Characterization of a Hyperactive Fast Radio Burst

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Repeating Fast Radio Bursts

Fast Radio Bursts

- Detected at radio frequencies
- Millisecond transient signal at extremely high energy
- 600+ have been published, 50 repeaters, 39 localized to host galaxies

Non-repeating / Repeating → Low burst activity / High burst activity → FRB20220912A

We seek to constrain our models of FRBs by studying the characteristics of repeating sources such as FRB20220912A, including burst rates, signal to noise ratio (S/N), dispersion measure (DM), and flux and fluence.

More about FRB source FRB20220912A:

- Discovered by the CHIME/FRB collaboration on September 12, 2022 at 400 MHz.
- 192 total bursts were recorded from 2022-10 to 2023-05, 135 detected within beam.
- Localized to arcsecond accuracy; RA, Dec: 347.270417, 48.707056 [1]

CHIME

CHIME/FRB has revolutionized FRB science with real time detection, long-term monitoring, and wide field of view

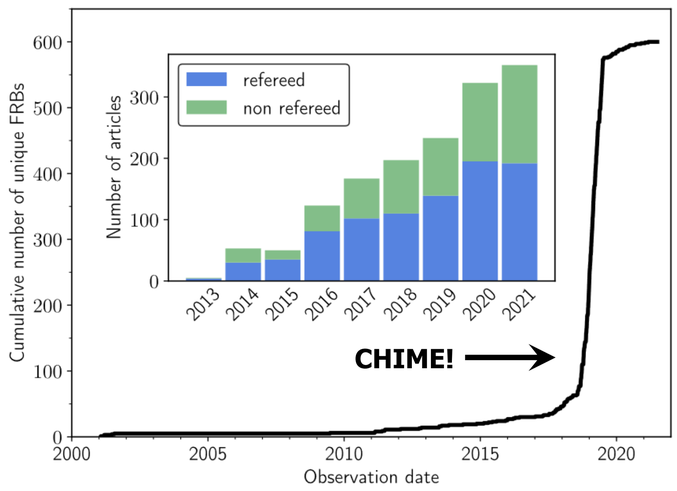


Figure 1. Cumulative number of published FRB sources as a function of their arrival time [2].

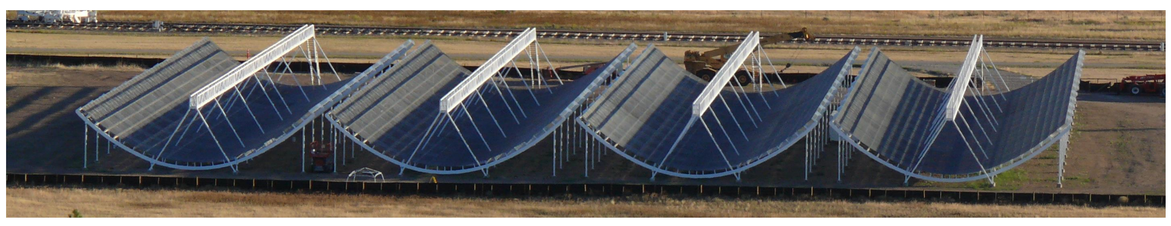


Figure 2. Chime Telescope. Image Credit: DRAO/CHIME

Detections

In Beam Detections

- 135 detections made within the FWHM of a CHIME/FRB beam at 600 MHz

Out of Beam Detections

- Does not give good record of the exposure towards the source.
- Including these might introduce additional noise.

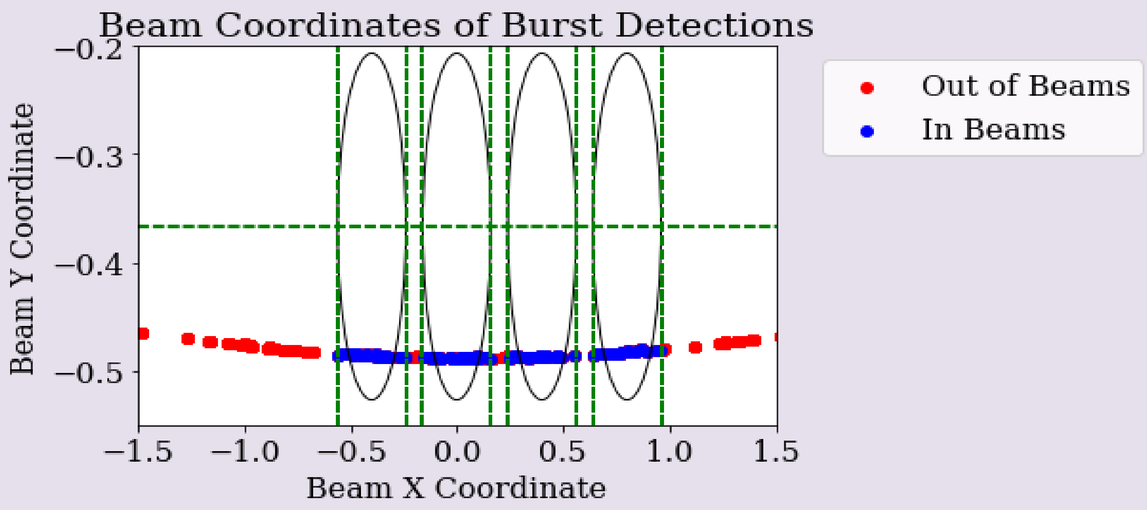


Figure 3. CHIME Beam Model and Burst Detection Coordinates.

Exposure to Source Position

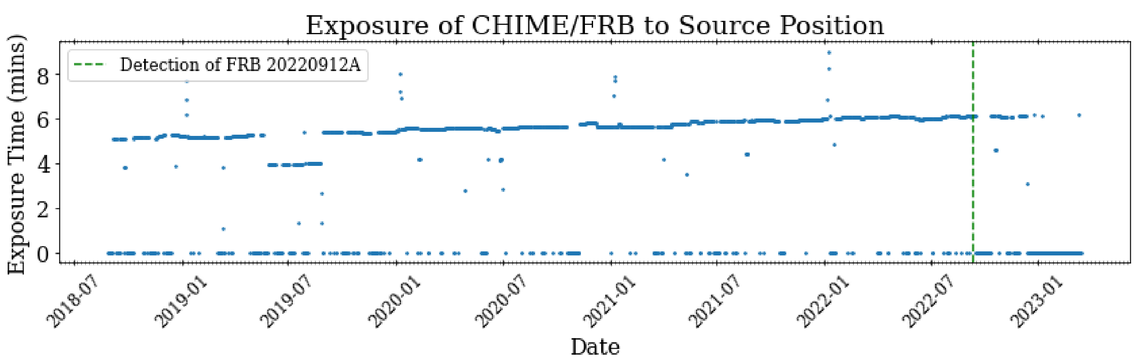


Figure 4. CHIME/FRB Exposure to Source Position.

****First detection does not occur until 2022 despite previous exposure to source position. ****

Burst Rate Evolution

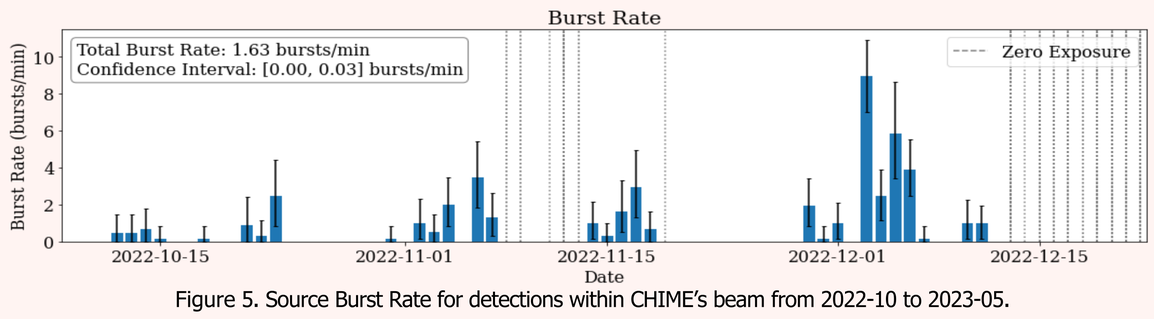
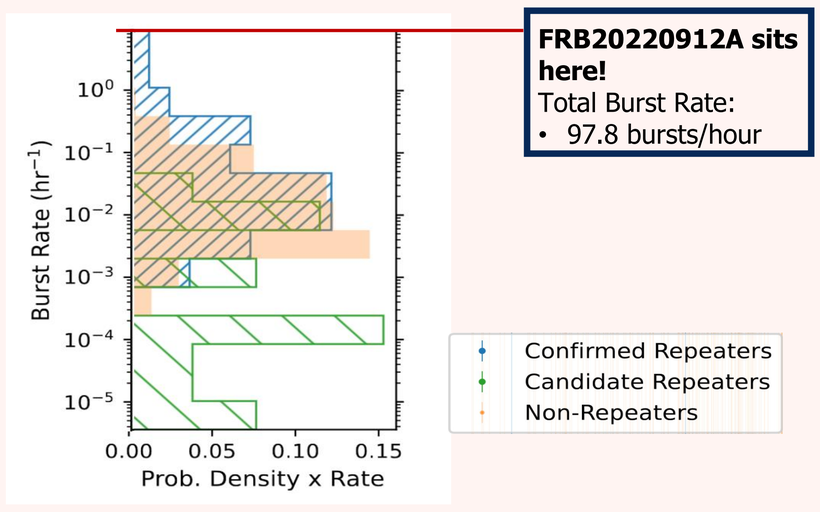


Figure 5. Source Burst Rate for detections within CHIME's beam from 2022-10 to 2023-05.

Calculated the Poisson Burst Rate for each detection:

- Total # of In-Beam Detections / Daily Exposure Time



FRB20220912A sits here!
Total Burst Rate:

- 97.8 bursts/hour

Figure 6. Histograms of the rate estimates for each class of source [3].

So, what do we know?

- The source's burst rate and energetics indicate dormancy for at least four years.
- By multiplying the burst rate by energy per burst, we can calculate the required energy release, confirming the source must have a reservoir larger than that amount.

Dispersion Measure

As the transient signal travels through space, the interstellar medium disperses the signal's frequencies. The dispersion measure (DM) can be determined by integrating over the electron number density (n_e) if the distance (d) to the object is known:

$$DM = \int_0^d n_e \, \mathrm{d}l$$

Data must first be dedispersed and the correct DM must be determined. Since all FRB20220912A events come from the same source, they should all have the same DM.

We find that most FRB20220912A events have a relative low S/R. We apply one fiducial DM from a bright event to all detections:

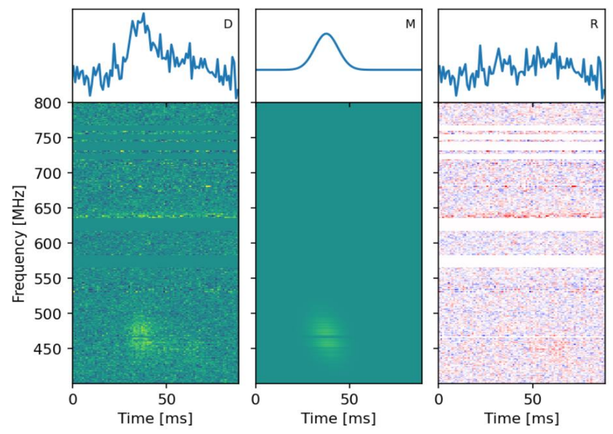


Figure 7. Dynamic Spectra of Event 298768864 with DM: 220.45626 pc/cc.

Next Steps

Improving Flux & Fluence Measurements
We fit the burst for various observational properties.
Measuring a more accurate flux/fluence of repeating FRBs will allow us to better constrain FRB progenitor models and the FRB luminosity function.

To improve the flux/fluence measurements we want to:

1. Fix the DM for all events
2. Write an algorithm that finds the burst & automatically fixes the optimal burst extent. This will allow us to better constrain the observational properties of the detected events.
3. Implement algorithm into CHIME/FRB Fluence calculation pipeline

****Applicable to anyone wishing to do the same!****

Burst Rates
Try the Weibull distribution instead of Poisson. Poisson models events at a constant mean rate, independently of the last event's timing. Weibull adds a shape parameter (k), where k=1 reduces to Poisson; k≠1 describes clustering; k<1 favors small intervals, so subsequent bursts are more likely [4].

Extend data scope
Current scope is only 2022-10 to 2023-05, want to extend this to include more recent data.

References

[1] V . Ravi et *al.* Deep Synoptic Array Science: Discovery of the host galaxy of FRB 20220912A. *The Astrophysical Journal Letters*, vol. 949, no. 1, 2023.

[2] E. Petroff, J. W. Hessels, and D.R. Lorimer. Fast radio bursts at the dawn of the 2020s. *The Astronomy and Astrophysics Review*, vol. 30, np.1, 2022.

[3] The CHIME FRB Collaboration 2023 CHIME/FRB Discovery of 25 Repeating Fast Radio Burst Sources. *The American Astronomical Society*, vol. 947, no. 2, 2023.

[4] The N. Oppermann, H. R. Yu, and U. L. Pen. On the non-Poissonian repetition pattern of FRB121102. *The Monthly Notices of the Royal Astronomical Society,* vol. 475, no. 4, pp. 5109-5115, 2018.

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