Utilizing the 25m Dwingeloo Radio Telescope (DRT) to Study Fast Radio Bursts (FRBs)

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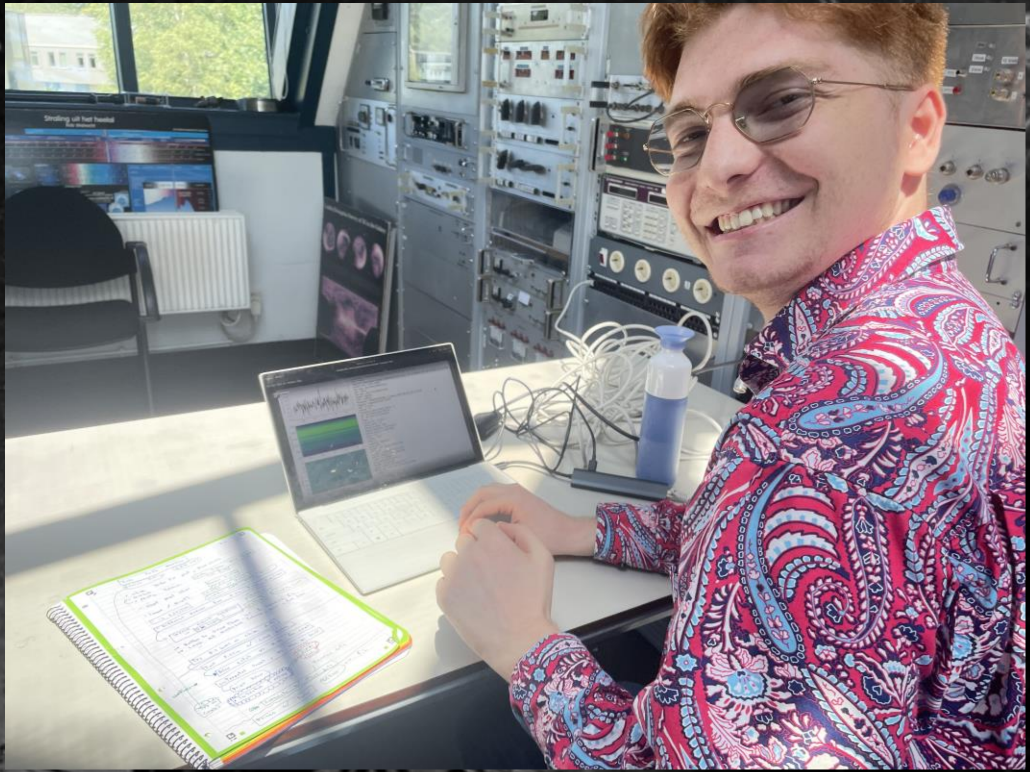

Here is me working at the DRT. Image credit Prof Jason Hessels.

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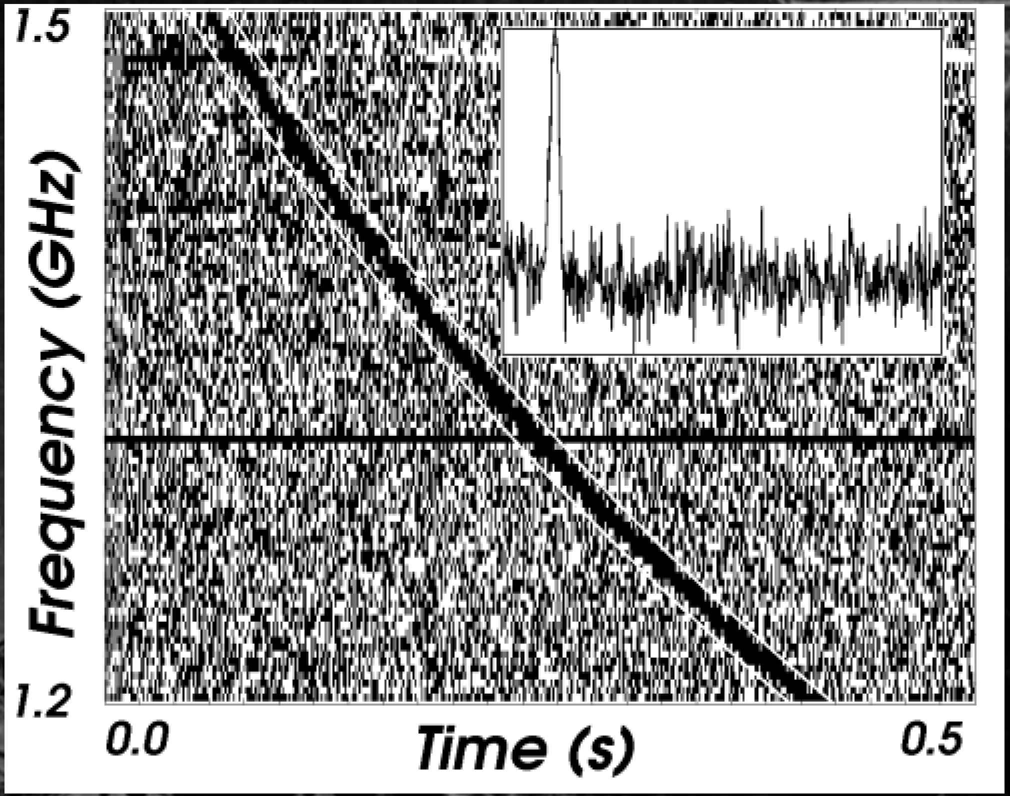
Background Image: D. Futselaar/ASTRON

Fast Radio Bursts (FRBs)

- **Fast Radio Bursts (FRBs):** brief, intense radio emission from unknown extragalactic sources that last milliseconds
- **FRB Characteristics**:
  - Detected across a wide frequency range 110 MHz to 8 GHz
  - Dispersion Measure (DM) causes a frequency-dependent arrival time delay
  - $E_{iso} \sim 10^{36\text{-}41}$ erg
  - ~2% are known to repeat
- **Possible Origins**: typical theories involve neutron stars & magnetars



Dynamic spectrum of the first detected Fast Radio Burst, known as the Lorimer burst. (Lorimer et al. 2007)

Dispersion (Measure)

- Free electrons in space cause a frequency dependent arrival time delay – known as a **dispersive** sweep
- DM has units of pc/cm^3 (**column density**)
- Probe of the free electron density between us, and the source

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

$$\Delta t = \frac{(e^-)^2}{2\pi m_e c}\left(\frac{1}{\nu_2^2} - \frac{1}{\nu_1^2}\right)\mathrm{DM}$$

Question:

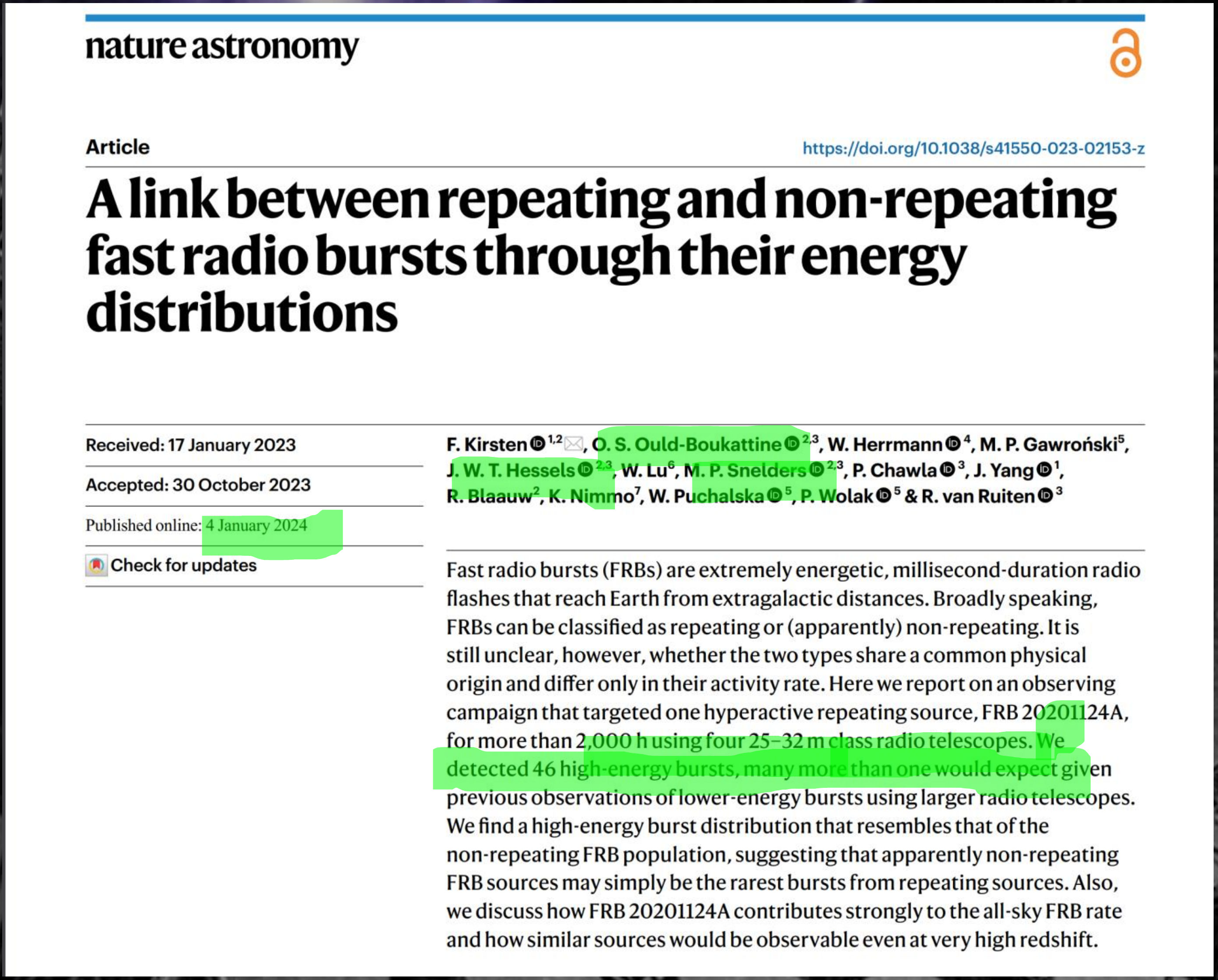
The Crab Pulsar is located ~1,800 pc away and has a DM of ~60 pc/cm^3.

What is the average n_e between us and the Crab Pulsar?

First correct answer gets a box of Kraft!*

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

Must be in person to claim



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Article

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A link between repeating and non-repeating fast radio bursts through their energy distributions

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Check for updates

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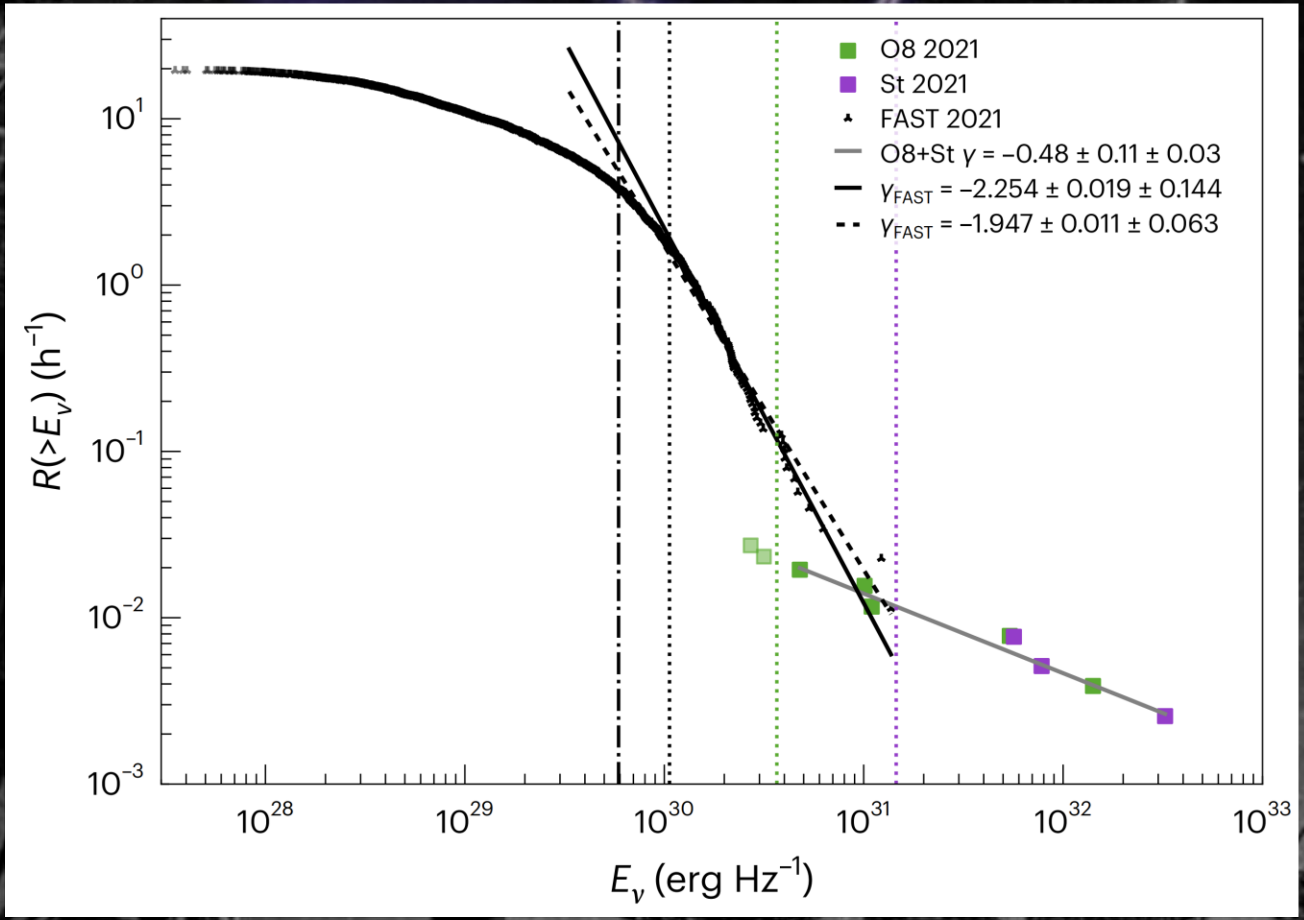
Fast radio bursts (FRBs) are extremely energetic, millisecond-duration radio flashes that reach Earth from extragalactic distances. Broadly speaking, FRBs can be classified as repeating or (apparently) non-repeating. It is still unclear, however, whether the two types share a common physical origin and differ only in their activity rate. Here we report on an observing campaign that targeted one hyperactive repeating source, FRB 20201124A, for more than 2,000 h using four 25–32 m class radio telescopes. We detected 46 high-energy bursts, many more than one would expect given previous observations of lower-energy bursts using larger radio telescopes. We find a high-energy burst distribution that resembles that of the non-repeating FRB population, suggesting that apparently non-repeating FRB sources may simply be the rarest bursts from repeating sources. Also, we discuss how FRB 20201124A contributes strongly to the all-sky FRB rate and how similar sources would be observable even at very high redshift.

Motivation

- Recent interest In using 'small' 25m radio telescopes for high cadence FRB follow-up observations of repeating FRBs
- Limited number of observation time, and telescopes in the world
- The Dwingeloo Radio Telescope (DRT) is 25m
- Why not use the DRT?

Motivation

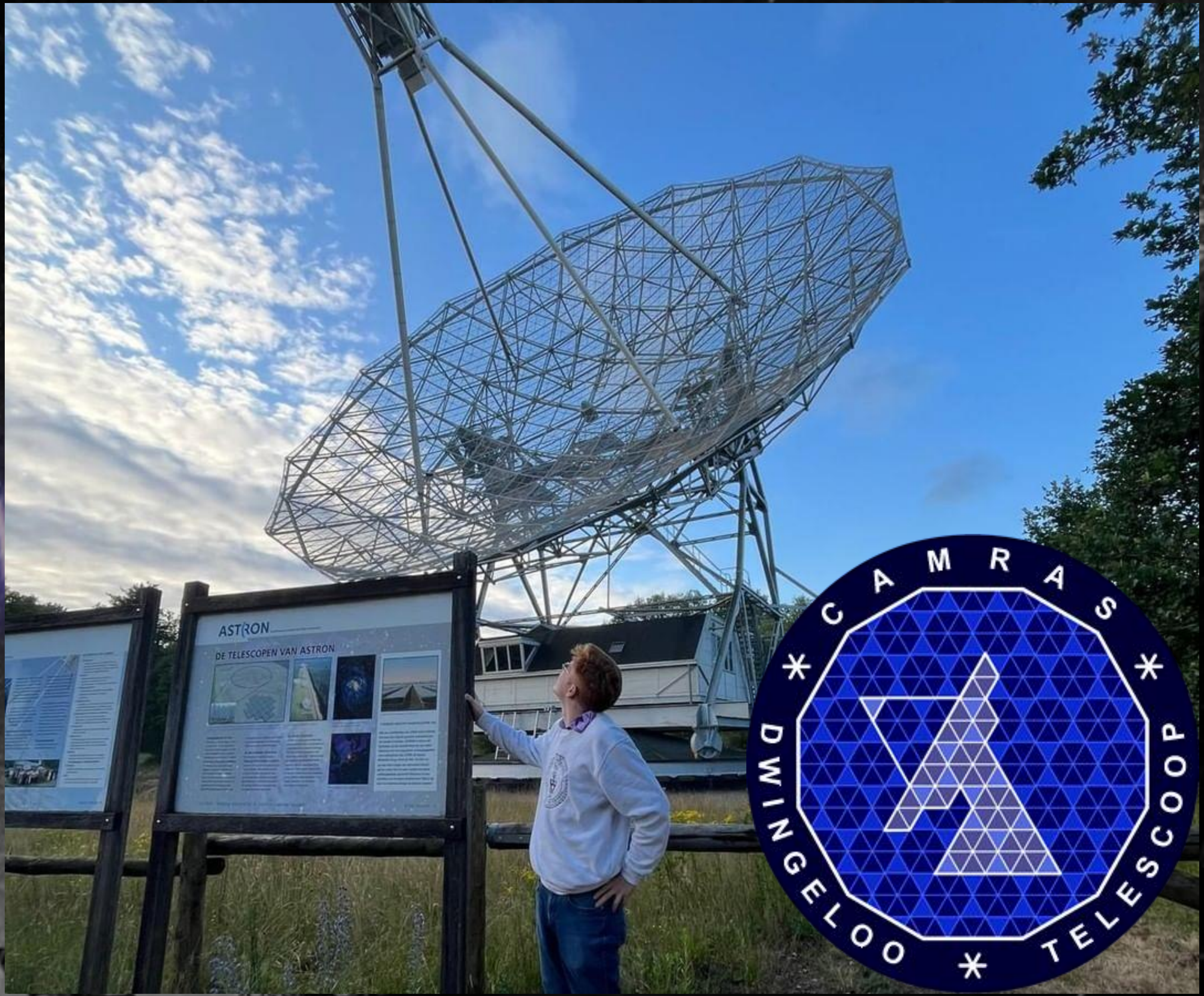


Broken power law fit for hyperactive repeating FRB 20201124A (Kirsten et al. 2024)

- A Westerbork 25m Dish observed for
  - 512 hours in L-band and detected 24 bursts
  - 650 hours in P-band and detected 0 bursts
- Kirsten et al used four 25–32m radio telescopes located throughout Europe
- Results indicate that (apparently) non-repeating FRBs could be rare bursts from repeating FRBs

The 25m Dwingeloo Radio Telescope (DRT)

- Hydrogen Maser clock
  - It's Westerbork's clock!
- Can observe simultaneously in L and P band
  - L-Band 1200-1400 MHz
  - P-Band 400-420 MHz
- Records data
  - ~ 1 Gb/s for baseband data
  - ~1 Gb/min for filterbank data
- Sensitivity is comparable to a single 25m Westerbork dish
  - 80% at P-Band
  - 20% at L-Band



Here is me with the DRT

Project Goals:

- Have Fun
- Build a real time FRB detection pipeline for the DRT
- If lucky, detect an FRB
- Observe Crab Pulsar

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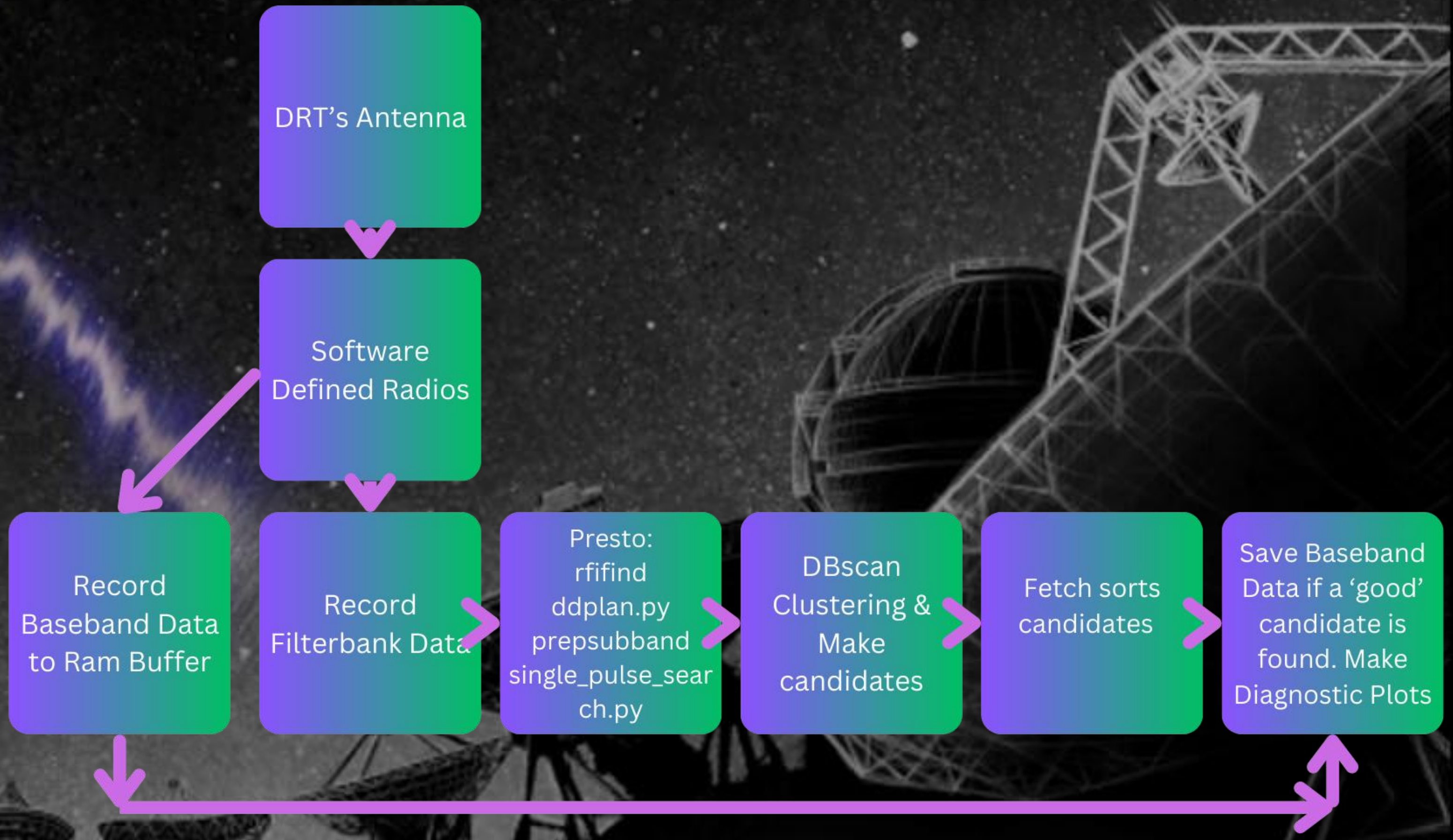
Real-Time FRB detection pipeline for the DRT

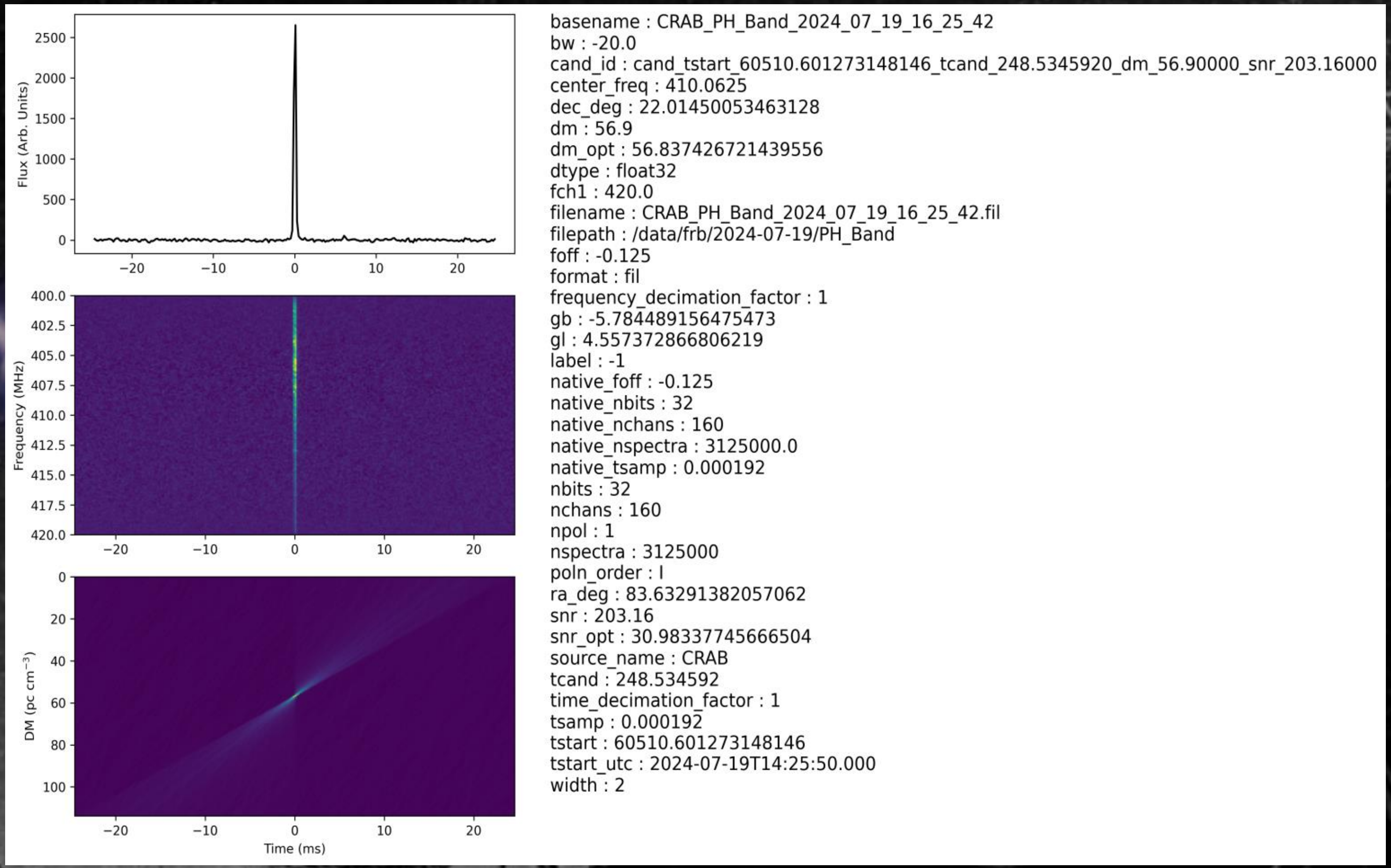
- Search's at ± 10% DM, Boxcar sizes between 1-30, 30s integration for Radio Frequency Interference (RFI) find
- Records data in **filterbank** format files, and **baseband** (amplitude & phase) data
- Writes data in 10-minute chunks to search
- Pipeline is open source https://gitlab.camras.nl/dijkema/frbscripts



Real-Time FRB detection pipeline for the DRT

- **Pipeline is based on** `presto`
  - `rfifind`
  - `ddplan.py`
  - `prepsubband`
  - `single_pulse_search.py`

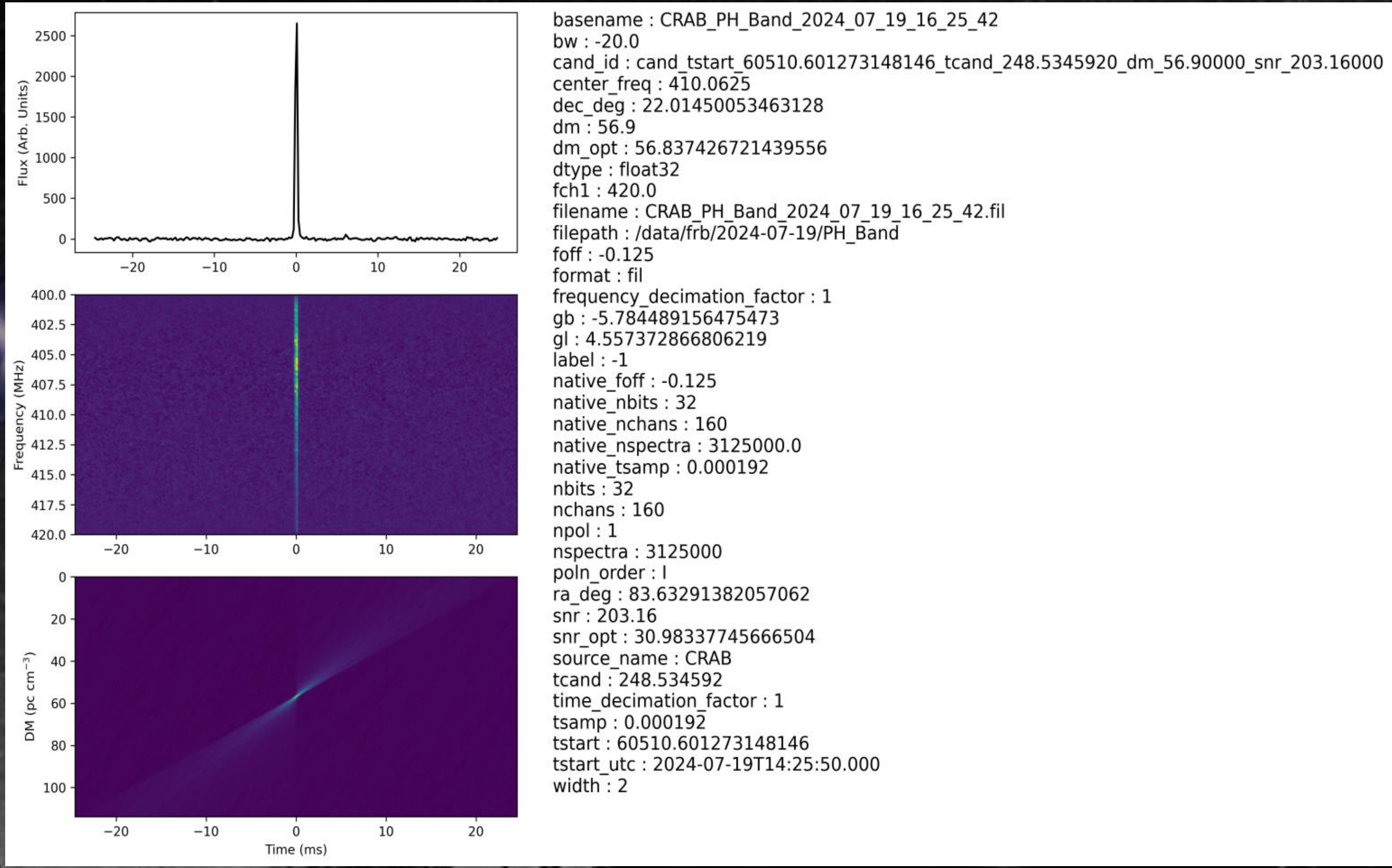
- Candidates are written as `.h5` files



Diagnostic plot displaying the contents of a bright (SNR > 200) candidate `.h5` file for the Crab Pulsar

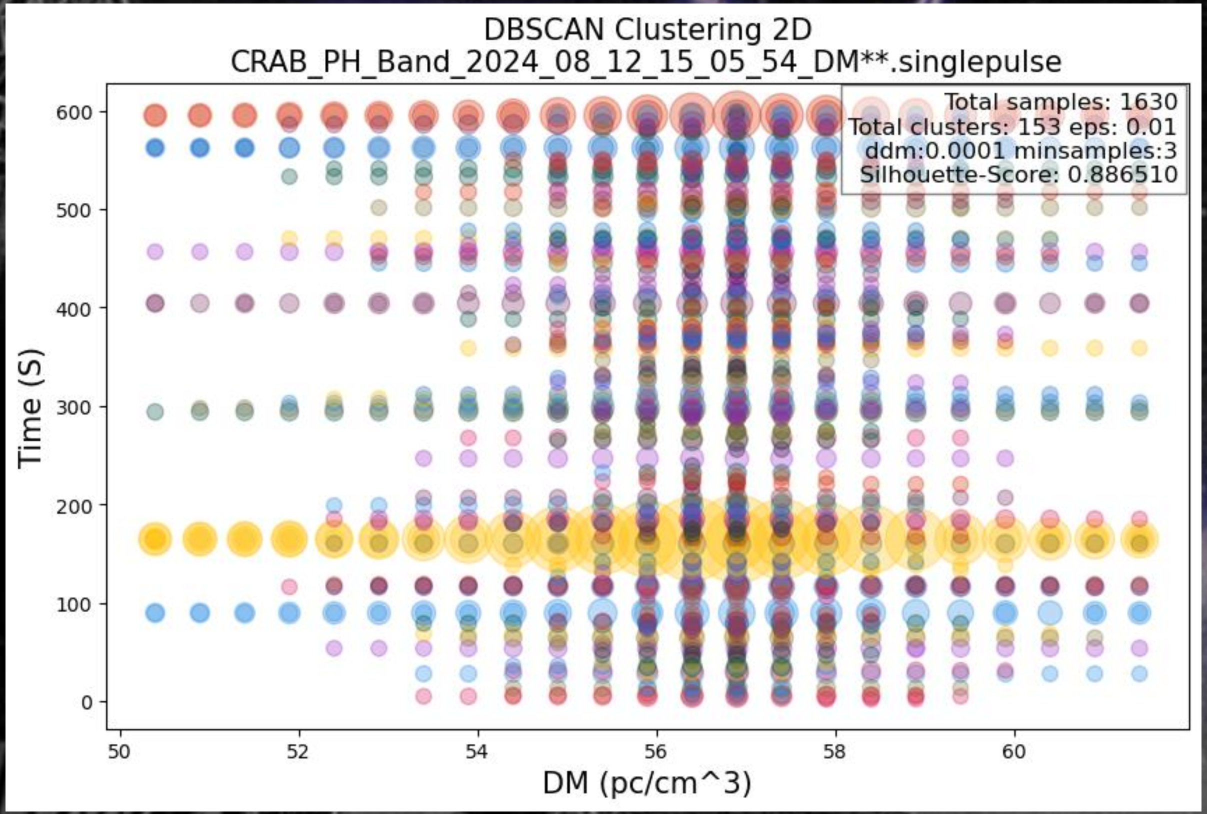
Real-Time FRB detection pipeline for the DRT

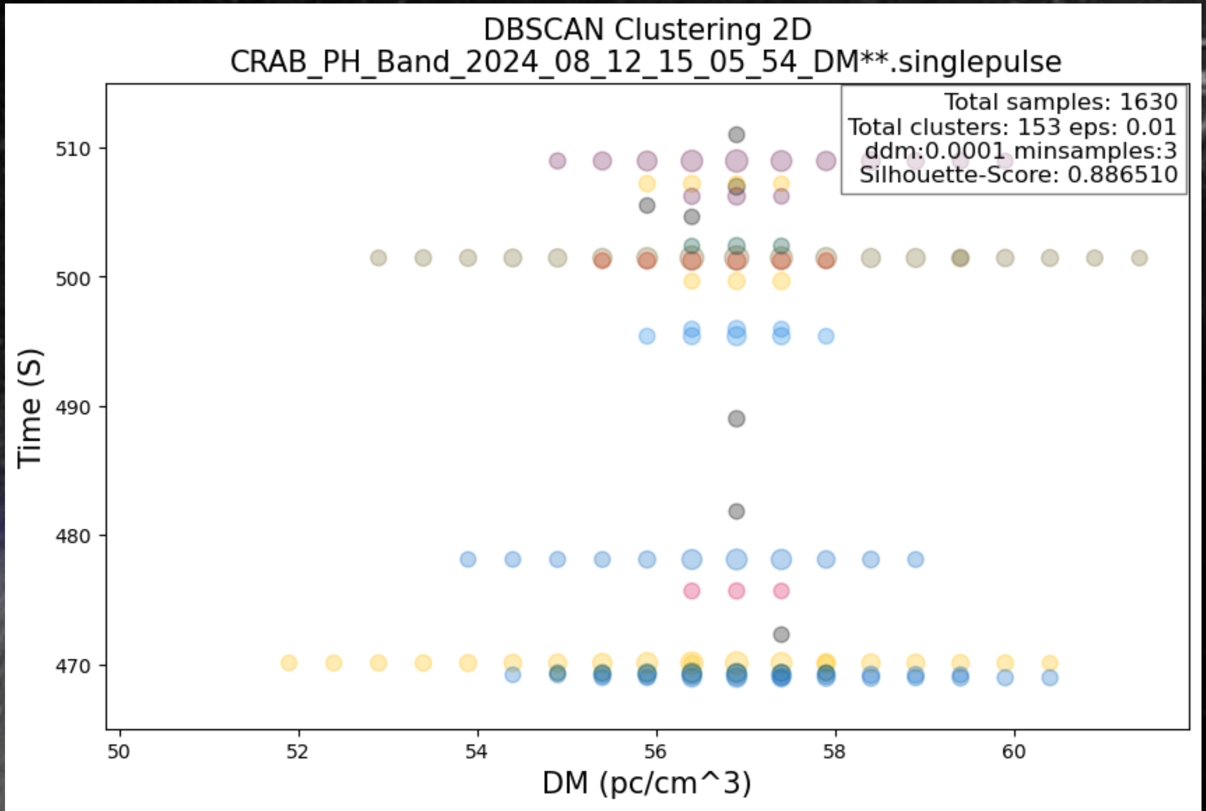
- Most candidates are still RFI, or spurious, need to mitigate this
- **'Machine Learning' Techniques**
  - DBscan Clustering candidates
  - `Fetch`'s `predict.py` sorts candidates into 'good' and 'bad'
- Save's baseband data if a "good" candidate is made
- Baseband data could be used in VLBI to localize FRBS



Diagnostic plot displaying the contents of a bright (SNR > 200) candidate `.h5` file for the Crab Pulsar

DBscan Clustering





after clustering if there are 800> candidates the filterbank file is not processed further

Project Goals:

- Have Fun ✓
- Build a real time FRB detection pipeline for the DRT ✓
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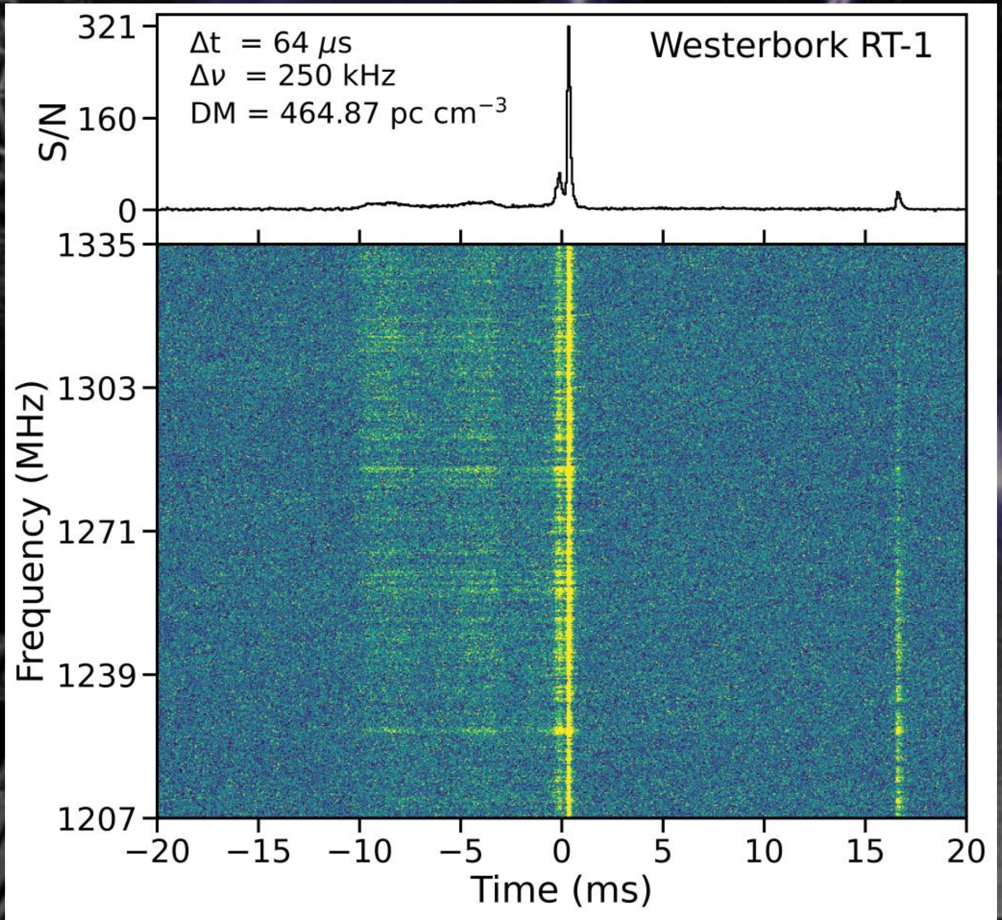
If lucky, detect an FRB

- Unlucky, no super bright hyperactive active repeaters over summer
- FRB 20240619D ~ 20 hours
- Other FRBs ~ 50 hours
- **Even no detections of FRBs is important!**
- Westerbork made several FRB detections that the DRT would have been able to observe

If lucky, detect an FRB



FRB 20240619D detected with 25m Westerbork dish on 2024-07-21 UTC. Ould-Boukattine et al. 2024, The Astronomer's Telegram, No. 16732.

- Even no detections of FRBs is important!
- Westerbork made several FRB detections that the DRT would have been able to observe
- While the DRT did not make any detections, we did contribute to studying burst rates of FRB 20240619D

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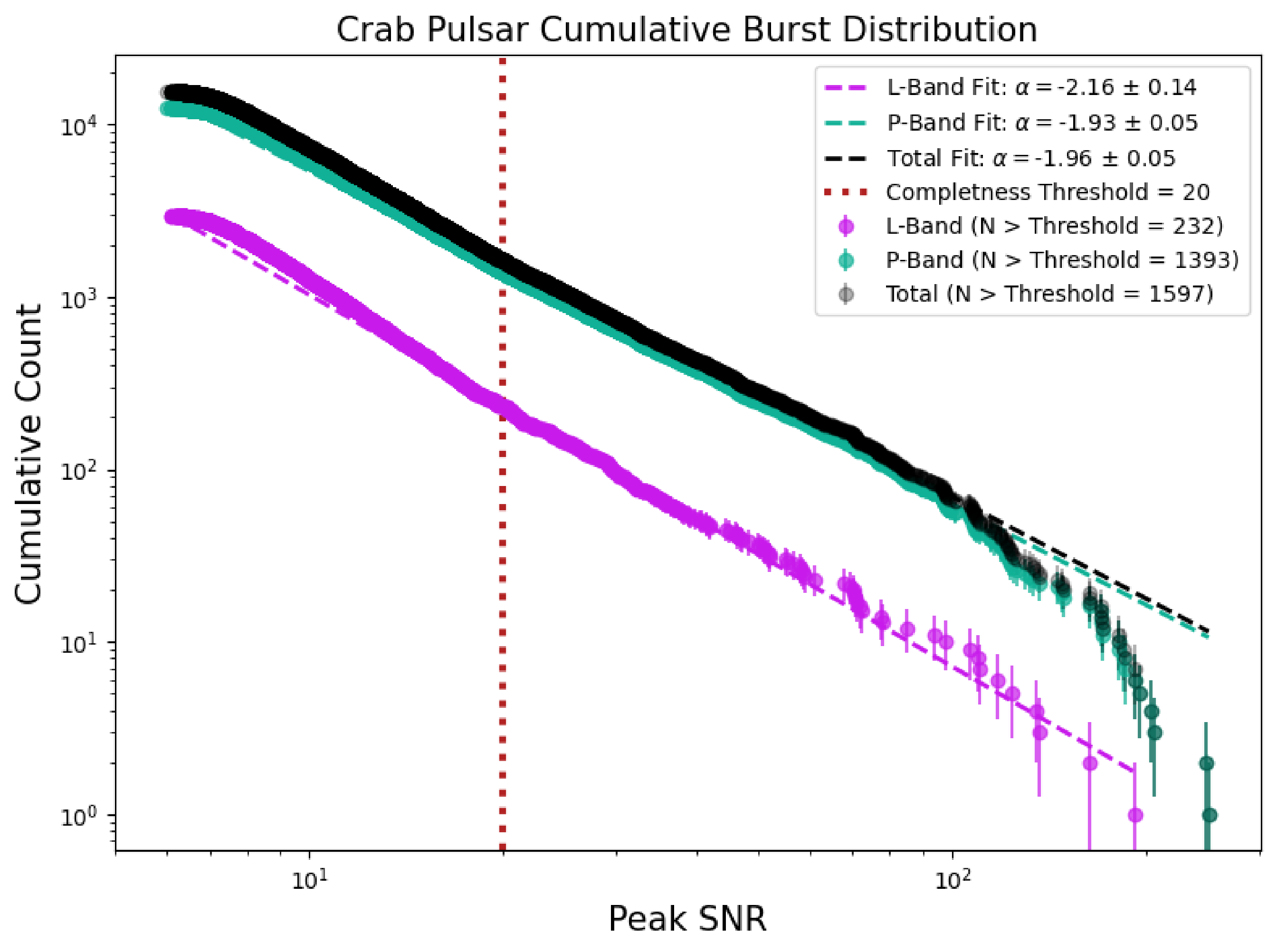
Crab Analysis



- Observed:
  - P-Band 29.28 Hours
  - L-Band 25.91 Hours
- Fitted Power Law Index (**α**) with maximum likelihood method of James et al. 2018
- Power Law results consistent with Bera et al. 2019

Summary

- **The DRT now has a real-time FRB detection pipeline** that can save **baseband data**
- DRT is capable of joining high cadence FRB follow-up observations
- **When, not if** the DRT makes an FRB detection its data can be used in the VLBI network to help localize FRBs
- Pipeline is open source: https://gitlab.camras.nl/dijkema/frbscripts

Next Steps for the DRT

- Train Camras volunteers to run the observation program, write directions for them
- Recruit PhD researchers at Astron to use the DRT as their office, if they are willing to observe
- Increase bandwidth in L-band, P-Band
- Post the "good" candidates to the Camras mastodon bot
- Prototype of new receiver?

max.fine@mail.student.uva
https://afinemax.github.io/afinemax1/