Studying Fast Radio Bursts (FRBs) with the 25m Dwingeloo Radio Telescope (DRT)

By: Maxwell Fine

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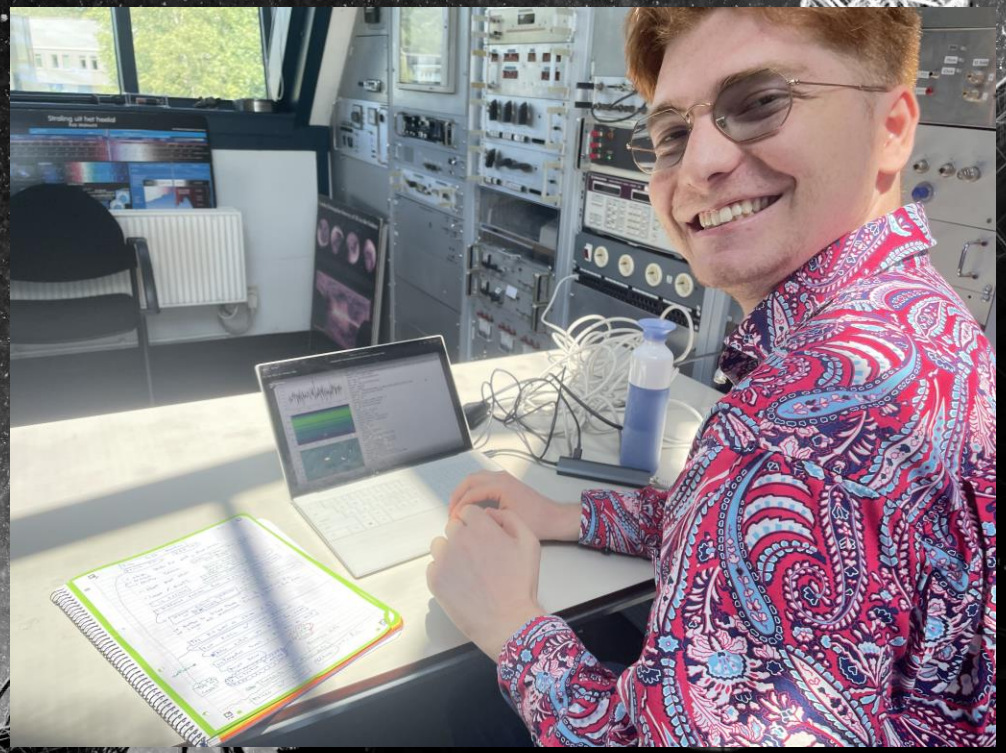
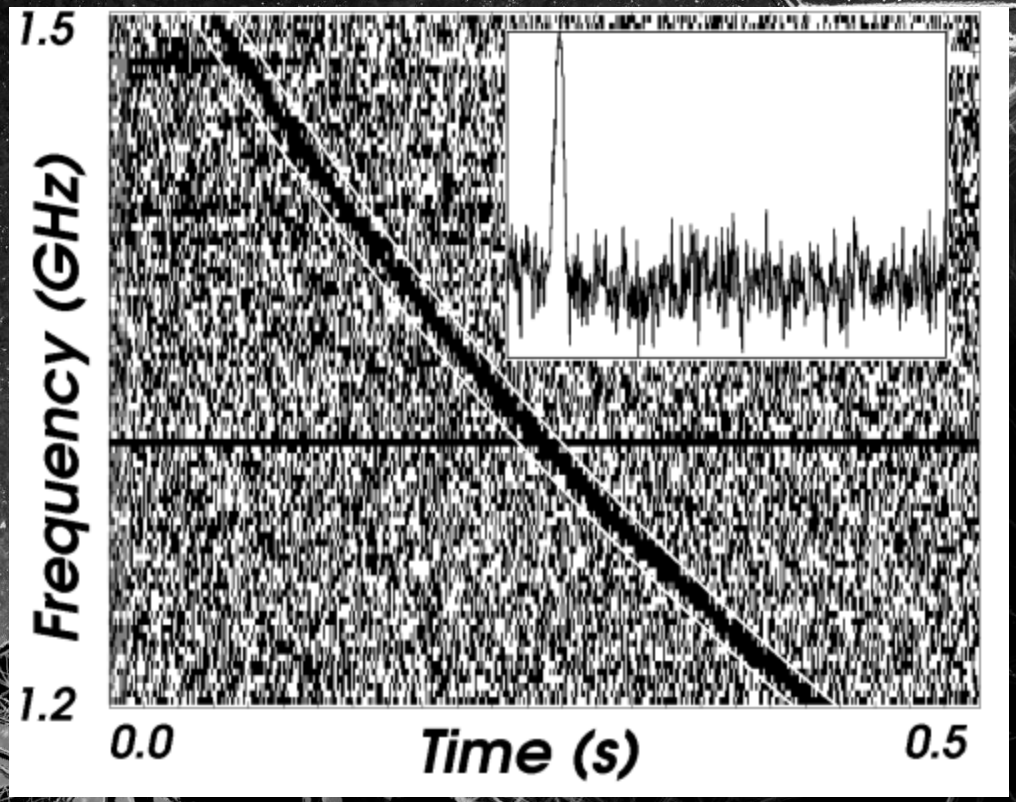


Fast Radio Bursts (FRBs)

- **Fast Radio Bursts (FRBs):** brief, intense radio emission from unknown extragalactic sources that last milliseconds
- **FRB Characteristics**:
  - Detected across a wide frequency range of 110 MHz to 8 GHz
  - Dispersion Measure (DM) causes a frequency-dependent arrival time delay
  - $E_{iso} \sim 10^{36\text{-}41}$ erg
  - ~2% 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/cm3 (**collum 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

nature astronomy

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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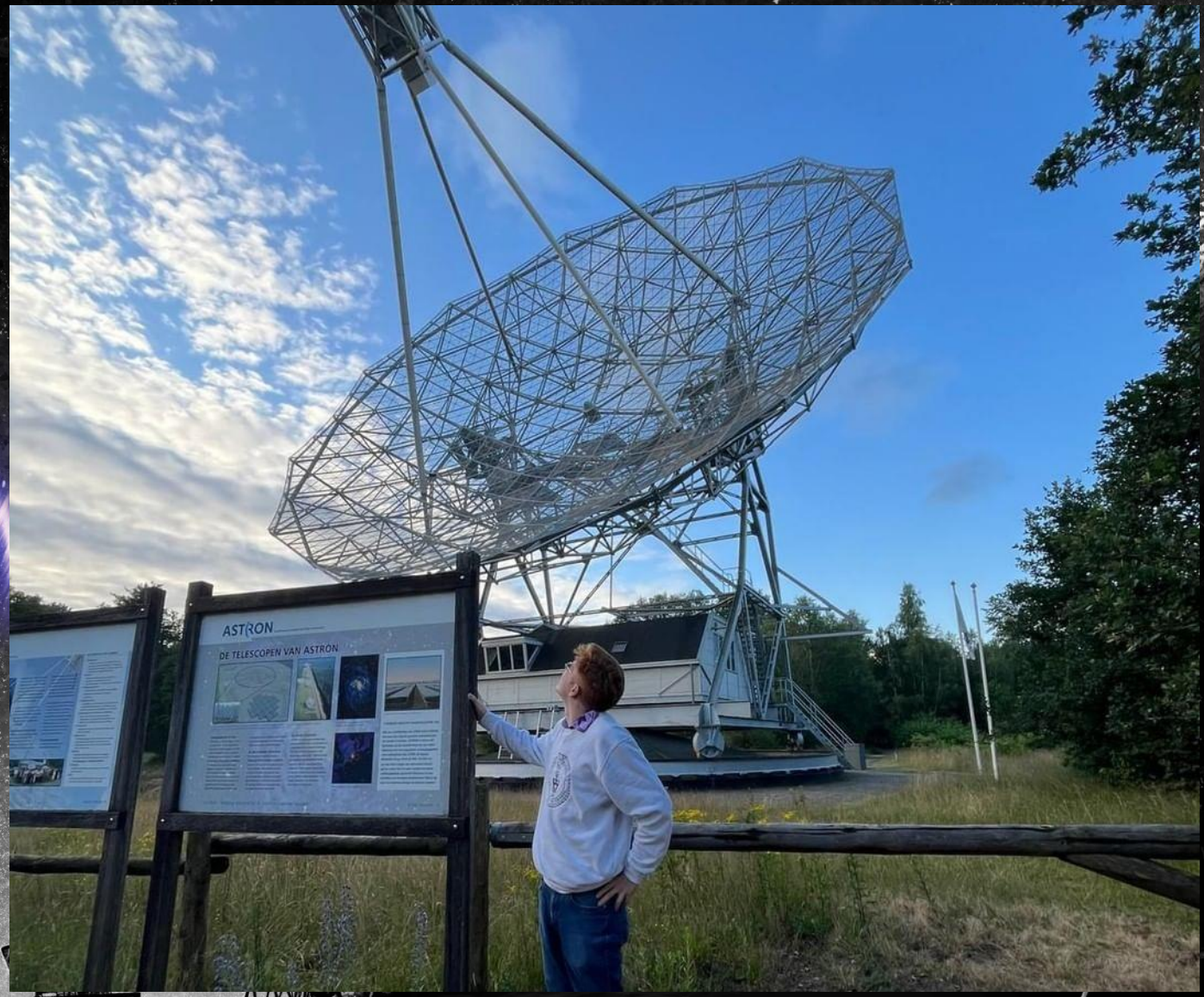
Fast radio bursts (FRBs) are extremely energetic, millisecond-duration radio flashes that reach Earth from extragalactic distances. Broadly speaking, FRBs can be classified as repeating or (apparently) non-repeating. It is still unclear, however, whether the two types share a common physical origin and 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 extended 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?

The 25m Dwingeloo Radio Telescope (DRT)

- Is a rijksmonument – a national heritage site, and is operated by volunteers
- Hydrogen Maser clock
- Can observe simultaneously in L and P band
  - L Band 1200-1400 Mhz
  - P Band 400 – 420 Mhz
- Records data at:
  - ~ 1 gb/s for baseband data (raw voltages)
  - ~1 gb/min for filterbank data



Project Goals:

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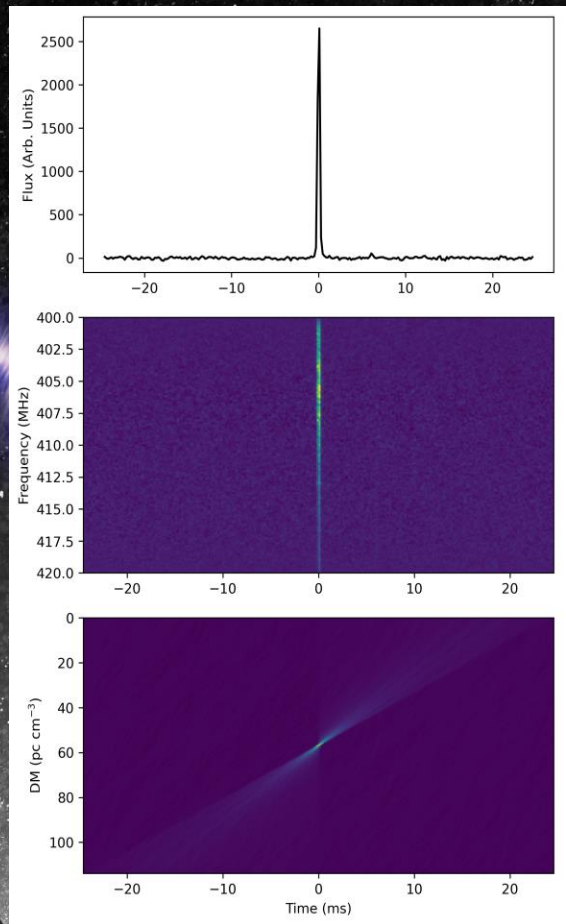
Real-Time FRB detection pipeline for the DRT

- Records data in filterbank format files, and baseband data
- **Pipeline is based on** `presto`
  - `rfifind`
  - `ddplan.py`
  - `prepsubband`
  - `single_pulse_search.py`
- `Presto` handles noise elimination, dedispersing the data, and finding potential bursts with a boxcar search convolution
- Candidates are written as `.h5` files



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dm : 56.9
dm_opt : 56.837426721439556
dtype : float32
fch1 : 420.0
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nchans : 160
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tcand : 248.534592
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tsamp : 0.000192
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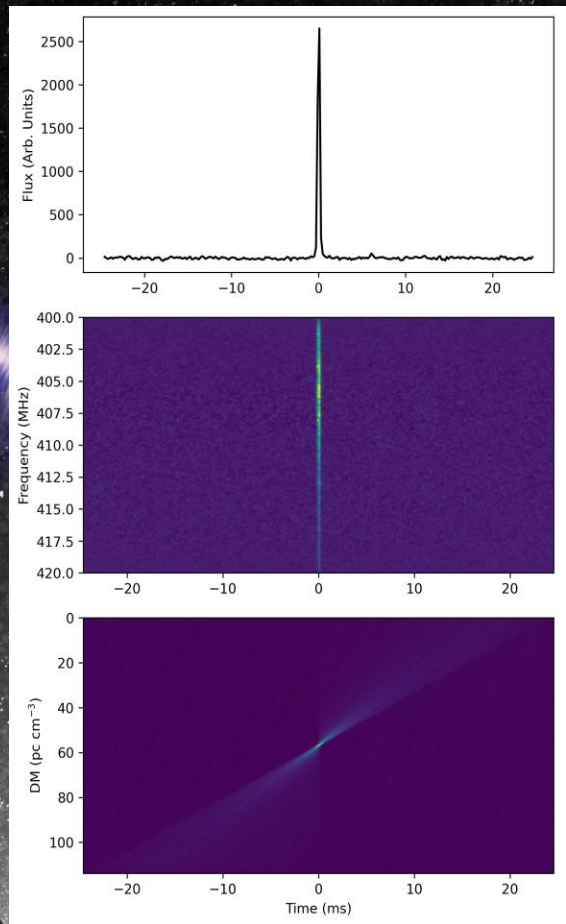
width : 2

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 techniques to mitigate this
- **'Machine Learning' Techniques**
  - Dbscan Clustering candidates
  - Fetch's `predict.py` sorts candidates into 'good' and 'bad'
- Produces diagnostic plots for human review
- Save's baseband data if a good candidate is made



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dec_deg : 22.01450053463128
dm : 56.9
dm_opt : 56.837426721439556
dtype : float32
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gl : 4.557372866806219
label : -1
native_foff : -0.125
native_nbits : 32
native_nchans : 160
native_nspectra : 3125000.0
native_tsamp : 0.000192
nbits : 32
nchans : 160
npol : 1
nspectra : 3125000
poln_order : I
ra_deg : 83.63291382057062
snr : 203.16
snr_opt : 30.98337745666504
source_name : CRAB
tcand : 248.534592
time_decimation_factor : 1
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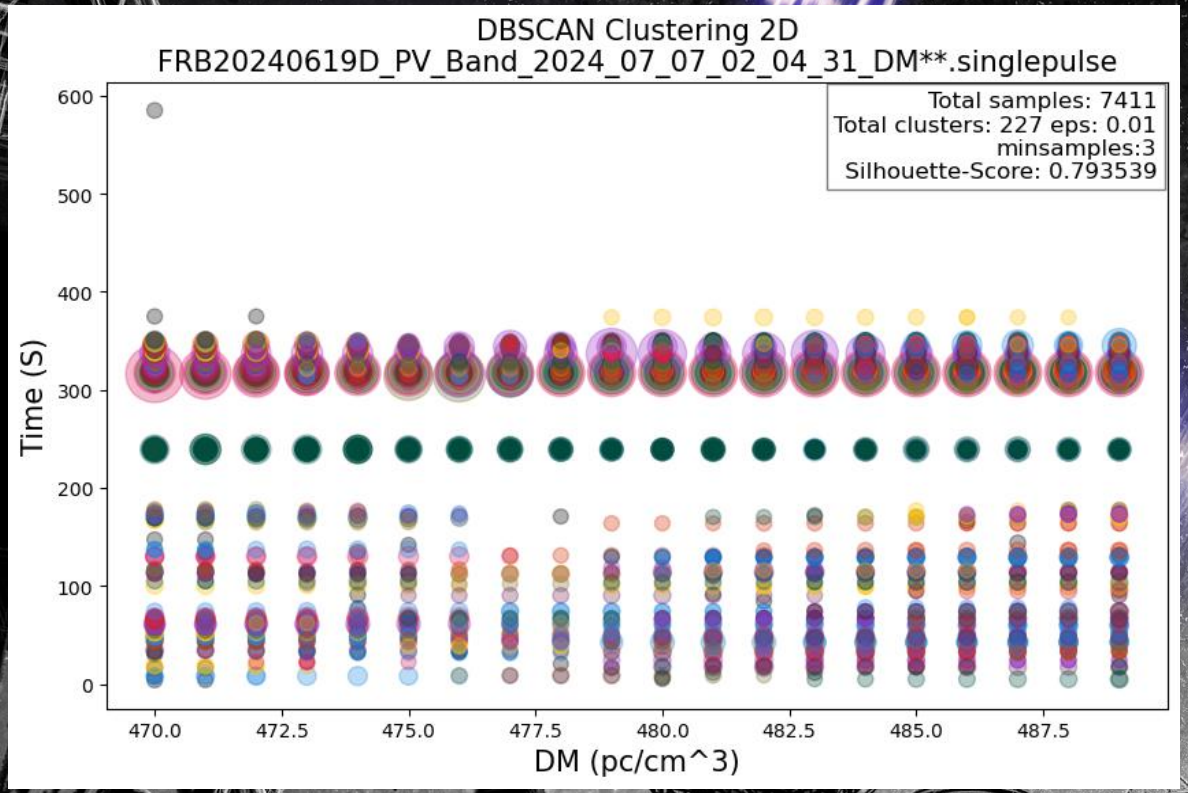
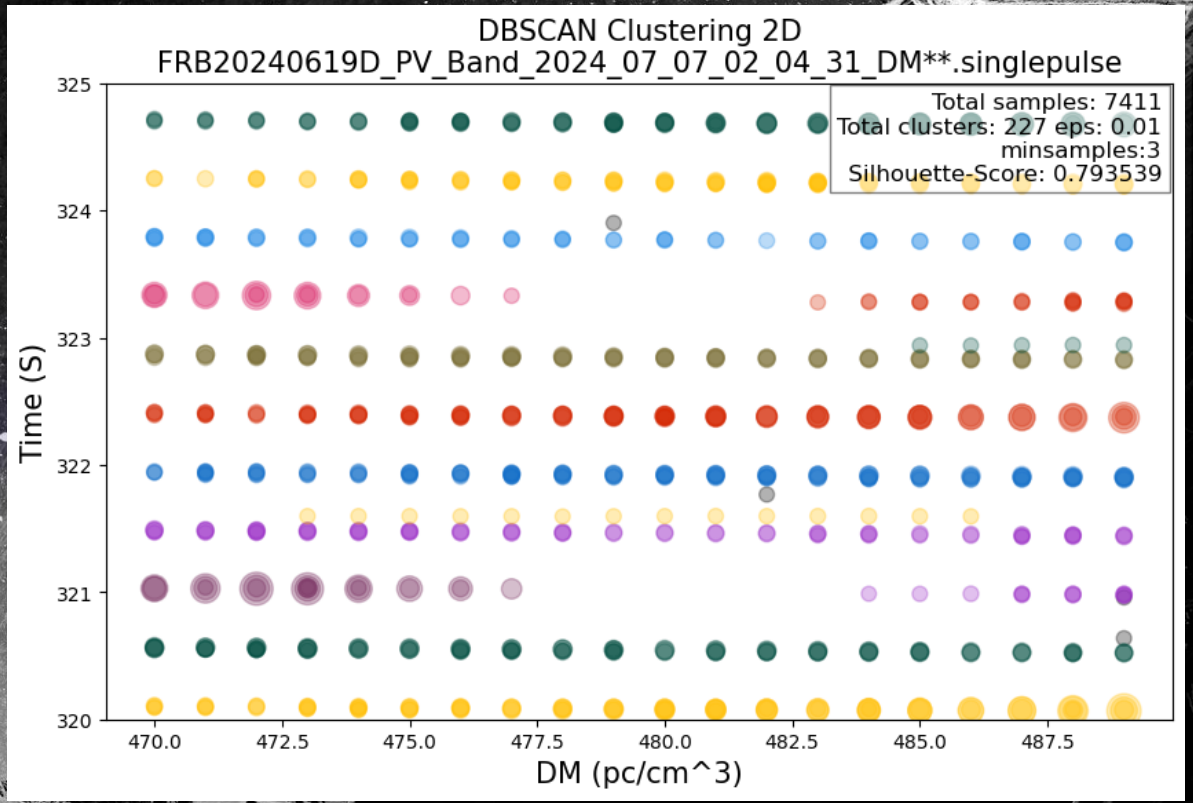
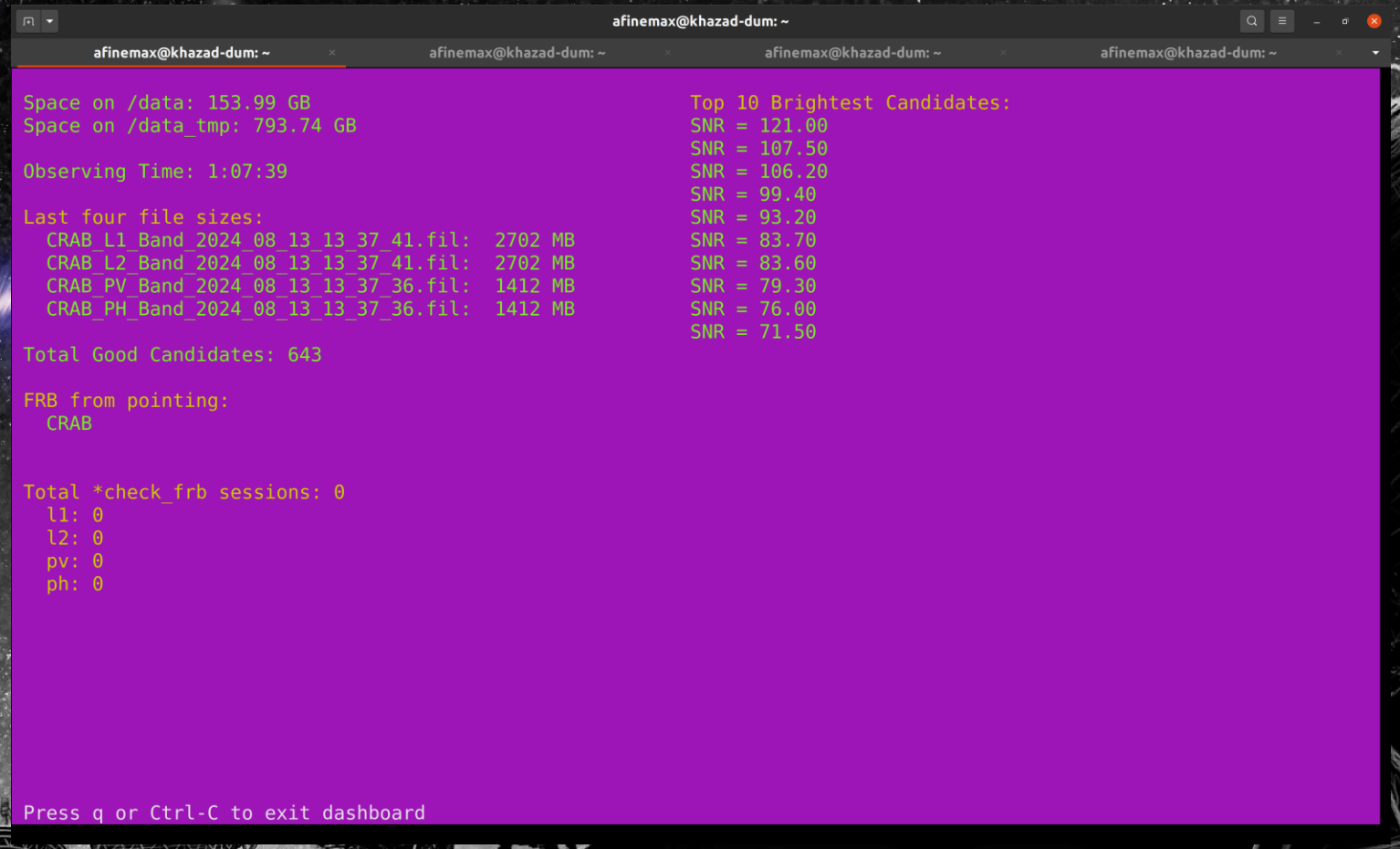
Real-Time FRB detection pipeline for the DRT





Real-Time FRB detection pipeline for the DRT

- Pipeline is open source https://gitlab.camras.nl/dijkema/frbscripts
- There is a useful Dashboard while observing



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If lucky, detect an FRB

- Unlucky, no super bright highly active repeaters over summer
- Spent time observing a few repeaters, but no luck.
- Westerbork made a detection of a repeating FRB on 2024-07-21 around 2 AM our time. I was not observing at the time :(

  - Source: Ould-Boukattine et al. 2024, The Astronomer's Telegram, No. 16732.

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Crab Analysis


Summary