A comprehensive broadband analysis of the high-redshift GRB 240218A

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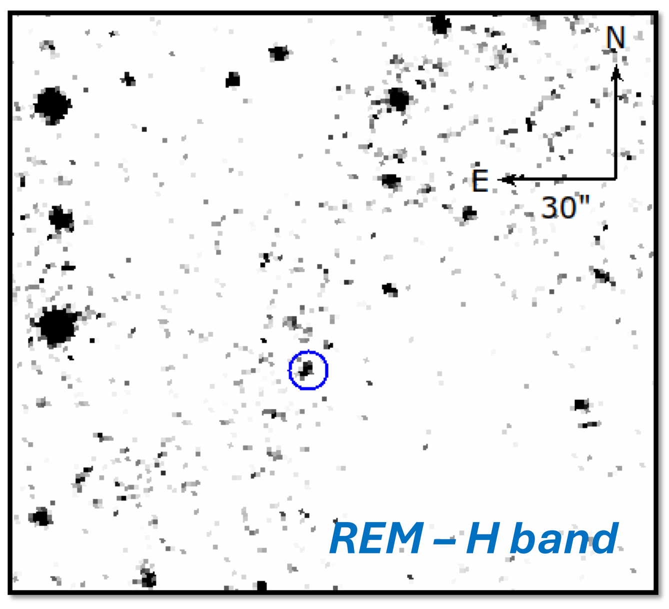
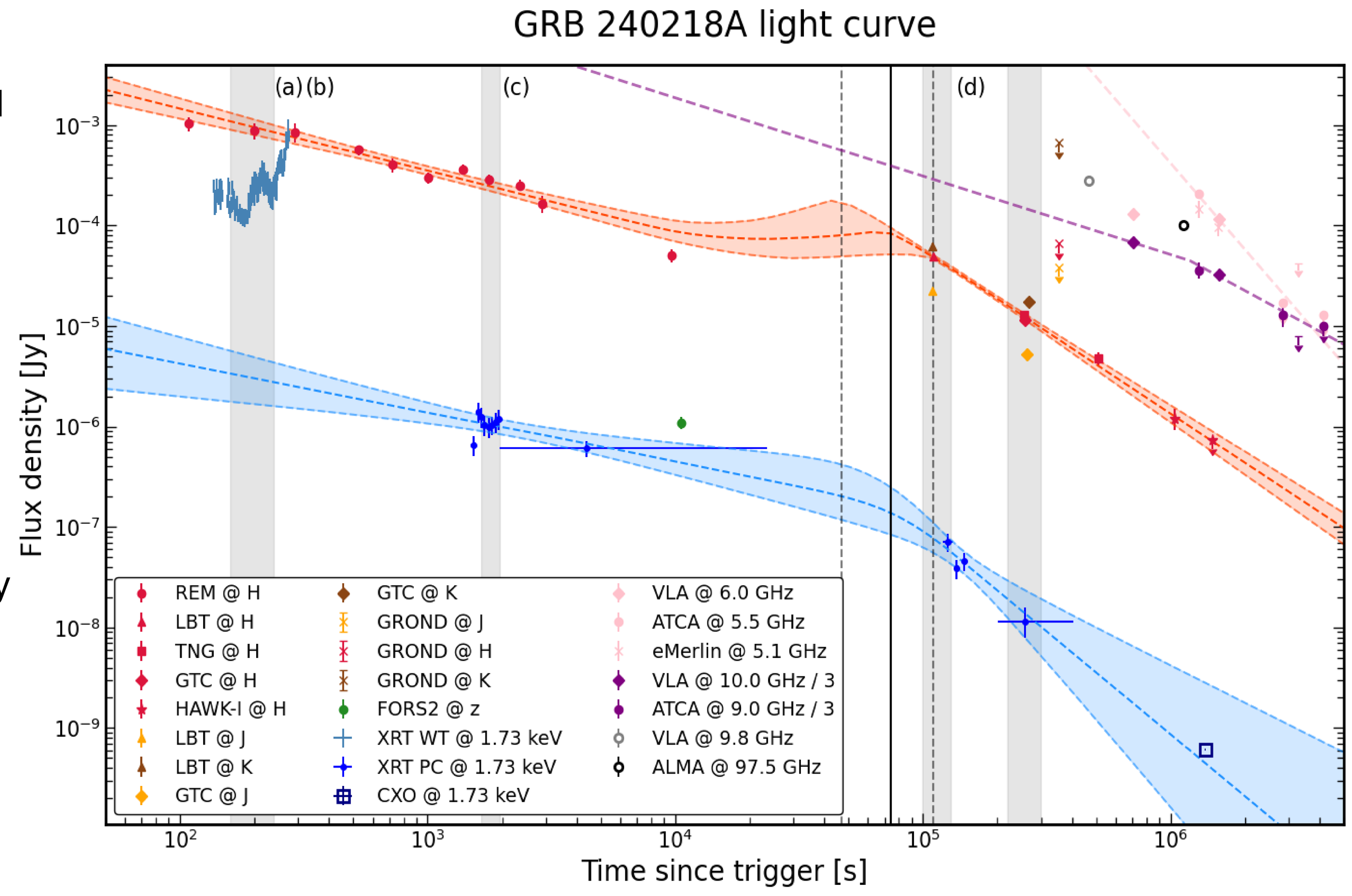
GRB 240218A - observations and the light curve

- GRB 240218A was initially discovered by the *Neil Gehrels Swift Observatory* and *Fermi*-GBM Telescope. Follow-up observations with multiple ground-based instruments enabled the construction of a multi-band, multi-epoch light curve.
- The near-infrared (**NIR**) afterglow was discovered by the **REM** telescope. We obtained long-lasting **X-ray** and NIR (*H*-band) light curves, with one detection in the optical band as well. **Radio** observations in the C (5-6 GHz) and X (9-10 GHz) bands were also secured.

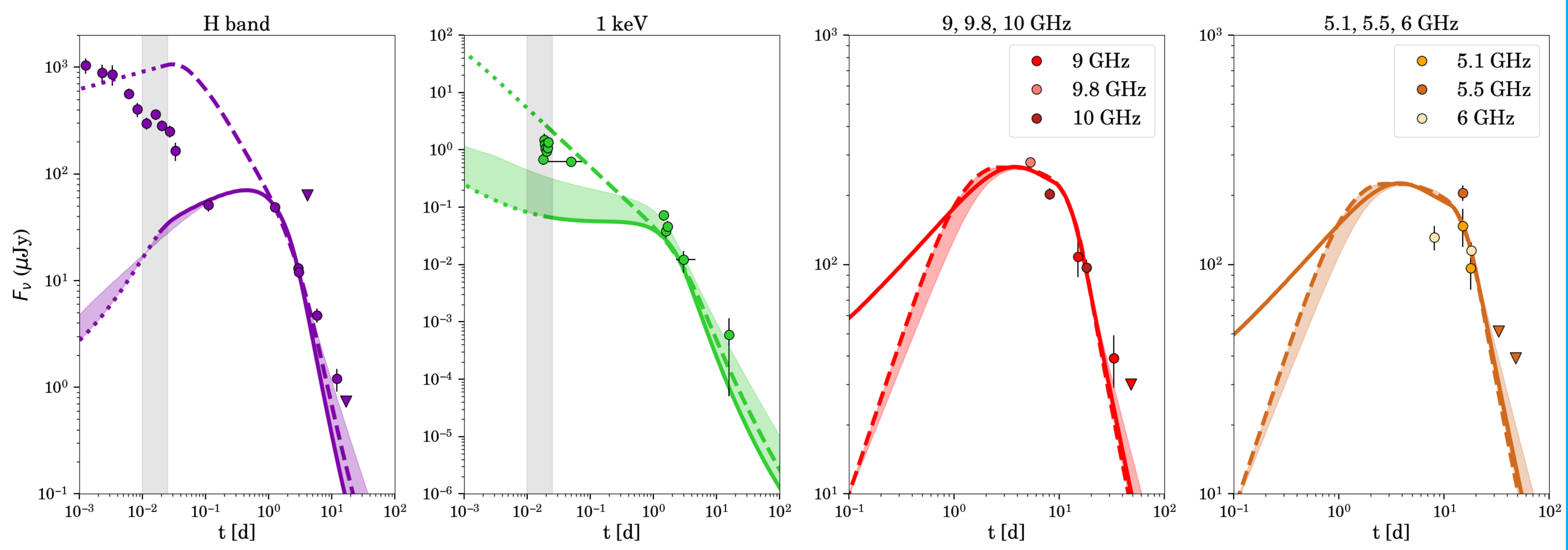


- The light curve spans from the radio to the X-rays, **from 68 s to 48 d** from the GRB initial discovery. We studied in detail its temporal and the spectral energy distribution (SED) evolution.
- A comparison of its prompt-phase and afterglow properties with previously discovered high-z GRBs and with the population of LGRBs (BAT6 sample) at lower distances was also performed.



Broad-band physical modelling and SED results

- We performed a **physical modelling** of the X ray-to-radio data using the afterglowpy package, both with a top-hat on-axis model and with a Gaussian off-axis jet. Both models fit the radio, NIR and X-ray light curves well after 0.1 days from the GRB trigger, and under/over-predict the early X-ray and NIR fluxes. As also indicated by the simultaneous X-ray **flaring** activity, these observations could be associated with some still-ongoing central engine activity.
- The **off-axis Gaussian jet** fit with jet spreading suggests a **very narrow jet** with a total jet energy of log(E_{jet}/erg) = 52.5 and an ISM density of log(n/cm^{-3}) = 1.2. The jet core opening angle is $\boldsymbol{\theta_c} = 1.26^{+0.17}_{-0.06}$ deg, while the observer's viewing angle is $\boldsymbol{\theta_V} = 2.52^{+0.57}_{-0.29}$ deg.



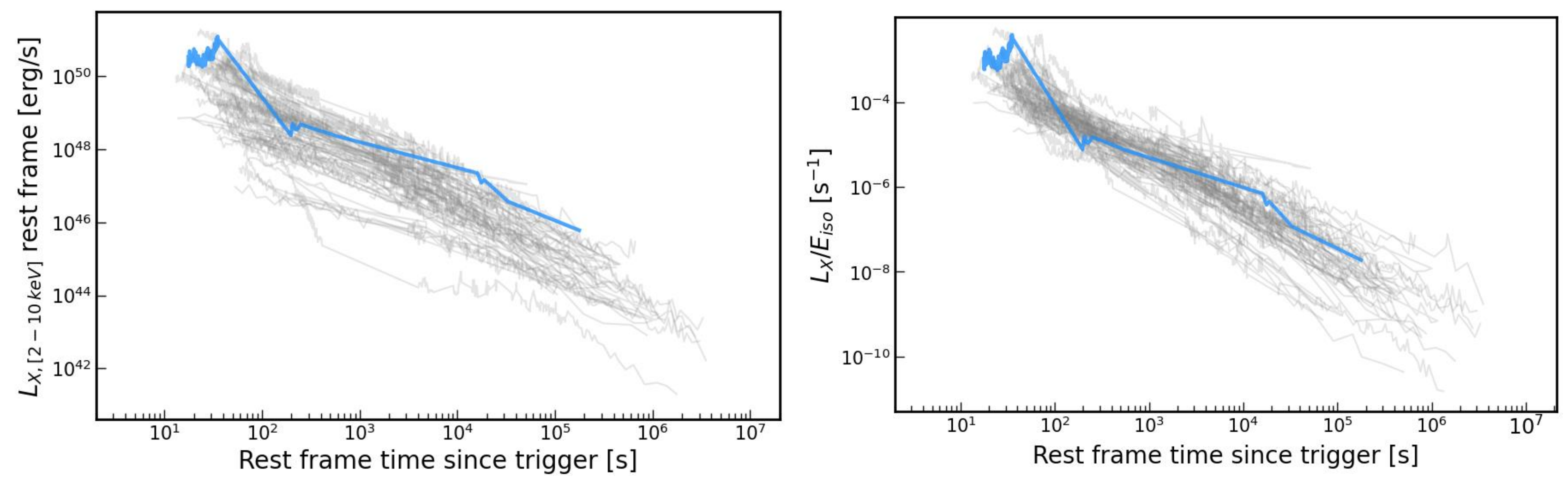
- We derived a lower limit, $\Gamma > 80$, from which we estimated the corrected $E_{iso,corr} > 2 \times 10^{54}$ erg and $E_{p,z,corr} > 10^4$ keV, accounting for the jet inclination. These results make GRB 240218A **more energetic** than the majority of LGRBs but **still within** the 3σ scatter region of the **Amati relation**, as expected from small θ_V.
- From the SED analysis results, at early time it is not possible to safely associate the gamma, X-ray and NIR emissions to the same origin, but the physical modelling suggests the presence of an extra compontent on top of the NIR afterglow. At later times, results align with expectations from the forward shock (FS) model in a uniform interstellar medium (ISM), supporting the afterglow origin for the broad-band emission.

The jet opening angle of high-z GRBs

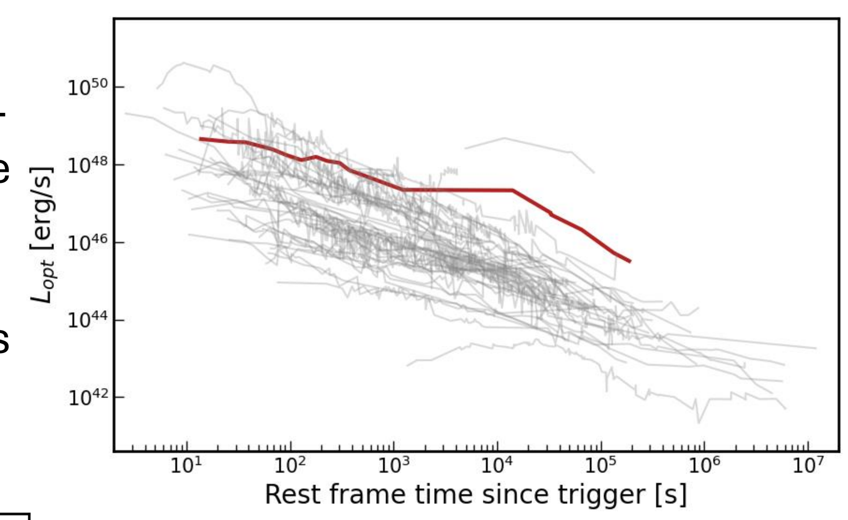
- From our modelling we estimated the time of a common break in the X-ray and NIR light curves: $\boldsymbol{t_b} = t - t_0 \sim 74132$ *s* = 0.86 d. The SED analysis and the physical modelling support its **jet break** nature. From this estimate, we computed the jet opening angle to compare GRB 240218A with the population of LGRBs. We obtained $\theta_{jet} = 2.20^{+0.32}_{-0.39}$ deg, that is **narrower than the majority of long GRBs** ($\theta_{z\sim1} = 7.4^{+11}_{-6.6}$ deg), and consistent with the estimates of other (see e.g. Laskar+14, Laskar+18), but not all (GRB 210905A, Rossi+22), high-z bursts.
- GRB 240218A supports the hypothesis of **more collimated jets at high redshift**, though potential **observational bias** may influence this result. Confirming this requires further future observations.

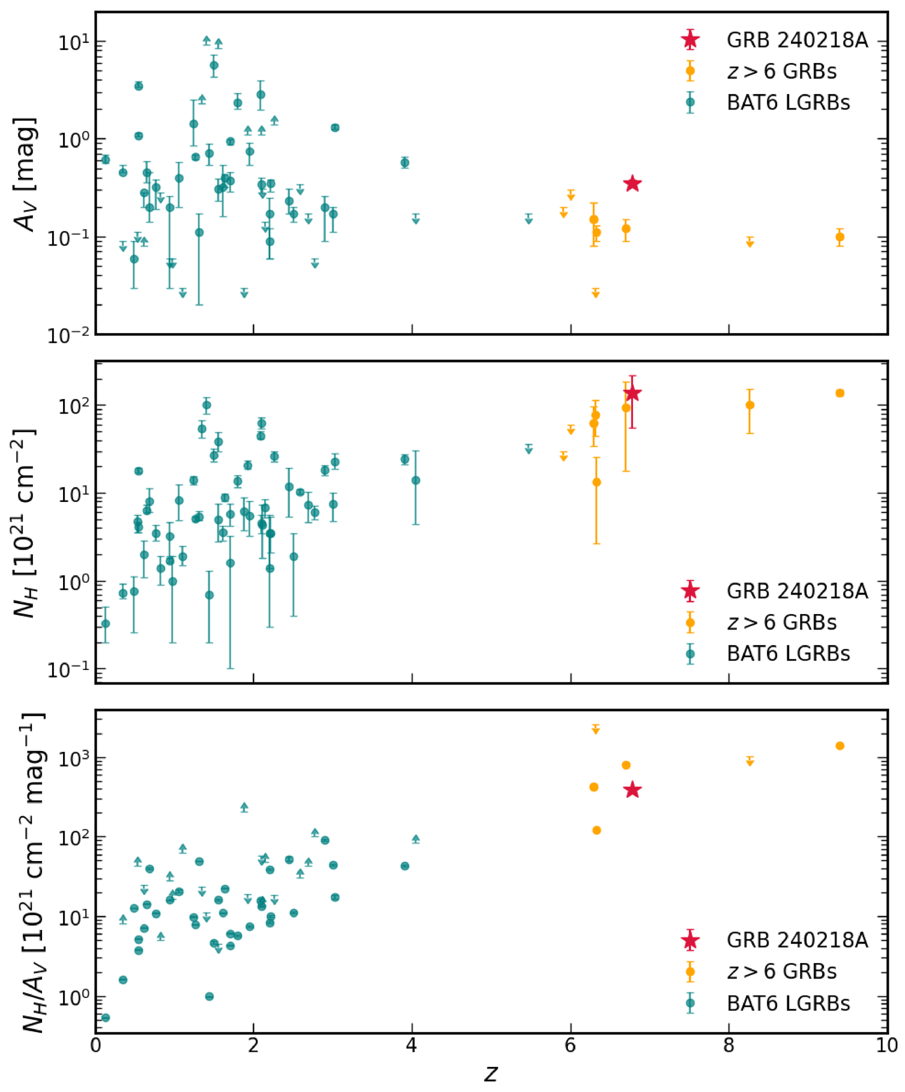
Comparison with high- and low-z GRBs

- GRB 240218A is consistent with the Amati and Yonetoku relations and with the 'Ghirlanda' relation between the E_{peak} and the $E_{jet,corr}$, consistently with LGRBs with early jet break time (Wang et al., 2018). This confirms that GRB 240218A is not different in terms of **energetics** from low-z bursts, nor does it support the presence of different progenitors at high z.
- We put the X-ray light curve in the GRB rest frame to test its consistency with the LGRBs belonging to the BAT6 sample (Salvaterra et al., 2012). The GRB 240218A light curve aligns with the most luminous curves of the distribution, as expected for a high-redshift event.
- The E_{iso}-normalized curve closely matches the low-z bursts population. The **similarity of high- and low-z GRBs for the X-ray emission** is further strenghtened by the consistency of GRB 240218A with the prompt-afterglow correlations derived by D'Avanzo et al. (2012).



- We moved the **NIR** light curve to the *U*-band **rest frame** to compare it with the BAT6 sample (Melandri et al., 2014). GRB 240218A is consistent with the LGRBs population at early time, then is brighter than the other curves but one.





- From the SED analysis results, we derived an optical extinction of $\boldsymbol{A_V}$ = 0.35 mag, in line with the population of LGRBs exhibiting **negligible extinction**. This is expected for high-z events and supported by previous studies.
- We obtained log($\boldsymbol{N_{H,rf}}$/cm^{-2}) = 23.1, consistent with other high-z GRBs and with a potential redshift evolution of this parameter. However, this trend arises from the lack of low N_H values for high-z events due to the absorption by intervening systems and diffuse intergalactic medium along the line of sight.

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Based on the paper Brivio et al. (2025), Astronomy & Astrophysics, in press.