

$E_{\text{iso}} = 1.5 \times 10^{54}$ erg
Most Luminous UL-GRB

$T_{90} > 1000$ s
Ultra-Long Duration GRB

$z = 3.084$
Cosmological Redshift

14σ Detection
Fermi-LAT GeV Emission

01 INTRODUCTION

Ultra-long GRBs ($T_{90} > 1000$ s) challenge standard collapsar models due to prolonged central engine activity.

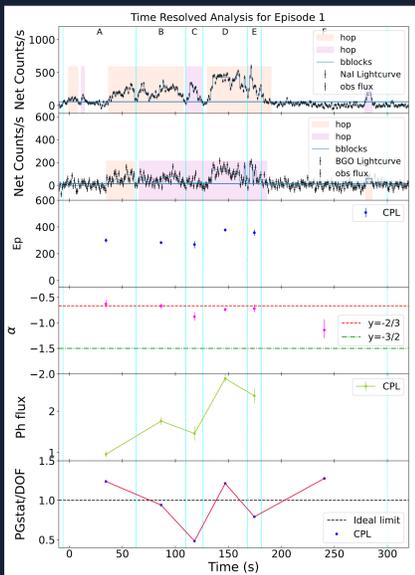
GRB 220627A (detected 27 Jun 2022) showed two distinct episodes separated by ~ 600 s quiescence, initially hypothesised as gravitational lensing (Roberts et al. 2022).

Methodology

- HOP-block time-resolved spectroscopy (Bayesian Blocks + HOP; Scargle 2013)
- CPL spectral modelling per episode, -10 to 300 s
- Comparison with GRB 091024A (magnetar) & GRB 130925A (BSG)
- CPL+BB thermal modelling; K-edge excluded $31-35$ keV
- CCF lag analysis (FFT) testing lensing vs. intrinsic origin

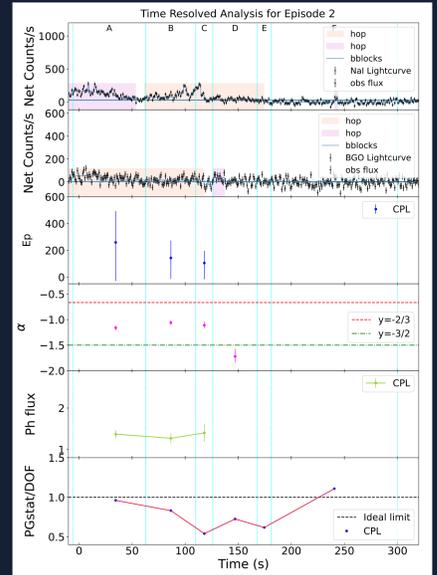
Multi-diagnostic approach resolves the progenitor debate for the most luminous ul-GRB detected ($E_{\text{iso}} = 1.5 \times 10^{54}$ erg, $z = 3.084$).

01 TIME-RESOLVED SPECTROSCOPY — EPISODE I



Six sub-panels: NaI/BGO lightcurves with HOP-blocks; E_p ; α ; photon flux; PGStat/DOF. **Hard-to-soft:** $\alpha = -0.71 \pm 0.03$ (slow-cooling); $E_p = 325$ keV. Death-lines prove cooling at $R \sim 10^{14-15}$ cm.

02 TIME-RESOLVED SPECTROSCOPY — EPISODE II



Episode II: $\alpha = -1.13 \pm 0.03$ (fast-cooling $\approx -3/2$); $E_p = 185$ keV. Evolution across 900 s quiescence **proves radiative cooling transition**, ruling out magnetar spin-down and WD-TDE alternatives.

04 KEY SPECTRAL FINDINGS

Hard-to-Soft CPL Evolution

Episode I
 $\alpha = -0.71 \pm 0.03$ $E_p = 325$ keV
Slow-cooling synchrotron ($< -2/3$)

Episode II
 $\alpha = -1.13 \pm 0.03$ $E_p = 185$ keV
Fast-cooling synchrotron ($\approx -3/2$)

Flux peaks ~ 3 ph cm⁻² s⁻¹; PGStat/DOF ≈ 1 .

Death-lines prove cooling at $R \sim 10^{14-15}$ cm.

CCF:

Peak = 0.51 , lag = 44.9 s (SNR = 1.87). Incompatible with lensing (expected CCF ≈ 0). Peak width ~ 50 s matches MVT = $2 - 7$ s.

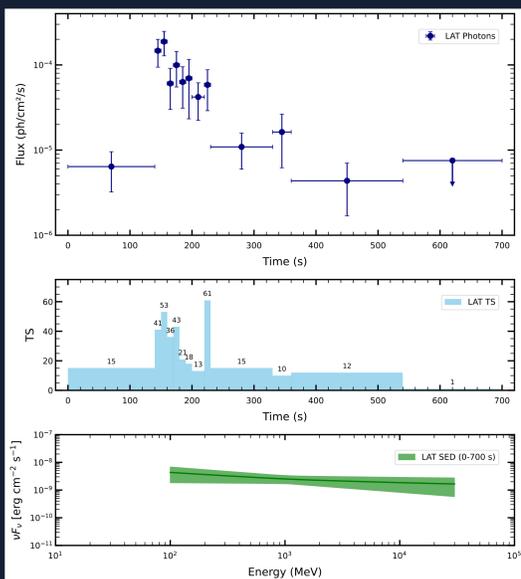
GeV:

TS = 192 ($\sim 14 \sigma$) only in Episode I; absent in Episode II despite GBM trigger, rules out lensing.

Thermal:

CPL+BB ($kT = 22 - 31$ keV) improves $\Delta\chi^2 \sim 50 - 100$. $R_{\text{ph}} = 10^{14}$ cm matches MVT radii. K-edge excluded ($31-35$ keV). Proves BSG jet-cocoon interaction.

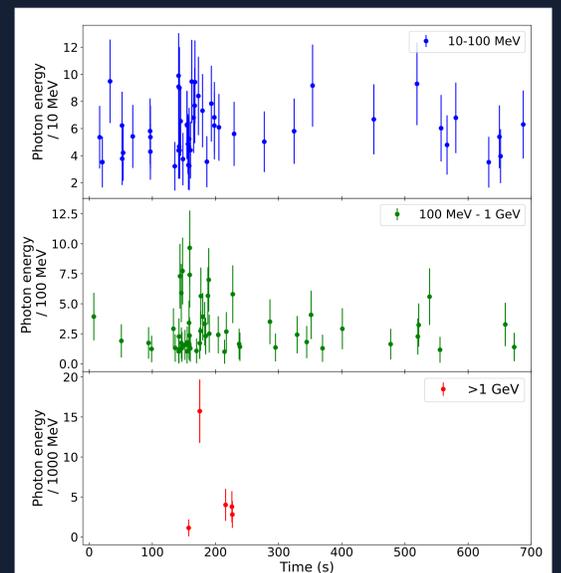
05 FERMI-LAT HIGH-ENERGY ANALYSIS



LAT photon flux, TS evolution, SED (100 MeV – 300 GeV). TS = 192 ($\sim 14 \sigma$) in Ep. I only ($\Gamma = -2.18 \pm 0.15$; flux = 6.4×10^{-8} erg cm⁻² s⁻¹). LAT photon flux is absent in Ep. II, rules out lensing.

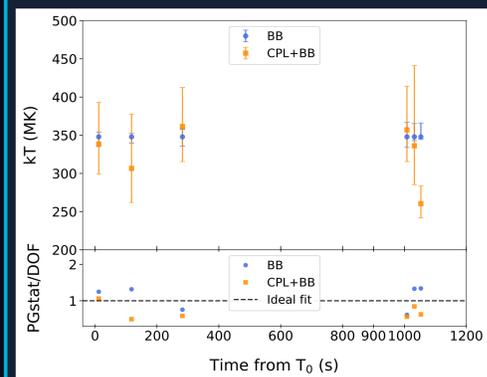
15.7 GeV Highest photon at $t = 175$ s

06 LAT GeV PHOTON COUNTS



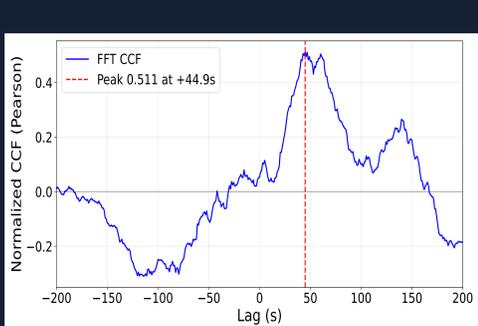
Photon counts in $10 - 100$ MeV, 100 MeV – 1 GeV, and > 1 GeV. All 5 high-energy photons were detected in Episode I only. No GeV emission in Episode II directly rules out gravitational lensing.

07 THERMAL BB EMISSION



CPL+BB ($kT = 22 - 31$ keV); $\Delta\chi^2 \sim 50 - 100$ improvement. $R_{\text{ph}} = 10^{14}$ cm matches MVT. **Proves BSG jet-cocoon.**

08 CROSS-CORRELATION

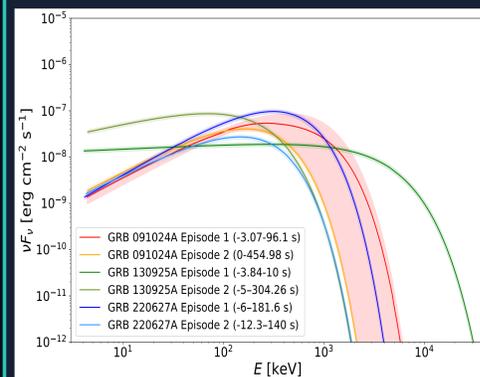


Peak = 0.51 at lag = 44.9 s.

Incompatible with lensing.

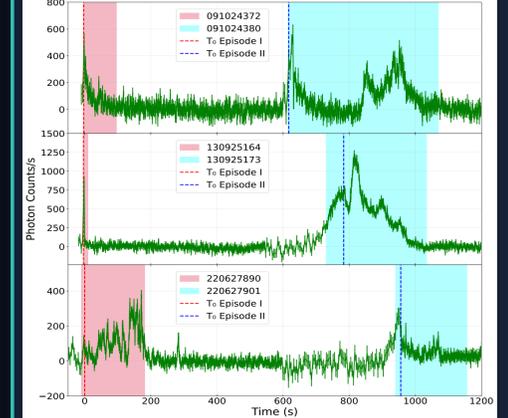
Narrow peak (~ 50 s) = MVT confirms coherent central engine.

09 SED COMPARISON



SED for GRB 091024A & 130925A vs. 220627A. **Hard-to-soft track favours BSG collapsar** over magnetar/WD-TDE.

10 LIGHTCURVE COMPARISON



Stacked GBM rates for GRB 091024A & 130925A vs. 220627A. GRB 220627A's E_{iso} & quiescence demand **H-envelope fallback**, unlike magnetar plateau.

11 CONCLUSIONS

HOP-block analysis: hard-to-soft CPL ($\alpha_{\text{I}} = -0.71 \rightarrow \alpha_{\text{II}} = -1.13$; $E_p = 325 \rightarrow 185$ keV) across 900 s quiescence, **first proving BSG fallback accretion** via multi-episode spectral divergence vs. lensing hypotheses.

Transient $kT = 22 - 31$ keV photospheric emission (CPL+BB, K-edge excluded) with $R_{\text{ph}} = 10^{14}$ cm matching MVT, **definitively proves BSG collapsar** jet-cocoon origin (Izzo et al. 2023, Roberts et al. 02 had no thermal confirmation).

CCF = 0.51 (lag 44.9 s) + LAT 14σ only in Ep. I — together rule out gravitational lensing and confirm **intrinsic multi-episode physics** via coherent fallback accretion.

References

De Wet et al. 2023, A&A, 677, A32 | Leung et al. 2026, ApJ 996, 22 | Scargle et al. 2013, ApJ 764, 167
Roberts et al. 2022, GCN 32288 | Wagner et al. 2021, PoS ICRC2021, 868

