Journal Club

GeV emission from
a compact binary merger

JC – 01 - 2023

The paper

GeV emission from a compact binary merger

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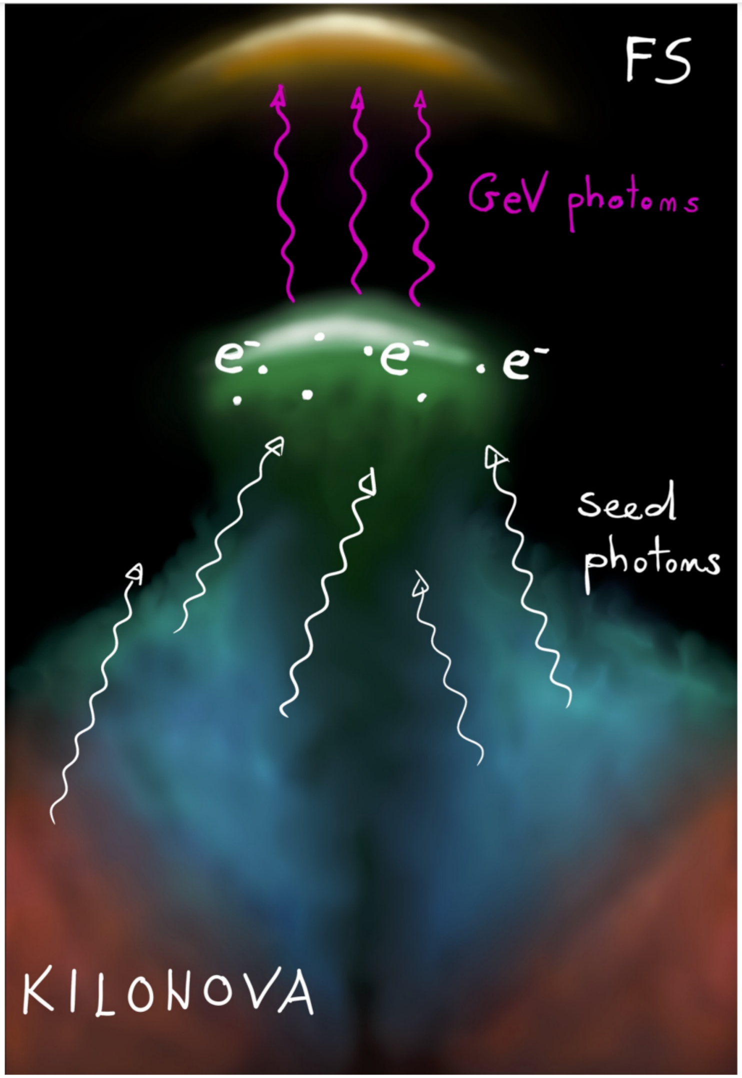


https://arxiv.org/pdf/2205.08566.pdf

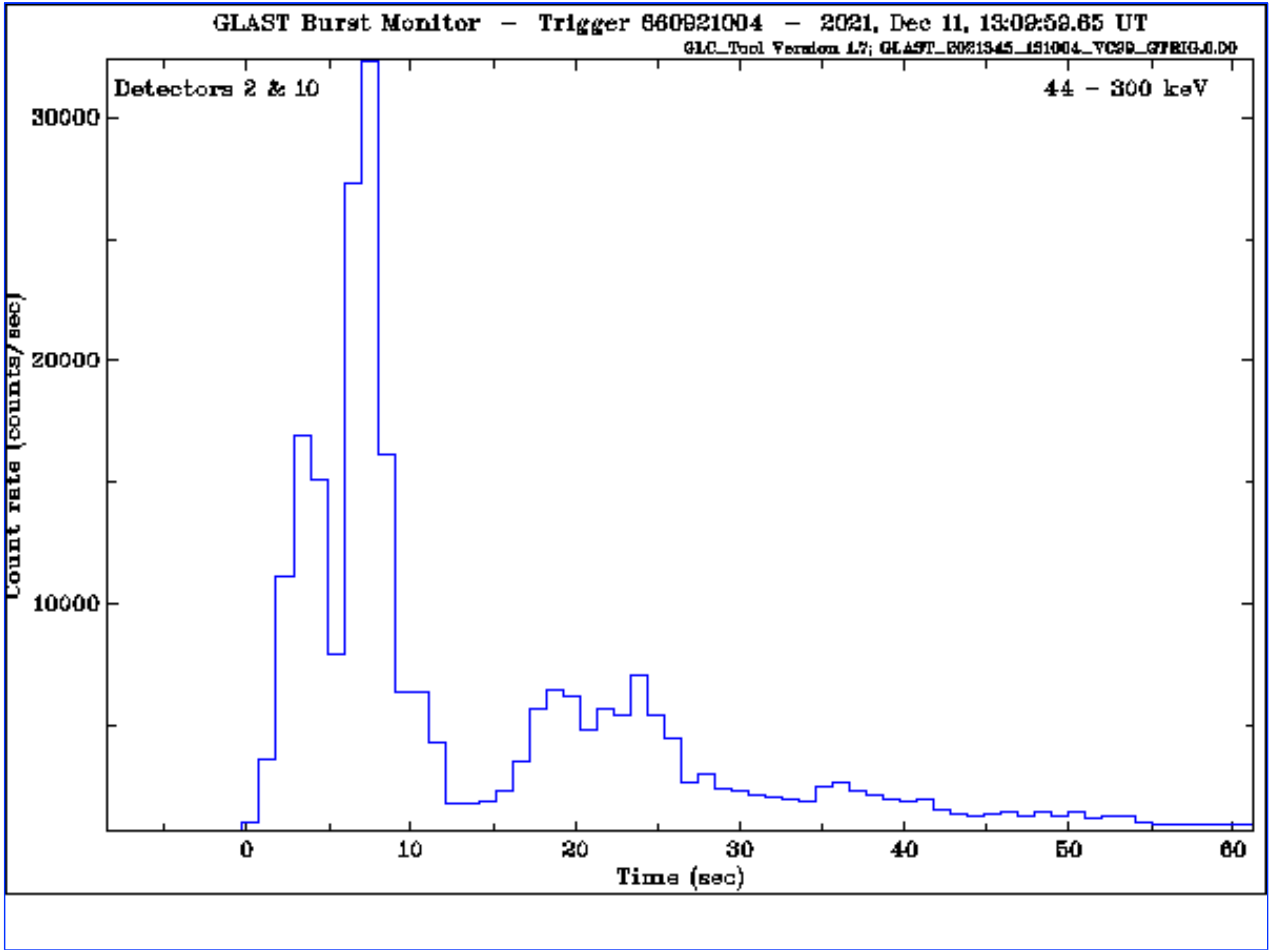
The abstract

Abstract

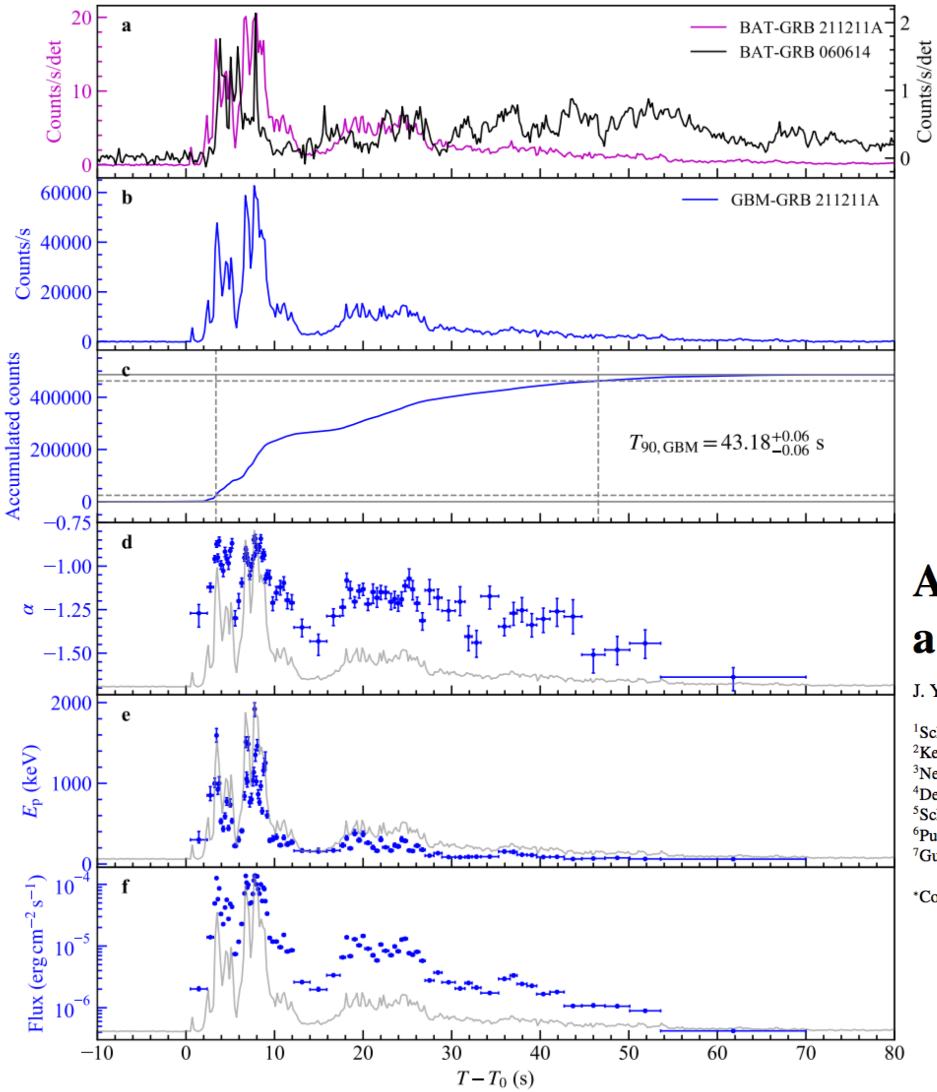
An energetic γ-ray burst (GRB), GRB 211211A, was observed on 2021 December 11 by the Neil Gehrels Swift Observatory. Despite its long duration, typically associated with bursts produced by the collapse of massive stars, the discovery of an optical-infrared kilonova and a quasi-periodic oscillation during a gamma-ray precursor points to a compact object binary merger origin. The complete understanding of this nearby

($\sim$ 1 billion light-years) burst will significantly impact our knowledge of GRB progenitors and the physical processes that lead to electromagnetic emission in compact binary mergers. Here, we report the discovery of a significant ($> 5\sigma$) transient-like emission in the high-energy γ-rays (HE; E$>$ 0.1 GeV) observed by *Fermi*/LAT starting at 10^3 s after the burst. After an initial phase with a roughly constant flux ($\sim 5 \times 10^{-10}$ erg s^{-1} cm^{-2}) lasting $\sim 2 \times 10^4$ s, the flux started decreasing and soon went undetected. The multi-wavelength 'afterglow' emission observed at such late times is usually in good agreement with synchrotron emission from a relativistic shock wave that arises as the GRB jet decelerates in the interstellar medium. However, our detailed modelling of a rich dataset comprising public and dedicated multi-wavelength observations demonstrates that GeV emission from GRB 211211A is in excess with respect to the expectation of this scenario. We explore the possibility that the GeV excess is inverse Compton emission due to the interaction of a long-lived, low-power jet with an external source of photons. We discover that the kilonova emission can provide the necessary seed photons for GeV emission in binary neutron star mergers.

GRB 211211A


GLAST Burst Monitor – Trigger 660921004 – 2021, Dec 11, 13:09:59.65 UT
Detectors 2 & 10
44 – 300 keV
30000
20000
10000
Count rate (counts/sec)
0
10
20
30
40
50
60
Time (sec)

The light curve …



A peculiar, long-duration gamma-ray burst from a neutron star-white dwarf merger

J. Yang[1,2], B.-B. Zhang[1,2*], S.-K Ai[3,4], Z.-K. Liu[1,2], X. I. Wang[1,2], Y.-H. Yang[1,2], Y.-H. Yin[5], Y. Li[6], H.-J. Lü[7], B. Zhang[3,4]

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[6]Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210023, China
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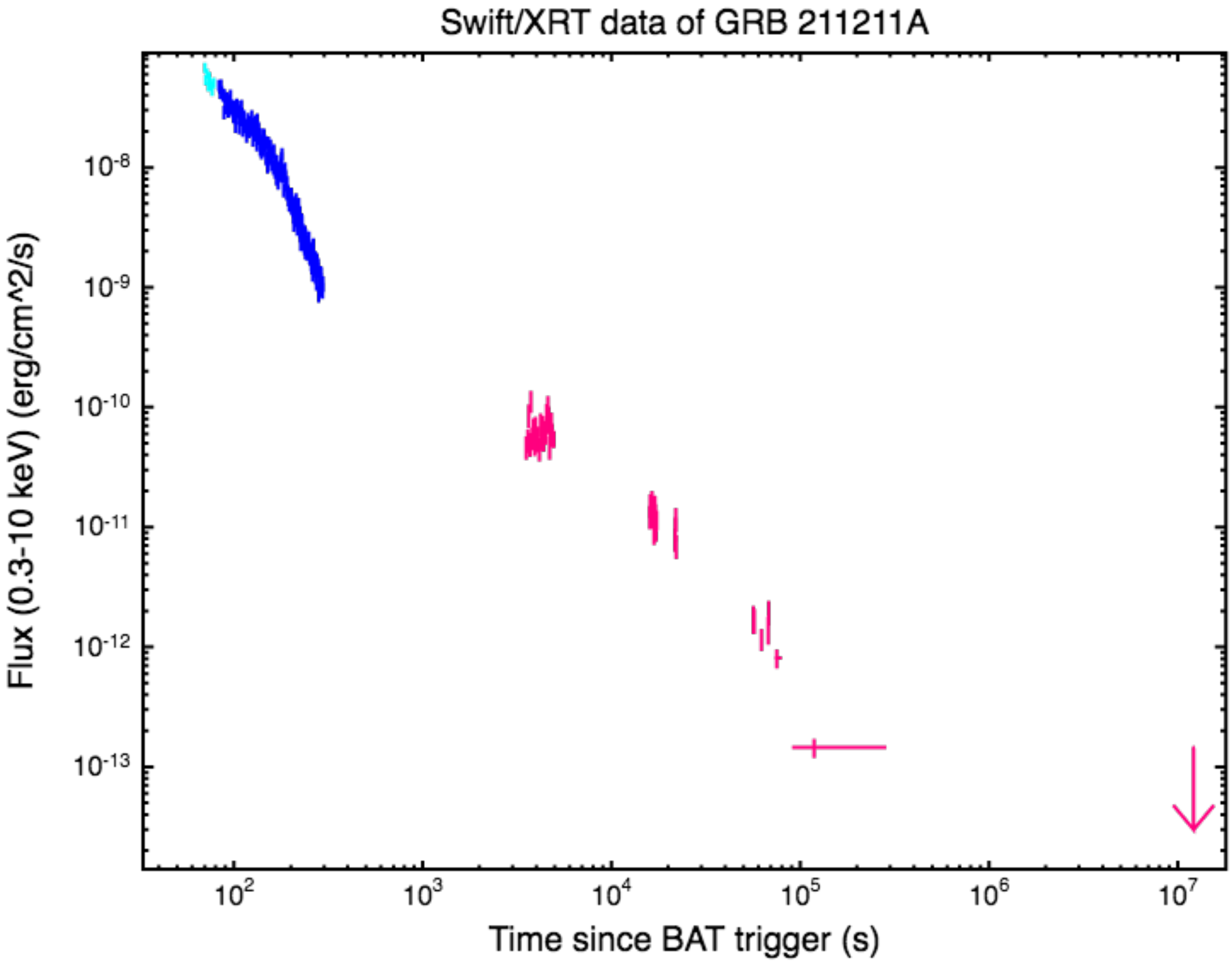
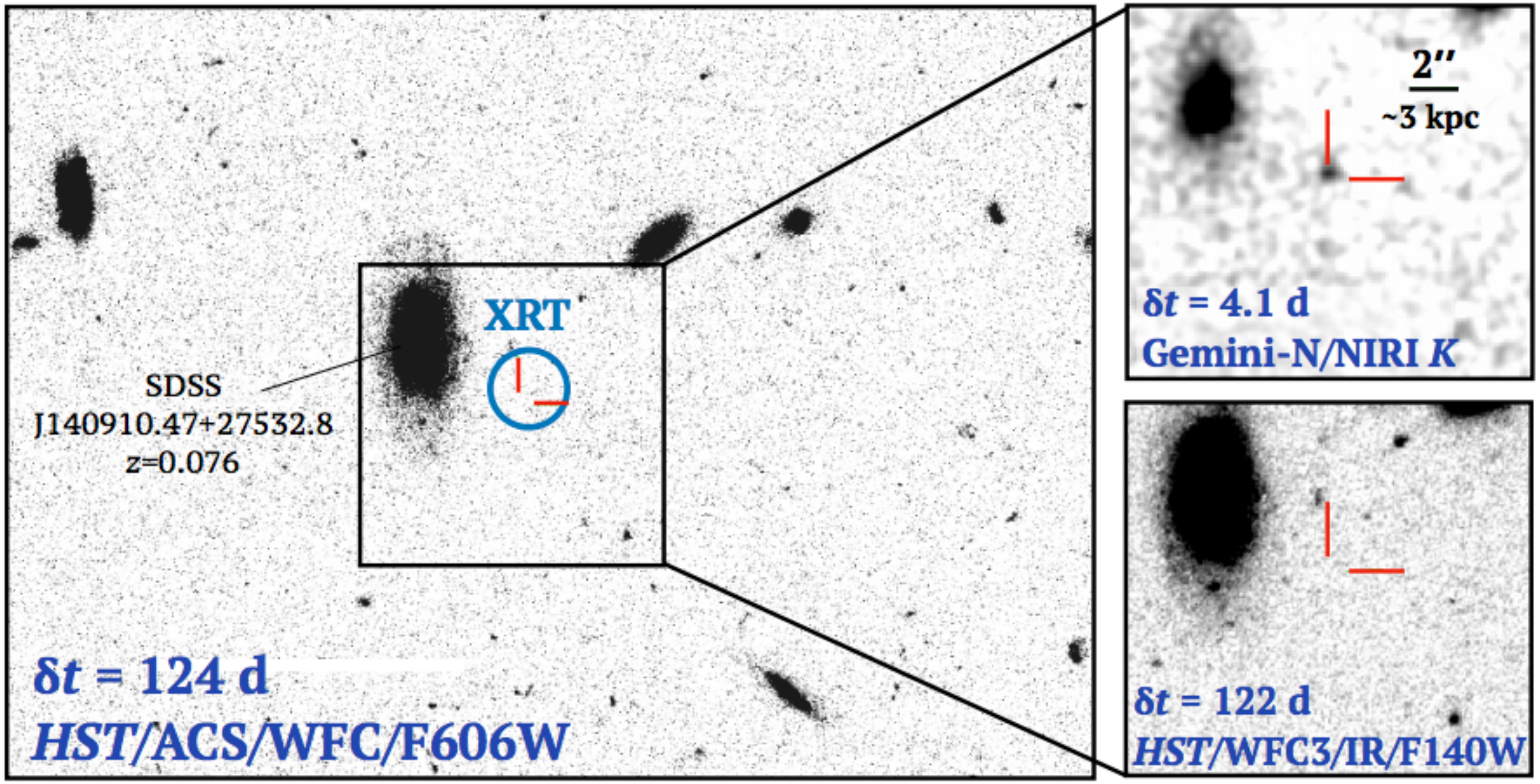
https://arxiv.org/pdf/2204.12771.pdf

GRB 211211A



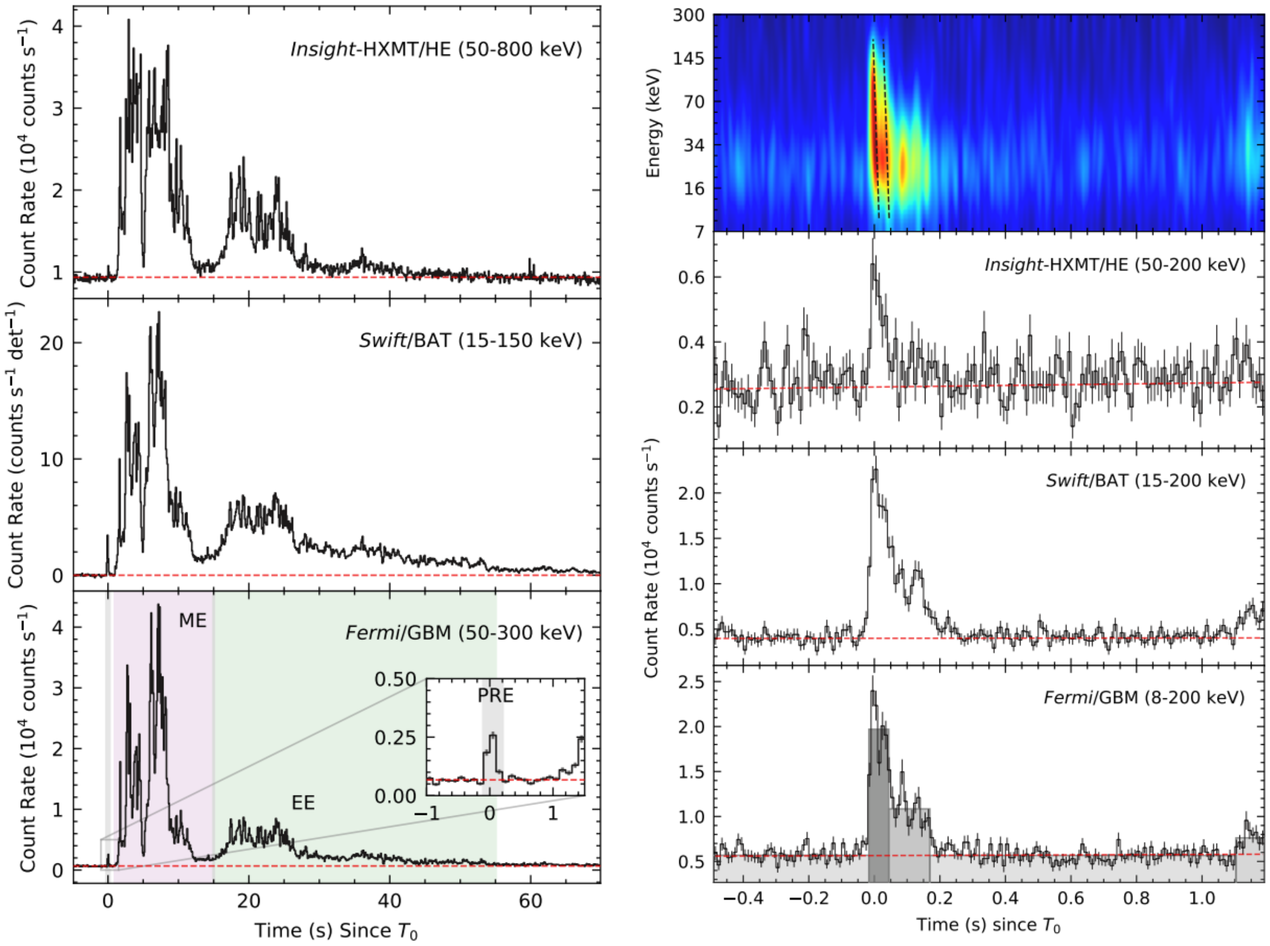
Swift/XRT data of GRB 211211A
Flux (0.3-10 keV) (erg/cm^2/s)
10-8
10-9
10-10
10-11
10-12
10-13
10^2
10^3
10^4
10^5
10^6
10^7
Time since BAT trigger (s)

The Kilonova



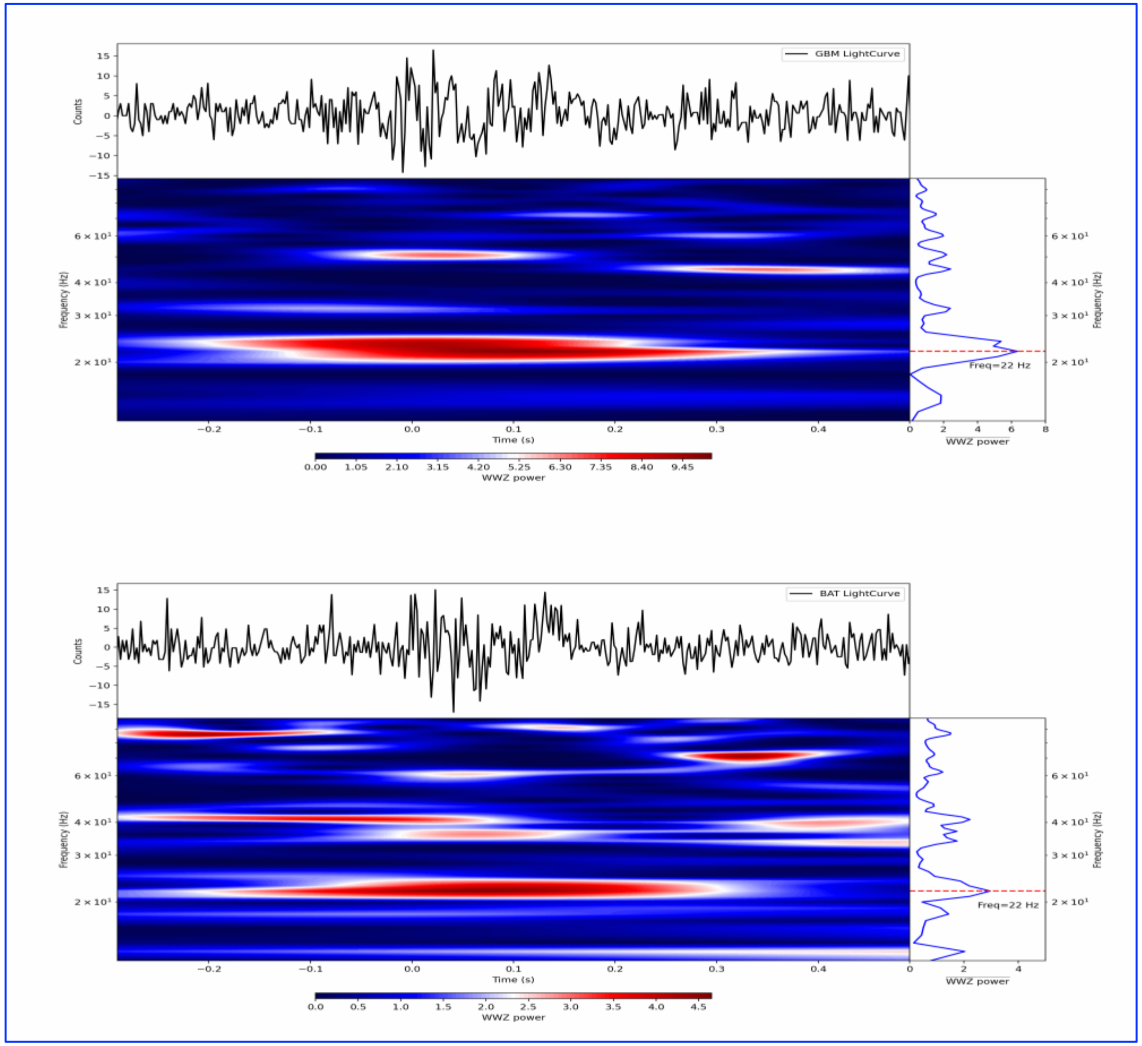
https://arxiv.org/pdf/2204.10864.pdf

The QPOs



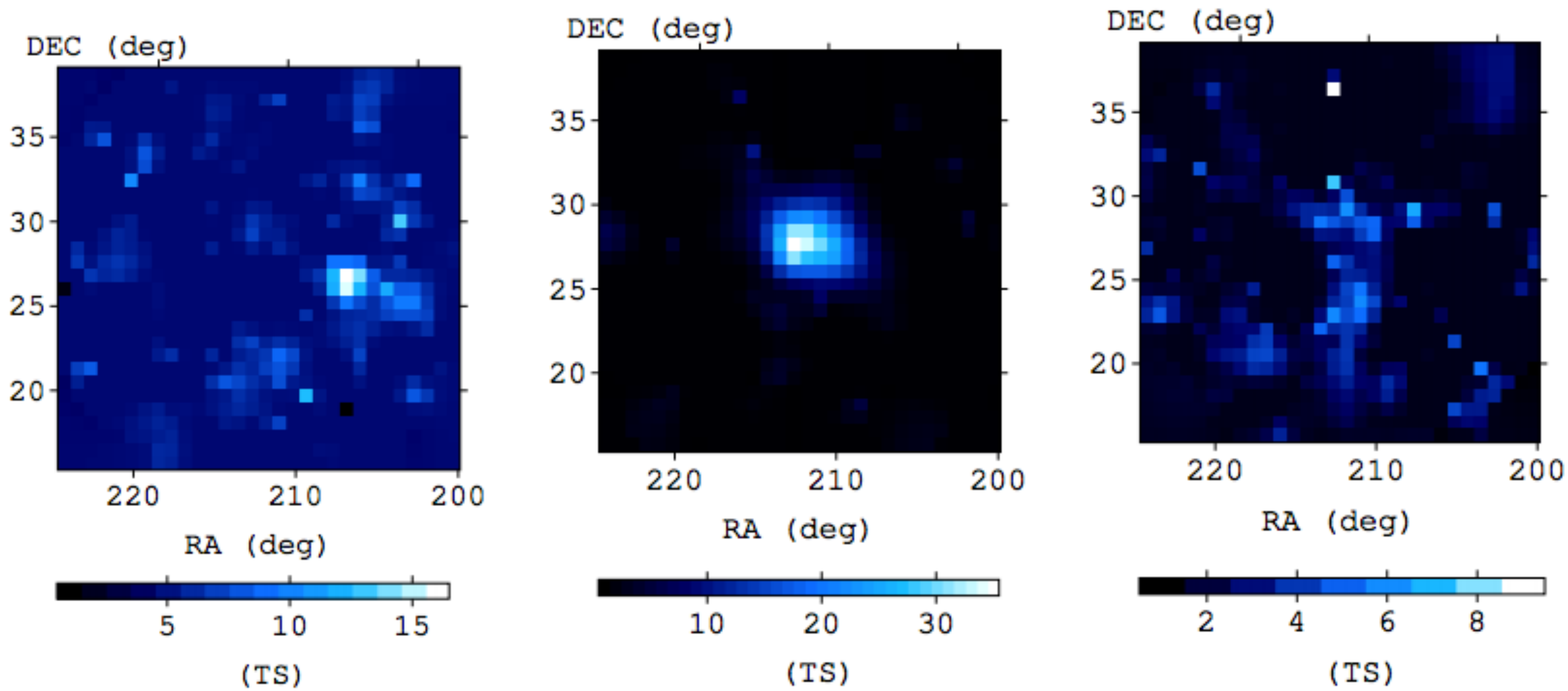
https://arxiv.org/pdf/2205.02186.pdf

The QPOs



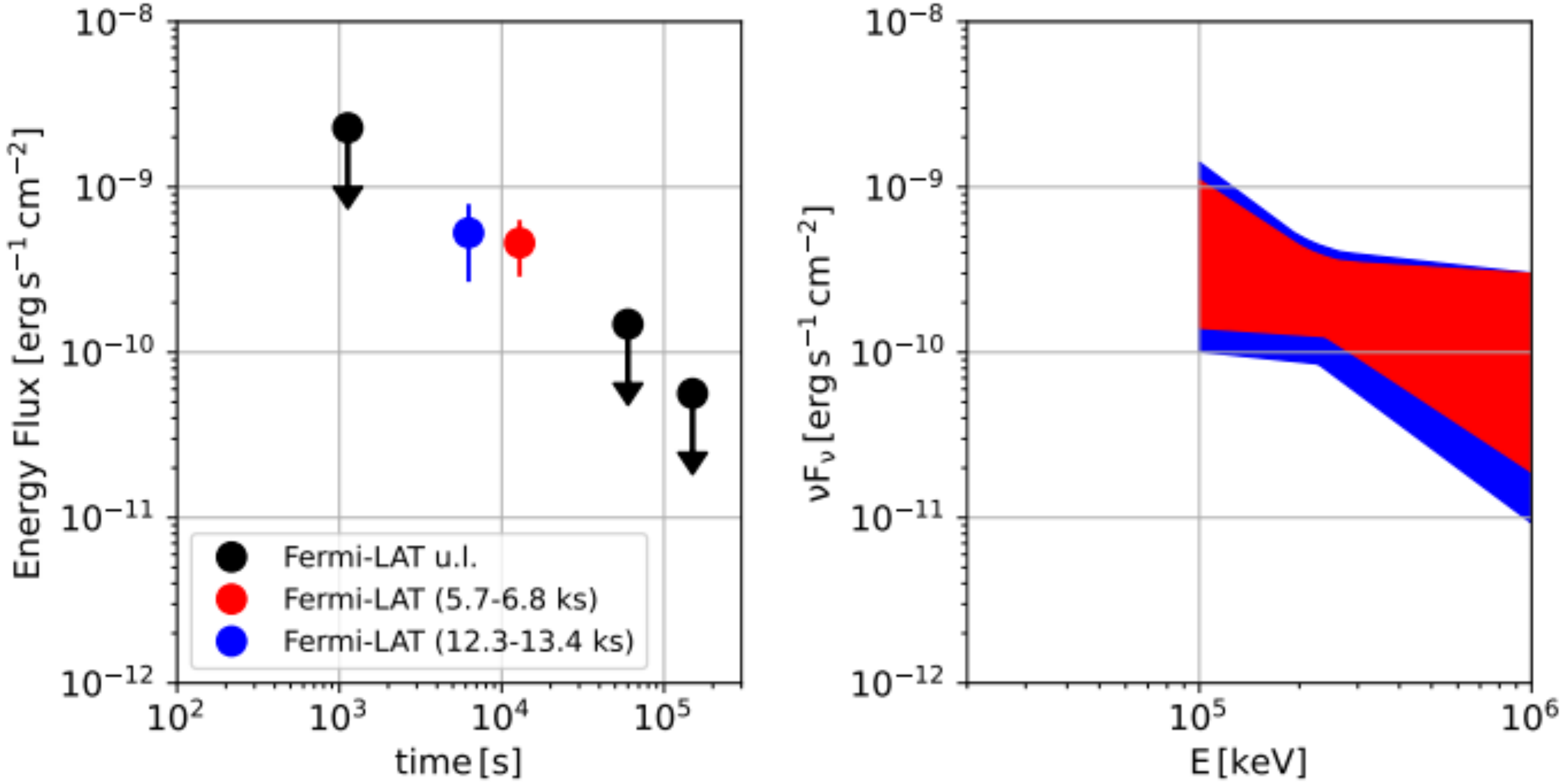
https://arxiv.org/pdf/2205.02186.pdf

LAT detection



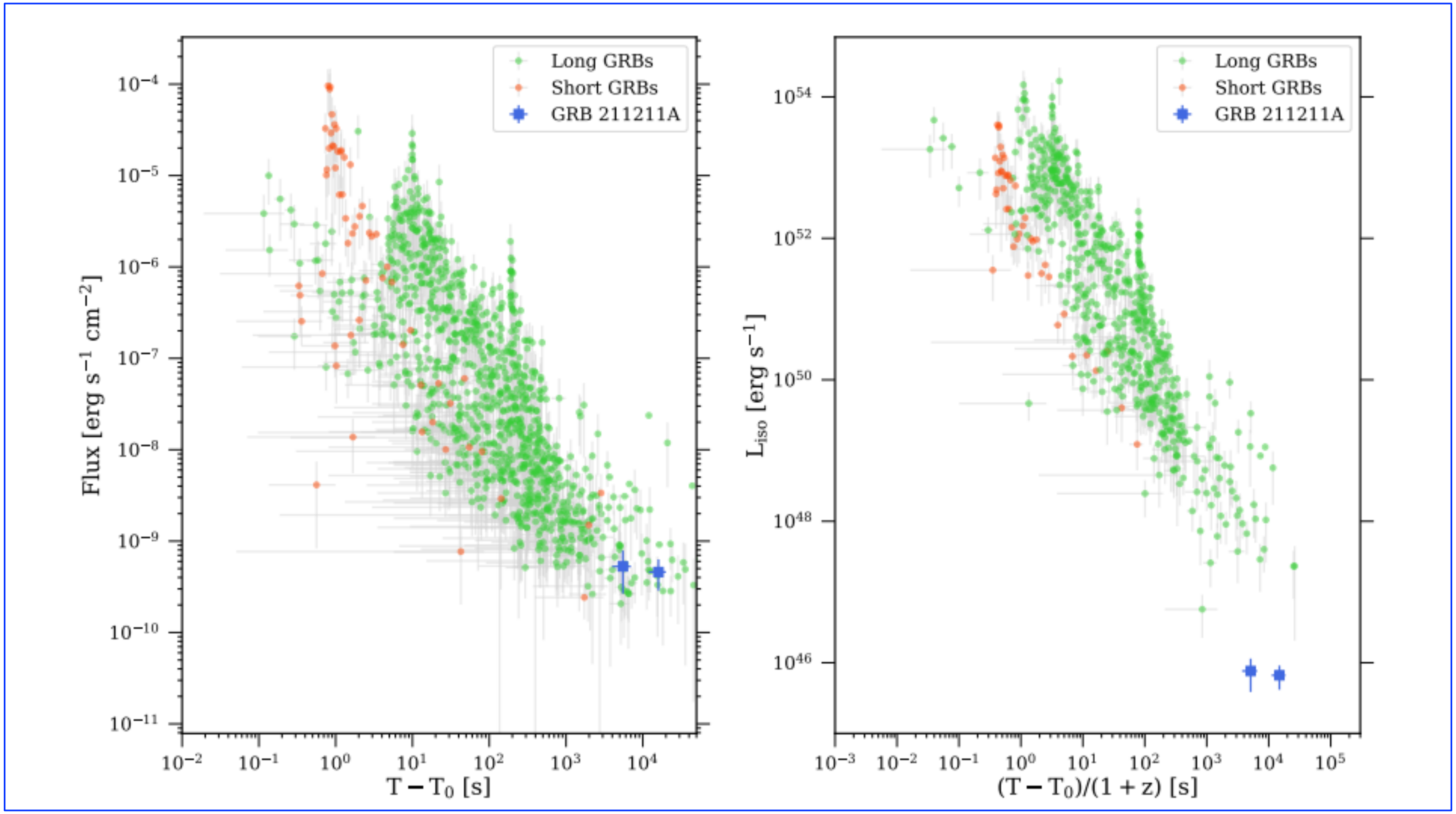
(a) t_0-1 d to t_0 (b) t_0 to t_0+20 ks (c) t_0+1 d to t_0+2 d

LAT detection

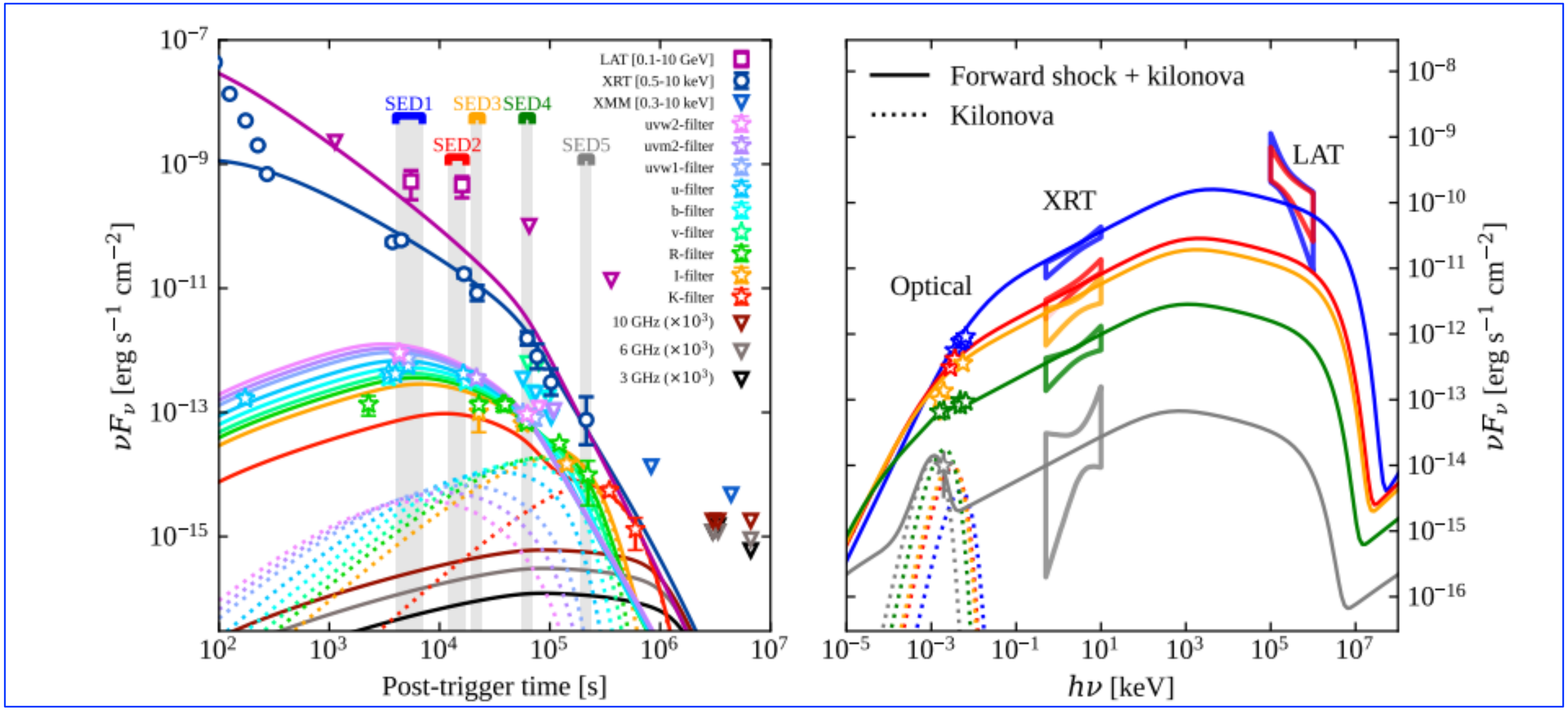


(d) t_0 to t_0+2 d

LAT lightcurve



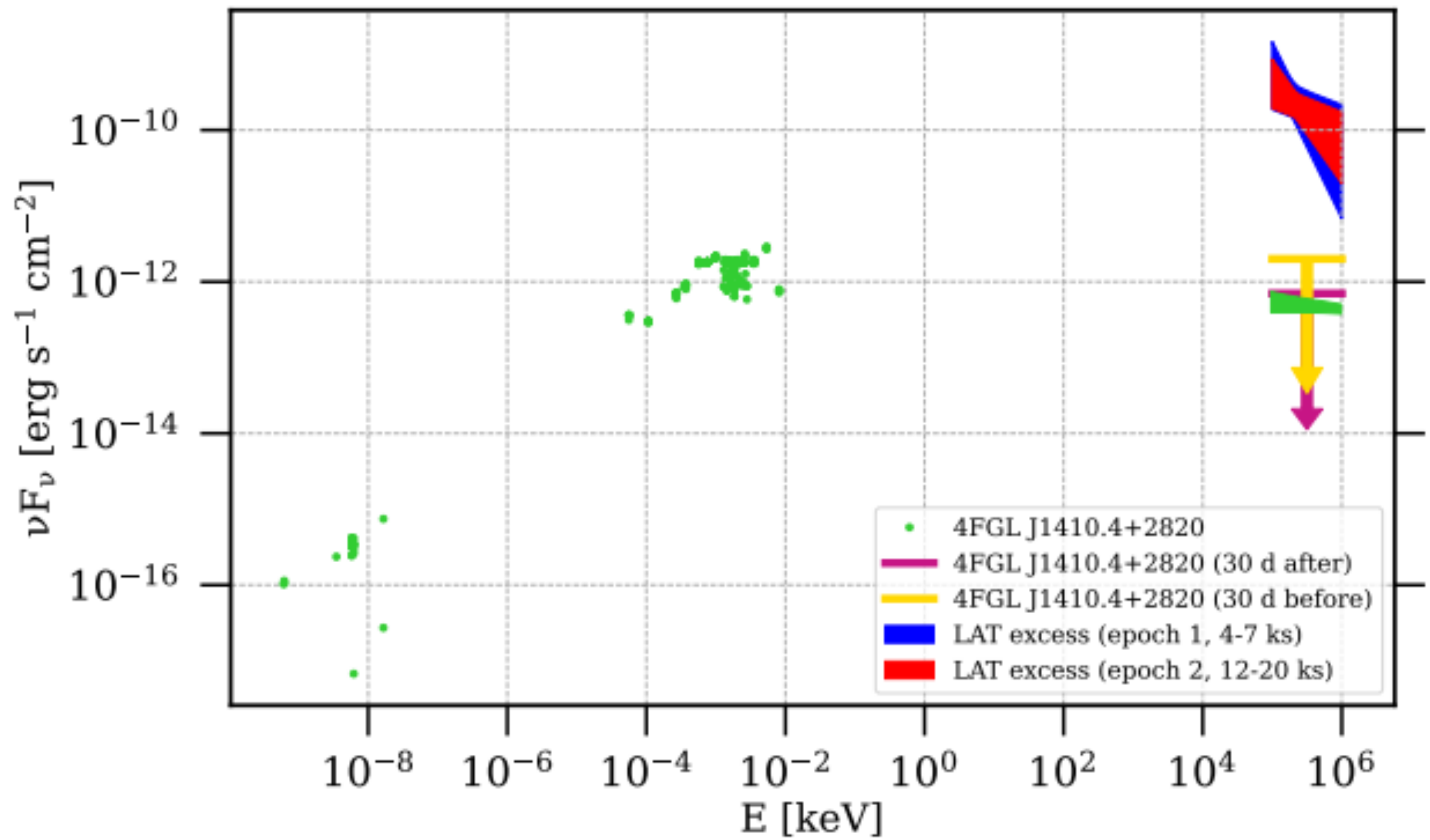
Multiwavelength SED



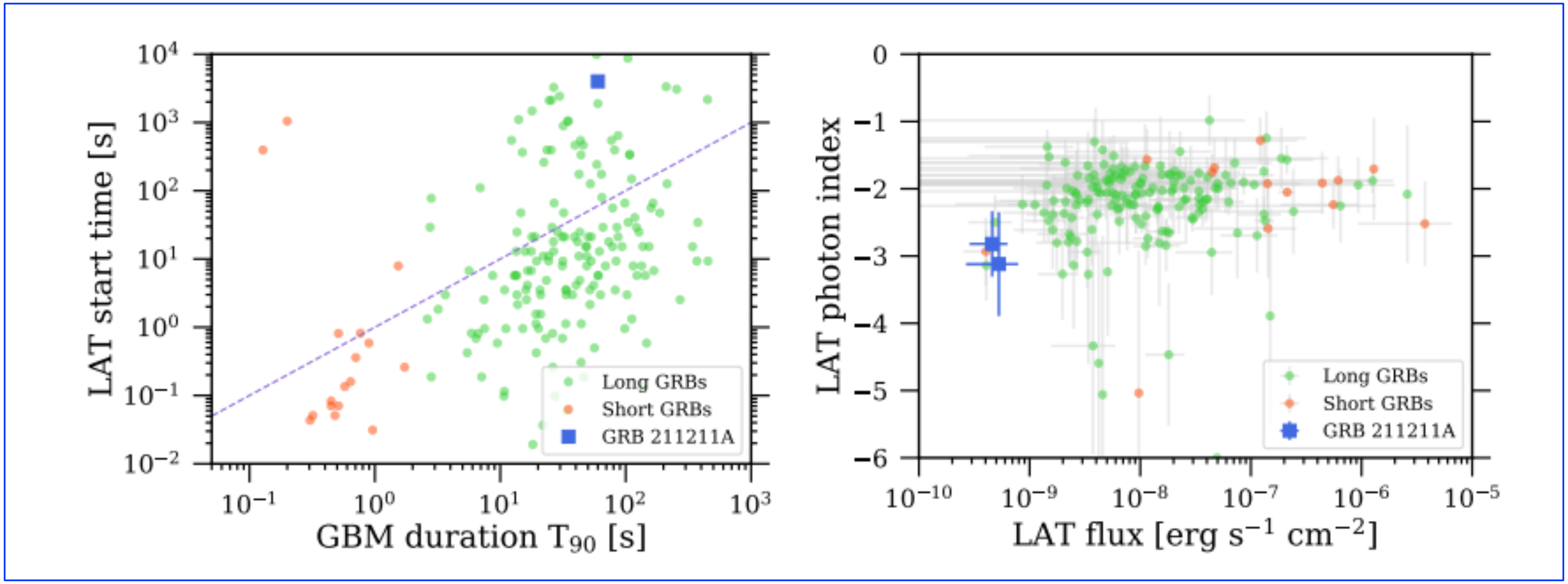
Single Photons

Energy (GeV)	Probability	Distance (deg.)	Arrival time (sec.)
0.21	0.94	0.36	6438.18
0.19	0.95	1.04	6647.43
0.16	0.93	1.34	12493.41
0.12	0.96	0.71	12612.52
1.74	0.97	0.32	12966.74
0.10	0.96	0.77	13053.43
0.12	0.92	1.69	13292.13
0.29	0.91	1.22	17860.45
0.23	0.97	0.67	18127.51

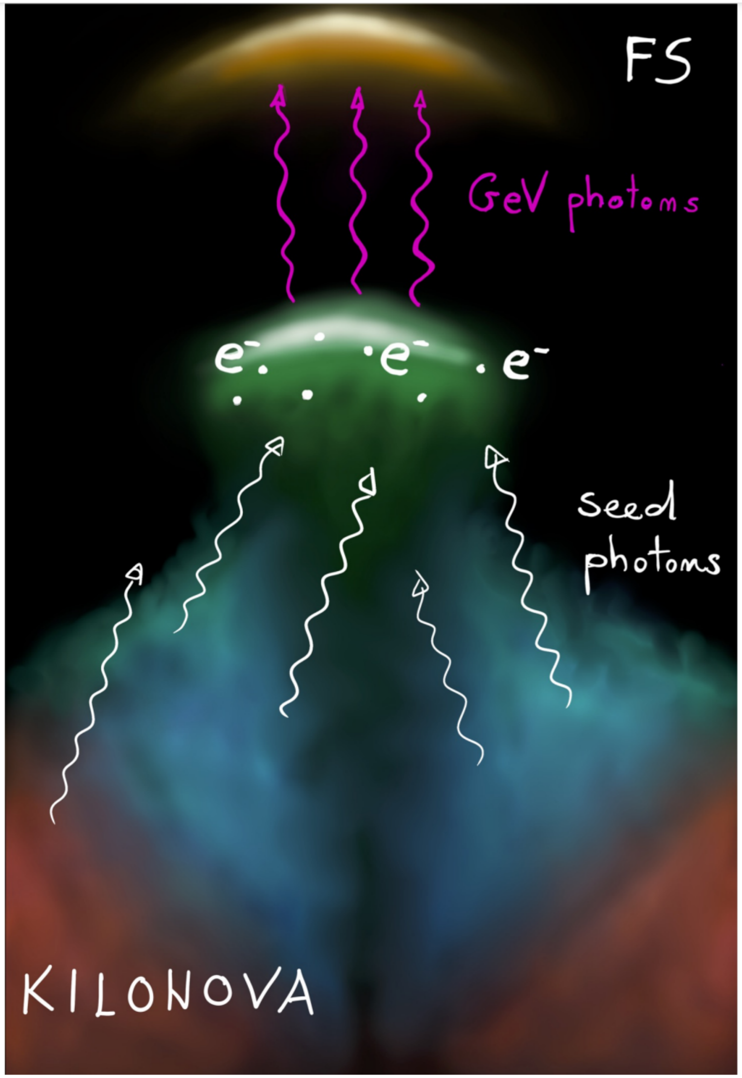
Background Source?



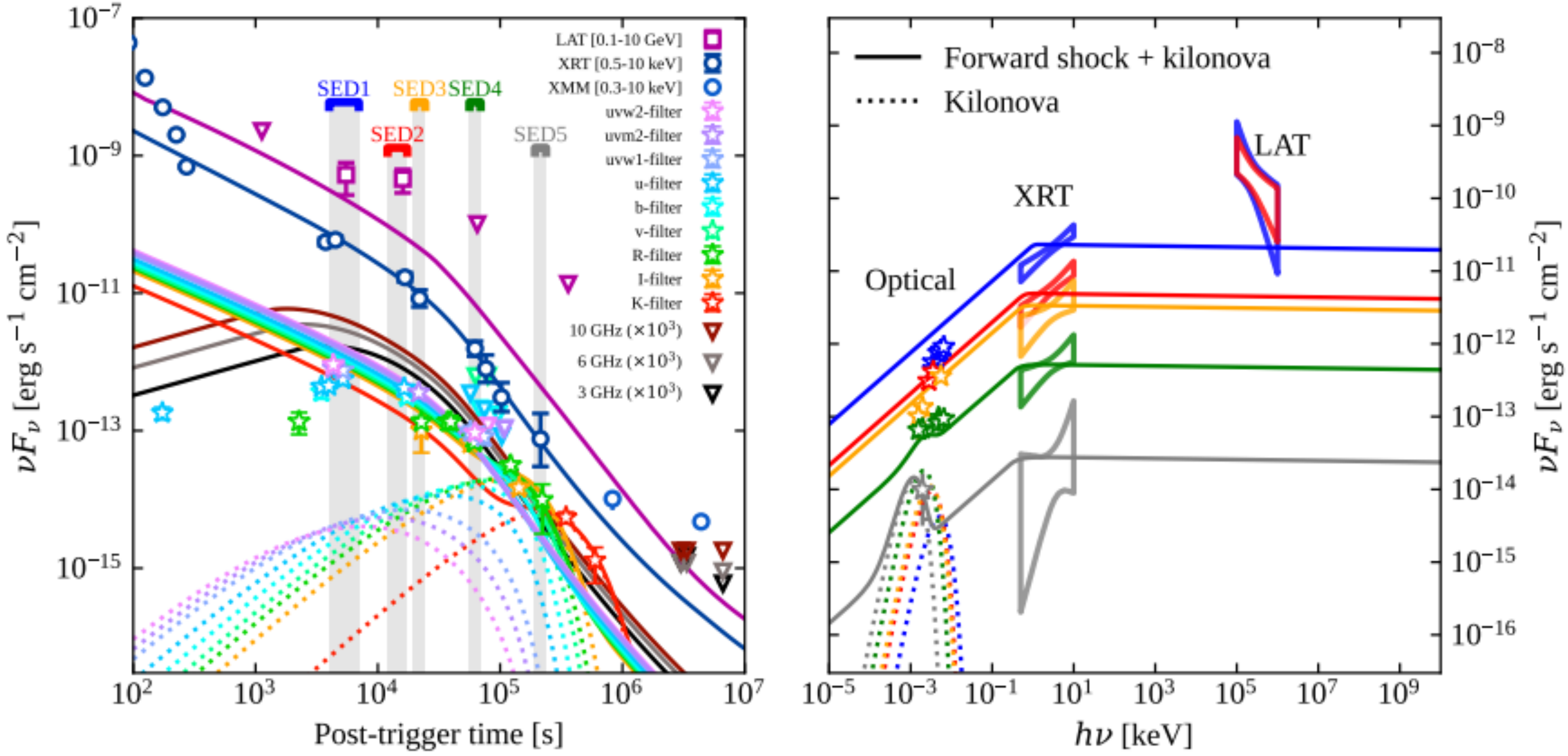
Similarity to other LAT GRBs



The model



Other models



Other models

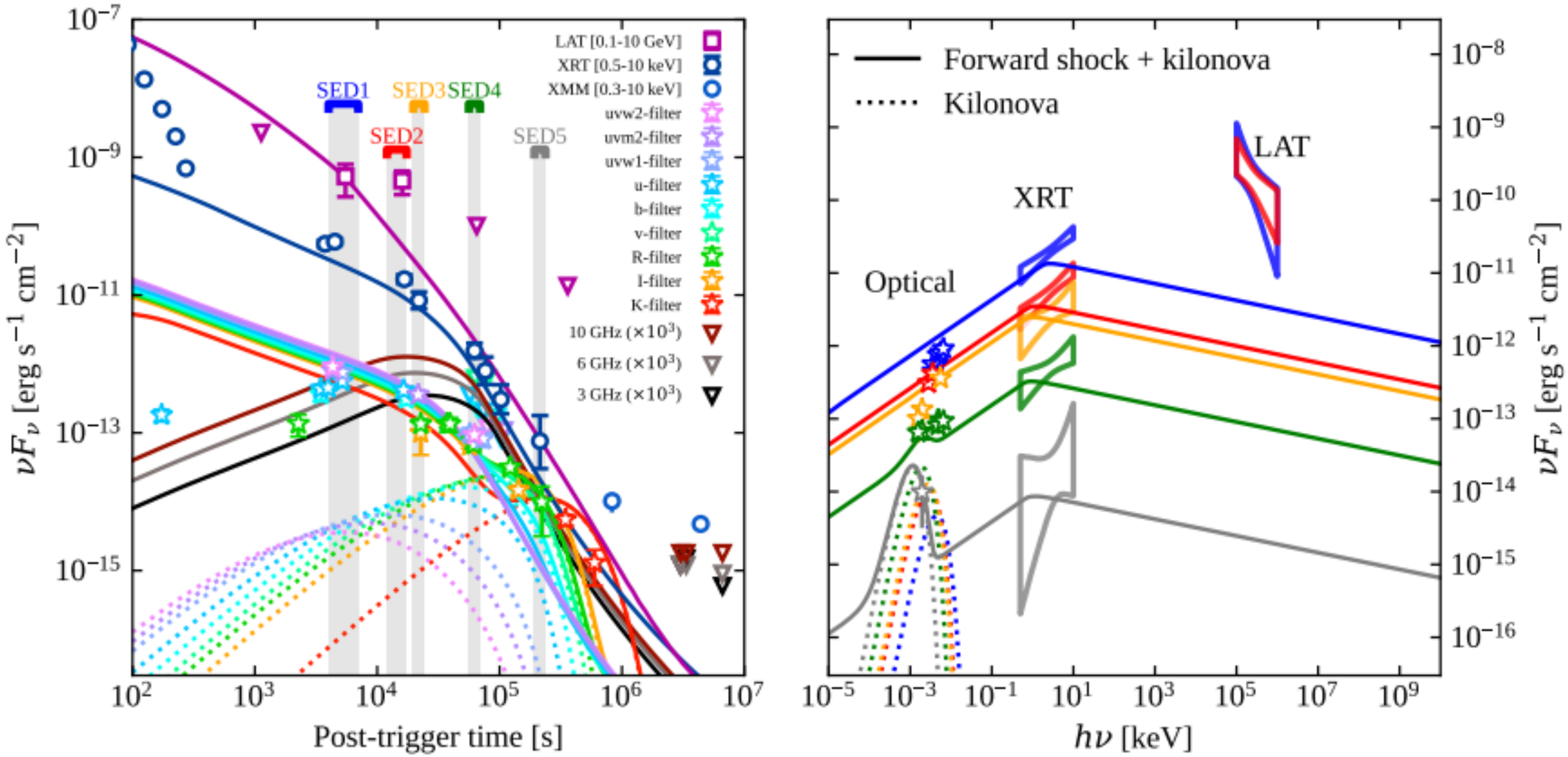
A Kilonova Following a Long-Duration Gamma-Ray Burst at 350 Mpc

J. C. Rastinejad (CIERA/Northwestern), B. P. Gompertz, A. J. Levan, W. Fong, M. Nicholl, G. P. Lamb, D. B. Malesani, A. E. Nugent, S. R. Oates, N. R. Tanvir, A. de Ugarte Postigo, C. D. Kilpatrick, C. J. Moore, B. D. Metzger, M. E. Ravasio, A. Rossi, G. Schroeder, J. Jencson, D. J. Sand, N. Smith, J. F. Agüí Fernández, E. Berger, P. K. Blanchard, R. Chornock, B. E. Cobb, M. De Pasquale, J. P. U. Fynbo, L. Izzo, D. A. Kann, T. Laskar, E. Marini, K. Paterson, A. Rouco Escorial, H. M. Sears, C. C. Thöne

Here, we report the discovery of a kilonova associated with the nearby (350 Mpc) minute-duration GRB 211211A. In tandem with deep optical limits that rule out the presence of an accompanying supernova to $M_I > -13$ mag at 17.7 days post-burst, the identification of a kilonova confirms that this burst's progenitor was a compact object merger. While the spectrally softer tail in GRB 211211A's gamma-ray light curve is reminiscent of previous extended emission short GRBs (EE-SGRBs), its prompt, bright spikes last $\gtrsim 12$ s, separating it from past EE-SGRBs. GRB 211211A's kilonova has a similar luminosity, duration and color to AT2017gfo, the kilonova found in association with the gravitational wave (GW)-detected binary neutron star (BNS) merger GW170817. We find that the merger ejected $\approx 0.04 M_\odot$ of r-process-rich material, and is consistent with the merger of two neutron stars (NSs) with masses close to the canonical $1.4 M_\odot$. This discovery implies that GRBs with long, complex light curves can be spawned from compact object merger events and that a population of kilonovae following GRBs with durations $\gg 2$ s should be accounted for in calculations of the NS merger r-process contribution and rate. At 350 Mpc, the current network of GW interferometers at design sensitivity would have detected the merger precipitating GRB 211211A, had it been operating at the time of the event. Further searches for GW signals coincident with long GRBs are therefore a promising route for future multi-messenger astronomy.

https://arxiv.org/abs/2204.10864

Other models



Other models

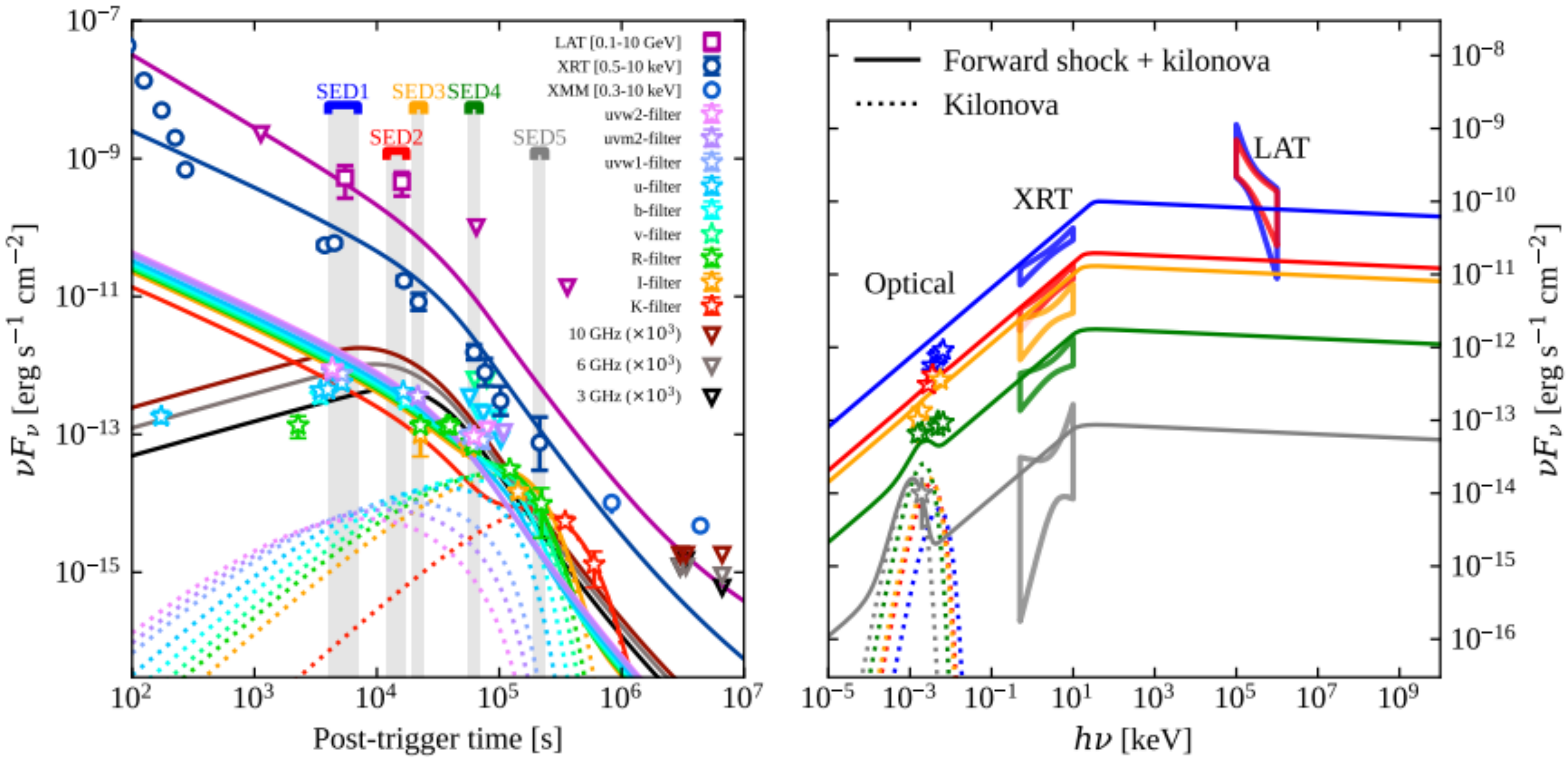
A peculiar, long-duration gamma-ray burst from a neutron star-white dwarf merger

J. Yang, B.-B. Zhang, S.-K Ai, Z.-K. Liu, X. I. Wang, Y.-H. Yang, Y.-H. Yin, Y. Li, H.-J. Lü, B. Zhang

Even though it is generally believed that long-duration gamma-ray bursts (GRBs) are associated with massive star core collapse whereas short-duration GRBs are associated with mergers of compact star binaries, growing observations have confirmed the earlier suggestion that multiple criteria (prompt emission properties, supernova/kilonova associations, and host galaxy properties) rather than burst duration only are needed to classify GRBs physically. A previously reported long-duration burst, GRB 060614, was of the compact star merger origin (Type-I GRB) but could be still viewed as a short GRB with extended emission if it were less energetic or observed at a larger distance. Here we report a peculiar long-duration gamma-ray burst, GRB 211211A, which can be physically classified as a Type-I GRB based on its multi-band observations. The burst broadly resembles GRB 060614 but has a longer duration in the main emission phase and a harder spectrum in both the main and extended emission phases, making it difficult to be interpreted as a short GRB with soft tail emission. In addition, significant excesses in both optical and near-infrared wavelengths have been discovered, which could be successfully explained as kilonova emission with energy injection from a magnetar central engine. These observations point towards a neutron star-white dwarf merger progenitor, which leaves behind a rapidly spinning magnetar that powers gamma-ray prompt emission, afterglow, and kilonova emission.

https://arxiv.org/abs/2204.12771

Other models



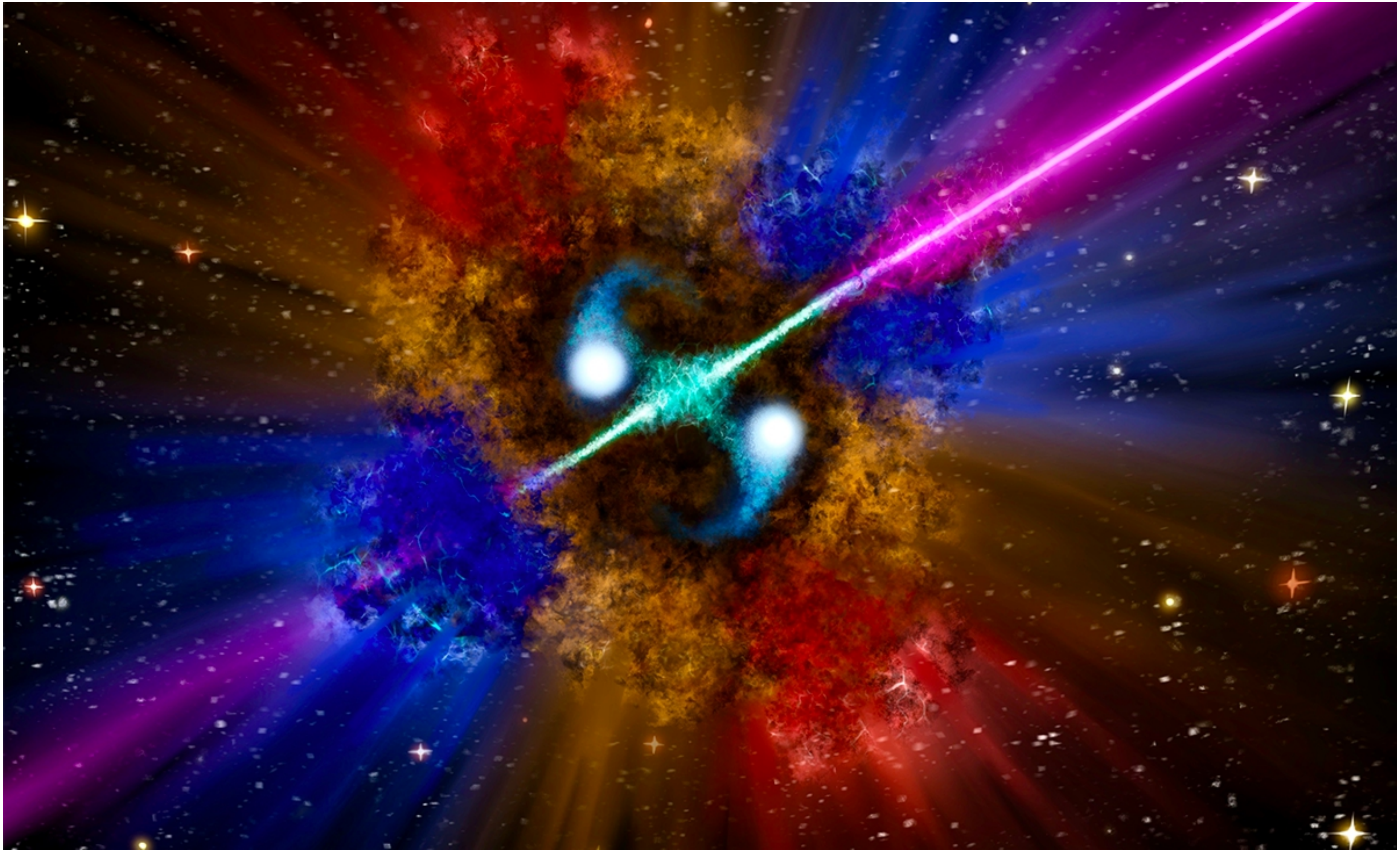
Other models

The quasi-periodically oscillating precursor of a long gamma-ray burst from a binary neutron star merger

Shuo Xiao, Yan-Qiu Zhang, Zi-Pei Zhu, Shao-Lin Xiong, He Gao, Dong Xu, Shuang-Nan Zhang, Wen-Xi Peng, Xiao-Bo Li, Peng Zhang, Fang-Jun Lu, Lin Lin, Liang-Duan Liu, Zhen Zhang, Ming-Yu Ge, You-Li Tuo, Wang-Chen Xue, Shao-Yu Fu, Xing Liu, An Li, Tian-Cong Wang, Chao Zheng, Yue Wang, Shuai-Qing Jiang, Jin-Da Li, Jia-Cong Liu, Zhou-Jian Cao, Ce Cai, Qi-Bin Yi, Yi Zhao, Sheng-Lun Xie, Cheng-Kui Li, Qi Luo, Jin-Yuan Liao, Li-Ming Song, Shu Zhang, Jin-Lu Qu, Cong-Zhan Liu, Xu-Fang Li, Yu-Peng Xu, Ti-Pei Li

The milestone of GW 170817-GRB 170817A-AT 2017gfo has shown that gravitational wave (GW) is produced during the merger of neutron star-neutron star/black hole and that in electromagnetic (EM) wave a gamma-ray burst (GRB) and a kilonovae (KN) are generated in sequence after the merger. Observationally, however, EM property during a merger is still unclear. Here we report a peculiar precursor in a KN-associated long GRB 211211A. The duration of the precursor is $\sim$ 0.2 s, and the waiting time between the precursor and the main emission (ME) of the burst is $\sim$ 1 s, which is about the same as the time interval between GW 170817 and GRB 170817A. Quasi-Periodic Oscillations (QPO) with frequency ~22 Hz (at $> 5\sigma$ significance) are found throughout the precursor, the first detection of periodic signals from any {\it bona fide} GRBs. This indicates most likely that a magnetar participated in the merger, and the precursor might be produced due to a catastrophic flare accompanying with torsional or crustal oscillations of the magnetar. The strong seed magnetic field of $\sim 10^{14-15}$ G at the surface of the magnetar may also account for the prolonged duration of GRB 211211A. However, it is a challenge to reconcile the rather short lifetime of a magnetar \cite{kaspi2017magnetars} with the rather long spiraling time of a binary neutron star system only by gravitational wave radiation before merger.

https://arxiv.org/abs/2205.02186



News

https://www.gssi.it/communication/news-events/item/20826-sorprendenti-lampi-gamma-ad-alta-energia-dalla-fusione-di-due-stelle-di-neutroni

Wednesday, 07 December 2022

back

Sorprendenti lampi gamma ad alta energia dalla fusione di due stelle di neutroni

Print

Si tratta di un'inattesa scoperta che apre nuove affascinanti prospettive nell'astronomia multi-messaggera. Lo studio dei ricercatori del GSSI è stato pubblicato su Nature

Fuori dalla nostra galassia, nell'universo più lontano, un miliardo di anni fa è accaduto qualcosa di straordinario: due stelle di neutroni hanno danzato una intorno all'altra fino a fondersi e ad emettere un lungo segnale di raggi gamma con un'energia mai vista prima per eventi astrofisici del genere. La ricostruzione di quanto successo e la possibile spiegazione sono state fornite da un giovane team di ricerca guidato dal Gran Sasso Science Institute dell'Aquila, in gran parte formato da assegnisti di ricerca e studenti di dottorato, in un articolo pubblicato su Nature.

PRODOTTI DALLA FUSIONE DI DUE STELLE DI NEUTRONI

Sorprendenti lampi gamma ad alta energia

News

La scoperta è stata realizzata dai ricercatori del Gssi osservando una lunga emissione di raggi gamma ad alta energia prodotta dallo scontro di due astri particolarmente densi che, ruotando uno attorno all'altro e fondendosi, inducono perturbazioni dello spazio-tempo e giganti flussi di materia ed energia. Si tratta di un'inattesa scoperta che apre nuove affascinanti prospettive nell'astronomia multi-messaggera

https://www.media.inaf.it/2022/12/07/gssi-inaf-grb-211211a/

Ufficio stampa Inaf 07/12/2022

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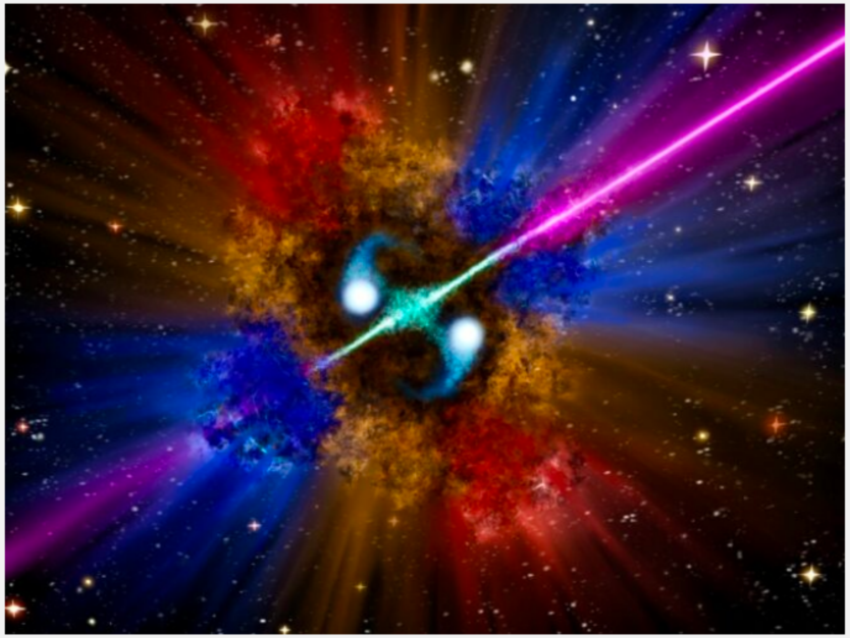

Riproduzione grafica del Grbt 211211A, analizzato dal team del Gssi – Gran Sasso Science Institute. Al centro è raffigu-