The peculiar short-duration GRB 200826A and its supernova

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Based on Rossi et al., 2022, ApJ, 932, 1
Gamma ray bursts

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

Temporal features: diverse and spiky light curves

Kouveliotu et al. 1993
Discovery of GRB 200826A
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
- $[\text{OII}]$, H-gamma, H-beta, $[\text{OIII}]/4959$, $[\text{OIII}]/5007$
- at redshift of $0.7481 \pm 0.0003$. 
GRB 200826A prompt emission

Rest-frame energetics

The prompt properties do not allow 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

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**short GRB 130603B**

- short GRB 130603B at z=0.356 (Tanvir et al. 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

Tanvir et al. Nature, 500, 547, 2013

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**GRB160821B**

Troja et al. 2019
Deep optical (rest-frame UV) imaging

- LBT+ TNG r-band imaging
  - +~32 days - ~+18 days 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 $\sim$37 days - $\sim$+21 days rest-frame
- Image subtraction with reference at $\sim$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
The LBT/MODS spectrum and SED (LBT/MODS+LBC) of the host:

- \( \log M_\ast = 8.6 \pm 0.2 \, M_\odot \)
- \( \text{SFR} \sim 4.0 \, M_\odot/\text{yr} \)
- \( \text{sSFR} \sim 10^{-8} \, \text{yr}^{-1} \)
- \( \text{AV} \sim 0.5 \, \text{mag} \) from spectra and SED
- \( Z = 0.4 \, Z_\odot \) 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?

- A failed collapsar?
- A mild relativistic jet?

See Zhang+21 for discussion

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

Plateau? New-born magnetar?
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 $E_{\text{p,i}} - E_{\text{iso}}$ "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

Zhang et al. 2021, Nature Astronomy, 5, 911

$E_p (1+z)$ (keV)

$E_{\text{iso}}$ (erg)

Short GRB (T<2s)

Long GRB (T>2s)

GRB 200826A
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 \( \sim 37 \) days - \( \sim +21 \) days rest-frame
- Image subtraction with reference at \( \sim 160 \) days
- Detection!
The afterglow in context
in between long and short GRBs

- 200826A
Short GRBs
GRB 200826A originated from a massive star explosion
Gamma ray bursts

~2800 GRBs observed during 1990s: isotropic sky distribution → cosmological origin → very energetic events ($\sim 10^{48} - 10^{55}$ erg)

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 ($\sim 10^{48} - 10^{55}$ 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

Costa et al. 1997

The cosmological origin of GRBs is confirmed!