# GRB 241030A:
# A puzzling afterglow in disguise


**Jean-Grégoire Ducoin**

CPPM, Aix-Marseille Université


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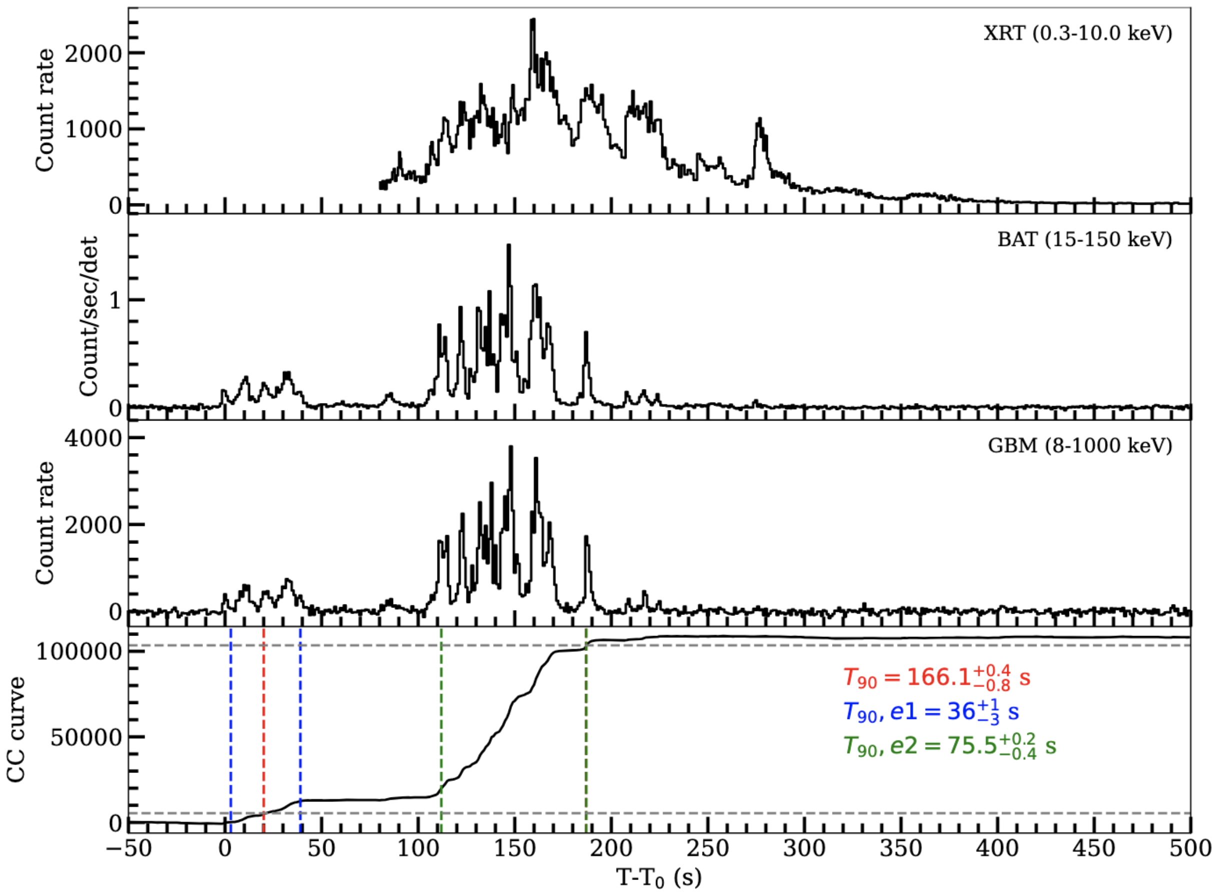
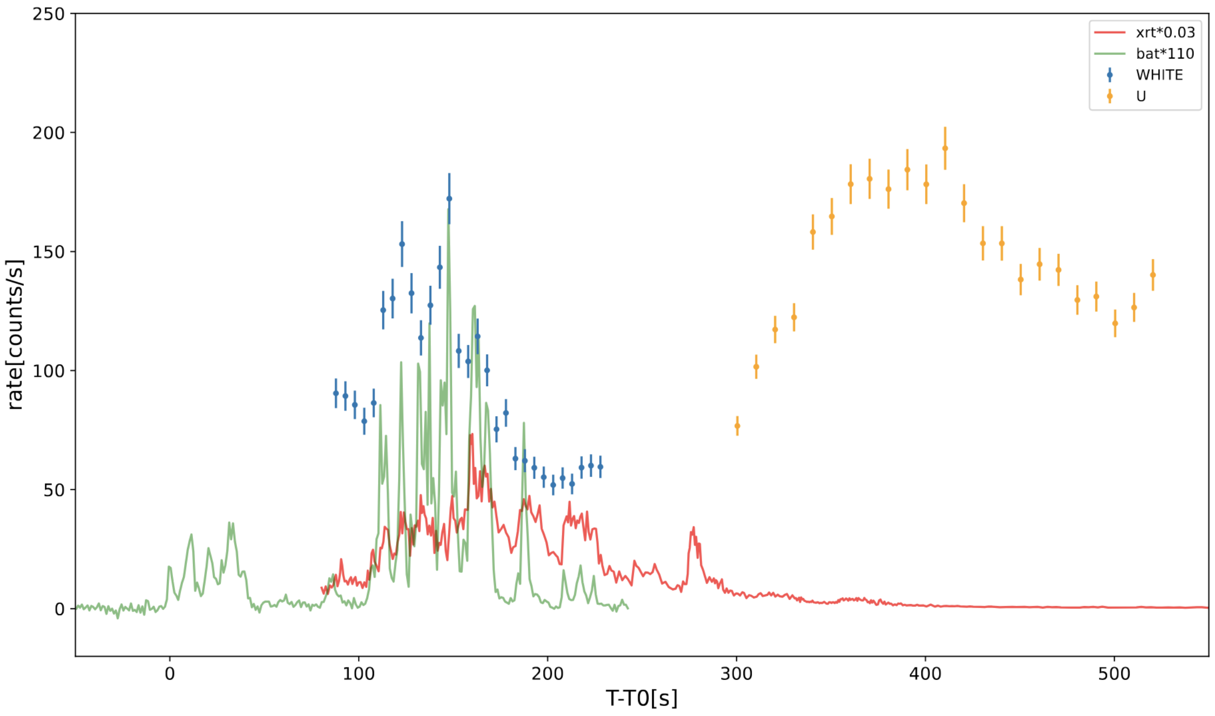
# GRB 241030A: prompt emission




Varun et al. | 2510.24864

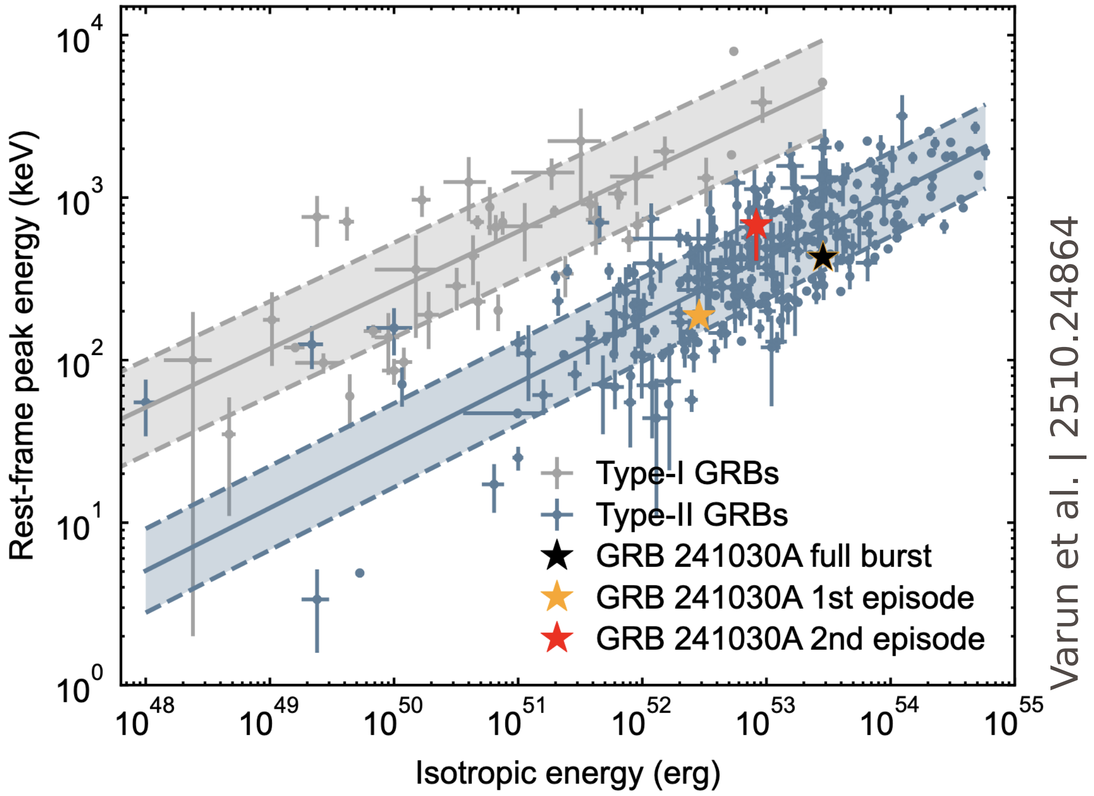



Wang Q.-L. et al. 2025 | ApJ 987, 129

# GRB 241030A: prompt emission

| | |
|---|---|
| **$T_{90}$** | 166s (50 – 300 keV, Fermi-GBM, 38015)<br>211s (18 keV – 1 MeV, Konus-Wind, 37982)<br>208s (80 – 950 keV, GRBAlpha, 38074)<br>? (15 keV – 5 MeV, SVOM-GRM, 37972)<br>173s (15 – 160 keV, Swift-BAT, 38010) |
| **Redshift** | z = 1.411 (spectroscopic, Zheng et al. 2024, 37959; Li et al. 2024, 38027) |
| **$E_{iso}$** | ~ 4 x $10^{53}$ erg |

A quite standard long GRB with multiple emission episodes during the prompt




$E_p$ – $E_{iso}$ diagram

# GRB 241030A: prompt emission

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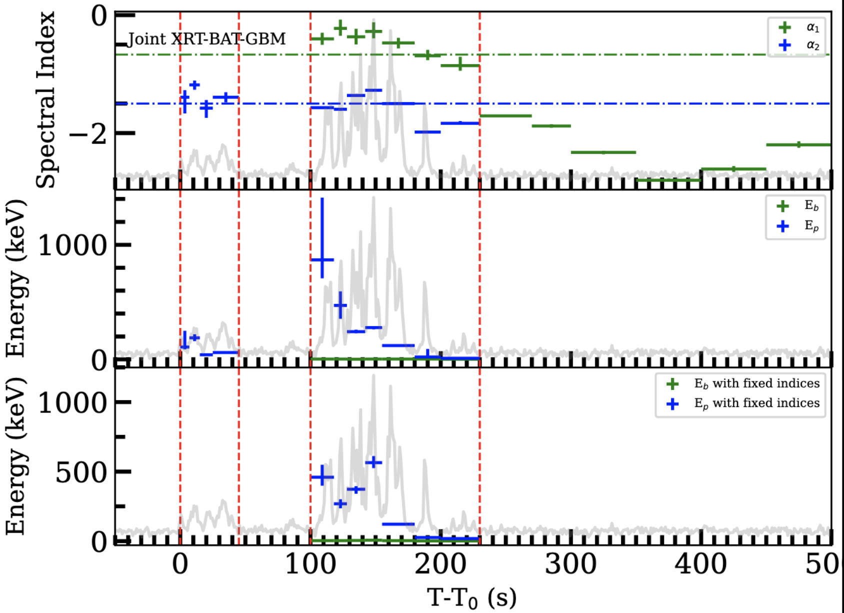
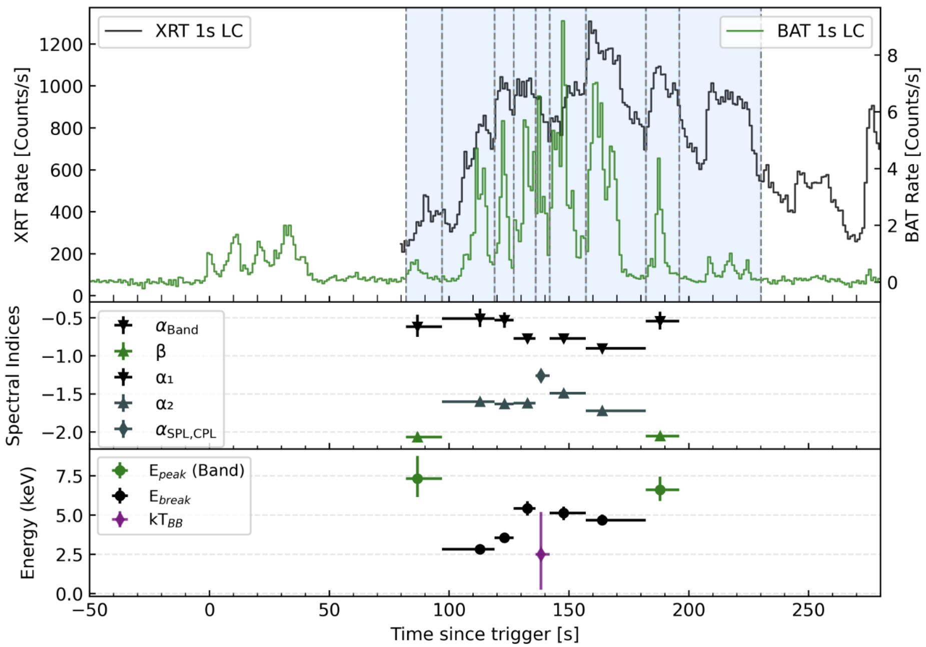
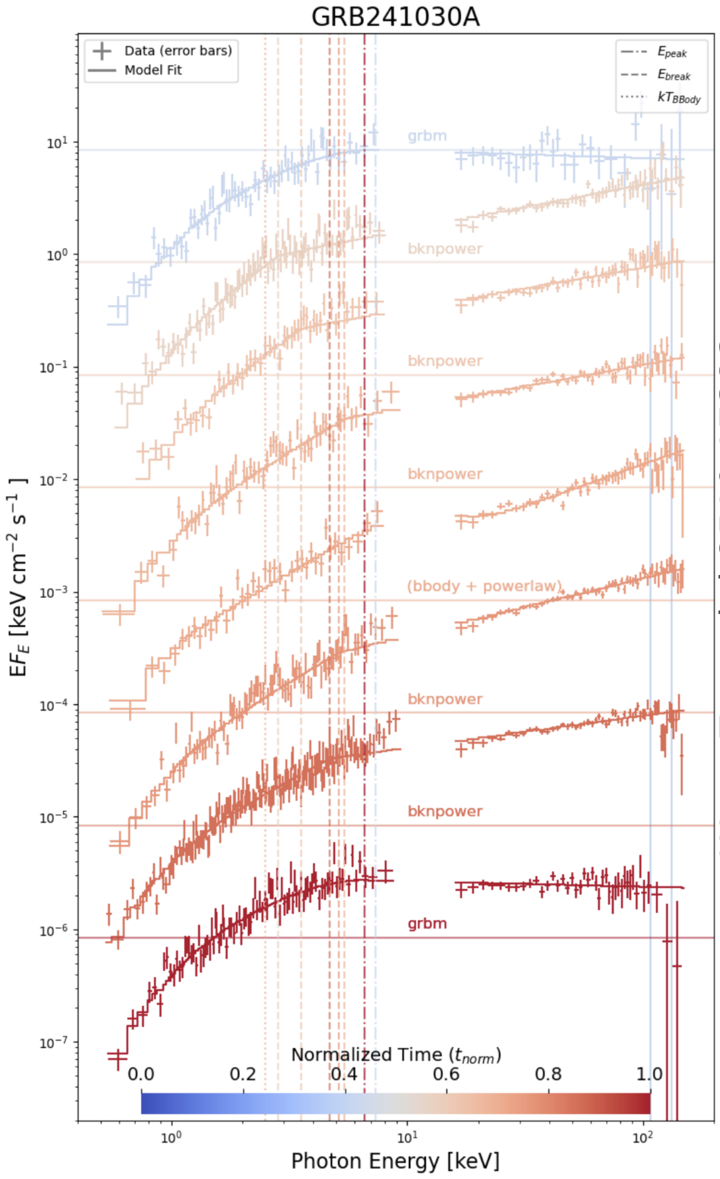



Study of time lags + joint gamma & X-ray data:
Internal shocks with varying injection LF

Wang Z. et al. | 2510.17323




Study of multiple (46) GRBs (110 pulses total):
- 241030A has bursts 1 & 9 not consistent with Band




Wang Z. et al. | 2510.17323

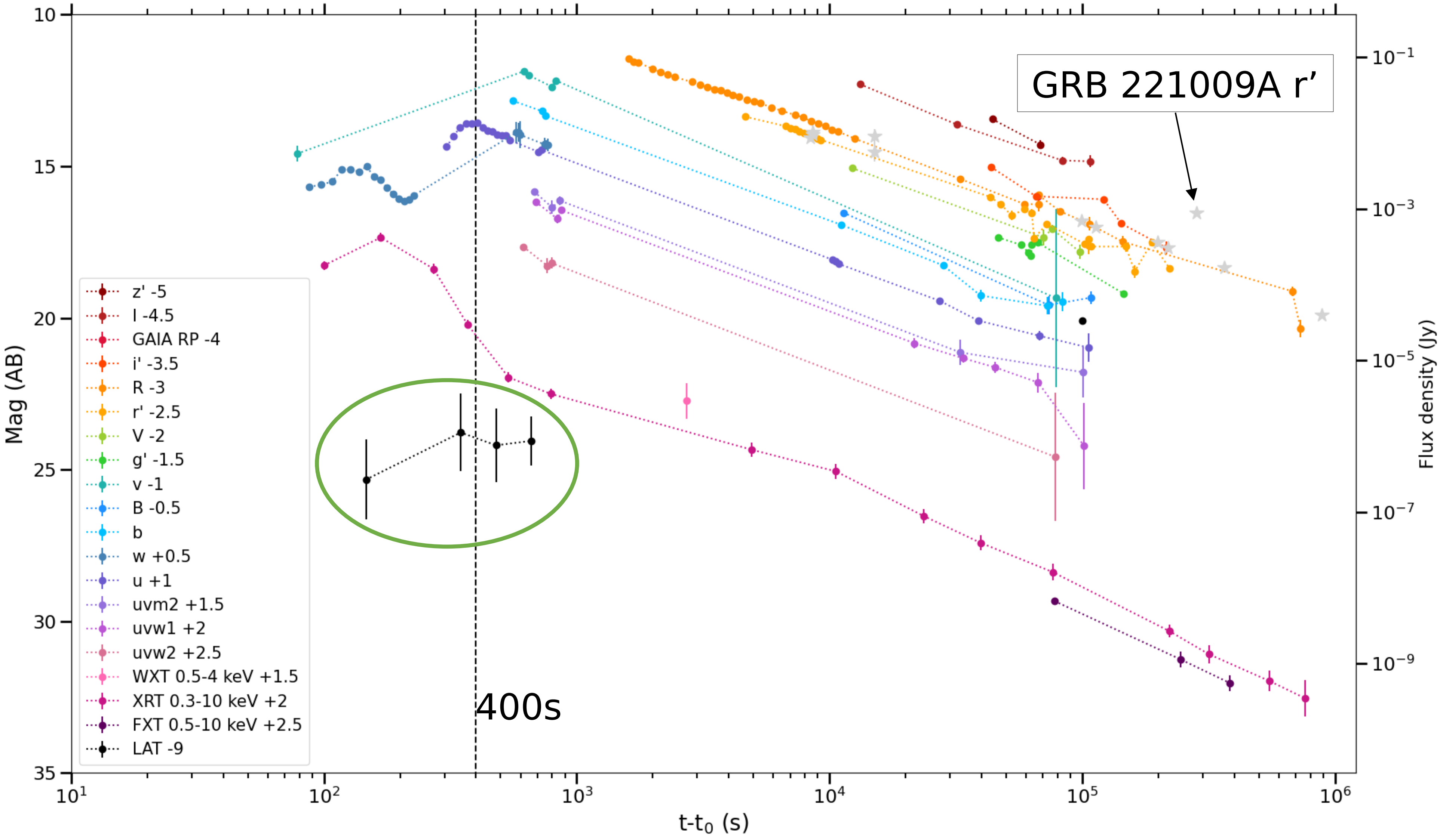
# GRB 241030A: afterglow observations

**Gamma/X-ray observations:**

- Swift-XRT
- Fermi-LAT
- EP-WXT
- EP-FXT

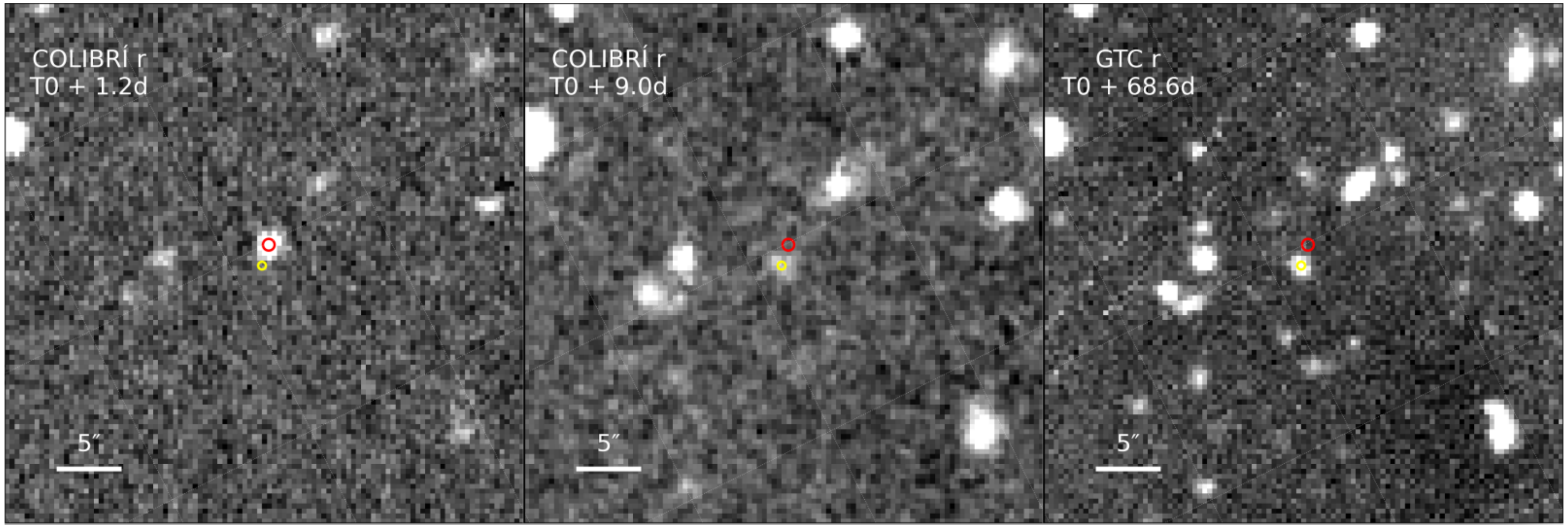
**Optical observations:**

- Swift-UVOT (w, u, v, b, uvw1, uvw2, uvm2)
- TRT-SRO (B, V, R, I)
- COLIBRÍ (r’)
- KNC (I, g’, r’, GAIA RP, V)
- AbAO-T70 (R)
- AbAO-T150 (i’, r’)
- KAO (i’, r’, z’, g’)
- HAO (R, g’)
- FRAM-CTA-N (R)
- TNOT (i’, r’)
- NAO-1.5m (R)
- NAO-2m (R)



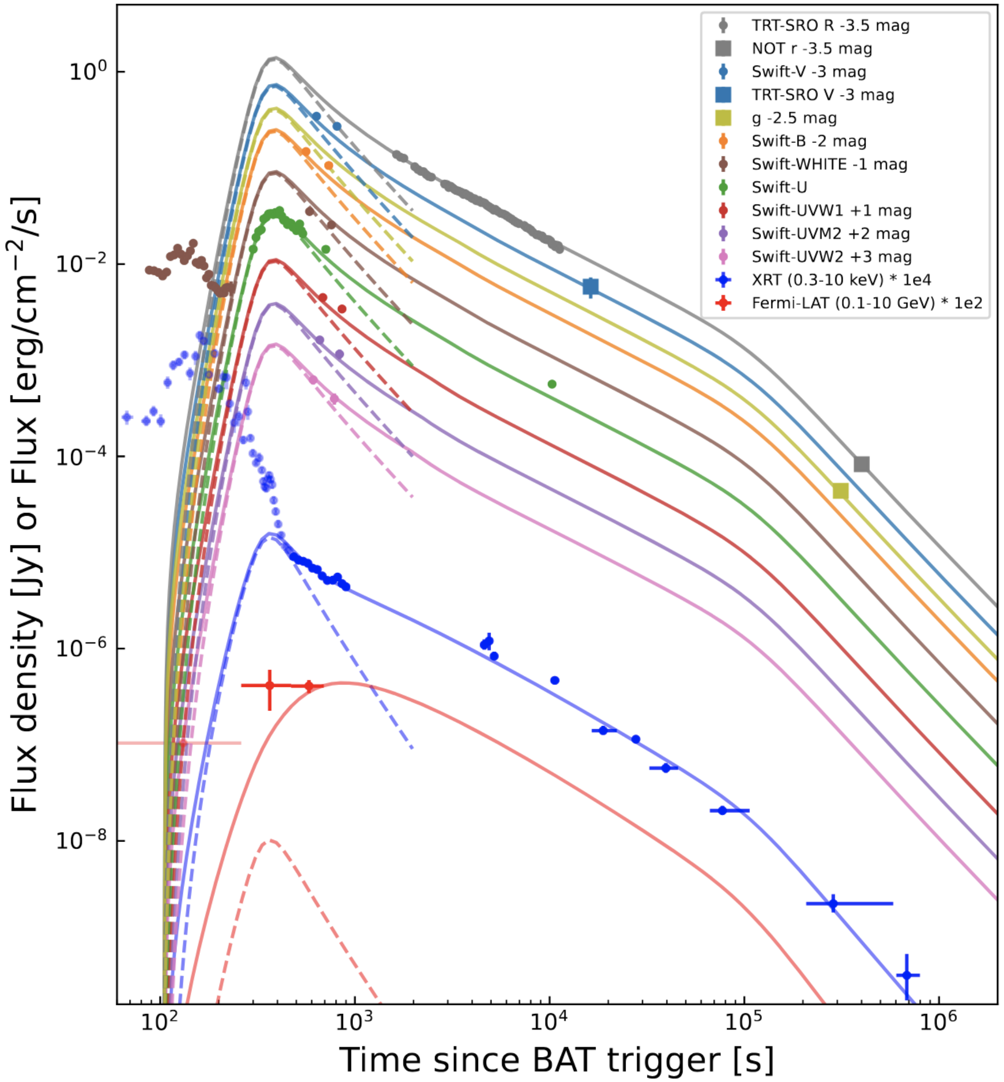
# GRB 241030A: host galaxy?

- Using the long-term observation from COLIBRÍ when the afterglow is not detectable, an extended source is found close to GRB site
- Follow-up observations with CFHT-MegaCam and GTC-HiPERCAM, with clear source detection
- But at a redshift of z = 1.411, this corresponds to a source offset of 15.10 ± 1.56 kpc, significantly larger than typical long GRBs offsets
- Galaxy SED fitting gives z ~ 0.5
- **Conclusion**: This is a foreground galaxy, and no host galaxy was detected down to magnitudes $i$ < 25.62 and $r$ < 25.82 (but this does not exclude the presence of a typical faint GRB host at > 26 mag)



# GRB 241030A: afterglow modeling

Wang Q.-L. et al. 2025 | ApJ 987, 129




Afterglow fit by Wang et al. 2025 with a jet break at $10^5$ s

Our data set is more complete, we do not see any jet break before $10^6$ s

# GRB 241030A: afterglow modeling

## Empirical analysis

- Temporal slope: $\alpha = -1.23 \pm 0.01$ (all bands)
- A slight steepening in X-rays after $10^4$ s
- Spectral slope: $\beta = -0.70 \pm 0.01$ (from optical to X-rays)

→ Temporal slope consistent with a slow-cooling ejecta propagating in a constant-density ISM, with optical and X-ray frequencies between $\nu_m$ and $\nu_c$

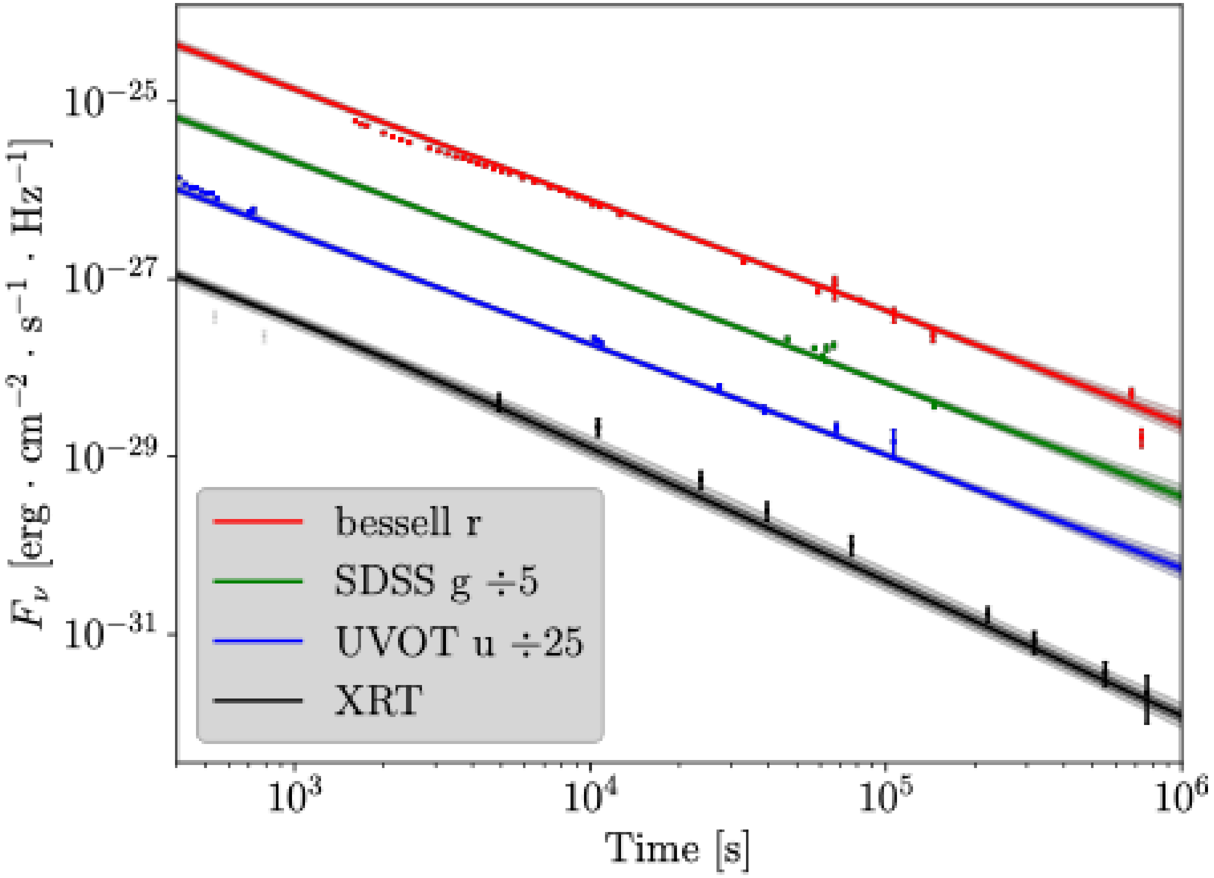
→ A wind-like medium is disfavoured

→ Slight inconsistency between $\alpha$ and $\beta$, giving $p = 2.64$ and $p = 2.40$ respectively (but consistent with particle acceleration theory)

# GRB 241030A: afterglow modeling

| Parameters | Symbol | Prior | NMMA/ AFTERGLOWPY |
|---|---|---|---|
| cos inclination [rad] | $\cos(\iota)$ | $[0, 1]$ | $0.97^{+0.02}_{-0.03}$ |
| log isotropic kinetic energy [erg] | $\log_{10}(E_0)$ | $[50, 60]$ | $56.9^{+1.6}_{-1.1}$ |
| jet core angle [rad] | $\theta_c$ | $[0.001, \frac{\pi}{18}]$ | $0.15^{+0.02}_{-0.04}$ |
| wing factor | $\alpha_w$ | $[0.2, 3.5]$ | $2.72^{+0.72}_{-1.02}$ |
| log interstellar medium density [cm$^{-3}$] | $\log_{10}(n_{ism})$ | $[-6, 4]$ | $2.9^{+1.0}_{-4.6}$ |
| electron spectrum power index | $p$ | $[2, 3]$ | $2.62^{+0.05}_{-0.04}$ |
| log electron energy fraction | $\log_{10}(\epsilon_e)$ | $[-4, 0]$ | $-2.25^{+0.67}_{-1.27}$ |
| log magnetic energy fraction | $\log_{10}(\epsilon_B)$ | $[-8, 0]$ | $-6.98^{+2.64}_{-0.90}$ |
| log accelerated electrons fraction | $\log_{10}(\zeta)$ | $[-3, 0]$ | - |
| initial Lorentz factor | $\Gamma_0$ | $[50, 500]$ | - |
| systematic uncertainty [mag] | $\sigma_{sys}$ | $[0.01, 2]$ | $0.21^{+0.03}_{-0.03}$ |

**Analysis with NMMA / afterglowpy**




Posterior light curve contours in three optical bands + X-rays

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## Analysis with NMMA / afterglowpy

**Extremely large jet energy**

- Even correcting for jet opening angle we get $E_k \sim 1.6 \times 10^{54}$ erg
- Assuming accretion-to-jet efficiency of 1% (BZ, optimistic scenario), that means $2 \times 10^{55}$ – $7 \times 10^{56}$ erg of accreted energy
- This is the rest-mass energy of 11 – 400 $M_{Sun}$ !
- Compared to the prompt $E_{iso} \sim 4 \times 10^{53}$ erg, this leads to a prompt efficiency of $< 10^{-2}$

**Large jet opening angle**

- Close to 10°, upper bound of our prior
- Not impossible, but not standard

**Large external density**

- Again very unusual

**Low $\epsilon_e$ and $\epsilon_B$**

- Again, very unusual. is typically 0.1 with little variability.
- This means we have an extremely energetic, but extremely inefficient jet unable to accelerate particles efficiently

# GRB 241030A: afterglow modeling

## Why is this afterglow hard to fit?

In a synchrotron-only scenario, this is due to the combination of:
- A very luminous afterglow intrinsically
- The necessity to be in the slow cooling regime and between $\nu_m$ and $\nu_c$ in optical and X-rays, in particular :
    - $\nu_m$ must be below the optical band at the earliest times
    - $\nu_c$ must pass in the X-ray band at $10^4$ s

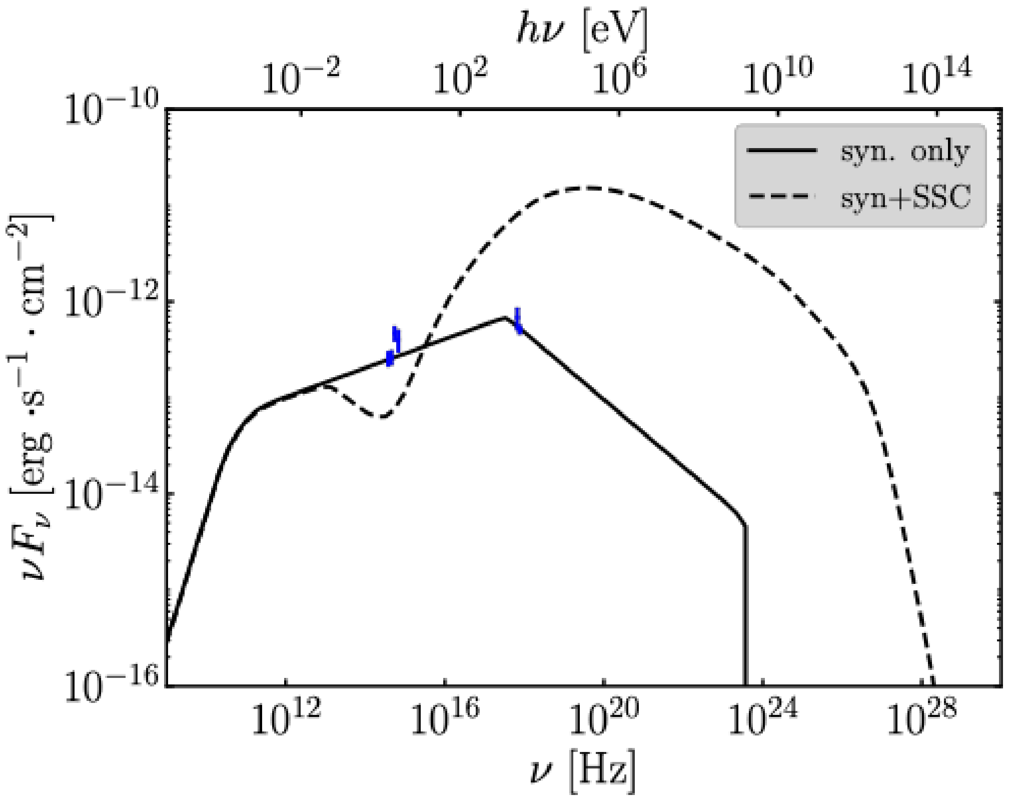
# GRB 241030A: afterglow modeling

**SSC emission with our parameters**

With $\epsilon_B \sim 10^{-6}$ naturally $\frac{\epsilon_e}{\epsilon_B} \gg 1$ ,

which implies **strong SSC emission**

The results obtained with NMMA / afterglowpy are impacted by SSC!




Spectrum at 8 x $10^4$ s (after the temporal break in X-rays)

# GRB 241030A: afterglow modeling

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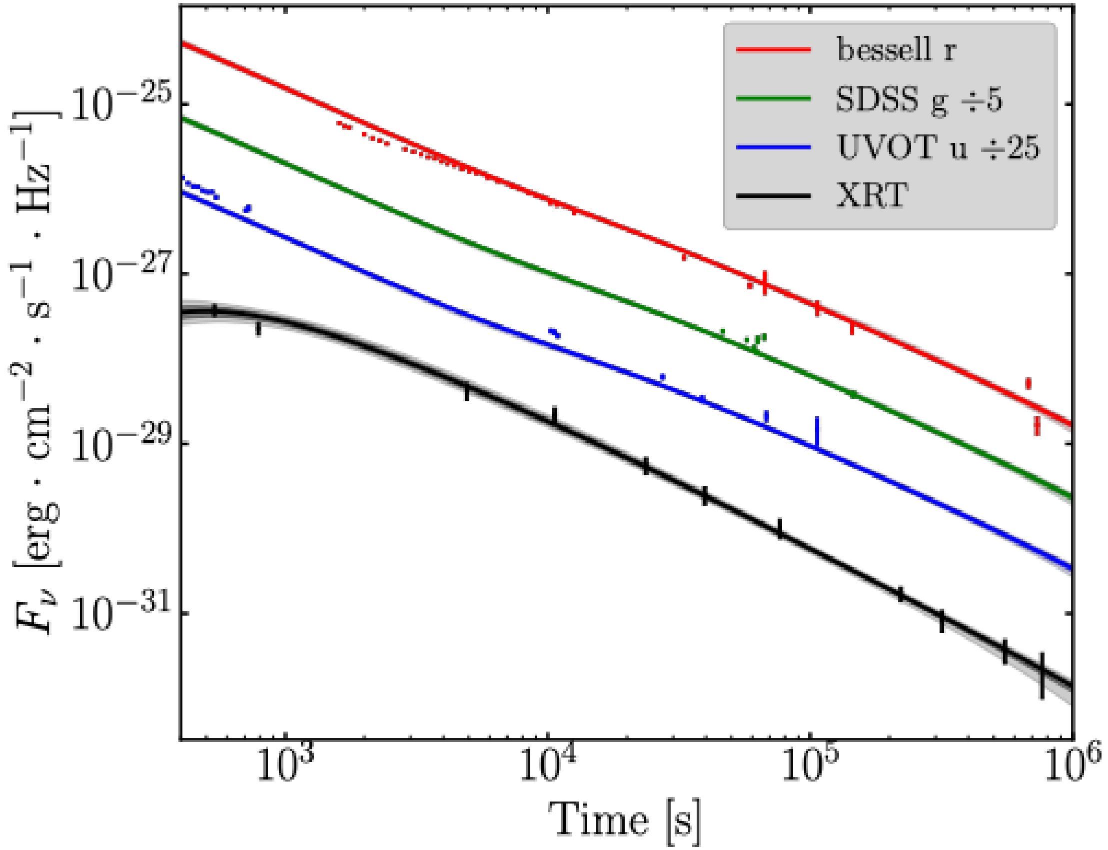
| wing factor | $\alpha_w$ | $[0.2, 3.5]$ | - |
| log interstellar medium density [cm$^{-3}$] | $\log_{10}(n_{ism})$ | $[-6, 4]$ | $2.5^{+0.7}_{-0.7}$ |
| electron spectrum power index | $p$ | $[2, 3]$ | $2.57^{+0.16}_{-0.06}$ |
| log electron energy fraction | $\log_{10}(\epsilon_e)$ | $[-4, 0]$ | $-3.32^{+0.67}_{-0.66}$ |
| log magnetic energy fraction | $\log_{10}(\epsilon_B)$ | $[-8, 0]$ | $-4.17^{+0.76}_{-0.72}$ |
| log accelerated electrons fraction | $\log_{10}(\zeta)$ | $[-3, 0]$ | $-0.70^{+0.67}_{-0.65}$ |
| initial Lorentz factor | $\Gamma_0$ | $[50, 500]$ | $432^{+65}_{-137}$ |
| systematic uncertainty [mag] | $\sigma_{sys}$ | $[0.01, 2]$ | - |

## Analysis with Pellouin & Daigne 2024

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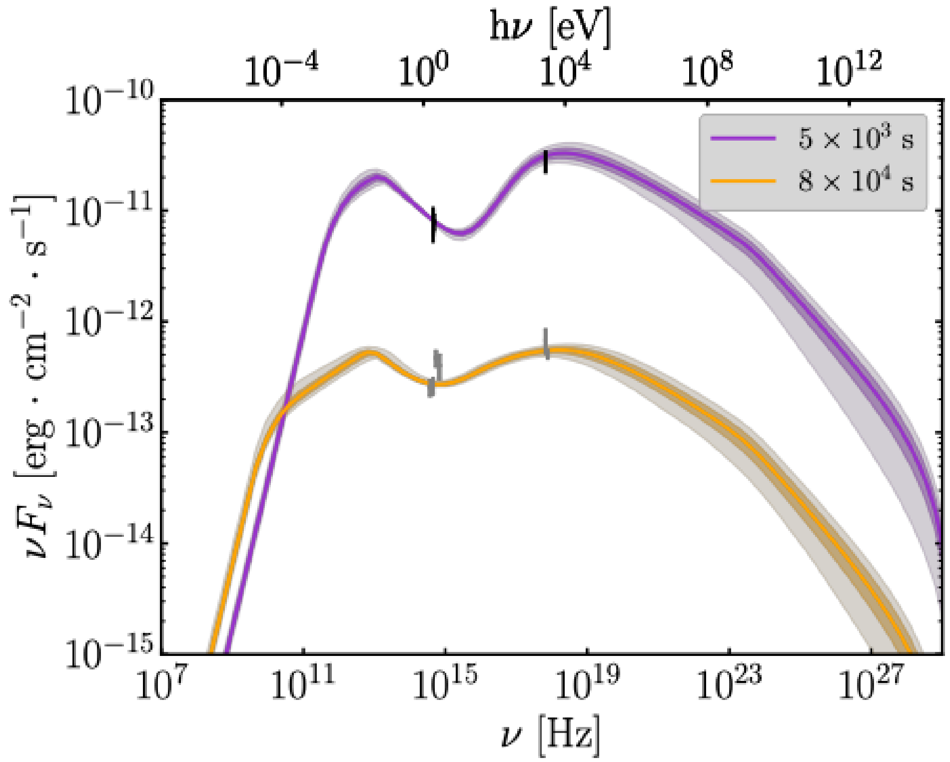
**Analysis with Pellouin & Daigne 2024**

Including SSC does not resolve the issues raised before




Posterior spectra before and after the break in X-rays

**The X-ray emission is dominated by SSC**

- Again, extremely unlikely

# GRB 241030A: Discussion

**What we can say**

- GRB 241030A is a long GRB ($T_{90}$ ~ 200s) with multiple emission episodes, with standard $E_{iso}$ / $E_p$ for a long GRB
- Redshift z = 1.411
- The GRANDMA collaboration gathered an exquisite multi-wavelength observational dataset of the afterglow
- The afterglow is non-standard: it is bright (comparable to GRB 221009A), while the prompt luminosity is standard
- If we interpret this afterglow with typical forward shock emission, the model faces several challenges, difficult to overcome:
    - Large jet energies and opening angles
    - Low particle acceleration and magnetic field amplification energies
    - High circumburst densities
- Most likely, emission behind the forward shock is not the explanation for this afterglow

# GRB 241030A: Discussion

**What solutions?**

- If optical emission is powered by a long-lasting reverse shock, then the constraint on $\nu_m$ can be released, potentially leading to more physical solutions
- Any scenario with a high velocity jet will be constrained by the absence of jet break up to $10^6$ s
- Any other scenario needs to accomodate for the smooth behaviour of the light curve at all wavelengths + the overall source luminosity

# Merci !