Probing FRB20180916B with the Allen Telescope Array

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Abstract

Fast Radio Bursts (FRBs) are bright, highly dispersed, millisecond-duration transients. This study focuses on FRB20180916B, a unique repeating FRB which displays periodic activity. We conducted an observing campaign utilizing the Allen Telescope Array, a radio interferometer with 20 dishes in the current beamformer. Our observations were centered at 1236 MHz and 8000 MHz to simultaneously target a familiar lower frequency range and a less explored higher frequency range, designed to place stronger limits on the source's high frequency activity. Using SPANDAK, an FRB detection software, we looked for dispersed pulses with dispersion measures centered at 349.4 pc cm^-3 and signal-to-noise ratios greater than 10. No bursts were detected from within the time frame, indicating an upper limit of 3.5 bursts for 100 hours of observation, under these conditions, on FRB activity. The study underscores the challenges of capturing stochastic or highly variable sources such as repeating FRBs.

Background

Fast Radio Bursts (FRBs) are powerful, highly dispersed, fleeting bursts of radio waves originating from **unknown** celestial sources. While most FRBs manifest as single occurrences, some FRB sources are known to repeat and produce multiple random FRBs, so called "**repeaters**." The prevailing scientific consensus points towards magnetars as potential sources by observed radio bursts from galactic magnetars (Collaboration (2020b)). Our campaign utilized the Allen Telescope Array, For additional details on technical specifications of the ATA, refer to Farah et al. 2023 (in prep).

Still, FRB source known as FRB20180916B, discovered by the Canadian Hydrogen Intensity Mapping Experiment (Collaboration et all. 2022), appears to exhibit a distinct 16-day activity cycle with a 5-day active window at 600 MHz(Collaboration(2020a)).

Relevant Equations:

System Equivalent Flux Density

$$SEFD_{beamformer} = \frac{\frac{\sum_{x,y} SEFD_{x,y}}{N_{x,y}}}{N_{el}}$$

Lens Equation

$$\theta = 1.22\frac{\lambda}{D}$$

Radiometer Equation

$$S_{\nu,min} = \frac{(SNR)(SEFD)}{\sqrt{2\tau\Delta\nu}}$$

Observing Campaign

First, we identified FRB20180916B as the focus of our campaign due to its consistent activity from Chime/FRB Collaboration Repeaters Catalog. From June 27th to August 8th, we conducted a total of 8 observing sessions, totaling **28.5 hours** of on-source observation time with the 20-element beamformer, focusing on the central region of FRB20180916B based on CHIME detection coordinates. For our observations, the ATA beamformer generated 32-bit SIGPROC "filterbank" files with a frequency resolution of 0.5 MHz and time resolution of 64 μs. For FRB detection, we utilized the **SPANDAK** pipeline (Gajjar et al. 2022), a GPU-accelerated code, for dispersed signal searching.

We collected data centered at 1236 MHz and 8000 MHz, **covering 900 to 1572 MHz and 7664 to 8336 MHz**, respectively and prior to each observing session, instrument calibrations were carried out using a phase calibrator with coefficients from Perley & Butler (2017) to generate flux densities and an observation of pulsar J0332+5434 from the initial observation onward to validate our system and the SPANDAK pulse detection pipeline.

Figure Explanation:
i) The candidates optimized burst profile, peak intensity
ii) The dedispersed dynamic spectrum
iii) The power levels at various combinations of dispersion measure (DM) and trigger time
iv) The dispersed dynamic spectrum

Allen Telescope Array

Results & Data

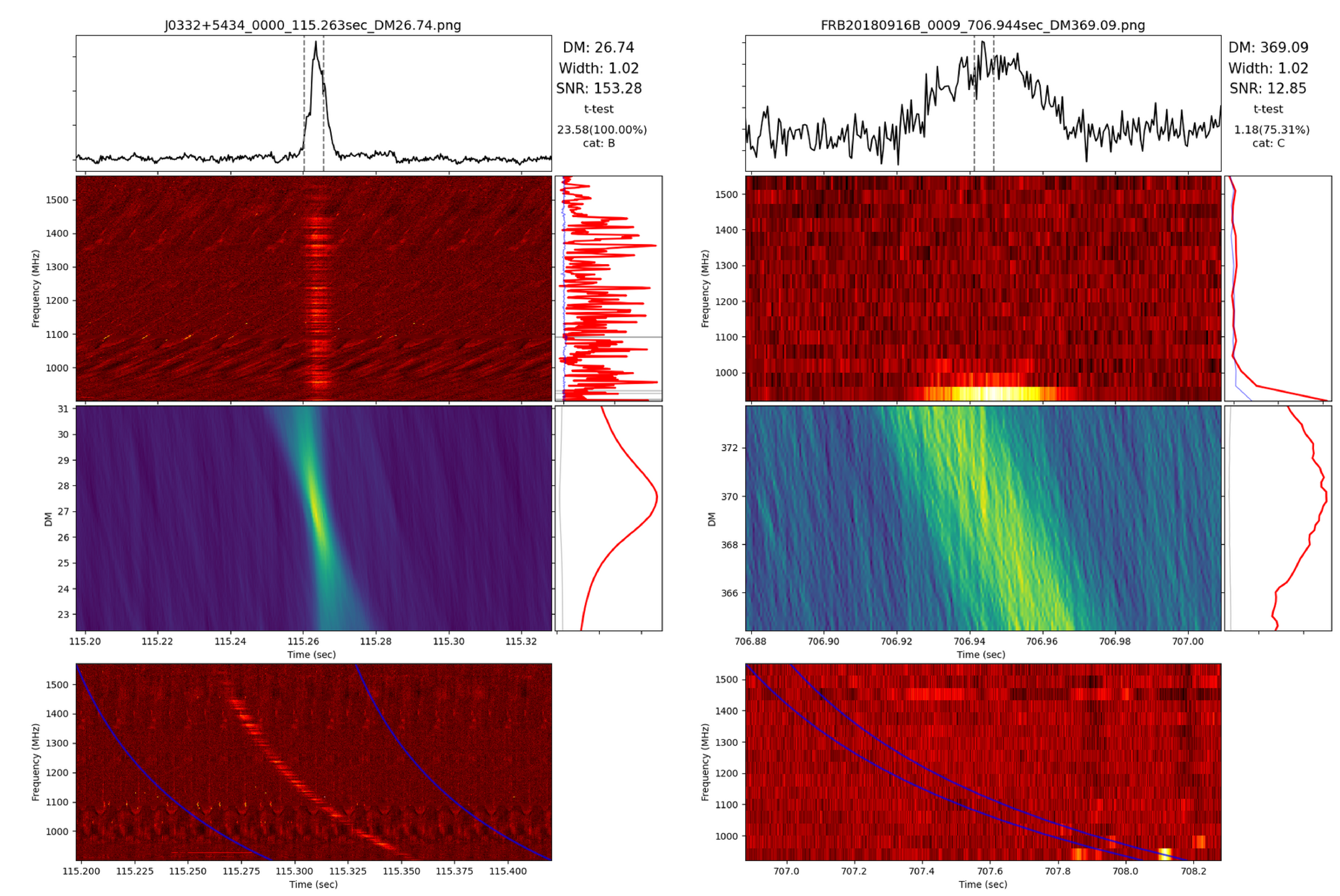

Figure 1. SPANDAK .png of a pulsar burst, compared to an "FRB Burst", though it appears to be RFI.

Despite 28.5 hours of dedicated observations to FRB20180916B, **no detections were made**, except for some radio frequency interference (RFI) "dropouts." There we bursts detected from FRB20180916B at lower frequencies suggesting the possibility of more limited activity at higher frequencies. Nevertheless, we evaluated the SEFD to assess instrument sensitivity, finding an average SEFD at 1236 MHz was 534.423 Jy, and at 8000 MHz was 1208.825 Jy; providing a minimum detectable flux density at 1236 MHz of **4.62 Jy** and at 8000 MHz of **10.427 Jy** tuning. Results align with typical brightness of radio sources (1-100 Jy).

Conclusions & Future Work

While the of FRB20180916B has been done across many frequencies, detections have centered around comparatively low frequencies. Tendulkar et al. (2021) postulated that FRB20180916B is likely an old neutron-star High Mass X-ray Binary (HMXB) or gamma-ray binary system with a late O-type or B-type companion. We ultimately hope more time on the sky with an emphasis on the activity windows will help us capture the elusive high frequency burst and the upper limits we obtained, coupled with the sensitivity of our observations and the potential for future detections using the ATA. Until then we are refining our technology which include implementation of ML algorithms in our FRB detection pipeline.

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References

Collaboration T. C., 2020a, Nature, 582, 351–355
Collaboration T. C., 2020b, Nature, 587, 54
Collaboration T. C., et al., 2022, The Astrophysical Journal Supplement Seeries, 261, 29
Gajjar V., et al., 2022, The Astrophysical Journal, 932, 81
Perley R. A., Butler B. J., 2017, The Astrophysical Journal Supplement Series, 230, 7
Tendulkar S. P., et al., 2021, The Astrophysical Journal Letters, 908, L12