Fast Radio Burst Detection (FRB) with CHIME

And optimizing the detection process using Injections and Data Analytics

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Contents

Background, Contributions, Findings and Takeaways

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- The injections system at CHIME
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- Findings and conclusion

What is CHIME?

- CHIME or the Canadian Hydrogen Intensity Mapping Experiment is a novel radio telescope with NO moving parts
- Located at the Dominion Radio Astrophysical Observatory, Canada
- Originally conceived to map hydrogen - over a good fraction of the observable universe
- The digitized signals collected by CHIME will be processed to form a 3-D map of H-density
- Signals can be combed for fast, transient radio emission for discovering new FRBs and for monitoring many pulsars on a daily basis

FRBs and their Characteristic Features

Fast Radio Bursts are brief (few millisecond) bursts of radio waves coming from far beyond our Milky Way galaxy. The phenomenon was first reported in 2007. Their origin is unknown.

The average FRB releases as much energy in a millisecond as the Sun puts out in 3 days!

The CHIME telescope's large collecting area, wide bandwidth and enormous field-of-view make it a superb detector of FRBs.

As of mid 2020, CHIME has detected well over 1000 Fast Radio Burst sources.

Major characteristics taken into account for detection

1. **Dispersion Measure**:

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

2. **Width:**

   FRBs have an associated intrinsic timescale, as emitted by the source

3. **Scattering**
4. **Brightness**

CHIME/FRB Injections

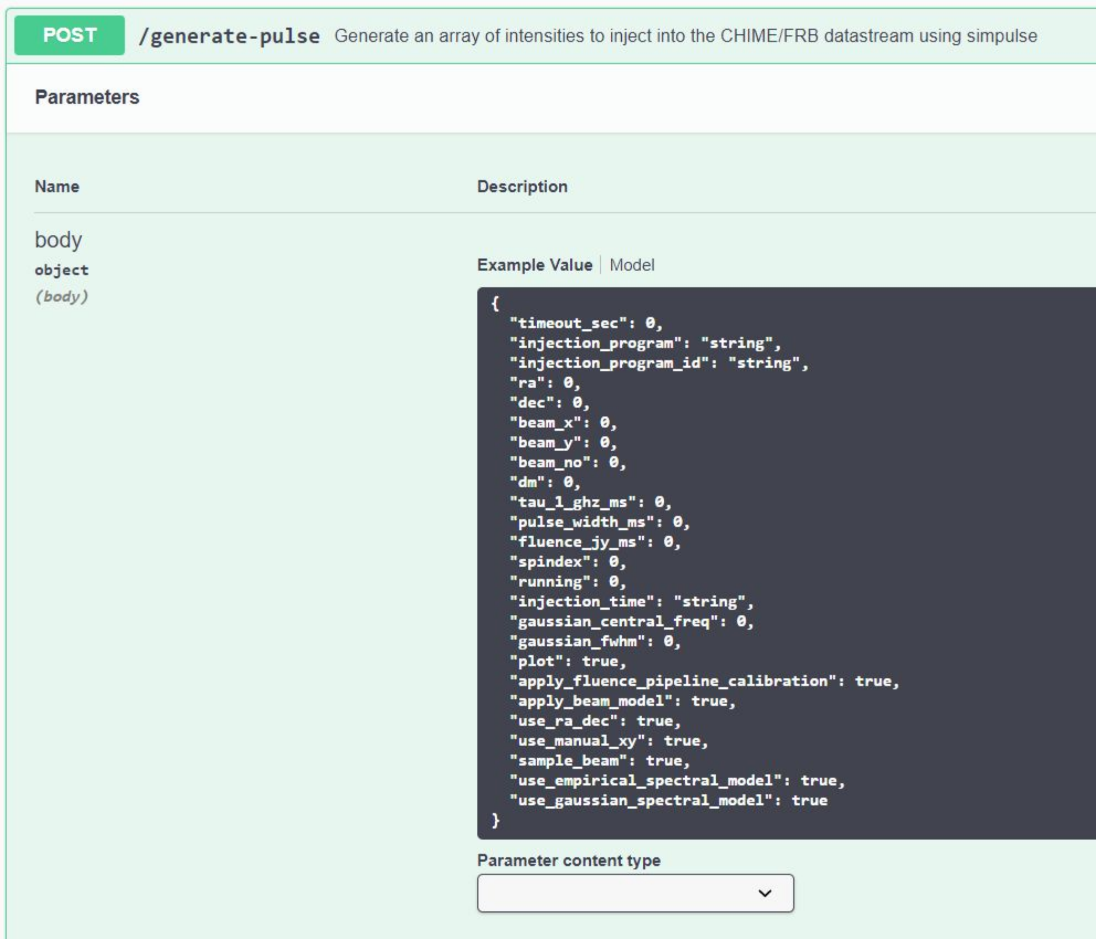
While CHIME/FRB's design allows for the highest FRB detection rate of all current surveys, like any telescope, it is subject to selection biases affecting our interpretation of the observed population of bursts.

These biases come primarily from the fact that CHIME's beams are complicated, and from the RFI littering on-sky data.

In order to undo the biases which are introduced in the real-time pipeline, CHIME/FRB has developed a service which **injects model populations** of **synthetic FRBs** into the live detection pipeline.

Creating Synthetic Pulse “Injection” Datasets

- Setting Parameter values,
- Following distributions
- Monitoring detections based on specific FRB characteristics



A Real Time Monitoring/Analytics Dashboard for injections

1. Running programs
2. Recently run programs
3. Directory of all programs run in the past

Program wise details

1. Program Name
2. Time- when the program was run- start time, end time
3. Total Injections
4. Total Detections
5. Details of parameters used + distribution followed for parameters if any

Plots

- Histograms- Fluence, DM, L1/L2 grades
- Detection fraction as a function of fluence, width and DMs
- A table-
  - number of injections,
  - number of detections by the de dispersion algorithm
  - number of detections passing rfi_grade_l1/ avg_l1_grade cutoff
  - Number of detections passing rfi_grade_l2
- Fetch a list of those injections which did cross the L1/L2 cutoff and analyze the parameters for these.
  - Fluence
  - SNR
  - DM
  - Width
- The next step could be- looking at injections which did not get detected by the dedispersion algorithm and trying to find reasons for the same

Running Injection Programs

Plots

Simpulse running status

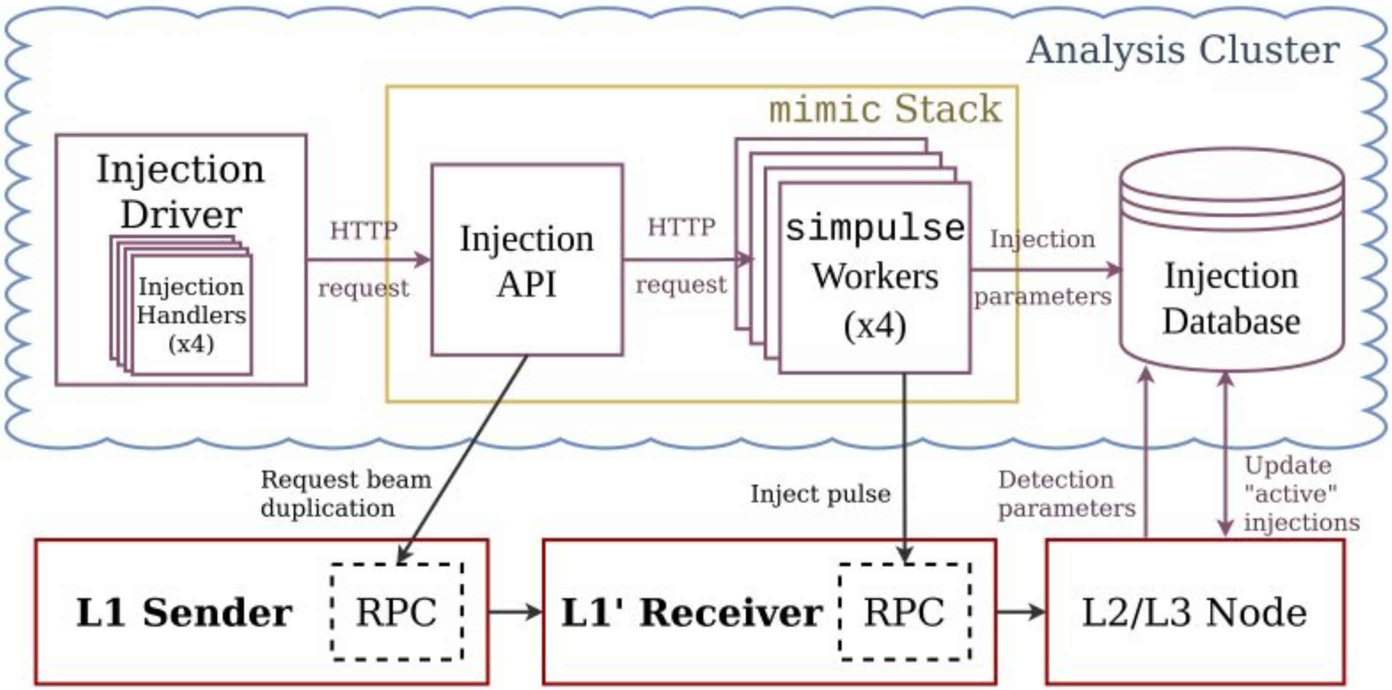
Recently Completed

Name	Injections	Detections
Program 1		
Program 2		

Past Programs

Name	Injections	Detections
Program 1		
Program 2		

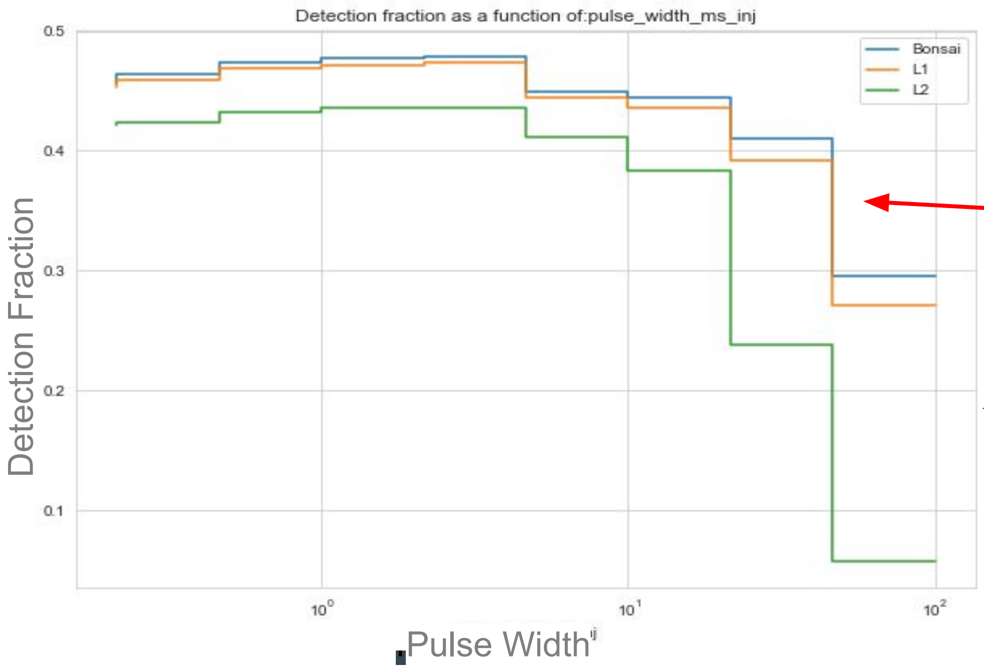
The Detection Pipeline



Important Findings

Detected as a trigger by bonsai
Identified as astrophysical by L1
Identified as astrophysical by L2

A. Detection Fraction vs Pulse Width

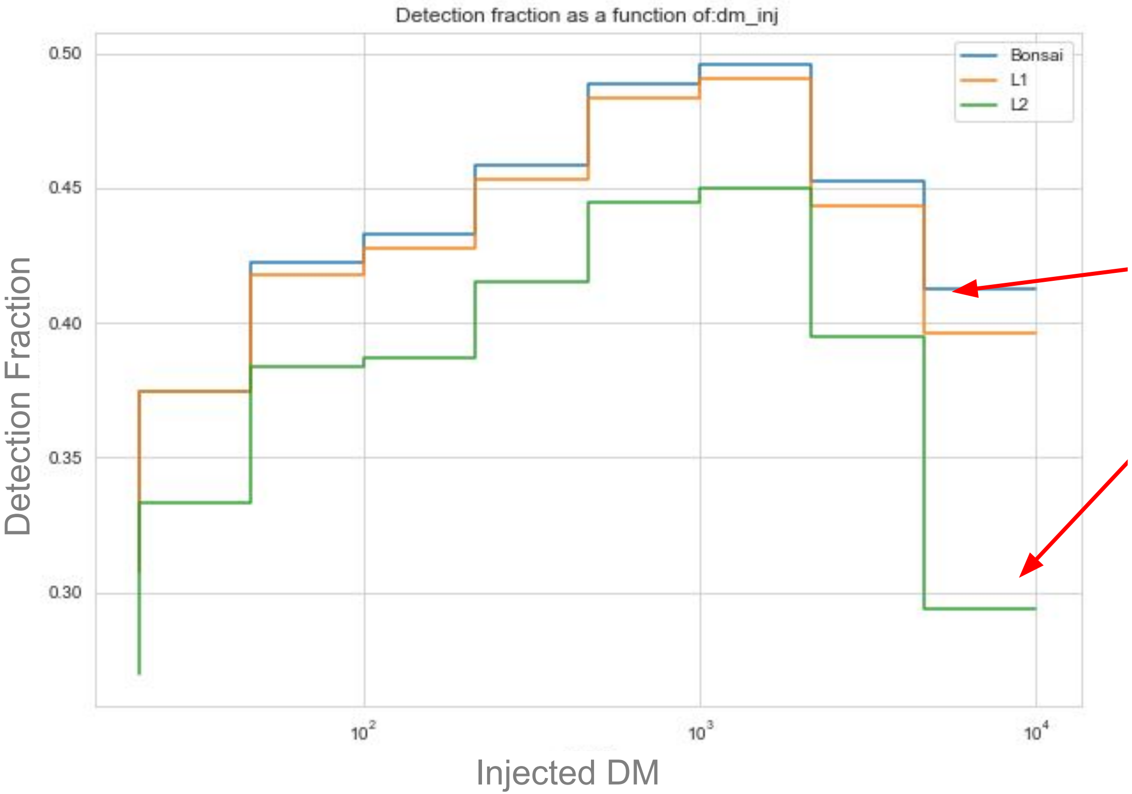


Injections dataset used: from August
Injections: 84,000
Total detections: 35,000

For injections with pulse width values between 20 and 40 ms, the DF drops from about 0.4 at bonsai and L1 to 0.2-0.25 at L2

Between 40 and 100 ms, DF drops from about 0.3 at bonsai and L1 to 0.05 at L2

B. Detection Fraction vs Injected DM



- An increase in DFs is seen as DM values increase up till Fluence value of 2000 pc/cm^3
- For pulses with DM values between 2000 and 4500 pc/cm^3, the DF drops from about 0.45 at bonsai and L1 to 0.40 at L2
- Between 4500 and 10000 pc/cm^3, DF drops from about 0.42 at bonsai and L1 to 0.30 at L2

We are missing high DM and high Pulse Width FRBs that L2 classifies as RFI!

References

1. CHIME Experiment (chime-experiment.ca)
2. MS Thesis- Marcus Meryfield
3. Injections Operations Manual by Marcus Merryfield