

GOTO identification and broad-band modelling of the counterpart to the SVOM GRB 250818B

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ABSTRACT

We present the discovery and multiwavelength follow-up of gamma-ray bursts (GRB) 250818B, detected by the *Space Variable Objects Monitor* (SVOM) and localized by the Gravitational-wave Optical Transient Observer. We compile X-ray, optical/near-infrared, and radio data into broad-band light curves and spectral energy distributions. Despite being initially reported as short, the public prompt light-curve figure suggests a duration of ~ 5 s, arguing against a secure short-duration classification. The afterglow is unusually bright relative to short-GRB samples: in X-rays and optical it is broadly consistent with the long-GRB population, while in the radio it is among the most luminous events in the short-GRB comparison sample and remains within the long-GRB range. MeerKAT detects the source at 3.1 GHz, while the Atacama Large Millimetre/submillimetre Array provides deep higher-frequency limits. Keck/LRIS spectroscopy shows continuum and metal absorption (Fe II, Mg II, Mg I), giving $z = 1.216$. Synchrotron forward-shock modelling favours a constant-density medium and refreshed (energy-injection) emission, well described by a two-component jet with core isotropic-equivalent kinetic energy $E_0 \sim 8 \times 10^{52}$ erg, ambient number density $n_0 \sim 12 \text{ cm}^{-3}$, jet half-opening angle $\theta_j \simeq 0.13 \text{ rad}$ ($\sim 7.4^\circ$), and electron index $p \simeq 1.67$. We do not identify a host conclusively: the data admit either a faint LS DR10 galaxy at $\sim 4 \text{ arcsec}$ ($\sim 34 \text{ kpc}$) as an offset candidate, or a fainter, near-coincident uncatalogued host. GRB 250818B highlights the power of rapid counterpart identification in the SVOM era, while uncertain prompt classification and inconclusive host association still limit progenitor interpretation.

Key words: (transients:) gamma-ray bursts – gamma-ray burst: individual: GRB 250818B.

1 INTRODUCTION

Gamma-ray bursts (GRBs) were discovered serendipitously in the late 1960s as brief flashes of high-energy photons on the sky (R. W. Klebesadel, I. B. Strong & R. A. Olson 1973). Subsequent observations have established GRBs as among the most luminous electromagnetic explosions in the Universe, with isotropic-equivalent γ -ray energy releases spanning $\sim 10^{51}$ – 10^{55} erg and durations

from milliseconds to minutes (e.g. T. Piran 2004; P. Kumar & B. Zhang 2015; F. Y. Wang, Z. G. Dai & E. W. Liang 2015; J.-L. Atteia et al. 2017; Z. Cao et al. 2023; B. O’Connor et al. 2023; A. Pe’er 2024). A key step in organizing this diversity was the recognition that the distribution of prompt-emission durations is bimodal, allowing GRBs to be divided into two broad classes, ‘short’ and ‘long’, typically separated at $T_{90} \simeq 2 \text{ s}^1$ (C. Kouveliotou et al.

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¹ T_{90} is the time interval containing 90 per cent of the prompt γ -ray fluence.

1993). Long-duration GRBs are most commonly associated with the core collapse of massive, stripped-envelope stars, as demonstrated by numerous cases with accompanying broad-lined Type Ic supernovae (e.g. T. J. Galama et al. 1998; J. Hjorth et al. 2003; S. E. Woosley & J. S. Bloom 2006; Z. Cano et al. 2017; A. Kumar et al. 2024), whereas short-duration GRBs are predominantly associated with compact-object mergers involving neutron stars and/or black holes (e.g. D. Eichler et al. 1989; R. Narayan, B. Paczynski & T. Piran 1992; M. Tanaka 2016), supported by the detection of kilonovae and, most dramatically, by the joint GW170817/GRB 170817A event (e.g. B. P. Abbott et al. 2017; A. Goldstein et al. 2017; E. Pian et al. 2017; V. Savchenko et al. 2017; N. R. Tanvir et al. 2017; E. Troja et al. 2017; S. Valenti et al. 2017; H. Wang et al. 2017). At the same time, recent discoveries have revealed events that blur this simple mapping between duration and progenitor: the short (rest-frame $T_{90} \sim 0.5$ s) GRB 200826A showed a collapsar-like supernova (B.-B. Zhang et al. 2021; A. Rossi et al. 2022), while long-duration bursts such as GRB 211211A (J. C. Rastinejad et al. 2022; E. Troja et al. 2022; J. Yang et al. 2022; B. P. Gompertz et al. 2023) and GRB 230307A (C.-Y. Dai et al. 2024; A. J. Levan et al. 2024; H. Sun et al. 2025) exhibit kilonova signatures indicative of compact-binary mergers. A further notable example is GRB 191019A, which has been interpreted as a merger produced by dynamical capture (A. J. Levan et al. 2023; G. Stratta et al. 2025), perhaps within the accretion disc of an active galactic nucleus (D. Lazzati et al. 2023). Taken together, these ‘hybrid’ cases demonstrate that T_{90} and spectral hardness alone are imperfect discriminants of progenitor type. Although additional prompt-emission diagnostics may help where sufficiently informative data are available (e.g. T. Q. Donaghy et al. 2006; R. Maccary et al. 2026), broad-band afterglow and host-galaxy information are often essential, particularly when prompt constraints are limited or inconclusive, for interpreting the diversity of the GRB population and placing individual events in their physical context.

Broad-band afterglow emission is commonly modelled as synchrotron radiation from a relativistic outflow decelerating in the circumburst medium, and encodes the kinetic energy, ambient density profile, microphysical parameters, and outflow geometry (e.g. R. Sari, T. Piran & R. Narayan 1998; J. Granot & R. Sari 2002; A. Panaitescu & P. Kumar 2002; D. Miceli & L. Nava 2022). Multiband light-curve and spectral energy distribution (SED) evolution can therefore test the simplest forward-shock scenario and reveal additional ingredients such as jet breaks and angular structure (e.g. J. E. Rhoads 1999; R. Sari & T. Piran 1999), refreshed shocks/energy injection (e.g. M. J. Rees & P. Mészáros 1998; B. Zhang & P. Mészáros 2002; J. A. Nousek et al. 2006), and reverse-shock or other extra components (e.g. S. Kobayashi 2000; B. Zhang, S. Kobayashi & P. Mészáros 2003). Host-galaxy context provides complementary constraints on the environment and potential progenitor channel through offsets and association statistics (e.g. J. S. Bloom, S. R. Kulkarni & S. G. Djorgovski 2002; W. Fong & E. Berger 2013; E. Berger 2014; P. K. Blanchard, E. Berger & W.-f. Fong 2016; K. E. Heintz et al. 2020; W.-f. Fong et al. 2022a; A. E. Nugent et al. 2024; C. Castrejon et al. 2025), but faint hosts near survey limits can complicate interpretation, particularly at $z \gtrsim 1$ where even moderate-luminosity galaxies begin to approach detectability limits in wide-field imaging. These considerations are especially relevant for events whose prompt-emission classification is uncertain or whose prompt constraints are incomplete, such that the afterglow and host environment

carry a disproportionate share of the interpretive weight (e.g. B. Zhang et al. 2009; O. Bromberg et al. 2012, 2013).

The detection and characterization of GRBs have been transformed by the advent of dedicated space-based observatories. The *Swift* mission detects ~ 90 GRBs per year (A. Lien et al. 2016) with the Burst Alert Telescope (BAT; S. D. Barthelmy et al. 2005) and provides rapid follow-up and arcsecond localizations of GRB afterglows with its narrow-field X-ray and UV/optical instruments, enabling systematic afterglow studies (S. D. Barthelmy et al. 2005; D. N. Burrows et al. 2005; P. W. A. Roming et al. 2005). Complementing this, the *Fermi* Gamma-ray Burst Monitor (GBM; C. Meegan et al. 2009; A. Kienlin et al. 2020) discovers ~ 250 GRBs per year but typically with degree-scale localization uncertainties (e.g. V. Connaughton et al. 2015; K. O. C. López et al. 2024), so bursts detected solely by GBM often rely on external facilities for afterglow identification and characterization (e.g. Y.-L. Mong et al. 2021; T. Ahumada et al. 2022; A. Kumar et al. 2025a). More recently, new missions such as the *Einstein Probe* (EP; W. Yuan et al. 2015) and the *Space Variable Objects Monitor* (SVOM; J. Wei et al. 2016; J.-L. Atteia, B. Cordier & J. Wei 2022), both launched in 2024, provide complementary coverage and low-latency triggering: *Einstein Probe* combines the Wide-field X-ray Telescope (0.5–4 keV) with the Follow-up X-ray Telescope (FXT; 0.5–10 keV), while *SVOM* detects GRBs with ECLAIRS (4–150 keV) and the Gamma-Ray Monitor (GRM; 15 keV–5 MeV), and refines afterglows with the Microchannel X-ray Telescope (0.2–10 keV) and the Visible Telescope (VT; 450–950 nm).

For GRBs discovered by wide-field γ -ray monitors, initial localizations can range from arcminutes (e.g. *SVOM*/ECLAIRS; typically $\lesssim 10$ arcmin, down to ~ 3 arcmin for bright events) to tens of degrees (e.g. *Fermi*/GBM; localization uncertainties can be ~ 10 – 15° ; (V. Connaughton et al. 2015)). In the degree-scale regime, these localizations are also affected by substantial systematic uncertainties, and although improved positions can be obtained with more advanced methods (e.g. J. M. Burgess et al. 2018; F. Berlato, J. Greiner & J. M. Burgess 2019; A. Goldstein et al. 2020; K. O. C. López et al. 2024), the localization region often remains large enough that efficient optical counterpart identification requires ground-based facilities capable of tiling tens to hundreds of square degrees on time-scales of minutes to a few hours. Wide-field, robotic optical surveys can fill this gap by rapidly covering the localization region and performing real-time transient discovery.

Rapid localization and follow-up of GRBs increasingly rely on low-latency triggers from new missions working in concert with wide-field robotic optical facilities. The Gravitational-wave Optical Transient Observer (GOTO; D. Steeghs et al. 2022; M. J. Dyer et al. 2024) has been designed as an array of wide-field optical telescopes with sites at Roque de los Muchachos Observatory on La Palma and at Siding Spring Observatory in Australia, together providing near-continuous coverage of both hemispheres and an instantaneous field of view (FoV) of $\gtrsim 80$ deg² per site (two mounts). GOTO’s fast-response scheduling and wide FoV allow it to begin tiling degree-scale *Fermi*/GBM localizations and arcminute-scale *SVOM*/ECLAIRS error regions within minutes of a trigger, offering a complementary discovery channel to narrow-field facilities and helping to mitigate localization-driven selection effects (e.g. L. P. Singer et al. 2015; D. Turpin et al. 2016). Previous campaigns have already demonstrated that GOTO can effectively search large *Fermi*/GBM error regions and identify GRB afterglows (e.g. Y.-L. Mong et al. 2021; S. Belkin et al. 2024;

A. Kumar et al. 2025a), illustrating its potential as a discovery engine for GRBs with large high-energy localizations and motivating its use in conjunction with *SVOM* triggers such as GRB 250818B.

GRB 250818B provides a timely case study in the *SVOM* era: rapid triggering enabled extensive multiwavelength follow-up. However, the prompt classification of the burst is not securely established from the publicly available data alone. In particular, while the discovery notice labels the event as ‘short’ (Z. Q. Wang et al. 2025), the public GRMlight-curve information is limited, and our interpretation is therefore driven primarily by the broad-band afterglow behaviour and the host-galaxy context. Keck/LRIS afterglow spectroscopy established an absorption redshift of $z = 1.216$ (W. Fong et al. 2025), enabling rest-frame modelling of the afterglow and conditional candidate-host properties.

At the same time, the host association is non-trivial: the nearest catalogued LS DR10 galaxy candidate is faint and offset by several arcseconds, while the imaging depth does not exclude a fainter, near-coincident host below the survey threshold. Because these scenarios imply very different physical offsets (and therefore limit the use of offset-based arguments), we place particular emphasis on constraints that arise directly from the broad-band afterglow data. Specifically, we use the multiband evolution to infer the circumburst environment and outflow dynamics, and to test whether a standard single-component forward-shock model is adequate or whether additional ingredients (e.g. energy injection and/or multiple components) are required. Where relevant, we comment on which inferences are insensitive to the uncertain physical offset and which depend on assumptions about the host association.

In this paper, we present the multiwavelength follow-up of GRB 250818B and the identification of its optical afterglow by GOTO, and we use the resulting data set to model the broad-band afterglow and assess the host-galaxy association. In Section 2, we describe the available observations across X-ray, optical/near-infrared (NIR), and radio bands, together with the afterglow spectroscopy used to establish the absorption redshift. In Section 3, we construct broad-band light curves and SEDs, perform afterglow modelling with *afterglowpy* (via *redback*, including tests for energy injection and/or additional components), and analyse the candidate host galaxy through association metrics (Bayesian and chance-coincidence statistics); we also construct a single-epoch optical afterglow SED to constrain line-of-sight extinction at $z = 1.216$. In Section 4, we discuss the implications for the burst energetics, environment, and progenitor interpretation, including the host-association ambiguity and its impact on offset-based arguments. Supplementary analysis of the LS DR10 candidate host, including photometry, conditional *Prospector* SED modelling, and COSMOS-Web comparison-sample constraints, is presented in the Appendix. Our conclusions are summarized in Section 5.

Throughout this paper, we assume a flat Λ CDM cosmology with $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$, and quote magnitudes in the AB system unless stated otherwise.

2 OBSERVATIONS

At 2025-08-18T03:29:09 UTC (hereafter T_0), *SVOM*/ECLAIR triggered on GRB 250818B and distributed via the General Coordinates Network (GCN) an on-board

localization with a 90 per cent confidence radius of $7.44'$ (Z. Q. Wang et al. 2025). The burst also triggered *SVOM*/GRM at T_0 with a 1 s integration time-scale (Z. Q. Wang et al. 2025). The discovery circular title labels the event as ‘short’, but publicly available prompt-emission data products sufficient for a standard duration analysis were not available to us. To assess what can be inferred from the material in the circular alone, we digitized the published *SVOM*/GRMlight-curve figure linked there and performed an approximate image-based cumulative-count analysis. The two highest-contrast detectors yield consistent T_{90} -like durations of order $\sim 5 \text{ s}$, with plausible values spanning roughly 5.0–5.5 s depending on the adopted background treatment and source-window definition. We emphasize that this is not a formal instrument-level T_{90} measurement, but it indicates that the published prompt light curve does not support an unambiguous classical short-duration ($< 2 \text{ s}$) event. We therefore treat the prompt classification of GRB 250818B as uncertain throughout this work.

We inspected the publicly available *Fermi*/GBM time-tagged event (TTE) data around T_0 and found that the spacecraft appears to have been traversing the South Atlantic Anomaly at that time; accordingly, no on-board or ground trigger was reported.² A targeted search of the available TTE data also showed no significant excess. We therefore do not report prompt-emission parameters from *Fermi*/GBM for this event, and no useful high-energy constraints from *Fermi*/LAT are available from public burst products.³

Wide-field optical imaging reported a fading counterpart within the *SVOM* localization region, providing a precise position and enabling rapid coordination of follow-up (Section 2.2; A. Kumar et al. 2025c). Subsequent *Swift*/XRT observations detected an uncatalogued X-ray source consistent with the *SVOM* localization and coincident with the optical counterpart position (M. Ferro et al. 2025). The *SVOM* VT also reported the same optical transient at a consistent position, and the *Einstein Probe* Follow-up X-ray Telescope (FXT) detected an X-ray source consistent with the counterpart (R.-Z. Li et al. 2025). These detections established the broad-band afterglow and triggered an extensive multiwavelength campaign from optical to radio. In the following subsections, we describe the high-energy, X-ray, optical/NIR, and radio data sets in more detail and outline the processing steps used to construct the broad-band light curves and spectra employed in our analysis.

2.1 X-rays

The *Swift* X-Ray Telescope (XRT; 0.3–10 keV; D. N. Burrows et al. 2005) began follow-up observations of GRB 250818B at $T_0 + 1.7 \text{ ks}$ after the *SVOM* trigger. We use the XRT data to perform a time-resolved spectral analysis of the afterglow. Using the UK Swift Science Data Centre SWIFTTOOLS API (P. A. Evans et al. 2009)⁴, we downloaded and binned the data into bins with a signal-to-noise ratio (SNR) threshold of 10, which we adopt for spectral extraction and fitting in Section 3.2.

²GBM burst data products are publicly available via HEASARC: <https://heasarc.gsfc.nasa.gov/FTP/fermi/data/gbm/bursts/>.

³LAT burst data products are publicly available via Fermi/SSC: <https://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/LATDataQuery.cgi>.

⁴<https://www.swift.ac.uk/API/>

2.2 Optical and NIR

GOTO responded to the *SVOM* alert and began observations of the *SVOM*/ECLAIRs localization at $T_0 + 0.54$ h, obtaining a sequence of 4×90 s exposures in the wide L band (400–700 nm) between $T_0 + 0.54$ and $T_0 + 1.67$ h. Images were processed with the standard GOTO pipeline (J. D. Lyman et al. 2026), including difference imaging against deeper templates and automated candidate filtering, followed by human vetting. These observations revealed a fading optical source, GOTO25fzq/AT 2025ukm (A. Kumar et al. 2025b), within the ECLAIRs90 per cent localization region at R.A. = $03^{\text{h}}04^{\text{m}}13^{\text{s}}.52$, Dec. = $-03^{\circ}07'30''.82$ (J2000), with $L = 18.71 \pm 0.14$ mag at $T_0 + 0.54$ h and $L = 19.49 \pm 0.18$ mag (AB) at $T_0 + 1.67$ h. No source was detected at this position in pre-trigger GOTO images obtained 9.23 h before the burst, down to a 3σ limit of $L > 20.3$ mag, supporting the association with GRB 250818B (A. Kumar et al. 2025c).

The optical counterpart was subsequently detected by *SVOM*/VT in the VT_B band at $T_0 + 198.5$ and $T_0 + 3963.5$ s (Z. H. Yao et al. 2025), by *Swift*/UVOT in the u band (M. H. Siegel & *Swift*/UVOT Team 2025), and by numerous ground-based facilities including KAIT (W. Zheng et al. 2025), NOT (J. Broe Bendtsen et al. 2025), SAO RAS (A. Moskvitin et al. 2025), TRT (J. An et al. 2025), Lesedi (A. Kumar et al. 2025d), LT (Dimple, B. P. Gompertz & A. Kumar 2025b), the GRANDMA/Kilonova-Catcher network (R. Hellot et al. 2025), and the Wendelstein FTW telescope (M. Busmann et al. 2025), providing multiepoch photometry from minutes to several days after the burst.

The full optical/NIR data set compiled in this work is given in Table A1. Where necessary, we converted literature photometry to the AB system using the offsets in Table A2 and corrected for Galactic extinction using the coefficients in Table A3. For completeness, we also list the catalogue photometry of the LS DR10 candidate host galaxy in Appendix Table B1.

2.3 Radio and millimetre/submillimetre

We observed GRB 250818B with the MeerKAT radio telescope (in the Karoo desert, South Africa) through Director’s Discretionary Time (DDT-20250822-GS-01 PI Schroeder) at mean frequencies of 1.3 GHz (0.856 GHz bandwidth) and 3.1 GHz (0.875 GHz bandwidth) for four epochs in each band, spanning mid-times of 5.0–32.1 d. J0323 + 0534 was used as a complex gain calibrator, and J0408-6545 was used as a flux calibrator for all observations and bands. We downloaded the SARAO Science Data Processor pipeline images for all observations and used the `pwkit/imtool` program (P. K. G. Williams et al. 2017) to measure the flux density and image RMS at the GOTO position. The radio afterglow of GRB 250818B is detected in the first 3.1 GHz observations, as reported in G. Schroeder et al. (2025d), and rises and fades over the course of the observations. The radio afterglow is only detected in the 1.3 GHz epoch at ~ 15 d.

We observed GRB 250818B with the Atacama Large Millimetre/Submillimetre Array (ALMA; Program 2024.1.01131.T, PI: W. Fong) in standard continuum mode with 4 GHz bandwidth at a mean frequency of 97.5 GHz for two epochs at mid-times of 10.14 and 17.19 d, respectively. Both observations utilized J0312 + 0133 as a complex gain calibrator and J0327+0044 as a check source, while J0238 + 1636 and J0423 – 0120 were employed as the bandpass and flux density calibrators for the first and second epochs, respectively. We downloaded the final image products

from the ALMA science archive. In the Quality Assurance Level 2 (QA2) images, no significant emission is seen in a 0.5 (arcsec) circle at the GOTO position. The image root-mean-square (rms) at the expected position of the target in the observations is 13.2 and 10.7 μJy , respectively.

The 36.8 GHz observations were carried out with the 22-m RT-22 radio telescope located in Simeiz (Crimea). The antenna has a half-power beam width of ~ 100 arcsec. Observations were performed in a beam-switching mode: the telescope was alternately pointed at the source with each of the two beam lobes produced by diagram modulation and having mutually orthogonal polarizations.

The antenna temperature of the source was determined from the difference between the radiometer outputs, each averaged over 30 s at the two antenna positions. For each epoch, we obtained a series of 200–250 such measurements, from which we computed the mean signal and its rms error. The measured antenna temperatures, corrected for atmospheric attenuation, were converted to flux densities by comparison with observations of standard calibration sources (A. Volvach, L. Volvach & M. Laktionov 2025). The resulting 36.8 GHz flux densities are listed in Table A4 and plotted in Fig. 2.

In addition, we include the 10 GHz flux density reported in GCN 41 455 (R. Ricci et al. 2025b). As no uncertainty was provided, the point is shown as indicative in Fig. 2; for modelling, we assign an assumed uncertainty to prevent the fit from being dominated by this measurement.

2.4 Spectroscopy

We obtained optical spectroscopy of the GRB 250818B afterglow with the Low-Resolution Imaging Spectrograph (LRIS; J. B. Oke et al. 1995) mounted on the Keck I telescope (PI: C. Liu; Program O397). The observations comprised three 300 s exposures using the 400/3400 grism on the blue arm and the 400/8500 grating on the red arm, starting at 2025 August 18 14:10 UT (≈ 10.7 h post-burst), under clear conditions with ~ 0.9 arcsec seeing at airmass ~ 1.2 . The combined spectrum covers $\approx 3500 - 9500$ Å in the observer frame (Fig. 1).

We reduce and co-add the data using the Python Spectroscopic Data Reduction Pipeline (`PyPeIt`⁵; J. Prochaska et al. 2020; J. X. Prochaska et al. 2020). `PyPeIt` performs bias-subtraction, flat-fielding, cosmic ray masking, and wavelength calibrations on the individual frames. We perform 1D extraction and then co-add the spectrum. We then perform flux calibration and telluric correction, and corrected for foreground Milky Way extinction along the line of sight to the GRB, adopting $E(B - V)_{\text{MW}} = 0.0633$ mag from the Schlafly & Finkbeiner recalibration of the Schlegel et al. dust map (D. J. Schlegel et al. 1998; E. F. Schlafly & D. P. Finkbeiner 2011), and an $R_V = 3.1$ Milky Way extinction law (E. L. Fitzpatrick & D. Massa 2007). The continuum is detected across most of the wavelength range and exhibits several prominent metal absorption features.

We determine the redshift by identifying a consistent set of metal absorption lines, including Fe II $\lambda\lambda 2344, 2374, 2382$, the Mg II doublet $\lambda\lambda 2796, 2803$, and Mg I $\lambda 2852$. We refine the redshift by maximizing the alignment of these transitions with absorption troughs in the spectrum, yielding $z = 1.216$. We adopt this value as the redshift of GRB 250818B throughout the paper.

⁵<https://pypeit.readthedocs.io/en/latest/>

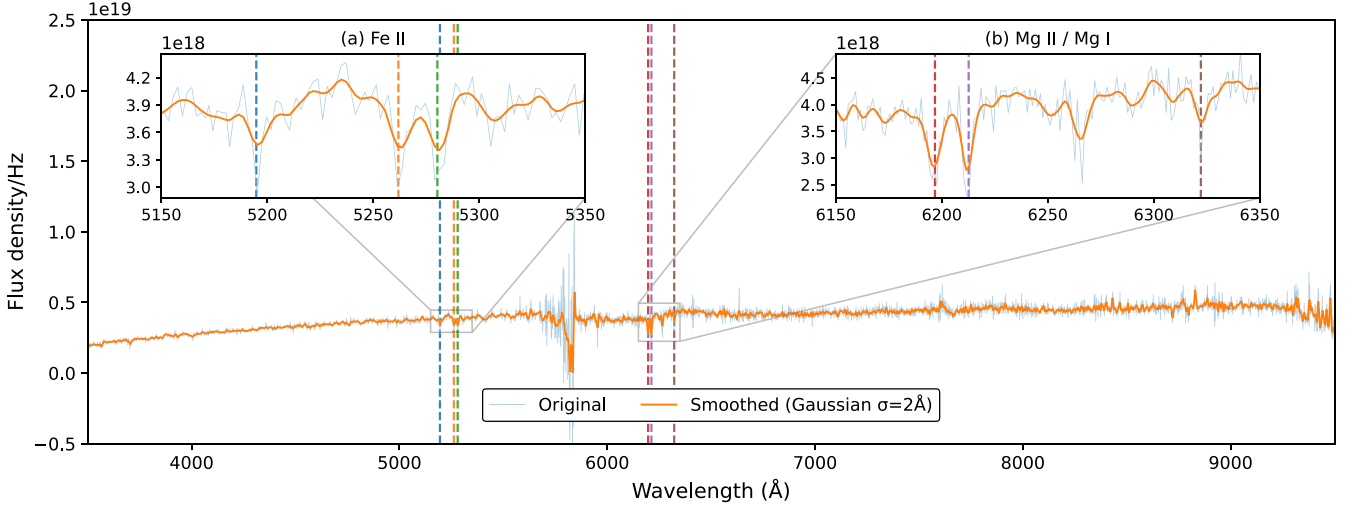


Figure 1. Keck I/LRIS flux-calibrated, Galactic-extinction-corrected spectrum of the optical afterglow of GRB 250818B obtained at ≈ 10.7 h post-burst; wavelengths are shown in the observer frame. The original spectrum is shown together with a Gaussian-smoothed version ($\sigma = 2 \text{ \AA}$) for display purposes. Vertical dashed lines mark the expected observed-frame wavelengths of the Fe II $\lambda\lambda 2344, 2374, 2382$, Mg II $\lambda\lambda 2796, 2803$, and Mg I $\lambda 2852$ absorption transitions at the best-fitting redshift $z = 1.216$. Insets highlight the Fe II and Mg II/Mg I regions used to refine the redshift estimate.

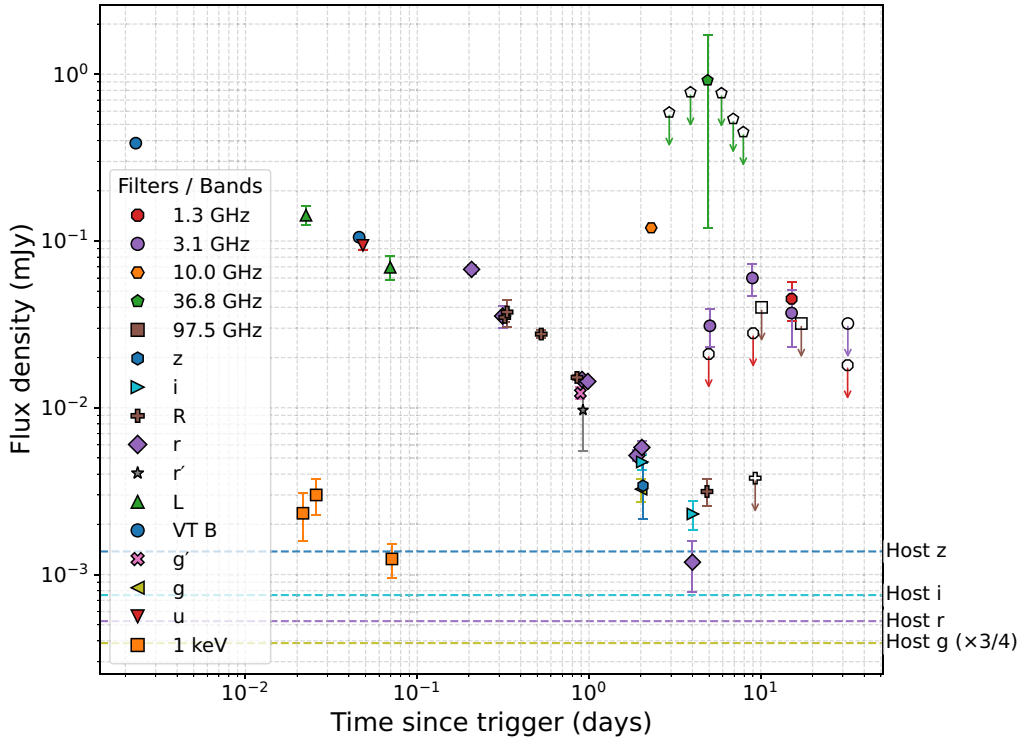


Figure 2. Multiwavelength light curve of GRB 250818B, showing X-ray, optical/NIR, and radio flux densities as a function of time since the SVOM/ECLAIR trigger. Optical points are corrected for Galactic extinction and converted to AB flux densities. Triangles with arrows indicate 3σ upper limits. The host-galaxy fluxes shown in g, r, i , and z correspond to the LS DR10 candidate host galaxy (Tractor obj id 5790) discussed in Section 3.4.1. For visual clarity, the plotted g -band host level is vertically offset by a factor of 3/4 to avoid overlap with the r -band host level; all analysis uses the unscaled host flux.

3 ANALYSIS AND RESULTS

3.1 Broad-band light-curve construction

For our analysis, we compiled all publicly available photometric measurements reported in GCN circulars and in our own follow-up before constructing the optical/NIR light curves. All optical

and NIR measurements were homogenized onto the AB magnitude system (J. B. Oke & J. E. Gunn 1983). For data reported in the Vega system, we applied fixed offsets of the form $m_{\text{AB}} = m_{\text{Vega}} + \Delta m$ appropriate for each filter. For Johnson–Cousins $UBVRi$ and NIR JHK_s filters, as well as Sloan-like $griz$, we adopted the standard Vega-to-AB offsets from M. R. Blanton & S. Roweis (2007).

For the *Swift*/UVOT *u*, *b*, and *v* bands we used the AB–Vega corrections from the UVOT photometric calibration (e.g. T. S. Poole et al. 2008; A. A. Breeveld et al. 2011). The values of Δm used in this work are listed in Table A2. Measurements already reported in AB magnitudes were left unchanged.

We corrected all photometry for Milky Way extinction using a single colour excess $E(B - V)_{\text{MW}} = 0.0633$ mag along the GRB sightline (consistent with Section 2.4), adopting the Schlafly & Finkbeiner recalibration of the Schlegel et al. dust map (D. J. Schlegel et al. 1998; E. F. Schlafly & D. P. Finkbeiner 2011). We assumed a standard $R_V = 3.1$ Milky Way extinction curve. For Sloan-like *ugriz* filters we used the tabulated coefficients $A_\lambda/E(B - V)$ from E. F. Schlafly & D. P. Finkbeiner (2011); for Johnson–Cousins *UBVRI* and NIR bands we used coefficients appropriate for an $R_V = 3.1$ Milky Way law (e.g. E. L. Fitzpatrick 1999). For the *Swift*/UVOT filters we employed the passband-integrated $A_\lambda/E(B - V)$ values from F. Yi et al. (2023), rescaled to be consistent with our adopted $E(B - V)$. For non-standard filters, we adopted approximate coefficients: for the GOTO *L* band, we used $A_L \simeq 0.997 A_V$, and for the *SVOM*/VT_B band we set $A_{V_{TB}}$ to the average of the SDSS *g* and *r* coefficients. The resulting A_λ values for the filters used in this work are given in Table A3.

After correcting for Galactic extinction, we converted all magnitudes to monochromatic flux densities F_ν following the definition of the AB system (J. B. Oke & J. E. Gunn 1983), adopting a zero-point $F_{\nu,0} = 3631$ Jy. For non-detections, we converted the limiting magnitudes to 3σ upper limits on F_ν . The resulting extinction-corrected optical/NIR flux densities, together with the *Swift*/XRT and radio measurements (Sections 2.1 and 2.3), are shown in Fig. 2 and form the basis for the afterglow analysis in the following subsections.

3.2 X-ray spectral analysis

Using the $S/N = 10$ binning, we identified three time intervals from which we extracted and simultaneously fit spectra. We fit the *Swift*/XRT spectra with a power-law model using PYXSPEC version 2.1.4 (XSPEC version 12.15.0), adopting the Cash statistic (W. Cash 1979) and Wilms solar abundances (J. Wilms, A. Allen & R. McCray 2000). We modelled absorption by the neutral hydrogen column along the line of sight using components of the form TBABS*ZTBABS*CFLUX*POWERLAW. TBABS accounts for the neutral hydrogen in the Milky Way, fixed to $N_{\text{H,Gal}} = 6.49 \times 10^{20} \text{ cm}^{-2}$ (R. Willingale et al. 2013), ZTBABS parametrizes the absorption contribution from the burst rest frame ($N_{\text{H,Intr}}$) with redshift fixed to the spectroscopic value of 1.216, and CFLUX calculates the flux of the model components. Two sets of fits were performed: one calculating the unabsorbed flux (with the model form above), and another calculating the absorbed flux (CFLUX*TBABS*ZTBABS*POWERLAW). $N_{\text{H,Intr}}$ was tied between spectra, as it is not expected to evolve with time, while the photon index Γ was left free to vary between spectra, as was the flux (calculated between 0.3 and 10 keV). Cash statistics are appropriate for these low-count Poisson data. Because CSTAT/DoF is not a statistically robust goodness-of-fit measure in this regime, we do not interpret its absolute value as a reduced- χ^2 -like diagnostic. The absorbed power-law model leaves no obvious systematic residuals, and given the limited photon statistics, we therefore do not explore more complex spectral models. The time intervals for the extracted spectra and the evolution of Γ are shown in Fig. 3. We also repeated the time-resolved spectral fitting using finer $S/N = 5$ bins. The resulting photon indices were consistent, within

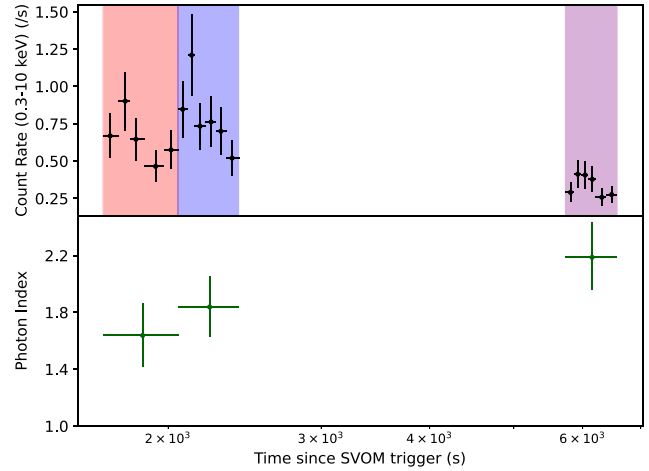


Figure 3. Top: XRT count rate light curve of the three flaring episodes, where the highlighted sections indicate the three $S/N = 10$ spectral bins. The late-time XRT data at ~ 3.35 d does not meet the S/N threshold and so is not included in the spectral analysis. Bottom: evolution of the best-fitting photon index with time.

uncertainties, with those obtained from the $S/N = 10$ analysis and did not reveal any additional spectral evolution; the smaller bins simply carried larger statistical uncertainties.

3.3 Afterglow

3.3.1 X-ray afterglow brightness in context

To place the early-time X-ray behaviour of GRB 250818B in context, we compared its *Swift*/XRT 0.3–10 keV afterglow to the population of *Swift*-detected events using UKSSDC XRT light curves (Fig. 4). Short-duration and long-duration bursts are shown in darker and lighter grey, respectively, using a T_{90} -based duration classification from the *Swift*/BATGRB summary catalogue. Bursts whose $BAT T_{90} \pm \sigma$ interval straddles 2 s are flagged as ‘borderline’ between the two classes and plotted in an intermediate grey shade; they are not included when computing the short-GRB medians quoted below. In this comparison, GRB 250818B lies on the bright end of the *Swift* short-duration sample at early times, while remaining much closer to the median of the long-duration population. At the three epochs corresponding to our $S/N = 10$ XRT spectral bins (1869, 2232, and 6153 s; Table A5), its unabsorbed 0.3–10 keV flux is ~ 12.7 , ~ 17.1 , and ~ 9.5 times higher than the median of the *Swift* short-duration sample with coverage at these times ($N_{\text{short}} = 46, 47$, and 35, respectively). For completeness, the corresponding XRT spectral results obtained using a lower $S/N = 5$ binning threshold are provided in Table A6; the $S/N = 10$ binning is used for the population comparison quoted here. Relative to the *Swift* long-duration sample, the same epochs correspond to only ~ 2.1 , ~ 2.9 , and ~ 2.5 times the long-GRB median ($N_{\text{long}} = 994, 994$, and 1041). While this comparison is made in the observer frame and does not account for redshift or sample heterogeneity, it supports the qualitative impression that the early afterglow of GRB 250818B is unusually X-ray bright relative to typical *Swift* short-duration GRBs, but comparatively typical within the long-duration population.

A qualitatively similar conclusion is obtained in rest-frame X-ray luminosity space. Using the unabsorbed *Swift*/XRT 0.3–10 keV fluxes from our $S/N = 10$ spectral analysis, we ob-

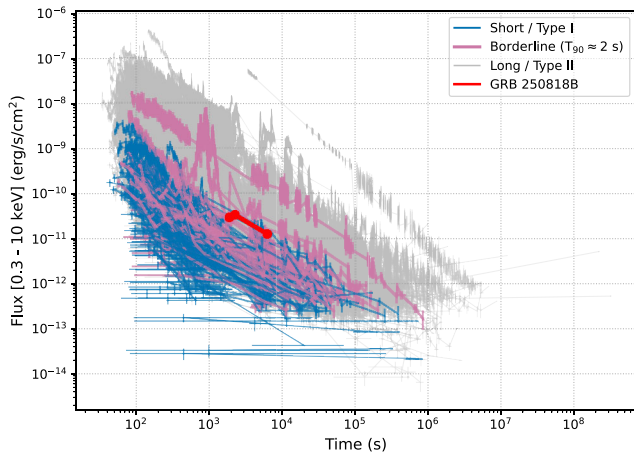


Figure 4. *Swift*/XRTobserver-frame 0.3–10 keV afterglow comparison for GRB 250818B. Light-grey curves show 0.3–10 keV XRT light curves of *Swift*-detected GRBs downloaded from the UKSSDC repository and classified as long-duration (Type II) using a *Swift*/BAT T_{90} -based duration classification from the *Swift*/BATGRB summary catalogue (excluding events with unidentified T_{90}). Short-duration (Type I) bursts are highlighted in blue, while bursts whose BAT $T_{90} \pm \sigma$ interval straddles 2 s (‘borderline’ between short and long) are plotted in purple; these comparison subsets are also identified in the figure legend. Red points show the unabsorbed 0.3–10 keV fluxes of GRB 250818B from our XRT spectral analysis with SNR = 10 binning (Table A5); the red line connects the measurements to guide the eye. Times are measured relative to the prompt trigger in the observer frame (BAT trigger for the *Swift* comparison sample; *SVOM*/ECLAIRs T_0 for GRB 250818B).

tain $\log L_X \approx 47.27$, 47.39, and 47.09 erg s $^{-1}$ at rest-frame times $\log(t_{\text{rest}}/\text{s}) \approx 2.93$, 3.00, and 3.44, respectively. A visual comparison with the short- and long-GRB luminosity distributions compiled by A. Rouco Escorial et al. (2021) suggests that GRB 250818B lies well within the observed long-GRB locus at these early rest-frame times, while remaining brighter than most of the short-GRB population.

The relatively bright early-time X-ray afterglow of GRB 250818B could reflect a combination of higher-than-average afterglow energetics, and/or a favourable viewing geometry (e.g. a more on-axis sightline or a narrow/structured jet component; e.g. R. Sari et al. 1998; J. Granot & R. Sari 2002; A. Panaitescu & P. Kumar 2002). In the standard forward-shock synchrotron framework, if the X-ray band lies above the cooling break ($\nu_X > \nu_c$; as suggested by the optical–X-ray spectral slopes), the X-ray flux depends only weakly on the external density, while density variations primarily affect the location and evolution of ν_c and hence the optical/radio behaviour (e.g. R. Sari et al. 1998; J. Granot & R. Sari 2002). If instead ν_c lies above the X-ray band ($\nu_c > \nu_X$), the X-ray flux would have a stronger dependence on the circumburst environment and the expected spectral/temporal indices would differ, but this appears less consistent with the observed broad-band slopes. A contribution from early-time energy injection is also plausible (e.g. M. J. Rees & P. Mészáros 1998; B. Zhang & P. Mészáros 2002; J. A. Nousek et al. 2006); however, the X-ray comparison is not diagnostic, and distinguishing between these possibilities requires dedicated broad-band modelling (and, where possible, rest-frame comparisons).

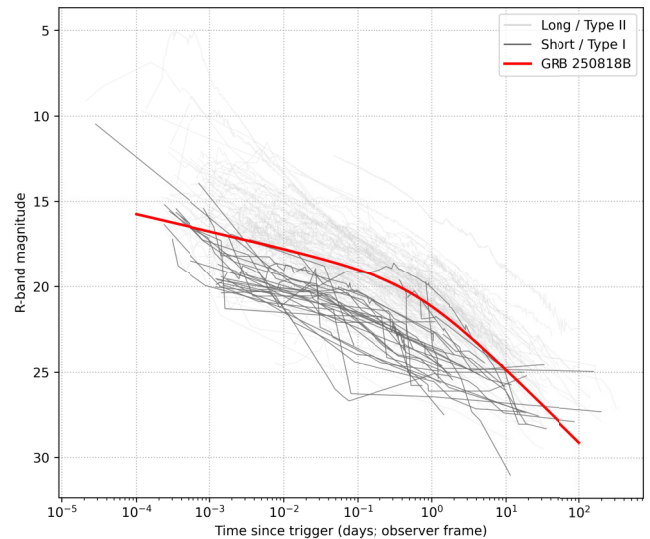


Figure 5. Observer-frame R -band afterglow comparison for GRB 250818B. Grey curves show literature R -band afterglow light curves compiled from D. A. Kann et al. (2006); D. A. Kann et al. (2010, 2011); A. Nicuesa Guelbenzu et al. (2012). The short/Type I subset (as classified in D. A. Kann et al. 2011) is highlighted in darker grey, while long/Type II events are shown in light grey. The red curve shows the R -band model of GRB 250818B derived from our simultaneous multiband SBPL fit. All magnitudes are corrected for Galactic extinction.

3.3.2 Optical afterglow brightness in context

To place the optical afterglow of GRB 250818B in the broader GRB population, we compare its observer-frame R -band evolution with the literature compilation of D. A. Kann, S. Klose & A. Zeh (2006); D. A. Kann et al. (2010, 2011) and the sGRB sample of A. Nicuesa Guelbenzu et al. (2012). For the D. A. Kann et al. (2011) comparison sample, we adopt the Type I/Type II classifications reported therein (a progenitor-motivated scheme that is not strictly equivalent to a T_{90} -based short/long division). Given the limited number of direct R -band measurements for GRB 250818B, we show the R -band projection of our simultaneous multiband SBPL fit (Fig. 5). All magnitudes are corrected for Galactic extinction.

At the epochs corresponding to our R -band observations (0.32, 0.33, 0.53, and 0.85 d), we interpolate the comparison light curves in $\log t$ -magnitude space, using only events with data bracketing each epoch (yielding $N_{\text{all}} \simeq 136 - 142$, $N_{\text{short}} \simeq 29 - 31$, and $N_{\text{long}} \simeq 105 - 113$). The full sample spans $R \approx 14.2 - 26.7$ mag with medians of $R \approx 20.4 - 21.3$ mag, while the short/Type I subset has fainter medians of $R \approx 22.6 - 23.9$ mag. GRB 250818B has $R \approx 19.9 - 20.9$ mag at these times, placing it only $\sim 0.3 - 0.6$ mag brighter than the median of the overall population, but $\sim 2.7 - 3.0$ mag brighter than the median of the short/Type I subset. For reference, relative to the long/Type II subset alone, GRB 250818B is within $\lesssim 0.2$ mag of the median at these epochs. Thus, in this comparison, GRB 250818B is significantly brighter than the median short/Type I afterglow at $\sim 0.3 - 0.9$ d, but remains close to the median of the long/Type II population in the same band.

3.3.3 Optical SED and line-of-sight extinction

To constrain the line-of-sight extinction at the absorption redshift $z = 1.216$, we constructed a single-epoch optical SED at $t_{\text{ref}} =$

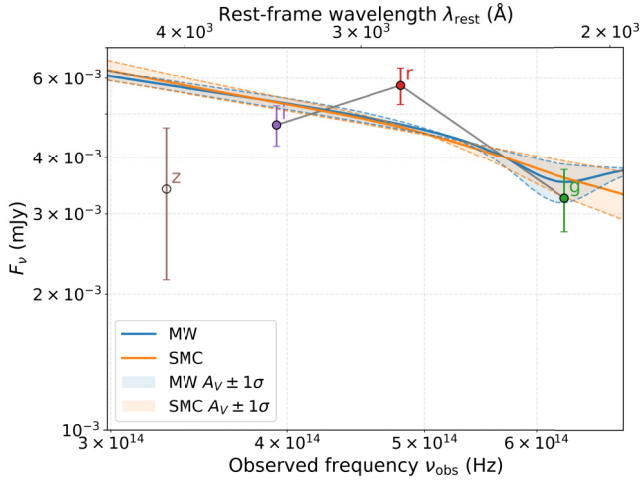


Figure 6. Optical SED of GRB 250818B at $t \simeq 2.0$ d, without subtraction of the offset LS DR10 host-galaxy candidate. Filled points show the Galactic-extinction-corrected *gri* flux densities; the open *z* point is shown for comparison but excluded from the fit. Solid curves show the best-fitting dust-attenuated power-law models for a Milky Way extinction law (F99; $R_V = 3.1$) and an SMC Bar law (G03; $R_V = 2.74$) at $z = 1.216$. Dashed curves and shaded bands illustrate the effect of varying the fitted A_V by $\pm 1\sigma$ (with the power-law normalization and slope refit at fixed A_V). The two laws are nearly indistinguishable across the observed optical bands, and the line-of-sight extinction at $z = 1.216$ is weakly constrained ($A_V \sim 0.2$).

2.035 d after the trigger using nearly contemporaneous LT *gri* photometry. We do not subtract the LS DR10 host-galaxy candidate flux here, because that source is offset from the afterglow position and does not contribute to the LT photometry used for the SED fit. Throughout this subsection, we adopt the standard convention $F_\nu \propto \nu^{-\beta}$ for the flux-density spectral index β . For reference, the X-ray photon index Γ (defined by the photon spectrum $N_E \equiv dN/dE \propto E^{-\Gamma}$) corresponds to $\beta_X = \Gamma_X - 1$.

All measurements were corrected for Galactic foreground extinction (E. F. Schlafly & D. P. Finkbeiner 2011). The resulting Galactic-extinction-corrected flux densities are shown in Fig. 6 as a function of observed frequency (bottom axis; the top axis gives the corresponding rest-frame wavelength at $z = 1.216$). The *z*-band point is plotted for reference but excluded from the fit because its uncertainty is dominated by low S/N systematics.

We model the SED as a power law modified by dust extinction at the absorber redshift,

$$F_\nu(\nu_{\text{obs}}) = C \left(\frac{\nu_{\text{obs}}}{\nu_0} \right)^{-\beta} 10^{-0.4 A_V k(\lambda_{\text{rest}})}, \quad (1)$$

where C is a normalization at reference frequency ν_0 , β is the intrinsic optical spectral index, A_V is the rest-frame *V*-band extinction at $z = 1.216$, and $k(\lambda_{\text{rest}}) \equiv A_\lambda/A_V$ is the extinction curve evaluated at $\lambda_{\text{rest}} = c/[\nu_{\text{obs}}(1+z)]$. We consider a Milky Way law (E. L. Fitzpatrick 1999, F99) with fixed $R_V = 3.1$ and an SMC Bar law (K. D. Gordon et al. 2003, G03) with $R_V = 2.74$, as implemented in `dust_extinction` (K. Gordon 2024). We do not consider the M14/LMC family further because it is undefined below $\lambda_{\text{rest}} \sim 3000$ Å, whereas at $z = 1.216$ the observed *g* and *r* bands probe $\lambda_{\text{rest}} \lesssim 3000$ Å.

To reduce the strong β - A_V degeneracy inherent to three-band photometry, we incorporate an X-ray-informed prior on β . Our time-resolved *Swift*/XRT spectroscopy yields photon in-

dices $\Gamma_X \simeq 1.6$ – 2.2 , with a weighted mean $\langle \Gamma_X \rangle \approx 1.9$, i.e. $\beta_X \approx 0.9$ (Section 2.1). In the slow-cooling synchrotron model, the spectrum steepens by $\Delta\beta = 0.5$ across the cooling break, so a physically plausible configuration is $\nu_{\text{opt}} < \nu_c < \nu_X$, which would imply $\beta_{\text{opt}} \approx \beta_X - 0.5 \simeq 0.4$. We therefore adopt a broad Gaussian prior $\beta \sim \mathcal{N}(0.40, 0.30)$, which also allows the possibility that optical and X-rays lie on the same spectral segment. We fit equation (1) in flux space using χ^2 minimization (`scipy.optimize.least_squares`; P. Virtanen et al. 2020), with the prior implemented as an additional term in the residual vector. The XRT flux itself is not used in the optical extinction fit.

Fitting the *gri* SED without host-candidate subtraction yields consistent results for both extinction laws (Fig. 6). For the MW law we obtain $A_V = 0.217 \pm 0.159$ mag and $\beta_{\text{opt}} = 0.245 \pm 0.294$ ($\chi^2/\text{dof} \approx 5.58/1$); for the SMC law we find $A_V = 0.201 \pm 0.171$ mag and $\beta_{\text{opt}} = 0.279 \pm 0.297$ ($\chi^2/\text{dof} \approx 6.21/1$). Given that the fit is constrained by only three photometric points (one degree of freedom), these numerical values should be regarded as indicative rather than definitive. The relatively large χ^2 values and the sparse three-point SED emphasize that A_V is only weakly constrained (Fig. 6). None the less, both laws point to low-to-moderate extinction and remain compatible with $A_V \approx 0$ within $\sim 1\sigma$. Accordingly, we do not apply any additional correction for rest-frame line-of-sight extinction in the broad-band light-curve analysis, and use only Galactic-extinction-corrected photometry throughout.

We also investigated joint optical + X-ray SED fits at the same epoch imposing $\beta_X = \beta_{\text{opt}} + 0.5$, as expected for a standard slow-cooling synchrotron spectrum when the cooling break lies between the optical and X-ray bands (e.g. R. Sari et al. 1998; J. Granot & R. Sari 2002). However, at $t \simeq 2$ d the contemporaneous 1 keV flux is only a marginal detection and does not meet the quality cuts adopted for our X-ray analysis. Including this point does not materially change the best-fitting A_V , but it introduces additional assumptions (e.g. the location of ν_c , the validity of the fixed $\Delta\beta = 0.5$ relation, and potential X-ray absorption/cross-calibration systematics) that can dominate the inference when the X-ray constraint is weak. We therefore adopt the optical-only fit with the XRT-informed β prior as our baseline.

3.3.4 Radio afterglow brightness in context

At a spectroscopic redshift of $z = 1.216$, the radio afterglow of GRB 250818B lies among the most luminous events in the radio-detected short-GRB comparison sample, while also remaining within the typical radio-afterglow range of long GRBs shown in Fig. 7. Thus, the radio brightness alone does not uniquely distinguish between short-GRB and long-GRB interpretations. The 10 GHz luminosity is $\sim 5 \times 10^{30}$ erg s $^{-1}$ Hz $^{-1}$ at a rest-frame time of $\delta t_{\text{RF}} \approx 1$ d, based on the 10 GHz measurement reported in GCN 41 455 (no formal uncertainty was provided) (R. Ricci et al. 2025b). In comparison, most radio-detected short GRBs have 10 GHz afterglow luminosities of $\sim 2 - 8 \times 10^{29}$ erg s $^{-1}$ Hz $^{-1}$ at similar rest-frame times (Fig. 7). GRB 170728B (with a spectroscopic redshift of $z = 1.272 \pm 0.002$; W.-f. Fong et al. 2022b) and GRB 250221A (spectroscopic redshift of $z = 0.768$; C. Angulo-Valdez et al. 2025) have comparable radio afterglow luminosities to GRB 250818B at $\delta t \approx 1$ d, whereas GRB 210726A peaked at $\sim 2 \times 10^{31}$ erg s $^{-1}$ Hz $^{-1}$ at a rest-frame time of $\delta t_{\text{RF}} \approx 6$ d (Fig. 7).

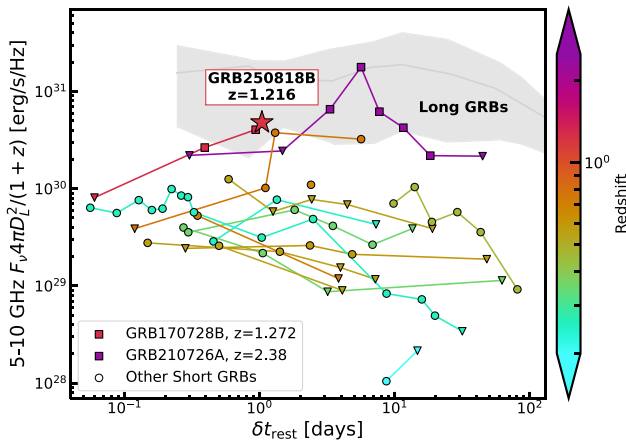


Figure 7. 5–10 GHz (observer frame) afterglow luminosity versus rest-frame time of radio-detected short GRBs (E. Berger et al. 2005; A. Panaitescu 2006; A. M. Soderberg et al. 2006; W. Fong et al. 2014, 2015; G. P. Lamb et al. 2019; W. Fong et al. 2021; T. Laskar et al. 2022; G. Schroeder et al. 2024; G. E. Anderson et al. 2025; C. Angulo-Valdez et al. 2025; A. Gulati et al. 2025; R. Ricci et al. 2025a; G. Schroeder et al. 2025a), with points coloured by redshift (redshifts from W.-f. Fong et al. 2022b; A. E. Nugent et al. 2024; G. Schroeder et al. 2024; C. Angulo-Valdez et al. 2025; G. Schroeder et al. 2025a). Triangles represent 3σ upper limits. The 10 GHz afterglow of GRB 250818B (R. Ricci et al. 2025b) is represented as a star, and the two other radio-detected short GRBs at $z > 1$ (GRB 170728B at $z = 1.272$ and GRB 210726A at $z = 2.38$) are represented as squares. Also shown is the typical radio afterglow range for long GRBs (shaded grey, P. Chandra & D. A. Frail 2012).

Among the few high-redshift events in this comparison sample with detected radio afterglows, useful reference points include GRB 170728B and GRB 210726A (with a photometric redshift of $z = 2.38^{+0.39}_{-0.75}$; G. Schroeder et al. 2024). Several of the most radio-luminous short GRBs have been modelled with additional components beyond a single forward shock (e.g. energy injection and/or reverse-shock contributions; see Section 4 for further discussion).

The MeerKAT detection of GRB 250818B adds to the still small sample of radio-detected events in this comparison set with low-frequency coverage at $\lesssim 5$ GHz, now totaling 7 (GRBs 140903A, 210726A, 230217A, 231117A, 250520A, 250704B, and 250818B; A. J. Nayana & P. Chandra 2014; G. E. Anderson et al. 2024; S. I. Chastain et al. 2024; G. Schroeder et al. 2024; G. E. Anderson et al. 2025; G. Schroeder et al. 2025a, b, c). A tentative very-low-frequency radio counterpart has also been reported for GRB 201006A (A. Rowlinson et al. 2024). The late-time rise of the 1.3 GHz afterglow is reminiscent of GRB 210726A (G. Schroeder et al. 2024), and highlights the utility of low-frequency ($\lesssim 5$ GHz) observations extended to later times ($\gtrsim 10$ d) to capture the afterglow peak as the synchrotron spectrum evolves to lower frequencies (e.g. R. Sari et al. 1998; J. Granot & R. Sari 2002). In particular, when prompt-emission constraints are weak or unavailable, the afterglow becomes the primary handle on the explosion energetics and environment. Locating the low-frequency peak and its time evolution anchors the synchrotron spectrum (i.e. the characteristic frequency and flux scale), helping to constrain the kinetic energy and circumburst density and to reduce degeneracies among the microphysical parameters in broad-band modelling.

Measuring the peak time and flux at these frequencies provides direct leverage on the afterglow energetics and circumburst

environment (and helps break degeneracies in broad-band modelling), which is particularly valuable when prompt-emission constraints are weak or unavailable.

3.3.5 afterglowpy baseline modelling

A rapid afterglow modelling tool is provided by *afterglowpy* (G. Ryan et al. 2020), and in combination with *redback* (N. Sarin et al. 2024), this enables end-to-end modelling and inference. Using the available detections and upper limits, we fit a simple uniform (top-hat) jet model to the data. We sample the posterior with the nested sampler *nessai* (M. J. Williams, J. Veitch & C. Messenger 2023), adopting the priors listed in Table 1t. The resulting 1σ credible intervals for each observing band are shown in Fig. 8.

Although these fits return parameters that are consistent with expectations for GRB afterglows, it should be noted that the posterior distribution for p is pushing up against the imposed lower boundary of $p = 2$. This suggests that, within this simple top-hat forward-shock model family, the data would prefer a harder electron spectrum (formally $p < 2$); we therefore interpret this as an indication of model tension rather than a precise physical constraint on p . The baseline *afterglowpy* top-hat model does not reproduce the full X-ray evolution, with noticeable mismatch after the first data point (see Fig. 8). The optical data from ~ 3 d are additionally in excess of the model light curve, suggesting either an additional component to the emission at late times or limitations of the simple top-hat forward-shock description. The radio data and limits sit well above the model radio posterior distribution, which does not violate the limits used; however, the model underpredicts by $> 1\sigma$ uncertainty the 36.8 GHz detection at $\sim 4 - 5$ d, noting that this detection has a large uncertainty.

3.3.6 Refreshed-shock and two-component modelling with redback

The variability within the afterglow suggests that there may have been a period of energy injection. Additionally, the late data appears to indicate either a further period of injection or an energetic wider component coming into view (i.e. K. Takahashi & K. Ioka 2021, a sheath surrounding a hollow/lower-energy jet). To demonstrate the viability of this model, we adopt fiducial model parameters informed via the *afterglowpy* fit, setting $p = 1.8$ (i.e. $p < 2$), isotropic kinetic energy $E_{\text{iso}} = 3.15 \times 10^{52}$ erg, and ambient particle number density $n_0 = 1 \text{ cm}^{-3}$. For the fiducial illustrative model shown as the dotted curve in Fig. 9, we further adopt $\epsilon_e = 0.1$, $\epsilon_B = 0.01$, $\xi_N = 1$, $\Gamma_0 = 140$, $\gamma_{\text{col}} = 28$, $e_t = 3.5$, $\Gamma_{0,2C} = 12$, and $\epsilon_{2C} = 2.5$. We adopt $\epsilon_B = 0.01$ as a conventional fiducial choice often used when the microphysics are not directly constrained (e.g. W. Fong et al. 2015); however, published estimates of ϵ_B span several orders of magnitude (e.g. A. Hennessey et al. 2025). The normalization of this illustrative curve (and the implied energy/density scalings) should therefore be regarded as conditional on the assumed microphysical parameters.

We use a refreshed-shock, two-component model (see e.g. G. P. Lamb & S. Kobayashi 2017; G. P. Lamb, I. Mandel & L. Resmi 2018; G. P. Lamb, A. J. Levan & N. R. Tanvir 2020) from *redback*, namely *twocomponent_redback_refreshed*. For the full

Table 1. The model parameter prior distributions and posterior medians for the afterglowpy and twocomponent_redback_refreshed model fit to data via redback using the nessai sampler. The model parameters are: θ_{obs} , the observer angle from the jet central axis; E_{iso} , the initial isotropic equivalent jet kinetic energy for a point at the jet axis; θ_c , the jet core half-opening angle; θ_j , the maximum angular extent of the second component; n_0 , the ambient particle number density; p , the accelerated electron distribution index within the afterglow shock; ε_e , the fraction of energy in shocked electrons; ε_B , the fraction of energy in the magnetic field; ξ_N , the synchrotron participation fraction; Γ_0 , the initial bulk Lorentz factor of the core; γ_{col} , the Lorentz factor at shell collision; e_t , the factor by which the energy increases during refreshed injection; e_s , the mass-injection index; ϵ_{2C} , the isotropic-equivalent energy factor of the second component relative to the core; and $\Gamma_{0,2C}$, the initial bulk Lorentz factor of the second component.

Parameter	Prior	Afterglowpy		twocomponent_redback_refreshed		
		Condition	Posterior	Prior	Condition	Posterior
θ_{obs} (rad)	$0, \pi/2$	$\theta_{\text{obs}}/\theta_j \leq 3/2$	$0.07^{+0.03}_{-0.02}$	$\sin(0, \pi/2)$	$\theta_v/\theta_c < 3/2$	0.04 ± 0.01
$\log E$ (erg)	44, 54	–	$52.48^{+0.23}_{-0.22}$	44, 54	–	$52.88^{+0.58}_{-0.57}$
θ_c (rad)	–	–	–	0.01, 0.14	$\theta_c < \theta_j$	0.07 ± 0.02
θ_j (rad)	0, 0.3	–	$0.07^{+0.03}_{-0.02}$	0.02, 0.16	$\theta_j > \theta_c$	$0.13^{+0.02}_{-0.03}$
$\log n_0$ (cm $^{-3}$)	–5, 2	–	$-0.21^{+0.93}_{-0.67}$	–5, 2	–	$1.08^{+0.55}_{-0.63}$
p	2, 3	–	$2.05^{+0.03}_{-0.02}$	1.4, 3.1	–	$1.67^{+0.18}_{-0.08}$
$\log \varepsilon_e$	–5, 0	$\varepsilon_e + \varepsilon_B \leq 0.9$	$-0.26^{+0.13}_{-0.19}$	–5, 0	$\varepsilon_e + \varepsilon_B \leq 0.9$	$-1.39^{+0.57}_{-0.56}$
$\log \varepsilon_B$	–5, 0	$\varepsilon_e - \varepsilon_B > 0.0$	$-1.12^{+0.43}_{-0.62}$	–5, 0	$\varepsilon_e > \varepsilon_B$	$-2.64^{+0.67}_{-0.57}$
ξ_N	0.1, 1	–	$0.16^{+0.08}_{-0.04}$	0.01, 1	–	$0.58^{+0.27}_{-0.31}$
Γ_0	100, 2000	–	1055^{+634}_{-634}	40, 250	$\Gamma_0 > 2\gamma_{\text{col}}$	174^{+45}_{-38}
γ_{col}	–	–	–	2, 50	$\gamma_{\text{col}} < \Gamma_0/2$	40 ± 6
e_t	–	–	–	1, 50	–	$2.99^{+1.39}_{-0.78}$
e_s	–	–	–	0, 10	–	5.25 ± 3.00
ϵ_{2C}	–	–	–	$10^{-3}, 10$ (log-uni)	–	$0.88^{+0.49}_{-0.86}$
$\Gamma_{0,2C}$	–	–	–	3, 20	–	$5.8^{+5.4}_{-0.9}$
Information		ln Z		Information		ln Z
25.82		58.142 ± 0.114		26.52		96.487 ± 0.094

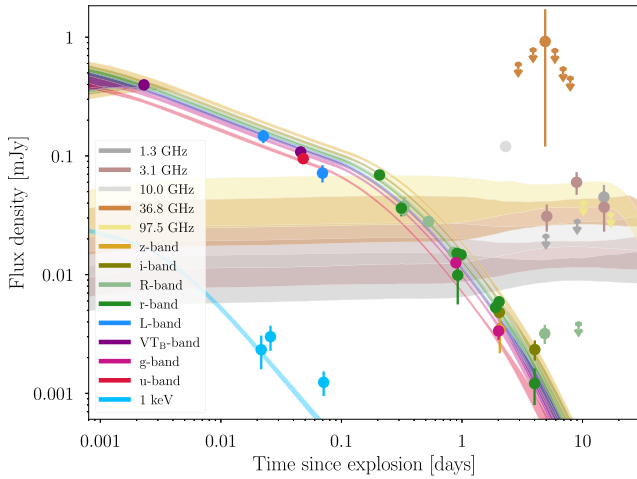


Figure 8. The 1σ confidence interval for light curves drawn from the posterior sample for a simple top-hat afterglow model from afterglowpy.

posterior inference, we repeated the fit with all physical parameters free (except redshift), using the priors and conditions listed in Table 1. In particular, unlike the earlier trial run, the viewing angle was allowed to vary with a sine prior, subject to the condition $\theta_v/\theta_c < 3/2$, so that the line of sight remains within or close to the jet core.

The posterior favours a small but non-zero viewing angle, $\theta_v = 0.04 \pm 0.01$ rad, together with $\theta_c = 0.07 \pm 0.02$ rad and $\theta_j =$

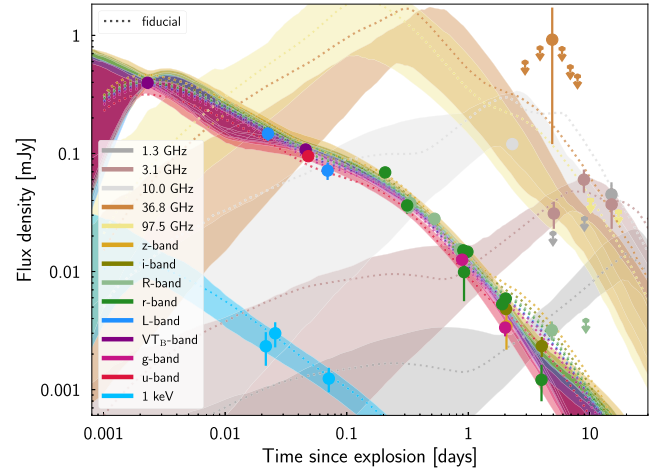


Figure 9. Refreshed-shock and two-component model fits to the broad-band afterglow of GRB 250818B. Shaded regions indicate the 1σ confidence intervals inferred from 250 randomly drawn light curves from the posterior distribution. The x-axis shows the observer time in days and the y-axis the flux density in units of milli-Jansky. The fiducial proof-of-principle model, with parameters listed in the text, is shown as a dotted line. The jet has a refreshed shock episode early in the deceleration, characterized by a collision at ~ 0.05 d in the observer frame. The posterior fit allows a small but non-zero viewing angle and broader angular structure than in the earlier trial run. In the fiducial illustrative model, the second component contributes significantly to the optical and radio emission from $\gtrsim 1 - 2$ d. In the posterior fit, the relative contribution of the two components depends on the sampled parameter combination and is therefore not uniquely characterized by the fiducial behaviour.

$0.13^{+0.02}_{-0.03}$ rad. The corresponding physical parameters are $\log E_0 = 52.88^{+0.58}_{-0.57}$, $\log n_0 = 1.08^{+0.55}_{-0.63}$, $p = 1.67^{+0.18}_{-0.08}$, $\log \varepsilon_e = -1.39^{+0.57}_{-0.56}$, and $\log \varepsilon_B = -2.64^{+0.67}_{-0.57}$, with the remaining refreshed-shock and second-component parameters given in Table 1. For completeness, the full posterior corner plot is shown in Appendix Fig. C4.

For the fiducial proof-of-principle model (dotted curve in Fig. 9), we adopted narrow opening angles ($\theta_c \sim 2:2$, $\theta_j \sim 2:5$) to reproduce the apparent break in the light curve. For the posterior fit, the sampler instead prefers broader angular scales, as listed in Table 1. This model is shown against the data in Fig. 9; additionally plotted are the confidence intervals inferred via 250 random draws from the posterior distribution fit for this model.

Using the same likelihood set-up for both models (Gaussian for detections and a censored-data likelihood for upper limits), the refreshed two-component model yields a higher Bayesian evidence than the baseline *afterglowpy* top-hat fit, with $\ln Z = 96.487 \pm 0.094$ compared to 58.142 ± 0.114 . Within the model families considered here, this supports a more complex afterglow description involving additional structure and/or refreshed energy injection over the simple top-hat baseline. Because the two model families differ in parametrization and physical assumptions, we interpret this comparison as evidence that the simple top-hat model is inadequate for the full data set, rather than as a unique identification of the underlying jet structure.

3.4 Host Galaxy

3.4.1 Association

We searched the Legacy Survey (LS DR10; A. Dey et al. 2019) catalogue around the position of GRB 250818B and identified a faint galaxy-like source as a candidate host at $\alpha = 03^{\text{h}}04^{\text{m}}13^{\text{s}}.79$, $\delta = -03^{\circ}07'30''.4$ (J2000), classified by *The Tractor* (D. Lang, D. W. Hogg & D. Mykytyn 2016) as a round exponential source (REX, objid 5790). The location of this candidate host source is shown in Fig. 10. The LS DR10 *r*-band catalogue magnitude is $r_{\text{AB}} = 24.74 \pm 0.36$, corresponding to a marginal detection ($S/N \approx 3$). Its angular separation from the GOTO afterglow position ($\alpha = 03^{\text{h}}04^{\text{m}}13^{\text{s}}.52$, $\delta = -03^{\circ}07'30''.8$) is $R_{\text{off}} = 4''.03$. Adopting $z = 1.216$ (from afterglow absorption), this corresponds to a projected physical offset of $R_{\text{off}} = 33.51$ kpc.⁶

To quantify the probability that this candidate, or another nearby source, is associated with the burst, we follow the Bayesian association method of K. Ackley (2025). In this framework, for a set of N candidate hosts $G = \{G_j\}_{j=1}^N$ within a search region, the probability that G_j is the true host is

$$p(G_j | d) = \frac{p(d | G_j) \pi(G_j)}{\sum_{k=1}^N p(d | G_k) \pi(G_k) + p(d | \varnothing) \pi(\varnothing)}, \quad (2)$$

where d is the GRB afterglow position and redshift, $p(d | G_j)$ is the likelihood, $\pi(G_j)$ is the prior on each galaxy, and $p(d | \varnothing) \pi(\varnothing)$ accounts for the possibility that the true host is not represented by any catalogued object, either because it is outside of the search region or below detection thresholds. We adopt equal prior weight among the N catalogued candidates, conditional on the host being present in the catalogue, so that $\pi(G_j) = \frac{1 - \pi(\varnothing)}{N}$.

⁶We assume a flat Λ CDM cosmology with $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_m = 0.3$, and $\Omega_\Lambda = 0.7$, and quote magnitudes in the AB system unless stated otherwise.

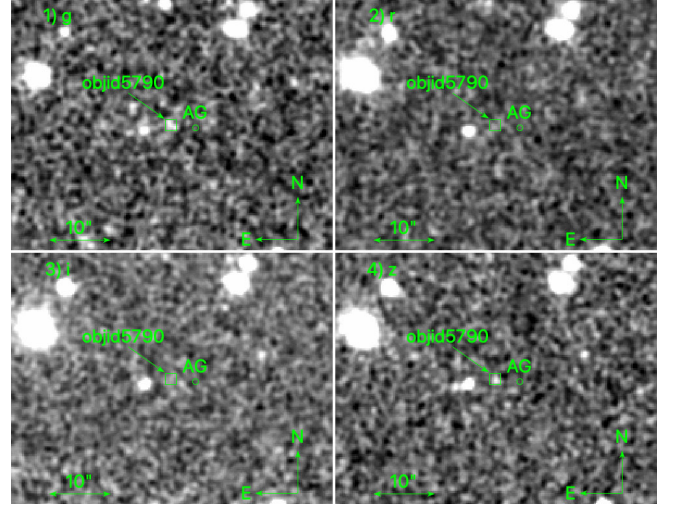


Figure 10. Legacy Survey DR10 image cutouts of the GRB 250818B field in the optical bands: (1) *g*, (2) *r*, (3) *i*, and (4) *z*. The circle marks the position of the optical transient (OT), while the square marks the position of the LS DR10 candidate host galaxy (objid 5790). A faint flux excess is visible at the candidate-host location, most clearly in *g*, and is less significant in *r* and *i*, consistent with the catalogue photometric uncertainties. North and east are indicated, and the scale bar corresponds to 10 arcsec.

The host-association likelihood is factorized into an offset term and a redshift-consistency term,

$$p(d | G_j) = p(r_{\text{DLR}} | G_j) \times p(z | G_j) \equiv p_{\text{offset}}(G_j) \times p_z(G_j), \quad (3)$$

where $r_{\text{DLR}} \equiv \Delta\theta/\text{DLR}$ is the dimensionless host-normalized separation, $\Delta\theta$ is the angular separation between the afterglow and the galaxy centroid, and DLR is the directional light radius of the galaxy in the direction of the afterglow, computed from the galaxy morphology parameters calculated by *the Tractor* (D. Lang et al. 2016).

For the offset likelihood, we marginalize over the unknown true host-normalized offset r_0 as

$$p_{\text{offset}}(G_j) = \sum_c \pi(c) \int_0^\infty p(r_{\text{DLR}} | r_0, \sigma_{r_0}) \pi(r_0 | G_j, c) dr_0, \quad (4)$$

where $c \in \{\text{short}, \text{long}\}$ is the class condition. We adopt equal class weights, $\pi(c) = 0.5$, so that the offset prior is treated as a class-conditional mixture rather than as a single-progenitor assumption. Assuming isotropic 2D Gaussian astrometric uncertainties, the radial likelihood $p(r_{\text{DLR}} | r_0, \sigma_{r_0})$ is a Rice distribution with non-centrality r_0 and scale $\sigma_{r_0} \equiv \sigma_{\text{ast}}/\text{DLR}$. The astrometric error σ_{ast} includes both centroid and registration terms, each conservatively estimated to be on the order of ~ 0.2 arcsec. We note that for the host candidates considered here $\sigma_{r_0} \ll \Delta\theta$, and thus the association is dominated by the offset prior.

We adopt a class-conditional Gamma-family prior to the host-normalized offset

$$\pi(r_0 | c) = \text{Gamma}(r_0; \lambda_c, \kappa_c) \propto r_0^{\lambda_c - 1} \exp(-r_0/\kappa_c) \quad (5)$$

with hyperparameters chosen to reproduce the observed host-normalized offset distributions of short and long GRBs from (P. K. Blanchard et al. 2016; W.-f. Fong et al. 2022a). In our analysis we fix $\lambda_c = 2$ and allow κ_c to vary with class c . To avoid imposing a single progenitor-class assumption on the association calculation, we marginalize over short- and long-GRB offset priors with equal weights and search for sources within a large angular radius

Table 2. Bayesian host-association results for the highest-ranked LS DR10 candidates within a 0.1° cone centred on GRB 250818B. The columns list the sky position and morphological type, the host-normalized offset $r_{\text{DLR}} \equiv \Delta\theta/\text{DLR}$, the angular separation from GRB 250818B in units of arcseconds, the projected physical separation at the redshift of GRB 250818B ($z = 1.216$), and the reported redshift of the host with uncertainty ($z_{\text{gal}} \pm \sigma_{z_{\text{gal}}}$). The other columns represent the offset likelihood P_{offset} , the redshift likelihood p_z , the probability that the host is missing from the catalogue P_{out} , and the total probability for the host association P_{assoc} (equation (2)).

RA (J2000)	Dec (J2000)	Type	r_{DLR}	Separation ($\Delta\theta$, ")	Separation (kpc)	$z_{\text{gal}} \pm \sigma_{z_{\text{gal}}}$	P_{offset}	p_z	P_{out}	P_{assoc}
03 ^h 04 ^m 13 ^s .79	−03°07′30″.40	REX	15.99	4.030	32.930	1.10 ± 0.32	1.000	0.752	0.882	0.0048
03 ^h 04 ^m 12 ^s .99	−03°06′18″.46	REX	38.59	72.79	583.01	1.00 ± 0.54	0.000	0.653	0.882	0.0000
03 ^h 04 ^m 15 ^s .23	−03°07′22″.31	DEV	35.88	27.05	152.52	0.43 ± 0.03	0.000	0.022	0.882	0.0000
03 ^h 04 ^m 13 ^s .08	−03°07′14″.81	EXP	20.53	17.30	102.86	0.48 ± 0.07	0.000	0.023	0.882	0.0000

($R_{\text{max}} = 0.1^\circ$), for which truncation of the offset prior is negligible for both classes.

For the redshift term, the host galaxy candidates have photometric redshift estimates, while the GRB afterglow has a precise spectroscopic redshift. Therefore, the redshift likelihood $p(z|G_j)$ treats the GRB afterglow redshift as a delta function and the host redshift as a Gaussian with uncertainty given by the photometric redshift uncertainty. In practice, this reduces to evaluating the host redshift probability distribution function at the GRB afterglow redshift, $p_z(G_j) \propto p_j(z)$.

In addition to the set of catalogue candidates, the normalization term of equation (2) includes an uncatalogued/missing host term that accounts for the possibility that the true host is not present in the LS DR10 source list. For GRB 250818B, we model this contribution using a limiting-magnitude completeness prescription as implemented in K. Ackley (2025). We define a catalogue completeness fraction $C(z)$ as the probability that a typical host at $z = 1.216$ would be brighter than the local LS DR10 depth at the burst position. Using the local r -band limiting magnitude m_{lim} (Section 3.4.2), we convert to an absolute threshold $M_{\text{lim}} \approx m_{\text{lim}} - \text{DM}(z)$. To compute the completeness fraction $C(z)$, we adopt a Schechter r -band luminosity function using the best-fitting parameters of M. R. Blanton et al. (2003), $M_r^* - 5 \log(h) = -20.44$ mag with $h \equiv H_0/100$, $\alpha = -1.30$, and absolute magnitude limits $M_{\text{lim}} \in [-24.26, -16.11]$, integrated above M_{lim} , where

$$C(z) = \frac{\int_{-\infty}^{M_{\text{lim}}} \phi(M) dM}{\int_{-\infty}^{M_{\text{max}}} \phi(M) dM}. \quad (6)$$

The faint/missed host probability is then

$$P_{\text{faint}} = 1 - C(z). \quad (7)$$

We note that we keep $C(z)$ as a term independent of the GRB source type and do not take into consideration any weights to the luminosity function. We also include an outside search cone term that accounts for the fraction of the offset prior that lies beyond the maximum search radius, R_{max} ,

$$P_{\text{out}} = \int_{R_{\text{max}}}^{\infty} p(R) dR. \quad (8)$$

The resulting uncatalogued host term is then denoted as P_{out} , which includes contributions from both hosts fainter than the catalogue limit and hosts lying outside the search cone. Because these terms are not mutually exclusive, we calculate the union of the probabilities $P_{\text{out}} \approx P_{\text{faint}} \cup P_{\text{out}} = P_{\text{faint}} + P_{\text{out}} - P_{\text{faint}}P_{\text{out}}$.

We identify candidate host galaxies by querying the LS DR10 catalogue within a 0.1° cone centred on the GRB with the following filters. We select galaxy-like sources with `type` ∈ {REX, EXP, DEV, SER}, `brick_primary` = 1, `allmask_g`

= `allmask_r` = `allmask_z` = 0, and significant r -band flux (`flux_r` > 0, `flux_ivar_r` > 0). For each candidate returned, we calculate the host-association probability; the highest-ranked candidates are listed in Table 2.

Given the limiting magnitude of the catalogue, we find that none of the candidate host galaxies in our selection is strongly favoured as the true host galaxy. The LS DR10 source (`objid` 5790) has the highest association probability, $P_{\text{assoc}} = 0.0048$, which is driven primarily by the offset likelihood term together with moderate support from the photometric-redshift term. The low absolute value of P_{assoc} does not by itself imply that `objid` 5790 is implausible; rather, it reflects the combination of a large missing-host probability and the fact that no single catalogued source is strongly preferred over the other candidates in the search region. Here, the offset likelihood is evaluated under the class-mixture prior described above, rather than under a single short-GRB assumption. Thus, within the LS DR10 catalogue and in this framework, we cannot definitely identify that `objid` 5790 is the true host. The analysis instead favours the host being absent from the catalogue, with $P_{\text{out}} \approx 0.882$, where we find that $P_{\text{out}} \approx 0.084$ and $P_{\text{faint}} \approx 0.871$.

We compare our host association probability results against the chance-coincidence formalism of J. S. Bloom et al. (2002). The chance-coincidence probability that an unrelated field galaxy of apparent magnitude $\leq m_r$ lies within an angular distance R_{off} of the GRB is

$$P_{\text{cc}} = 1 - \exp[-\pi R_{\text{off}}^2 \sigma(< m_r)], \quad (9)$$

where $\sigma(< m_r)$ is the surface density of galaxies brighter than m_r , in units of arcsec^{-2} . Rather than adopting a generic number-counts model, we measure $\sigma(< m_r)$ directly from the LS DR10 field around GRB 250818B (within 0.1° of the burst position, applying the same catalogue quality and morphology cuts used throughout this work). The resulting cumulative counts $N(< m_r)$, shown in Fig. C5, follow an approximately log-linear relation with slope $d \log_{10} N/dm_r \simeq 0.32$ over $22.5 \lesssim m_r \lesssim 24.5$, consistent with standard faint galaxy number counts in the R band (e.g. D. W. Hogg et al. 1997), but with an overall normalization lower by a factor of ~ 2.4 relative to that model, likely due to our strict source selection and the limited field size.

At the magnitude of the candidate host ($m_r = 24.74$), the empirical counts imply a surface density of $\sigma(< m_r) \simeq 4.3 \times 10^{-3} \text{ arcsec}^{-2}$ (see Fig. C5), which yields $P_{\text{cc}} \approx 0.195$ (range ≈ 0.18 – 0.20 when propagating the r -band uncertainty). This relatively high P_{cc} reflects the large angular offset and the high surface density of faint galaxies, and implies that the association is tentative rather than definitive. For comparison, using a simple Hogg-like number-counts model normalized to deep R -band surveys would increase P_{cc} to ~ 0.4 ; we adopt the local empirical counts

as our baseline, noting that this estimate depends on the chosen field size and the quality/morphology cuts applied to the catalogue.

We also compute P_{cc} for all LS DR10 galaxies in the same 0.1° cone and rank them by increasing chance probability. The LS DR10 object 5790 is among the lowest- P_{cc} galaxies within ~ 40 arcsec of the GRB position. The only source with a formally comparable P_{cc} lies at an angular distance of $\simeq 27$ arcsec, corresponding to a projected offset of $\simeq 225$ kpc at $z = 1.216$, which is implausibly large for a GRB host (e.g. S. Mandhai et al. 2022). On this basis, we consider LS DR10 objid 5790 to be a viable catalogued host galaxy candidate of GRB 250818B. We caution that the current data do not exclude an even fainter, near-coincident host galaxy candidate below the LS DR10 detection threshold, which would reduce the inferred offset and therefore weaken any interpretation that depends strongly on a large projected offset. We note that P_{cc} quantifies the probability of a chance alignment given only local number counts, whereas the Bayesian framework additionally incorporates a class-mixture offset (via DLR) and redshift consistency; this changes the relative weight of objid 5790 among the catalogued candidates compared to other nearby sources.

To further constrain the redshift of the LS DR10 candidate source, we compare its photometry to the galaxy population in the COSMOS-Web DR1 catalogue (M. Shuntov et al. 2026). COSMOS-Web DR1 provides photometric redshifts for over 700 000 galaxies in the Cosmic Evolution Survey (COSMOS) field, derived from deep *James Webb Space Telescope* NIR imaging combined with extensive HST and ground-based data. In total, 37 photometric bands spanning $0.3\text{--}8\ \mu\text{m}$ are used, yielding some of the most tightly constrained photometric redshifts available for any extragalactic field.

We select COSMOS-Web galaxies whose photometric measurements are consistent with those of the LS DR10 candidate, requiring agreement within 1σ of the detected fluxes or fainter than the corresponding upper limits. This selection identifies galaxies with photometry compatible with the candidate source, but whose redshifts are constrained by substantially richer multi-wavelength data. The resulting photometric-redshift distribution therefore provides an empirical estimate of the redshift expected for galaxies with photometry similar to that of the LS DR10 candidate. Using this approach, we obtain a median redshift of $z = 1.118 \pm 0.202$. This result is robust to reasonable variations in the matching criteria (e.g. adopting 3σ rather than 1σ thresholds). Notably, this is close to the measured spectroscopic afterglow redshift, which is consistent with – but does not by itself establish – an association between the absorber and objid 5790.

3.4.2 Limit on an underlying coincident host galaxy candidate

The LS DR10 candidate host source (objid 5790) is offset by $R_{\text{off}} = 4.03$ arcsec from the afterglow position and is detected only marginally in the LS DR10 catalogue ($r_{\text{AB}} = 24.74 \pm 0.36$, $S/N \approx 3$). Motivated by the relatively large offset and the proximity of the candidate to the survey detection threshold, and noting that the Keck/LRIS spectrum of the afterglow shows metal absorption at the burst redshift (imprinted on the afterglow continuum; Section 2.4), we assess whether the current imaging could plausibly miss a fainter, near-coincident host at (or very close to) the afterglow position.

We use the LS DR10 Tractor depth quantities, which are designed to quantify the limiting flux that would have been detected at a given sky position. The LS DR10 catalogues are produced with the TRACTOR image-modelling code (D. Lang et al. 2016). The `psfdepth_<band>` and `galdepth_<band>` columns encode inverse-variance depth in flux units (nMgy^{-2}), appropriate for point-source and small-galaxy detection, respectively.⁷ For an $N\sigma$ detection threshold, the corresponding limiting flux in nanomaggies is $f_{N\sigma} = N/\sqrt{\text{depth}}$, which converts to an AB magnitude via $m_{\text{AB}} = 22.5 - 2.5 \log_{10}(f_{\text{nMgy}})$. We query the LS DR10 Tractor catalogue within a $1'$ radius of the afterglow position and adopt the median depth values in this region as representative of the local detection threshold. For the r band, this yields median depths of `psfdepthr` $\simeq 666$ and `galdepthr` $\simeq 439\ \text{nMgy}^{-2}$, corresponding to $r_{3\sigma}^{\text{psf}} \simeq 24.84$ and $r_{3\sigma}^{\text{gal}} \simeq 24.61$ ($r_{5\sigma}^{\text{psf}} \simeq 24.28$, $r_{5\sigma}^{\text{gal}} \simeq 24.06$). We treat $m_{\text{lim}} \equiv r_{3\sigma}^{\text{gal}}$ as a conservative limit for an underlying host galaxy candidate, and quote $r_{3\sigma}^{\text{psf}}$ as an optimistic (compact-source) case.

As in Section 3.4.1 (Fig. C5), we measure the cumulative surface density $\sigma(< m_r)$ directly from LS DR10 sources in a 0.1° cone around the GRB, selecting galaxy-like morphologies and applying strict quality cuts (`brick_primary`, `zero_allmask`, and `positive_flux_r` with `fluxivar_r`). We then evaluate equation (9) for a hypothetical host located essentially at the afterglow position by substituting $R_{\text{off}} \rightarrow R_0$ and $m_r \rightarrow m_{\text{lim}}$, where R_0 is a small ‘coincident’ radius. For $R_0 = 0'.5$ (with $0'.3$ in parentheses) and $m_{\text{lim}} = r_{3\sigma}^{\text{gal}} = 24.61$, we obtain

$$P_{cc}(m_r = m_{\text{lim}}, R_0) \approx 4.2 \times 10^{-3} \quad (1.5 \times 10^{-3}). \quad (10)$$

Adopting the point-source limit $r_{3\sigma}^{\text{psf}} = 24.84$ changes these values only slightly ($\approx 4.3 \times 10^{-3}$ and 1.6×10^{-3} for $R_0 = 0'.5$ and $0'.3$, respectively). Thus, if a host galaxy were present at (or very near) the afterglow position and were bright enough to be detected at the LS DR10 threshold, it would have a very small chance-coincidence probability and would constitute a much stronger association than the offset LS DR10 candidate.

Conversely, we estimate how faint a near-coincident host galaxy would need to be for its chance-coincidence probability to be comparable to that of the offset candidate ($P_{cc} \approx 0.20$; Section 3.4.1). Solving equation (9) for the required surface density gives

$$\sigma_{\text{req}} = \frac{-\ln(1 - P_{cc})}{\pi R_0^2}. \quad (11)$$

For $P_{cc} = 0.20$, we obtain $\sigma_{\text{req}} \approx 2.84 \times 10^{-1}\ \text{arcsec}^{-2}$ at $R_0 = 0'.5$ ($\sigma_{\text{req}} \approx 7.89 \times 10^{-1}\ \text{arcsec}^{-2}$ at $0'.3$). In contrast, our empirical LS DR10 counts in this field reach a maximum of only $\sigma_{\text{max}} \approx 5.7 \times 10^{-3}\ \text{arcsec}^{-2}$ by the faintest magnitudes sampled ($r \simeq 27.3$). Therefore, the magnitude at which a near-coincident source would attain $P_{cc} \approx 0.20$ lies far beyond the regime probed by our catalogue (and would require much deeper data), implying that any genuinely near-coincident host would have $P_{cc} \ll 0.20$.

No galaxy is detected at the afterglow position down to the local LS DR10 limits ($m_{\text{lim}} = r_{3\sigma}^{\text{gal}} \simeq 24.61$), so the current data do not exclude a fainter, near-coincident host below the DR10 detection threshold. If present, such a host would reduce the inferred physical offset relative to objid 5790 and weaken any interpretation that depends strongly on a

⁷<https://www.legacysurvey.org/dr10/catalogs/>

large projected offset; we discuss the implications further in Section 4.2.

4 DISCUSSION

4.1 Afterglow brightness and broad-band interpretation

GRB 250818B displays an unusually bright afterglow relative to short/Type I comparison samples across X-ray, optical, and radio bands. In the observer-frame *Swift*/XRT 0.3–10 keV light curve, it lies on the bright end of the short-GRB population at early times (Section 3.3.1). In the optical, its R-band brightness at ~ 0.3 – 0.9 d is comparable to the median of the overall GRB population, but ~ 2.8 – 3.2 mag brighter than the median of the short/Type I subset (Section 3.3.2). In the radio, GRB 250818B is among the most luminous short-GRB afterglows at ($z > 1$) (Section 3.3.4). Together, these comparisons indicate that the afterglow emission is bright relative to typical short GRBs, motivating dedicated broad-band modelling.

The optical SED at $t_{\text{ref}} = 2.035$ d after the trigger suggests low line-of-sight extinction at $z = 1.216$, with $A_V \sim 0.2$ mag and no strong preference between MW- and SMC-like extinction curves (Section 3.3.3). This extinction remains weakly constrained and is consistent with zero within the uncertainties, so we do not apply any additional rest-frame extinction correction in the broad-band light-curve analysis. The inferred optical spectral index is consistent with the X-ray spectral slope and with a standard slow-cooling synchrotron spectrum, potentially with the cooling break between the optical and X-ray bands (e.g. R. Sari et al. 1998; J. Granot & R. Sari 2002). Thus, the observed optical brightness is unlikely to be dominated by dust obscuration, and the broad-band behaviour can be interpreted within the synchrotron afterglow framework.

We modelled the multiwavelength afterglow using *afterglowpy* (via *redback*) as a baseline forward-shock description. A single-component top-hat jet provides a reasonable overall fit but does not reproduce the full evolution: it exhibits a noticeable mismatch to the X-ray light curve from ~ 0.02 d, underpredicts the optical emission at $\gtrsim 3$ d, and underpredicts the 36.8 GHz detection at ~ 4 – 5 d (noting the large uncertainty on this point). These discrepancies suggest additional structure beyond a simple top-hat forward shock.

Motivated by this behaviour, we explore an energy-injection scenario with a refreshed shock, and a two-component jet model (inner core surrounded by a wider, sheath-like component). In this picture, an early injection episode and a slower, baryon-loaded sheath component surrounding the relativistic core can naturally produce a more complex multiband evolution, with the sheath contribution becoming important at optical and radio wavelengths from $\gtrsim 1$ – 2 d. Within the model families considered here, Bayesian model comparison favours the refreshed two-component model over the single-component top-hat fit (Table 1). We therefore interpret the data as supporting additional dynamical structure – energy injection and/or angular stratification – relative to the simple top-hat baseline, rather than as uniquely determining the underlying jet structure.

Physically, such energy injection can be produced either by slower ejecta catching up with the decelerating blast wave (refreshed shocks; M. J. Rees & P. Mészáros 1998; R. Sari & P. Mészáros 2000) or by sustained power from a long-lived central engine (e.g. magnetar spin-down; Z. G. Dai & T. Lu 1998; B. Zhang & P. Mészáros 2001; B.

D. Metzger et al. 2011; A. Rowlinson et al. 2013), while reverse-shock contributions can further enhance very early optical/radio emission at the afterglow onset (deceleration time, (e.g. R. Sari & T. Piran 1999; S. Kobayashi 2000; B. Zhang & S. Kobayashi 2005); as the excess emission is seen at times later than the afterglow peak, we can rule out any reverse shock component for the afterglow variability.

Overall, the broad-band brightness of GRB 250818B can be understood as the outcome of one (or more) of the standard levers that control synchrotron afterglow luminosity: higher kinetic energy, a denser circumburst medium, and/or a favourable viewing geometry (e.g. a more on-axis line of sight or a narrow/structured energetic component), potentially augmented by energy injection (e.g. E. Nakar 2007; E. Berger 2014). In the baseline fit, relatively high inferred microphysical parameters could also contribute to the flux normalization; however, these parameters are strongly degenerate with energetics, density, and the location of spectral breaks. In the refreshed two-component model, the microphysical parameters are not fixed; the posterior instead favours a relatively energetic and dense solution, with $\log E_0 = 52.88^{+0.58}_{-0.57}$, $\log n_0 = 1.08^{+0.55}_{-0.63}$, and a broader outer component with $\theta_j = 0.13^{+0.02}_{-0.03}$ viewed at a small but non-zero angle, $\theta_v = 0.04 \pm 0.01$. In this framework, refreshed energy injection and angular structure provide a natural explanation for the combination of early-time variability and late-time optical/radio excesses. These inferred parameters are comparatively high and are consistent with the qualitative impression from the observer-frame afterglow comparisons that GRB 250818B is unusually luminous relative to much of the radio-detected short-GRB comparison sample, while still remaining compatible with the broader long-GRB afterglow range discussed above.

Similar modelling ingredients (energy injection and/or reverse-shock-related components) are commonly invoked to explain the radio behaviour of the most radio-luminous short GRBs, including high-redshift events such as GRB 210726A and GRB 250221A (Section 3.3.4; G. Schroeder et al. 2024; G. E. Anderson et al. 2025; G. Schroeder et al. 2025a). However, energy injection and/or a two-component jet structure are commonly invoked for long-duration GRBs (e.g. J. Granot, E. Nakar & T. Piran 2003; Y. Sato et al. 2023). In this sense, GRB 250818B links phenomenology often discussed in the context of radio-luminous short GRBs with modelling ingredients that are also widely used for long-duration bursts. More generally, GRB 250818B shows that refreshed shocks and an energetic wide-angle second component provide a viable description of the afterglow, using ingredients that are often invoked in the modelling of long-duration GRBs.

GRB 250818B favours an accelerated electron index $p < 2$, with the refreshed two-component fit giving $p = 1.67^{+0.18}_{-0.08}$. Values of $p > 2$ are often associated with standard relativistic-shock Fermi acceleration, whereas a preference for $p < 2$ is frequently found when the prior range and fitting method allow it (e.g. X.-G. Wang et al. 2015). In this case, the low- p solution should be interpreted as a feature of the preferred afterglow model rather than as definitive evidence for a particular particle-acceleration mechanism, although it may indicate that multiple or alternative acceleration processes contribute within the forward shock.

4.2 Host-galaxy association: two viable scenarios

The available imaging and catalogue information admit (at least) two plausible host-galaxy scenarios for GRB 250818B. With the

current data, we cannot unambiguously distinguish between them, and we therefore treat the host association as tentative and discuss both possibilities below. We stress that the redshift $z = 1.216$ is derived from metal absorption features imprinted on the afterglow continuum, i.e. material along the GRB sightline, and therefore does not uniquely identify which galaxy (if any) in the LS DR10 imaging is the host. If objid 5790 is the host, the absorption could plausibly arise in its extended circumgalactic medium at projected separations of tens of kpc (e.g. N. M. Nielsen, C. W. Churchill & G. G. Kacprzak 2013; N. M. Nielsen et al. 2016; J. Tumlinson, M. S. Peebles & J. K. Werk 2017). Alternatively, it could originate in a fainter, near-coincident host below the LS DR10 detection threshold, or in an unrelated intervening absorber along the line of sight (e.g. G. E. Prochter et al. 2006).

Scenario A: the offset LS DR10 galaxy (objid 5790) is the host. In LS DR10 we identify a faint galaxy-like source (objid 5790; $r_{AB} = 24.74 \pm 0.36$, $S/N \approx 3$) at an angular separation $R_{off} = 4''.03$ from the afterglow position (Section 3.4.1). At $z = 1.216$, this corresponds to a projected physical offset of ≈ 33.51 kpc. Using the chance-coincidence formalism of J. S. Bloom et al. (2002) together with empirical galaxy number counts measured locally from the LS DR10 field (Fig. C5), we obtain a relatively high chance-alignment probability of $P_{cc} \approx 0.20$, implying that the association is *plausible but not definitive* when judged by angular proximity alone. Nevertheless, we retain objid 5790 as a viable candidate because (i) it is among the lowest- P_{cc} galaxy-like sources in the immediate field at reasonable offsets, and (ii) association information beyond angular proximity (e.g. DLR-based offset priors and redshift consistency) increases its relative weight compared to other nearby catalogued sources within the same framework.

A complementary Bayesian association analysis (Section 3.4.1; K. Ackley 2025) identifies objid 5790 as the highest-ranked catalogued candidate, although its absolute association probability remains low once additional information is incorporated (e.g. offset priors via DLR and redshift consistency). In addition, an empirical photometric-analogue test using COSMOS-Web DR1 yields a median photometric redshift $z \approx 1.12 \pm 0.20$ for galaxies matched in photometry to the candidate host, consistent with the afterglow absorption redshift within uncertainties (Section 3.4.1). We emphasize that this analogue test evaluates whether the *candidate's* photometry is consistent with galaxies at $z \sim 1$; it does not by itself demonstrate that the absorber at $z = 1.216$ is physically associated with objid 5790. We note that if Scenario A is correct, the implied projected offset of $R_{off} \approx 33.5$ kpc provides additional contextual information; however, we defer any population-based comparison to Section 4.3, since offset-based arguments are conditional on the host association being correct.

Scenario B: the true host is a fainter, near-coincident galaxy below the LS DR10 detection threshold. Because objid 5790 lies close to the LS DR10 detection threshold and is substantially offset, the current data do not exclude an undetected host at (or very near) the afterglow position (Section 3.4.2). At $z \sim 1.2$, low-luminosity systems can readily fall below the LS DR10 depth, particularly because the observed r band probes the rest-frame near-UV. Using LS DR10 Tractor depth quantities at the GRB position, we estimate local 3σ limits of $r_{3\sigma}^{gal} \approx 24.61$ for a small galaxy and $r_{3\sigma}^{psf} \approx 24.84$ for a point source (with corresponding 5σ limits $r_{5\sigma}^{gal} \approx 24.06$ and $r_{5\sigma}^{psf} \approx 24.28$). Combining these limits with the locally measured number counts, a hypothetical coincident host within $R_0 = 0.3\text{--}0.5$ arcsec would have a very small

chance-coincidence probability if it were detectable at the LS DR10 threshold, $P_{cc}(m_{lim}, R_0) \approx 1.5 \times 10^{-3}$ (for 0.3 arcsec) to $\approx 4.2 \times 10^{-3}$ (for 0.5 arcsec). No such galaxy is detected at the afterglow position down to these limits, implying that any genuinely near-coincident host must be fainter than LS DR10.

At $z = 1.216$, the LS DR10 r -band limit corresponds to a relatively luminous rest-frame UV threshold, so the current data do not place a strong constraint on the stellar mass of any undetected coincident host. In particular, because the observed r band probes the rest-frame near-UV ($\lambda_{rest} \sim 2800 \text{ \AA}$), the mapping from an r -band non-detection to stellar mass is highly model dependent and sensitive to recent star formation and dust attenuation (e.g. C. Conroy 2013). We therefore avoid converting the LS DR10 limit into a stellar-mass constraint.

Taken at face value, the LS DR10 depth is sufficient to detect relatively luminous coincident hosts at $z \sim 1.2$, but it would still miss fainter systems. Thus, the present imaging does not exclude a sub-luminous or moderately faint host underlying the afterglow position. Substantially deeper imaging would be required to test this possibility more decisively.

Summary and outlook. In summary, Scenario A is the *best-supported association among catalogued sources* in the current framework (and is favoured by the Bayesian ranking when DLR-based offset priors and redshift consistency are included), but its absolute association probability remains low, and the relatively large P_{cc} together with the survey depth mean that Scenario B cannot be ruled out. Accordingly, we do not treat the large projected offset of objid 5790 as decisive evidence on its own, given the remaining uncertainty in the host association and the broad observed range of GRB host offsets; if Scenario B holds, the true offset could be small and offset-based classification arguments would be correspondingly weakened. Resolving this ambiguity will require deeper, higher-resolution imaging (to search for a faint coincident host and/or to confirm the morphology and colours of objid 5790) and, ideally, host spectroscopy.

4.3 Progenitor interpretation: merger versus collapsar contamination

Although GRB 250818B has been discussed in discovery notices as a nominally short event, we note that prompt-duration-based classifications are not definitive, and a non-negligible fraction of apparently short events can arise from collapsars ('short' GRBs drawn from the long/Type II population; e.g. B. Zhang et al. 2009; O. Bromberg et al. 2012, 2013). We therefore focus on the afterglow and host-galaxy context, using the extensive multiwavelength follow-up to assess whether the broad-band behaviour is more naturally explained within a compact-object merger (Type I) picture or whether a collapsar origin remains plausible.

Our afterglow modelling (constant-density environment and a preference for energy injection and/or angular structure) does not uniquely distinguish between a compact-object merger and a collapsar origin: similar forward-shock phenomenology and refreshed-shock/engine activity are invoked across both GRB classes, and the inferred circumburst density and energetics are not by themselves decisive (e.g. S. E. Woosley & J. S. Bloom 2006; E. Berger 2014). The host-galaxy context provides an additional avenue for interpretation, but its constraining power is conditional on which of the currently viable host-association scenarios is correct. If Scenario A holds, the implied projected offset of $R_{off} \approx 33.51$ kpc would be unusual for a collapsar origin – which is expected to track star-forming regions closely – and

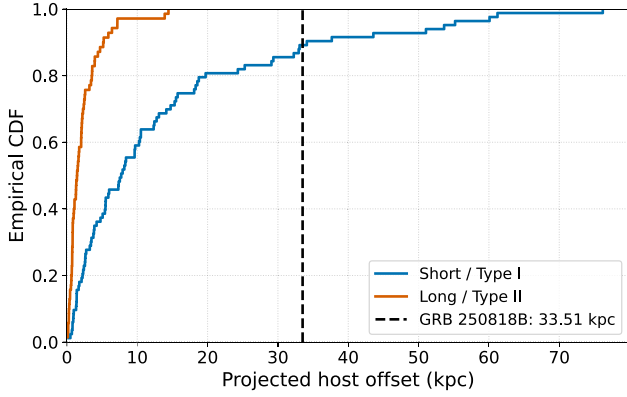


Figure 11. Empirical cumulative distributions of projected (2D) physical host offsets for short- and long-GRB host samples. The short-GRB (Type I) distribution (blue) is from the W.-f. Fong et al. (2022a) BRIGHT short-GRB host sample, restricted to the cosmological subset with measured offsets ($N = 83$; excluding GRB 170817A as in W.-f. Fong et al. 2022a). The long-GRB (Type II) distribution (orange) is from the P. K. Blanchard et al. (2016) long-GRB host sample, restricted to bursts with measured projected physical offsets ($N = 70$). The vertical dashed line marks the projected offset of GRB 250818B under Scenario A ($R_{\text{off}} = 33.51$ kpc).

would be more naturally accommodated within the broad offset distribution of short/Type I GRBs (e.g. W. Fong, E. Berger & D. B. Fox 2010; W. Fong et al. 2013). Conversely, if Scenario B is correct and the burst is associated with a faint, near-coincident host below the LS DR10 detection threshold, then a collapsar origin remains viable and offset-based arguments become correspondingly weaker.

To quantify how unusual the Scenario A offset is in known GRB populations, we compare R_{off} to published distributions of *projected physical offsets* for short and long GRBs (noting that the underlying samples are not population-complete and have different selection functions). For the short-GRB population, we adopt the BRIGHT host catalogue (W.-f. Fong et al. 2022a) and restrict to the cosmological subset with measured offsets, excluding GRB 170817A (included only as a local point of comparison in W.-f. Fong et al. 2022a), yielding $N = 83$ events. For our Scenario A offset estimate $R_{\text{off}} = 33.51$ kpc, the empirical tail probability is $f_{\text{short}} = P(R \geq R_{\text{off}}) \simeq 0.108$ (equivalently $\text{CDF}(R_{\text{off}}) \simeq 0.892$). Bootstrap resampling of the $N = 83$ offsets yields a 16–84 per cent range of 0.072–0.145. Thus, an ≈ 33.51 kpc offset lies in the upper tail of the short-GRB offset distribution but remains within the observed short-GRB range (Fig. 11).

In contrast, long GRBs are expected to trace star-forming regions closely, and observed offsets are typically small. Using the *HST*-based long-GRB host sample of P. K. Blanchard et al. (2016) and restricting to bursts with measured projected physical offsets ($N = 70$), we find no events with $R_{\text{off}} \geq 33.51$ kpc (Fig. 11). For this sample, the corresponding one-sided 95 per cent Clopper–Pearson upper limit is $f_{\text{long}} = P(R \geq R_{\text{off}}) \lesssim 0.0419$. Therefore, if Scenario A is correct, the large projected offset is atypical of the P. K. Blanchard et al. (2016) long-GRB host-offset distribution while remaining compatible with the observed short-GRB distribution; if Scenario B holds, however, the true physical offset could be small, and this discriminator would not apply.

Additional, non-decisive clues come from the afterglow brightness in the optical and X-ray bands. As shown in Fig. 5, we compare the observer-frame *R*-band evolution of GRB 250818B to the literature compilation of D. A. Kann et al. (2006); D. A.

Kann et al. (2010, 2011) and the short-GRB sample of A. Nicuesa Guelbenzu et al. (2012). We show the *R*-band projection of our simultaneous multiband SBPL fit and place all measurements on a consistent photometric system. Interpolating the comparison light curves in $\log t$ –magnitude space at the epochs of our *R*-band coverage (0.32, 0.33, 0.53, and 0.85 d), requiring the data to bracket each epoch, we find that GRB 250818B is brighter than ≈ 93 –97 per cent of Type I afterglows ($N_{\text{I}} = 29$ –31). In contrast, it is brighter than ≈ 58 –62 per cent of Type II afterglows ($N_{\text{II}} = 105$ –113), and brighter than ≈ 65 –70 per cent of the combined sample. These percentiles are intended as indicative brightness context (the comparison samples are heterogeneous and not population-complete), but they show that while GRB 250818B lies on the bright tail of the short/Type I afterglow distribution at ~ 0.3 –0.9 d, its optical brightness is broadly typical of the long/Type II population.

A similar conclusion is obtained in X-rays. Building on the population comparison in Section 3.3.1 (Fig. 4), we interpolate UKSSDC *Swift*/XRT 0.3–10 keV flux light curves in $\log t$ – $\log F$ space at the three early epochs used for our SNR = 10 spectral bins (1869, 2232, and 6153 s), again requiring the data to bracket each epoch and excluding borderline-duration events (defined via BATT_{90}). At these times, GRB 250818B is brighter than ≈ 96 –99 per cent of the *Swift* short-duration sample ($N_{\text{short}} = 35$ –47), but brighter than only ≈ 67 –73 per cent of the *Swift* long-duration sample ($N_{\text{long}} = 994$ –1041). As for the optical comparison, these percentiles are meant as context rather than classification, but they reinforce that GRB 250818B is an outlier among short-GRB afterglows while being comparatively typical of the long-GRB population at similar epochs.

Taken together, the afterglow-brightness context alone does not determine the progenitor class, but it is consistent with either an unusually luminous short-GRB afterglow or a burst whose prompt classification does not map cleanly onto the classical short/long division. At present, the most direct route to improving the progenitor interpretation is to resolve the host association more securely (see Dimple et al. 2025a, for similar conclusions regarding the nominally short GRB 241105A); deeper, high-resolution imaging and spectroscopy of any putative host would provide the most direct test of the collapsar versus merger interpretations.

5 CONCLUSIONS

We present the discovery and multiwavelength follow-up of GRB 250818B, a *SVOM*-triggered burst whose optical afterglow was identified by the wide-field GOTO. We compile and homogenize X-ray, optical/NIR, and radio observations into broad-band light curves and SEDs suitable for physical interpretation, and we investigate both the afterglow physics and the host-galaxy environment. Although GRB 250818B has been discussed in discovery notices as a nominally short event, our interpretation is driven primarily by the broad-band afterglow behaviour and the host-galaxy context.

Keck I/LRIS spectroscopy obtained at ≈ 10.7 hr post-burst reveals a continuum detection with metal absorption features (Fe II, Mg II, Mg I), yielding an absorption redshift of $z = 1.216$ (W. Fong et al. 2025), which we adopt throughout (Section 2.4; Fig. 1). Using *Swift*/XRT data, we performed time-resolved spectral fitting across three independent intervals, and we find that the X-ray afterglow is well described by an absorbed power-law model with a single intrinsic neutral-hydrogen column density (tied between

intervals) and a photon index that may vary with time; we find no compelling evidence that more complex spectral models are required.

We constrain dust extinction along the GRB sightline using a single-epoch optical SED at $t_{\text{ref}} \simeq 2.0$ d, constructed from nearly contemporaneous LT *gri* photometry without subtraction of the offset LS DR10 host-galaxy candidate (Fig. 6). Modelling the SED as a power law attenuated by dust at the absorption redshift $z = 1.216$ yields only modest line-of-sight extinction, with $A_V = 0.217 \pm 0.159$ mag (Milky Way law) and $A_V = 0.201 \pm 0.171$ mag (SMC law), which are statistically indistinguishable and consistent with low extinction within the uncertainties. The inferred optical spectral index is consistent with the XRT-informed prior, supporting a standard synchrotron interpretation at this epoch.

Placing GRB 250818B in context, we compare its afterglow brightness to literature samples and *Swift* GRB populations in the observer frame. In X-rays, optical, and radio, the burst is unusually bright relative to short-GRB comparison samples, while remaining broadly consistent with the long-GRB population. In particular, the X-ray afterglow is much brighter than the median of the *Swift* short-duration sample at early times, but only moderately above the long-duration median (Fig. 4), and the optical afterglow shows a similar pattern relative to short/Type I and long/Type II comparison samples (Fig. 5). In the radio, MeerKAT detections at 3.1 GHz (and later 1.3 GHz), together with deep higher-frequency limits, indicate that GRB 250818B is among the more radio-luminous events in the radio-detected short-GRB comparison sample at $z \gtrsim 1$, while still lying within the typical radio-afterglow range of long GRBs shown in Fig. 7.

We model the multiwavelength afterglow using *afterglowpy* (via *redback*) within the synchrotron forward-shock framework. A single-component top-hat jet provides a reasonable overall description but does not reproduce the full broad-band evolution, including mismatches in the X-ray light curve and late-time optical/radio behaviour. Within the model families considered here, Bayesian model comparison favours a refreshed two-component jet scenario (interpretable as energy injection and/or angular structure), supporting the conclusion that departures from the simplest single-component forward shock are required relative to the top-hat baseline.

Finally, we investigate the host-galaxy environment and show that the association is non-trivial (Section 4.2). The nearest LS DR10 galaxy-like source (Tractor *objid* 5790; $r_{\text{AB}} = 24.74 \pm 0.36$, $S/N \approx 3$) lies at an angular separation $R_{\text{off}} = 4.03$ arcsec (≈ 33.51 kpc at $z = 1.216$) and has a relatively high chance-alignment probability, $P_{\text{cc}} \approx 0.20$, implying that the association is plausible but not definitive. A Bayesian host-association analysis following K. Ackley (2025), which incorporates DLR-normalized offsets and redshift consistency, likewise finds that no catalogued galaxy is strongly favoured: *objid* 5790 is the highest-ranked catalogued candidate but with only $P_{\text{assoc}} = 0.0048$, while the probability that the host is missing from the LS DR10 catalogue is $P_{\text{off}} \approx 0.882$ (dominated by the faint-host term). At the same time, the imaging depth does not exclude a fainter, near-coincident host below the LS DR10 detection threshold, which would reduce the true physical offset and weaken interpretations that depend strongly on a large projected offset. We emphasize that the redshift $z = 1.216$ is measured from absorption along the GRB sightline and does not, by itself, uniquely identify the host in the available imaging. Thus, the current data admit two viable host scenarios: an offset LS DR10 candidate, or a fainter underlying host below the catalogue limit. Conditional on *objid* 5790 being

the host, a COSMOS-Web DR1 photometric-analogue test is also consistent with the candidate lying at $z \sim 1$.

Supplementary analysis of the LS DR10 candidate host is presented in the Appendix. Under the assumption that *objid* 5790 is the true host and lies at $z = 1.216$, conditional SED modelling with PROSPECTOR is consistent with a moderately low-mass system (formed stellar mass $\log(M_{\star, \text{formed}}/M_{\odot}) \approx 9.77$) with modest attenuation ($A_V \approx 0.39$ mag) and near-solar stellar metallicity ($\log(Z_{\star}/Z_{\odot}) \approx -0.19$), albeit with remaining degeneracies due to limited UV/NIR leverage. The homogenized data set, afterglow modelling, and host-association analysis presented here provide the foundation for interpreting the burst energetics, circumburst environment, and viewing geometry (including possible additional energy supply). Overall, GRB 250818B is difficult to place cleanly within the classical short/long framework: its afterglow is unusually bright relative to short-GRB comparison samples, while remaining compatible with the broader long-GRB population, and its host association remains inconclusive.

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DATA AVAILABILITY

All data sets supporting this study are provided in the paper. Additional data are available from the corresponding author upon reasonable request.

REFERENCES

- Abbott B. P. et al., 2017, *Phys. Rev. Lett.*, 119, 161101
- Ackley K., 2025, preprint (arXiv:2510.15836)
- Ahumada T. et al., 2022, *ApJ*, 932, 40
- An J. et al., 2025, GCN Circ., 41430, 1
- Anderson G. E. et al., 2024, *ApJ*, 975, L13
- Anderson G. E. et al., 2025, *ApJ*, 994, 5
- Angulo-Valdez C. et al., 2025, preprint (arXiv:2510.19132)
- Atteia J.-L. et al., 2017, *ApJ*, 837, 119
- Atteia J.-L., Cordier B., Wei J., 2022, *Int. J. Mod. Phys. D*, 31, 2230008
- Barthelmy S. D. et al., 2005, *Space Sci. Rev.*, 120, 143
- Belkin S. et al., 2024, *Res. Notes Am. Astron. Soc.*, 8, 6
- Berger E., 2014, *ARA&A*, 52, 43
- Berger E. et al., 2005, *Nature*, 438, 988
- Berlato F., Greiner J., Burgess J. M., 2019, *ApJ*, 873, 60
- Blanchard P. K., Berger E., Fong W.-f., 2016, *ApJ*, 817, 144
- Blanton M. R., Roweis S., 2007, *AJ*, 133, 734
- Blanton M. R. et al., 2003, *ApJ*, 592, 819
- Bloom J. S., Kulkarni S. R., Djorgovski S. G., 2002, *AJ*, 123, 1111
- Breeveld A. A., Landsman W., Holland S. T., Roming P., Kuin N. P. M., Page M. J., 2011, in McEnery J. E., Racusin J. L., Gehrels N. eds, AIP Conf. Ser. Vol. 1358, Gamma Ray Bursts 2010. AIP, p. 373, preprint (arXiv:1102.4717)
- Broe Bendtsen J. et al., 2025, GCN Circ., 41426, 1
- Bromberg O., Nakar E., Piran T., Sari R., 2012, *ApJ*, 749, 110
- Bromberg O., Nakar E., Piran T., Sari R., 2013, *ApJ*, 764, 179
- Burgess J. M., Yu H.-F., Greiner J., Mortlock D. J., 2018, *MNRAS*, 476, 1427
- Burrows D. N. et al., 2005, *Space Sci. Rev.*, 120, 165
- Busmann M., Fabà J., Jain V., Zuo X., Gruen D., O'Connor B., Palmese A., 2025, GCN Circ., 41445, 1
- Calzetti D., Armus L., Bohlin R. C., Kinney A. L., Koornneef J., Storchi-Bergmann T., 2000, *ApJ*, 533, 682
- Cano Z., Wang S.-Q., Dai Z.-G., Wu X.-F., 2017, *Adv. Astron.*, 2017, 8929054
- Cao Z. et al., 2023, *Sci. Adv.*, 9, ead27778
- Cash W., 1979, *ApJ*, 228, 939
- Castrejón C., Nugent A. E., Fong W.-f., Schroeder G., Rouco Escorial A., Guerra O., 2025, preprint (arXiv:2508.20156)
- Chabrier G., 2003, *PASP*, 115, 763
- Chandra P., Frail D. A., 2012, *ApJ*, 746, 156
- Chastain S. I. et al., 2024, *MNRAS*, 532, 2820
- Connaughton V. et al., 2015, *ApJS*, 216, 32
- Conroy C., 2013, *ARA&A*, 51, 393
- Conroy C., Gunn J. E., 2010, *ApJ*, 712, 833
- Conroy C., Gunn J. E., White M., 2009, *ApJ*, 699, 486
- Dai C.-Y., Guo C.-L., Zhang H.-M., Liu R.-Y., Wang X.-Y., 2024, *ApJ*, 962, L37
- Dai Z. G., Lu T., 1998, *A&A*, 333, L87
- Dey A. et al., 2019, *AJ*, 157, 168
- Dimple et al., 2025a, *MNRAS*, 544, 548
- Dimple, Gompertz B. P., Kumar A., 2025b, GCN Circ., 41442, 1
- Donaghy T. Q. et al., 2006, preprint (astro-ph/0605570)
- Dyer M. J. et al., 2024, in Marshall H. K., Spyromilio J., Usuda T. eds, Proc. SPIE Conf. Ser. Vol. 13094, Ground-based and Airborne Telescopes X. SPIE, Bellingham, p. 130941X
- Eichler D., Livio M., Piran T., Schramm D. N., 1989, *Nature*, 340, 126
- Evans P. A. et al., 2009, *MNRAS*, 397, 1177
- Ferro M. et al., 2025, GCN Circ., 41407, 1
- Fitzpatrick E. L., 1999, *PASP*, 111, 63
- Fitzpatrick E. L., Massa D., 2007, *ApJ*, 663, 320
- Flaugher B. et al., 2015, *AJ*, 150, 150
- Fong W., Berger E., 2013, *ApJ*, 776, 18
- Fong W., Berger E., Fox D. B., 2010, *ApJ*, 708, 9
- Fong W. et al., 2013, *ApJ*, 769, 56
- Fong W. et al., 2014, *ApJ*, 780, 118
- Fong W., Berger E., Margutti R., Zauderer B. A., 2015, *ApJ*, 815, 102
- Fong W. et al., 2021, *ApJ*, 906, 127
- Fong W., Gordon A. C., Levan A. J., Tanvir N. R., Dong Y., Suresh A., Liu C., 2025, GCN Circ., 41419, 1
- Fong W.-f. et al., 2022a, *ApJ*, 940, 56
- Fong W.-f. et al., 2022b, *ApJ*, 940, 56
- Galama T. J. et al., 1998, *Nature*, 395, 670
- Goldstein A. et al., 2017, *ApJ*, 848, L14
- Goldstein A. et al., 2020, *ApJ*, 895, 40
- Gompertz B. P. et al., 2023, *Nat. Astron.*, 7, 67
- Gordon K., 2024, *J. Open Source Softw.*, 9, 7023
- Gordon K. D., Clayton G. C., Misselt K. A., Landolt A. U., Wolff M. J., 2003, *ApJ*, 594, 279
- Granot J., Sari R., 2002, *ApJ*, 568, 820
- Granot J., Nakar E., Piran T., 2003, *Nature*, 426, 138
- Gulati A., Anderson G. E., Morley C., Chastain S., Leung J. K., van der Horst A. J., Rhodes L., *ATCA PanRadio GRB Collaboration*, 2025, GCN Circ., 39501, 1
- Heintz K. E. et al., 2020, *ApJ*, 903, 152
- Hellot R. et al., 2025, GCN Circ., 41444, 1
- Hennessy A. et al., 2025, *MNRAS*, 544, 53
- Hjorth J. et al., 2003, *Nature*, 423, 847
- Hogg D. W., Pahre M. A., McCarthy J. K., Cohen J. G., Blandford R., Smail I., Soifer B. T., 1997, *MNRAS*, 288, 404
- Johnson B. D., Leja J., Conroy C., Speagle J. S., 2021, *ApJS*, 254, 22
- Kann D. A., Klose S., Zeh A., 2006, *ApJ*, 641, 993
- Kann D. A. et al., 2010, *ApJ*, 720, 1513
- Kann D. A. et al., 2011, *ApJ*, 734, 96
- von Kienlin A. et al., 2020, *ApJ*, 893, 46
- Klebesadel R. W., Strong I. B., Olson R. A., 1973, *ApJ*, 182, L85
- Kobayashi S., 2000, *ApJ*, 545, 807
- Kouveliotou C., Meegan C. A., Fishman G. J., Bhat N. P., Briggs M. S., Koshut T. M., Paciesas W. S., Pendleton G. N., 1993, *ApJ*, 413, L101
- Kumar A. et al., 2024, *MNRAS*, 531, 3297
- Kumar A. et al., 2025a, *MNRAS*, 544, 1541
- Kumar A. et al., 2025b, Transient Name Server Discovery Report, 2025-3254, 1
- Kumar A. et al., 2025c, GCN Circ., 41406, 1
- Kumar A. et al., 2025d, GCN Circ., 41431, 1
- Kumar A. et al., 2025e, GCN Circ., 41431, 1
- Kumar P., Zhang B., 2015, *Phys. Rep.*, 561, 1
- Lamb G. P., Kobayashi S., 2017, *MNRAS*, 472, 4953

- Lamb G. P., Mandel I., Resmi L., 2018, *MNRAS*, 481, 2581
- Lamb G. P. et al., 2019, *ApJ*, 883, 48
- Lamb G. P., Levan A. J., Tanvir N. R., 2020, *ApJ*, 899, 105
- Lang D., Hogg D. W., Mykytyn D., 2016, Astrophysics Source Code Library, record ascl:1604.008
- Laskar T. et al., 2022, *ApJ*, 935, L11
- Lazzati D., Perna R., Gompertz B. P., Levan A. J., 2023, *ApJ*, 950, L20
- Leja J., Johnson B. D., Conroy C., van Dokkum P. G., Byler N., 2017, *ApJ*, 837, 170
- Levan A. J. et al., 2023, *Nat. Astron.*, 7, 976
- Levan A. J. et al., 2024, *Nature*, 626, 737
- Li R.-Z., Fu Y.-C., Zhang W.-D., Liu Y., *Einstein Probe Team*, 2025, GCN Circ., 41424, 1
- Lien A. et al., 2016, *ApJ*, 829, 7
- López K. O. C., Watson A. M., Lee W. H., Becerra R. L., Pereyra M., 2024, *MNRAS*, 531, 2775
- Lyman J. D. et al., 2026, preprint (arXiv:2603.02330)
- Maccary R. et al., 2026, *J. High Energy Astrophys.*, 49, 100456
- Mandhai S., Lamb G. P., Tanvir N. R., Bray J., Nixon C. J., Eyles-Ferris R. A. J., Levan A. J., Gompertz B. P., 2022, *MNRAS*, 514, 2716
- Meegan C. et al., 2009, *ApJ*, 702, 791
- Metzger B. D., Giannios D., Thompson T. A., Bucciantini N., Quataert E., 2011, *MNRAS*, 413, 2031
- Miceli D., Nava L., 2022, *Galaxies*, 10, 66
- Mong Y.-L. et al., 2021, *MNRAS*, 507, 5463
- Moskvitin A., Spiridonova O., Vlasuk V., Sotnikova Y., An T., Liu Y., 2025, GCN Circ., 41428, 1
- Nakar E., 2007, *Phys. Rep.*, 442, 166
- Narayan R., Paczynski B., Piran T., 1992, *ApJ*, 395, L83
- Nayana A. J., Chandra P., 2014, GCN Circ., 16815, 1
- Nicuesa Guelbenzu A. et al., 2012, *A&A*, 548, A101
- Nielsen N. M., Churchill C. W., Kacprzak G. G., 2013, *ApJ*, 776, 115
- Nielsen N. M., Churchill C. W., Kacprzak G. G., Murphy M. T., Evans J. L., 2016, *ApJ*, 818, 171
- Nousek J. A. et al., 2006, *ApJ*, 642, 389
- Nugent A. E., Fong W.-f., Castrejón C., Leja J., Zevin M., Ji A. P., 2024, *ApJ*, 962, 5
- O'Connor B. et al., 2023, *Sci. Adv.*, 9, eadi1405
- Oke J. B., Gunn J. E., 1983, *ApJ*, 266, 713
- Oke J. B. et al., 1995, *PASP*, 107, 375
- Panaiteanu A., 2006, *MNRAS*, 367, L42
- Panaiteanu A., Kumar P., 2002, *ApJ*, 571, 779
- Pe'er A., 2024, *Galaxies*, 13, 2
- Pian E. et al., 2017, *Nature*, 551, 67
- Piran T., 2004, *Rev. Mod. Phys.*, 76, 1143
- Poole T. S. et al., 2008, *MNRAS*, 383, 627
- Prochaska J. et al., 2020, *J. Open Source Softw.*, 5, 2308
- Prochaska J. X. et al., 2020, *pypeit/PyPeIt: Release 1.0.0*, Zenodo
- Prochter G. E. et al., 2006, *ApJ*, 648, L93
- Rastinejad J. C. et al., 2022, *Nature*, 612, 223
- Rees M. J., Mészáros P., 1998, *ApJ*, 496, L1
- Rhoads J. E., 1999, *ApJ*, 525, 737
- Ricci R., Becerra R. L., Troja E., *ERC BHianca Team*, 2025a, GCN Circ., 41046, 1
- Ricci R., Yadav M., Troja E., 2025b, GCN Circ., 41455, 1
- Roming P. W. A. et al., 2005, *Space Sci. Rev.*, 120, 95
- Rossi A. et al., 2022, *ApJ*, 932, 1
- Rouco Escorial A. et al., 2021, *ApJ*, 912, 95
- Rowlinson A., O'Brien P. T., Metzger B. D., Tanvir N. R., Levan A. J., 2013, *MNRAS*, 430, 1061
- Rowlinson A. et al., 2024, *MNRAS*, 534, 2592
- Ryan G., van Eerten H., Piro L., Troja E., 2020, *ApJ*, 896, 166
- Sari R., Mészáros P., 2000, *ApJ*, 535, L33
- Sari R., Piran T., 1999, *ApJ*, 520, 641
- Sari R., Piran T., Narayan R., 1998, *ApJ*, 497, L17
- Sarin N. et al., 2024, *MNRAS*, 531, 1203
- Sato Y., Murase K., Ohira Y., Yamazaki R., 2023, *MNRAS*, 522, L56
- Savchenko V. et al., 2017, *ApJ*, 848, L15
- Schlaflly E. F., Finkbeiner D. P., 2011, *ApJ*, 737, 103
- Schlegel D. J., Finkbeiner D. P., Davis M., 1998, *ApJ*, 500, 525
- Schroeder G. et al., 2024, *ApJ*, 970, 139
- Schroeder G. et al., 2025a, *ApJ*, 982, 42
- Schroeder G., Rhodes L., Fong W., Levan A. J., 2025b, GCN Circ., 40546, 1
- Schroeder G., Rhodes L., Fong W., Laskar T., Berger E., 2025c, GCN Circ., 41060, 1
- Schroeder G., Fong W., Laskar T., Rhodes L., 2025d, GCN Circ., 41516, 1
- Shuntov M. et al., 2026, *A&A*, 704, A339
- Siegel M. H., *Swift/UVOT Team*, 2025, GCN Circ., 41435, 1
- Singer L. P. et al., 2015, *ApJ*, 806, 52
- Soderberg A. M. et al., 2006, *ApJ*, 650, 261
- Steehls D. et al., 2022, *MNRAS*, 511, 2405
- Stratta G. et al., 2025, *ApJ*, 979, 159
- Sun H. et al., 2025, *National Science Review*, 12, nwae401
- Takahashi K., Ioka K., 2021, *MNRAS*, 501, 5746
- Tanaka M., 2016, *Adv. Astron.*, 2016, 634197
- Tanvir N. R. et al., 2017, *ApJ*, 848, L27
- Troja E. et al., 2017, *Nature*, 551, 71
- Troja E. et al., 2022, *Nature*, 612, 228
- Tumlinson J., Peeples M. S., Werk J. K., 2017, *ARA&A*, 55, 389
- Turpin D., Heussaff V., Dezalay J.-P., Atteia J.-L., Klotz A., Dornic D., 2016, *ApJ*, 831, 28
- Valenti S. et al., 2017, *ApJ*, 848, L24
- Virtanen P. et al., 2020, *Nature Medicine*, 17, 261
- Volvach A., Volvach L., Larionov M., 2025, *ApJ*, 992, 60
- Wang F. Y., Dai Z. G., Liang E. W., 2015, *New A Rev.*, 67, 1
- Wang H. et al., 2017, *ApJ*, 851, L18
- Wang X.-G. et al., 2015, *ApJS*, 219, 9
- Wang Z. Q., Liang Y. F., Xie W. J., Zhao D. H., Robinet F., Zhang L., *SVOM mission Team*, 2025, GCN Circ., 41405, 1
- Wei J. et al., 2016, preprint (arXiv:1610.06892)
- Williams M. J., Veitch J., Messenger C., 2023, *Mach. Learn. Sci. Technol.*, 4, 035011
- Williams P. K. G., Clavel M., Newton E., Ryzhkov D., 2017, Astrophysics Source Code Library, record ascl:1704.001
- Willingale R., Starling R. L. C., Beardmore A. P., Tanvir N. R., O'Brien P. T., 2013, *MNRAS*, 431, 394
- Wilms J., Allen A., McCray R., 2000, *ApJ*, 542, 914
- Woosley S. E., Bloom J. S., 2006, *ARA&A*, 44, 507
- Yang J. et al., 2022, *Nature*, 612, 232
- Yao Z. H. et al., 2025, GCN Circ., 41409, 1
- Yi F., Haibo Y., Ruoyi Z., Jian G., Shuai X., 2023, *MNRAS*, 525, 2701
- Yuan W. et al., 2015, preprint (arXiv:1506.07735)
- Zhang B., Kobayashi S., 2005, *ApJ*, 628, 315
- Zhang B., Mészáros P., 2001, *ApJ*, 552, L35
- Zhang B., Mészáros P., 2002, *ApJ*, 571, 876
- Zhang B., Kobayashi S., Mészáros P., 2003, *ApJ*, 595, 950
- Zhang B. et al., 2009, *ApJ*, 703, 1696
- Zhang B.-B. et al., 2021, *Nat. Astron.*, 5, 911
- Zheng W., Han X., Zhang P., Filippenko A. V., *KAIT GRB team*, 2025, GCN Circ., 41417, 1

APPENDIX A: DATA TABLES

Table A1. Optical and NIR afterglow observations of GRB 250818B compiled in this work, including measurements reported in GCN Circulars. All magnitudes are in the AB system. Upper limits are 3σ and are indicated with a ‘>’ sign. Times are measured relative to the *SVOM*/ECLAIRstrigger at $T_0 = 2025-08-18T03:29:09$ UTC.

$T - T_0$ (h)	Instrument/Telescope	Exp. Time (s)	Filter	Mag	Mag err	Source
−9.23	GOTO-S	4×45	<i>L</i>	> 20.3		This work
0.06	SVOM/VT	50	<i>VT_B</i>	17.40	0.03	Z. H. Yao et al. (2025)
0.54	GOTO	4×90	<i>L</i>	18.48	0.14	This work
1.10	SVOM/VT	50	<i>VT_B</i>	18.81	0.03	Z. H. Yao et al. (2025)
1.16	Swift/UVOT	1544	<i>u</i>	18.96	0.06	M. H. Siegel & Swift/UVOT Team (2025)
1.67	GOTO	4×90	<i>L</i>	19.26	0.18	This work
4.97	KNC/CDK17-AITP	15×300	<i>r</i>	19.30	0.07	R. Hellot et al. (2025)
7.53	KNC/TEC160FL	11×300	<i>r</i>	20.00	0.16	R. Hellot et al. (2025)
7.75	TRT/0.7m	–	<i>R</i>	20.03	0.06	J. An et al. (2025)
8.00	KAIT	90×60	<i>R</i>	19.95	0.20	W. Zheng et al. (2025)
12.64	TRT/0.7m	–	<i>R</i>	20.28	0.06	J. An et al. (2025)
20.42	SAO RAS/Zeiss-1000	13×300	<i>R</i>	20.93	0.04	A. Moskvitin et al. (2025)
21.37	SAAO/1mLesedi	6×450	<i>g'</i>	21.15	0.09	A. Kumar et al. (2025e)
21.84	FTW/3KK	35×180	<i>r</i>	20.95	0.02	M. Busmann et al. (2025)
22.13	SAAO/1mLesedi	6×400	<i>r'</i>	21.41	0.47	A. Kumar et al. (2025e)
23.60	NOT/ALFOSC	3×300	<i>r</i>	20.98	0.04	J. Broe Bendtsen et al. (2025)
45.60	FTW/3KK	30×180	<i>r</i>	22.09	0.08	M. Busmann et al. (2025)
48.24	LT/IO:O		<i>g</i>	22.59	0.17	This work
48.72	LT/IO:O	5×240	<i>r</i>	21.97	0.10	Dimple et al. (2025b)
48.96	LT/IO:O		<i>i</i>	22.19	0.11	This work
49.44	LT/IO:O		<i>z</i>	22.56	0.40	This work
96.00	LT/IO:O		<i>r</i>	23.69	0.37	This work
96.48	LT/IO:O		<i>i</i>	22.97	0.21	This work
116.59	Terskol/Zeiss-2000	3420	<i>R</i>	22.64	0.20	This work
222.55	Terskol/Zeiss-2000	3720	<i>R</i>	> 22.44		This work

Table A2. Vega-to-AB magnitude offsets Δm adopted in this work, defined such that $m_{AB} = m_{Vega} + \Delta m$.

Filter	Photometric system	$\Delta m = m_{AB} - m_{Vega}$
<i>U</i>	Johnson–Cousins	0.79
<i>B</i>	Johnson–Cousins	−0.09
<i>V</i>	Johnson–Cousins	0.02
<i>R</i>	Johnson–Cousins	0.21
<i>I</i>	Johnson–Cousins	0.45
<i>J</i>	NIR (2MASS-like)	0.91
<i>H</i>	NIR (2MASS-like)	1.39
<i>K_s</i>	NIR (2MASS-like)	1.85
<i>g</i>	Sloan-like	−0.08
<i>r</i>	Sloan-like	0.16
<i>i</i>	Sloan-like	0.37
<i>z</i>	Sloan-like	0.54
<i>u</i>	Swift/UVOT	1.02
<i>b</i>	Swift/UVOT	−0.13
<i>v</i>	Swift/UVOT	0.00

Table A3. Milky Way extinction coefficients $A_\lambda/E(B-V)$ adopted in this work.

Filter	Origin	$A_\lambda/E(B-V)$
<i>g</i> (SDSS-like)	E. F. Schlafly & D. P. Finkbeiner (2011)	3.303
<i>r</i> (SDSS-like)	E. F. Schlafly & D. P. Finkbeiner (2011)	2.285
<i>i</i> (SDSS-like)	E. F. Schlafly & D. P. Finkbeiner (2011)	1.698
<i>z</i> (SDSS-like)	E. F. Schlafly & D. P. Finkbeiner (2011)	1.263
<i>U</i> (Landolt)	E. L. Fitzpatrick (1999)	4.334
<i>B</i> (Landolt)	E. L. Fitzpatrick (1999)	3.626
<i>V</i> (Landolt)	E. L. Fitzpatrick (1999)	2.742
<i>R</i> (Landolt)	E. L. Fitzpatrick (1999)	2.169
<i>I</i> (Landolt)	E. L. Fitzpatrick (1999)	1.505
<i>u</i> (UVOT) ^c	F. Yi et al. (2023)	4.80
<i>b</i> (UVOT) ^c	F. Yi et al. (2023)	3.97
<i>v</i> (UVOT) ^c	F. Yi et al. (2023)	2.99
<i>L</i> (GOTO)	This work ^a	$0.997 R_V \simeq 3.09$
<i>VT_B</i> (SVOM)	This work ^b	$(A_g + A_r)/2 \simeq 2.79$

Notes. ^a Approximated as $A_L \simeq 0.997 A_V$ with $R_V = 3.1$.

^b Approximated as the mean of the SDSS *g* and *r* coefficients.

^c UVOT coefficients are taken from F. Yi et al. (2023) and are tabulated per $E(B-V)$ from the SFD98 map (D. J. Schlegel, D. P. Finkbeiner & M. Davis 1998). Since we adopt the Schlafly & Finkbeiner (2011) recalibration $E(B-V)_{SF11} \approx 0.0633 E(B-V)_{SFD}$ (E. F. Schlafly & D. P. Finkbeiner 2011), we rescale the UVOT coefficients by $1/0.0633$ so that $A_\lambda/E(B-V)$ is consistent with our adopted $E(B-V)$.

Table A4. Radio observations of GRB 250818B. Upper limits are 3σ .

Facility	Frequency (GHz)	$T - T_0$ (d)	Flux density (μJy)	Flux err (μJy)	Source
VLA	10.0	2.30	120		R. Ricci, M. Yadav & E. Troja (2025b)
MeerKAT	1.3	4.97	<21		This Work
MeerKAT	1.3	9.02	<28		This Work
MeerKAT	1.3	15.05	45	12	This Work
MeerKAT	1.3	32.00	<18		This Work
MeerKAT	3.1	5.05	31	8	This Work
MeerKAT	3.1	8.93	60	13	This Work
MeerKAT	3.1	15.1	37	14	This Work
MeerKAT	3.1	32.1	<32		This Work
CrAO	36.8	2.93	< 590		This work
CrAO	36.8	3.89	< 780		This work
CrAO	36.8	4.90	920	800	This work
CrAO	36.8	5.90	< 770		This work
CrAO	36.8	6.90	< 540		This work
CrAO	36.8	7.91	< 450		This work
ALMA	97.5	10.14	< 40		This work
ALMA	97.5	17.19	< 32		This work

Table A5. *Swift*/XRT0.3–10 keV fluxes of GRB 250818B (SNR = 10 binning). The best-fitting hydrogen absorption is N_{H} (intrinsic) = $(2.09^{+2.51}_{-2.09}) \times 10^{21} \text{ cm}^{-2}$, consistent with no excess above the galactic value of $6.49 \times 10^{20} \text{ cm}^{-2}$ (R. Willingale et al. 2013). The reduced fit statistic is 0.24. All errors are to the 90 per cent tolerance level.

Bin centroid (s)	Bin width (s)	Absorbed flux ($10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$)	Unabsorbed flux ($10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$)	Photon index
1869	371.1	$2.58^{+0.55}_{-0.45}$	$2.91^{+0.51}_{-0.43}$	$1.64^{+0.23}_{-0.22}$
2232	355.3	$2.82^{+0.51}_{-0.42}$	$3.32^{+0.48}_{-0.42}$	$1.84^{+0.22}_{-0.21}$
6153	837.4	$0.96^{+0.16}_{-0.14}$	$1.25^{+0.18}_{-0.16}$	$2.19^{+0.24}_{-0.23}$

Table A6. *Swift*/XRT0.3–10 keV fluxes of GRB 250818B (SNR = 5 binning). The best-fitting hydrogen absorption is N_{H} (intrinsic) = $(0.79^{+2.21}_{-0.79}) \times 10^{21} \text{ cm}^{-2}$, consistent with no excess above the galactic value of $6.49 \times 10^{20} \text{ cm}^{-2}$ (R. Willingale et al. 2013). The reduced fit statistic is 0.12. All errors are to the 90 per cent tolerance level.

Bin centroid (s)	Bin width (s)	Absorbed flux ($10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$)	Unabsorbed flux ($10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$)	Photon index
1745	122.9	$2.51^{+0.82}_{-0.58}$	$2.97^{+0.76}_{-0.65}$	$1.94^{+0.35}_{-0.34}$
1892	170.5	$2.05^{+0.48}_{-0.38}$	$2.33^{+0.46}_{-0.38}$	$1.79^{+0.26}_{-0.25}$
2042	130.4	$3.48^{+1.28}_{-0.94}$	$3.68^{+1.26}_{-0.92}$	$1.29^{+0.33}_{-0.32}$
2159	102.8	$2.96^{+0.99}_{-0.74}$	$3.48^{+0.96}_{-0.77}$	$1.96^{+0.37}_{-0.35}$
2310	199.9	$2.42^{+0.64}_{-0.50}$	$2.79^{+0.62}_{-0.51}$	$1.87^{+0.29}_{-0.28}$
6153	837.4	$0.99^{+0.17}_{-0.14}$	$1.21^{+0.17}_{-0.15}$	$2.11^{+0.23}_{-0.21}$

APPENDIX B: HOST-CANDIDATE SUPPLEMENTARY ANALYSIS

B1 Photometry

We obtained photometry for the LS DR10 host-galaxy candidate discussed in Section 3.4.1 from the DESI Legacy Imaging Surveys DR10 Tractor catalogue (A. Dey et al. 2019), using DECam *griz* and unWISE/WISEW1–W4 bands (B. Flaugher et al. 2015; A. Dey et al. 2019). Catalogue fluxes and inverse variances were converted to AB magnitudes and 1σ uncertainties following the standard nanomaggy formalism. In the optical, the candidate source is detected in DECam *g*, *r*, and *z*, while the *i*-band measurement has low SNR and is treated as an upper limit in our SED

approximation. The mid-infrared *WISE* bands are also of low significance and are used as upper limits only. The LS DR10 Tractor photometry is based on forward modelling of the imaging with PSF convolution, returning band-by-band model fluxes for a common source morphology; we therefore treat the DECam *grz* fluxes as internally consistent total-flux estimates across those bands. The SkyMapper and *WISE* measurements are non-detections and are used only as upper limits; since these limits are substantially shallower than the LS DR10 detections, the SED constraints are dominated by the DECam *grz* points and are insensitive to modest cross-survey aperture/PSF differences. All magnitudes listed in Table B1 are on the AB system and are not corrected for Galactic extinction; for SED modelling, we apply the Milky Way extinction corrections described in Section 2.2. If this candidate is indeed

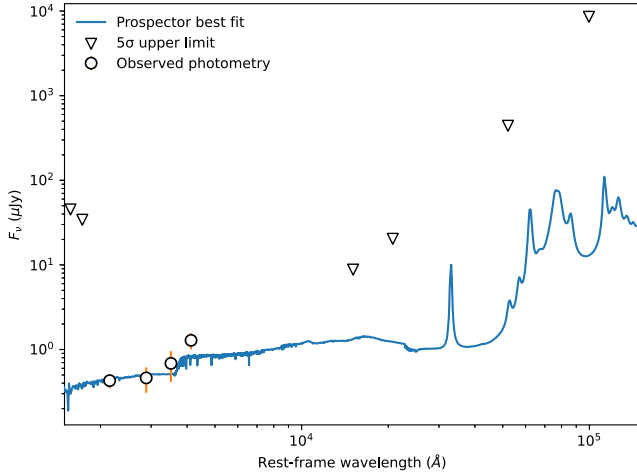


Figure B1. Rest-frame SED of the LS DR10 candidate host of GRB 250818B, under the assumption that it lies at $z = 1.216$, with the PROSPECTOR best-fitting spectrum (solid line). Points show DECam *griz* detections (AB, corrected for Galactic extinction); triangles indicate 5σ upper limits (SkyMapper *u*, *v*, and WISE bands). Limited blue/UV and NIR leverage leaves age–dust–metallicity partially degenerate, but the overall SED is well reproduced. The structured emission at $\gtrsim 3 \mu\text{m}$ arises from the model dust/PAH emission component in FSPS/PROSPECTOR; with only upper limits in the mid-IR, this part of the spectrum is effectively unconstrained and is shown for completeness only.

the true host, substantially deeper imaging and spectroscopy of the source would require large-aperture facilities and lie beyond the scope of this work.

B2 Prospector SED Modelling

We modelled the LS DR10 candidate host source near GRB 250818B with PROSPECTOR (J. Leja et al. 2017; B. D. Johnson et al. 2021), using the FSPS stellar-population models (C. Conroy, J. E. Gunn & M. White 2009; C. Conroy & J. E. Gunn 2010), a Chabrier IMF (G. Chabrier 2003), and a Calzetti foreground dust law (D. Calzetti et al. 2000). We fix the redshift to $z = 1.216$ from the afterglow absorption spectrum (W. Fong et al. 2025); therefore, the inferred candidate-host properties below are conditional on the assumption that the LS DR10 candidate galaxy is the true host and lies at this redshift (see Section 4.2). The star-formation history was modelled with a parametric delayed- τ form. As photometric constraints we used DECam *griz* detections from the DESI Legacy Surveys DR10 Tractor catalogue (Table B1), together with WISEW1–W4 and SkyMapper *u*, *v* non-detections as 5σ upper limits.⁸ As a check, repeating the fit using only the DECam *griz* detections (i.e. omitting the upper-limit bands) yields consistent posteriors for $M_{\star, \text{formed}}$ and A_V . The rest-frame SED fit is shown in Fig. B1; wavelengths are rest-frame unless stated otherwise.

Under this candidate-host assumption, we quote the following physical parameters from the posterior (medians with 16–84 percent credible intervals; Fig. B2; see Fig. C6 for the full

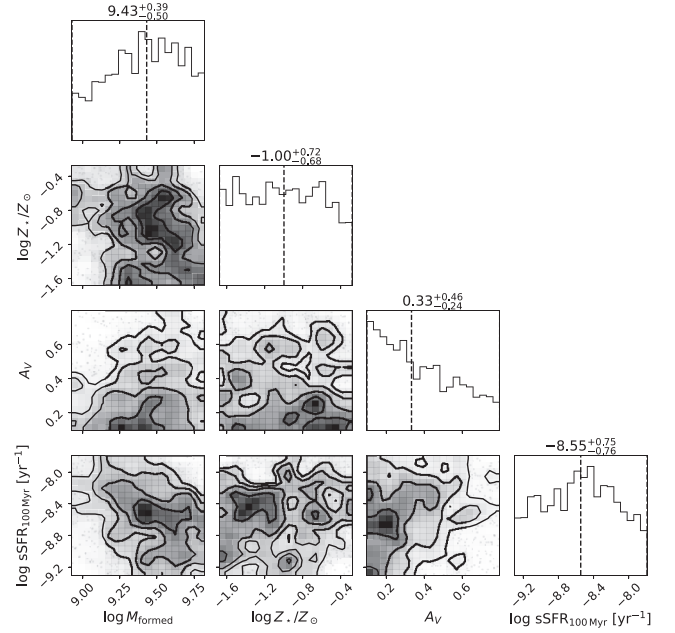


Figure B2. Posterior constraints on derived properties of the LS DR10 candidate host from the PROSPECTOR fit (Age_{MW} panel omitted). Medians and 68 percent credible intervals: $\log(M_{\text{formed}}/M_{\odot}) = 9.77^{+0.31}_{-0.37}$, $\log(Z_{\star}/Z_{\odot}) = -0.19^{+0.25}_{-0.22}$, $A_V = 0.39^{+0.34}_{-0.27}$ mag, $\log \text{sSFR}_{100 \text{ Myr}} [\text{yr}^{-1}] = -9.28^{+0.47}_{-0.42}$. Under the assumed association and redshift, the candidate is consistent with modest attenuation and near-solar metallicity; recent ($\lesssim 100$ Myr) activity remains weakly constrained. For completeness, the full PROSPECTOR parameter corner plot is shown in Fig. C6.

Table B1. Host-galaxy candidate photometry at the position of GRB 250818B, from the DESI Legacy Imaging Surveys DR10 Tractor catalogue (DECam *griz*) and WISE (W1–W4). All magnitudes are AB and are not corrected for Galactic extinction. For bands with low SNR, we quote 3σ upper limits.

Band	Instrument	m_{AB}	err
<i>u</i>	SkyMapper	> 19.76	
<i>v</i>	SkyMapper	> 20.07	
<i>g</i>	DECam	24.82	0.20
<i>r</i>	DECam	24.74	0.36
<i>i</i>	DECam	24.31	0.43
<i>z</i>	DECam	23.63	0.24
W1	WISE	> 21.54	
W2	WISE	> 20.63	
W3	WISE	> 17.29	
W4	WISE	> 14.07	

PROSPECTOR parameter corner plot): $\log(M_{\star, \text{formed}}/M_{\odot}) = 9.77^{+0.31}_{-0.37}$, $\log(Z_{\star}/Z_{\odot}) = -0.19^{+0.25}_{-0.22}$, $A_V = 0.39^{+0.34}_{-0.27}$ mag, and $\log \text{sSFR}_{100 \text{ Myr}} [\text{yr}^{-1}] = -9.28^{+0.47}_{-0.42}$.

Under the assumption that the LS DR10 candidate is the true host, the posterior favours a moderate-mass system with modest internal attenuation. In particular, $A_V = 0.39^{+0.34}_{-0.27}$ mag is weakly constrained: the 68 percent interval spans ~ 0.12 – 0.73 mag, so values consistent with very low attenuation are not excluded, while heavier dust is disfavoured by the blue SED. Given the limited UV/blue and NIR leverage (no deep *u/v* detection and only mid-IR limits), the age–dust–metallicity degeneracy remains significant and propagates into the posterior uncertainties in $\log Z_{\star}$.

⁸All measurements are AB and were corrected for Galactic extinction using $E(B-V)_{\text{MW}} = 0.0633$ (D. J. Schlegel et al. 1998; E. F. Schlafly & D. P. Finkbeiner 2011) and the band coefficients in Table A3. The upper limits are included in the fit but, given their depth relative to the DECam detections, do not materially impact the inferred posteriors.

and $\text{sSFR}_{100\text{ Myr}}$. We therefore treat the global candidate-host attenuation as small to moderate and avoid using it to draw strong conclusions about the recent ($\lesssim 100$ Myr) star-formation activity. These inferences are driven primarily by the DECAM *griz* detections; deeper UV and a redder/NIR detection (e.g. *YJH*) would substantially tighten the constraints. For completeness, the full PROSPECTOR parameter corner and the SFH summary are shown in Figs C6 and C7, respectively.

B3 COSMOS-Web comparison-sample constraints

As described in Section 3.4.1, we used COSMOS-Web DR1 to place empirical constraints on the redshift of the LS DR10 candidate host source by selecting COSMOS-Web galaxies with photometry consistent with the LS DR10 measurements (within the adopted tolerances). We extend the same matching approach to additional physical parameters available for the COSMOS-Web comparison sample. Using the matched galaxies, we infer a typical stellar mass of $\log_{10}(M_*/M_\odot) = 9.35 \pm 0.22$ and a typical star-formation rate of $\text{SFR} \approx 1.0 \pm 3.8 M_\odot \text{ yr}^{-1}$, corresponding to a median $\log_{10}(\text{sSFR}/\text{yr}^{-1}) \approx -9.34$. These values are consistent with the PROSPECTOR constraints (noting that PROSPECTOR reports a formed stellar mass) at the $\sim 1\sigma$ level. While this COSMOS-Web comparison does not constitute a direct measurement of the specific LS DR10 source, it provides an independent sanity check on the range of properties expected if that candidate is indeed the true host. Under that assumption, the candidate is plausibly a low-mass galaxy with at most modest ongoing star formation.

APPENDIX C: SUPPLEMENTARY FIGURES

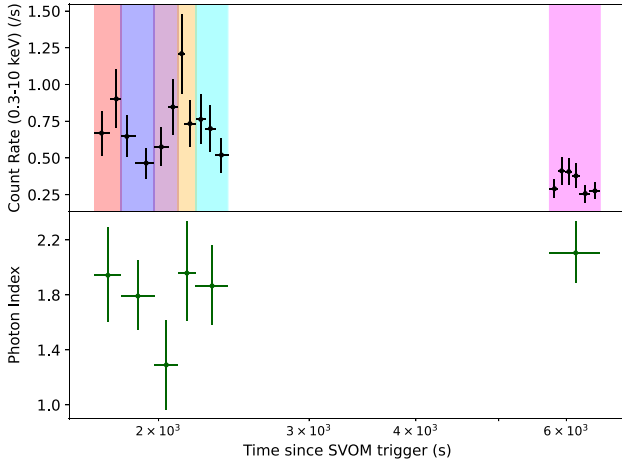


Figure C1. Top: XRT count rate light curve of the three flaring episodes, where the highlighted sections indicate the six $\text{SNR} = 5$ spectral bins. The late-time XRT data at ~ 3.35 d does not meet the SNR threshold and so is not included in the spectral analysis. Bottom: evolution of the best-fitting photon index with time.

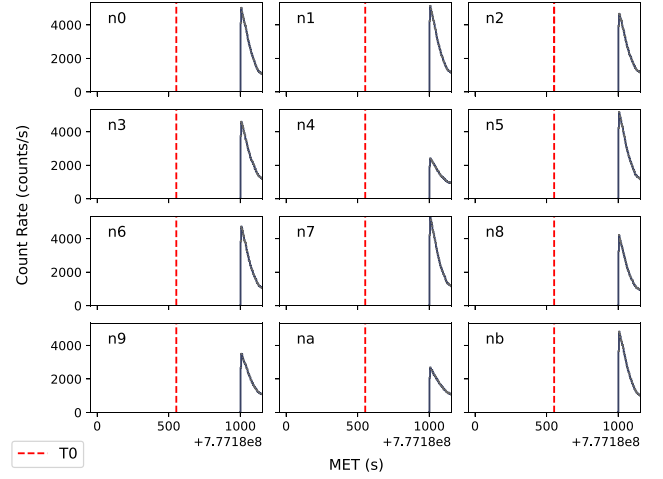


Figure C2. Light curves of all NaI detectors on *Fermi*/GBM between $T_0 - 600$ s and $T_0 + 600$ s (where T_0 is the *SVOM* trigger time, indicated by the dashed red line). The lack of counts around T_0 is due to *Fermi* being over the South Atlantic Anomaly.

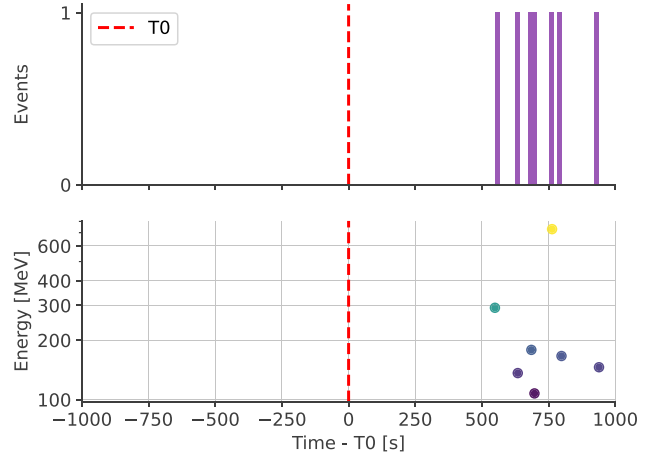


Figure C3. *Fermi*/LAT event data between $T_0 - 600$ s and $T_0 + 600$ s (where T_0 is the *SVOM* trigger time, indicated by the red dashed line). Top: number of events detected by the LAT. Bottom: energy of detected events. The lack of counts around T_0 is due to *Fermi* being over the South Atlantic Anomaly.

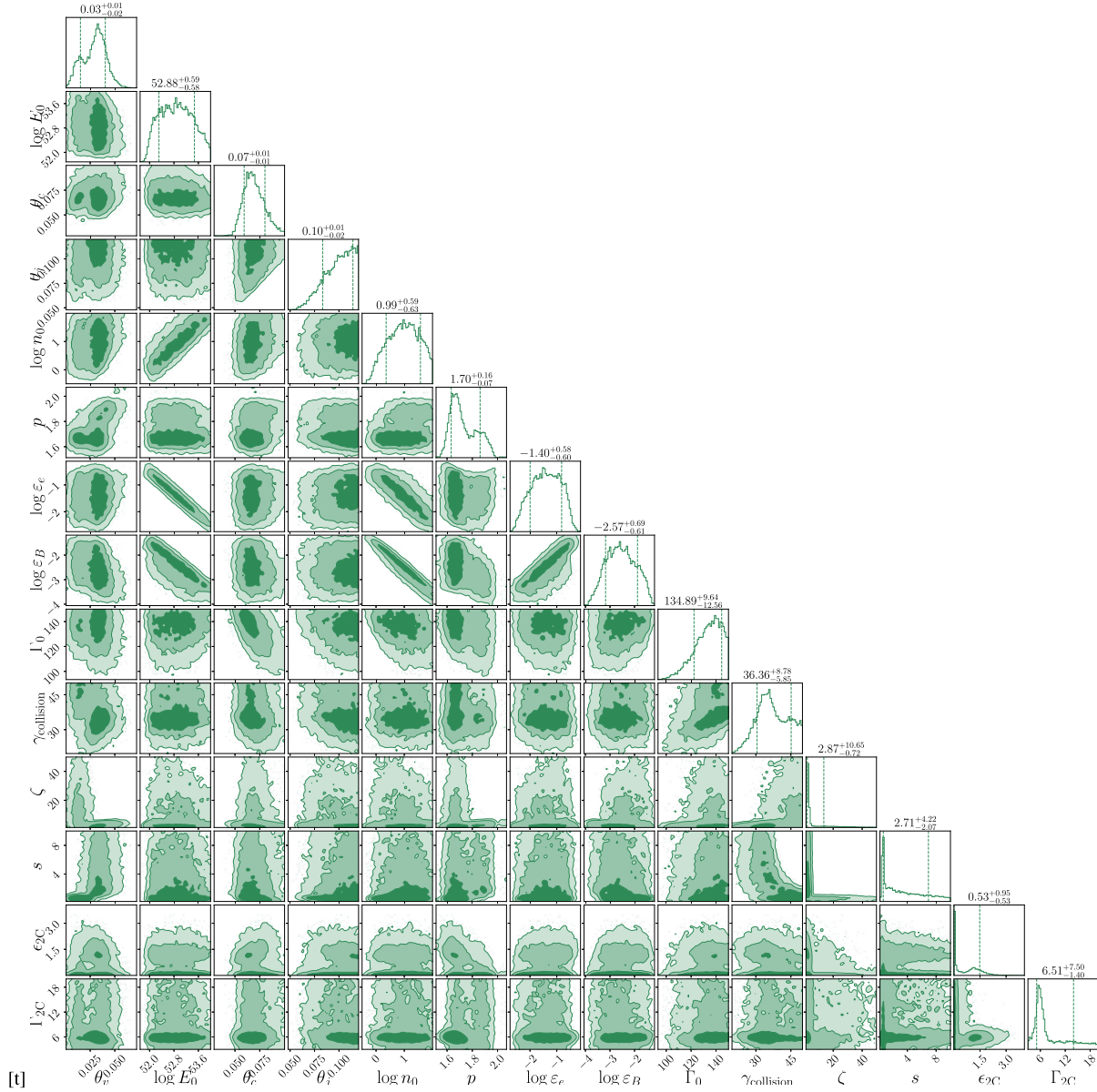


Figure C4. Posterior corner plot for the `twocomponent_redback_refreshed` fit to GRB 250818B. The panels show the marginalized posterior distributions and covariances of the free model parameters. Shown for completeness; see Table 1 for the adopted priors and posterior summaries.

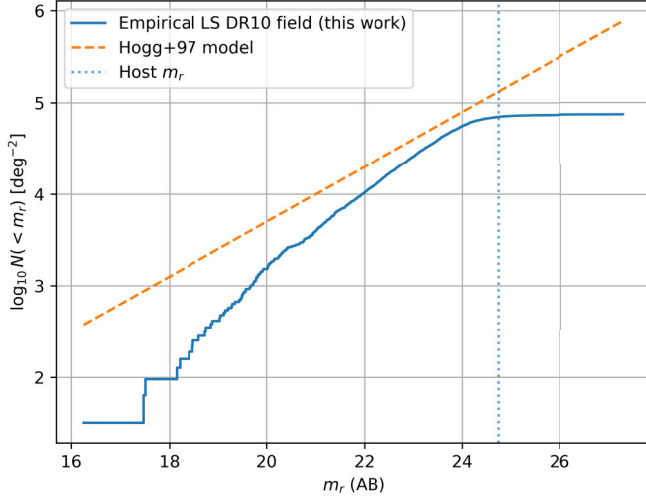


Figure C5. Cumulative galaxy counts in LS DR10 around GRB 250818B, measured within a 0.1° cone and restricted to galaxy-like, unmasked sources with significant r -band flux ($\text{type} \in \{\text{REX}, \text{EXP}, \text{DEV}, \text{SER}\}$, $\text{allmask}_g = \text{allmask}_r = \text{allmask}_z = 0$, $\text{flux}_r > 0$, $\text{flux_ivar}_r > 0$; blue step curve). The dashed line shows a simple D. W. Hogg et al. 1997 R -band number-counts model for comparison. The empirical counts follow a similar slope in $\log_{10} N(< m_r)$ versus m_r but with a lower normalization by a factor of ~ 2 , likely due to our strict selection and the limited field size. The dotted vertical line marks the LS DR10 candidate-host magnitude used to estimate $\sigma(< m_r)$ for the chance-coincidence calculation.

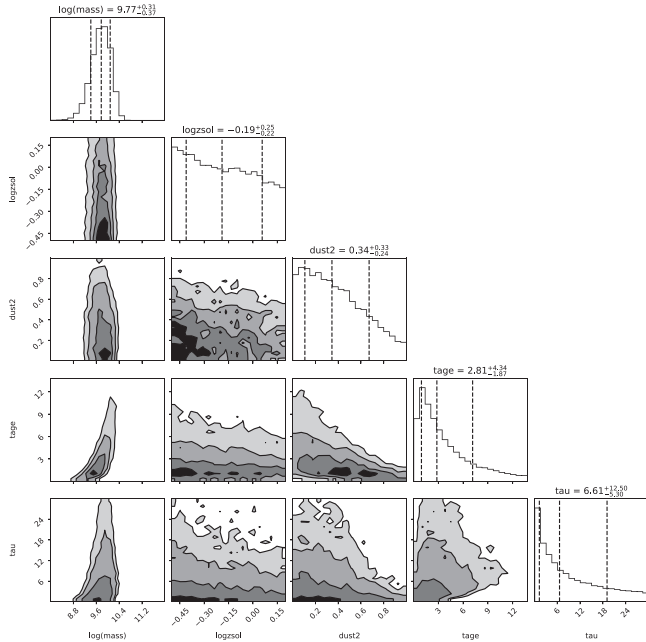


Figure C6. PROSPECTOR corner plot for the fitted parameters under the assumption that the LS DR10 candidate is the true host at $z = 1.216$ in the parametric delayed- τ model (e.g. stellar mass, metallicity, attenuation, population age, and τ). Shown for completeness; see Fig. B2 for the physically interpreted subset.

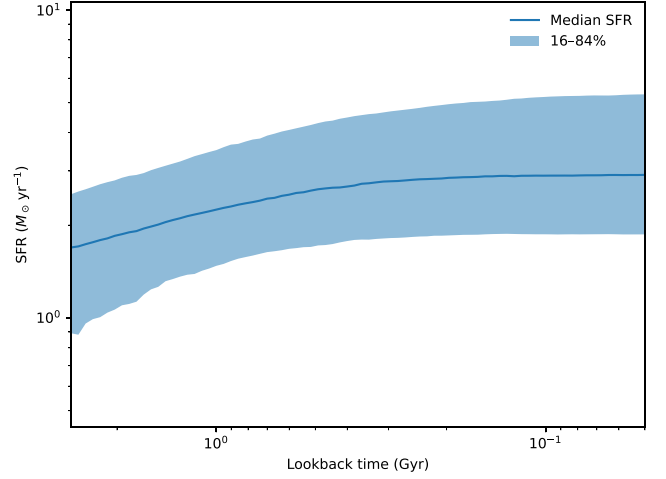


Figure C7. Star-formation history implied by the parametric delayed- τ PROSPECTOR fit under the assumption that the LS DR10 candidate is the true host at $z = 1.216$: posterior median SFR as a function of lookback time (solid line), with the 16–84 per cent credible interval (shaded). With the current photometric baseline, the recent SFR is weakly constrained; deeper blue/UV and NIR photometry would tighten the SFH constraints.

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