The peculiar short-duration GRB 200826A and its supernova

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on behalf of a larger collaboration

γ 2022
7th Heidelberg International Symposium on
High Energy Gamma-Ray Astronomy
Barcelona, July 4-8 2022

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

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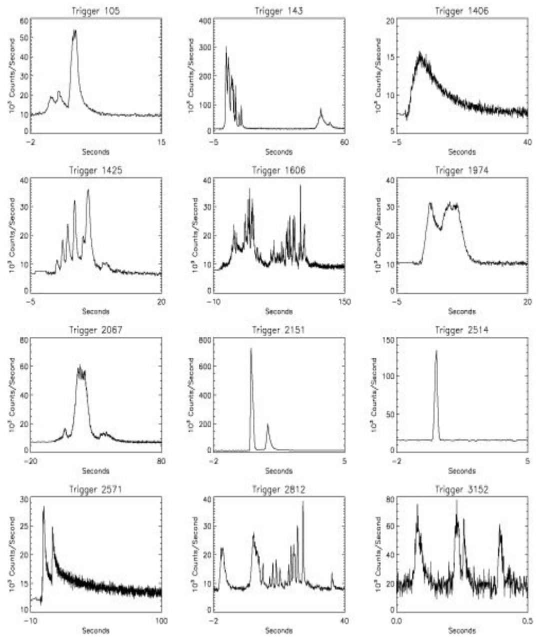
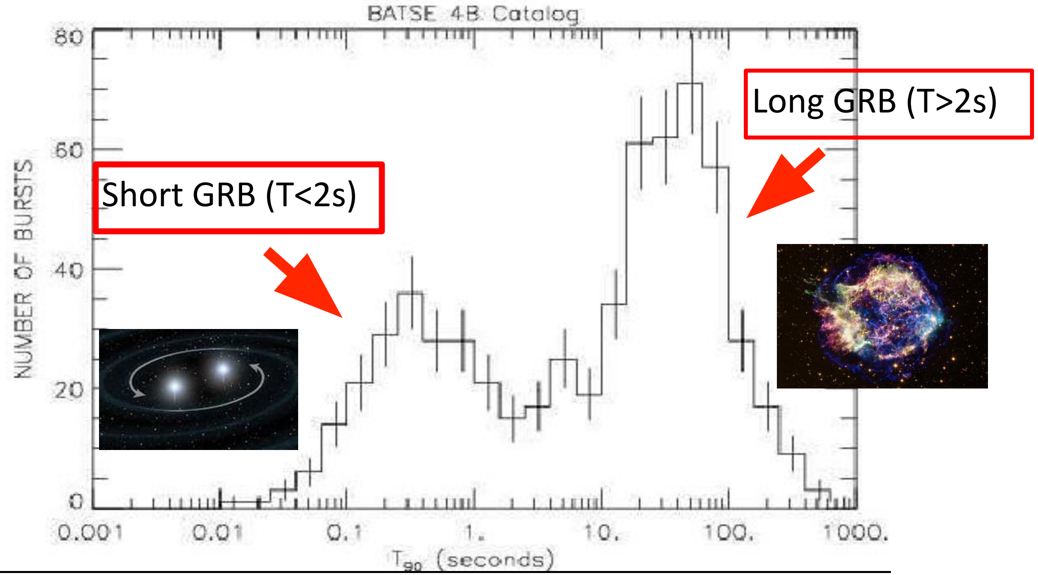
Gamma ray bursts



Temporal features: diverse and spiky light curves

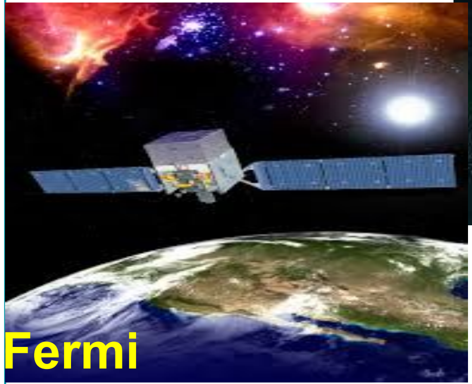
The burst durations show a bimodal distribution interpreted to be (indirect) evidence of two classes of progenitors

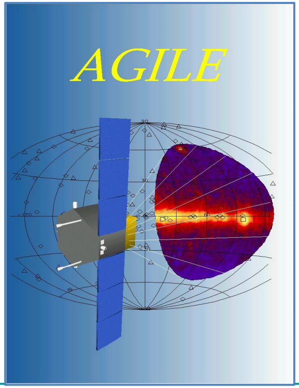


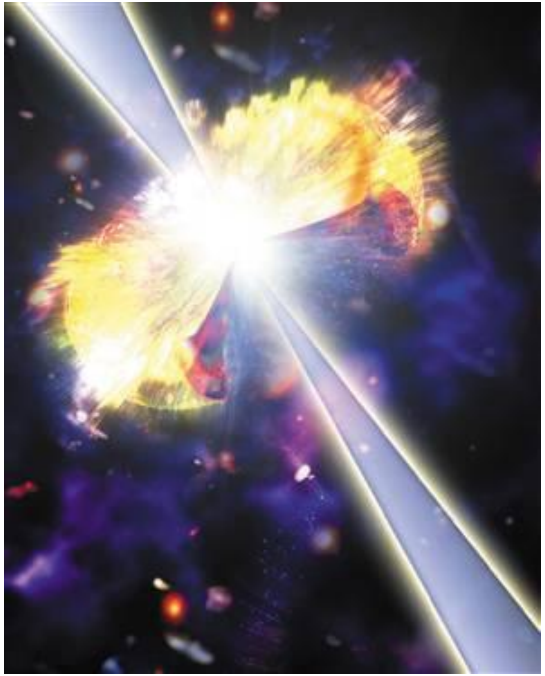
Kouveliotu et al. 1993

Discovery of GRB 200826A

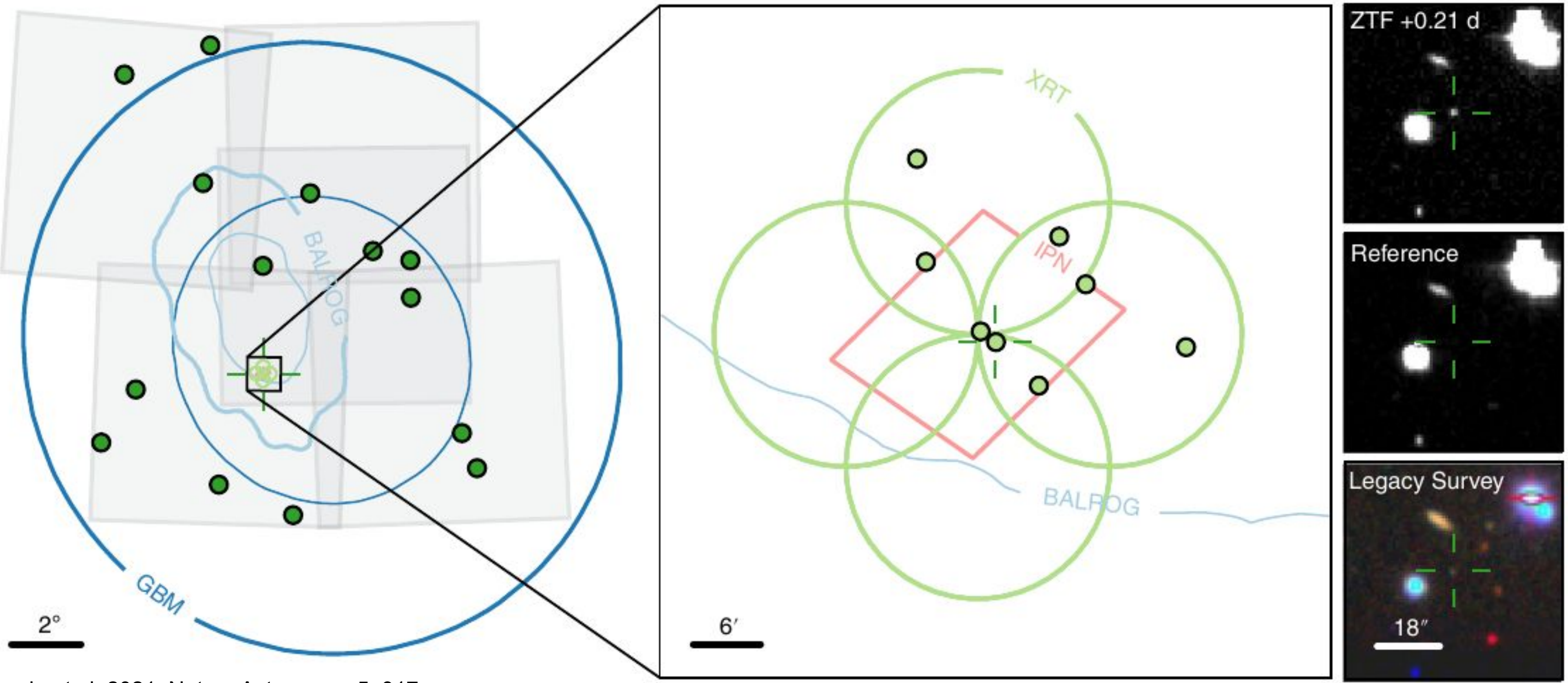
Prompt phase





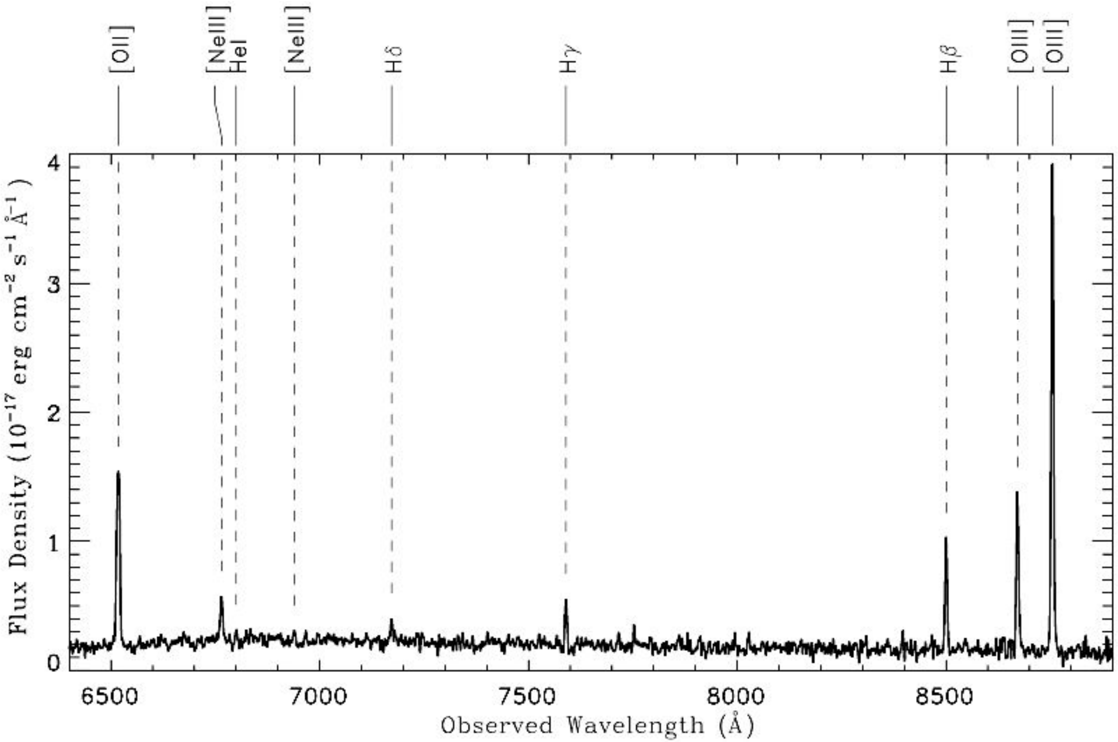


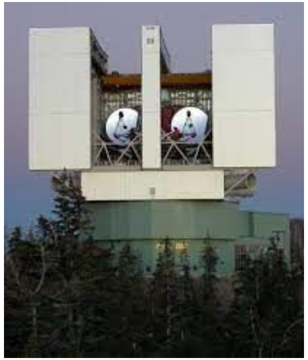
ZTF discovery of the afterglow of GRB 200826A.



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

LBT spectroscopy redshift z=0.7486

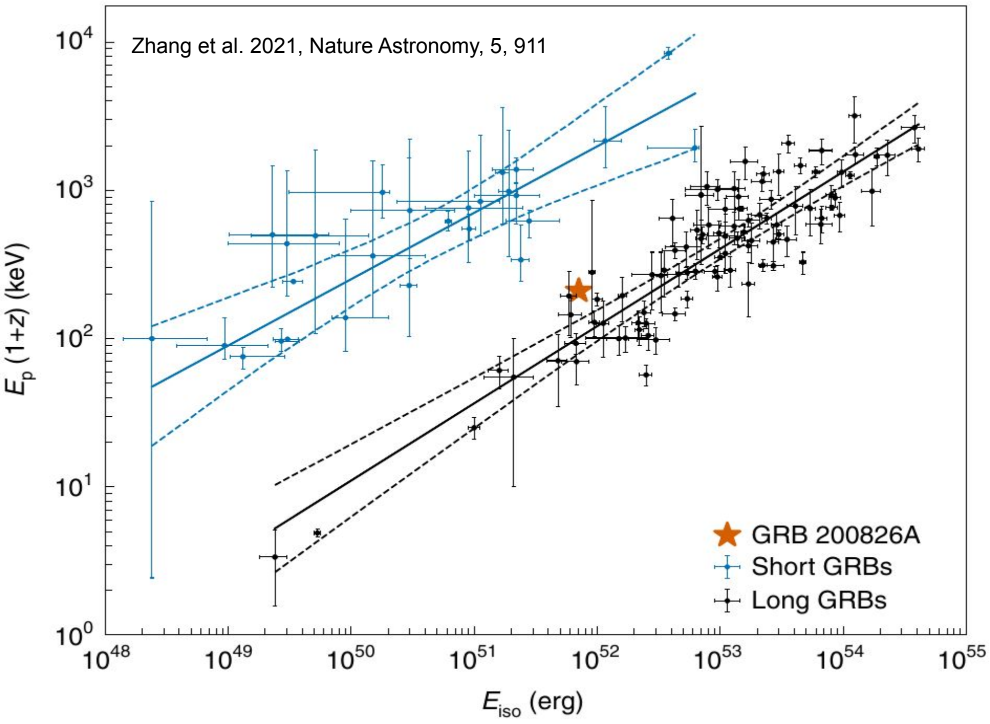


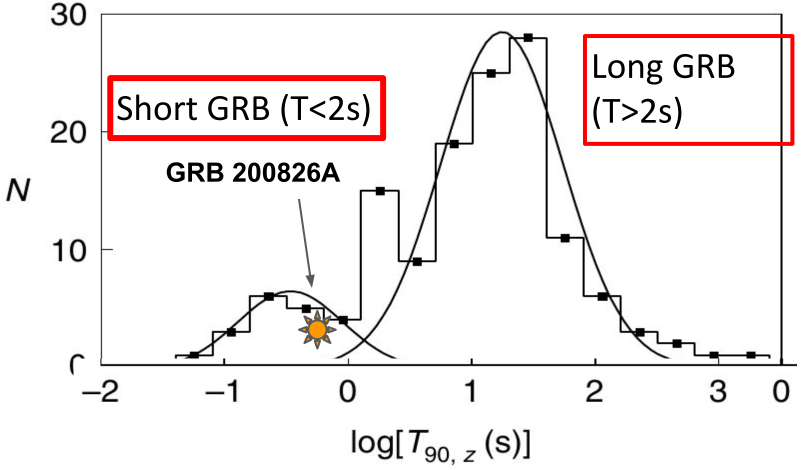


- LBT/MODS spectra at +8 days
- Detection of multiple emission lines
- [OII], H-gamma, H-beta, [OIII]/4959, [OIII]/5007
- at redshift of 0.7481 ±0.0003.

GRB 200826A prompt emission

Rest-frame energetics



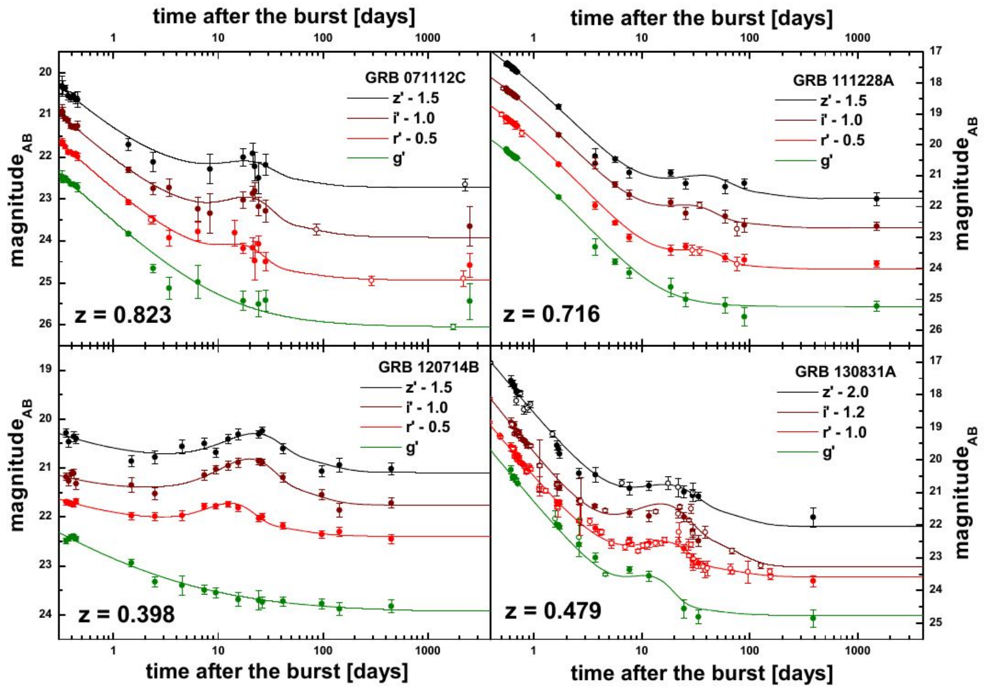


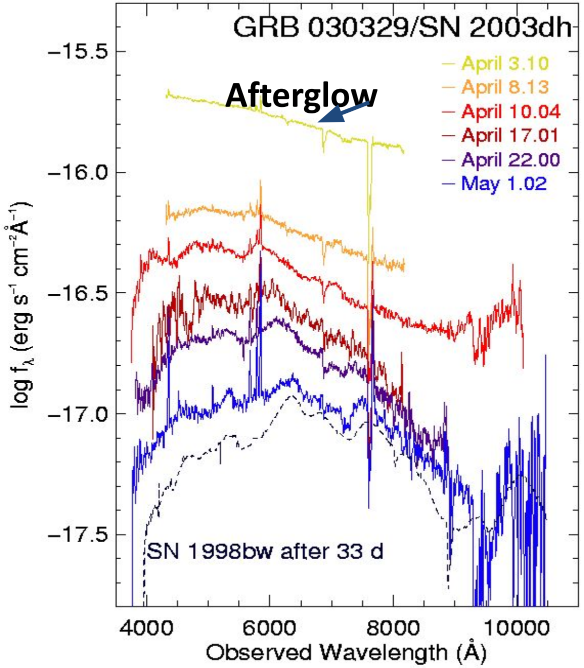
Rest-frame duration

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

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!





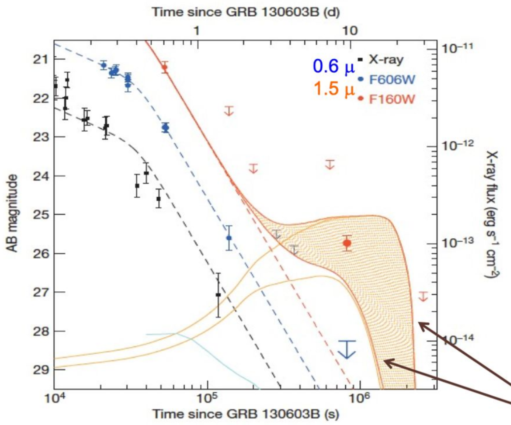
Klose et al. 2019

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

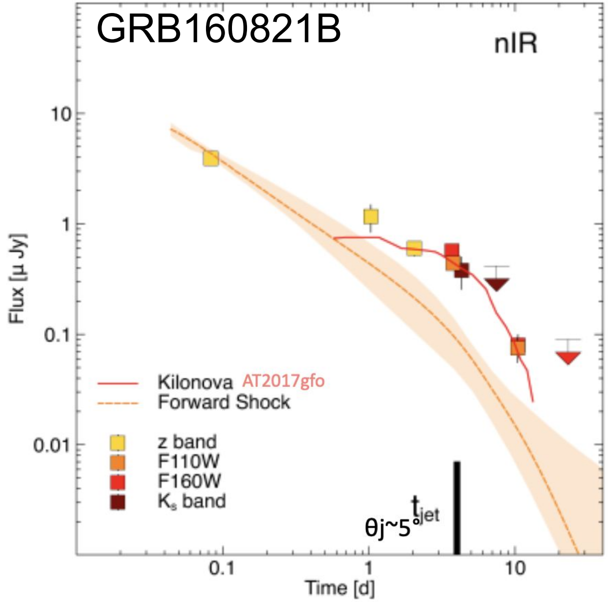
short GRB 130603B



Tanvir et al. Nature, 500, 547, 2013

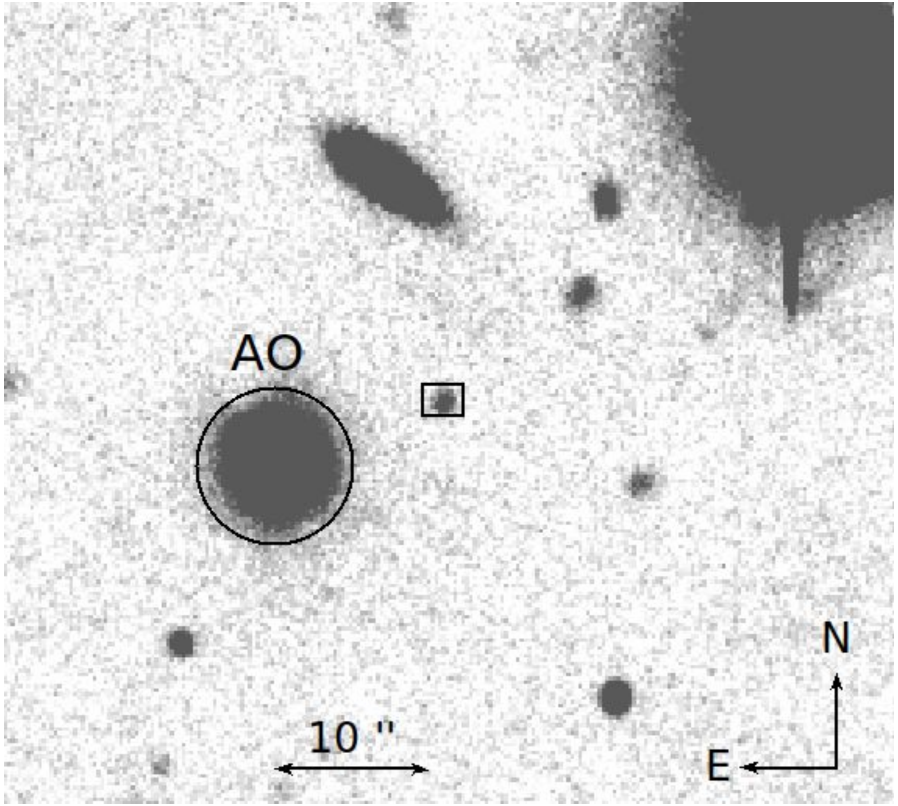
- short GRB 130603B a z=0.356 (Tanvir+2013)
- Possible evidence of kilonova 7 days after the burst as a significant deviation from expected afterglow flux

Ejected mass: 0.1 Mo
Ejected mass: 0.01 Mo



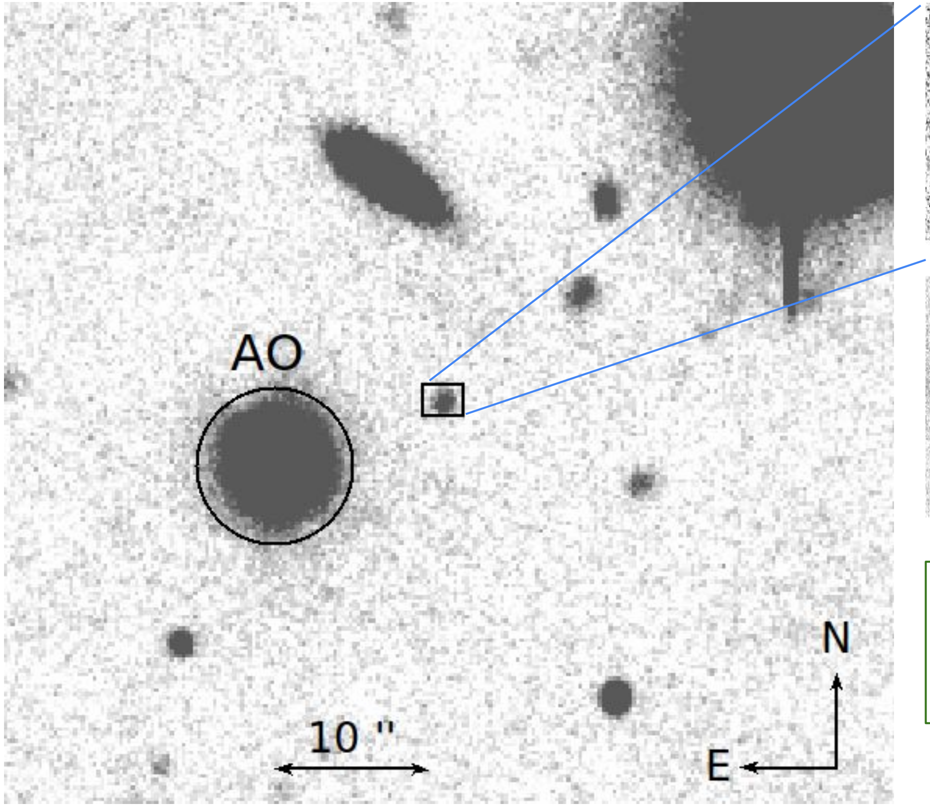
Troja et al. 2019

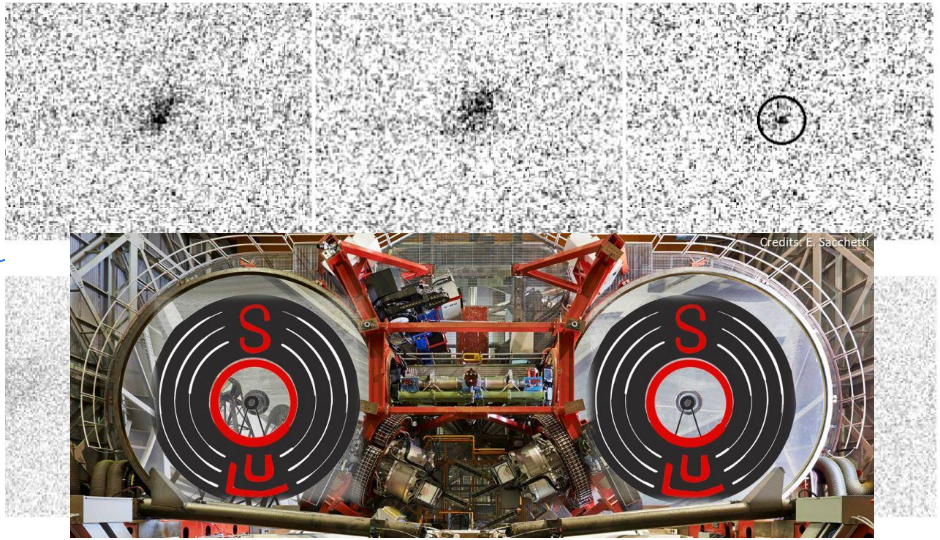
Deep optical (rest-frame UV) imaging



- LBT+ TNG r-band imaging
  - +~32 days - ~+18days rest-frame
- Bad weather did not allow us to observe sooner
- Image subtraction with a late reference at +~80 days
- No detection
- However, ZTF team reported the detection of a bump in i'-band with Gemini

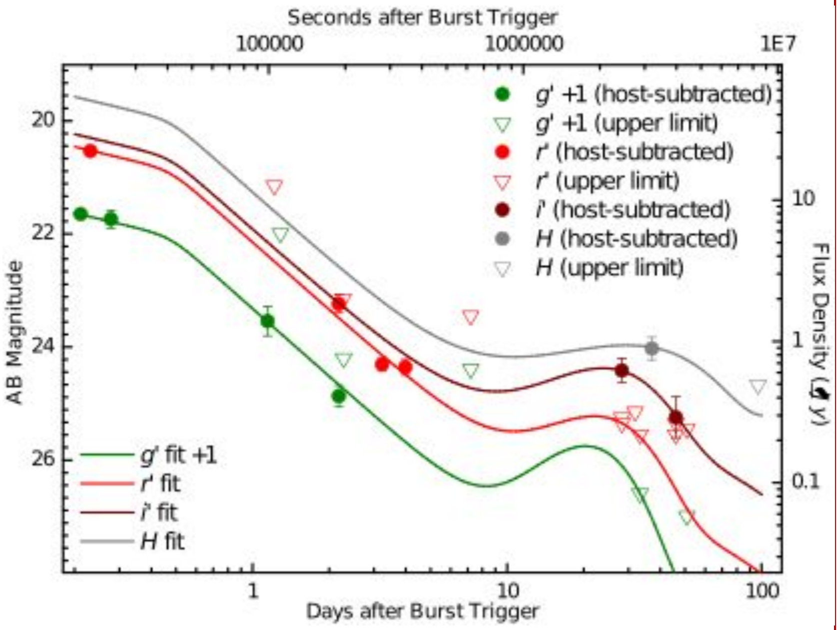
Deep NIR (rest-frame z-band) imaging in adaptive optics

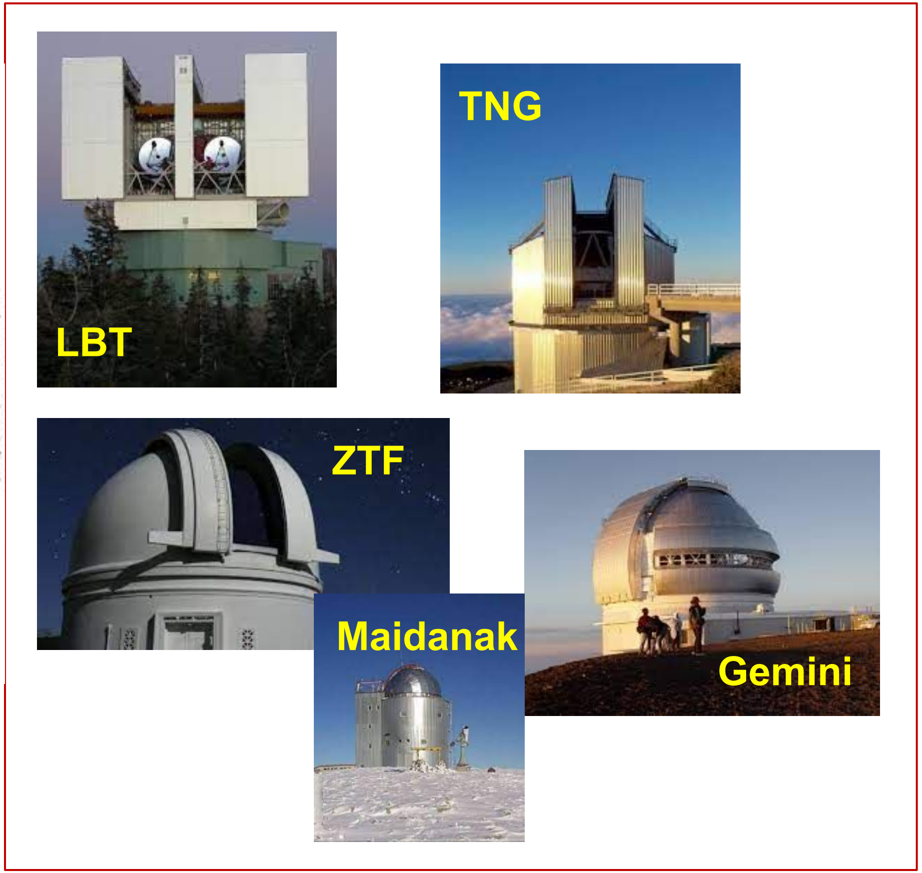




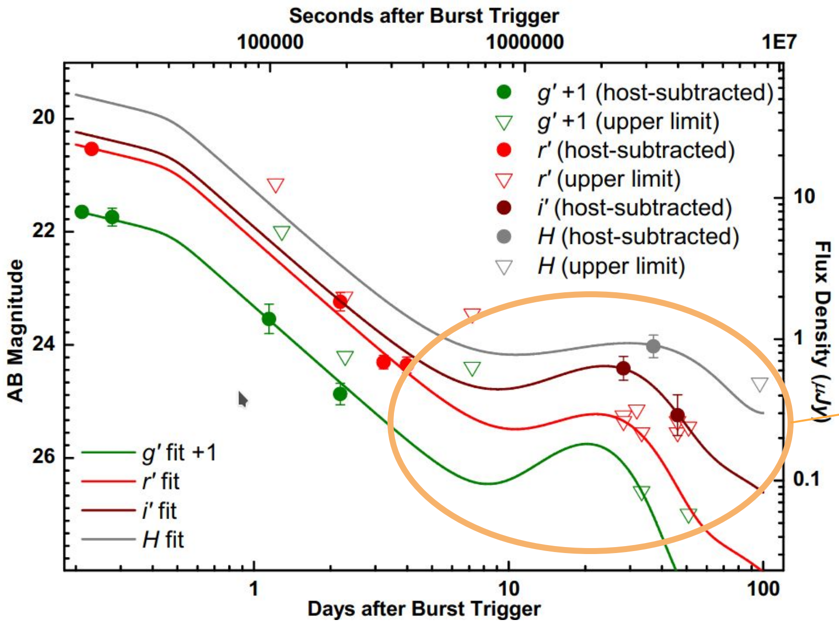
- LBT+ LUCI *H*-band +~37 days - ~+21days rest-frame
- Image subtraction with reference at ~160 days
- **Detection!**

The optical/NIR afterglow





The optical/NIR afterglow

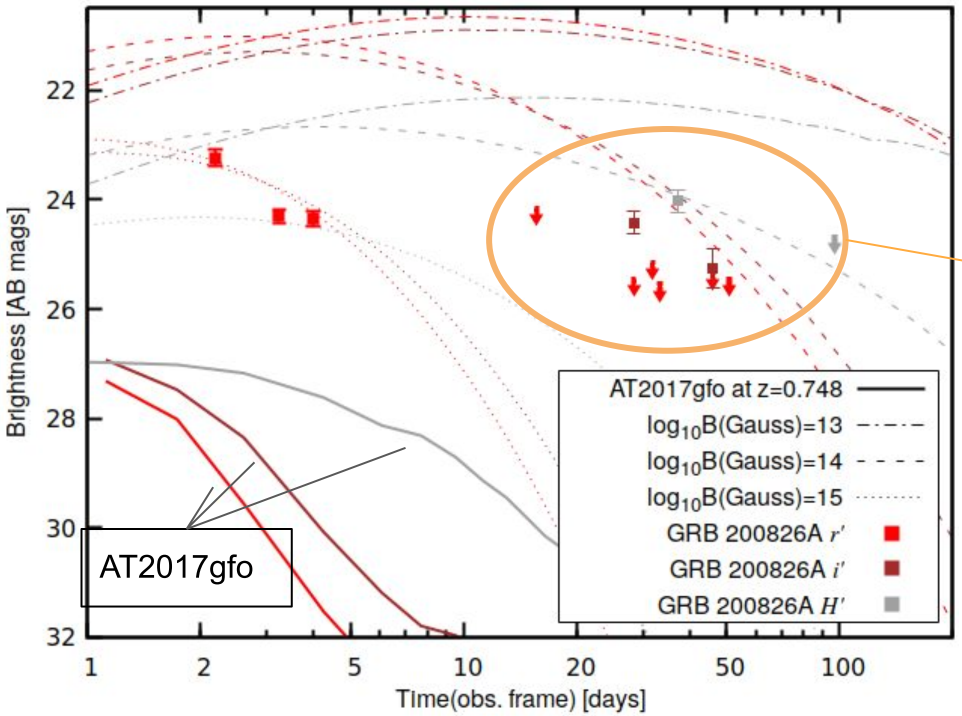


There is a late bump after subtraction of the host.

What is the origin of this bump?

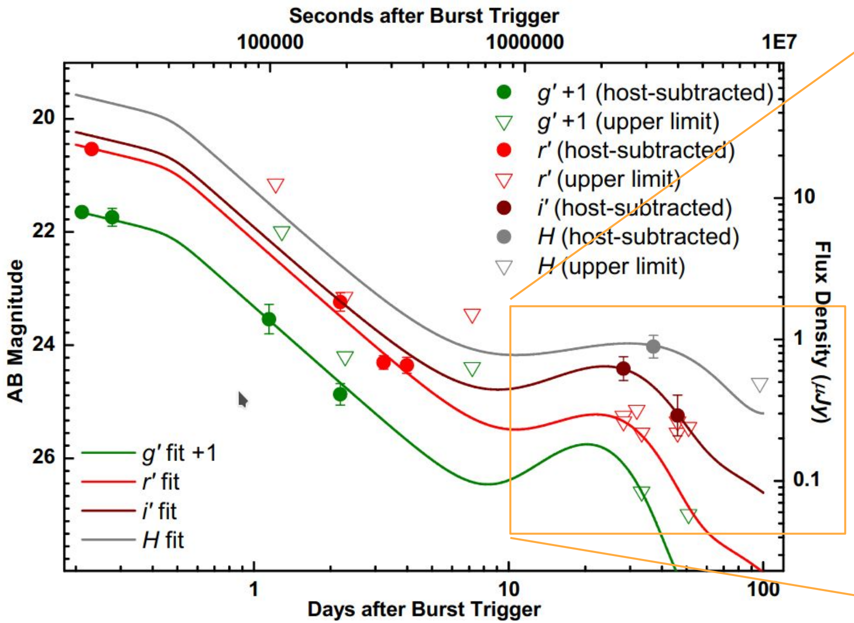
- **Is a supernova?**
- **Or a kilonova?**

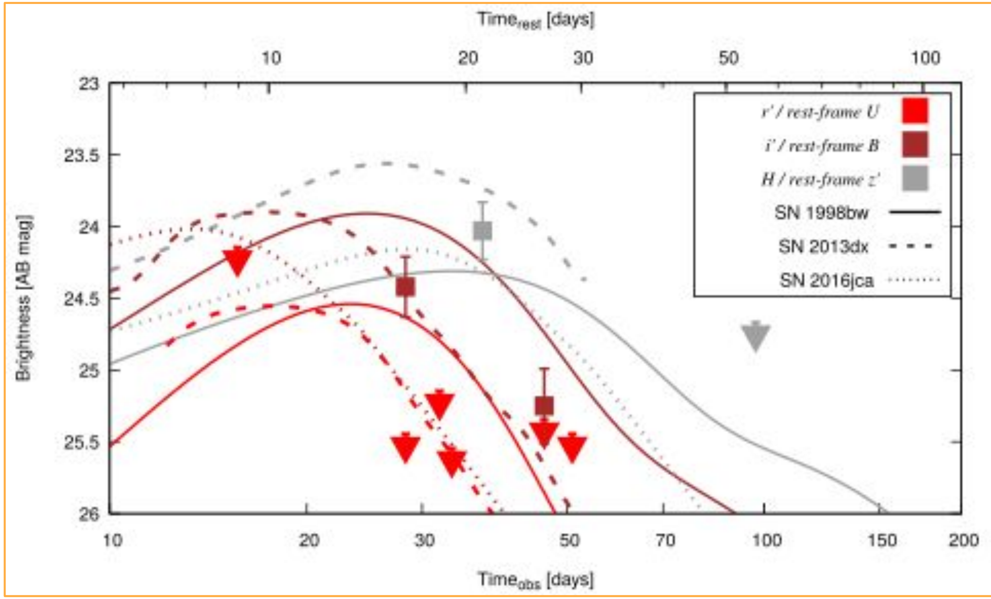
The optical/NIR afterglow



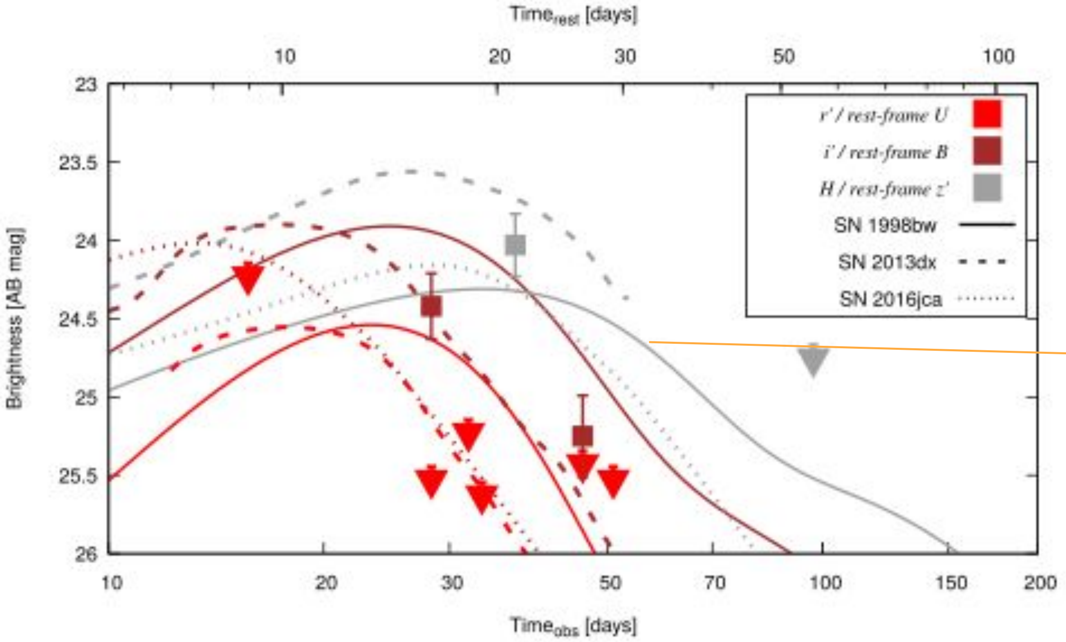
- **Observed bump is too bright for a kilonova like AT2017gfo**

The optical/NIR afterglow





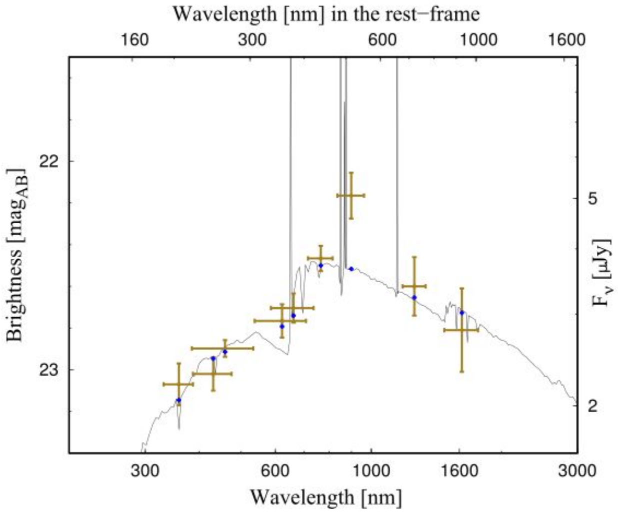
GRB 200826A originated from a massive star explosion

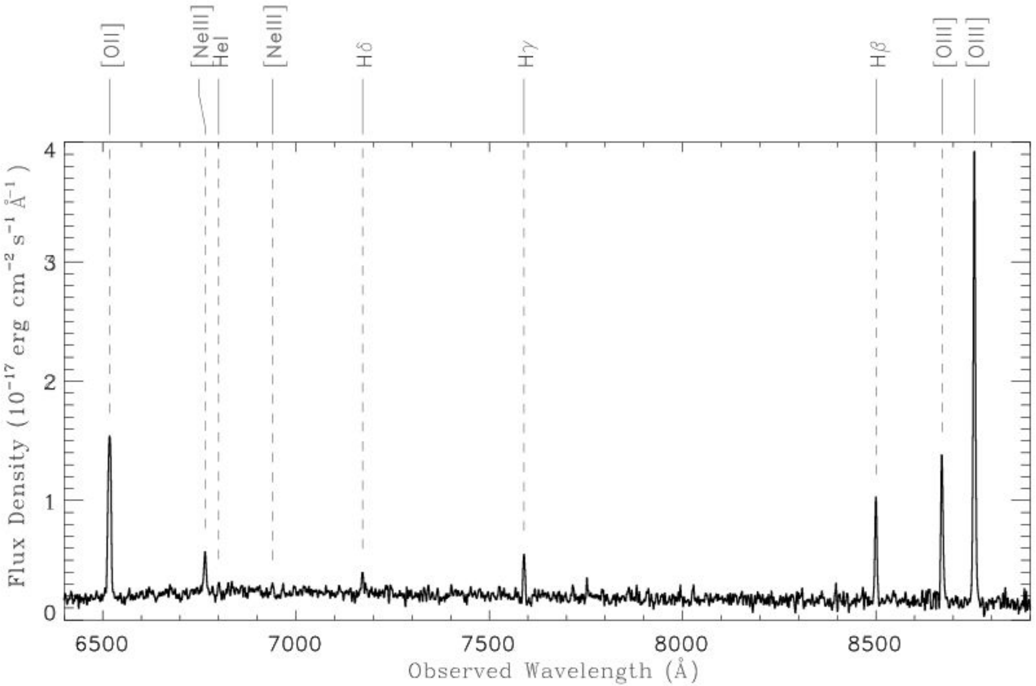


The light curve is:

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

Host galaxy properties

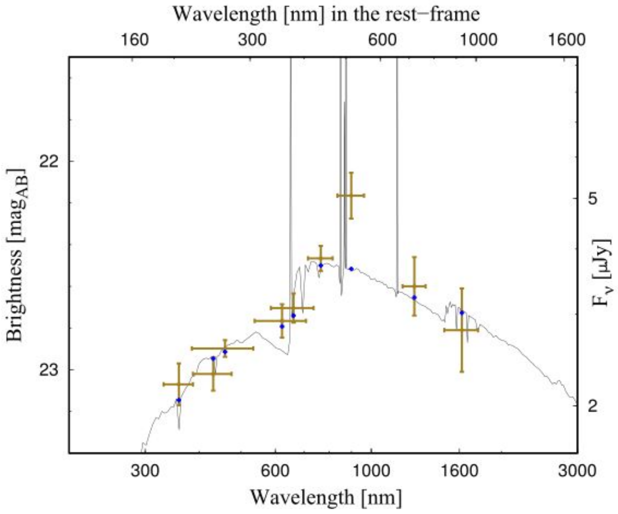


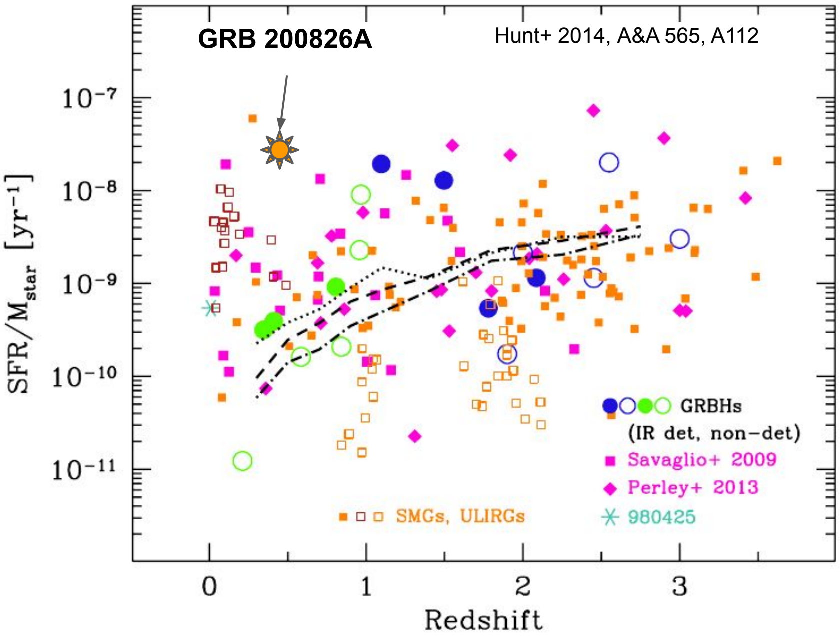


The LBT/MODS spectrum and SED (LBT/MODS+LBC) of the host:

- log M_* = 8.6 ± 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





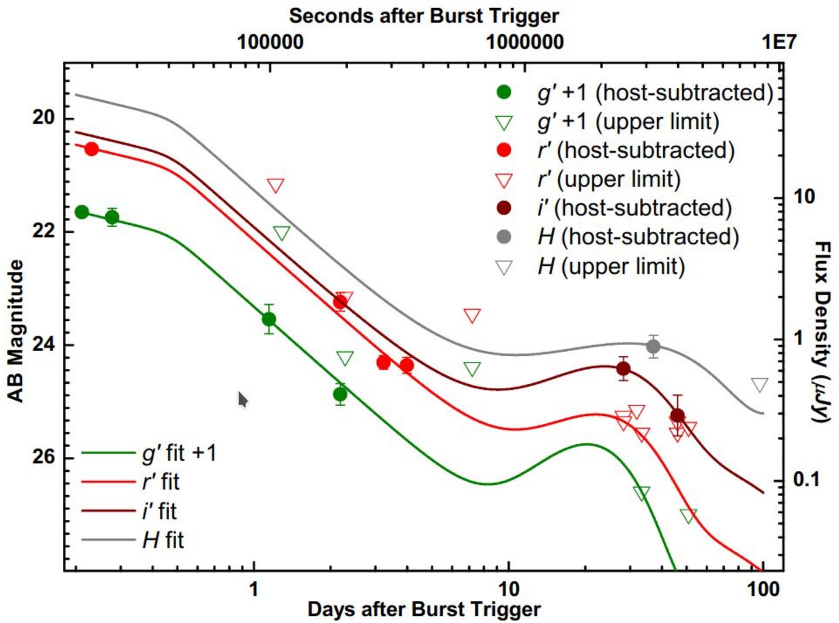
It is a small, star-forming galaxy with:

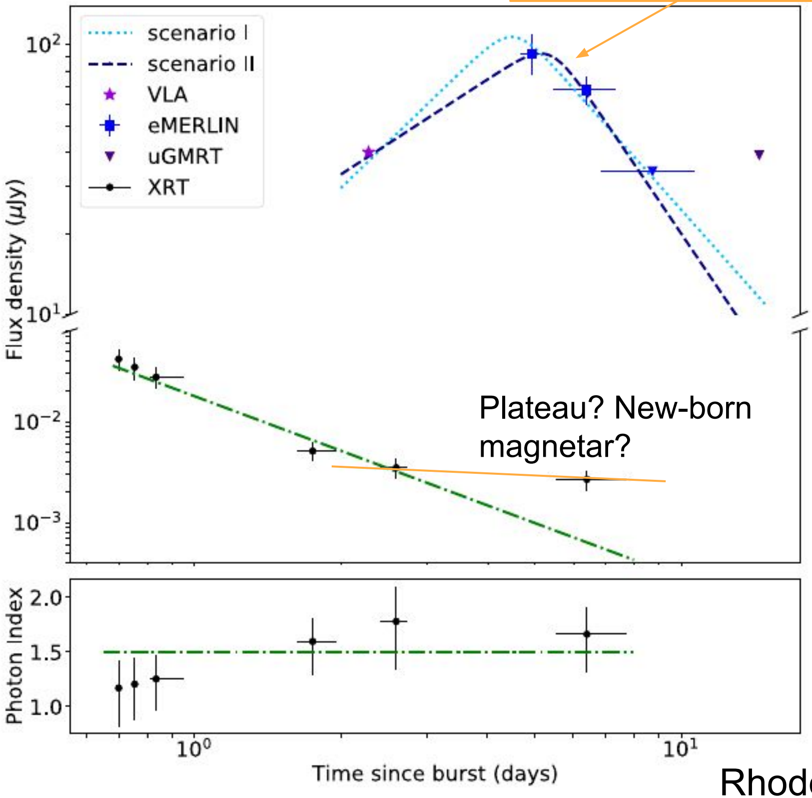
- a relatively high metallicity
- a sSFR among the highest within the LGRB host population

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

Why it was so short?

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





Plateau? New-born magnetar?

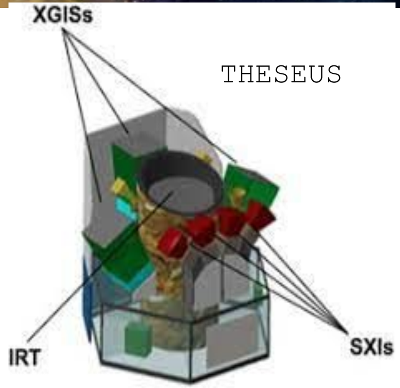
- **A failed collapsar?**
- **A mild relativistic jet?**

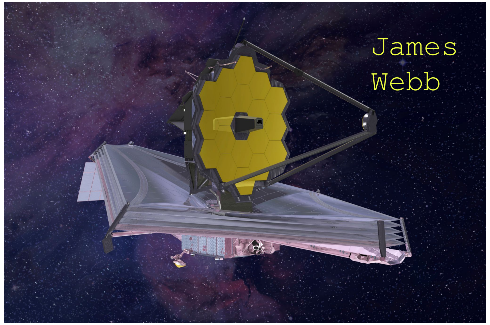
See Zhang+21 for discussion

Rhodes+21

Future scenarios

From Space





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.

Summary

- GRB 200826A is a short duration GRB.
- But is consistent with the Ep,i − Eiso “Amati” relation followed by LGRBs.

- We have found a late bump is in good agreement with other GRB-SNe.
- A KN like AT2017gfo is not supported.
- The first detection of a GRB-SN with AO observations.

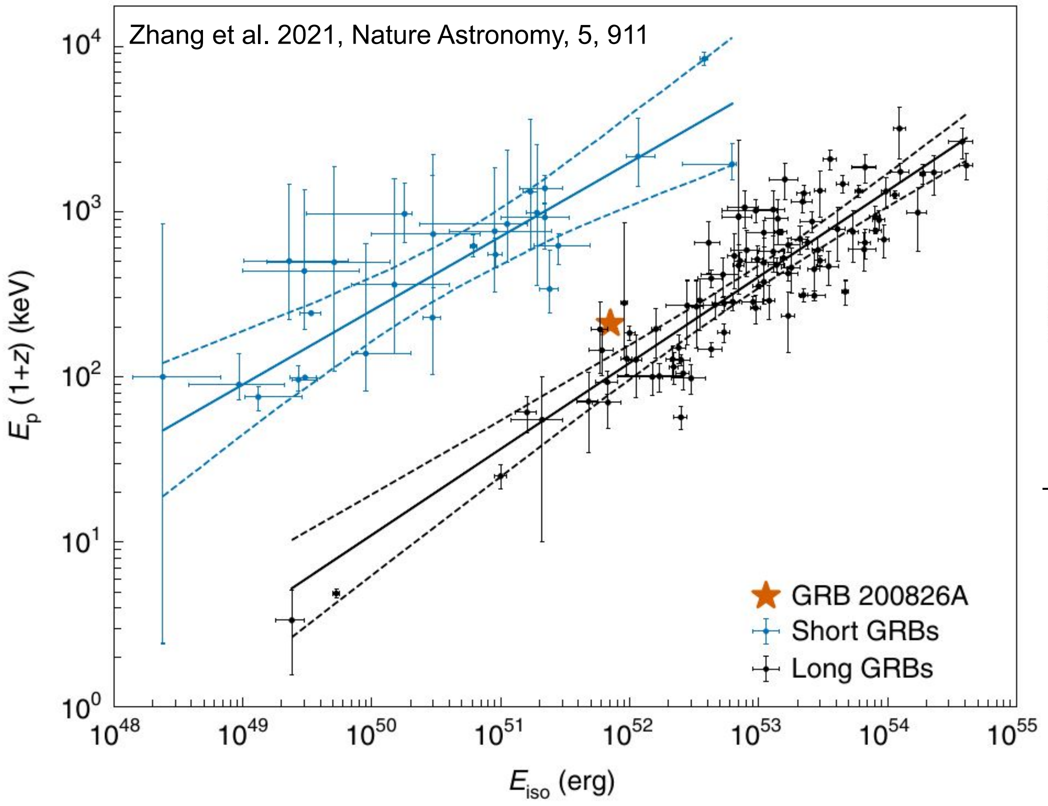
- Thus we firmly classify this burst as a collapsar event.
- **The simple duration is NOT an indicator of the origin of a GRB.**

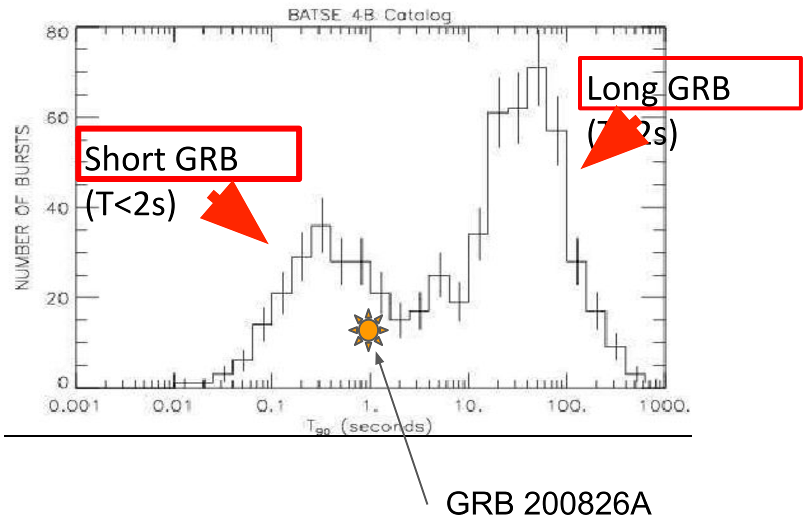
Please see Rossi et al., 2022, ApJ, 932, 1
https://ui.adsabs.harvard.edu/abs/2022ApJ...932....1R/abstract

See also Rastinejad et al. on the long GRB 211211A and its kilonova !
https://arxiv.org/abs/2204.10864

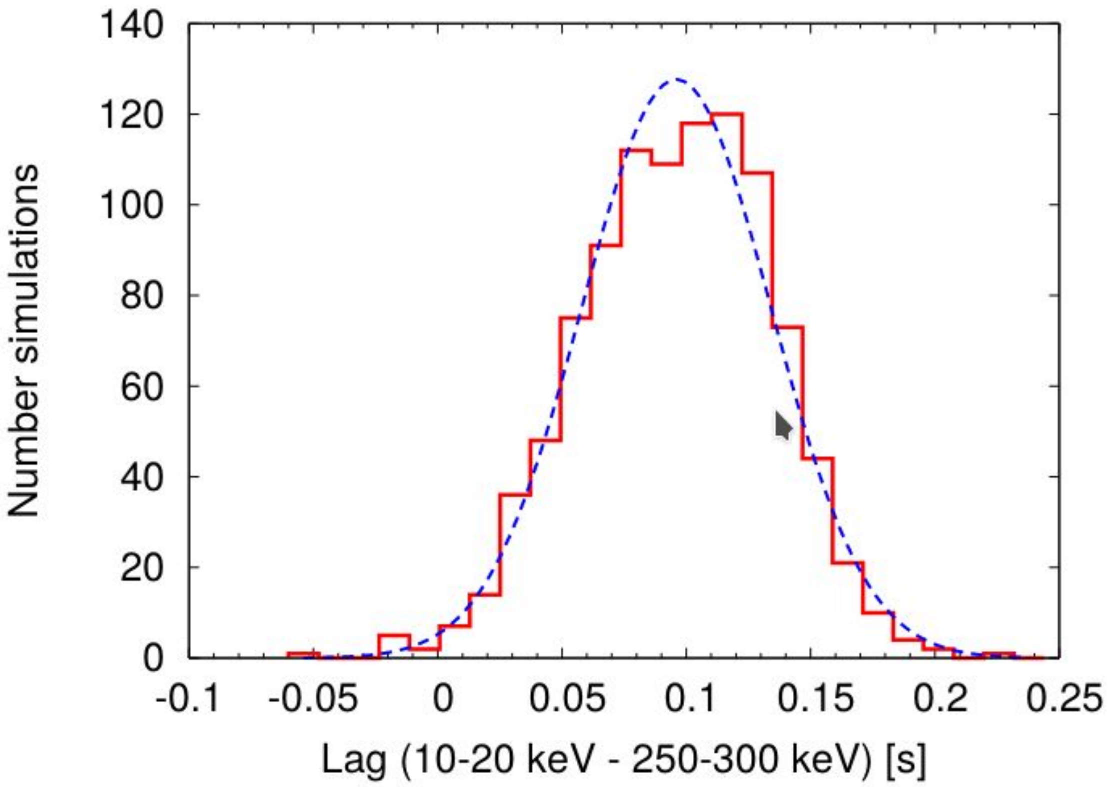
Thank you!

GRB 200826A prompt emission





Spectral lag analysis

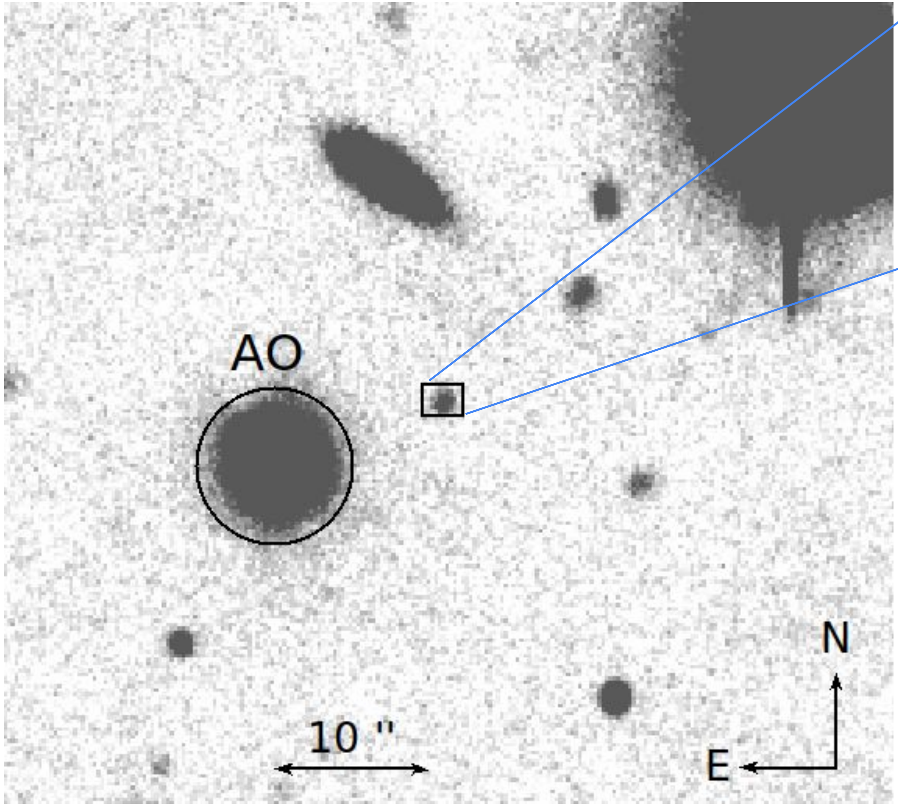


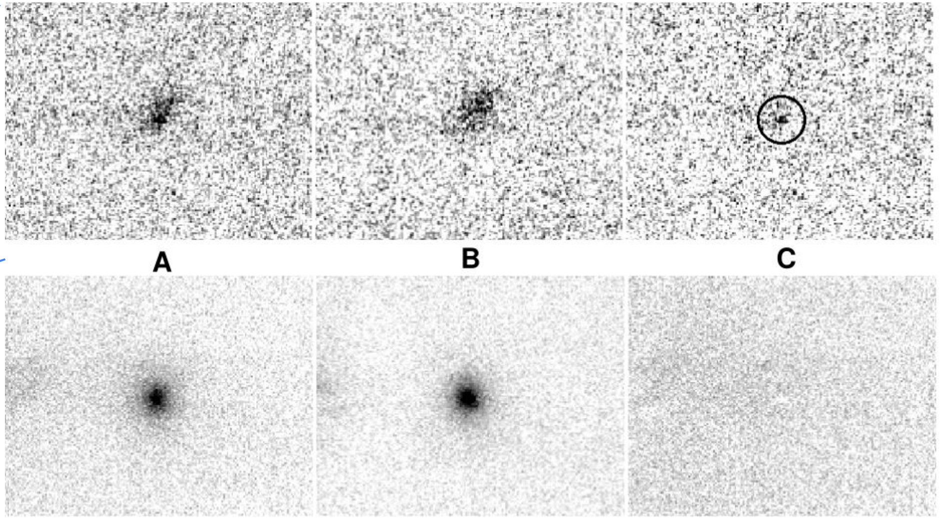
Distribution of the spectral lag analysis:

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

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

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

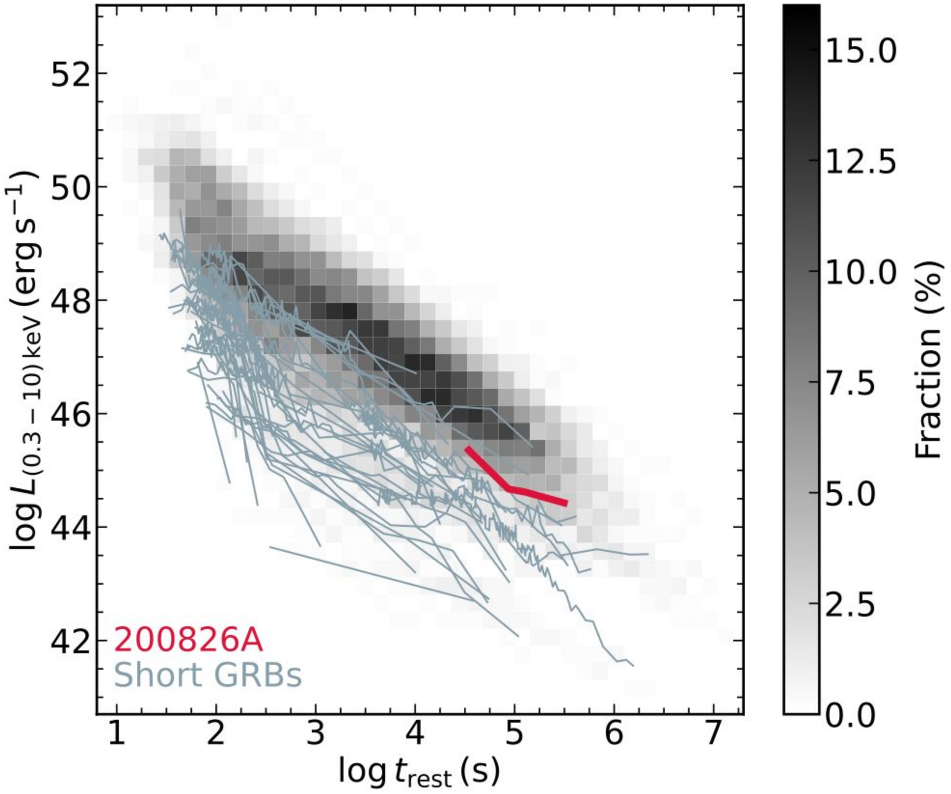


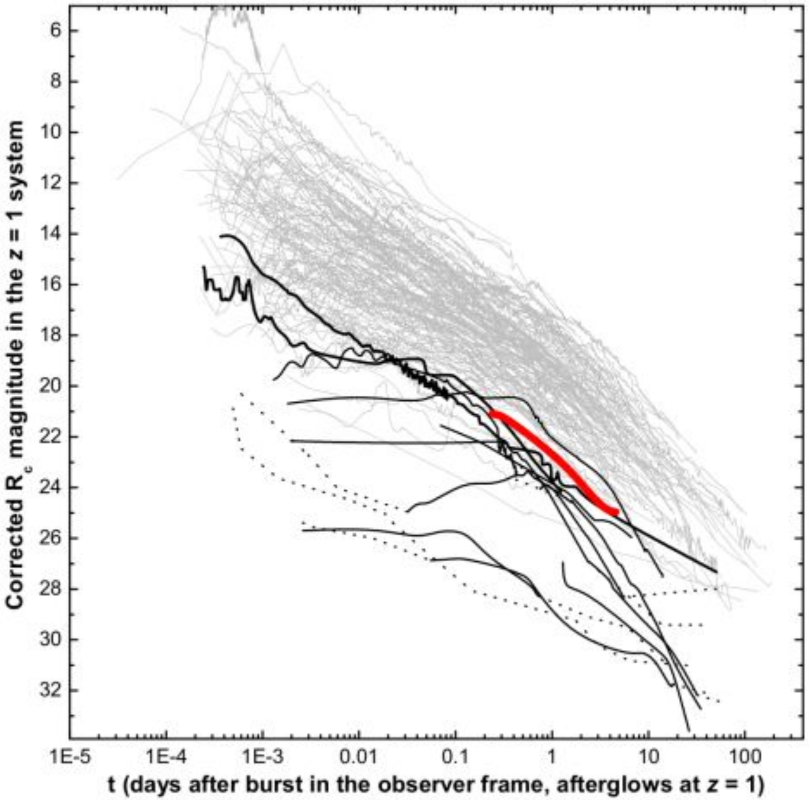


- LBT+ LUCI *H*-band +~37 days - ~+21days rest-frame
- Image subtraction with reference at ~160 days
- **Detection!**

The afterglow in context

in between long and short GRBs





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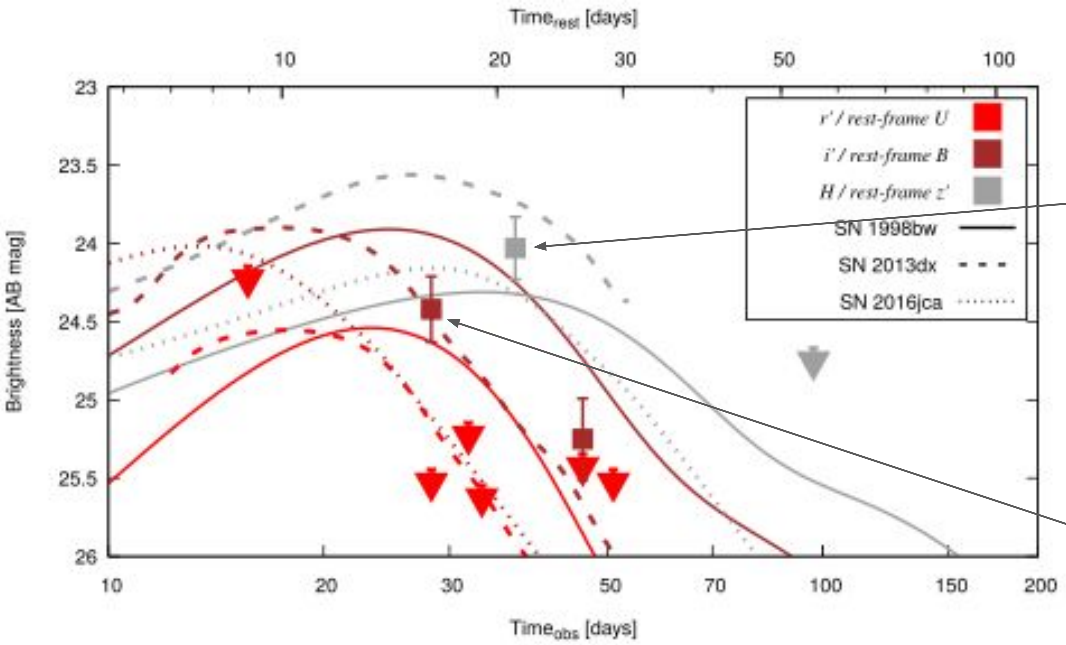
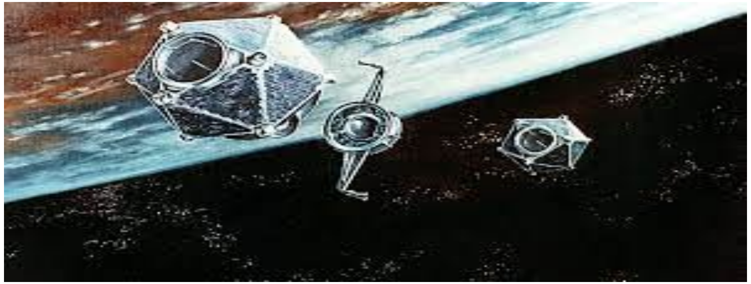
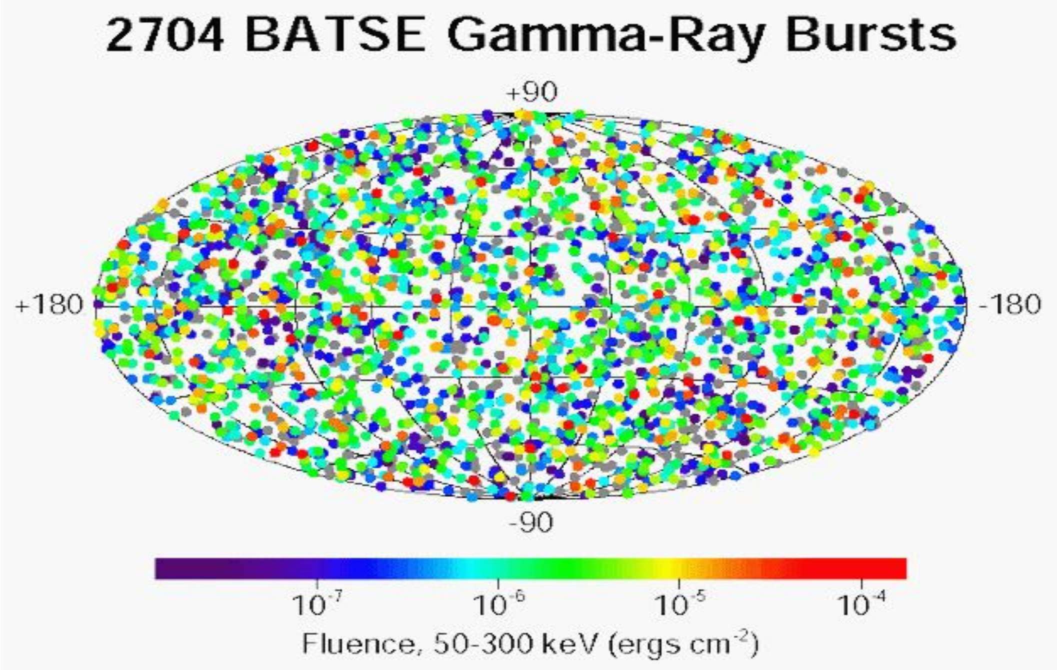


Gamma ray bursts



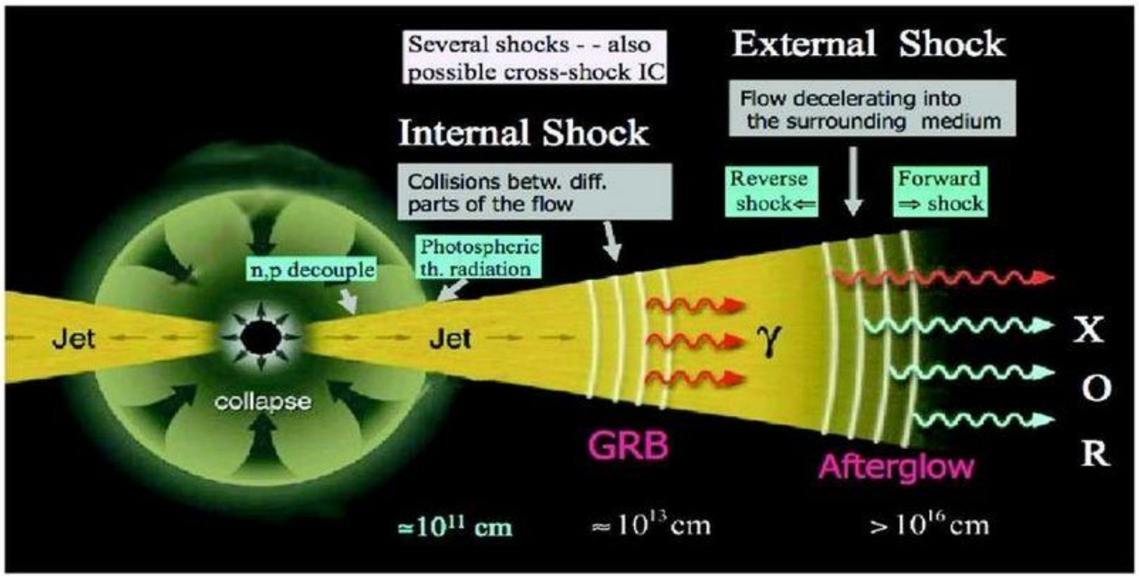
GRBs were serendipitously discovered in the late ‘60s by US military satellites VELA (Klebesadel et al. 1973) as bright flashes of gamma-rays from unpredictable directions in the sky



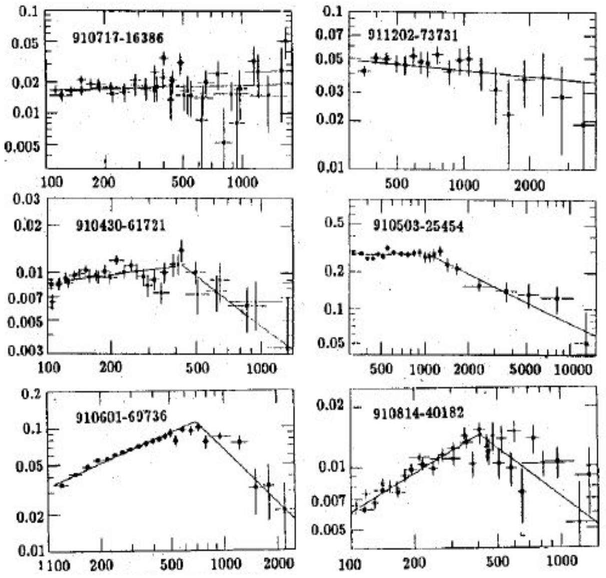
~3000 GRBs observed during 1990s: isotropic sky distribution → cosmological origin → very energetic events (~10^{48} - 10^{55} erg)

Gamma ray bursts

The observed radiation is interpreted within the framework of the “fireball model” where released energy is first converted into kinetic energy and then to the observed radiation through “internal” (prompt emission) and “external” (afterglow) shocks

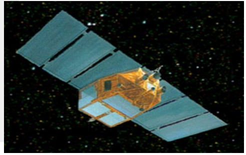


Meszaros & Rees 2014, arxiv:1401.3012

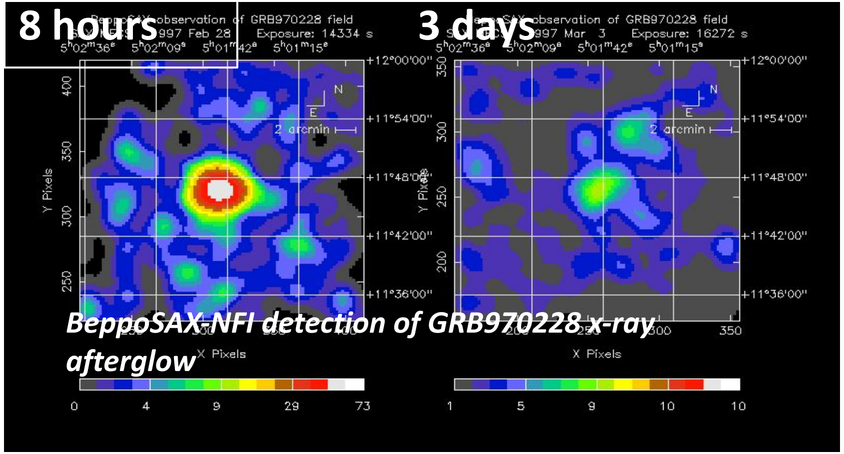


non-thermal spectra of prompt emission

GRB Multi-Wavelength Afterglow



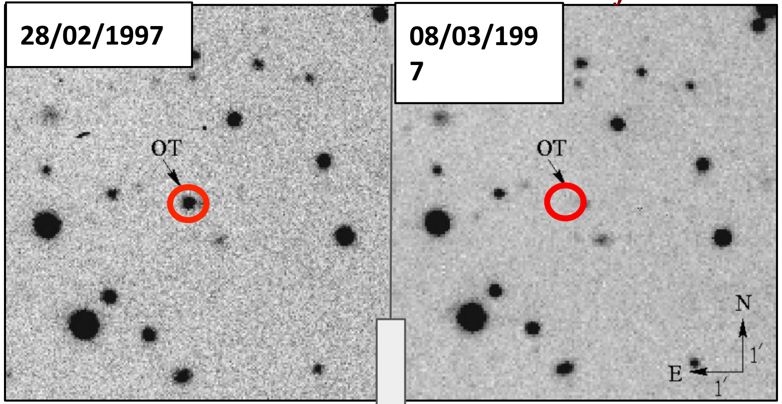
1997: the afterglow emission was discovered with BeppoSAX → confirmation of theoretical predictions + accurate sky localizations → redshift of several GRBs

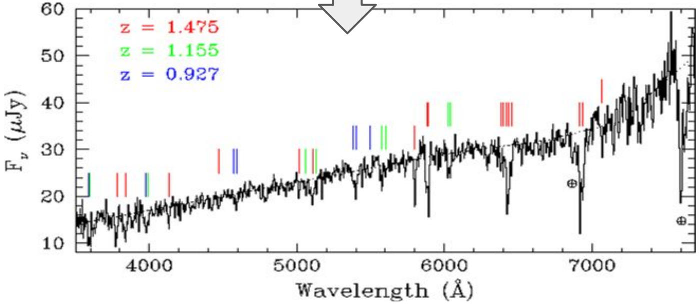


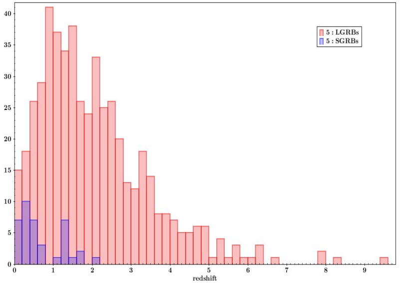
BeppoSAX-NFI detection of GRB970228 x-ray afterglow

Costa et al. 1997

Van Paradijs et al. 1997







The cosmological origin of GRBs is confirmed!