In Search of Gravitational Waves From Fast X-ray Transients

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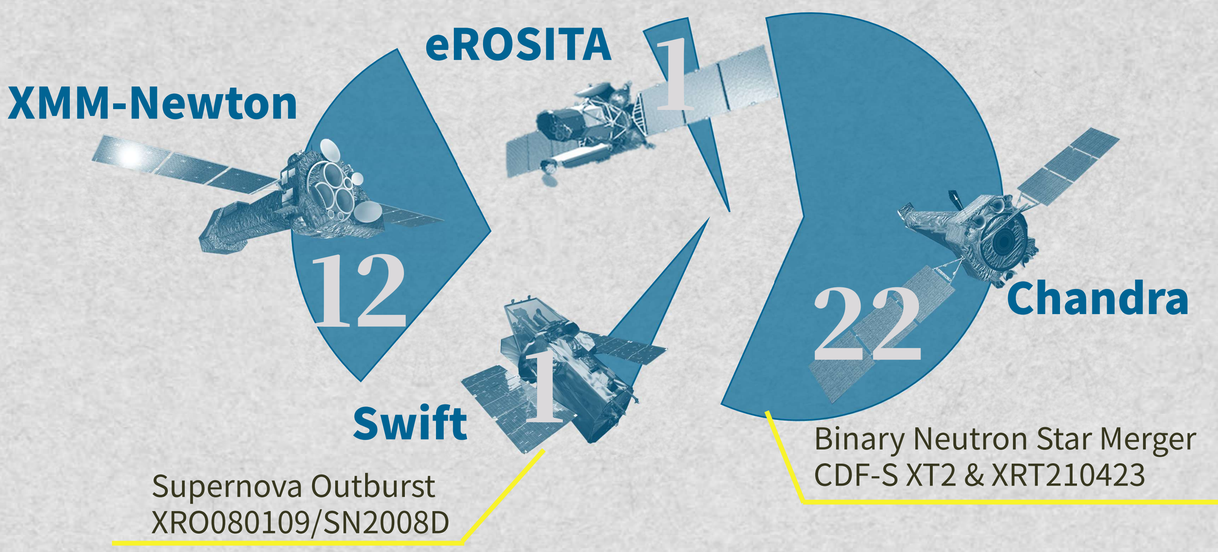
Introduction

What are Fast X-Ray Transients, and what are their origins?

Fast X-ray Transients (FXTs) are short-lived, extragalactic X-ray bursts lasting from seconds to hours. Of 36 archival events, only 3 have known progenitors while the rest remain unexplained.



These observations triggered the development of theories, suggesting these unknown events may origin from various phenomena:

- Gamma Ray Bursts
- Shock breakout of core-collapse supernovae
- Stochastic outburst from X-ray Binaries
- Tidal disruption effects
- Binary neutron star

These scenarios may produce gravitational waves, motivating a search in LIGO–Virgo–KAGRA data.

Methodology

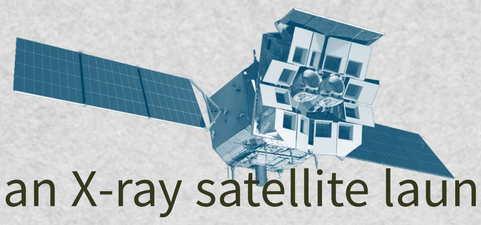
FXT Samples

We obtain the FXTs observed by Einstein Probe (EP) during the latest LVK observation run (O4b) through the General Coordinate Network (GCN) Notice, adopting their event time, sky position and positional error.

time	2024-04-10T15:00:00-2025-01-28T17:00:00
Event numbers	61
Number of sources associated with GRB	18 (~30%)

Table 1. Summary of the EP events detected during the O4b run.

Einstein Probe



EP[1] is an X-ray satellite launched at Jan,9 2024.

Wide Field X-ray Telescope
- FoV: 3600 sq.deg
- Energy range: 0.5-4 keV
- Spatial resolution: ~ 5 arcmin

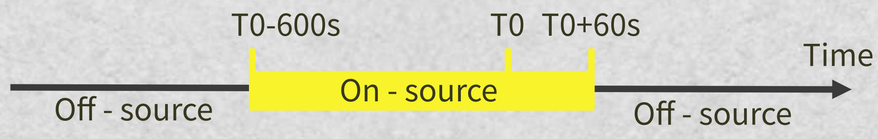
Follow-up X-ray Telescope
- FoV: 1 sq.deg
- Energy range: 0.3–10 keV
- Spatial resolution: ~ 30 arcsec

X-pipeline

X-pipeline[2] is a generic search algorithm that searches for excess coherent signals in LVK observations.

1 **Targeted Search**

Uses the event time and sky location of FXTs to define a search window (on-source) and background periods (off-source).



Source name	Time (utc)	R.A., Dec (deg)	Positional error
EP240426b	2024-04-26 14:19:06	173.7875, -40.7409	3.0 arcmin

Table2. Summary of EP240426b.

2 **Detector Response**

Detector pattern values (F_+, F_x) are computed to estimate the direction-dependent sensitivity.

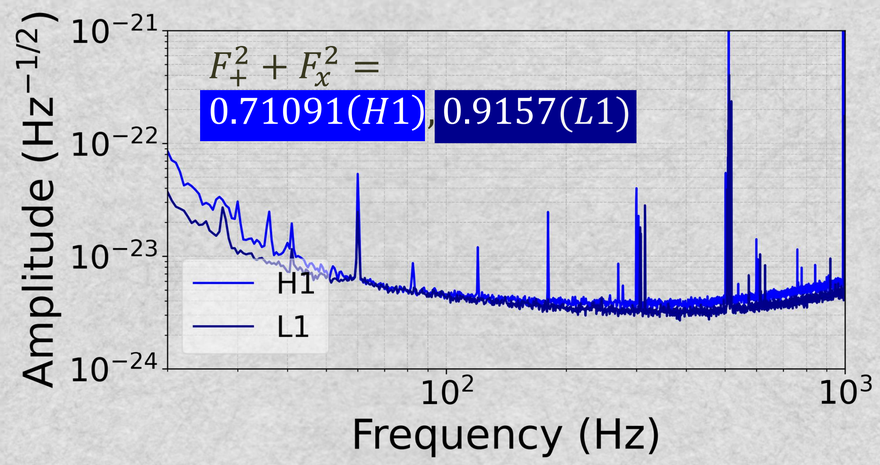


Figure 1. The detector responses within on-source window.

3 **Waveform Injections**

Theoretical waveforms are simulated to the off-source data to test detectability and essentially give upper limits.

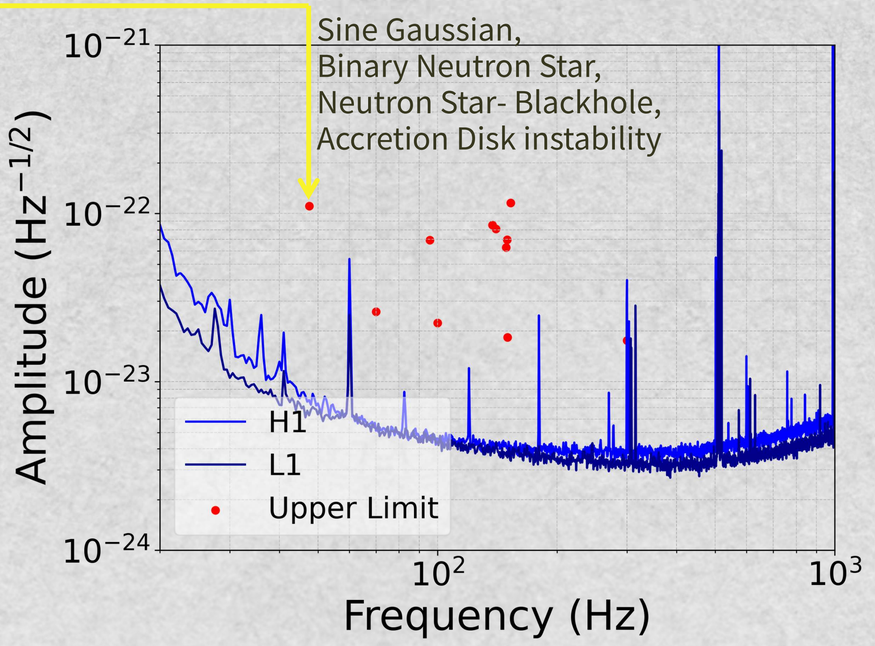


Figure 2. The detector responses and the upper limits of injected models.

4 **Detection criteria**

Coherent excess power would then be measured in the on-source data, giving the probability of the presence of such GW event.

Reference:
1. Yuan, W., Zhang, C., Chen, Y., & Ling, Z. (2022). The Einstein probe mission. In *Handbook of X-ray and Gamma-ray Astrophysics* (pp. 1-30). Singapore: Springer Nature Singapore.
2. Sutton, P. J., Jones, G., Chatterji, S., Kalmus, P., Leonor, I., Poprocki, S., ... & Was, M. (2010). X-Pipeline: an analysis package for autonomous gravitational-wave burst searches. *New Journal of Physics*, *12*(5), 053034.