

Probing the Low-Frequency Emission of Fast Radio Bursts

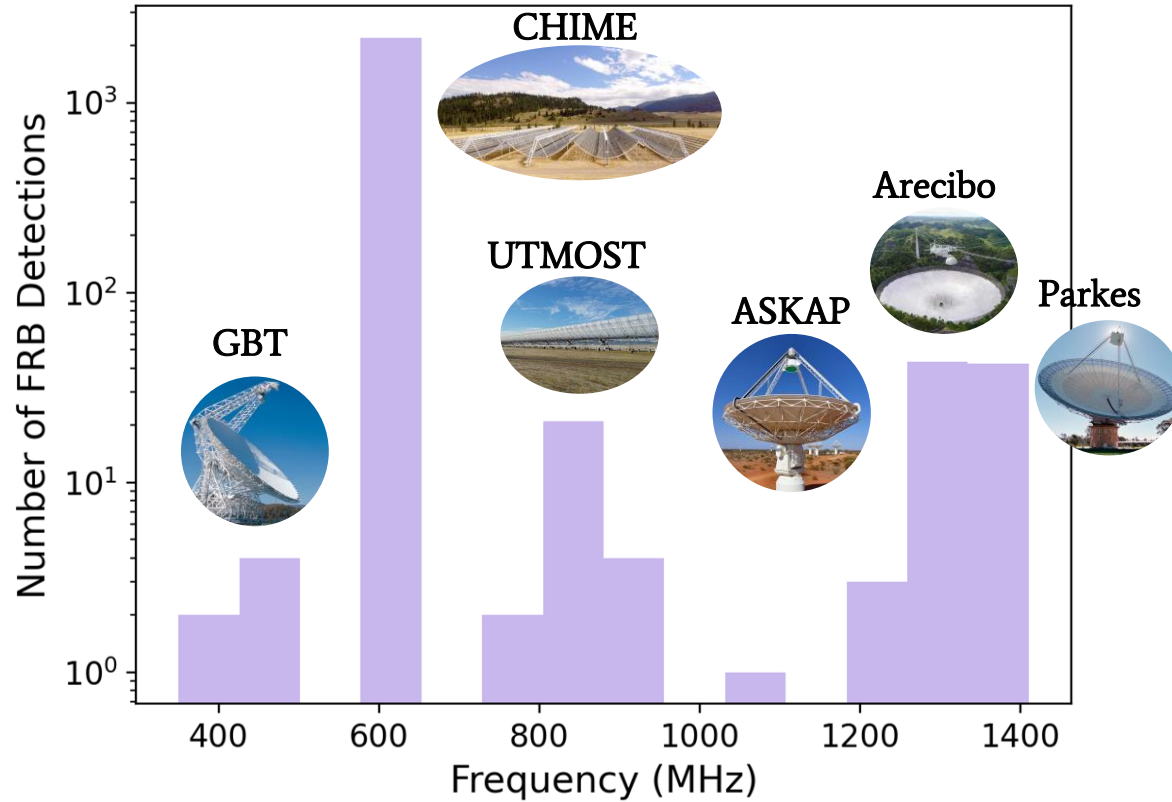
Pragya Chawla

University of Amsterdam



UNIVERSITY
OF AMSTERDAM





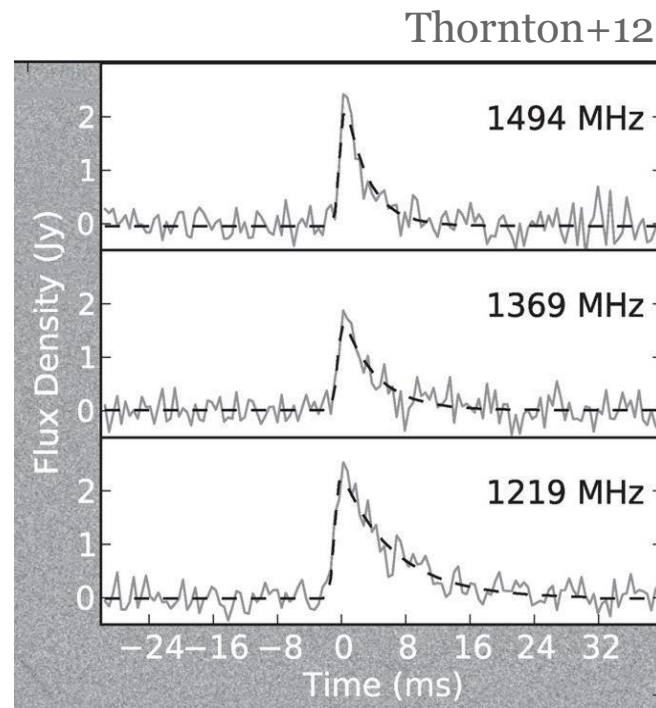
No FRBs have been detected below 300 MHz in all-sky surveys.

Why are FRBs hard to detect at low frequencies?

- Intrinsic spectrum
- Propagation effects
 - Scattering
 - Absorption in dense circumburst environments

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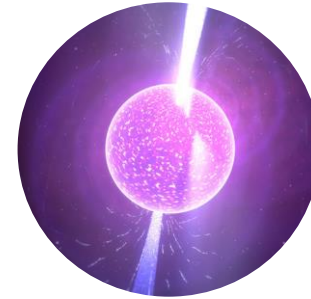
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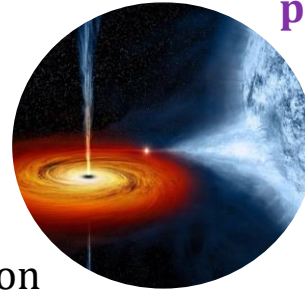
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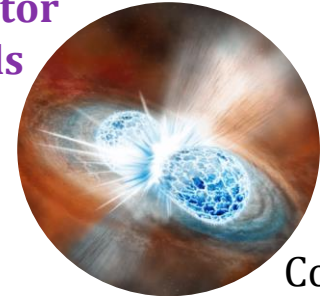
Isolated Neutron Stars



Proposed FRB progenitor models



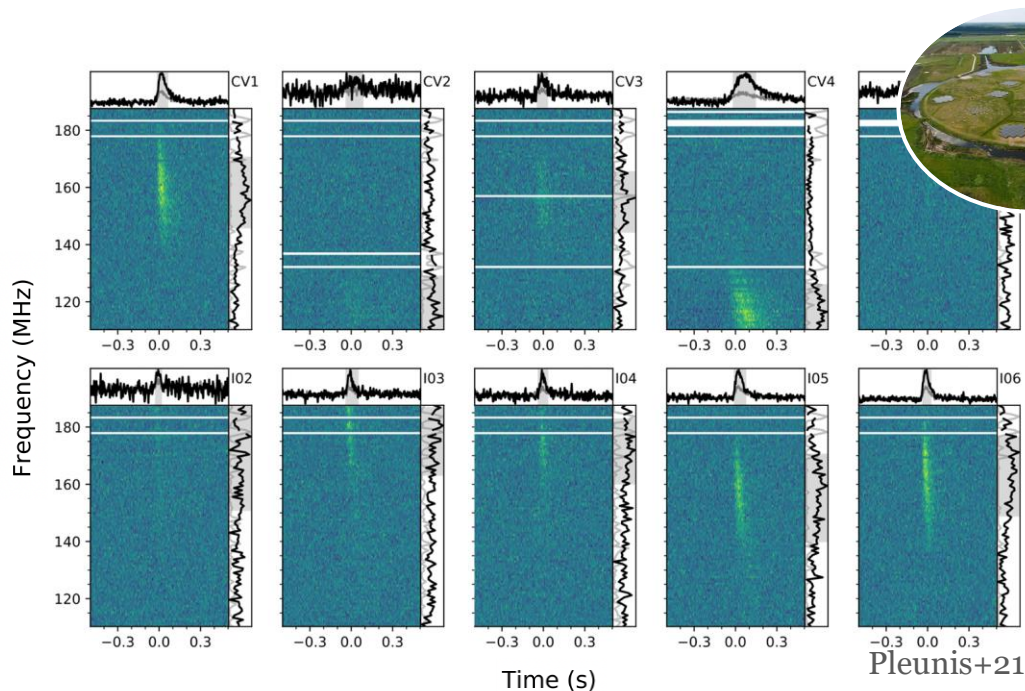
Interaction
(NS and companion star)



Compact
Object Mergers

How can we detect low-frequency emission? Through targeted searches of repeating FRBs!

Bursts from 2 repeating FRBs detected at low frequencies (110-190 MHz)



See talk by Akshatha
Gopinath



Discovery of a Population of Repeating FRBs with CHIME

400-800 MHz

- CHIME = Canadian Hydrogen Intensity Mapping Experiment

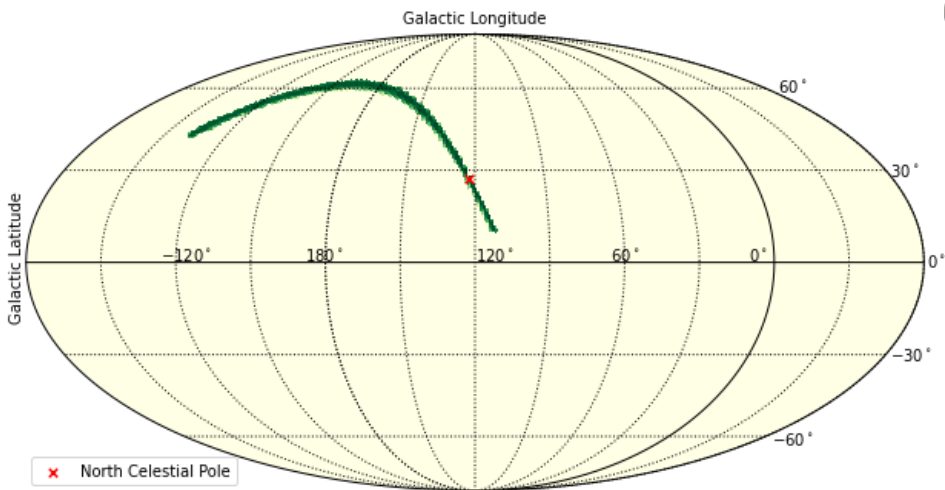


 British Columbia
Canada

Discovery of a Population of Repeating FRBs with CHIME

400-800 MHz

- CHIME = Canadian Hydrogen Intensity Mapping Experiment
- Transit telescope operating 24/7

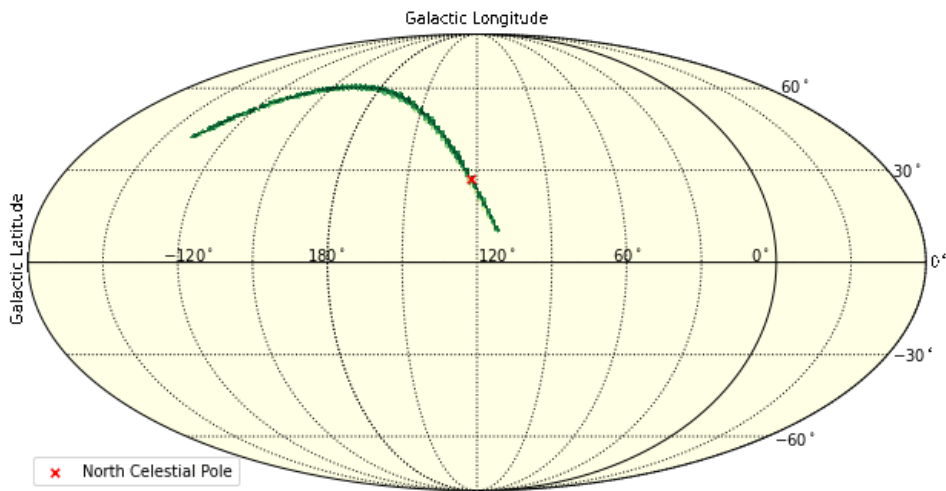


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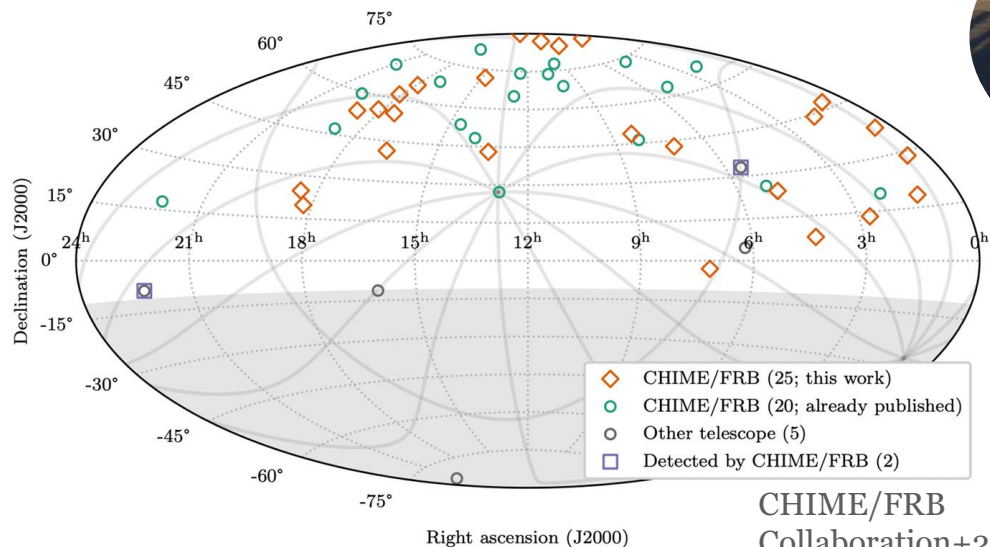


 British Columbia
Canada

Discovery of a Population of Repeating FRBs with CHIME

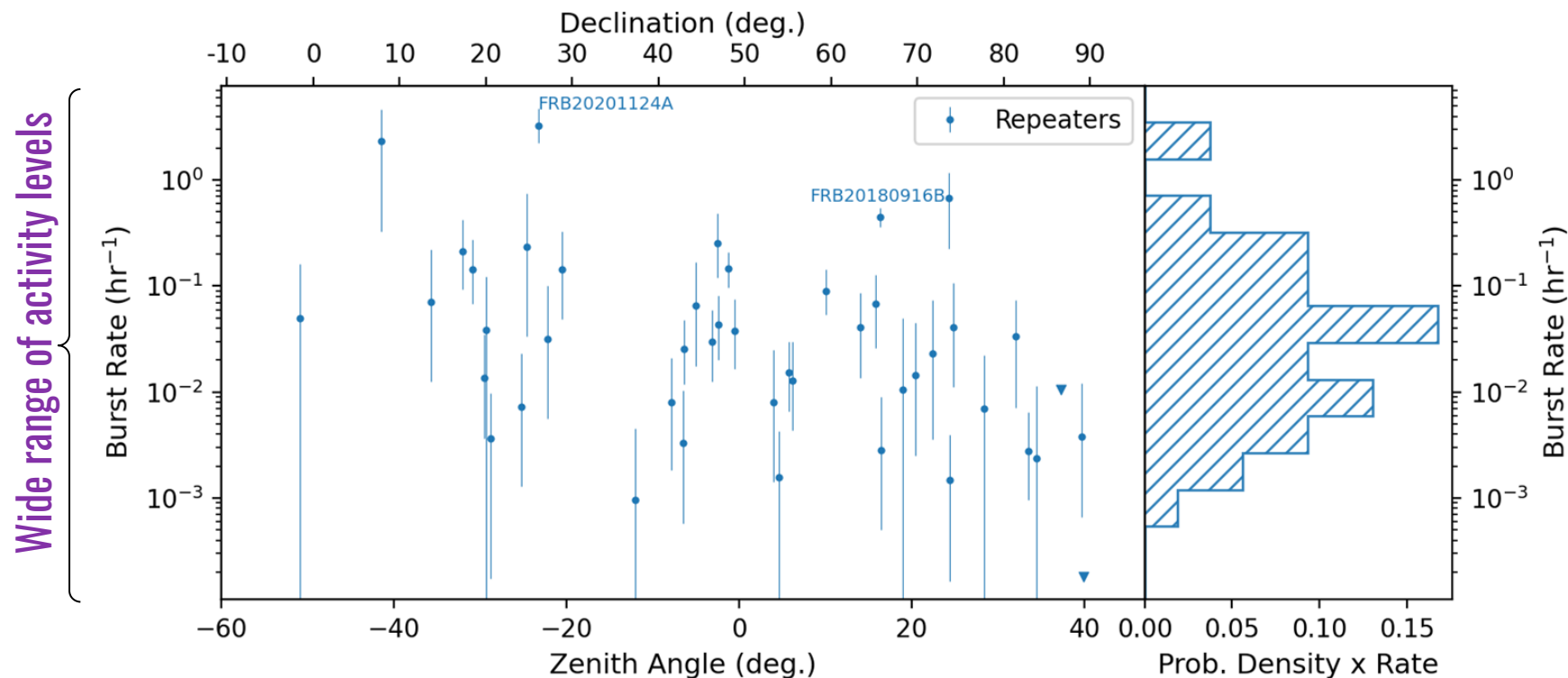
400-800 MHz

- Total number of CHIME repeaters = 46
 - Observed between Aug. 2018 - May 2021
- Recently discovered 25 new repeaters

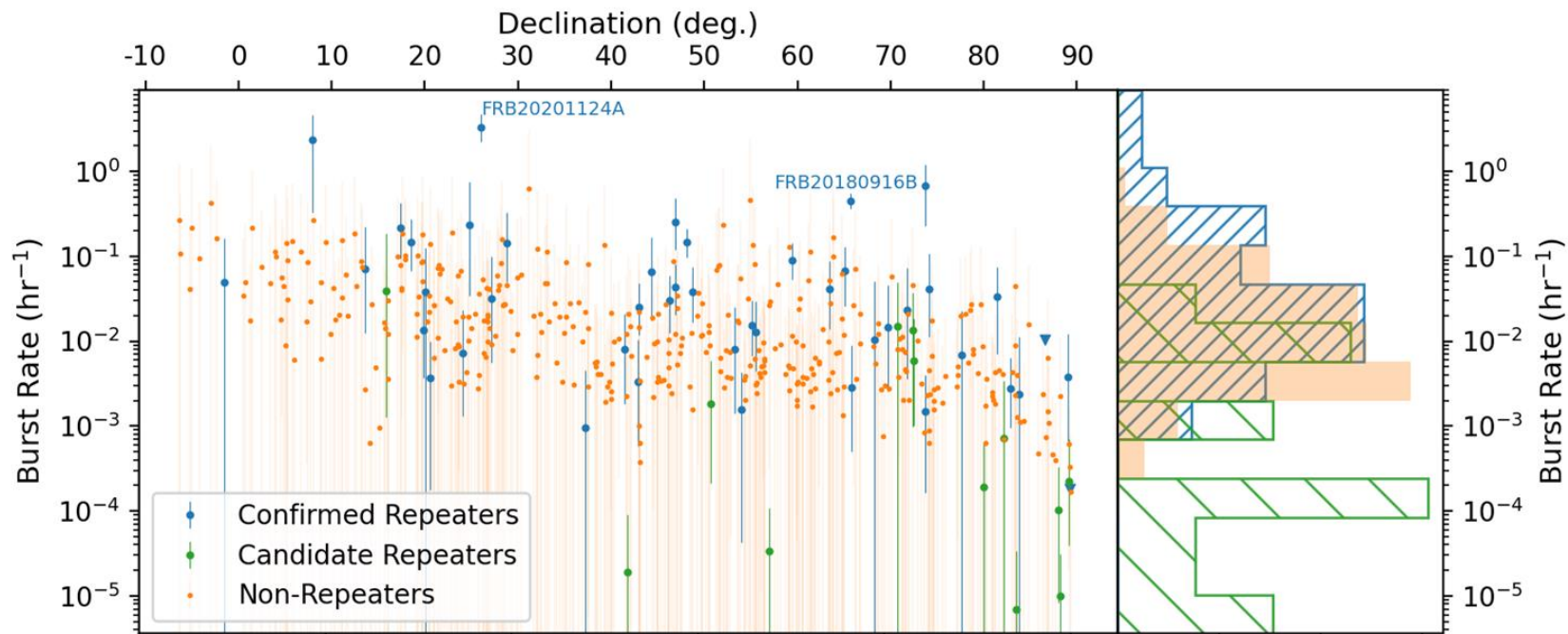


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Measuring Repetition Rates of CHIME FRBs



Measuring Repetition Rates of CHIME FRBs



No clear bimodality in rates → We cannot rule out the possibility that all FRB sources repeat!

Search for CHIME FRBs with LOTAAS

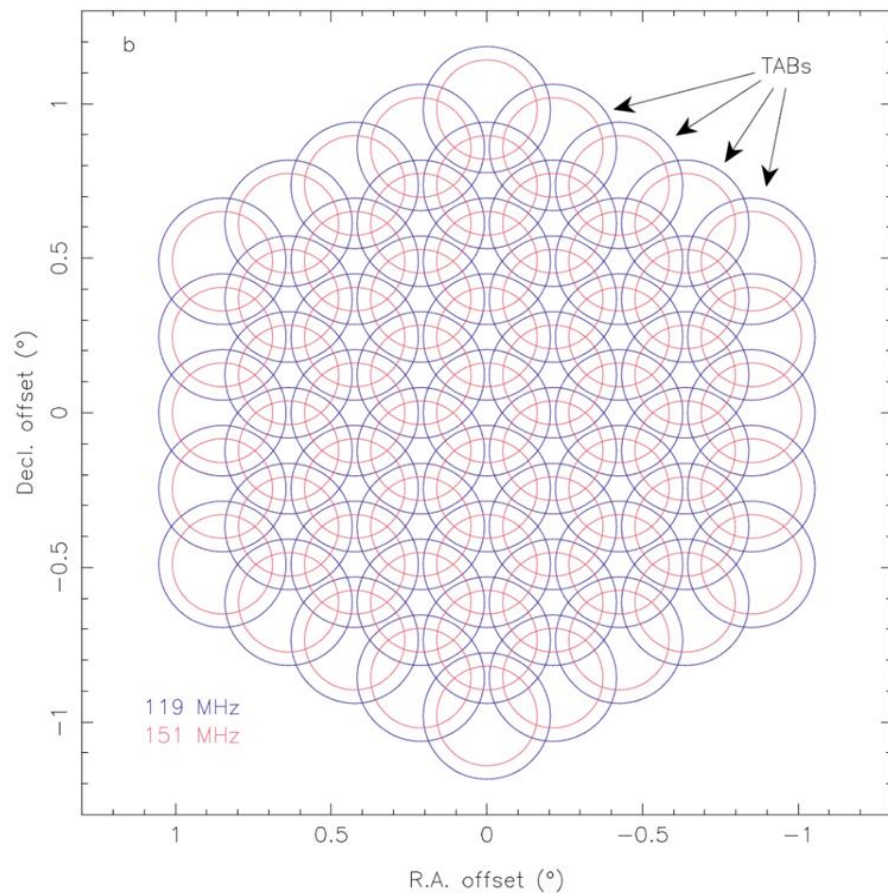
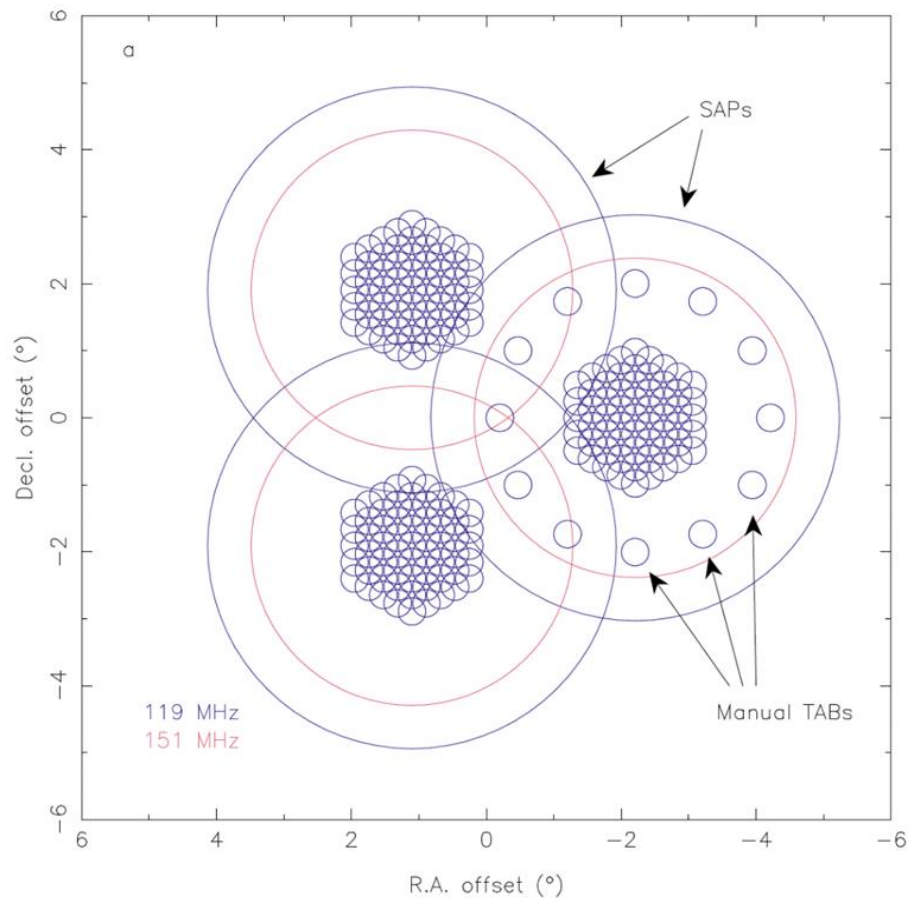
- Searching for 46 repeaters and 460 apparent non-repeaters
- In archival observations from the LOFAR Tied-Array All-Sky Survey

Sanidas+19

Observing Freq.	119-151 MHz
Time Resolution	491.52 μ s
Pointing Duration	1 hr



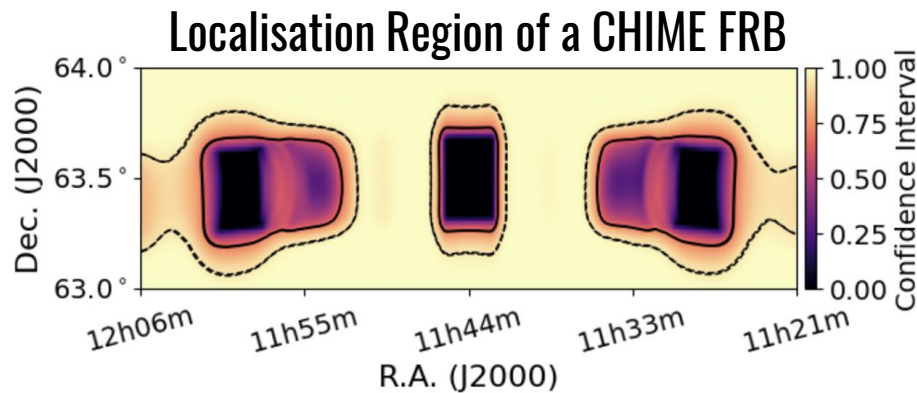
Uses the high-band antennas
of the LOFAR Superterp



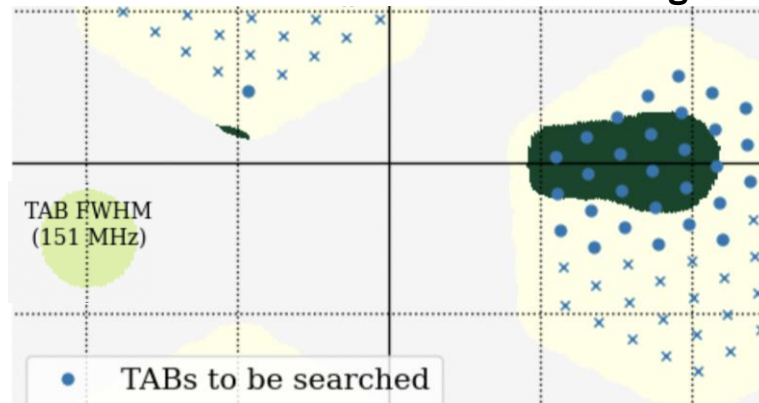
Tied-array beam FWHM of $0.32\text{-}0.41^\circ$

Search for CHIME FRBs with LOTAAS

Analysed observations for 46 repeaters and 460 apparent non-repeaters

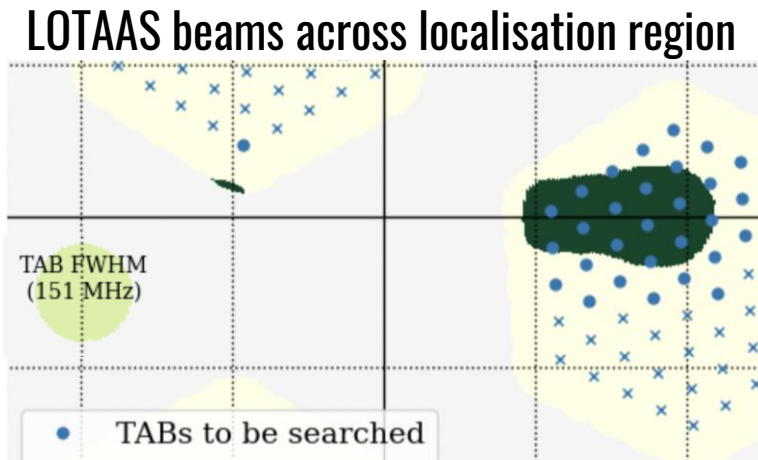
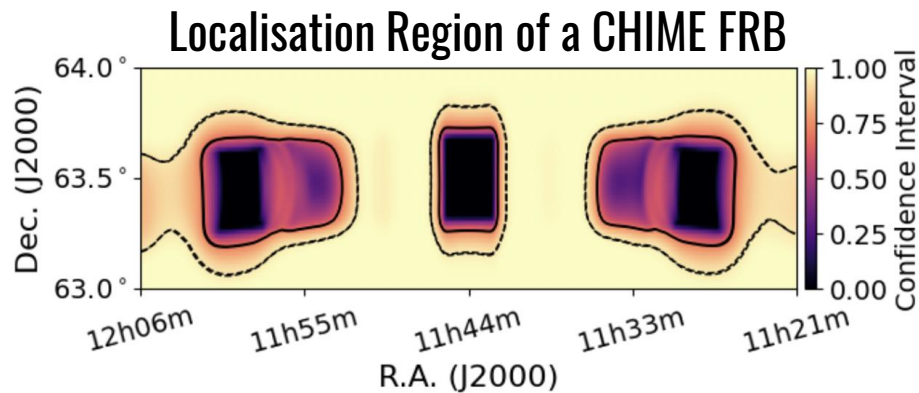


LOTAAS beams across localisation region



Search for CHIME FRBs with LOTAAS

Analysed observations for 46 repeaters and 460 apparent non-repeaters



Over 70% of the search complete

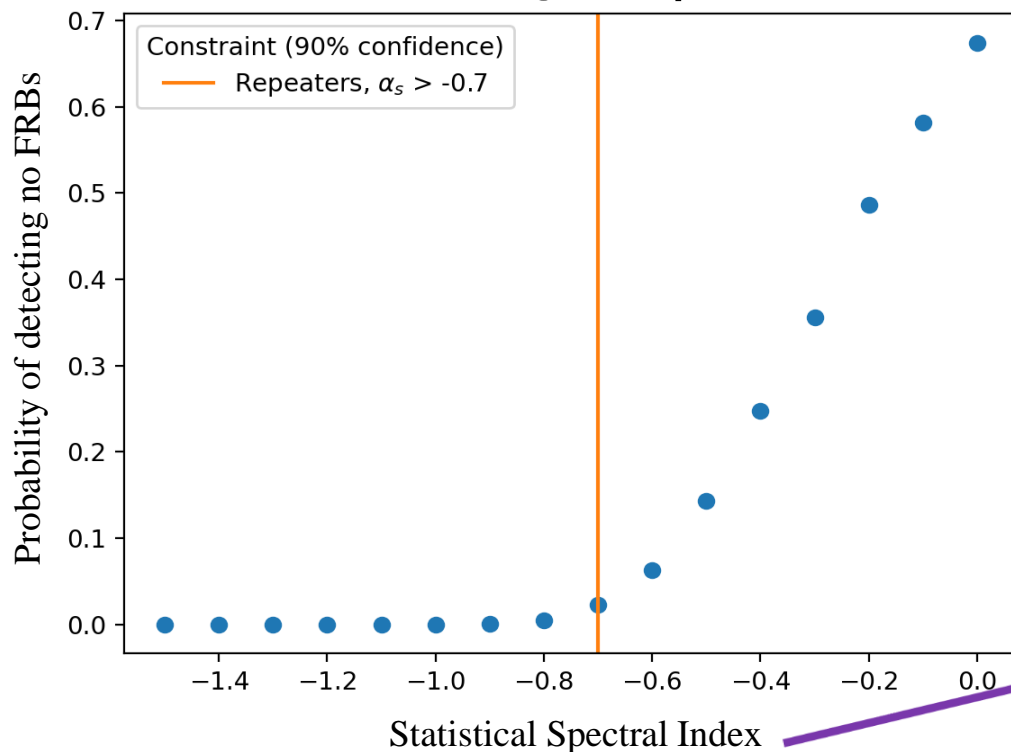
No low-frequency detections so far :(

Non-detection of low-frequency emission can constrain:

- Intrinsic spectrum
 - Propagation effects
 - Scattering
 - Absorption in dense circumburst environments
- *FRB emission mechanism*

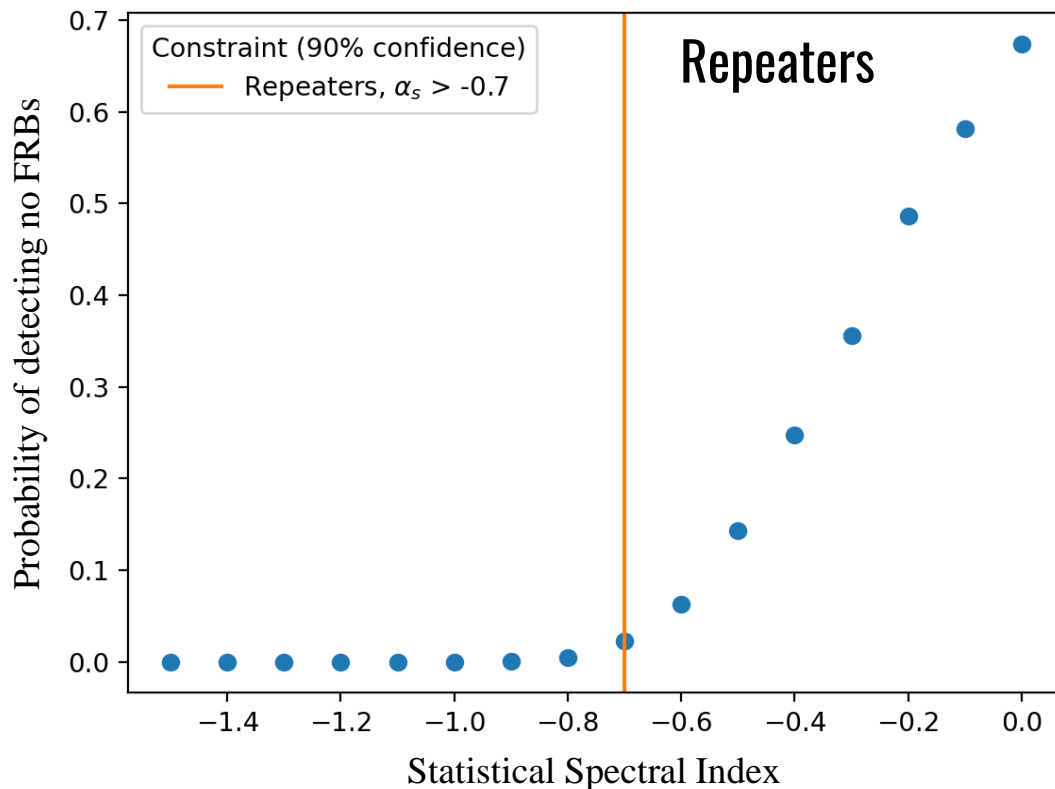
Constraints on FRB Emission

Through comparison with CHIME/FRB repetition rates

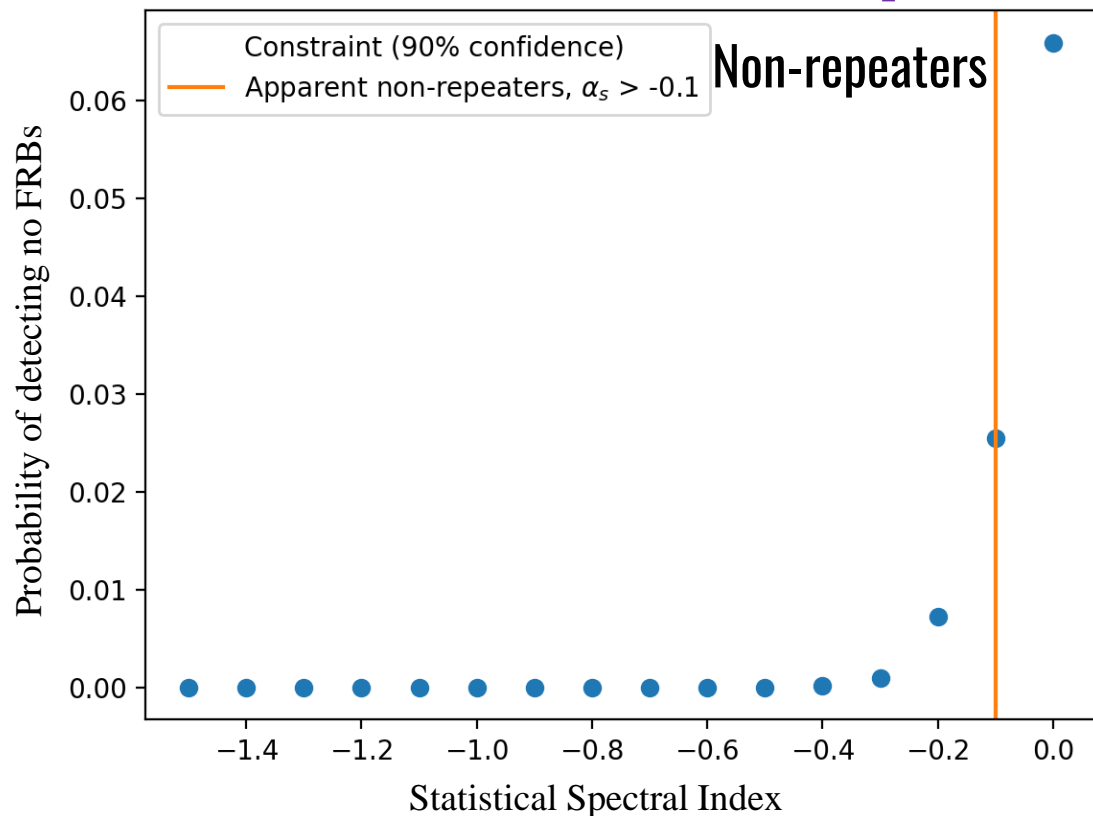


Characterises the
burst rate variation
with frequency

$\alpha_s > -0.7 \rightarrow$ Low repetition rate or less energetic bursts
at low frequencies



$\alpha_s > -0.1 \rightarrow$ Low repetition rate or less energetic bursts
at low frequencies



Non-detection of low-frequency emission can constrain:

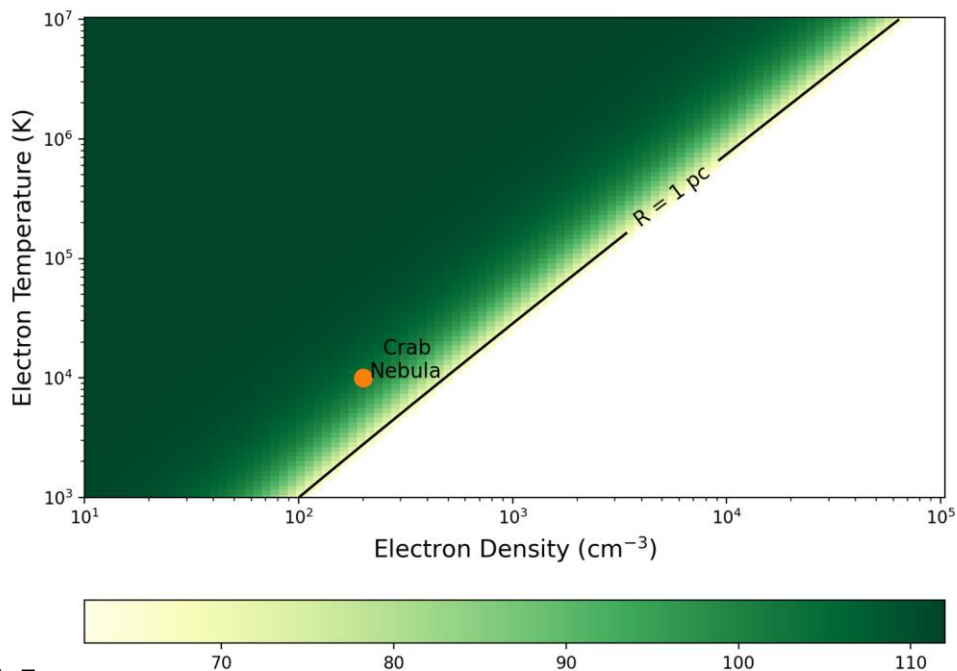
- Intrinsic spectrum
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Determining the Properties of the FRB Environment

for repeating FRB 20201124A

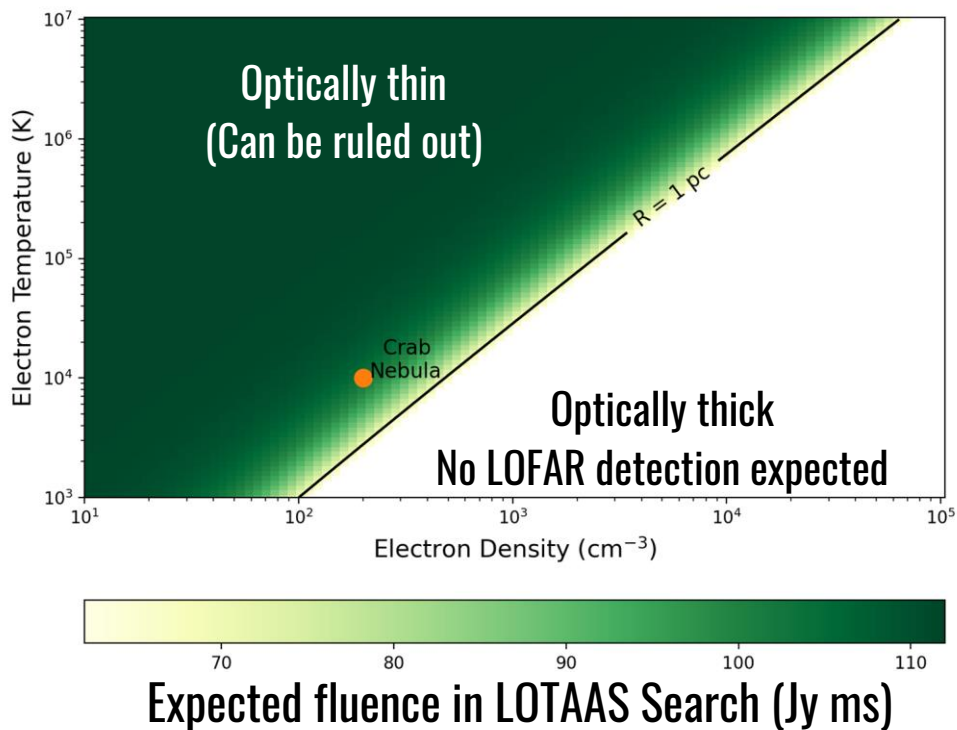


Assuming $F_\nu \propto \nu^\alpha$ $\alpha = -1.5$
Macquart+19

→ Expected fluence in LOTAAS Search (Jy ms)

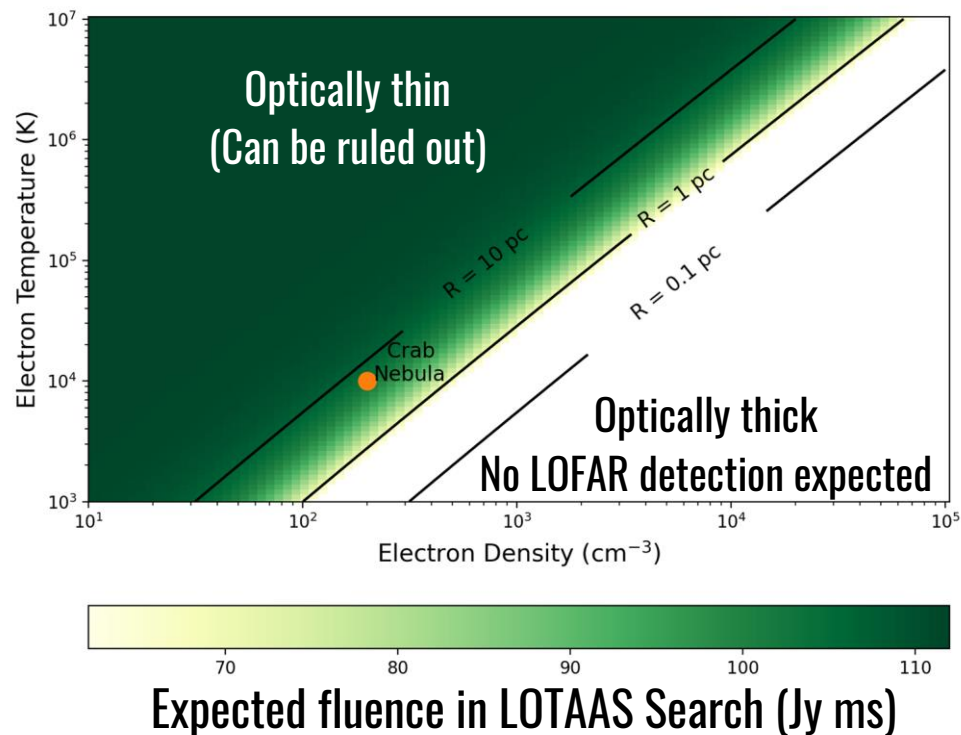
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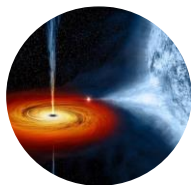
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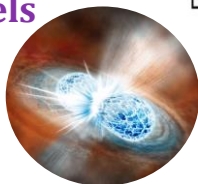
Isolated neutron stars



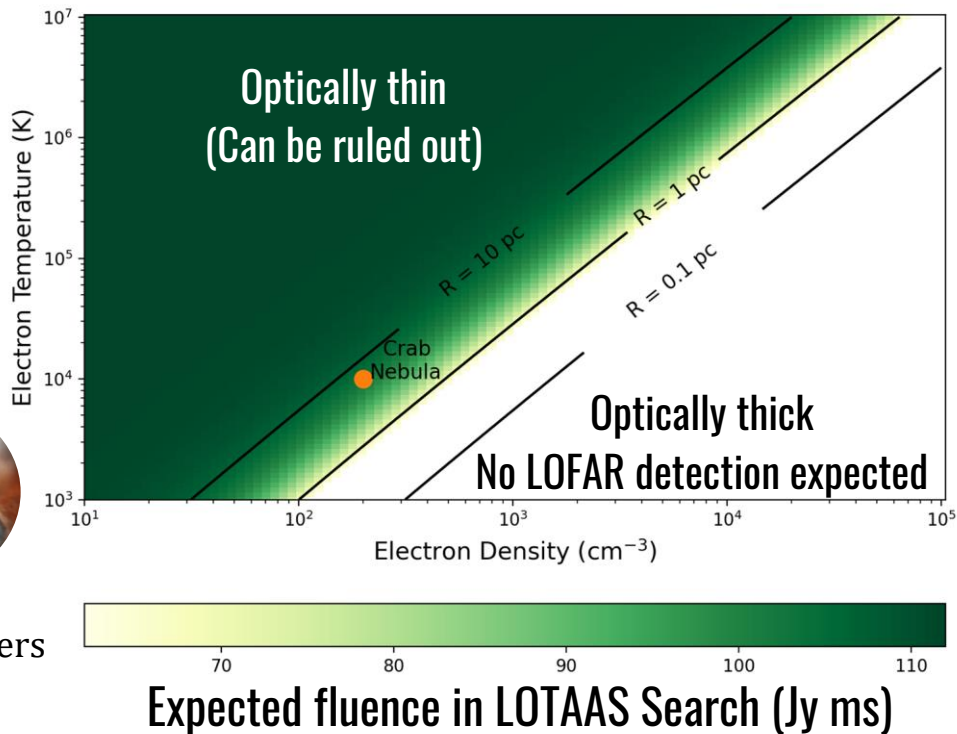
Proposed FRB progenitor models



Interaction models



Compact object mergers

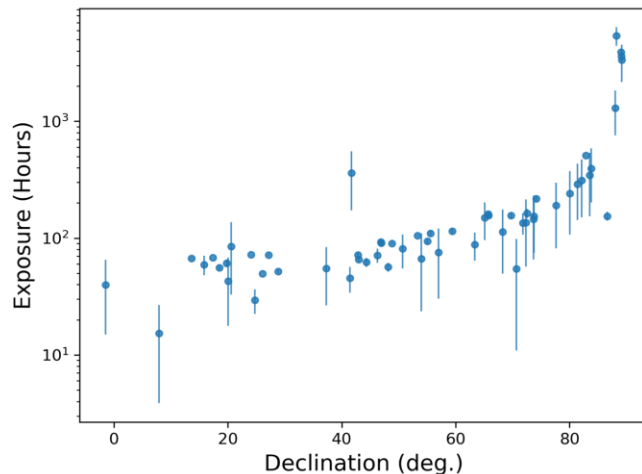
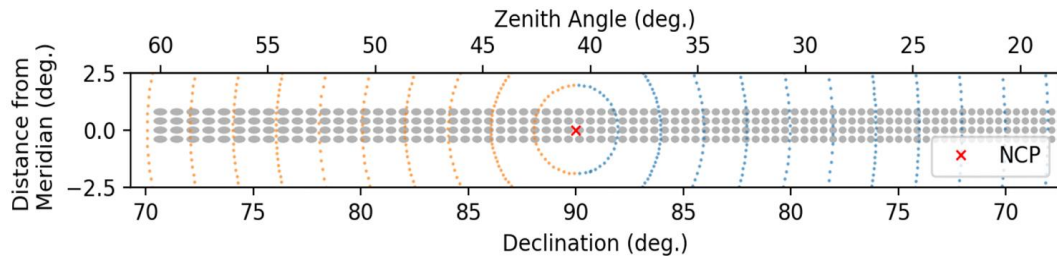


Summary

- Sample of known repeating FRBs has grown significantly (46 in total).
- No bimodality observed in repetition rates of repeaters and non-repeaters.
 - So apparent non-repeaters can also repeat
- No repeat bursts detected so far in LOTAAS data (119-151 MHz).
- Lack of detections constrains repetition and circumburst environments of FRBs.
- Any future detections at low frequencies will potentially have clean environments
→ Great for use as cosmological probes!

Measuring Repetition Rates of CHIME FRBs

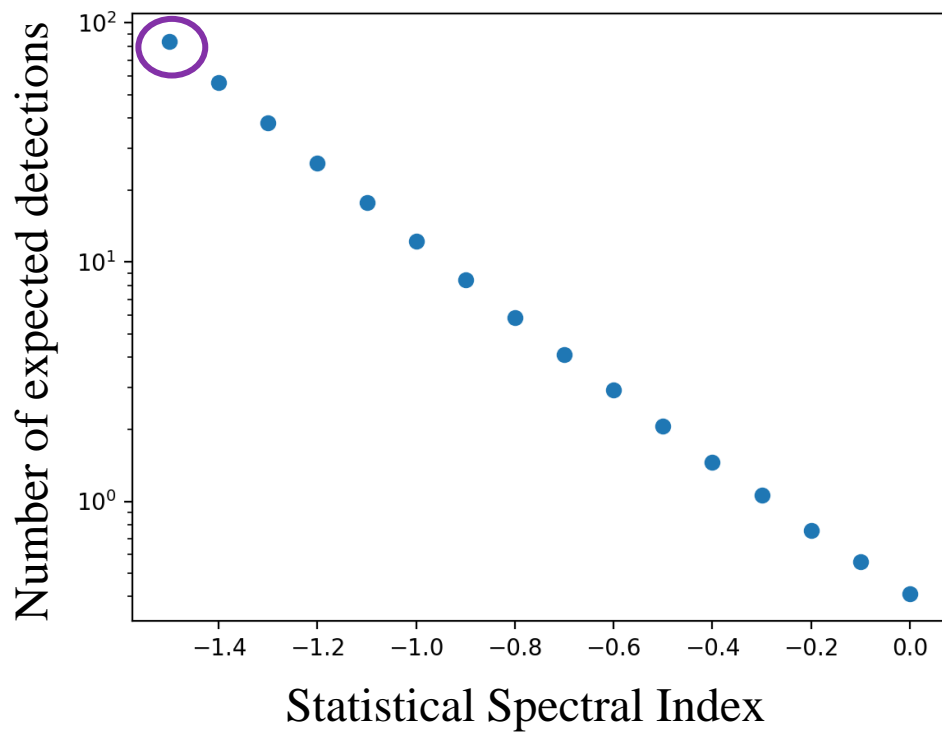
- Observed 1024 distinct locations for 730 days
 - Aug. 2018 - May 2021
- Source exposure based on:
 - Uptime and beam sensitivity
 - Transit time through the beams

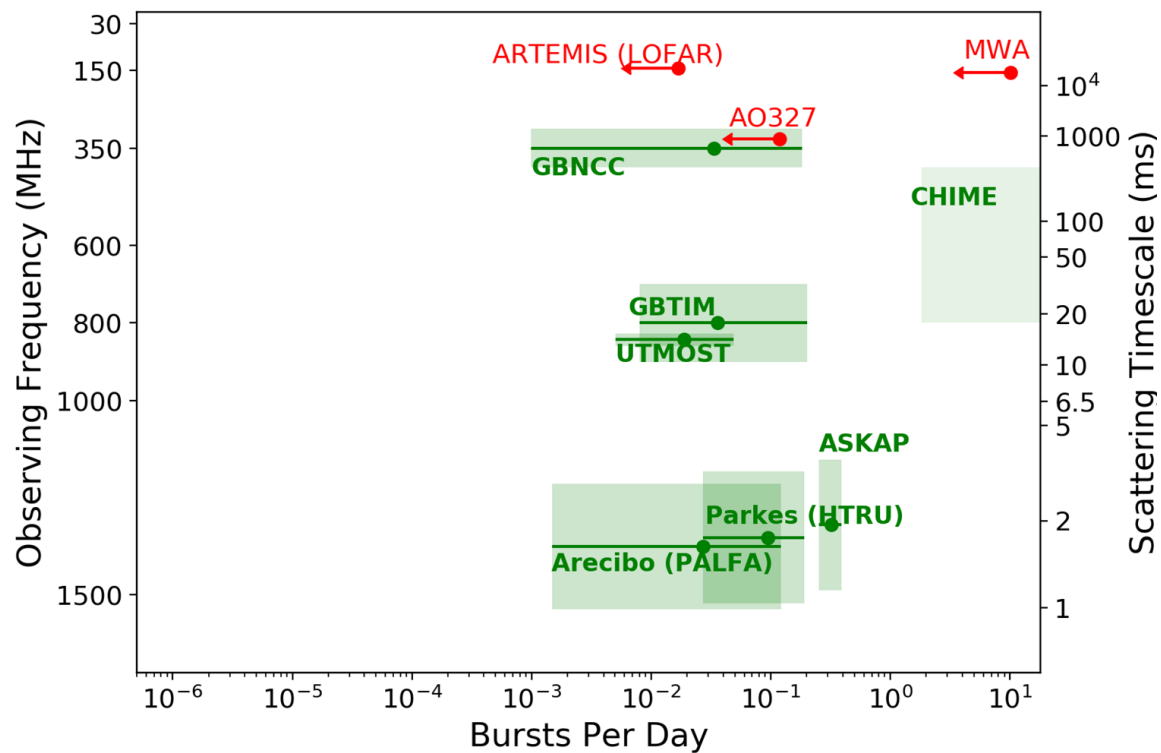


Statistical Spectral Index

$$\frac{\lambda_1}{\lambda_2} = \left(\frac{\nu_1}{\nu_2} \right)^{-\alpha_s \gamma} \left(\frac{F_{\nu_1, \min}}{F_{\nu_2, \min}} \right)^{\gamma+1}$$

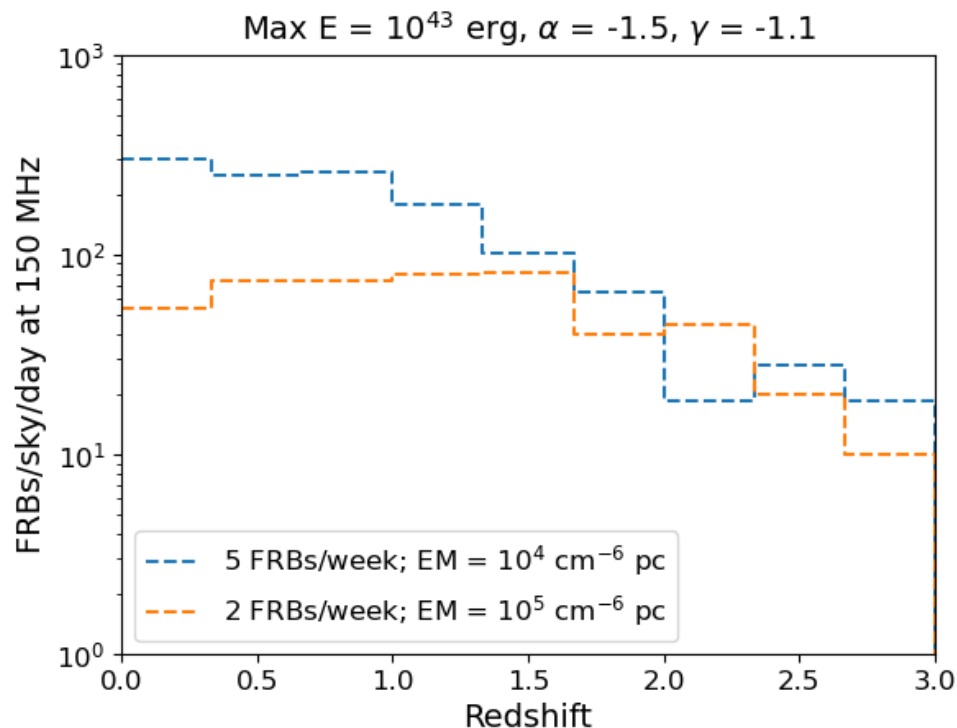
Based on the CHIME/FRB repetition rates, ~100 detections expected

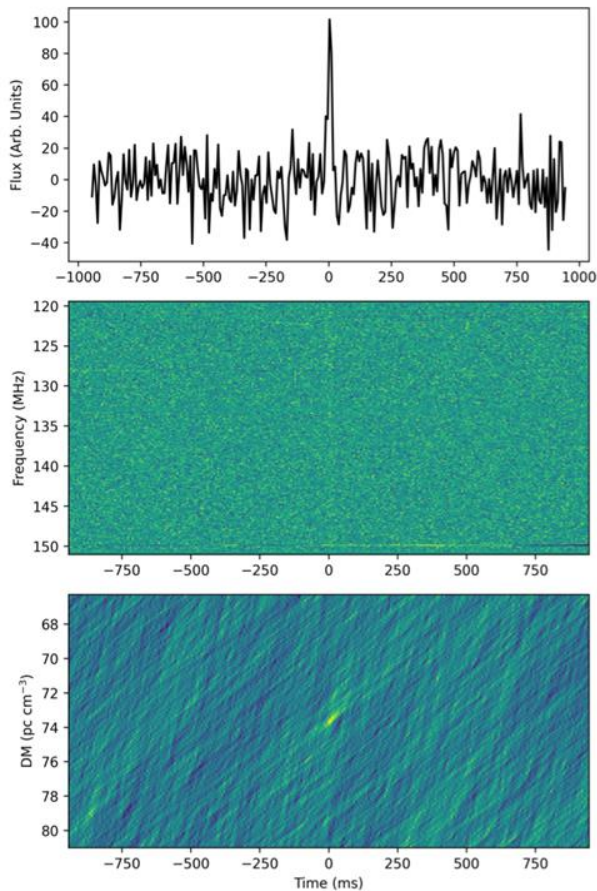




Looking Forward

- Predicted FRB yield for a search with LOFAR core stations
- FOV = 24 sq. deg.
- Observing bandwidth = 48 MHz
- Rate inferred from simulations based on recent constraints on
 - FRB energy distribution
 - Spectral index
 - Scattering
 - FRB rate





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 dec_deg : 21.191944444444445
 dm : 73.64
 dm_opt : -1
 dtype : uint8
 fch1 : 151.062010099375
 filename : L652978_SAP0_BEAM28.fil
 filepath : /projects/0/lotaas2/data/raw/SCRATCH/L652978_red/stokes/SAP0/BEAM28
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 frequency_decimation_factor : 1
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 gl : -117.58136704106826
 label : 5
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 native_nbits : 8
 native_nchans : 2592
 native_nspectra : 1826816.0
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 nchans : 2592
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 snr_opt : -1
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 tcand : 410.19998
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 tstart : 58264.14861111111
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