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# Supplementary information

# A nearby long gamma-ray burst from a merger of compact objects

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## Supplementary Methods

### Observations and Data Reduction

**Swift** - The *Swift* X-ray Telescope (XRT) began observations of GRB211211A at 69 s after the GRB trigger and continued monitoring for ~3 days. The X-ray lightcurve and spectra were retrieved from the *Swift* XRT GRB repository[77]. The GRB counterpart was detected by the UltraViolet and Optical Telescope (UVOT) in all filters. UVOT data were analyzed using HEASOFT v.6.30. Individual exposures from the same epoch were aligned and then combined using the task *uvotimsum*. To minimize the contamination from the nearby galaxy G1, we determined the source count-rates in 3” circular apertures with the background estimated in a concentric source-free annular region. We used an aperture correction to determine the equivalent source count-rates in a 5” aperture, and then applied standard UVOT magnitude zeropoints[78]. Late-time images were used to determine the host galaxy brightness using a 5” circular aperture. The photometry of the transient and its host galaxy is reported in Supplementary Table 1.

**Optical/nIR imaging** - Our observations of GRB211211A began at $T_0$+5.1 hr with the 50-cm Multicolor Imaging Telescopes for Survey and Monstrous Explosions (MITSUME[79,80,81]) acquiring 110×60 s simultaneous images in *g*, $R_c$, and $I_c$ filters. Observations were carried out for three consecutive nights, but the GRB counterpart was only detected on the first night. The data were reduced using the MITSUME pipeline[82] and image subtraction between the first, second and third epoch was performed using HOTPANTS[83]. Upper limits were derived by planting artificial sources of known brightness, then repeating the image subtraction step.

Starting on 2021 Dec 11 UT 22:11:29 (~$T_0$ + 9.0 hr), multi-band (*U, B*, *V*, *R*, *I*) optical observations of GRB211211A were carried out using the 4Kx4K CCD Imager mounted at the axial port of the 3.6m Devasthal Optical Telescope[84,85,86,87] (DOT). Observations continued until twilight time (~$T_0$ + 11.4 hr) and were repeated in subsequent nights until the optical counterpart was no longer detected. Starting on 12 Dec 2021 at 3:53 UT ($T_0$ + 15 hr), additional imaging of the GRB field was carried out with the 2.2m telescope, equipped with the Calar Alto Faint Object Spectrograph (CAFOS), at the Calar Alto Observatory in Almería (Spain) using the *g′r′i′* Sloan filters.

Additional epochs of observations were performed between 2021 Dec 31 and 2022 Jan 02 to search for the possible SN peak. We acquired multiple *R*-band images (24×300s) with the 1.3m Devasthal Fast Optical Telescope (DFOT) and deep *g′r′i′* exposures with the CAHA telescope. At late times, we targeted the field with the Large Monolithic Imager (LMI) on the 4.3-m Lowell Discovery Telescope (LDT) using the *u*, *g*, *r*, *i*, and *z* filters to refine the photometry of its host galaxy.

The data were pre-processed using standard CCD reduction techniques including bias subtraction, flat-fielding, fringe correction and cosmic-ray rejection. Aperture photometry on the GRB counterpart was performed using Source Extractor[88] and selecting circular apertures with radius 1.5 times larger than the image full width half maximum. Forced photometry was performed on images acquired at later times (>$T_0$ + 2 d). Host galaxy magnitudes were derived using Kron-like elliptical apertures (MAG AUTO). The photometric zeropoints were calibrated using the same nearby point sources in the Sloan Digital Sky Survey (SDSS[89]) and transformed using empirical equations[90].

We imaged the field with the *Hubble Space Telescope* (*HST*) using the WFC3/UVIS and IR cameras with the *F814W* and *F160W* filters, respectively. Observations were carried out between April 2 and April 21, 2022 (~$T_0$ + 4 months). The data were reduced using standard procedures within the DrizzlePac software[91] to align, drizzle, and combine exposures. We used Source Extractor to detect sources and perform aperture photometry. For each filter, we used the zeropoints stored in the keyword PHOTFLAM.

**Gemini Spectroscopy** - We utilized the Gemini Multi-Object Spectrograph (GMOS) mounted on the 8.1-m Gemini South telescope to obtain a series of 4×600 s spectra, using the R400 grating and a 1" slit. We chose a slit position angle (PA) of 64 deg such that the slit covers both the host galaxy's center and the GRB's optical position. The data were reduced and analyzed using standard procedures in Gemini IRAF. In order to correct for slit losses, the flux-calibrated spectra were matched to the photometry of the host galaxy. Line fluxes were derived by fitting each line with a Gaussian function and estimating the continuum from nearby spectral regions.

**White dwarf merger model**

One of the possible progenitors adopted to explain SN-less long GRBs is the merger of a white dwarf (WD) with either a NS or a stellar mass BH[92,93]. These are old stellar systems, and their mergers produce accretion disks with longer accretion timescales than those from compact binary mergers[94]. Therefore, they can potentially explain the lack of SN, the long gamma-ray duration, and the environment of hybrid GRBs. The merger ejecta contains a moderate amount (<0.1 $M_{sun}$) of radioactive $^{56}$Ni powering fast-evolving (weeks to month long) optical transients[95] with luminosities in the range $10^{40}$ - $10^{43}$ erg $s^{-1}$. However, past light curve calculations[96] of these electromagnetic counterparts resemble faint type Iax SNe, and do not match the colors and timescales of the excess emission in GRB211211A.

**Rate of events**

In 17 years of *Swift* operations at least 2 hybrid GRBs were identified, GRB211211A and GRB060614. This allows us to place a lower limit to the rate of hybrid GRBs:

$$R > 0.7 \frac{\Omega}{4\pi} \frac{1}{V_z} \frac{1}{\varepsilon T} \frac{1}{\eta} \approx 0.04\, Gpc^{-3}\, yr^{-1} \qquad (1)$$

where Ω~ 2.2 sr is the *Swift* field of view for partial coding >10%, $T$ ~ 17 yr the mission lifetime, ε ~78% its duty cycle[11], η ~ 17/20 the efficiency of SN searches, and $V_z$ ~ 7.3 $Gpc^3$ the comoving volume within $z \sim 0.3$. The factor 0.7 is the lower limit (68% confidence level, c.l.) on the number count derived from Poissonian statistics[97].

In a similar way we derive an upper limit to the rate by assuming that all the SN-less long GRBs within $z \sim 0.3$ belong to the class of nearby hybrid bursts. We consider events with $E_{\gamma,iso} > 10^{49}$ erg in order to minimize selection effects due to the trigger efficiency. This only excludes one burst (GRB111005A). The 68% c.l. upper limit on the number count is ~12, from which we derive $R < 0.8$ Gpc$^{-3}$ yr$^{-1}$ using Supplementary Equation (1).

For comparison, the observed rate of short GRBs[40] ranges between 2.2 Gpc$^{-3}$ yr$^{-1}$ and 6.4 Gpc$^{-3}$ yr$^{-1}$ (68% c.l.). This value was derived for luminosities $L_{iso} > 5 \times 10^{49}$ erg s$^{-1}$, and therefore does not include the contribution of under-luminous off-axis bursts. The observed ratio of hybrid to short GRBs is simply given by the ratio of the two distributions (0.8%-26% at the 68% c.l.). However, the local population of GW counterparts is likely dominated by faint events seen off-axis[98], whose rate of detection depends on the distribution of jet opening angles and their angular profiles. We parameterize these properties using the beaming factor $f_b$, and caution that its value may differ between the population of bursts (hybrid and short), thus affecting their relative ratio in the nearby Universe.

## Supplementary Table

### Supplementary Table 1 – UV, optical and nIR observations of GRB211211A.

Upper limits (u.l.) are 3σ. Values are corrected for Galactic extinction in the direction of the burst, $A_V = 0.047$ mag[99].

| $T - T_0$ (d) | Exposure (s) | Telescope | Filter | Magnitude AB | Error (68% c.l.) |
|---|---|---|---|---|---|
| 0.0009 | 9 | UVOT | *v* | 17.3 | u.l. |
| 0.0012 | 36 | UVOT | *White* | 20.33 | 0.25 |
| 0.0020 | 96 | UVOT | *White* | 21.2 | u.l. |
| 0.042 | 195 | UVOT | *u* | 19.75 | 0.13 |
| 0.044 | 193 | UVOT | *b* | 19.62 | 0.2 |
| 0.046 | 185 | UVOT | *White* | 19.6 | 0.06 |
| 0.049 | 196 | UVOT | *w2* | 19.59 | 0.12 |
| 0.051 | 195 | UVOT | *v* | 19.27 | 0.28 |
| 0.053 | 196 | UVOT | *m2* | 19.58 | 0.18 |
| 0.056 | 196 | UVOT | *w1* | 19.44 | 0.12 |
| 0.058 | 78 | UVOT | *u* | 19.38 | 0.16 |
| 0.19 | 877 | UVOT | *u* | 19.75 | 0.07 |
| 0.20 | 570 | UVOT | *b* | 19.79 | 0.17 |
| 0.24 | 3300 | MITSUME | *g* | 19.85 | 0.15 |
| 0.24 | 3300 | MITSUME | $R_c$ | 20.3 | 0.19 |
| 0.24 | 3300 | MITSUME | $I_c$ | 20.2 | u.l. |
| 0.25 | 467 | UVOT | *m2* | 20.5 | 0.16 |
| 0.29 | 3300 | MITSUME | *g* | 20.19 | 0.16 |
| 0.29 | 3300 | MITSUME | $R_c$ | 19.99 | 0.18 |
| 0.29 | 3300 | MITSUME | $I_c$ | 19.98 | 0.19 |
| 0.37 | 200 | DOT | *R* | 20.17 | 0.06 |
| 0.38 | 300 | DOT | *I* | 20.26 | 0.08 |
| 0.38 | 300 | DOT | *R* | 20.03 | 0.05 |
| 0.38 | 300 | DOT | *V* | 20.18 | 0.07 |
| 0.39 | 300 | DOT | *B* | 20.51 | 0.07 |
| 0.39 | 360 | DOT | *U* | 20.78 | 0.07 |
| 0.40 | 300 | DOT | *I* | 20.17 | 0.08 |
| 0.40 | 300 | DOT | *R* | 20.14 | 0.04 |
| 0.40 | 300 | DOT | *V* | 20.26 | 0.04 |
| 0.41 | 300 | DOT | *B* | 20.45 | 0.06 |

| | | | | | |
|---|---|---|---|---|---|
| 0.41 | 360 | DOT | *U* | 20.75 | 0.07 |
| 0.42 | 200 | DOT | *I* | 20.20 | 0.09 |
| 0.42 | 200 | DOT | *R* | 20.15 | 0.05 |
| 0.42 | 200 | DOT | *V* | 20.28 | 0.04 |
| 0.42 | 200 | DOT | *B* | 20.49 | 0.05 |
| 0.43 | 360 | DOT | *U* | 20.76 | 0.07 |
| 0.43 | 200 | DOT | *I* | 20.08 | 0.08 |
| 0.43 | 200 | DOT | *R* | 20.24 | 0.04 |
| 0.44 | 360 | DOT | *U* | 20.81 | 0.07 |
| 0.45 | 200 | DOT | *I* | 20.17 | 0.09 |
| 0.45 | 200 | DOT | *R* | 20.29 | 0.05 |
| 0.45 | 200 | DOT | *V* | 20.35 | 0.05 |
| 0.46 | 200 | DOT | *B* | 20.53 | 0.05 |
| 0.46 | 360 | DOT | *U* | 20.97 | 0.07 |
| 0.46 | 200 | DOT | *I* | 20.34 | 0.09 |
| 0.47 | 200 | DOT | *R* | 20.41 | 0.09 |
| 0.47 | 200 | DOT | *V* | 20.27 | 0.07 |
| 0.47 | 200 | DOT | *B* | 20.68 | 0.15 |
| 0.62 | 900 | CAHA | *i* | 20.71 | 0.09 |
| 0.63 | 900 | CAHA | *r'* | 20.73 | 0.09 |
| 0.64 | 720 | CAHA | *g'* | 21.16 | 0.08 |
| 0.75 | 1771 | UVOT | *w1* | 21.96 | 0.19 |
| 0.81 | 1771 | UVOT | *w2* | 22.32 | 0.20 |
| 0.83 | 370 | UVOT | *v* | 19.8 | u.l. |
| 0.93 | 1247 | UVOT | *u* | 22.15 | u.l. |
| 0.98 | 1949 | UVOT | *b* | 22.3 | 0.4 |
| 1.22 | 1422 | UVOT | *w1* | 22.3 | u.l. |
| 1.26 | 813 | UVOT | *m2* | 22.2 | u.l. |
| 1.26 | 6480 | MITSUME | *g* | 20.5 | u.l. |
| 1.26 | 6480 | MITSUME | $R_c$ | 20.8 | u.l. |
| 1.26 | 6480 | MITSUME | $I_c$ | 20.4 | u.l. |
| 1.41 | 900 | DOT | *R* | 22.54 | 0.09 |
| 1.42 | 900 | DOT | *I* | 22.1 | 0.15 |
| 1.43 | 1200 | DOT | *V* | 23.09 | 0.19 |
| 2.7 | 2550 | CAHA | *i'* | 24.51 | 0.28 |
| 2.9 | 4775 | UVOT | *m2* | 23.5 | u.l. |

| | | | | | |
|---|---|---|---|---|---|
| 3.4 | 3600 | DOT | *R* | 24.4 | u.l. |
| 4.0 | 900 | Gemini[100] | *K* | 22.4 | 0.1 |
| 4.4 | 3900 | DOT | *R* | 25.2 | u.l |
| 6.9 | 3780 | MMT[101] | *K* | 23.9 | 0.3 |
| 20.6 | 4000 | CAHA | *i'* | 23.2 | u.l. |
| 20.7 | 3200 | CAHA | *r'* | 24.4 | u.l. |
| 20.7 | 800 | CAHA | *g'* | 23.6 | u.l. |
| 22.5 | 7200 | DFOT | *R* | 24 | u.l. |
| | | Host Galaxy | | | |
| 142 | 1495 | UVOT | *w2* | 21.64 | 0.14 |
| 2.9 | 4775 | UVOT | *m2* | 21.52 | 0.15 |
| 140 | 2420 | UVOT | *w1* | 21.50 | 0.18 |
| 0.2 | 877 | UVOT | *u* | 21.08 | 0.18 |
| 0.5 | 200 | DOT | *B* | 20.14 | 0.10 |
| 1.4 | 200 | DOT | *V* | 19.60 | 0.10 |
| 3.4 | 200 | DOT | *R* | 19.46 | 0.05 |
| 22.5 | 7200 | DFOT | *R* | 19.50 | 0.10 |
| 131 | 1400 | LDT | *u* | 20.95 | 0.04 |
| 172 | 300 | LDT | *g* | 19.93 | 0.01 |
| 172 | 300 | LDT | *r* | 19.50 | 0.01 |
| 131 | 600 | LDT | *i* | 19.20 | 0.01 |
| 131 | 600 | LDT | *z* | 19.07 | 0.02 |
| 111 | 2160 | *HST* | *F814W* | 19.24 | 0.01 |
| 114 | 4823 | *HST* | *F160W* | 18.93 | 0.01 |
| Archival | – | WISE[102] | *W1* | 19.88 | 0.05 |
| Archival | – | WISE | *W2* | 20.68 | 0.19 |

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