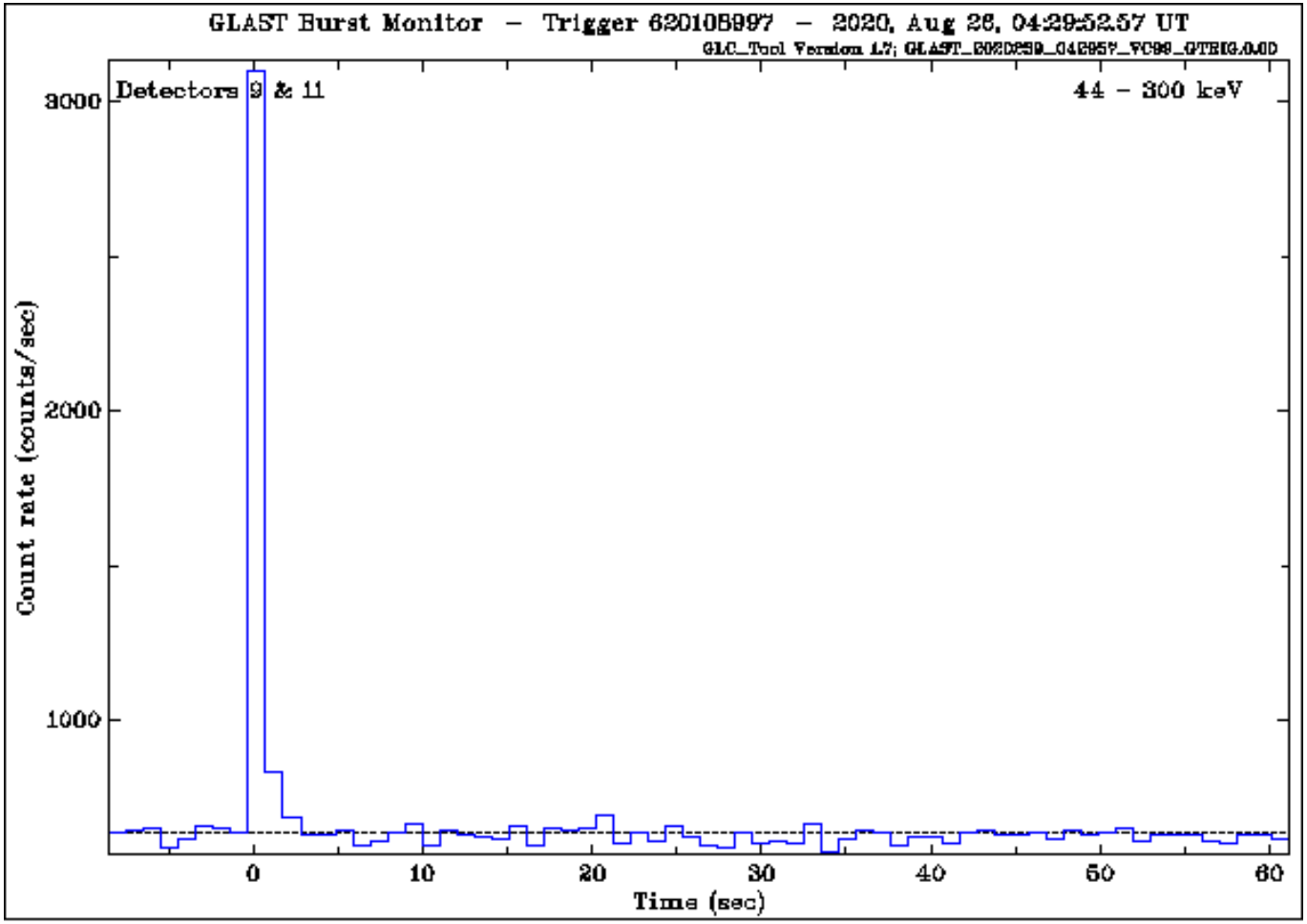
Journal Club #01 – 2021/2022

The peculiar short-duration GRB 200826A and its supernova

F.Longo

GRB 200826A

GCN 28284



https://www.mpe.mpg.de/~jcg/grb200826A.html

GRB 200826A

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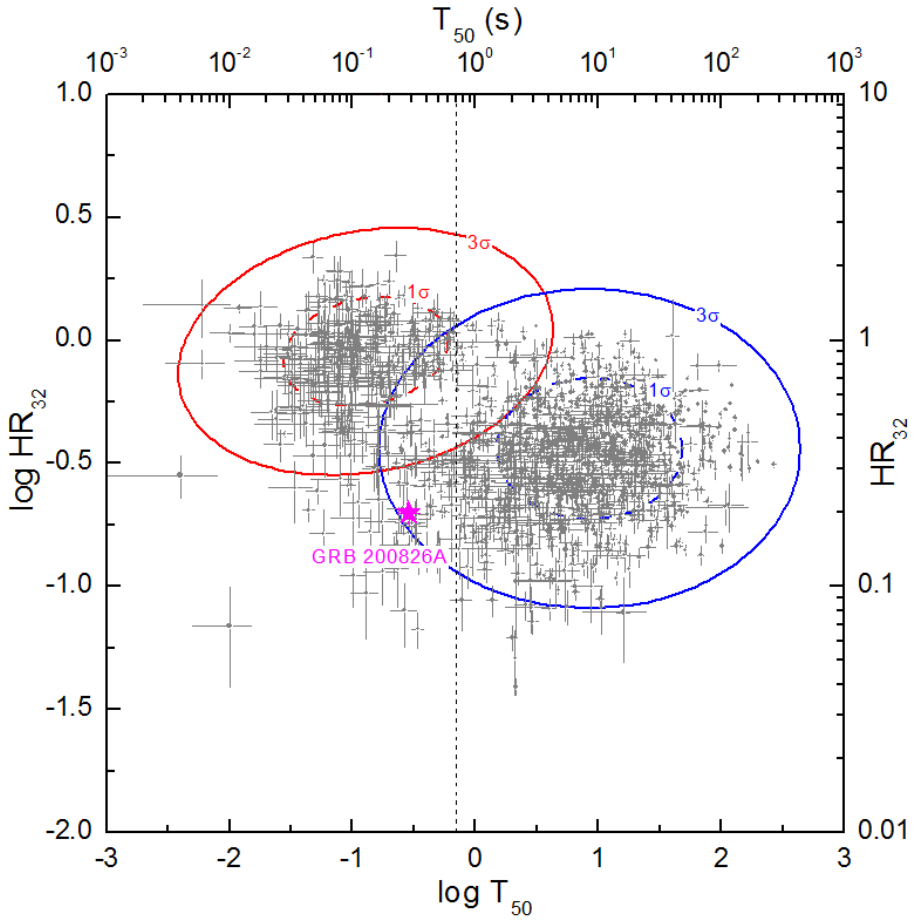

https://www.mpe.mpg.de/~jcg/grb200826A.html

The Article

The peculiar short-duration GRB 200826A and its supernova*

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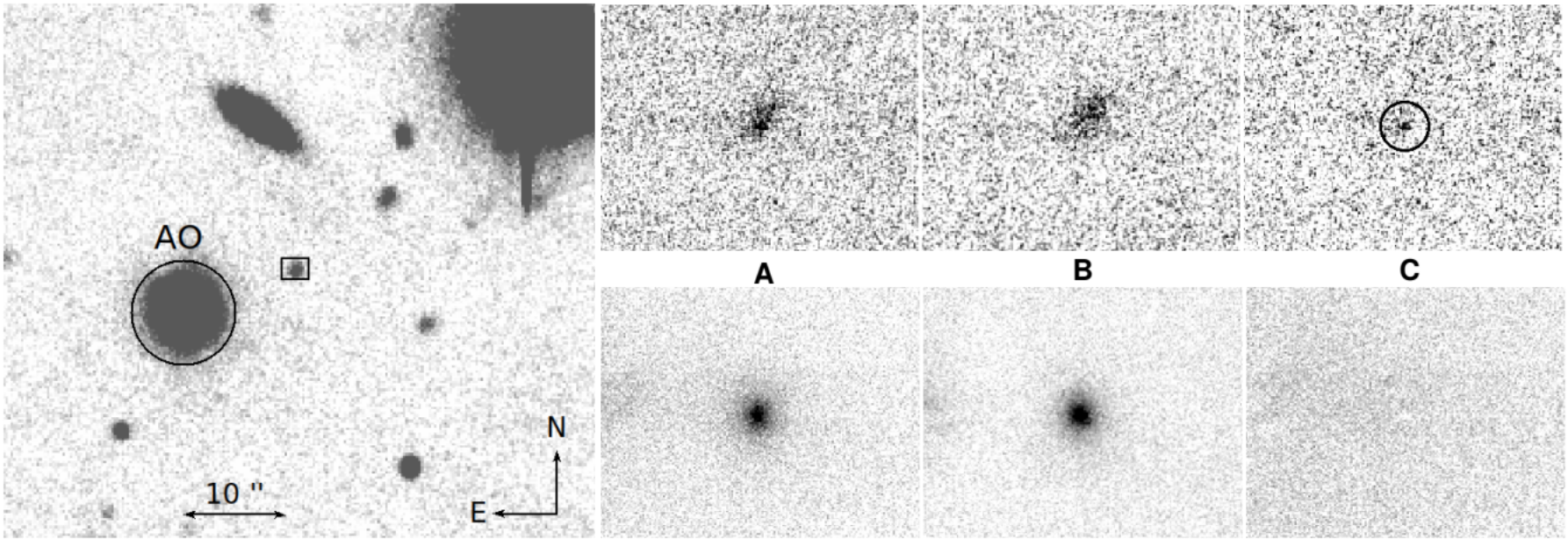
ABSTRACT

Gamma-ray bursts (GRBs) are classified as long and short events. Long GRBs (LGRBs) are associated with the end states of very massive stars, while short GRBs (SGRBs) are linked to the merger of compact objects. GRB 200826A was a peculiar event, because by definition it was a SGRB, with a rest-frame duration of ~ 0.5 s. However, this event was energetic and soft, which is consistent with LGRBs. The relatively low redshift ($z = 0.7486$) motivated a comprehensive, multi-wavelength follow-up campaign to characterize its host, search for a possible associated supernova (SN), and thus understand the origin of this burst. To this aim we obtained a combination of deep near-infrared (NIR) and optical imaging together with spectroscopy. Our analysis reveals an optical and NIR bump in the light curve whose luminosity and evolution is in agreement with several LGRB-SNe. Analysis of the prompt GRB shows that this event follows the $E_{p,i} - E_{iso}$ relation found for LGRBs. The host galaxy is a low-mass star-forming galaxy, typical for LGRBs, but with one of the highest star-formation rates (SFR), especially with respect to its mass ($\log M_*/M_\odot = 8.6$, SFR $\sim 4.0\, M_\odot$/yr). We conclude that GRB 200826A is a typical collapsar event in the low tail of the duration distribution of LGRBs.

These findings support theoretical predictions that events produced by collapsars can be as short as 0.5 s in the host frame and further confirm that duration alone is not an efficient discriminator for the progenitor class of a GRB.

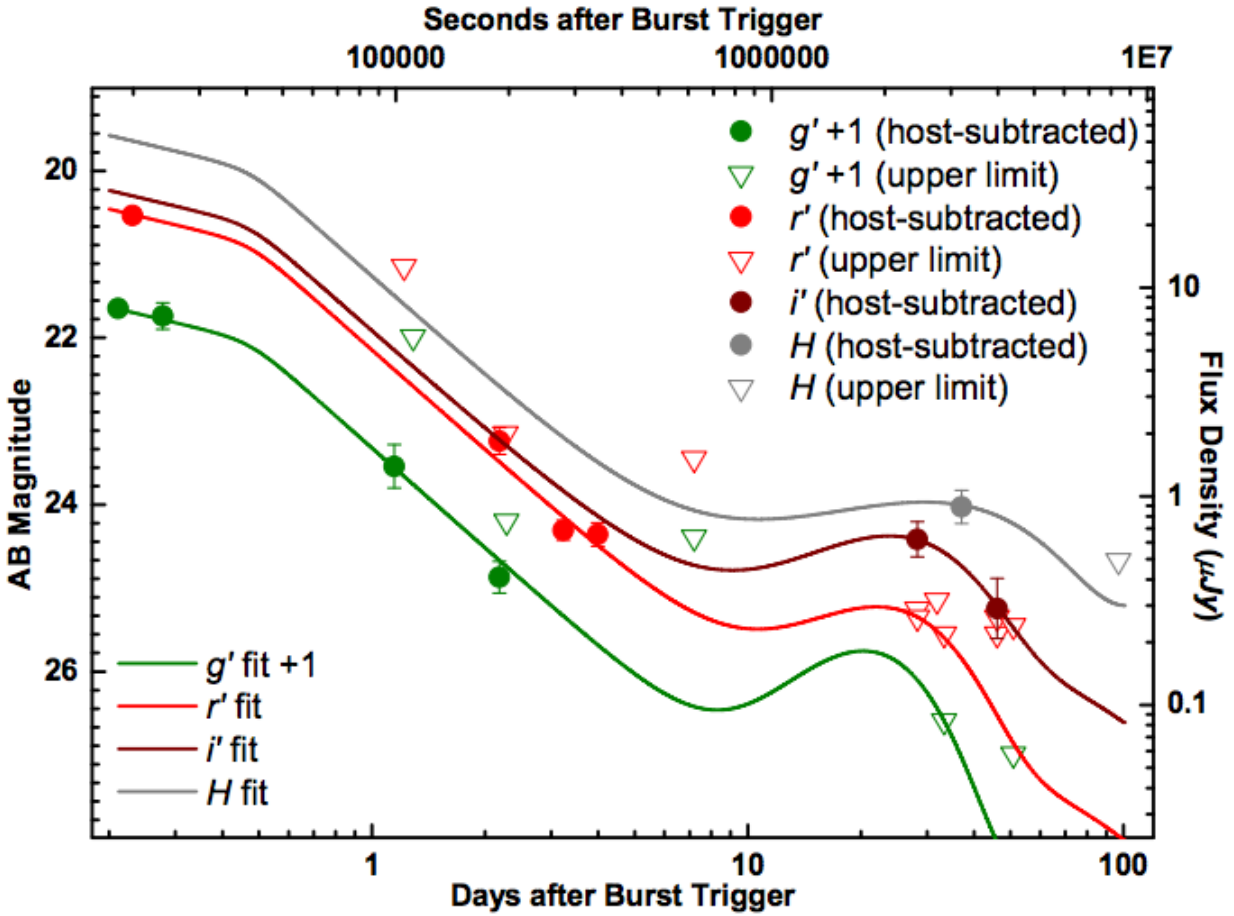
Accepted for publication in ApJ

Analysis



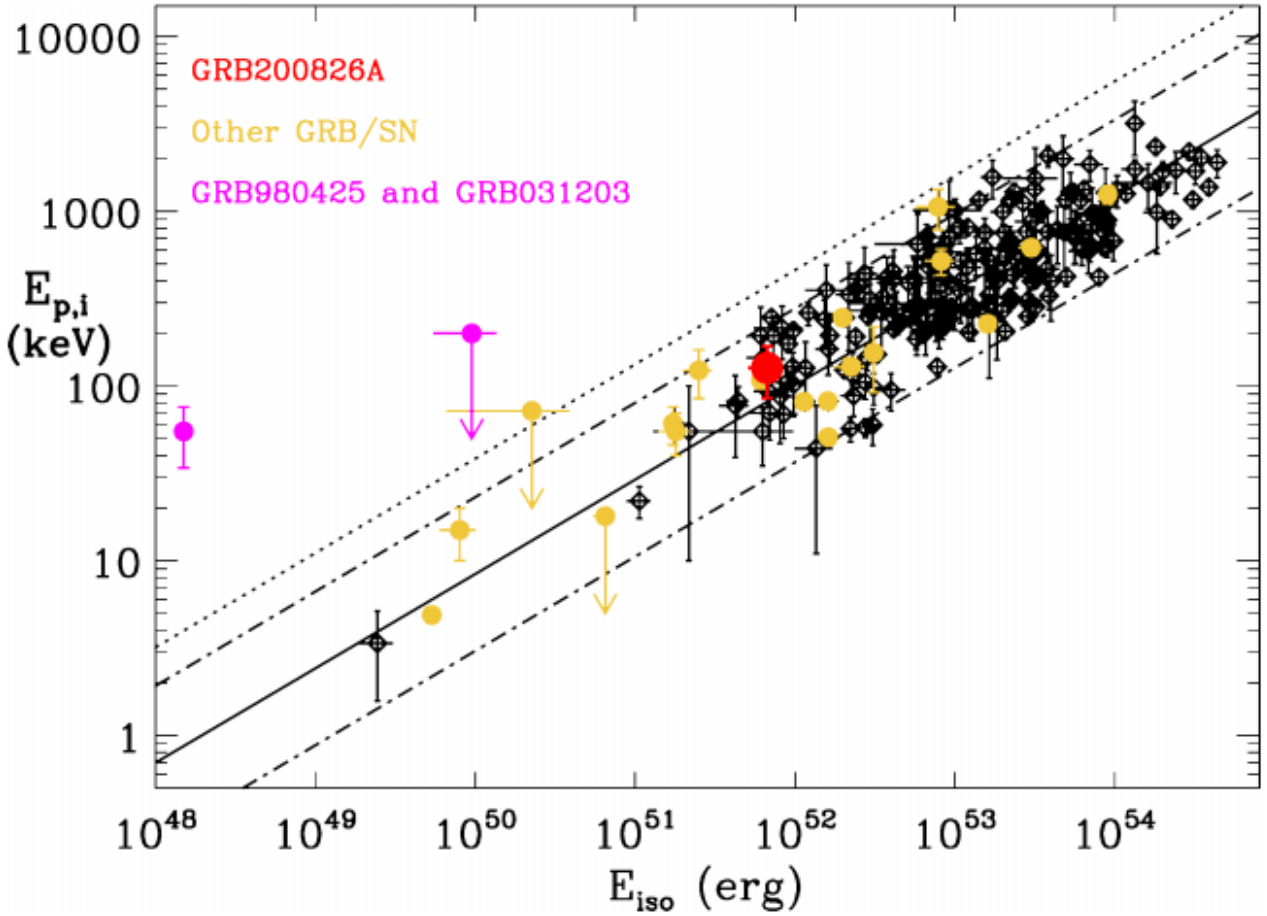
Optical/NIR analysis (TNG and LBT) and detection of OT

Analysis



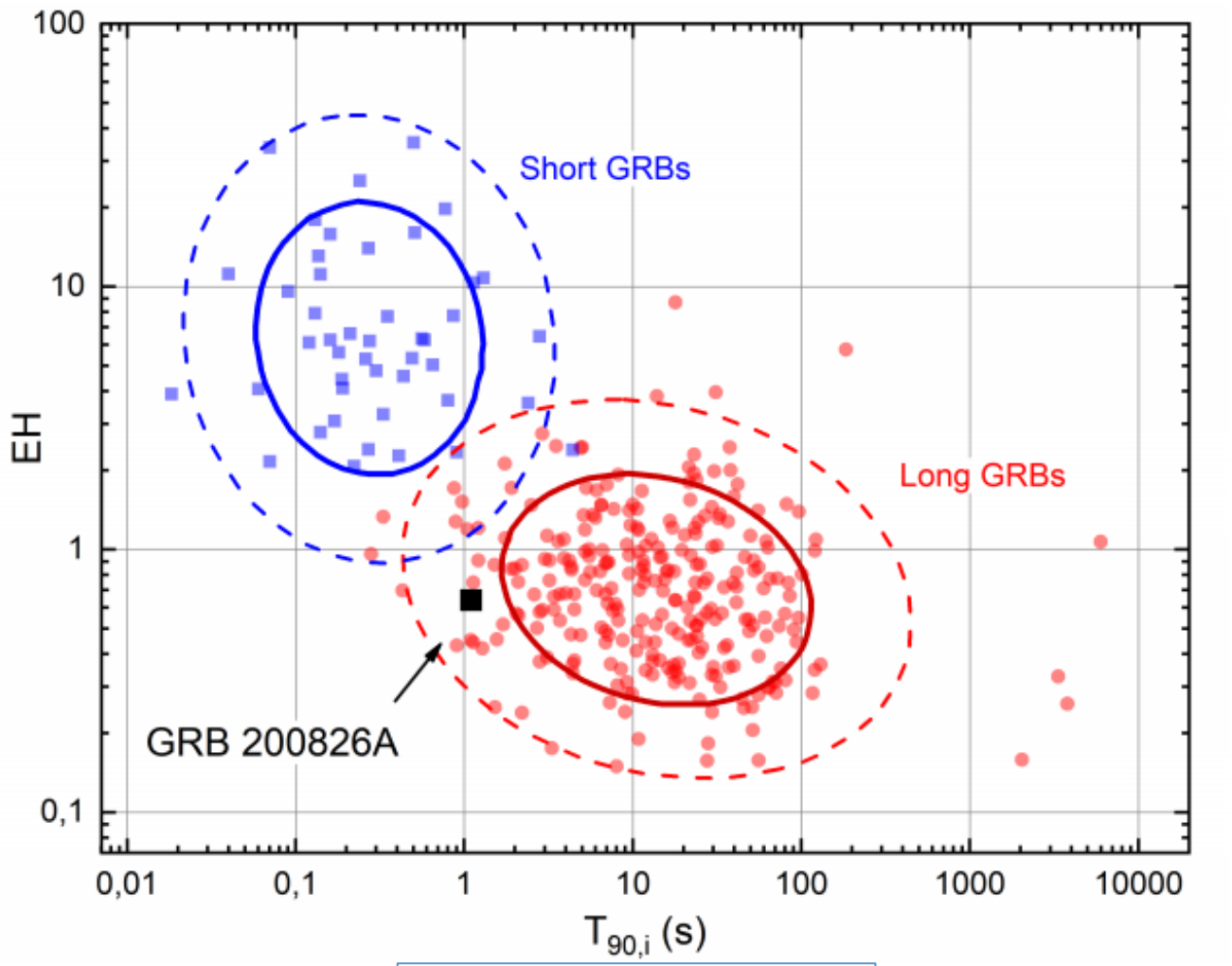
Light curve analysis: Afterglow and SN template (SN1998bw)

Analysis



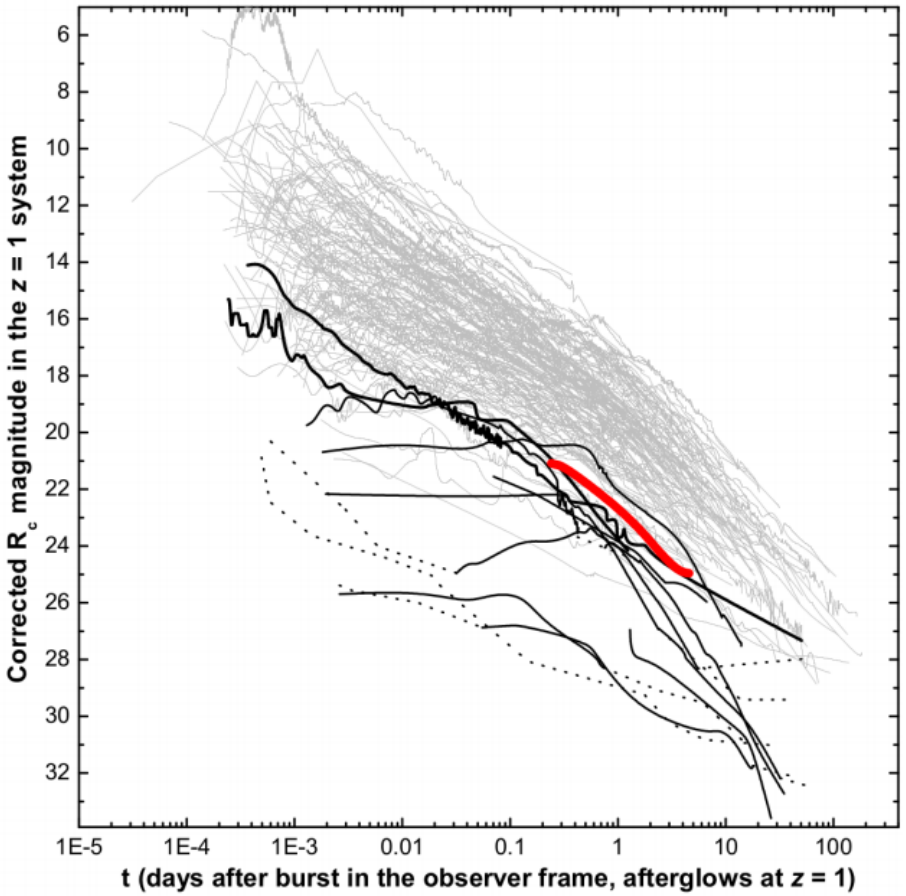
Location in the Amati relation

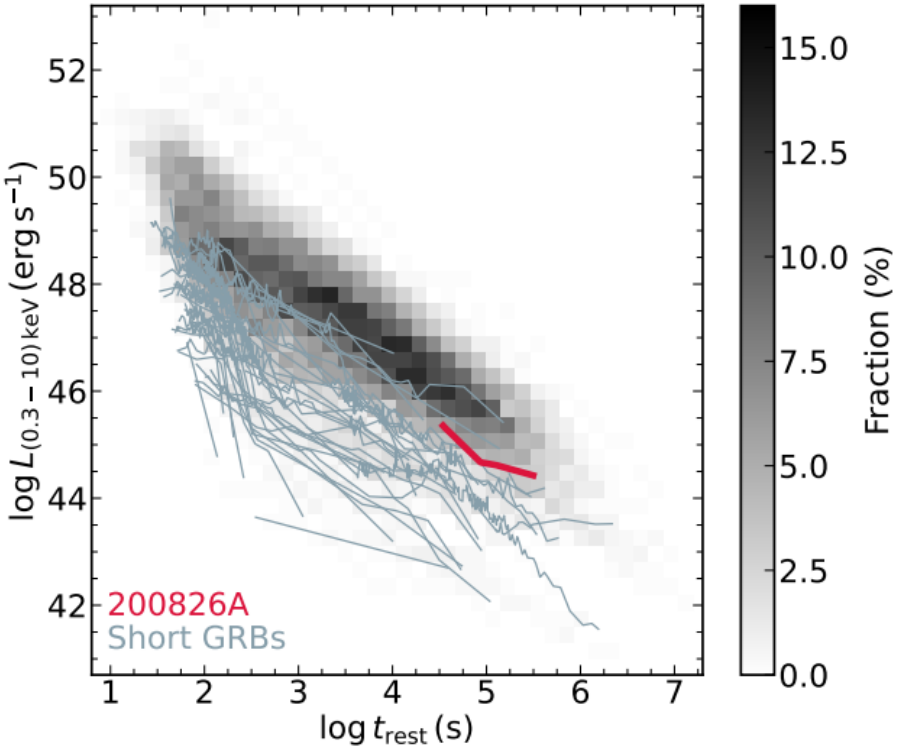
Analysis



T90 vs Energy Hardness

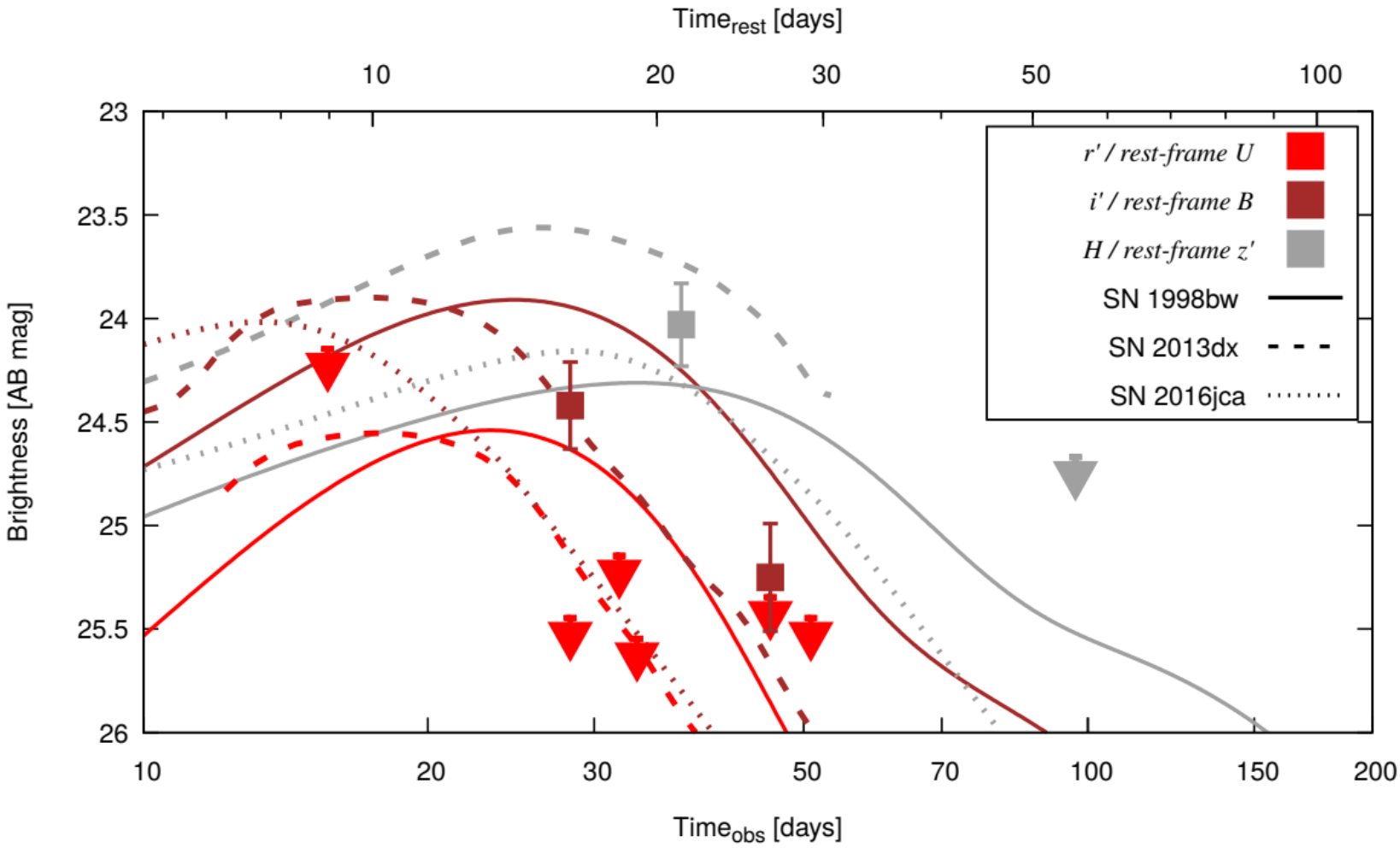
Analysis





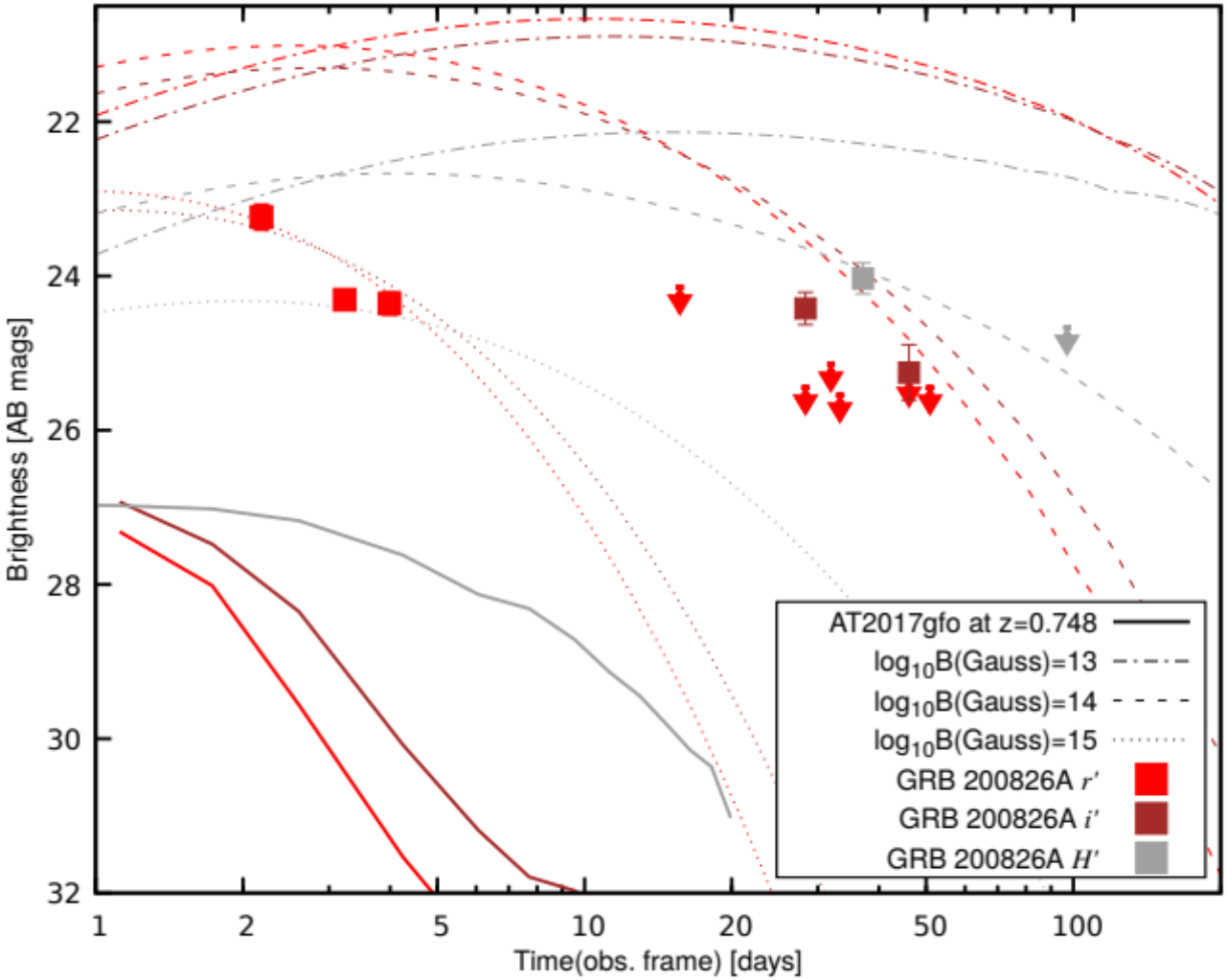
Optical and X-ray afterglow

Modeling



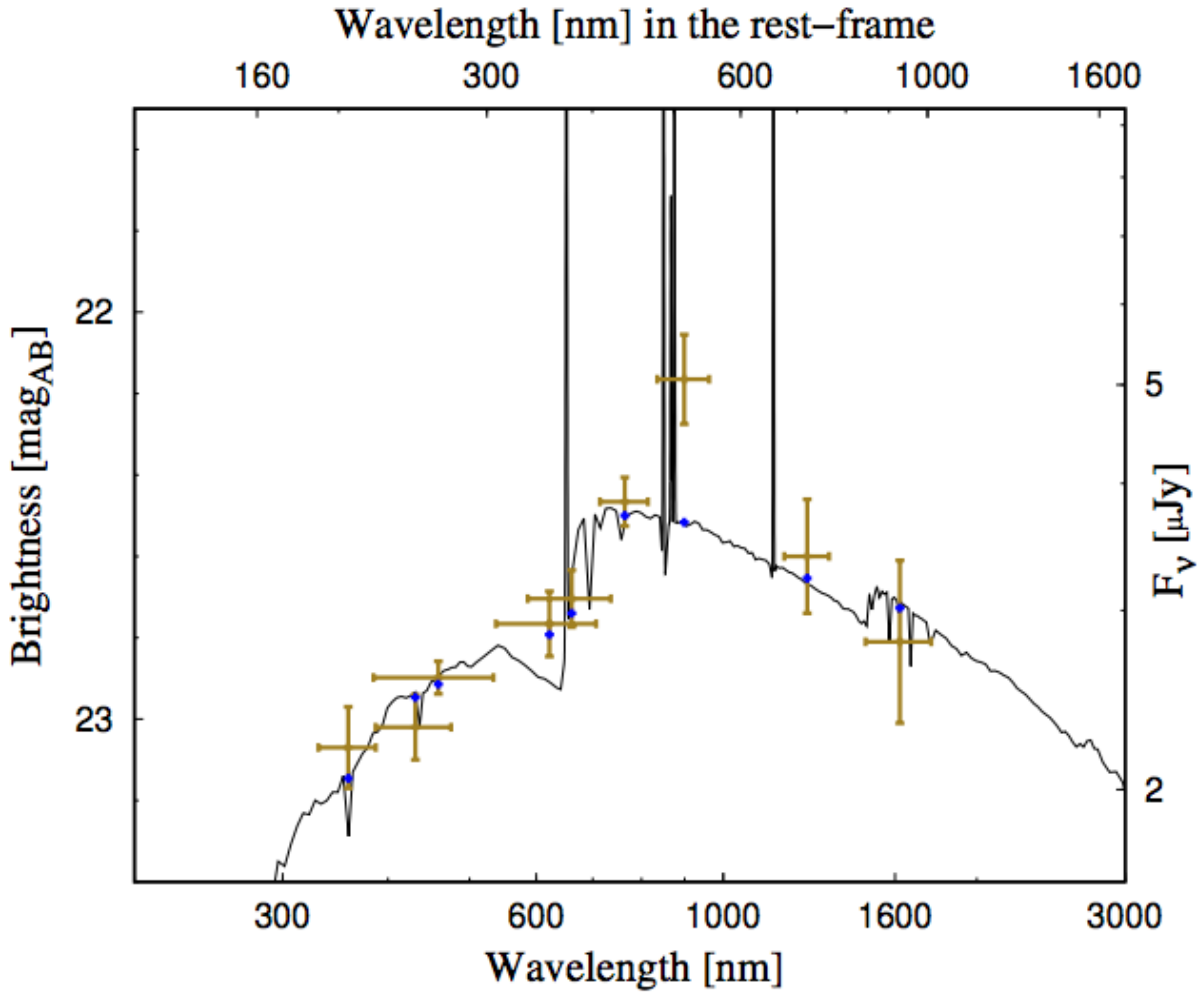
Comparison with SN templates

Modeling



Comparison with Kilonova+Magnetar templates

Modeling



Host Galaxy spectrum modeling

Conclusions

- GRB 200826A is a temporally short GRB at z = 0.748577 ± 0.000065 with a rest-frame duration of ~ 0.5 s, below the threshold of 2 s commonly used to separate SGRBs and LGRBs.
- To better understand the nature of this event, we initiated a follow-up campaign spanning a period of 1 year which involved the LBT telescope in Arizona (USA), the TNG telescope on La Palma (Canary Islands, Spain) and the Maidanak Astronomical Observatory (Uzbekistan).
- Taking advantage of the adaptive optics capabilities of LBT, we were able to obtain deep H-band observations between 37 and 159 d (observer frame), corresponding to the rest-frame z' band at 21 to 91 d after the burst trigger. Image subtraction shows a faint transient within its host galaxy.
- Moreover, image subtraction of archival Gemini i' band images with late reference observations obtained with the LBT revealed an optical transient which is less affected by over-subtraction than had been when reference images obtained at an earlier time after the GRB had been used. Finally, we were able to put strong upper limits on the UV rest-frame luminosity thanks to our LBT and TNG r' band observations.

Conclusions

- Despite its short duration, this event is consistent with the Ep,i – Eiso "Amati" relation followed by LGRBs. The spectral lag is also more typical of LGRBs.
- It was followed by a relatively faint optical and X-ray afterglow with a luminosity that lies in between those of LGRB and SGRB afterglows.
- The evolution and color of the late bump is in good agreement with other GRB-SNe, and especially with the fast rising GRB 130702A/SN 2013dx. GRB
- 200826A is one of the cosmologically most remote GRB-SNe detected to date, close to the sensitivity limit of the present generation of 8 to 10 m class optical telescopes.
- The possible alternative scenario of a genuine SGRB followed by a KN like AT2017gfo is not supported by the different evolution and luminosity of the light curve of the observed transient.
- The host galaxy of GRB 200826A is remarkable because it is typical of an LGRB host galaxy, but with higher SFR and sSFR rates than expected.
- The GRB lies at a projected distance of 0.75 kpc from the center of its host galaxy, which is consistent with the majority of LGRBs.

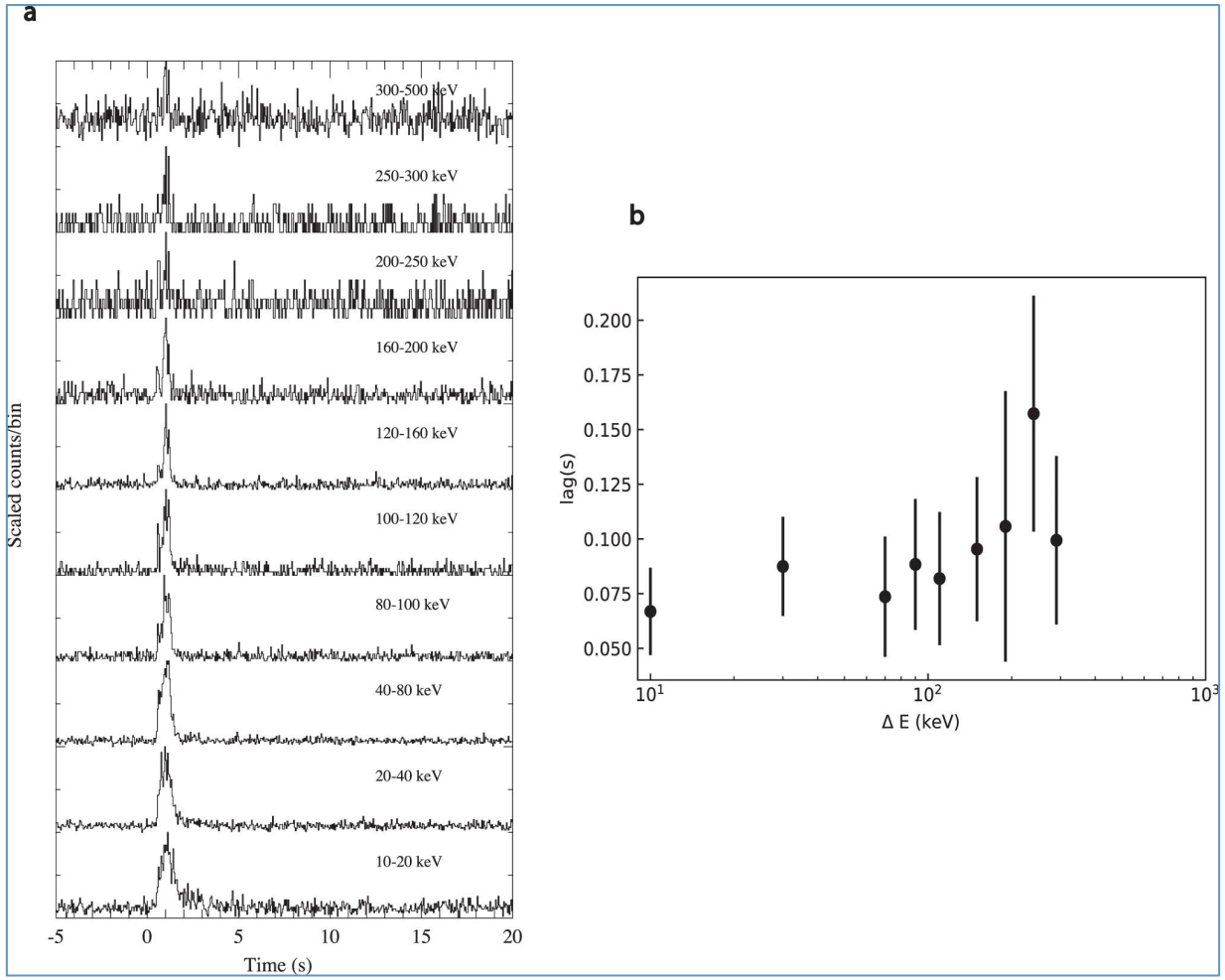
Conclusions

- We are faced with a GRB of short duration which exploded in a star-forming galaxy, with a moderately faint afterglow, emitted by a jet most likely propagating into a wind environment, and followed by a bump in the light curve whose color and luminosity are typical for a GRB-SN. Thus we firmly classify this burst as a collapsar event.
- This evidence, together with the analysis of the energetics of this burst, further weakens the effectiveness of simple duration as an indicator of the source of a GRB.
- In addition, strong support is provided to theoretical predictions that collapsar-produced events may have an observable duration well short of the classical short/long divide (about 2 s), and down to 0.5 s or less (e.g., Bromberg et al. 2013).

Conclusions

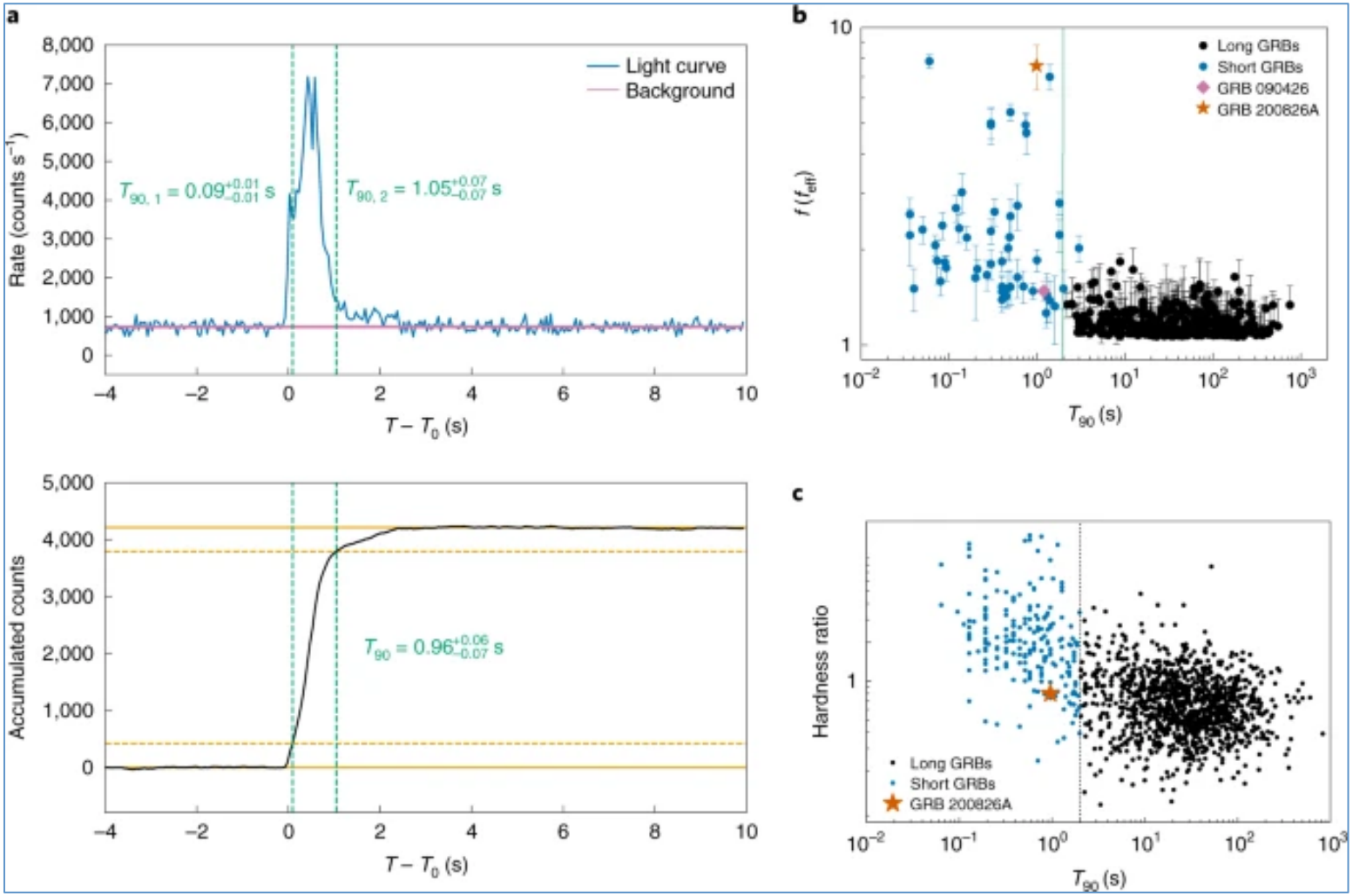
- In the next years future missions, like the Space Variable Objects Monitor (SVOM; Paul et al. 2011) and the Gamow Explorer (White et al. 2021) will offer a combination of extended sensitivity and energy bands that will increase the number of known GRBs. This, when coupled with the improved capabilities of the new generation of extremely large telescopes will allow us to observe both the GRB and SN components resulting from collapsar explosions in increasing numbers and at higher redshifts (e.g., Maiorano et al. 2018; Rossi et al. 2018).
- In this scenario, the first detection of a SN with AO observations represents what ground-based telescopes can achieve: they will not just offer a sharper view of the GRB-SN location within its host, but have the necessary depth to discover GRB-SNe at larger redshift than what has been possible up to now from the ground, and yet at similar wavelengths in rest-frame.
- Eventually, these future facilities will assess whether peculiar events like GRB 200826A are actually the result of the rich variety of the collapsar phenomenon (Amati 2021).

To continue …



Spectral lag analysis

To continue …



Temporal properties

To continue …

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A peculiarly short-duration gamma-ray burst from massive star core collapse

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