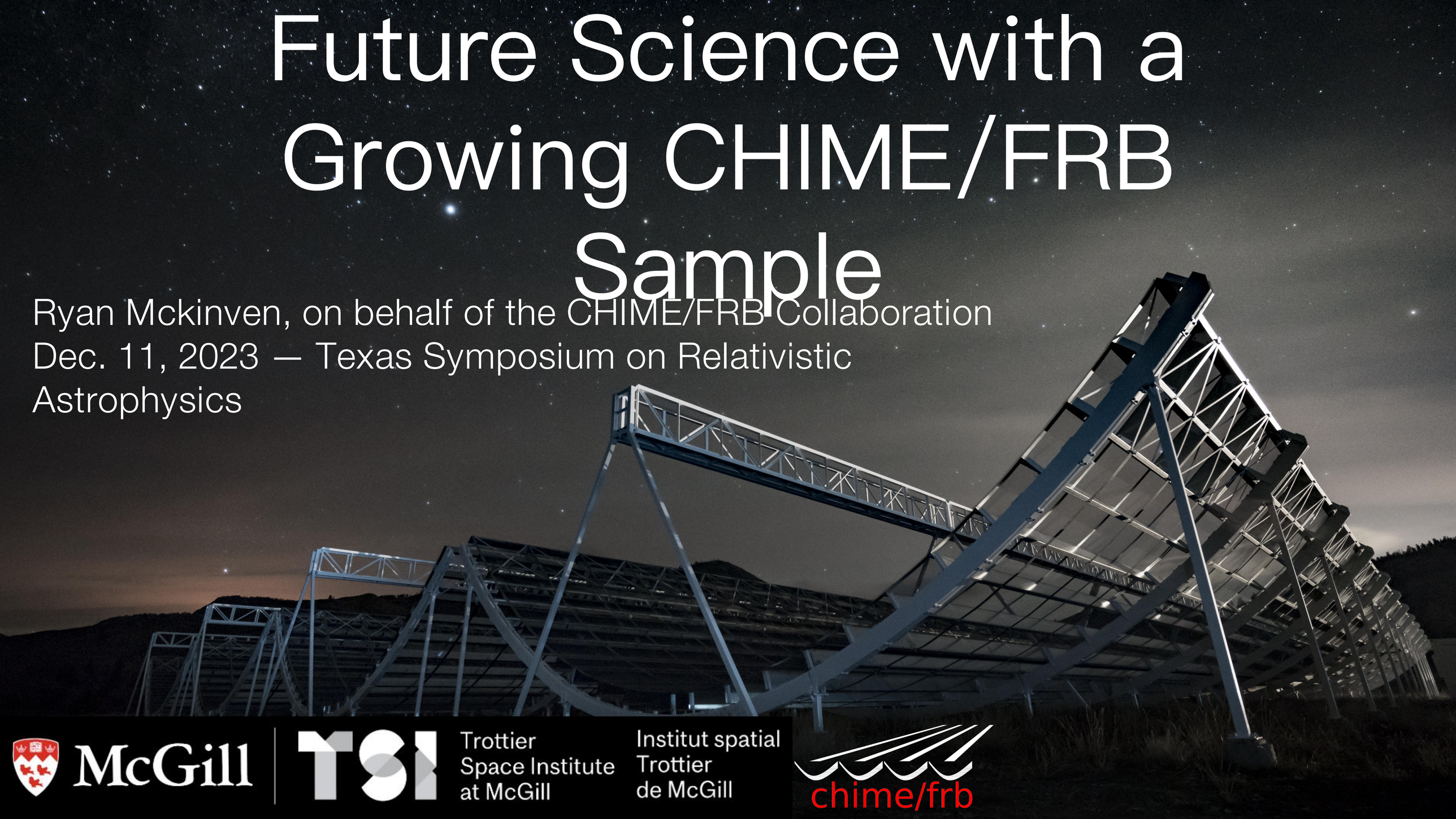
Future Science with a Growing CHIME/FRB Sample

Ryan Mckinven, on behalf of the CHIME/FRB Collaboration

Dec. 11, 2023 — Texas Symposium on Relativistic Astrophysics

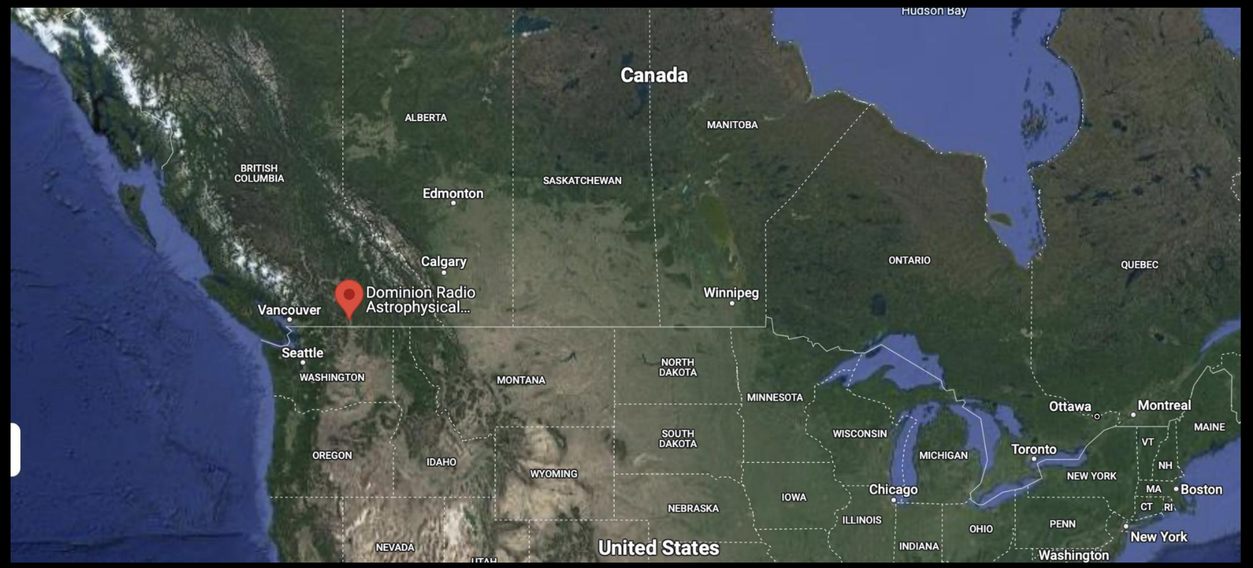


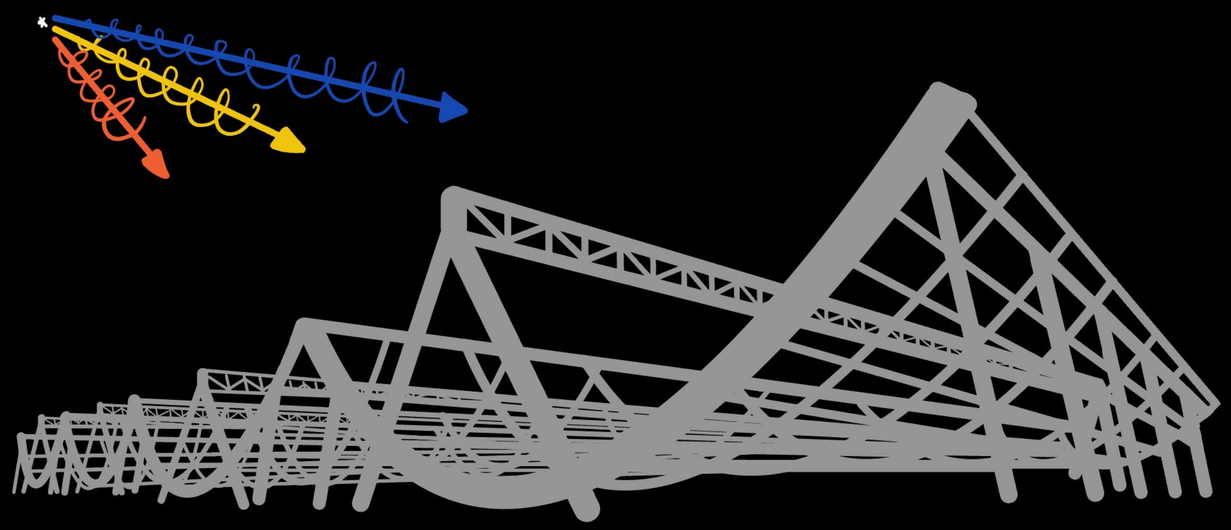
McGill | TSI Trottier Space Institute at McGill | Institut spatial Trottier de McGill

chime/frb

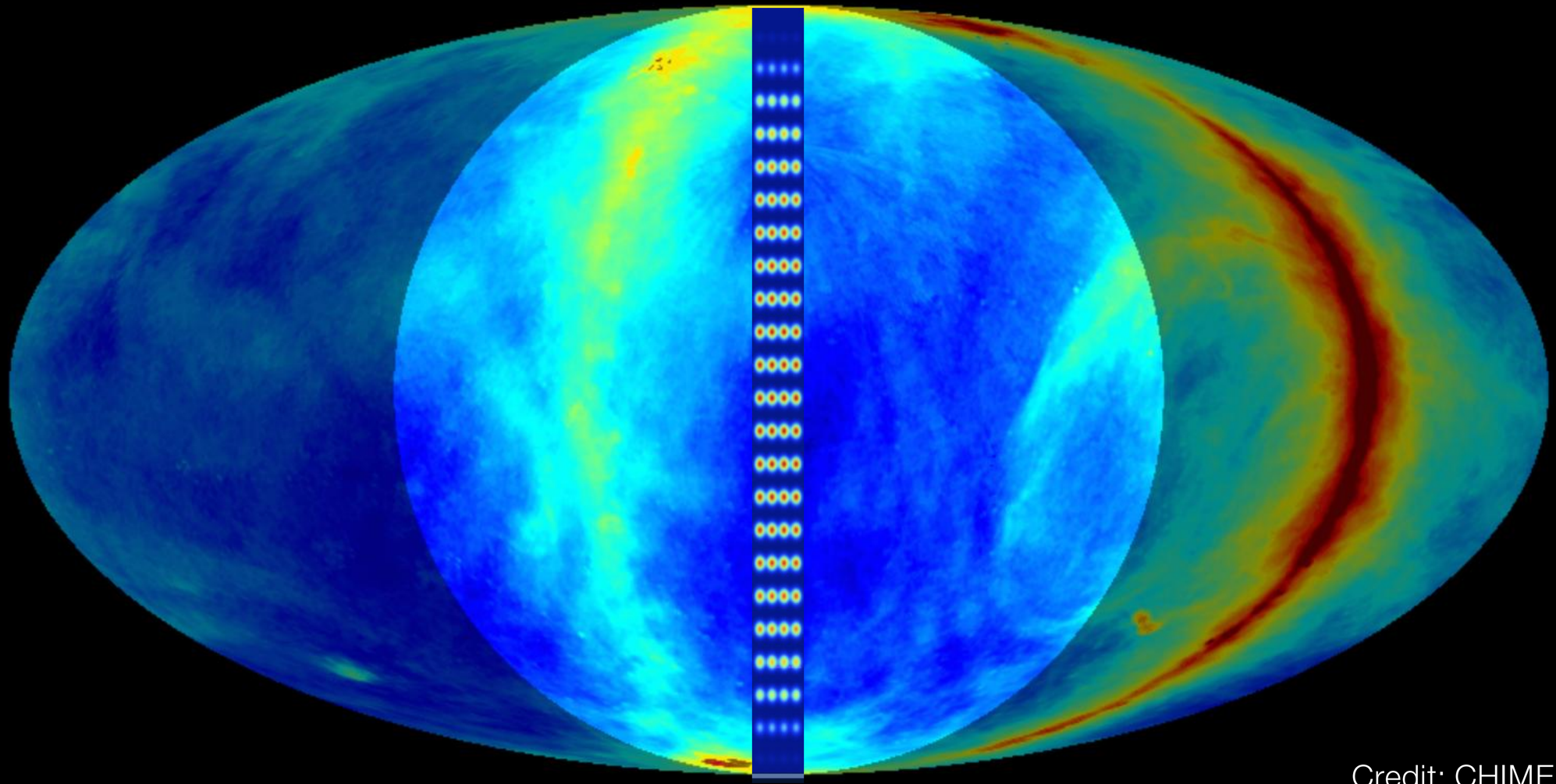
CHIME telescope

- Canadian Hydrogen Intensity Mapping Experiment
- At Dominion Radio Astrophysical Observatory, British Columbia
- Transit telescope
- Observes at 400 – 800 MHz
- 1024 dual-polarization antennas
- Digitally forms 1024 interferometric synthesized beams



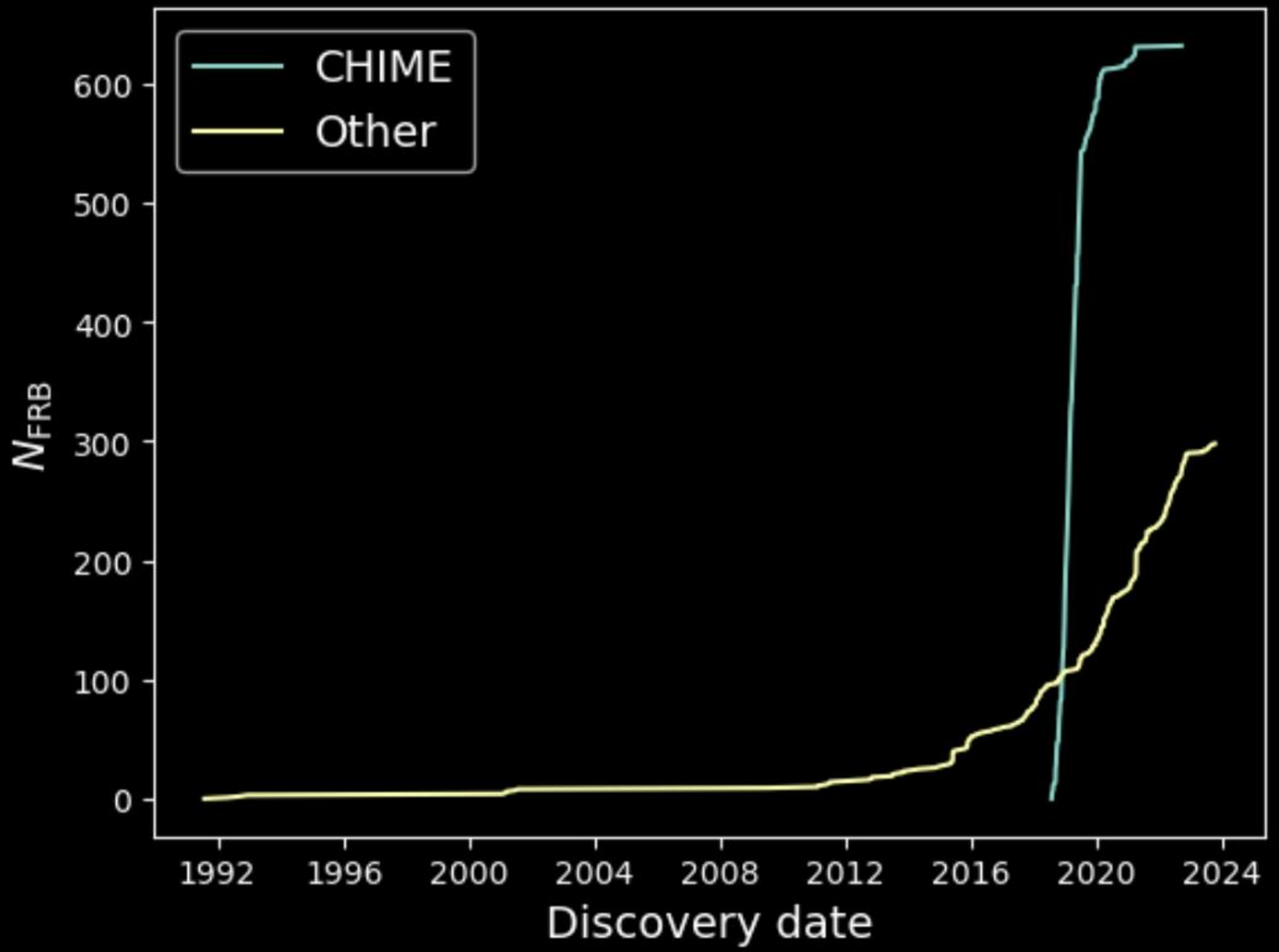


CHIME primary beam



Credit: CHIME

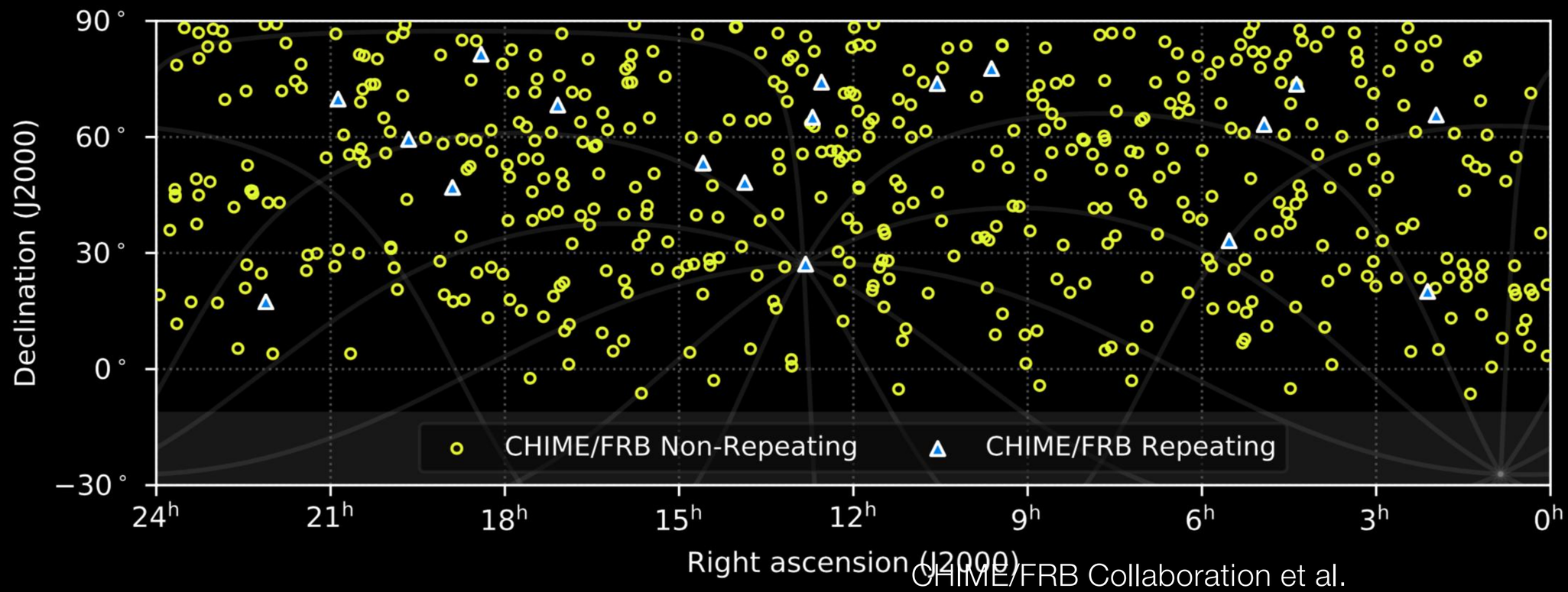
CHIME/FRB



Credit: Kaitlyn Shin

(With thanks to **frbcat** and TNS!)

CHIME/FRB: Catalog 1

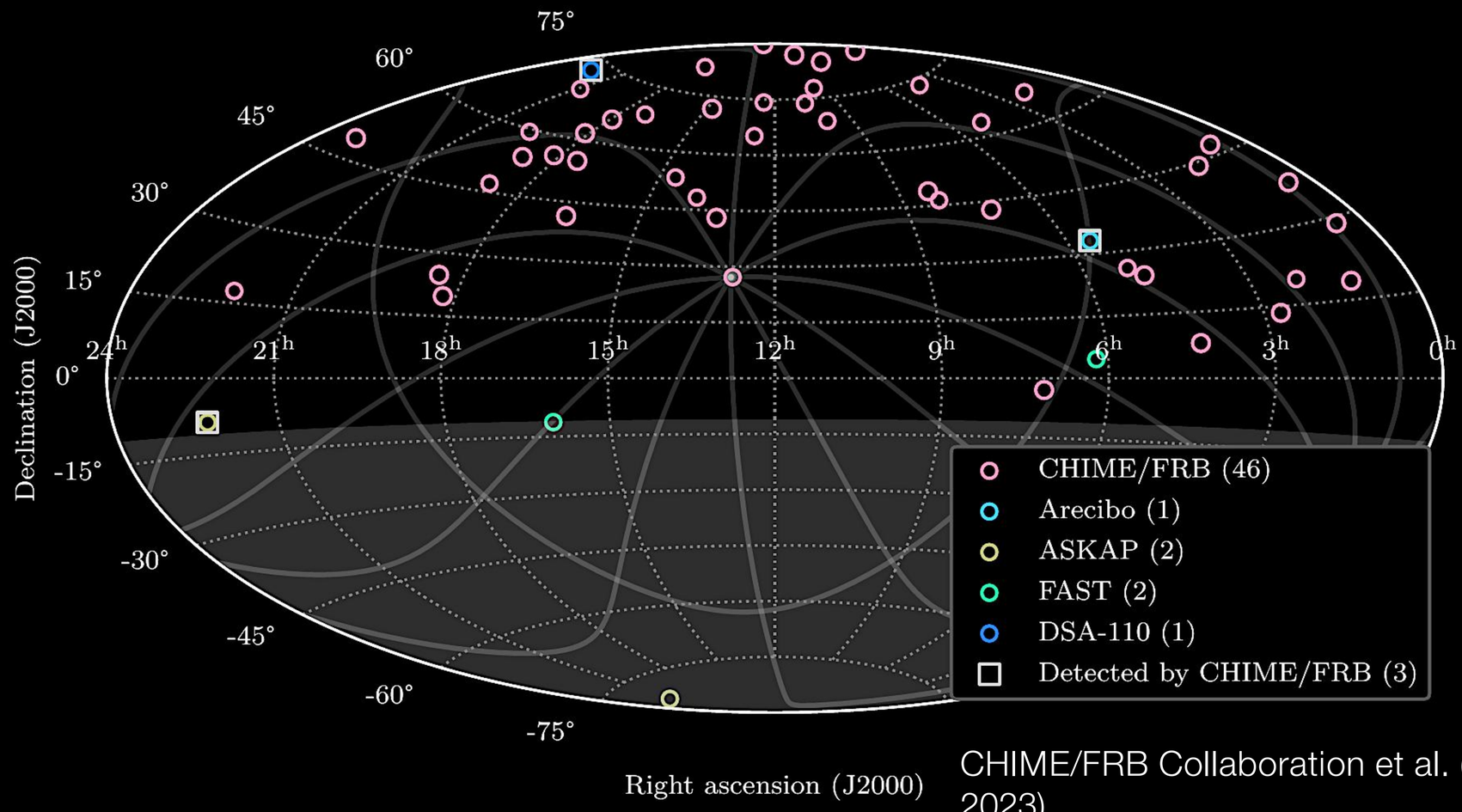


CHIME/FRB Collaboration et al. (2021)

To-date, still the largest publicly available sample of FRBs (**536**) from a single survey!

275 citations and counting…

CHIME/FRB: Repeaters



CHIME/FRB Collaboration et al. (2019, 2020, 2023)

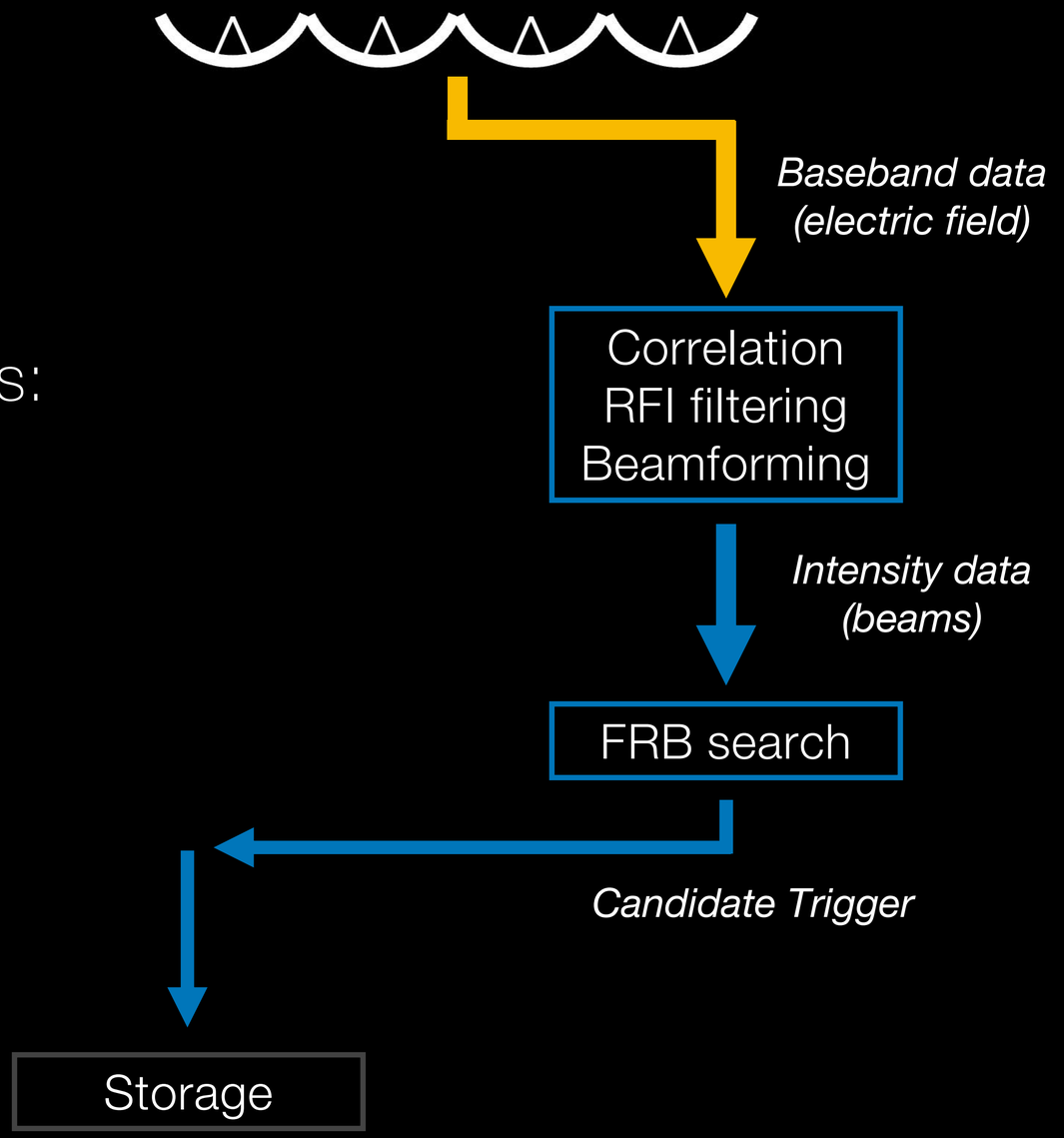
To-date, the largest number of repeating FRBs (**46**) from a single survey

What's next for CHIME/FRB?

Focus in on our **baseband** data!

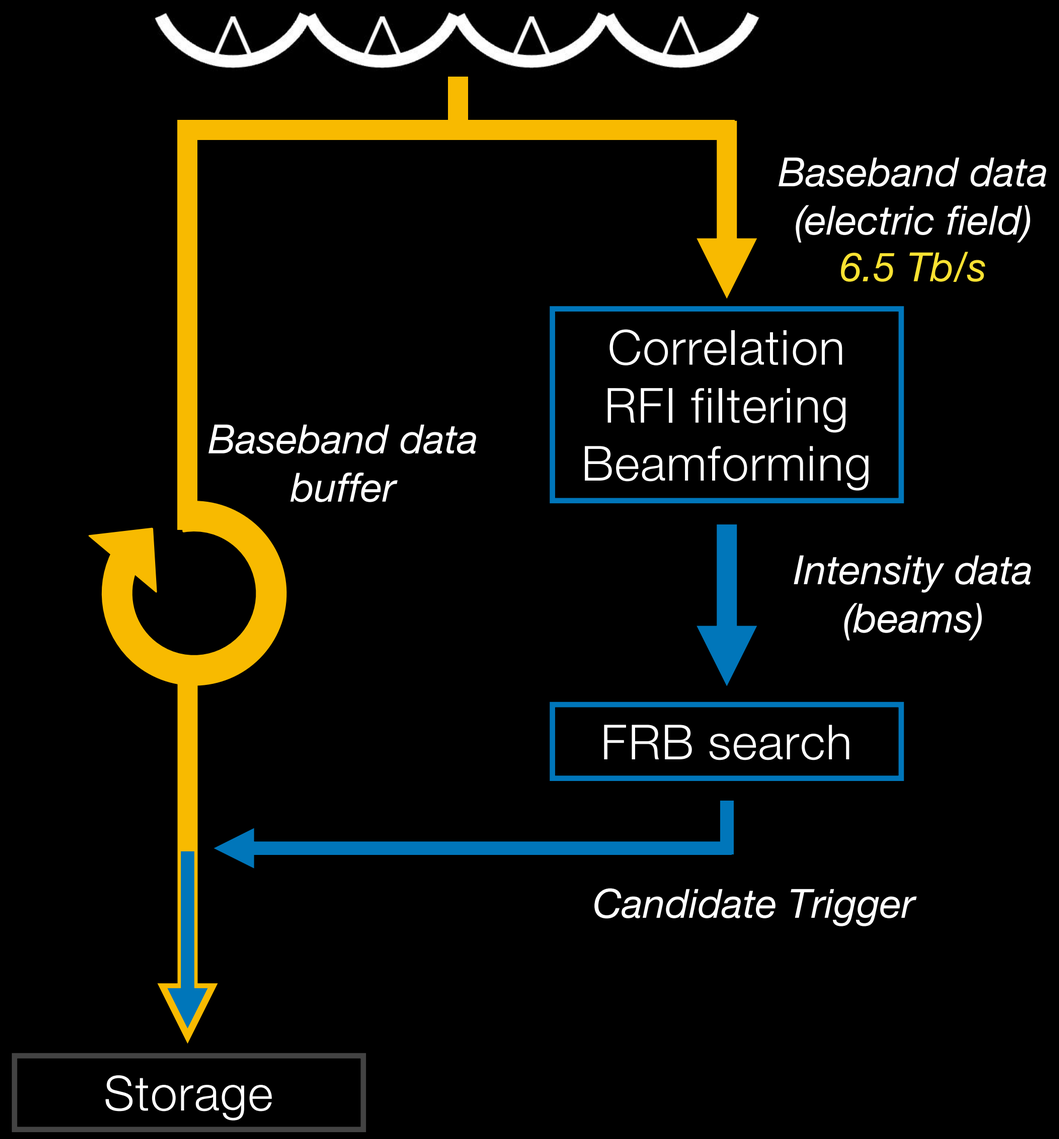
CHIME/FRB search (intensity)

- Data beamformed to 1024 beams on GPUs:
  - "**Intensity**" data
- Search:
  - DM ~ 0 to 13,000 pc cm^{-3}
  - ~1 ms time bins



CHIME/FRB search (baseband)

- "**Baseband**" data:
  - Complex voltages measured at each of the antennas
  - Native time resolution 2.56 μs
- Trigger baseband on **S/N > 12** candidate:
  - DM upper limit ~1,000 pc cm^{-3}
  - ~100 ms of data around signal



CHIME/FRB "BaseCat1"

- 536 Catalog 1 events with intensity data ⇒ tons of science, but has its limitations

CHIME/FRB "BaseCat1"

Dr. Daniele Michilli (MIT)

Kaitlyn Shin (MIT)

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- **140 FRBs** with successfully processed baseband data ("**Base**band **Cat**alog **1**")

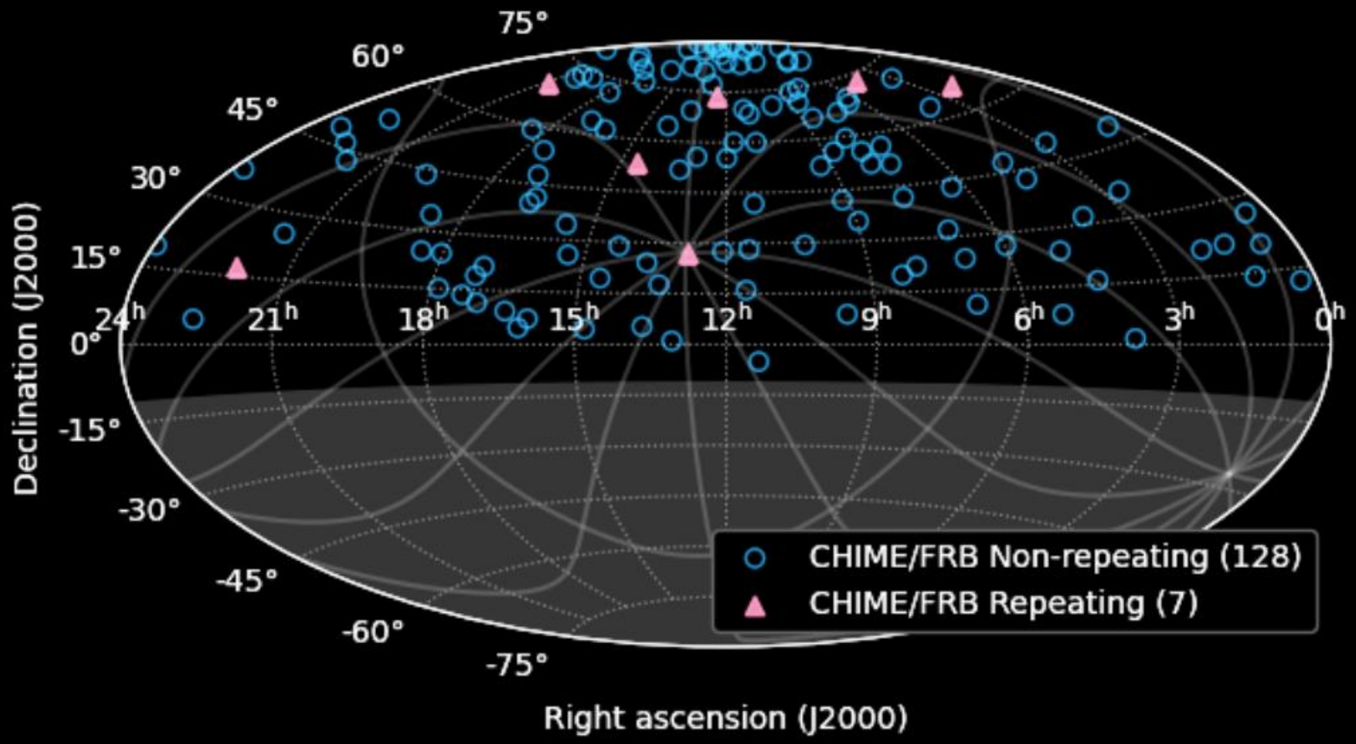
- Quality makes up for quantity:

  ★ Improved localizations and energetics

  ★ More accurate studies of burst properties

  ★ Polarization studies

  ★ And much more!



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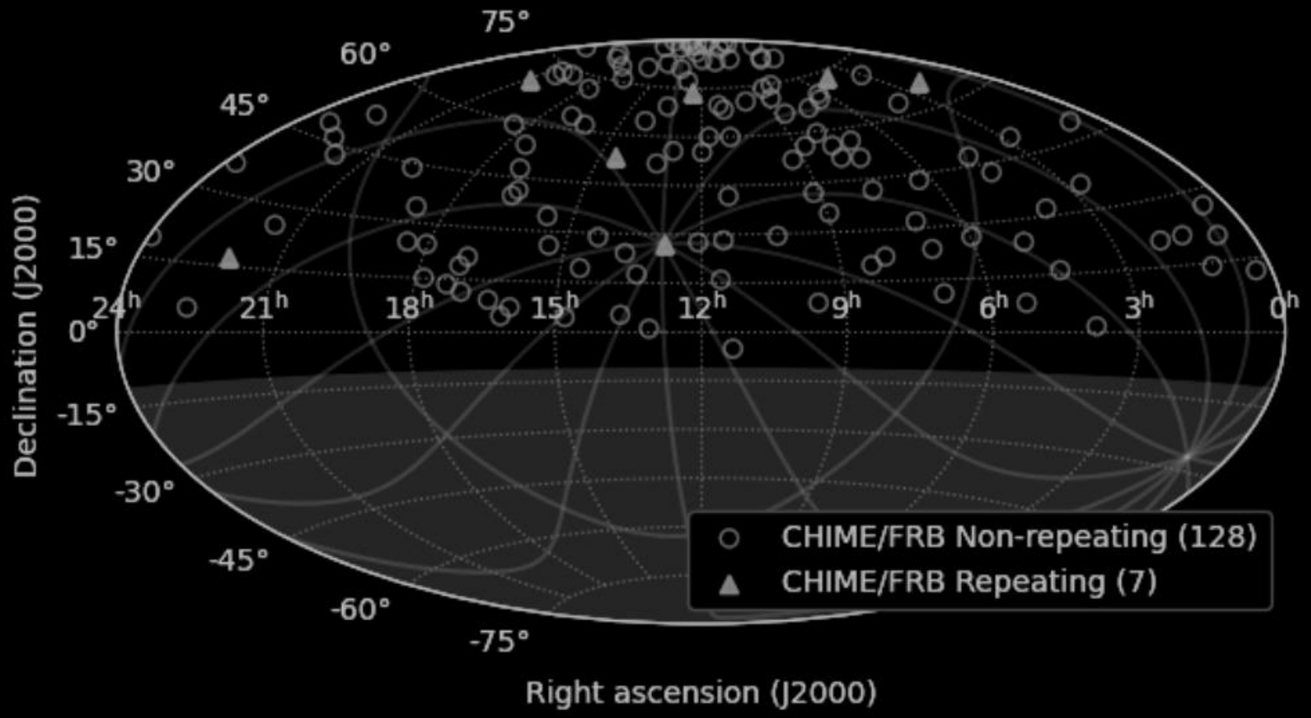
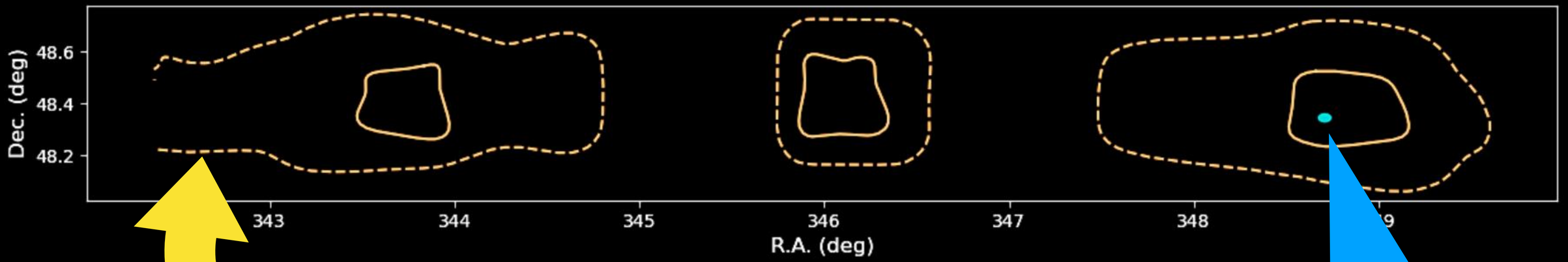


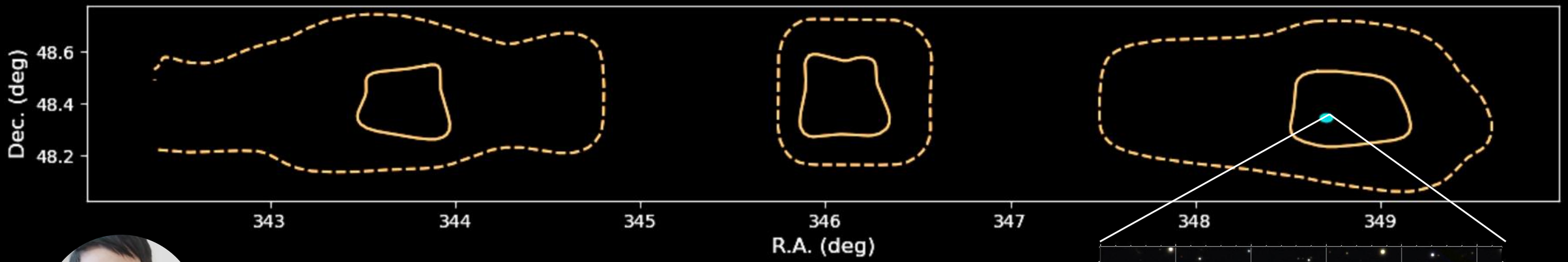
BaseCat1: localizations



Catalog 1 localization contours very big (~degrees)
Based on detection S/N from each formed beam

BaseCat1 localization ellipses **much smaller** (~arcmin)
Can repoint beam anywhere on the sky (no real-time constraints)

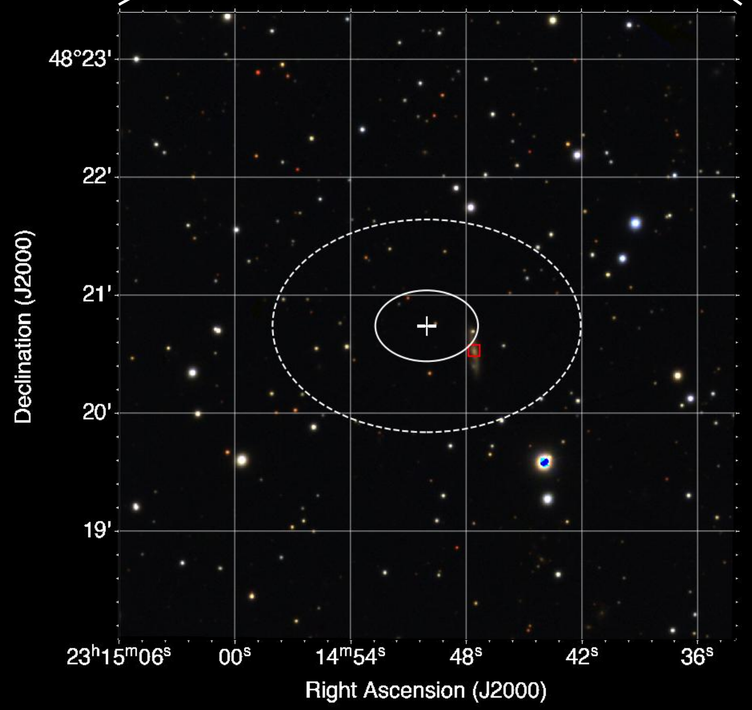
BaseCat1: localizations



Dr. Mohit Bhardwaj (CMU)

Bridget Andersen (McGill)

- For lower DM FRBs, baseband localizations good enough for host identification
- Have **already started** building up a sample of host galaxies!



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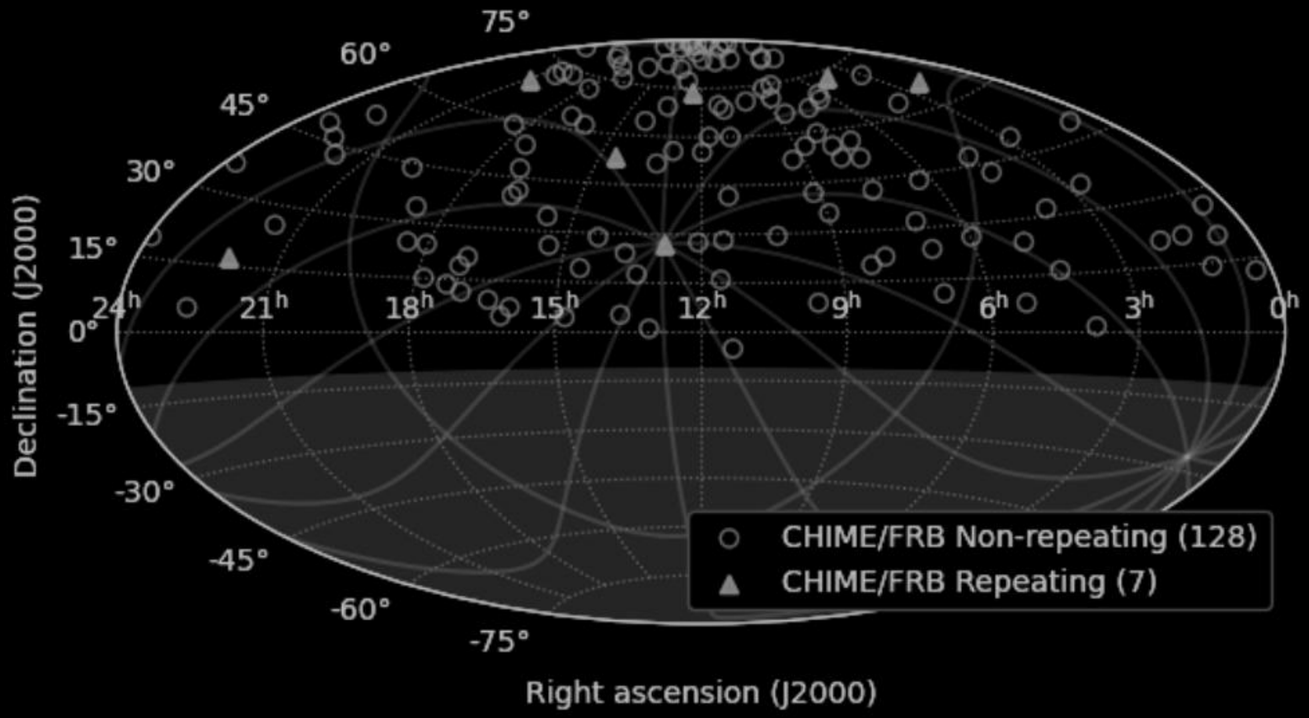
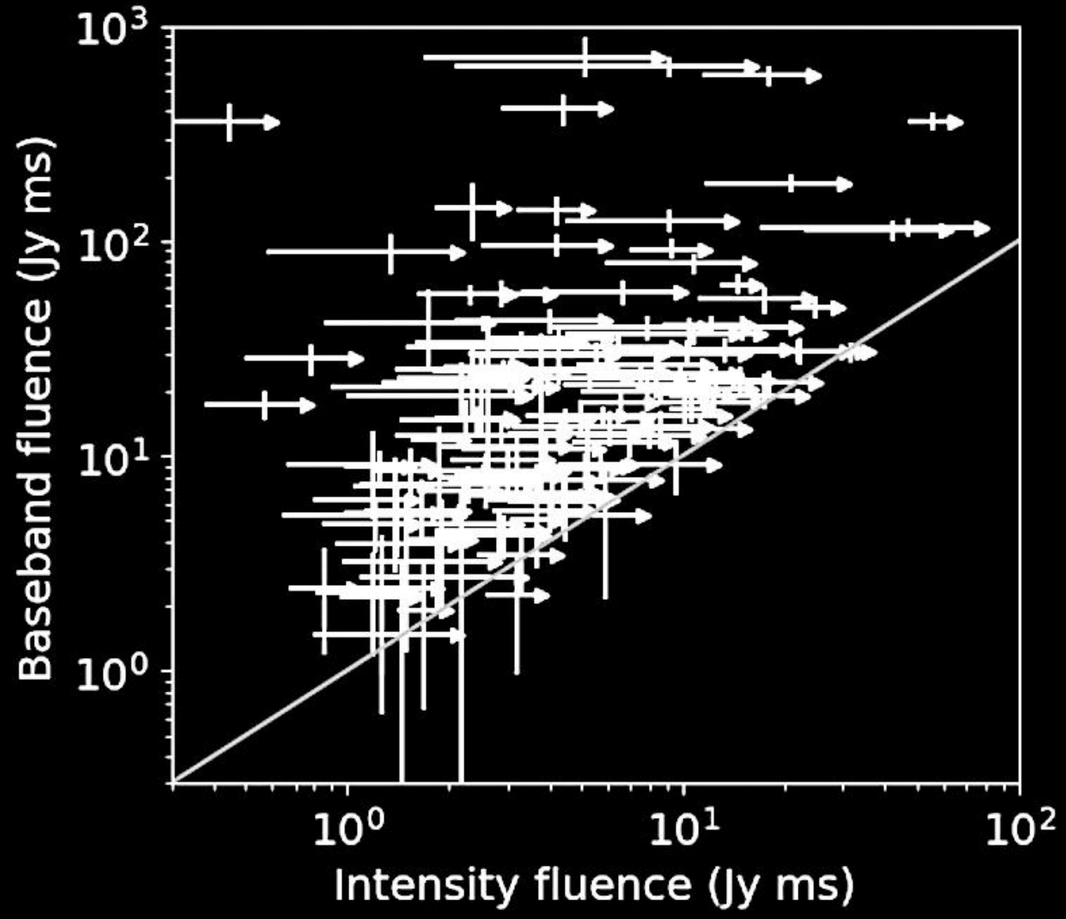


BaseCat1: fluxes & fluences

- Catalog 1: lower limits
- BaseCat1: **more accurate estimates**
  - Much better localizations
  - Better handle of the beam model
  - Above lower limits



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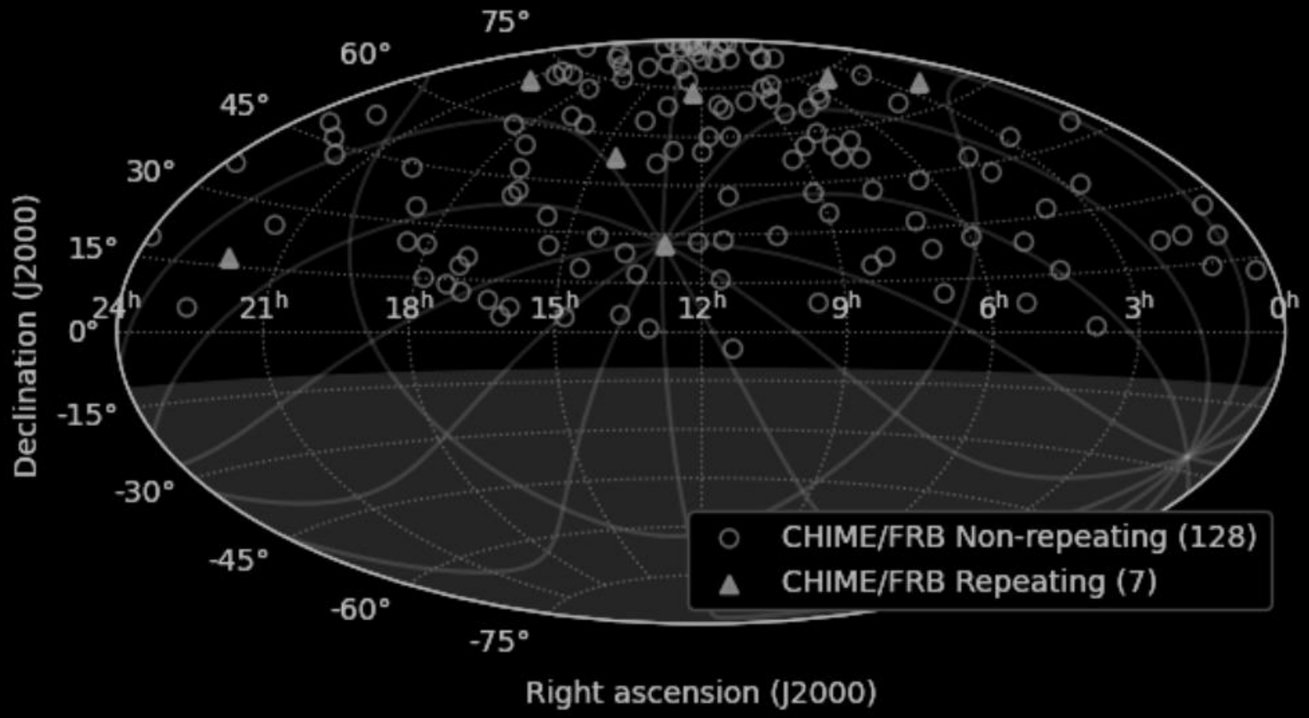
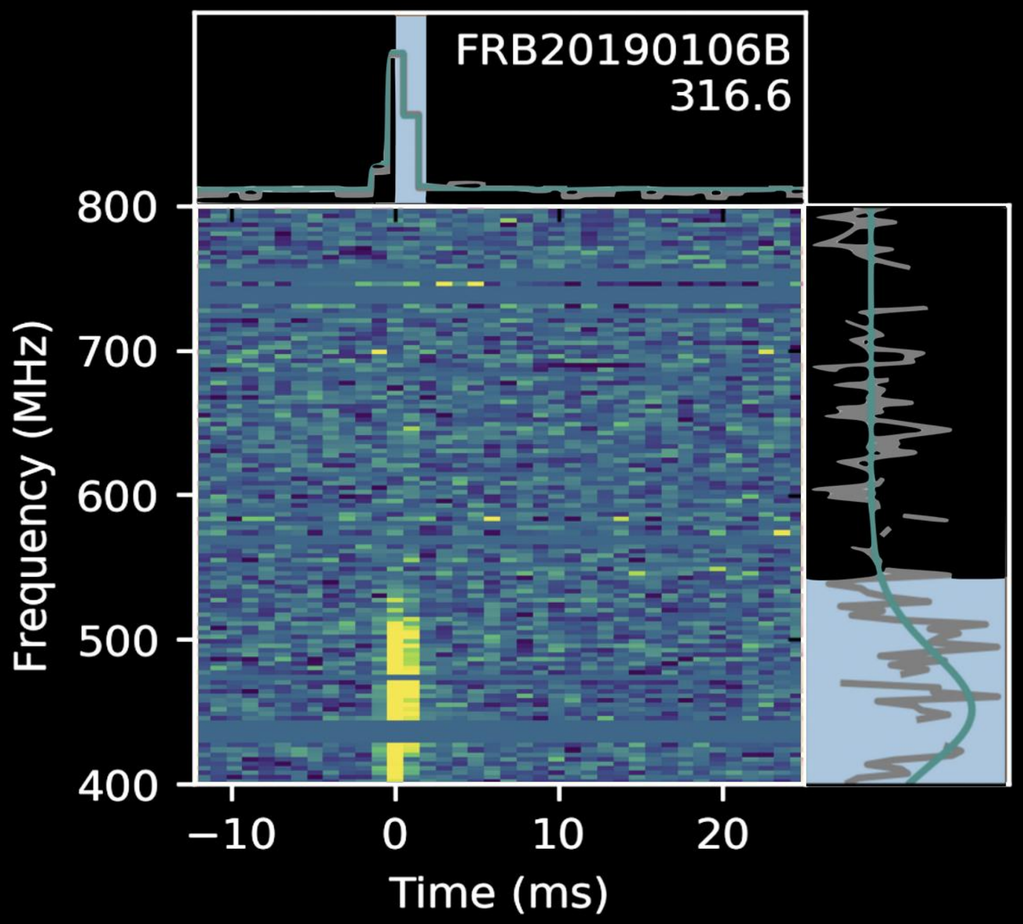
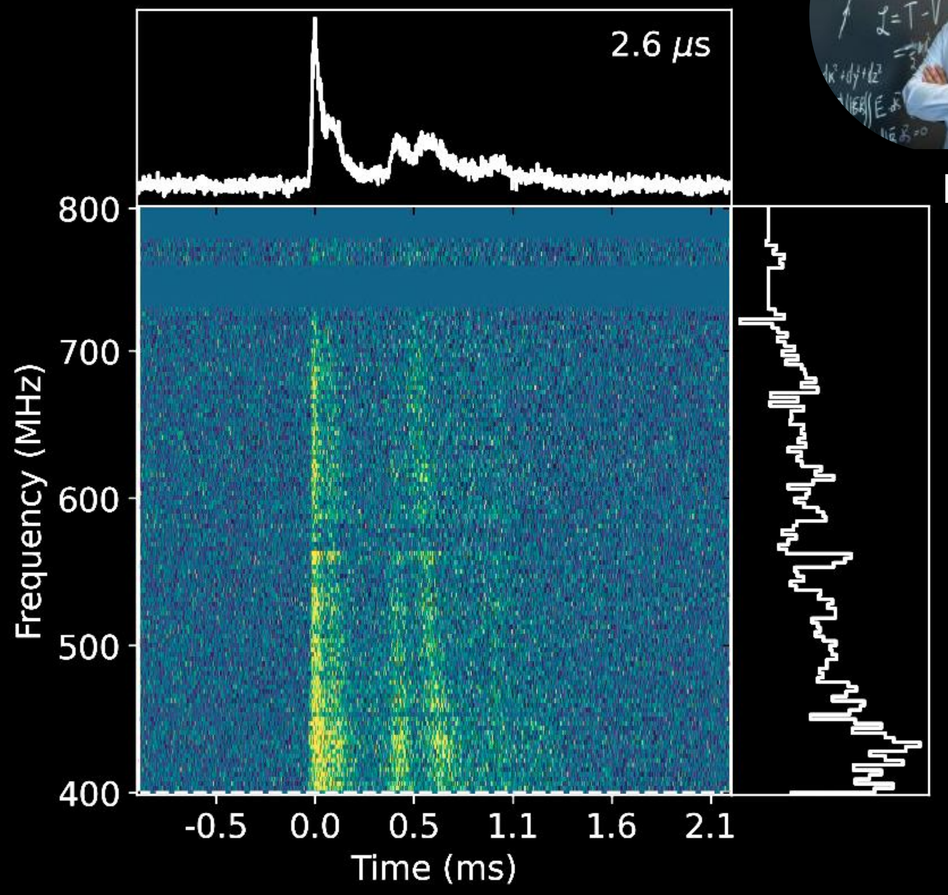


BaseCat1: higher time resolution

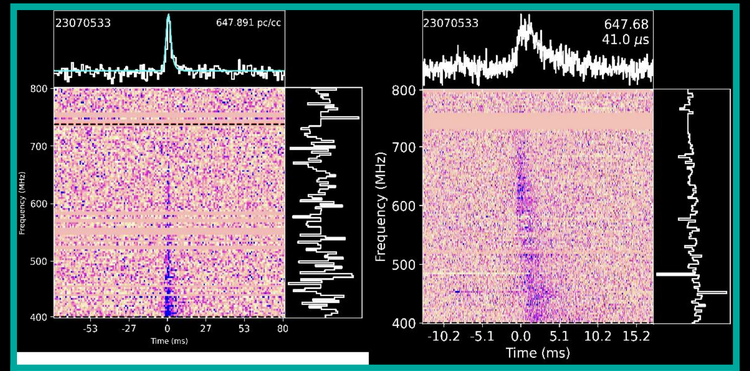
Intensity

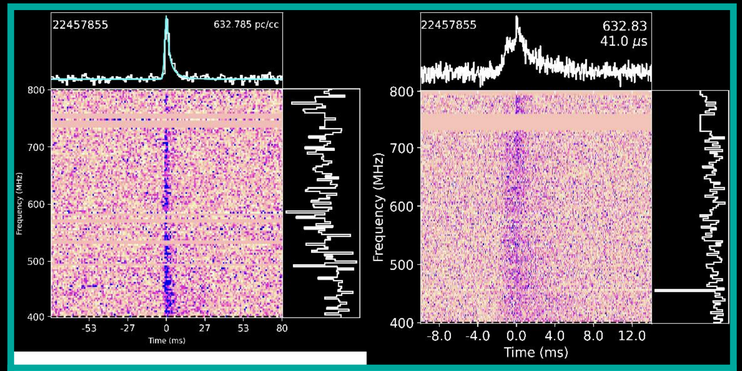


Baseband



Ketan Sand
(McGill)


23070533
647.891 pc/cc
23070533
647.68
41.0 μs
Frequency (MHz)
Time (ms)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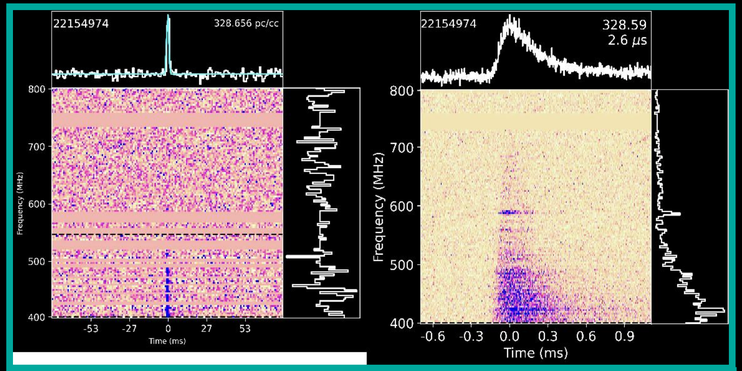
632.785 pc/cc
22457855
632.83
41.0 μs
Frequency (MHz)
Time (ms)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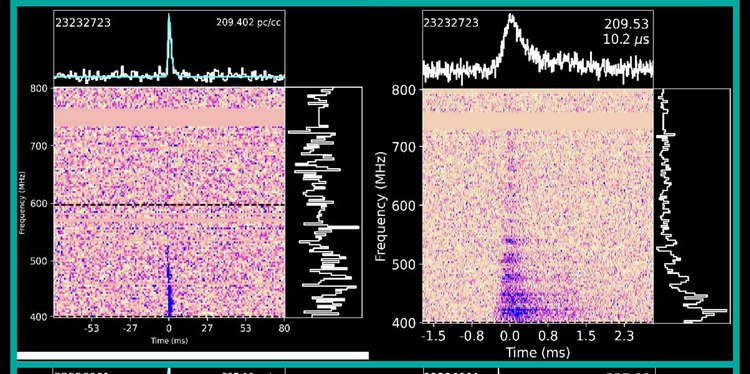
328.656 pc/cc
22154974
328.59
2.6 μs
Frequency (MHz)
Time (ms)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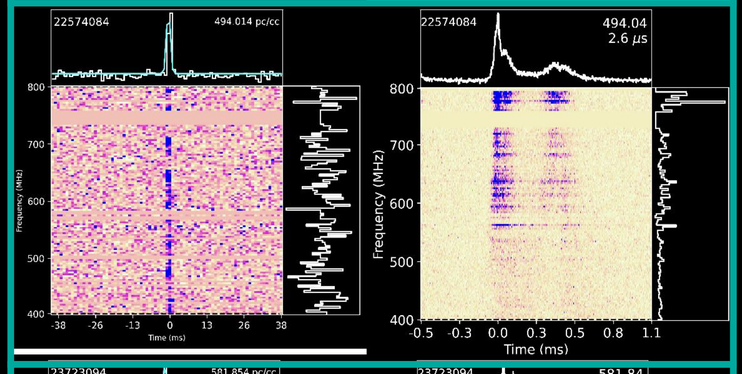
209.402 pc/cc
23232723
209.53
10.2 μs
Frequency (MHz)
Time (ms)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22574084
494.04
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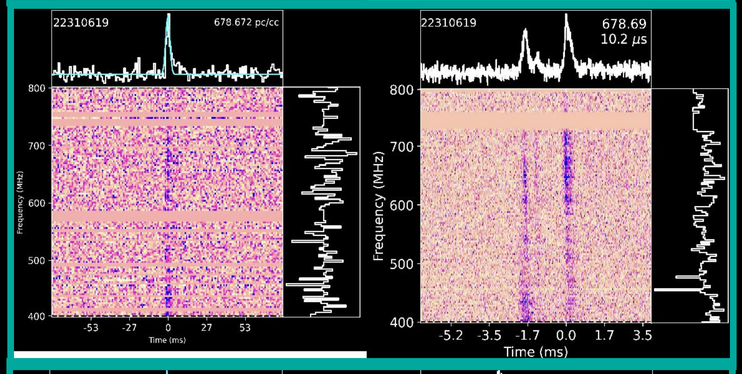
Frequency (MHz)
Time (ms)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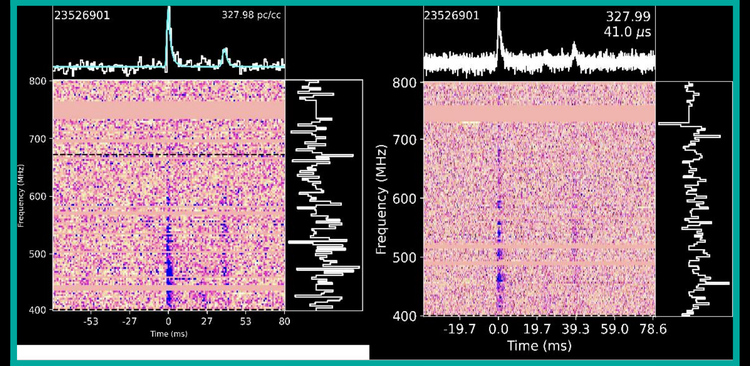
678.672 pc/cc
22310619
678.69
10.2 μs
Frequency (MHz)
Time (ms)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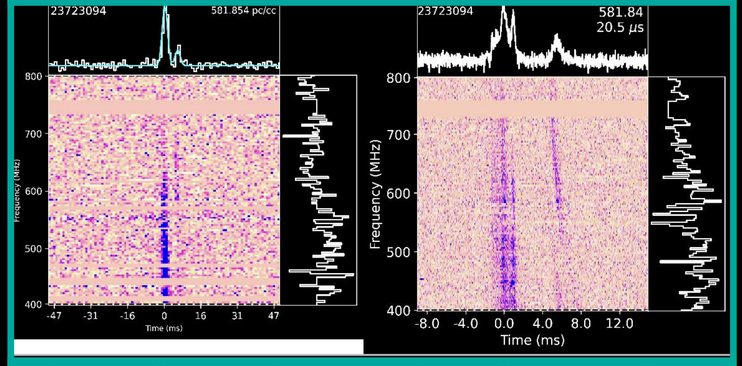
327.98 pc/cc
23526901
327.99
41.0 μs
Frequency (MHz)
Time (ms)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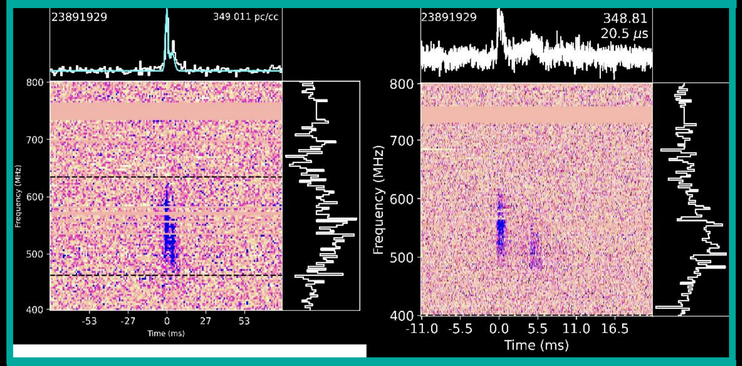
581.854 pc/cc
23723094
581.84
20.5 μs
Frequency (MHz)
Time (ms)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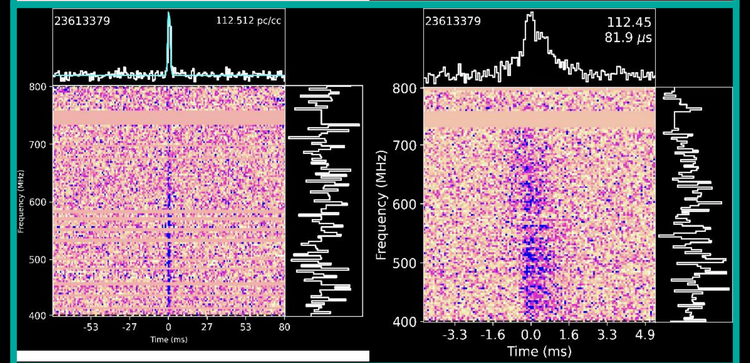
349.011 pc/cc
23891929
348.81
20.5 μs
Frequency (MHz)
Time (ms)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23613379
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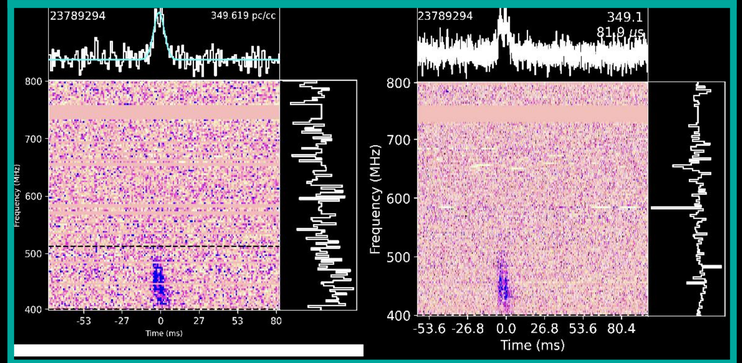
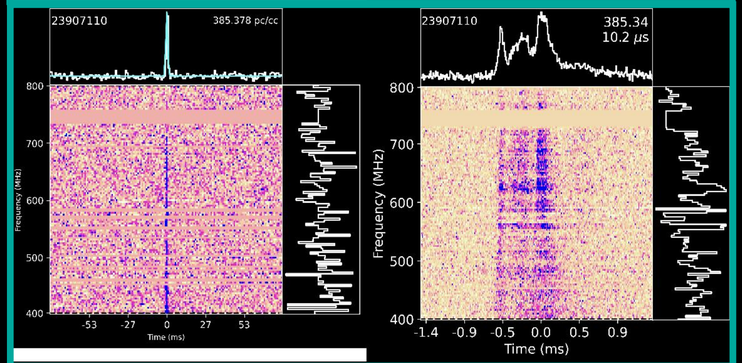
Frequency (MHz)
Time (ms)


23789294
349.619 pc/cc
23789294
349.1
81.9 μs
Frequency (MHz)
Time (ms)


23907110
385.378 pc/cc
23907110
385.34
10.2 μs
Frequency (MHz)
Time (ms)

CHIME/FRB "BaseCat1"

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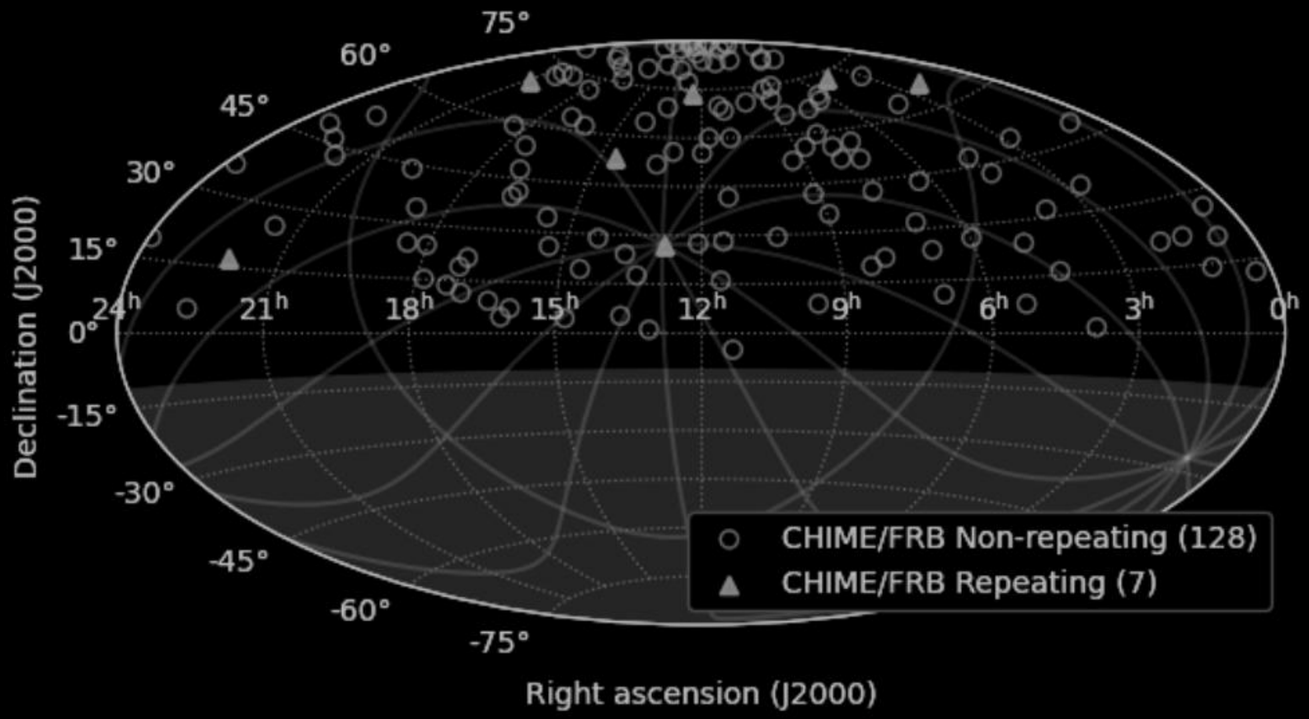
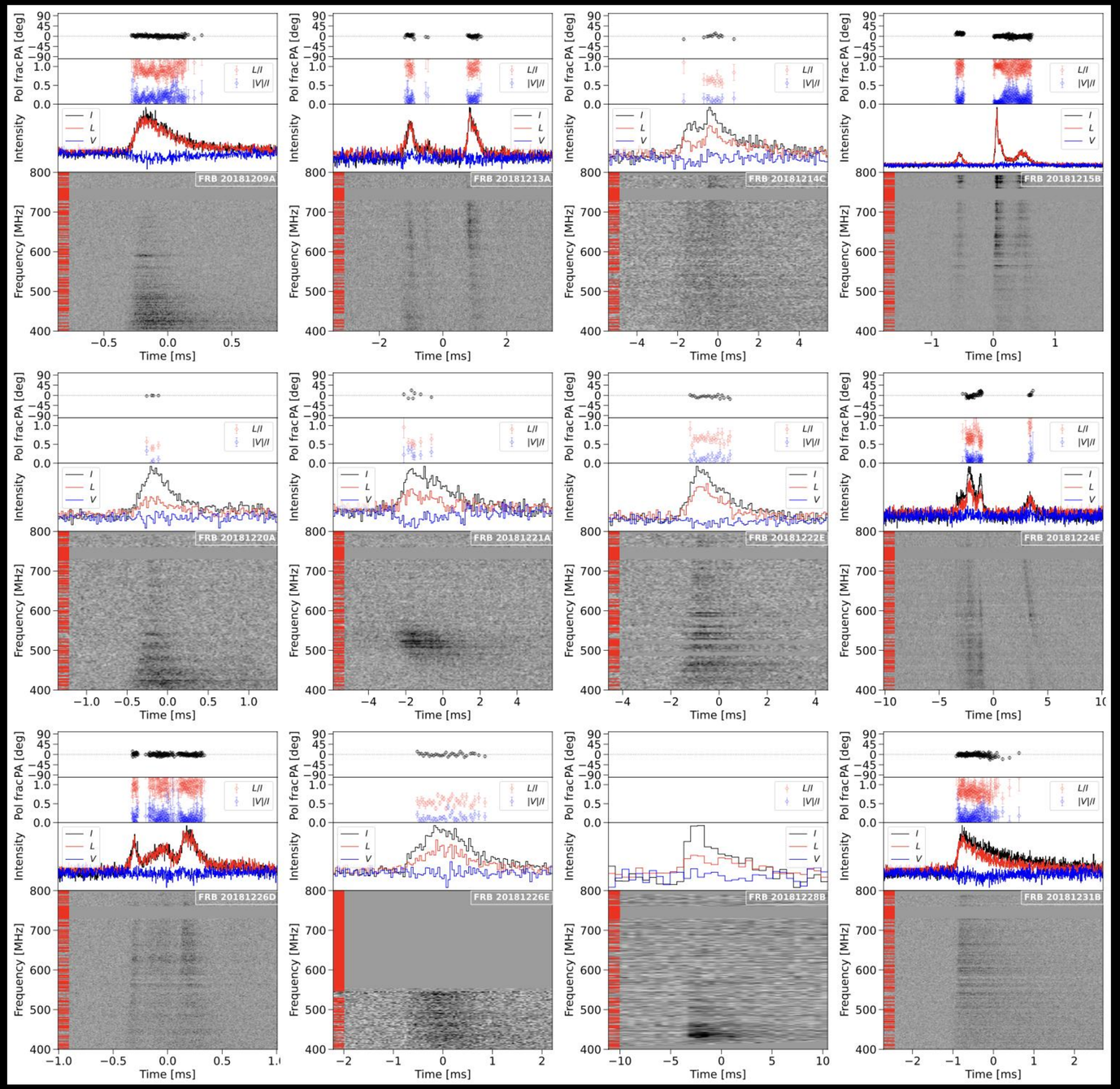
  - ★ **Polarization** studies
  - ★ And much more!



Ayush Pandhi
(Toronto)

BaseCat1: polarization

- Polarization Properties of 128 one-off CHIME FRBs
- 89 linearly polarized, 29 unpolarized
- $RM = 0 - 1160\ rad/m^2$ (median $\sim 50\ rad/m^2$)
- Statistical study of non-repeater vs. repeater samples



BaseCat1: polarization

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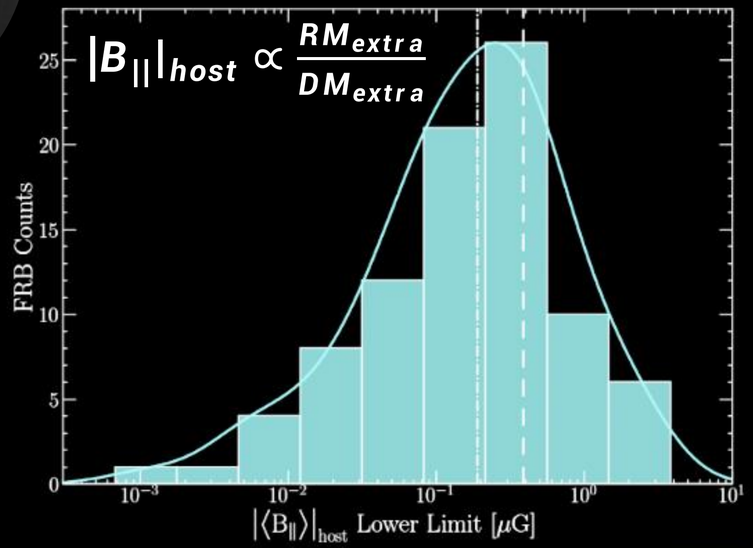
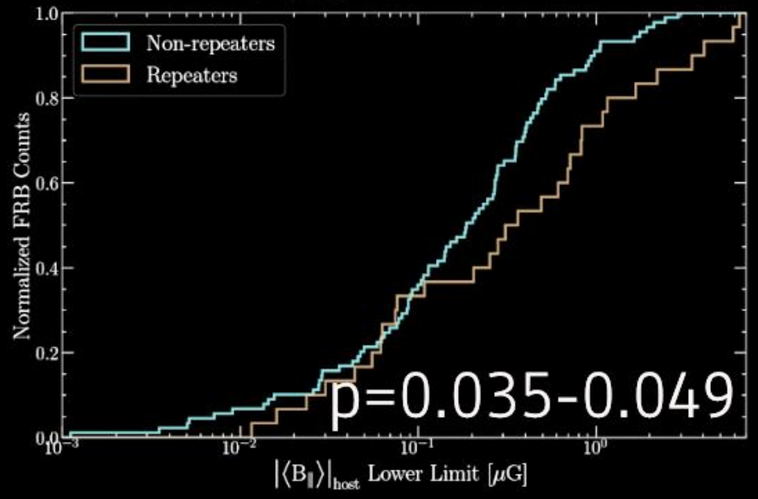
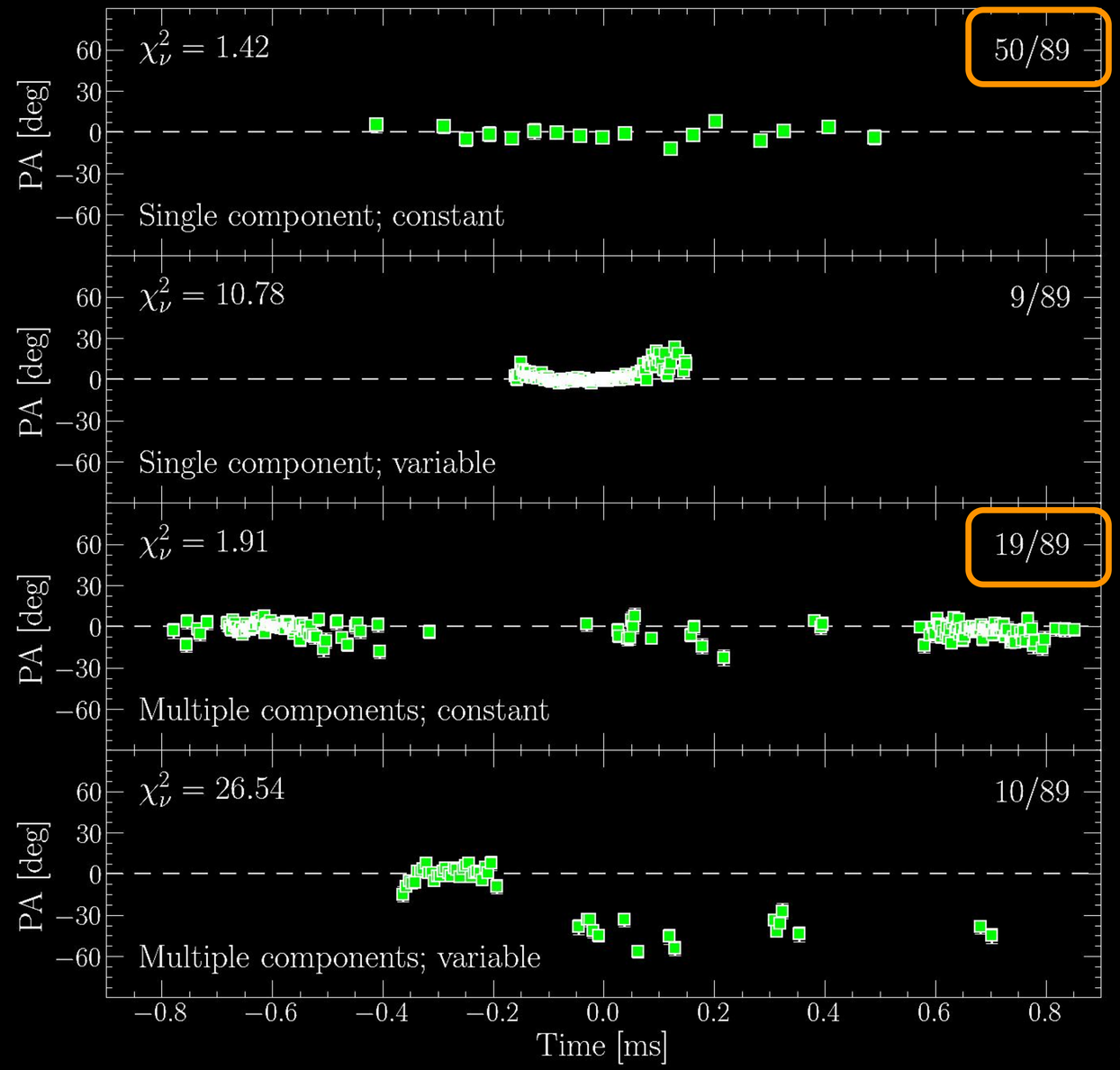




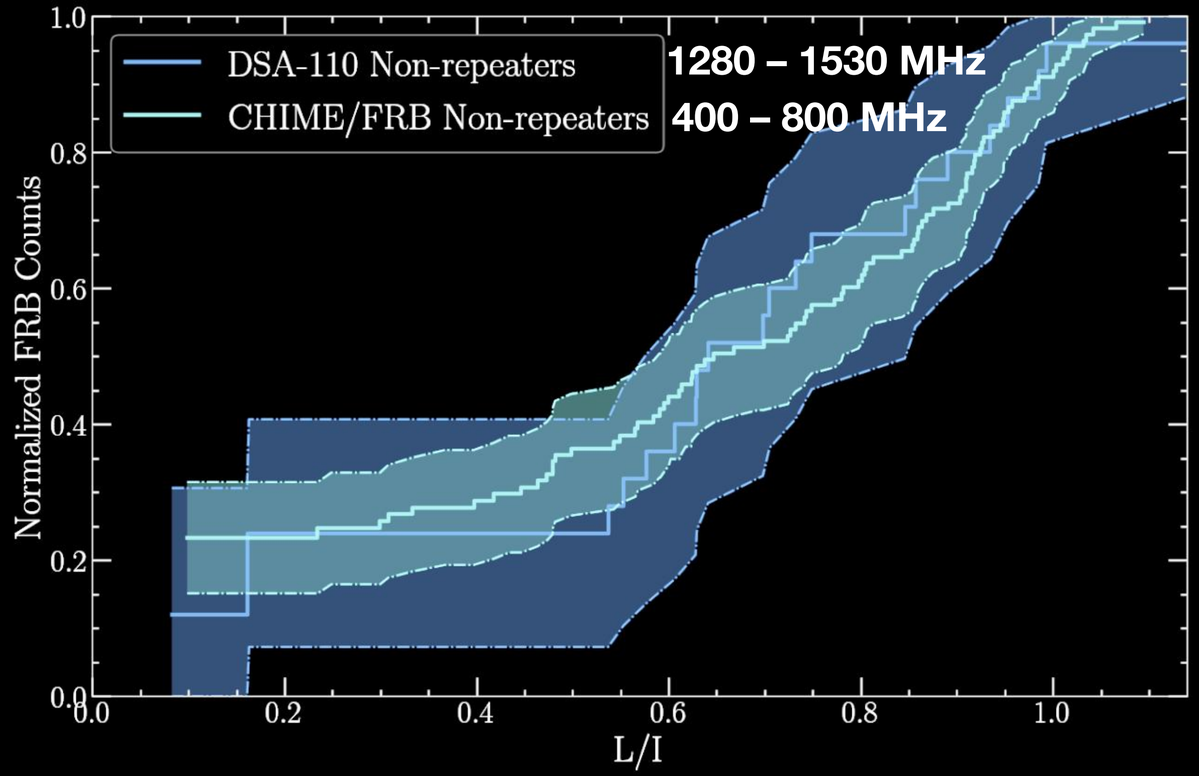


BaseCat1: polarization

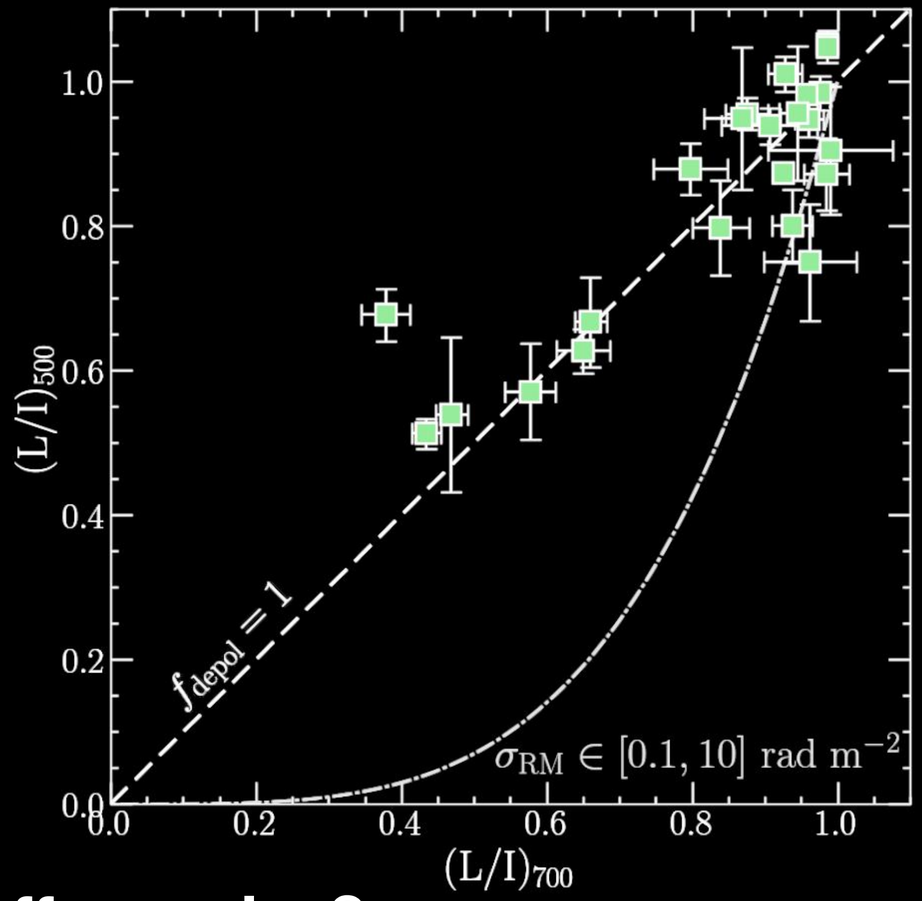
Ayush Pandhi
(Toronto)

Constraints on depolarization!

CHIME/FRB (n=84) vs DSA-110 (n=20)



CHIME/FRB broadband subsample



Differing environments of repeating & one-off samples?

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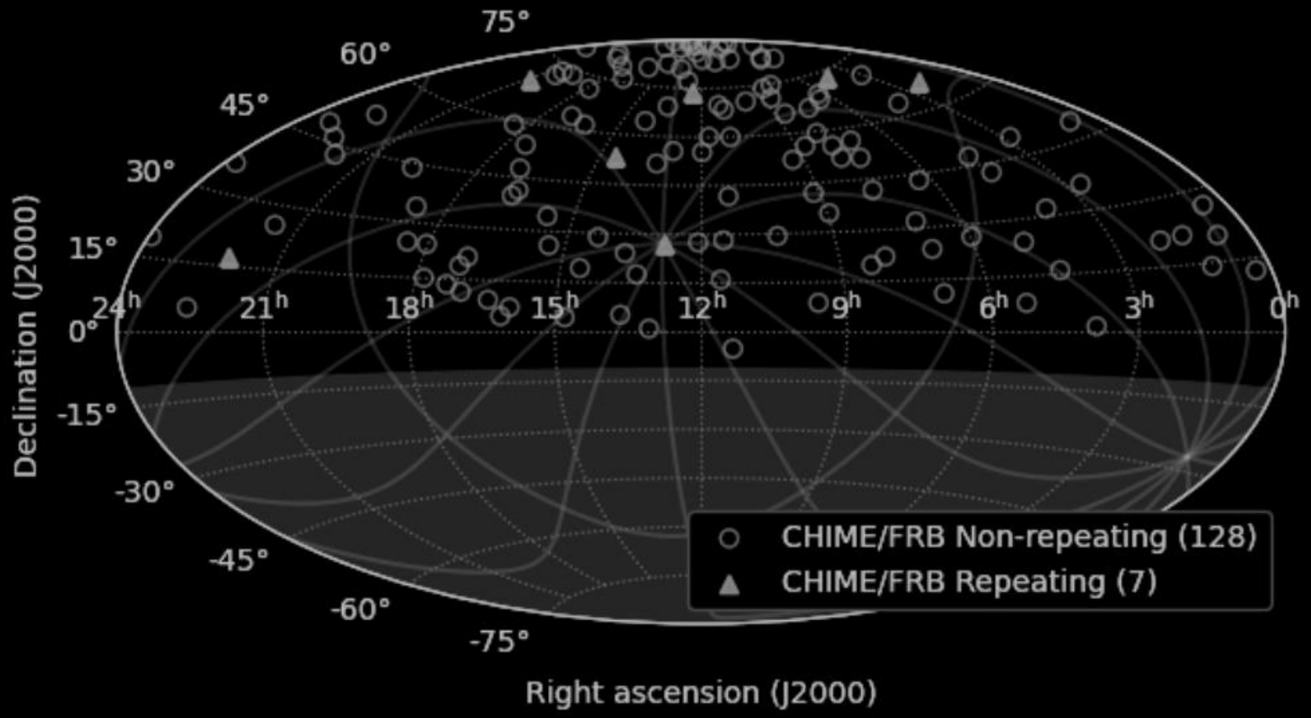


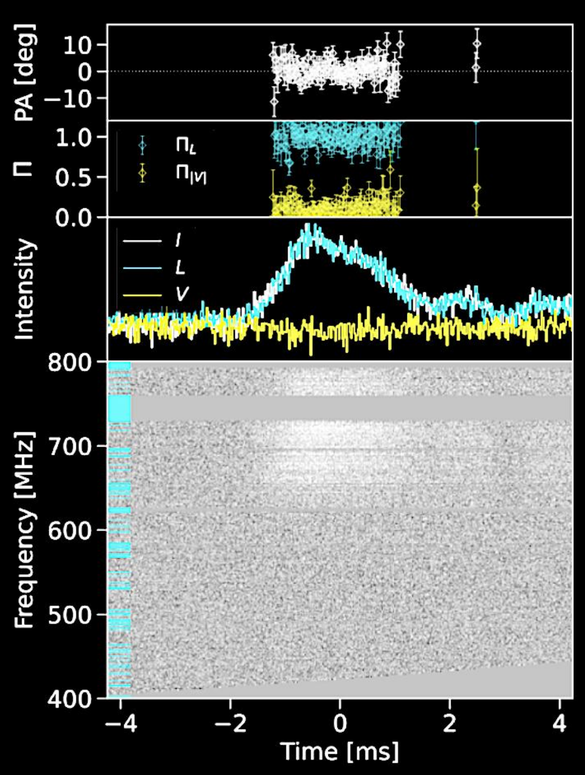
Beyond BaseCat1?

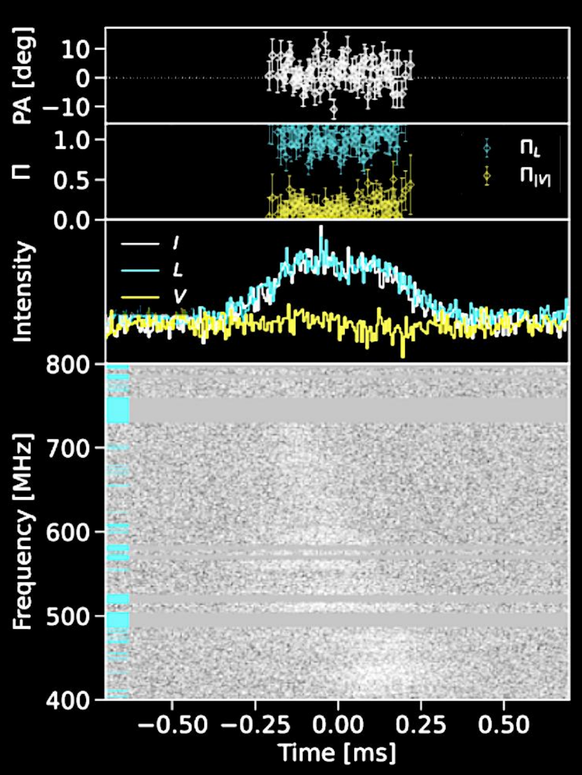
Dr. Cherry Ng
(CNRS)

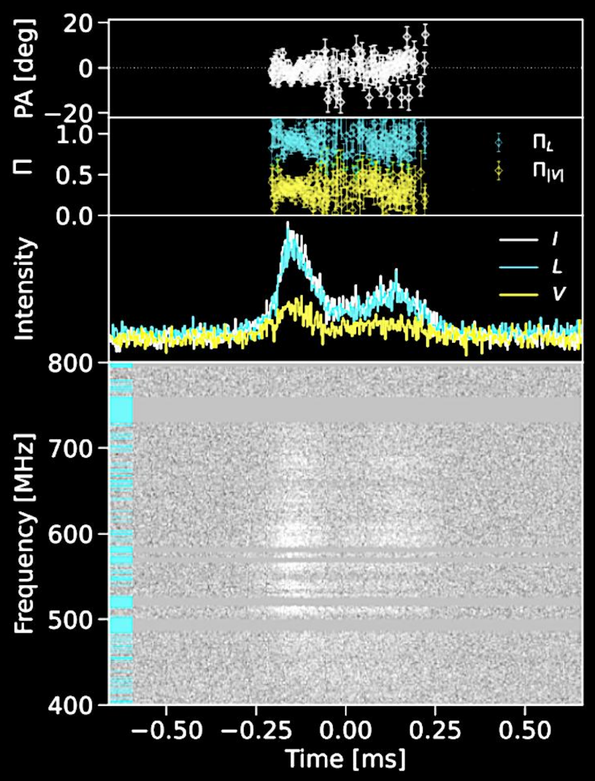
New Batch of Repeaters

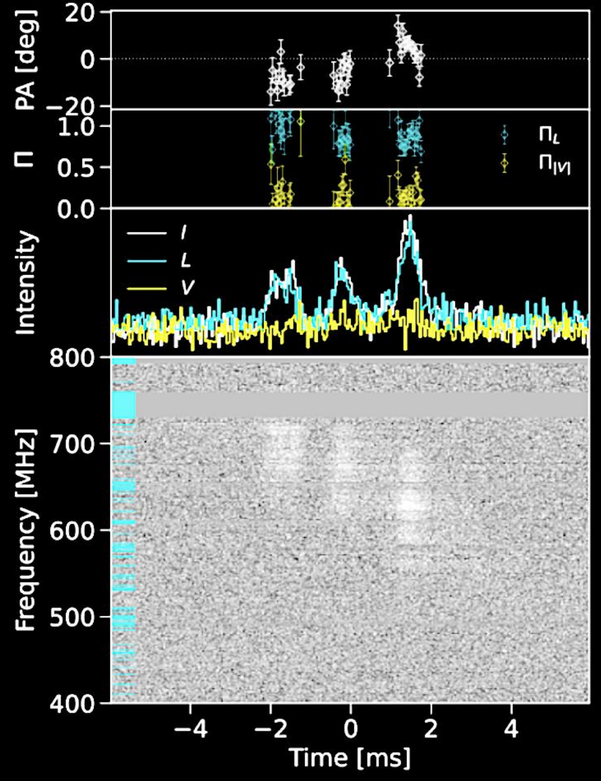
Alice Curtin
(McGill)

- 54 baseband events from 21 new repeaters + 94 new baseband events from previously published repeaters
- High time resolution, polarimetric studies ongoing!





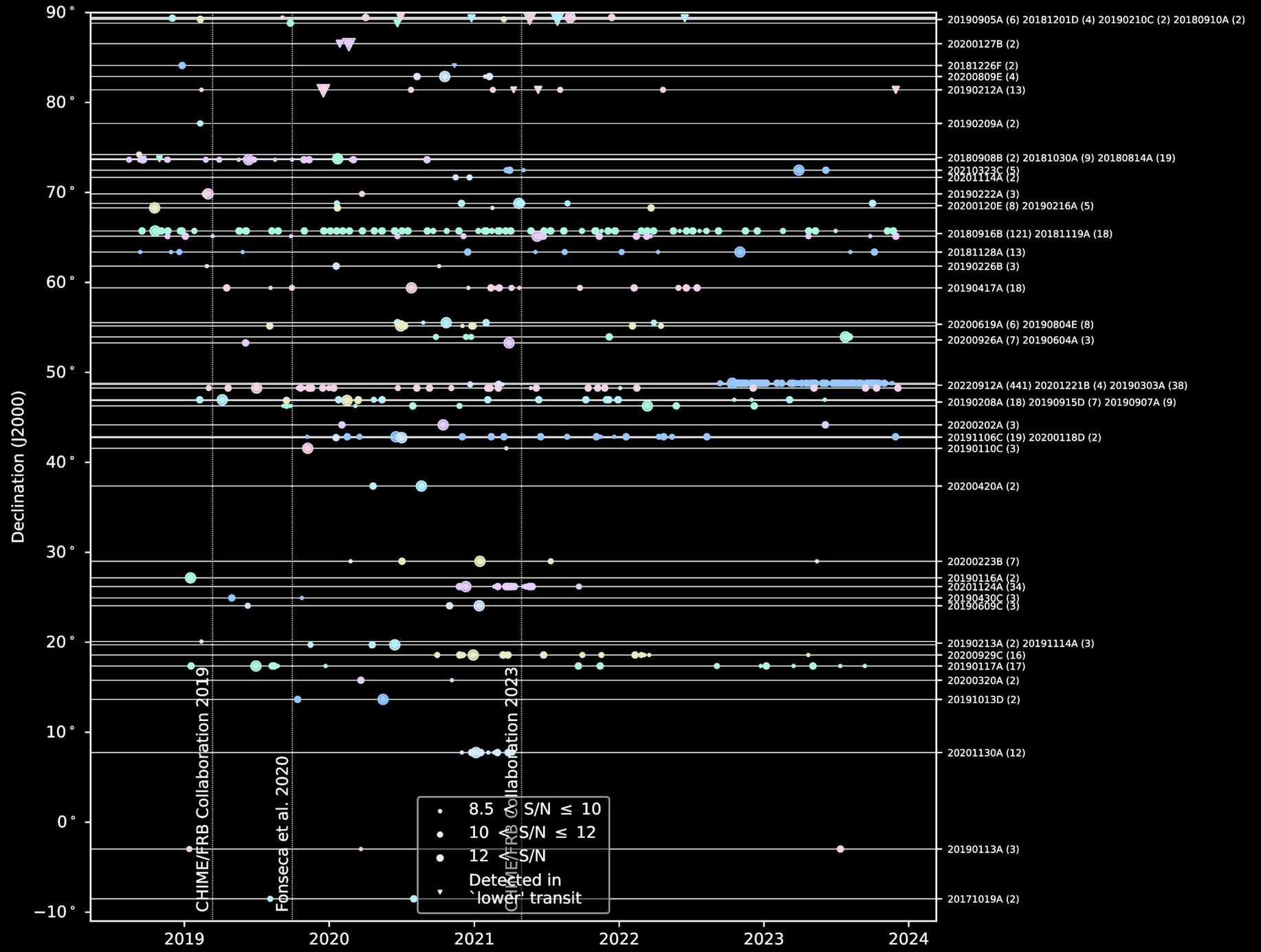




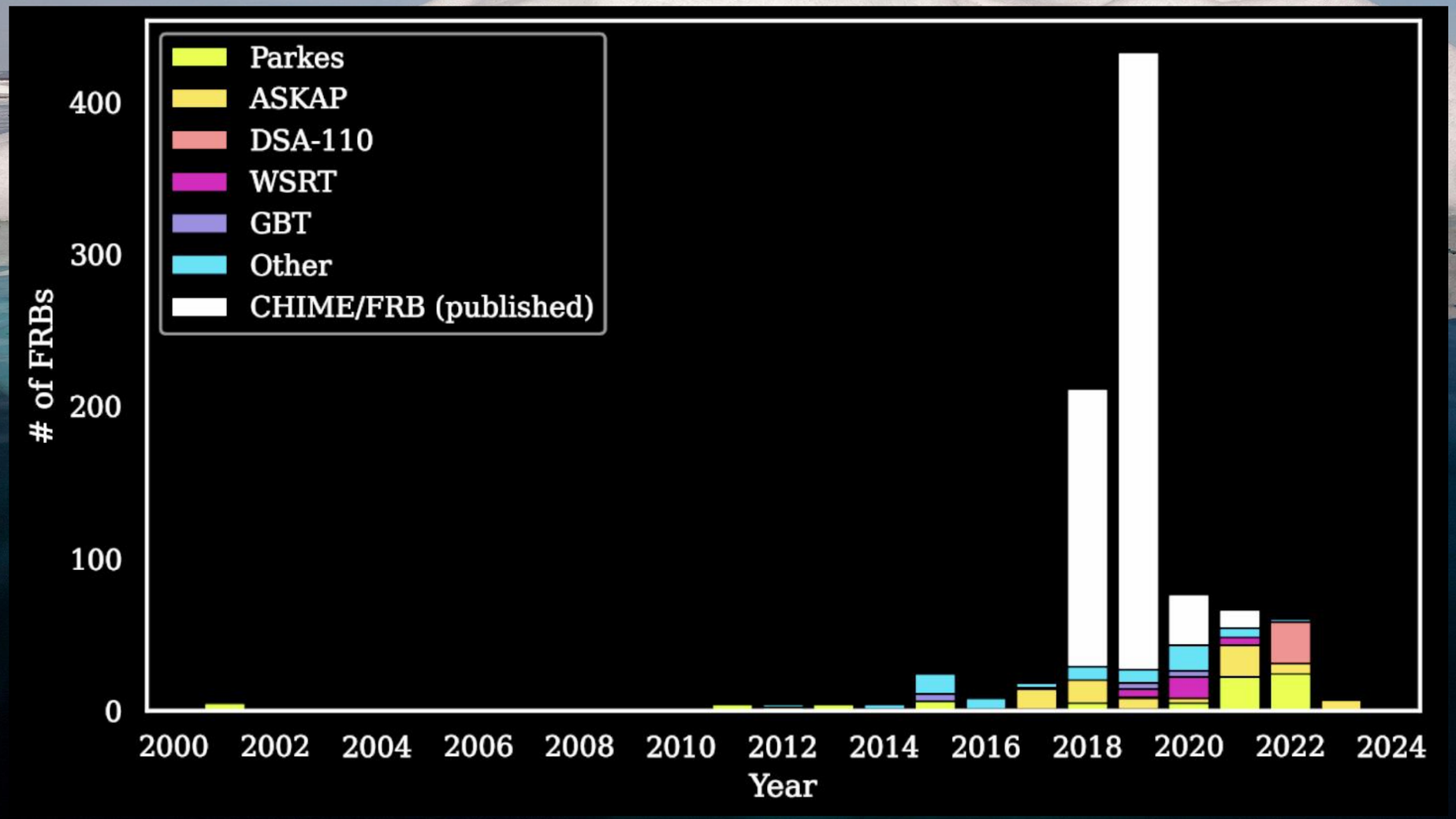
CHIME/FRB Repeater “Weather Report”

Dr. Ziggy Pleunis
(Toronto)

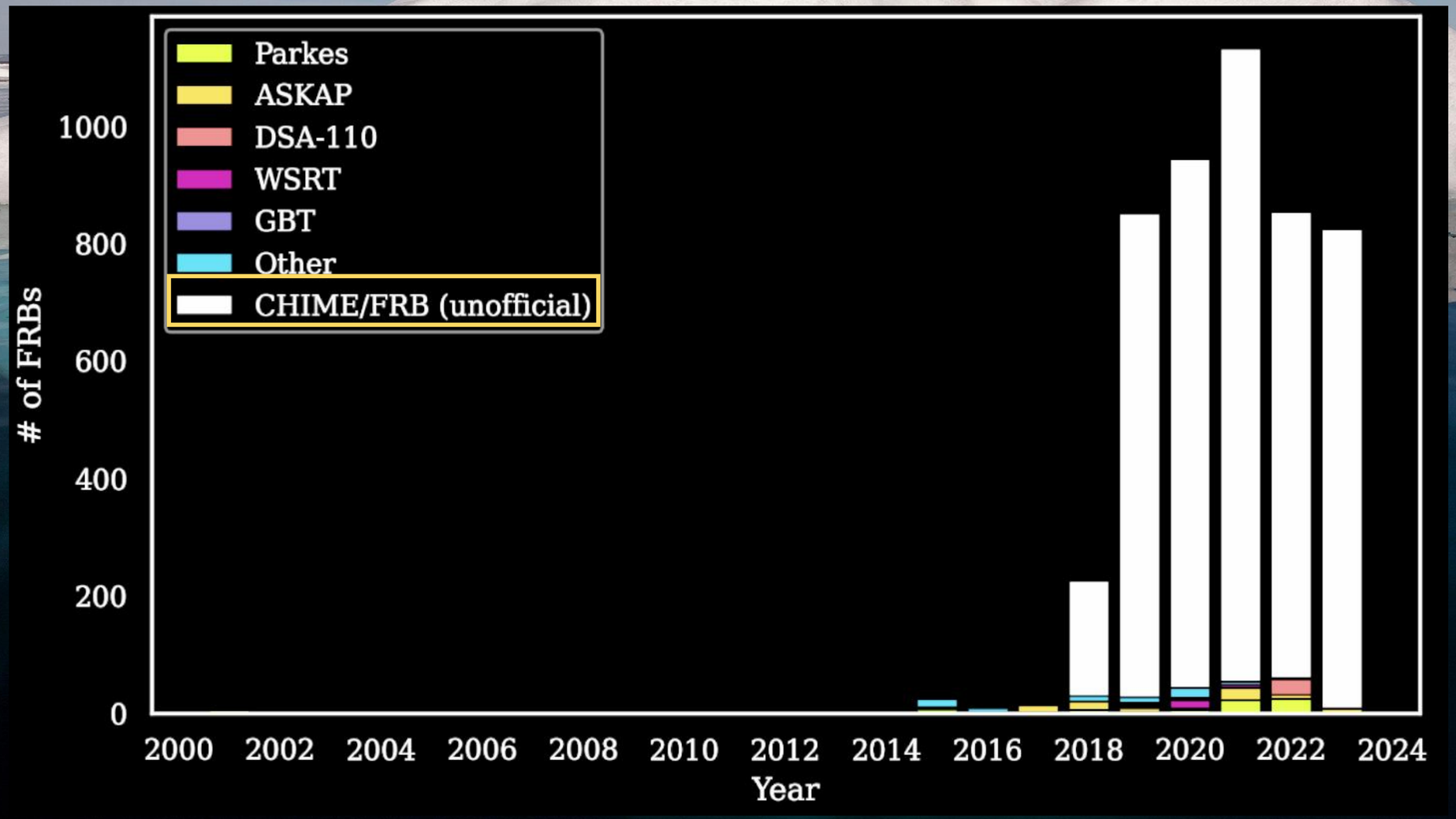
Better track repeater activity/properties vs. time and update community!



Catalog 1 was tip of iceberg…



CHIME/FRB Catalog 2!

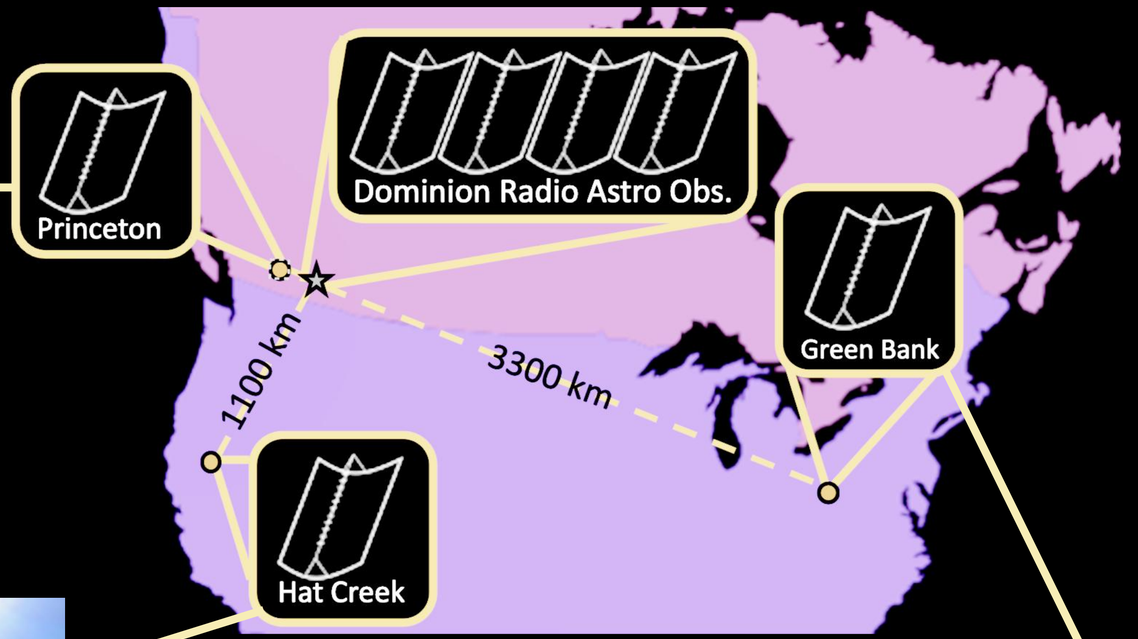


CHIME/FRB: Stay tuned!

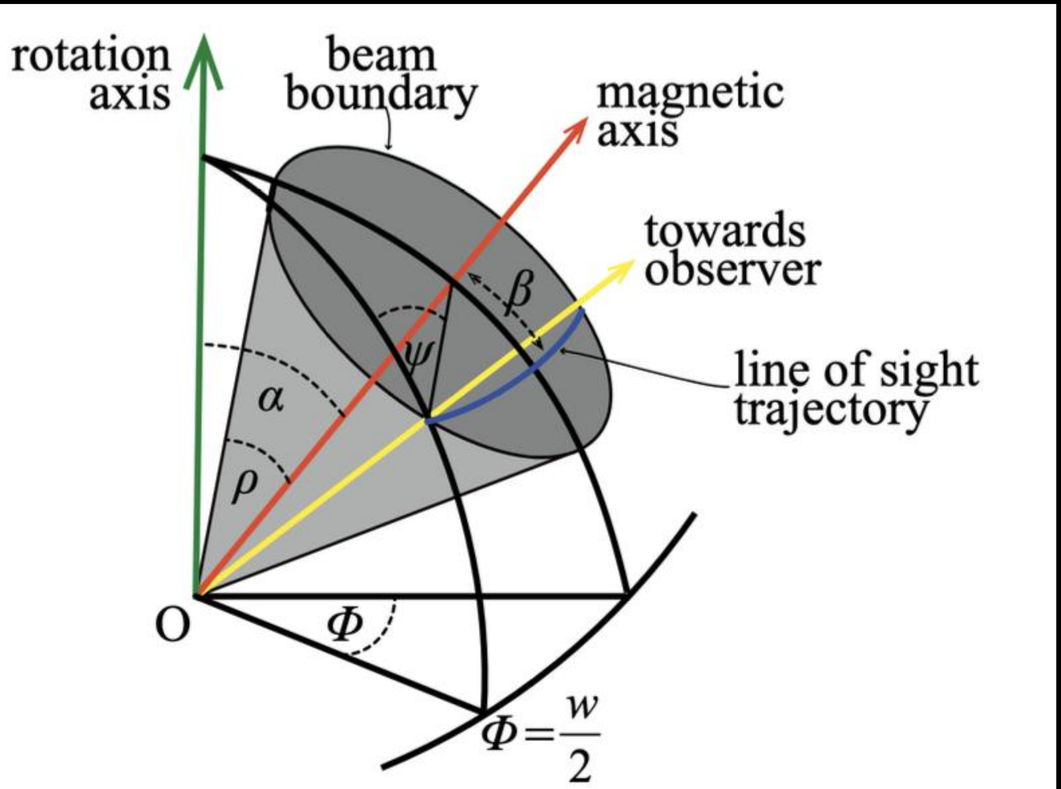
- **BaseCat1**: first CHIME/FRB catalog with public baseband data (**140 FRBs**)
  - Improved localizations, flux/fluence measurements, (eventually) singlebeam files
    - **arXiv:2311.00111** for more details!
  - Ongoing studies...
    - Improved redshift constraints, host galaxy identification, polarization demographics, high time resolution morphology, lensing, cross-correlation with LSS, and probably more!
- Catalog 2: hundreds --> thousands of FRBs!
- CHIME/FRB Outriggers commissioning!
- Many future & unexpected FRB discoveries await!

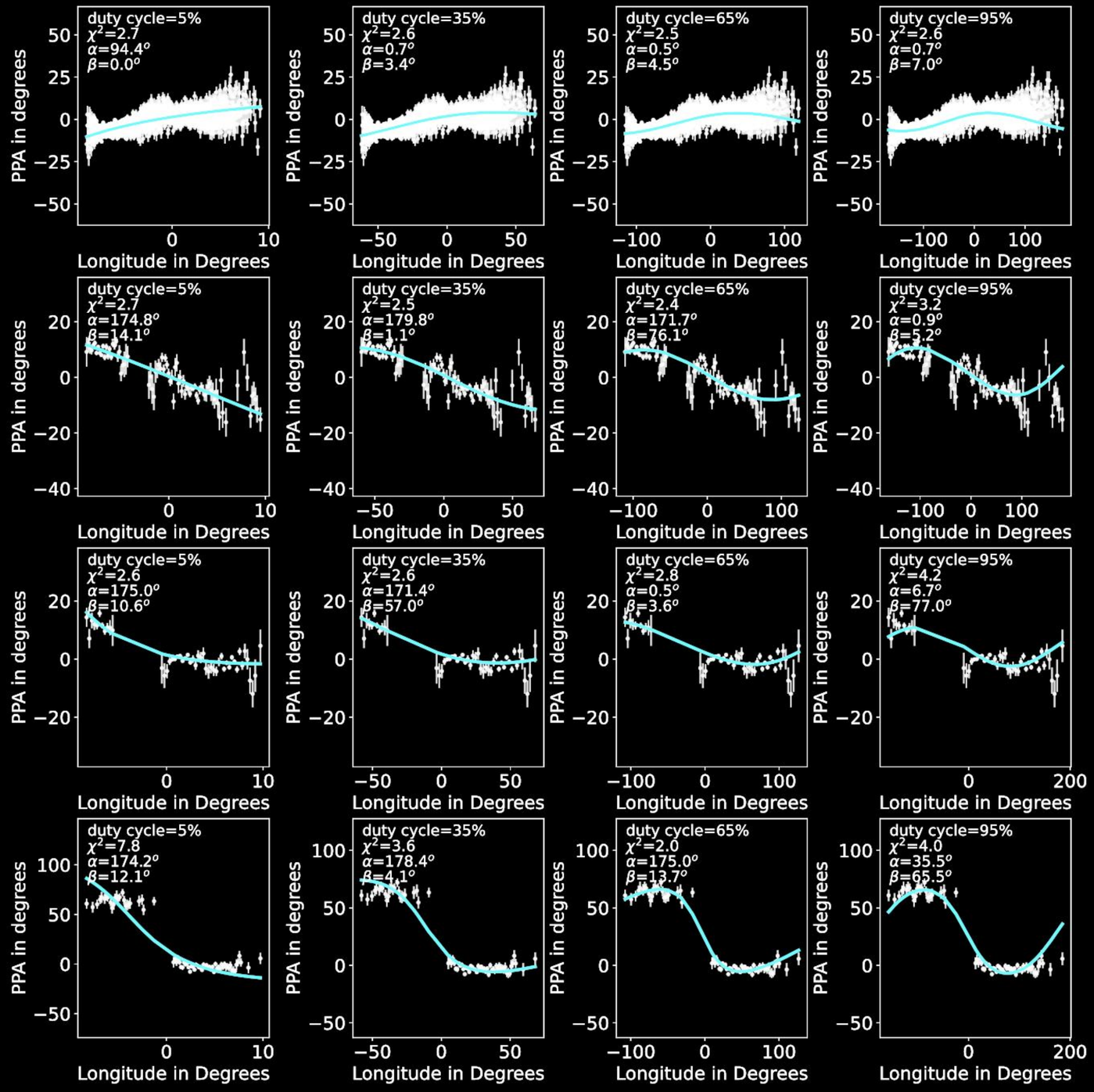
Bonus slides

CHIME/FRB Outriggers

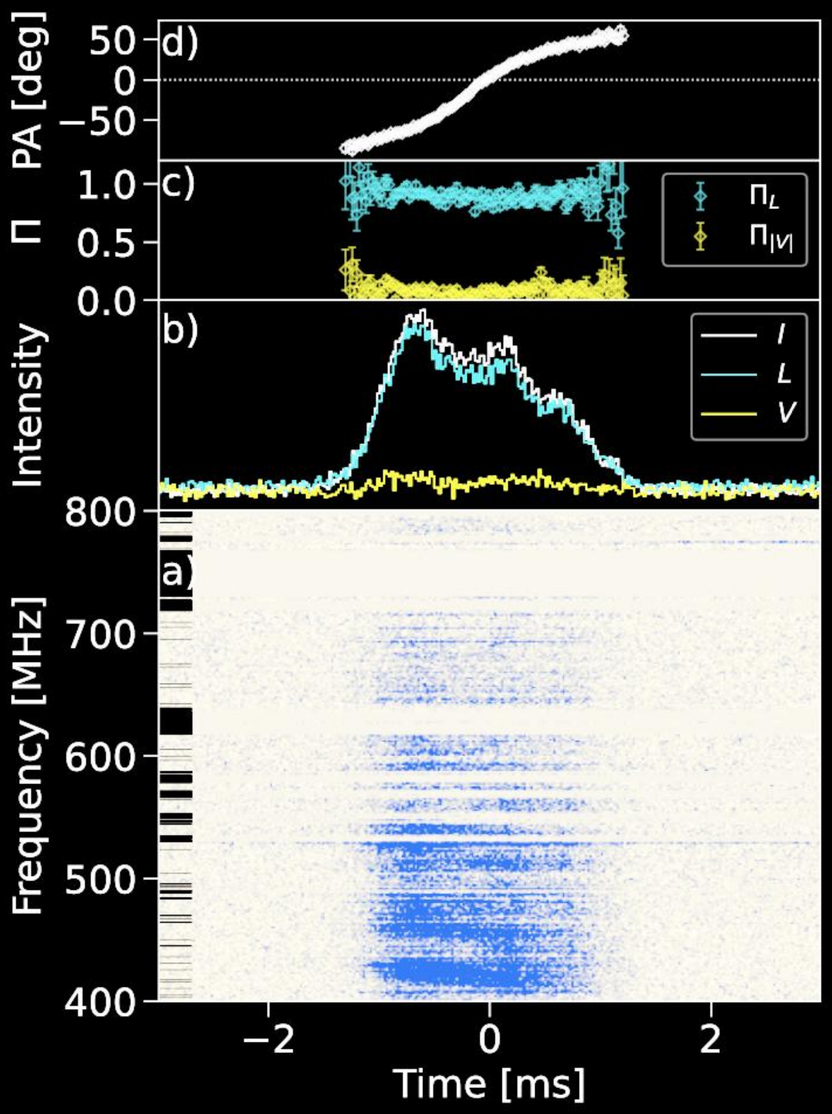


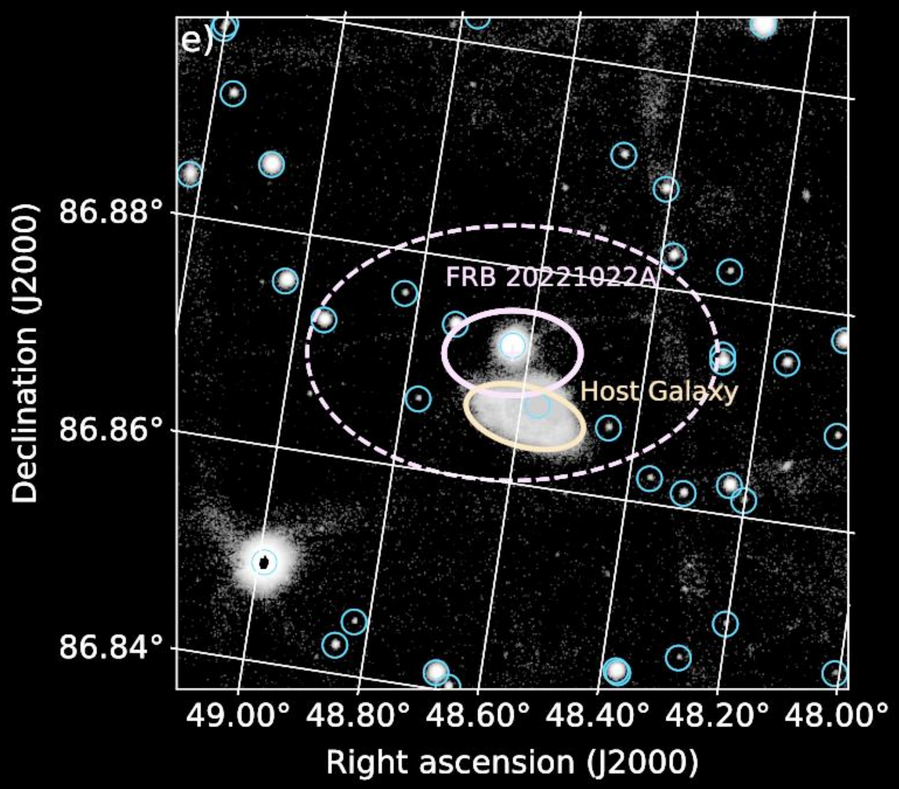
Rotating Vector Model





A PA-swing Gem





Catalog 1 Science

Constraining violations of the weak equivalence principle Using CHIME FRBs

Modeling the Morphology of Fast Radio Bursts and Radio Pulsars with fitburst

Fast Radio Burst Morphology in the First CHIME/FRB Catalog

Statistical Measurements of Dispersion Measure Fluctuations in Fast Radio Bursts

Associating fast radio bursts with compact binary mergers via gravitational lensing

A Comprehensive Analysis of Repeating Fast Radio Bursts

No Evidence for Galactic Latitude Dependence of the Fast Radio Burst Sky Distribution

A targeted search for FRB counterparts with Konus-Wind

The CHIME Fast Radio Burst Population Does Not Track the Star Formation History of the Universe

The z-DM distribution of fast radio bursts

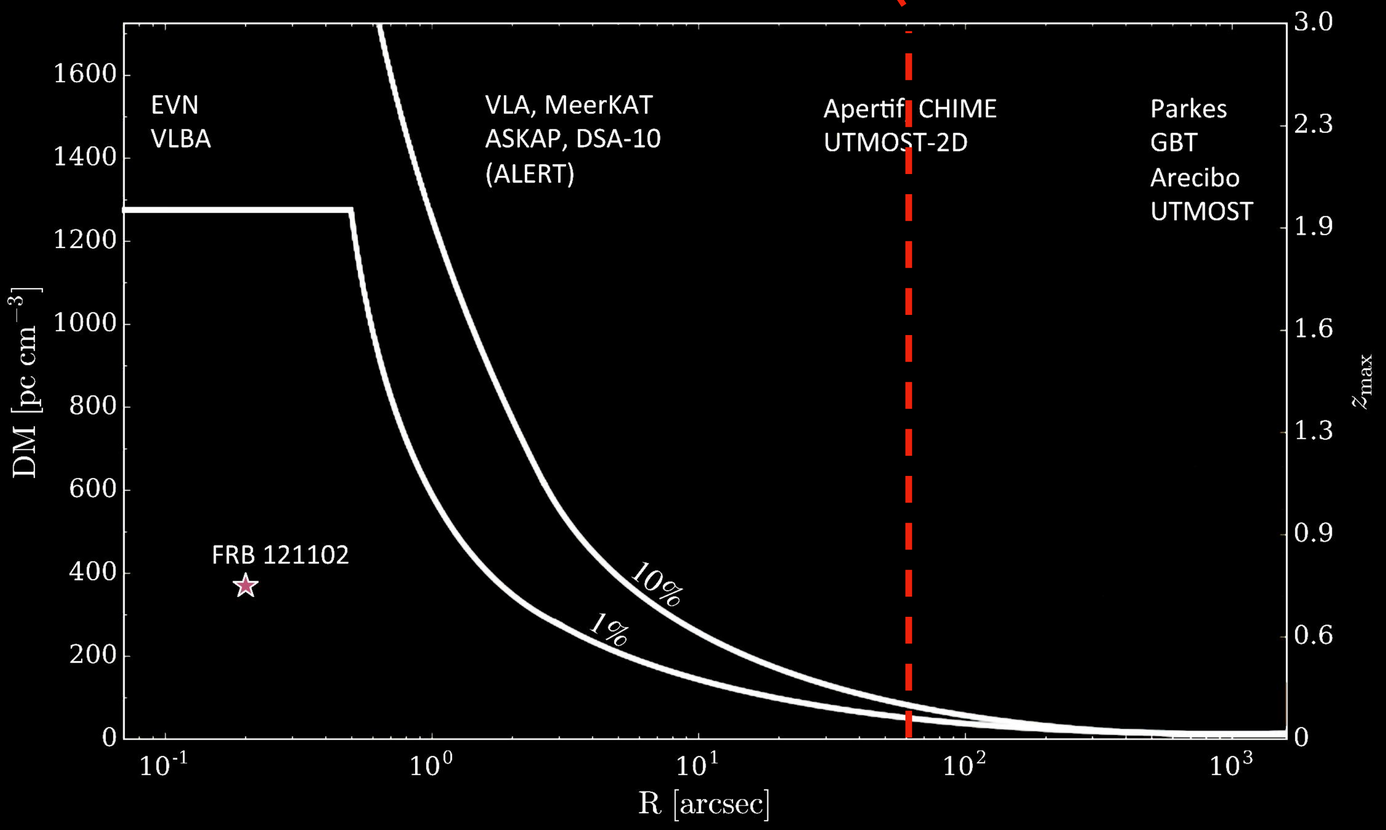
Can a Single Population Account for the Discriminant Properties in Fast Radio Bursts?

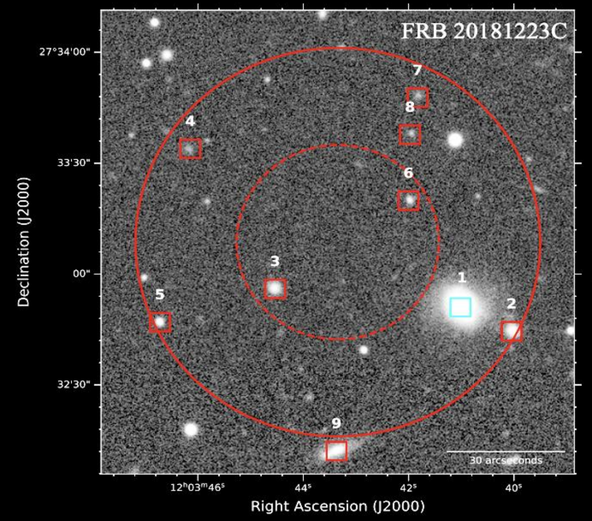
BaseCat1: host associations

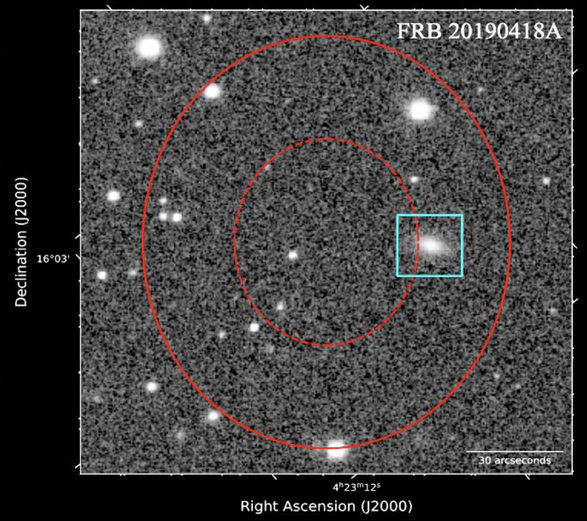
Dr. Mohit Bhardwaj (CMU)

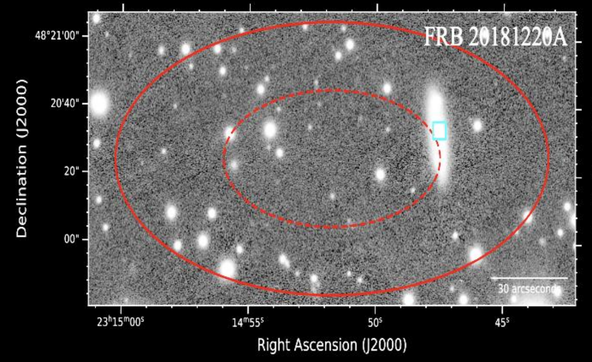
Bridget Andersen (McGill)

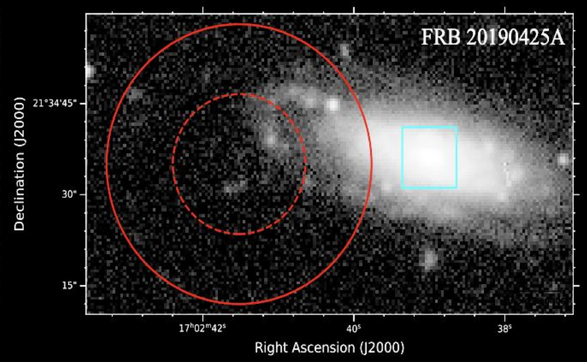
CHIME/FRB Baseband localization







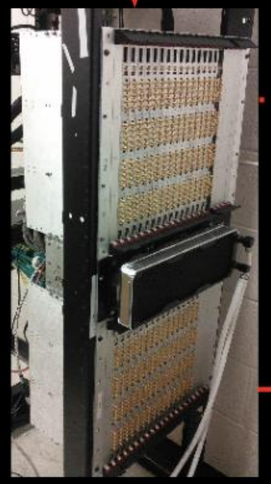




Baseband data

Amplified and digitized

L-engine: channelized baseband data



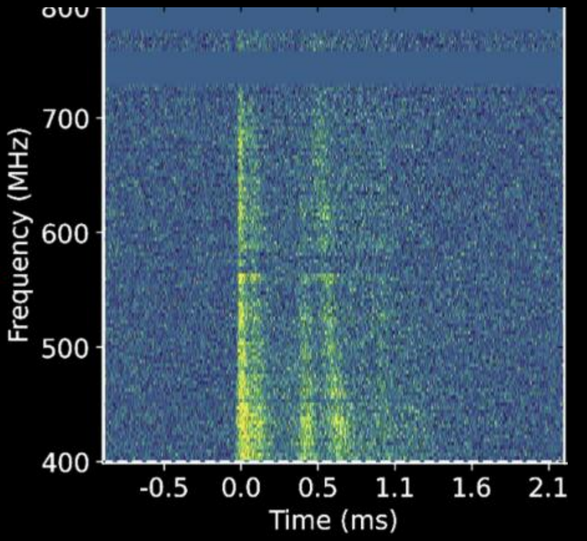
40-s memory ring buffer

X-engine: intensity data

FRB search

S/N>12

S/N> 8



Baseband dump

Intensity dump