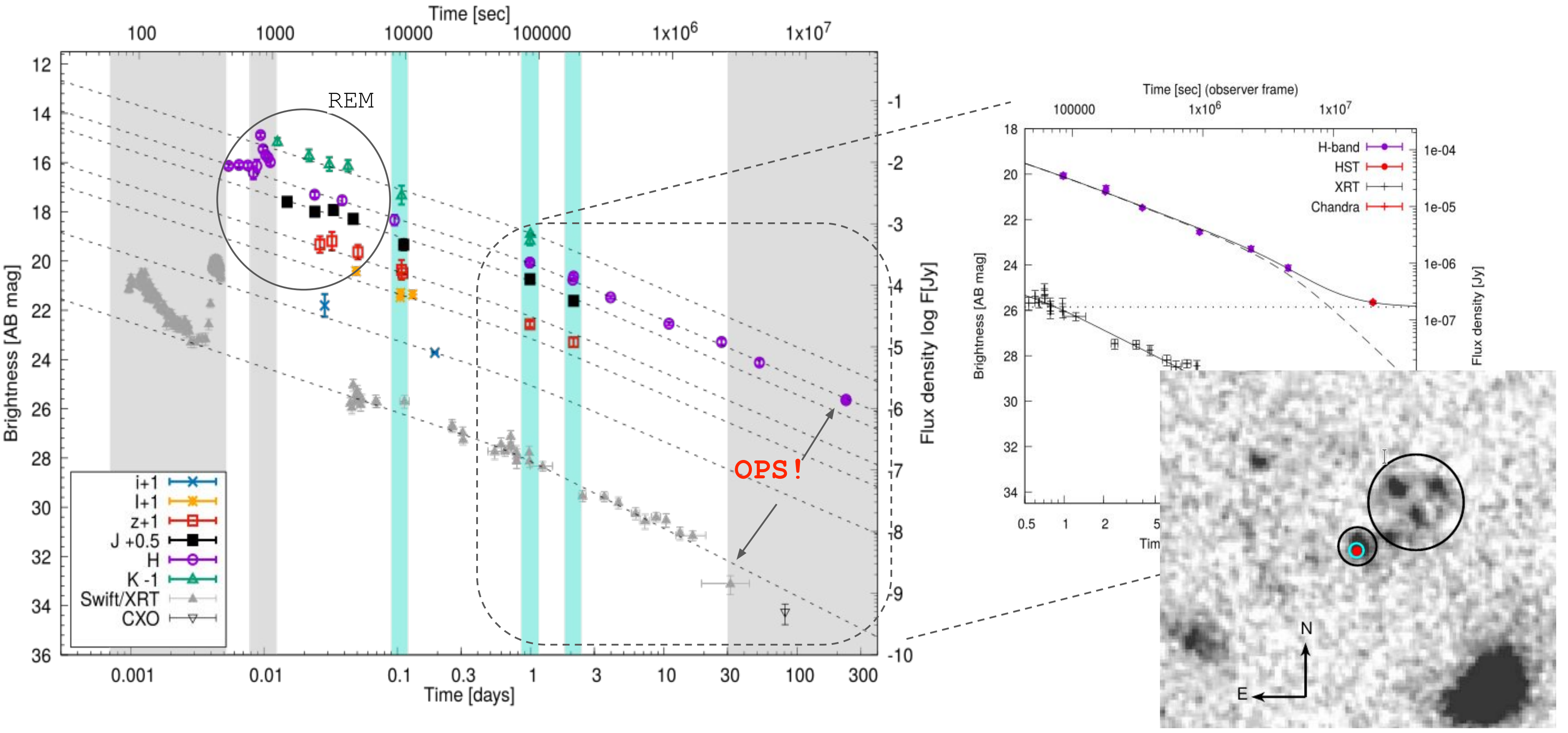
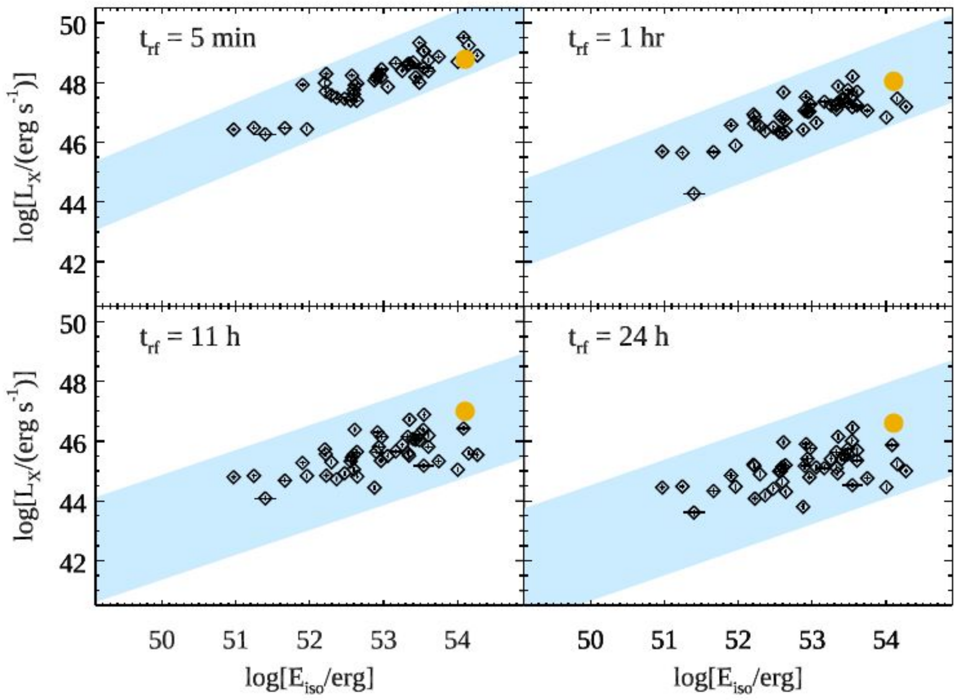
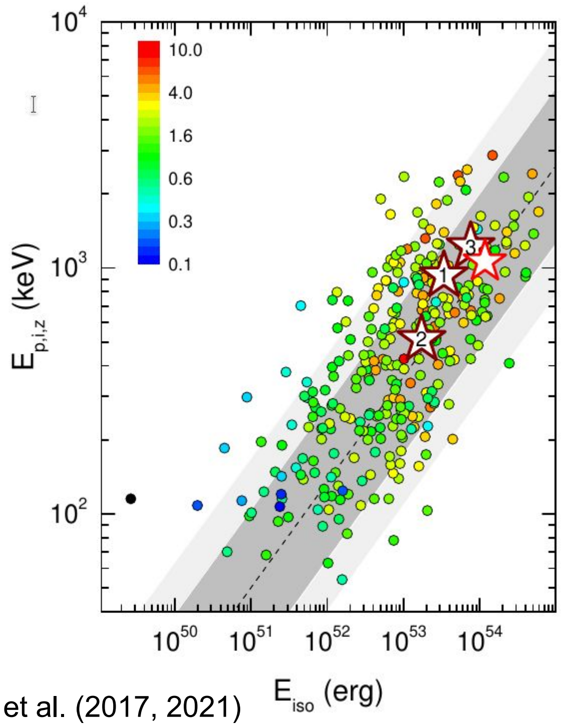


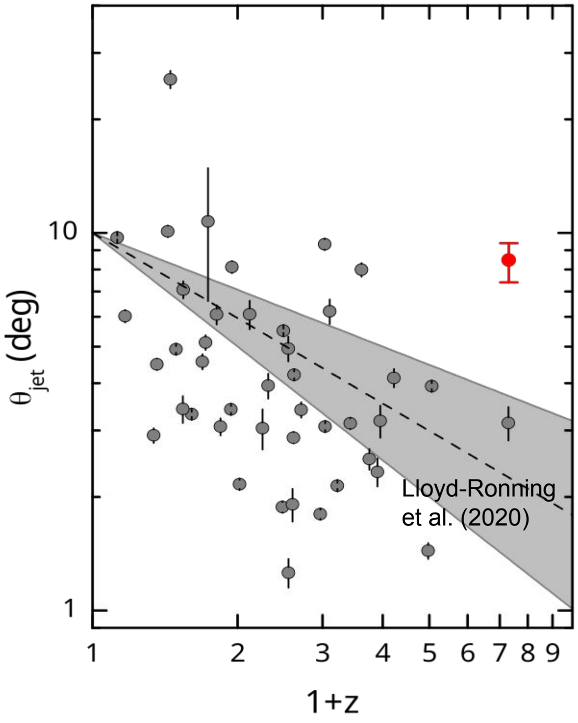
Follow-up of GRB 210905A: an extremely energetic but “normal” event in the infant Universe,





sample Tsvetkova et al. (2017, 2021)

Follow-up of GRB 210905A: an extremely energetic but “normal” event in the infant Universe,



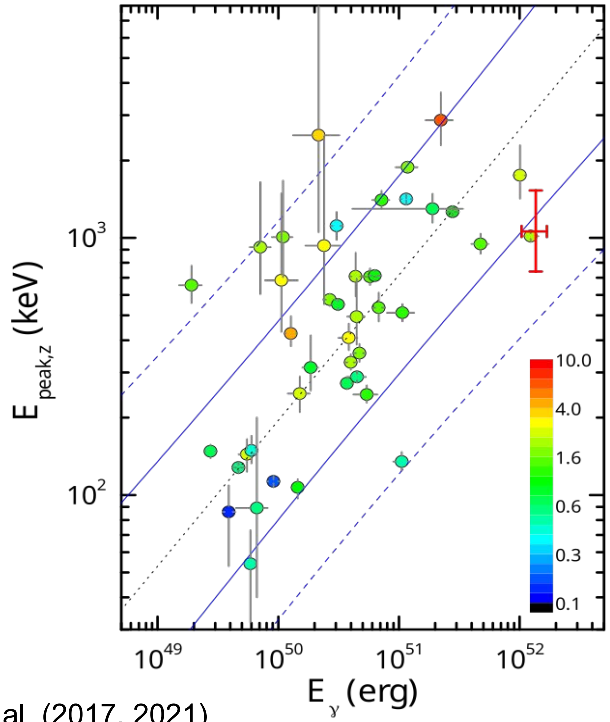
Collimated parameters

Left: θ_{jet} is consistent with the median value of $\theta_{jet}=7.4^{+11}_{-6.6}$ deg at z ~ 1 (Laskar et al., 2014, 2018).

Right: GRB 210905A follows the “*Ghirlanda*” relation.
GRB 210905A has the highest E_γ in the Konus-*Wind* catalogue.

The high energy points to a Black hole central engine

For more:
ISM abundancies, see the talk from Andrea Saccardi



KW sample Tsvetkova et al. (2017, 2021)

Summary

- **Thus GRB 200826A is the shortest collapsar event known to date.**

- **GRB 211211A is a longest merger event known to date at 330 Mpc!**

- **The simple duration is NOT an indicator of the origin of a GRB.**

- **GRB 210905A is a extremely energetic event in the infant Universe, but otherwise normal.** There is no indication for progenitors evolving with redshift. Its engine was very likely a black hole.

- **The study of GRBs can still offer surprises especially thanks to new and more capable telescopes+instruments: AO (LBT, ELT), robotic telescopes (e.g. REM), X-shooter.**
- **Looking forward to the synergy with GW detection.**

Thank you!

Discovery of GRB 211211A

Rastinejad et al. [*submitted to Nature*](https://arxiv.org/abs/2204.10864)
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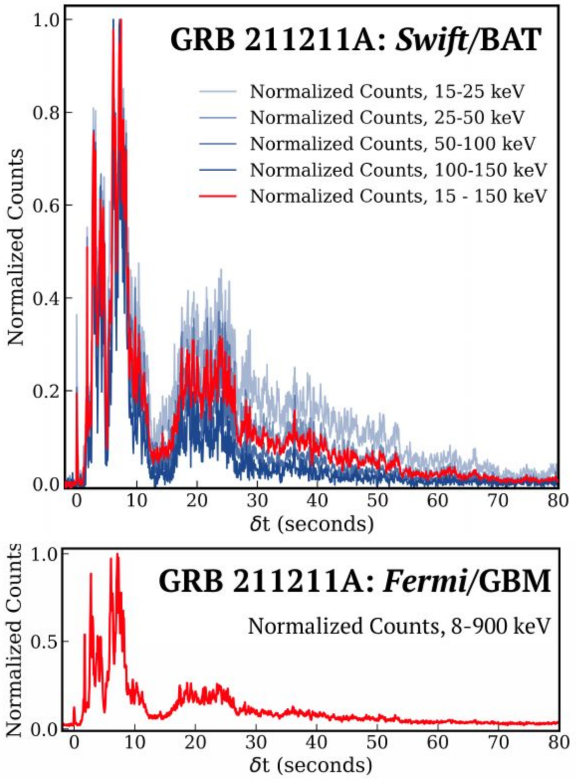
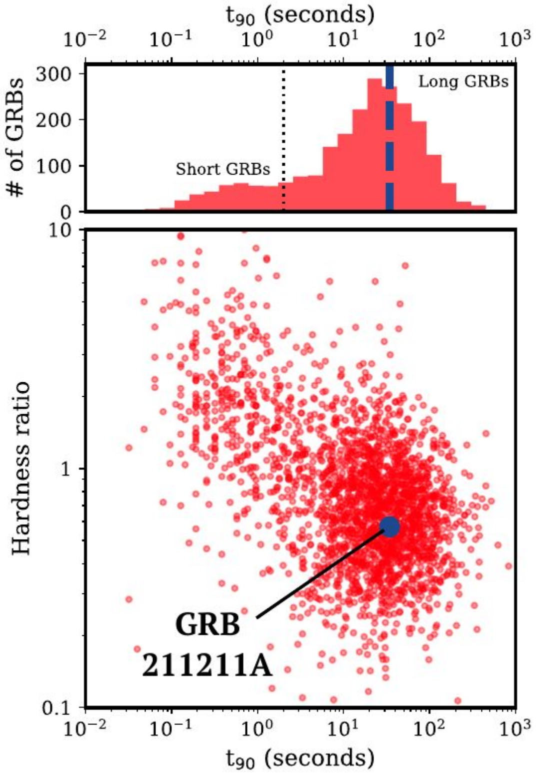
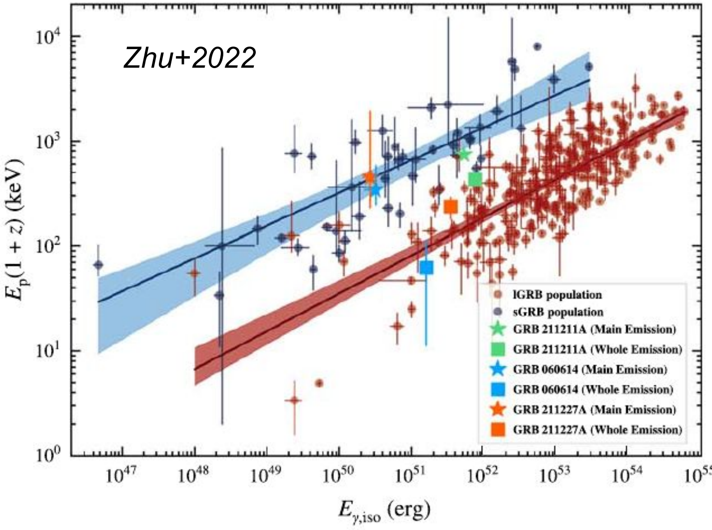


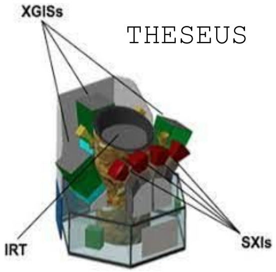


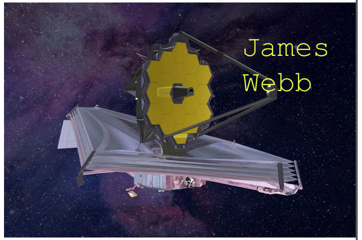
see also e.g., Gomperz+2022, …



What is this?

Future scenarios

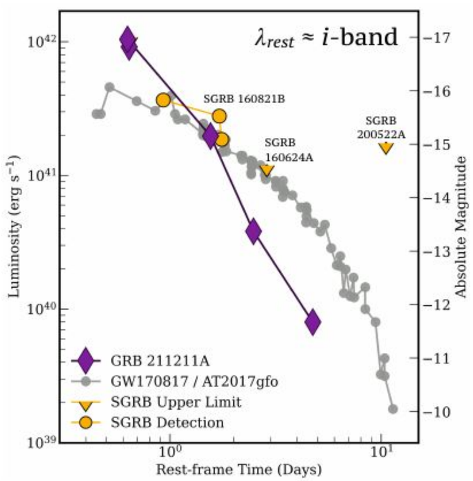


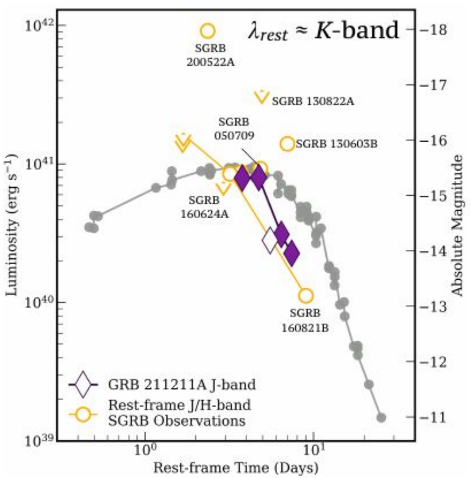


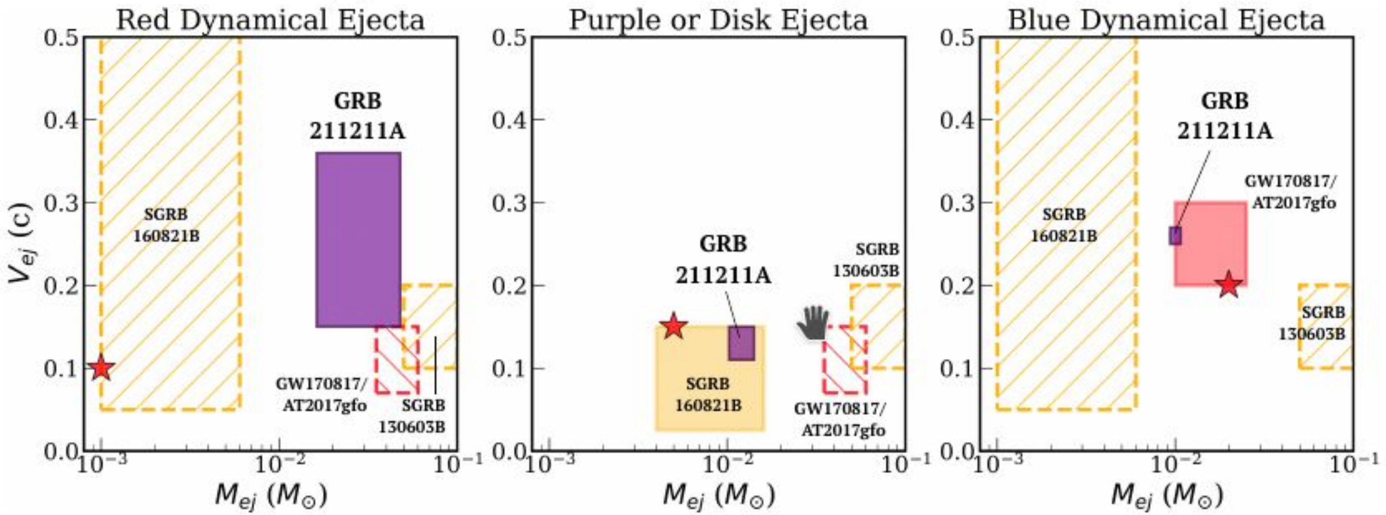
Ground-based telescopes + AO:

- Offer a sharper view of the GRB-SN location within its host.
- They can discover GRB-SNe at larger redshift.
- And at wavelengths comparable to low-redshift GRB-SN frame.

GRB 211211A: kilonova details

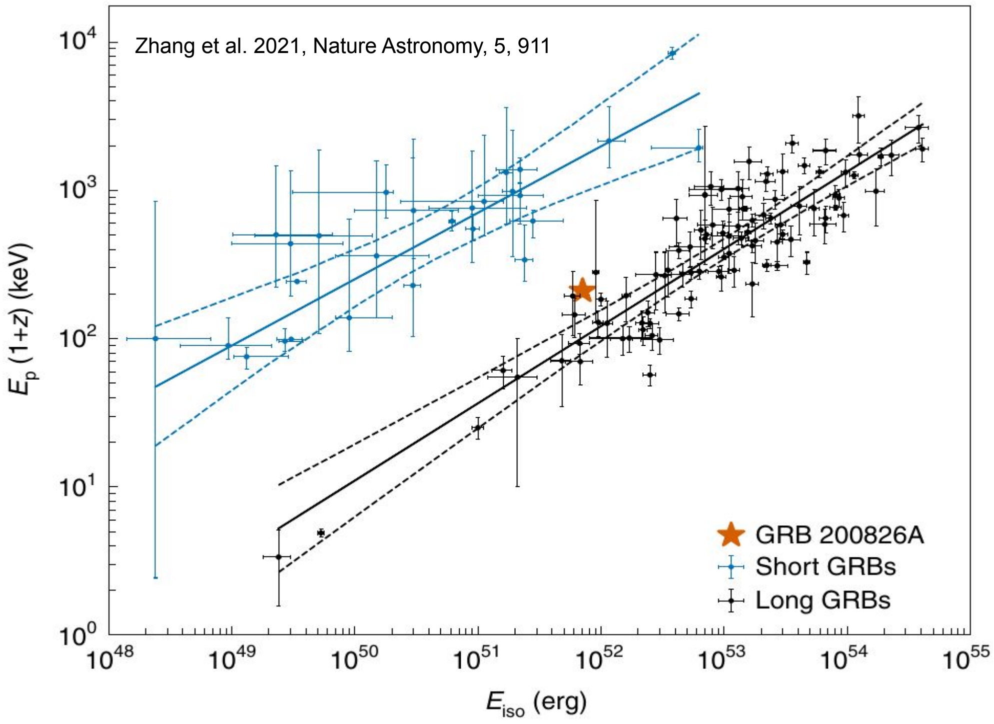


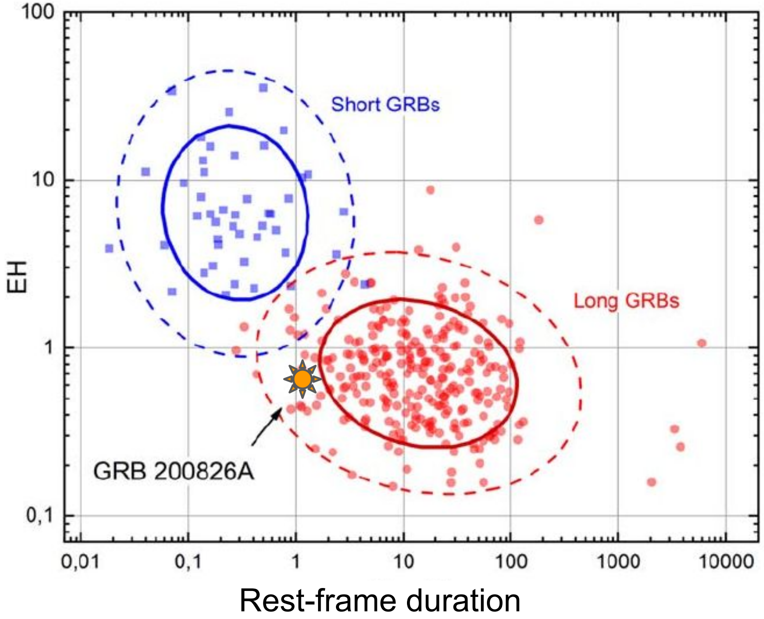




GRB 200826A prompt emission

Rest-frame energetics





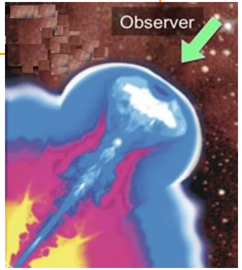
The prompt properties do not allows us to unambiguously understand the progenitor of GRB 200826A

Why GRB 200826A is so short?

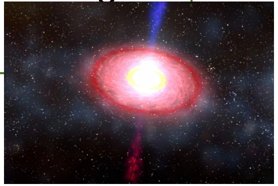
Tip of the iceberg effect like GRB 090426? (Moss+22)
No, the amplitude parameter (F_p/F_b) is too large (Zhang+21)

- Short duration GRB: $T_{90,i}$~0.5s
- Bump of a typical GRB-SN

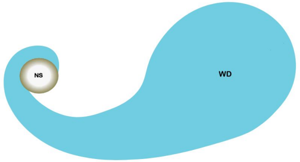
Failed collapsar? $\Delta t = \Delta t_{eng} - \Delta t_{star}$=10s - 9.5s=0.5
(Bromberg+13, Zhang+21, Ahumada+21)



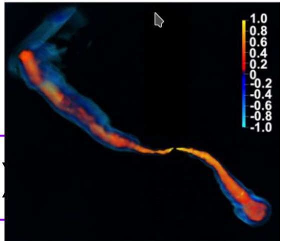
Mild/no-relativistic GRB
(Zhang+21, Metzger+11):
Γ too low to create a long GRB



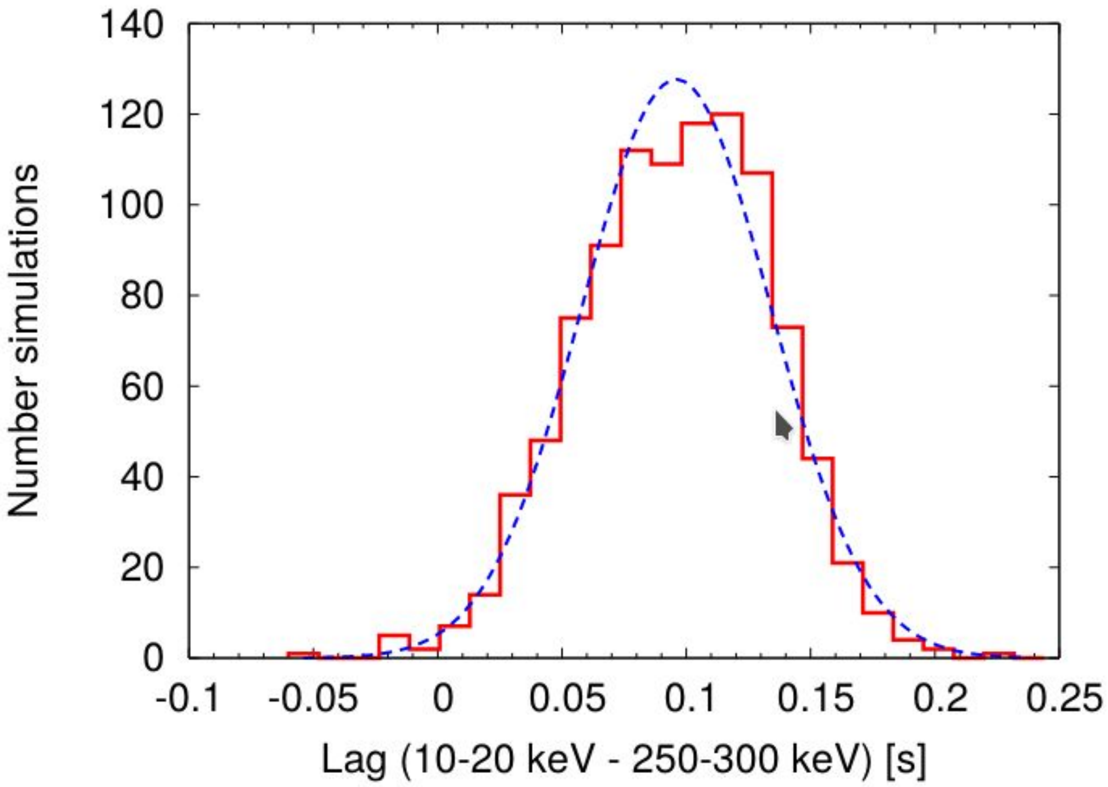
NS+WD envelope:
Thorne-Zytkow-like Object (Peng+21):
can explain the X-ray shallow decay.
Is the bump too bright?



Precession-oscillation (Wang+22; Gottlieb+22



Spectral lag analysis

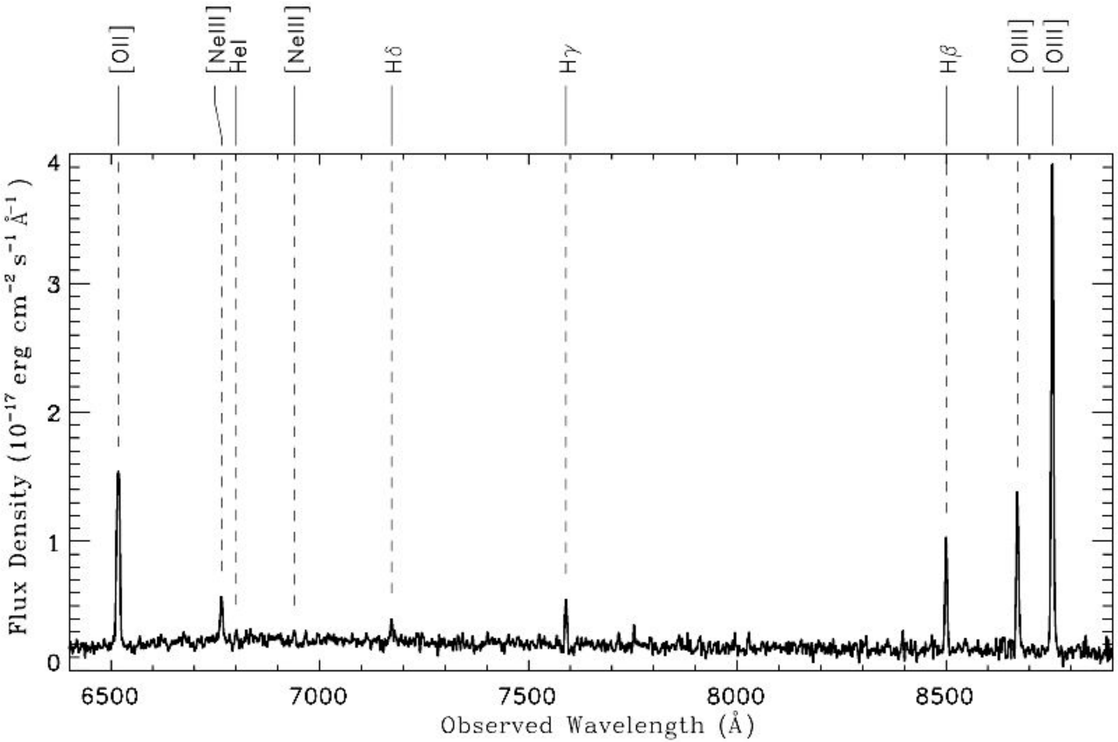


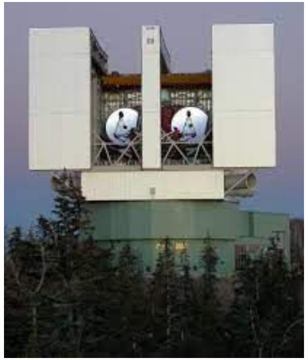
Distribution of the spectral lag analysis:

- We obtain a spectral lag of 96 ± 38 ms.
- The spectral lag is more typical of LGRBs.

Rossi et al., 2022, ApJ, 932, 1

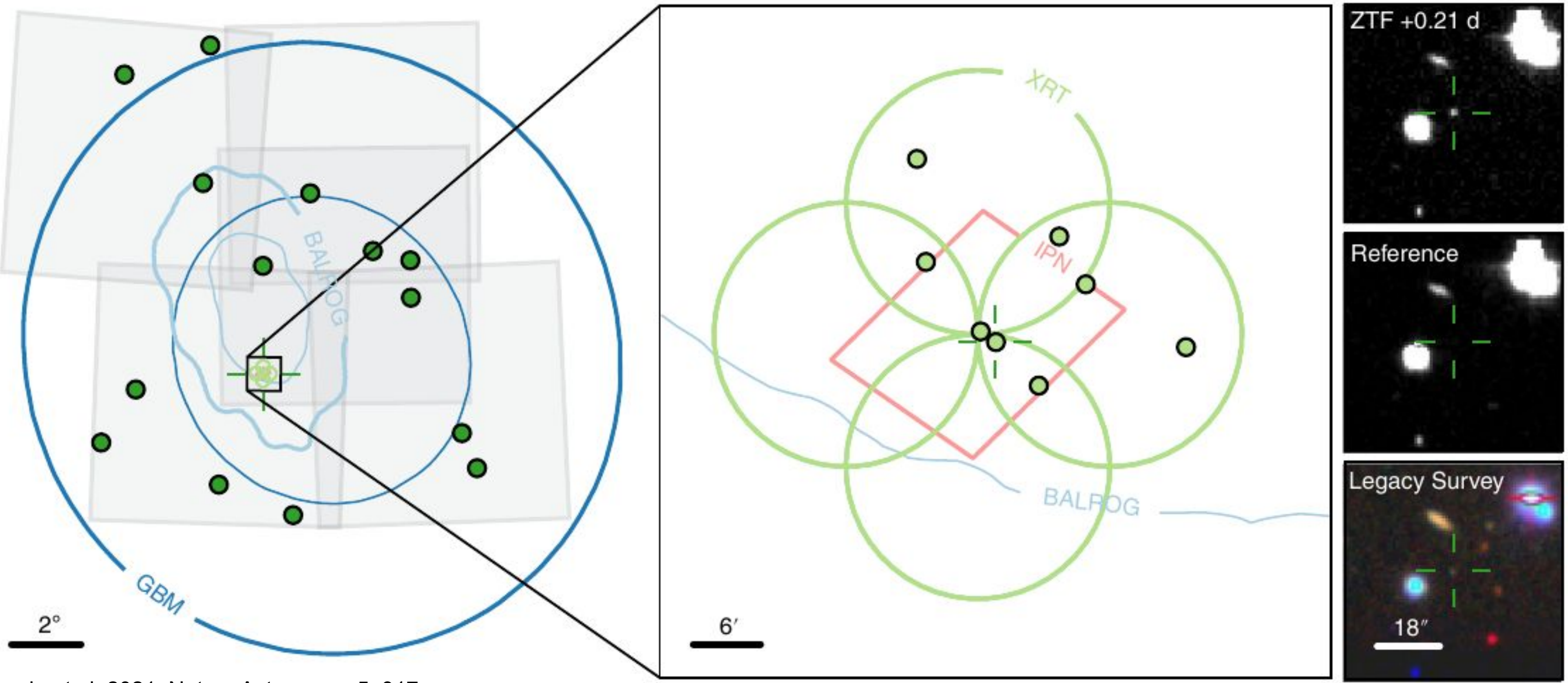
LBT spectroscopy redshift z=0.7486





- LBT/MODS spectra at +8 days
- Detection of multiple emission lines
- [OII], H-gamma, H-beta, [OIII]/4959, [OIII]/5007
- at redshift of 0.7481 ±0.0003.

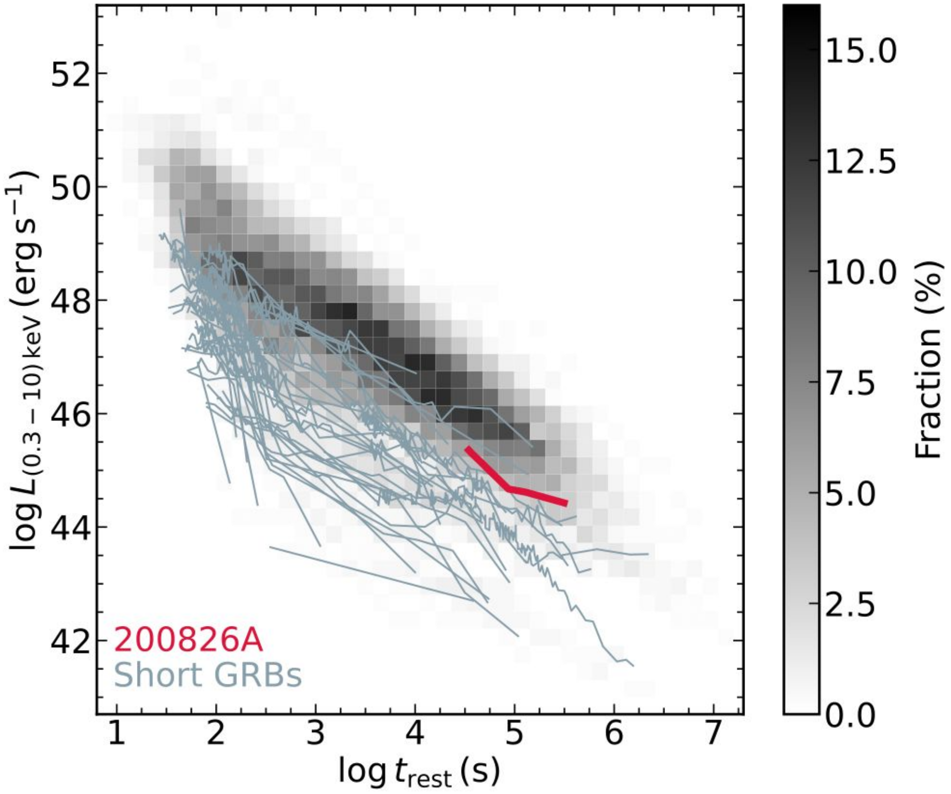
ZTF discovery of the afterglow of GRB 200826A.

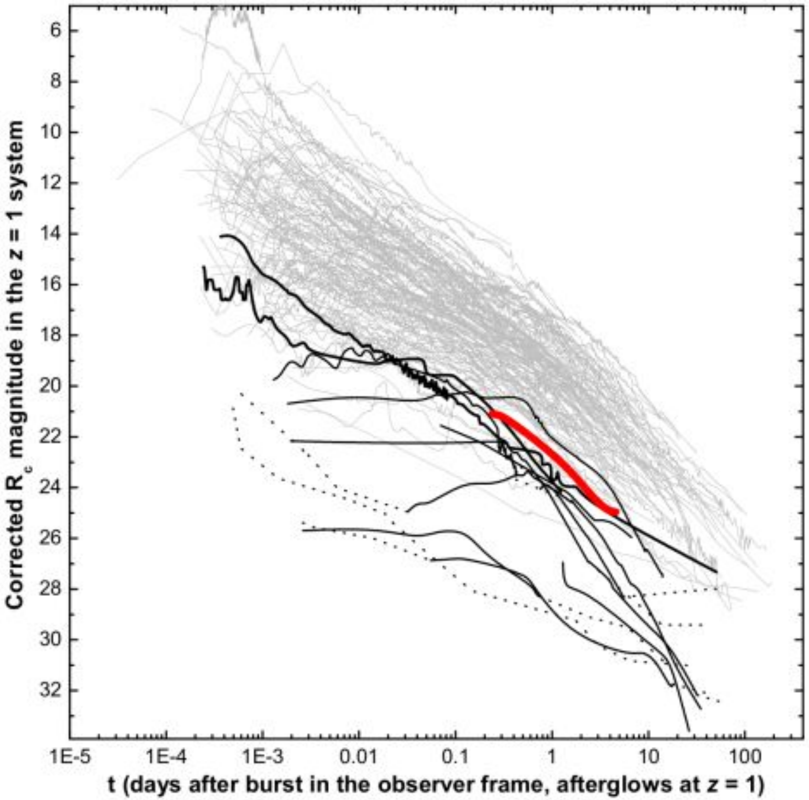


Ahumada et al. 2021, Nature Astronomy, 5, 917

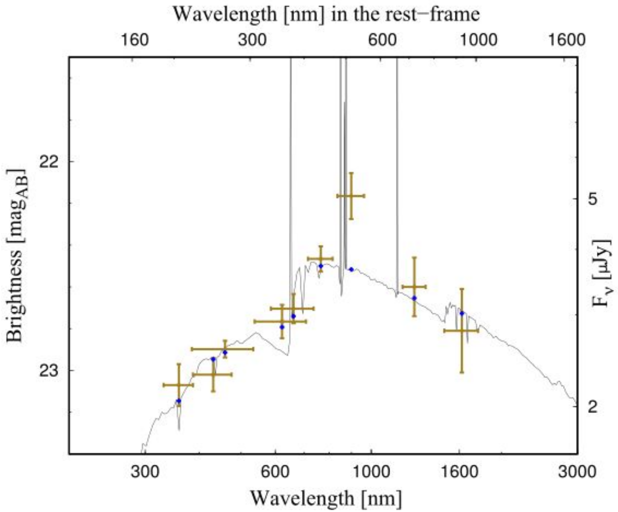
The afterglow in context

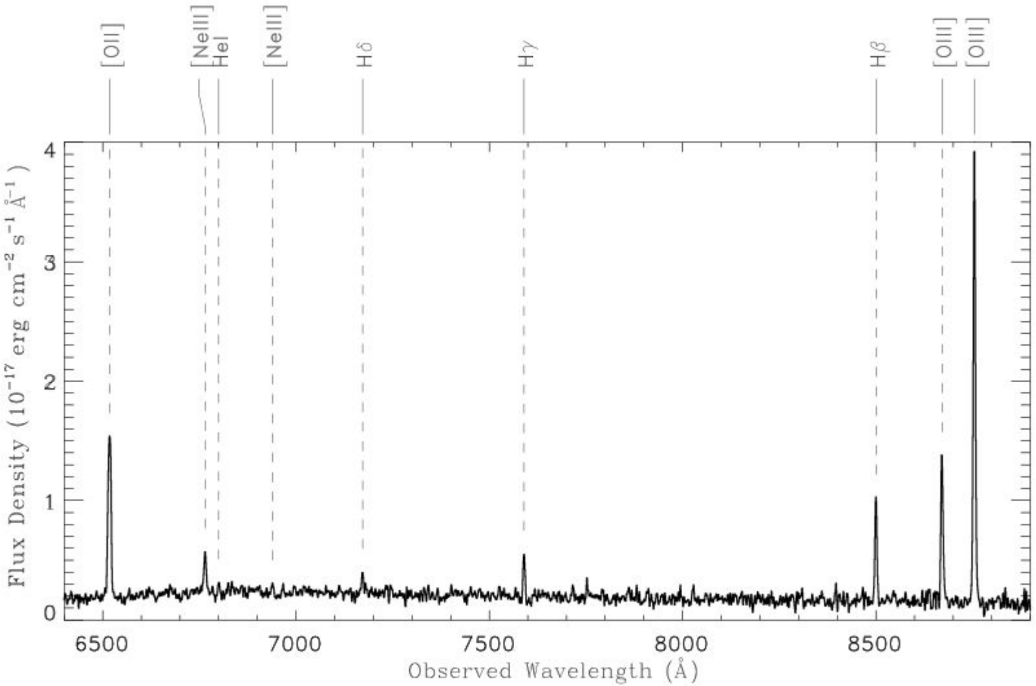
in between long and short GRBs





Host galaxy properties

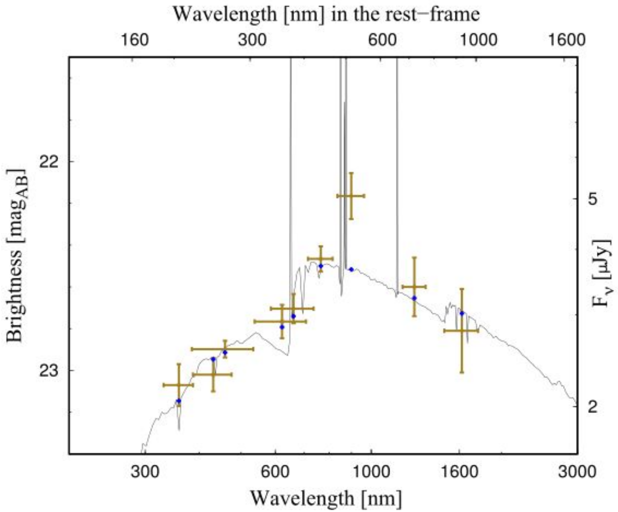


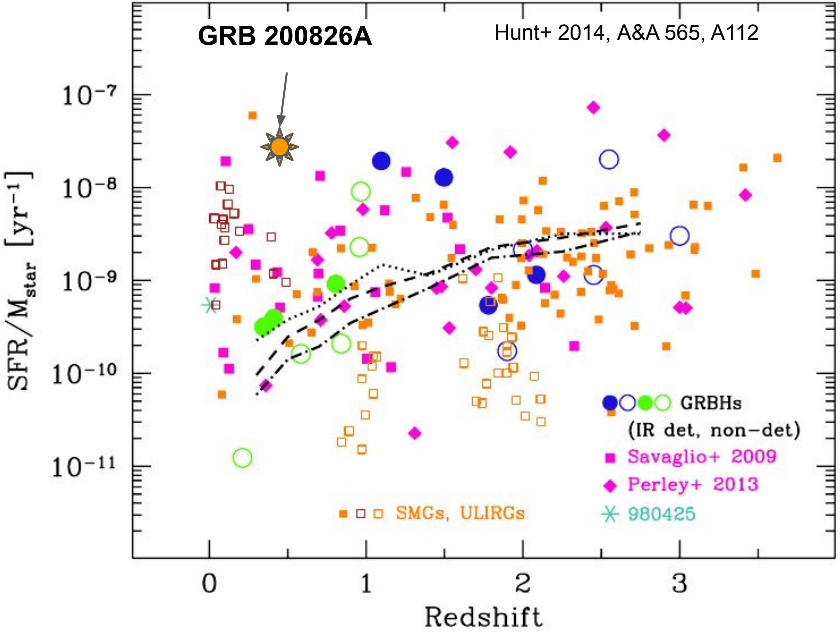


The LBT/MODS spectrum and SED (LBT/MODS+LBC) of the host:

- log $M_* = 8.6 \pm 0.2\ M_{sun}$
- SFR ~ 4.0 M_{sun}/yr
- sSFR~10^{-8} yr^{-1}
- AV ~ 0.5 mag from spectra and SED
- $Z=0.4\ Z_{sun}$ consistent with LGRB hosts (Japeli+16)

Host galaxy properties



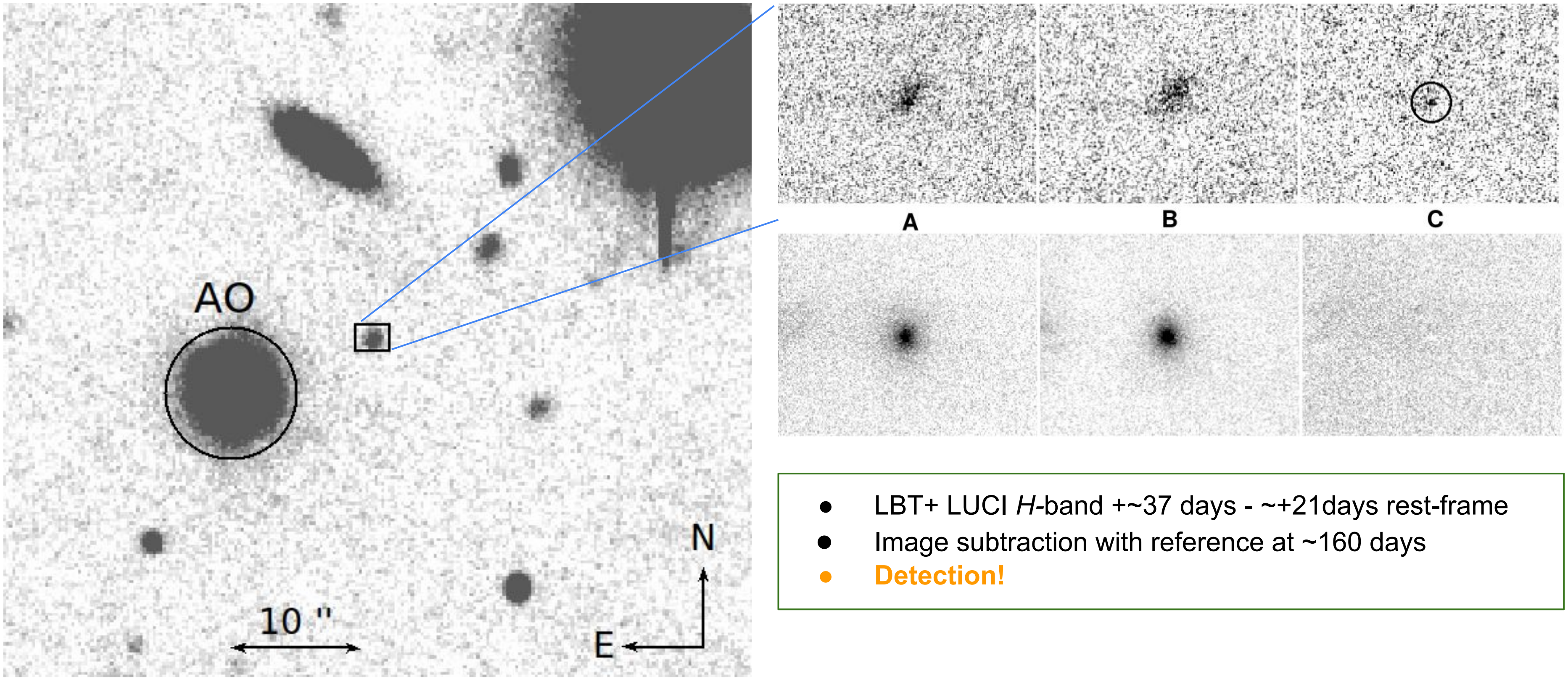


It is a small, star-forming galaxy with:

- a relatively high metallicity
- a sSFR among the highest within the LGRB host population

`Note:` The GRB lies at a projected distance of 0.75 kpc consistent with the majority of LGRBs.

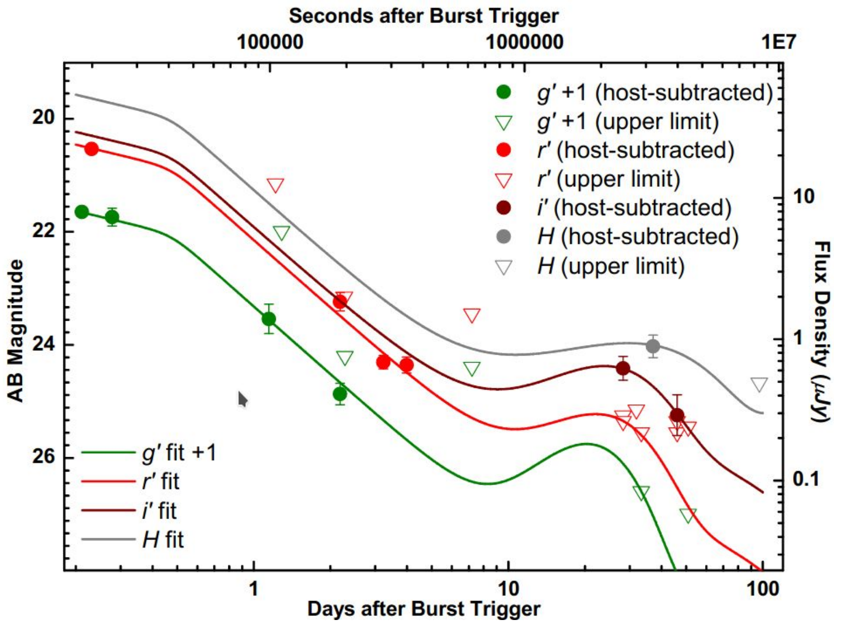
Deep NIR (rest-frame z-band) imaging in adaptive optics

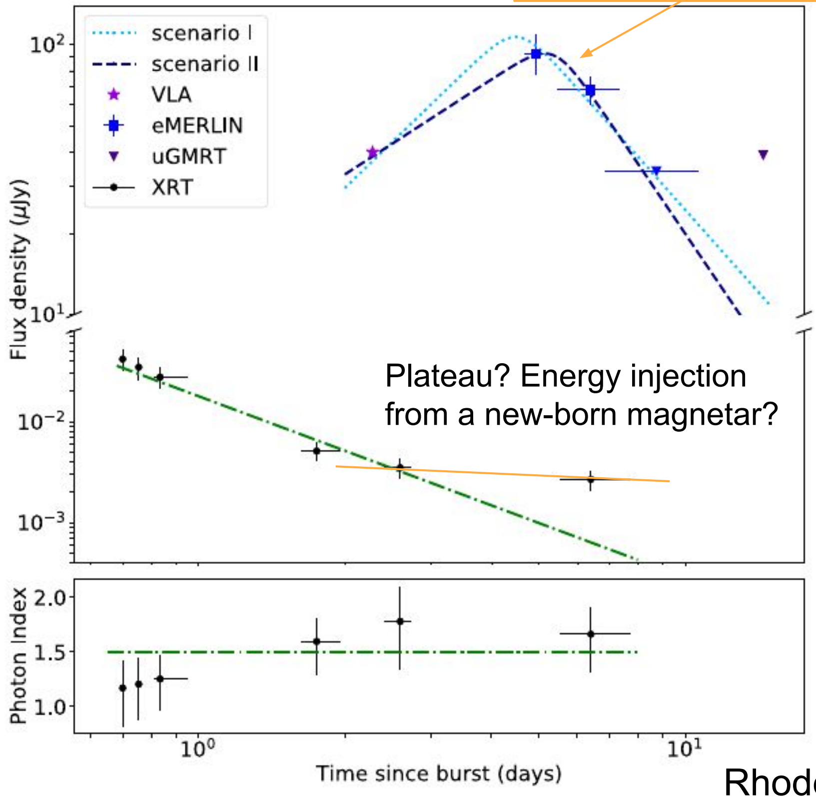


- LBT+ LUCI *H*-band +~37 days - ~+21days rest-frame
- Image subtraction with reference at ~160 days
- **Detection!**

The multi-wavelength afterglow

Self-abs. Peak from forward shock in wind-medium

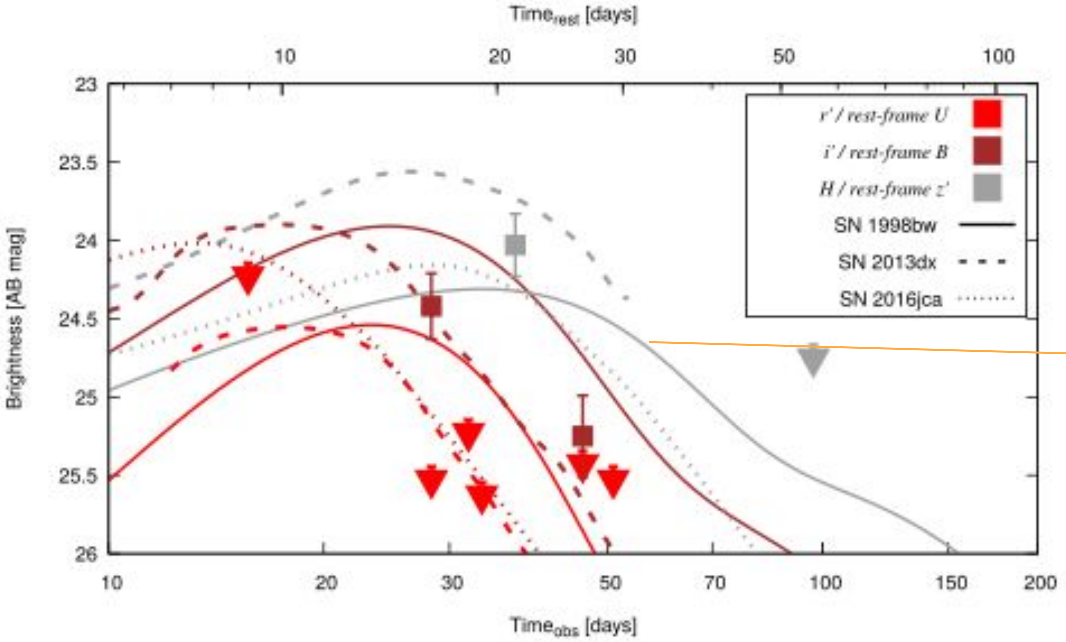




Plateau? Energy injection from a new-born magnetar?

Rhodes+21

GRB 200826A originated from a massive star explosion



The light curve is:

- Similar or faster than 98bw
- Fainter than 98bw
- Similar to SN2013dx/GRB 130702A

GRB 200826A originated from a massive star explosion