High-Energy Analysis of Periodic FRB 20250324

1 Abstract

The discovery of FRB 20250324, a fast radio burst exhibiting periodic behaviour every 13 days, presents a rare and valuable opportunity to search for a high-energy counterpart, such as the X-ray burst associated with FRB 20200428 (Rehan & Ibrahim 2025). *NuSTAR*'s ability to observe hard X-rays allows for the investigation of X-ray bursts simultaneous with FRB 20250324, and a 53ks observation is proposed to gain critical data in developing the understanding of both this individual FRB, as well as all FRBs and their high-energy counterparts. Observing an associated X-ray burst (FXRB), or the lack thereof, will help narrow down the unknown source of the FRB, as well as provide constraints on the emission mechanisms of FXRBs by comparing the resulting spectrum, duration, and peak energy observed, to that of various theoretical models.

2 Scientific Justification

2.1 Background and Proposed Models

Fast radio bursts, or FRBs, are extreme expels of radio energy that occur and end within milliseconds. Despite their short durations, FRBs emit more energy than the Sun puts out over a thousand years, making them the brightest observed burst in the radio band (Bhardwaj, McGill University 2024; Ge et al. 2023). Additionally, FRBs are thought to have brightness temperatures exceeding 10^{30} K, and the majority of those detected are thought to be single occurrences; however, multiple repeating bursts have been documented, notably FRB 20180916B which has an observed periodicity of 16 days (Wadiasingh et al. 2020; Lan et al. 2024). The sources of numerous FRBs, along with their physical emission processes are not yet known or established, but there is evidence pointing to at least some FRBs coming from magnetars (Zhong et al. 2024). This evidence was provided by simultaneous bright X-ray bursts being observed for FRB 200428, as they were localized to the source SGR 1935+2154 and their spectrum was consistent with that of ordinary magnetar bursts (XRB) (Ge et al. 2023; Liu et al. 2023). That being said, the typical energy limit associated with XRB is considerably lower than that which was documented for the FXRB, and there are certain properties which appear unique to the FXRB. More precisely, this associated burst demonstrated a lower flux density at the maximum energy, as well as a greater peak energy (Liu et al. 2023). Consequently, high-energy bursts coinciding with FRBs are suggested to be special, and several models have emerged as potential candidates to explain the emission of X-ray bursts associated with FRBs.

One model, referred to as the trapped fireball model, suggests that there is a sudden release of energy (a fireball), potentially caused by a crack in the magnetar's crust. This hot plasma becomes trapped by closed magnetic field lines and Resonant Compton Scattering (RCS) takes place, where the photons emitted by the fireball are up-scattered by the electrons and eventually escape producing an XRB (Zhong et al. 2024). Taking this a step further, Zhong et al. (2024) propose that the magnetic field lines are twisted, in turn accelerating the charges that undergo RCS, claiming that this modification allows for a better fit of the tail in the spectrum of the XRB that is associated with FRB 20200428.

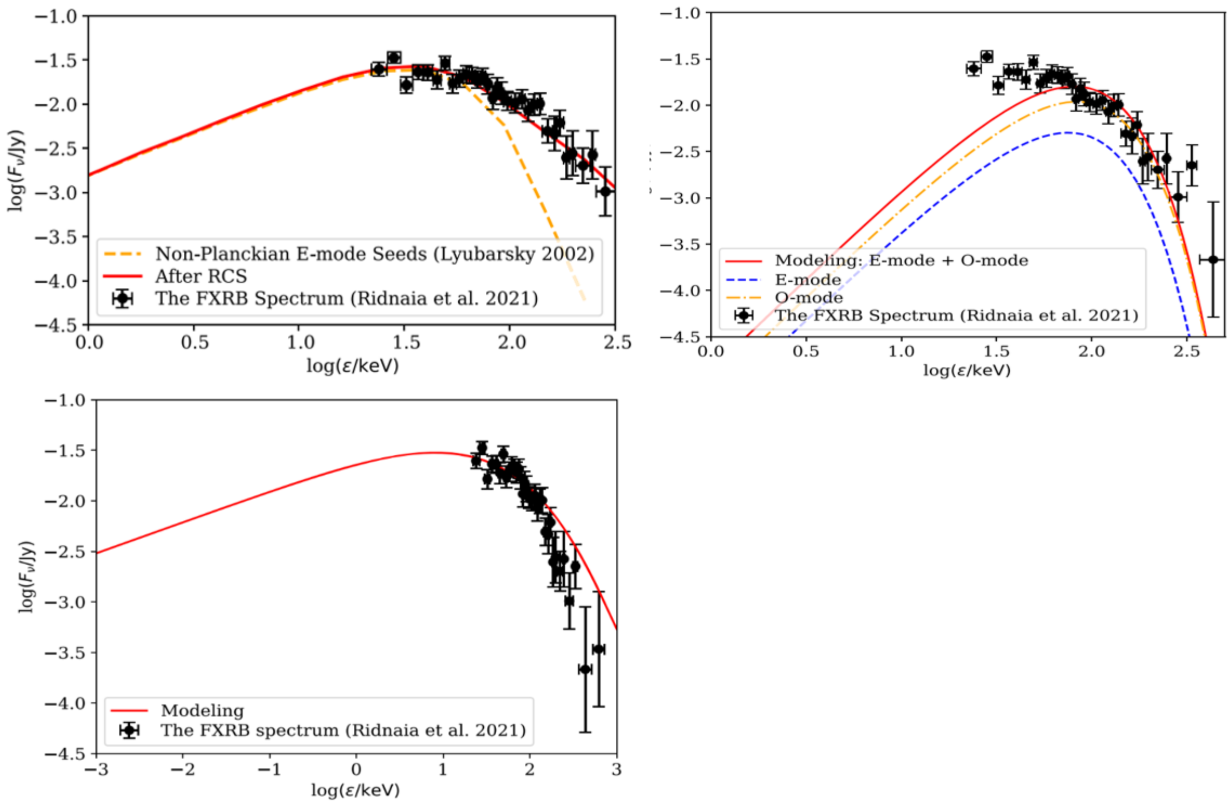

Figure 1: Each graph shown was created by Zhong et al. (2024), as they worked to fit the phase-averaged spectrum of the FXRB associated with FRB 20200428. **Top left:** The spectrum is fit to the trapped fireball and RCS model spectrum. The group performed 3D Monte Carlo (MC) simulations to model the spectrum of seed photons—the initial photons coming from the fireball—and their propagation. The dashed line represents the seed photons' spectral distribution, while the red line is the outflowing radiation post-RCS. **Top right:** The modeled spectrum is that of the trapped and expanding fireball model. An in-depth explanation of E-mode and O-mode photons can be found in Zhong et al. (2024), but briefly, O-mode refers to photons with scattering cross sections equal to that of the Thompson cross-section, while E-mode is when the scattering cross section is provided by the referenced work's equation 48. **Bottom left:** This model pulls from the dynamics of the synchrotron radiation and relativistic shock model, along with a performed spectral calculation shown in their equation 71. This was decided as their best model spectra for the FXRB.

This team went on to fit the spectrum of the currently sole observed FXRB to this model, as well as to the following two frequently debated models (Figure 1).

Another model, as explained by Wada & Ioka (2023) discusses a trapped expanding fireball, where the plasma undergoes an expansion along magnetic field lines, followed by photons and matter flowing out along open field lines. The team proposed that this model could be applied to the non-ordinary XRB, stating that this burst radiation is capable of accelerating the emitted matter with enough energy to power the FRB.

Touching on one more common model, Margalit et al. (2020) demonstrate that the properties of the simultaneous XRB, including its spectrum, agree with the synchrotron maser shock model. This model suggests that the magnetar releases a relativistic flare of energy, which collides with a shell of slower-moving debris from a previous flare. During this collision, electrons get energized and gyrate along the magnetic field lines in the shocked area, emitting incoherent synchrotron radiation, which is thought to be the origin of the FXRB (Metzger et al. 2019).

Observations of these high-energy FRB counterparts are critical to establishing the origin of FXRBs and are a significant means of evaluating proposed models. These observations not only aid in the understanding of FXRBs but can provide critical insights into the sources and models of FRB (Cook et al. 2024).

2.2 Observing FRB 20250324

On March 24th, 2025, a new fast radio burst, called FRB 20250324, was discovered by *CHIME* and was shown to exhibit a periodicity of 13 days. With FRB 20180916B being the only other FRB with documented periodic behaviour, this presents an invaluable moment to perform high-energy observations of a fast radio burst (Lan et al. 2024). Numerous FRB studies make predictions for FXRB, and not only will this opportunity to potentially identify an FXRB provide beneficial data to the comprehension of the mechanisms of these events and proposed magnetar models, but a high-energy spectrum of this radio event is critical to fully understanding FRB 20250324 (Cook et al. 2024). The study of FRB 20250342 using *NuSTAR* will allow for such a spectrum to be obtained, as well as the potential duration, light curve, and timing relative to the FRB of an FXRB. The spectrum of the prospective FXRB will be extracted from the data and compared to the model spectra, specifically of those mentioned in Sect 2.1, as well as to that of the FXRB from SGR 1935+2154. The peak energy of the potential burst will be measured and compared to that of the documented FXRB and to the ordinary peak energy range of magnetar X-ray flares. The event timing will also be analyzed with respect to that of the FRB, to examine any simultaneity. These comparisons will provide insights into the emission mechanisms of any FXRB, as well as shed light on the source of the FRB.

3 Technical Justification

3.1 *NuSTAR*

The large energy range of *NuSTAR* makes it well suited for observing an FXRB, as it is expected to range far beyond 10 keV, which *NuSTAR* is uniquely adept at observing. Although the entire tail of a potential FXRB may not be observed, that is if the observed burst behaves as the one observed from SGR 1935+2154 which of course has yet to be determined, this instrument remains an important starting point. In addition to seeing if such an event exists, *NuSTAR* enables the discovery of the energy point for a probable power-law cut-off spectrum and allows for the determination of peak energy. FXRB are expected to have durations of 30-50 ks, therefore, the timing resolution and capabilities of *NuSTAR* are sufficient and will allow for the measurement of the duration of a potential burst and the timing of any observed peaks (Tang et al. 2024). Furthermore, *NuSTAR* has been used to study ordinary XRB, notably those of the mentioned magnetar SGR 1935+2154, demonstrating its valuable insights into objects of this nature (Ibrahim et al. 2024).

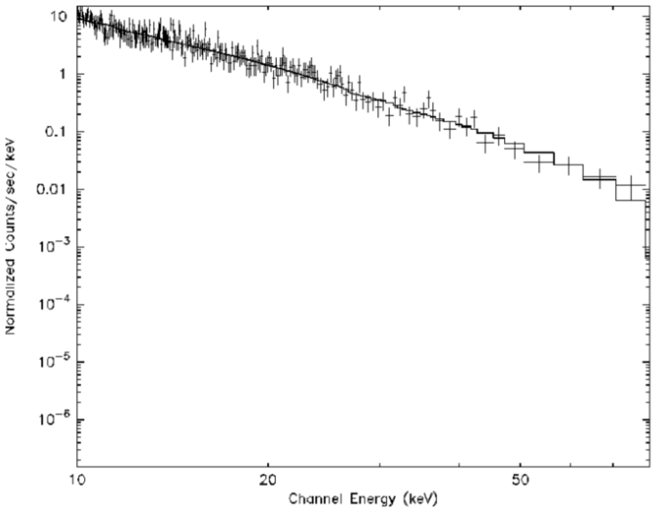

Figure 2: A photon index of 1.4, and a cut-off energy of 60 keV were used, as was measured by Ge et al. (2024) for the X-ray burst associated with FRB 20200428. A normalization of 1 was used, and the Galactic column density was input as 5.98 x$10^{20}$$cm^{-2}$.

3.2 Feasibility

An exposure time of 53ks is requested since FXRB are expected to have durations of 30-50 ks, as mentioned; therefore, this time should allow for observation before, during, and after any coinciding event (Tang et al. 2024). FRB 20250324 is situated at RA = 245.0583° and DEC = +85.34336°, and the HI 4 Pi Survey Map calculates an average column density of 5.98 x$10^{20}$$cm^{-2}$. The *NuSTAR* observing constraints were examined from June 1st, 2025 to May 31st, 2026. There are no solar aspect angle violations and no moon aspect angle violations. There are various days throughout the year that have spacecraft star tracker violations, but only 3 of these days coincide with the periodic behaviour of FRB 20250324. The stray light evaluation result claims no issues.

As no current high energy data exists for FRB 20250324, the findings of Ge et al. (2023) regarding the X-ray peak spectrum of the XRB associated with FRB 20200428 were adopted for simulating data (Fig. 2). This simulation done using WebSpec had a resulting count rate of approximately 51 counts per second, and roughly 1.35x10^{-8} ergs/cm^2/s for the 10-79 keV energy range. Overall, *NuSTAR* will provide a needed insight on the presence or absence of X-ray bursts associated with FRB 20250324, allowing for a direct measurement of potential timings and photon index, and for a peak energy to be extracted due to its broad range.

4 Conclusions

The recent discovery of FRB 20250324, the second fast radio burst to exhibit periodic behaviour, presents an invaluable opportunity to advance the understanding of FRB and look for its high-energy counterparts. Its 13-day period allows for multiple moments of observation using *NuSTAR*, whose hard X-ray range is important to the analysis of FRB 20250324. Confirmation of the existence, or lack thereof, of an associated X-ray burst, will help distinguish the source of the FRB, while any data obtained from an FXRB aids in assessing the validity of emission models.

5 References

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