New repeating sources of FRBs from CHIME/FRB

Ziggy Pleunis*
Plenty of Room at the Bottom: Fast Radio Bursts in our Backyard
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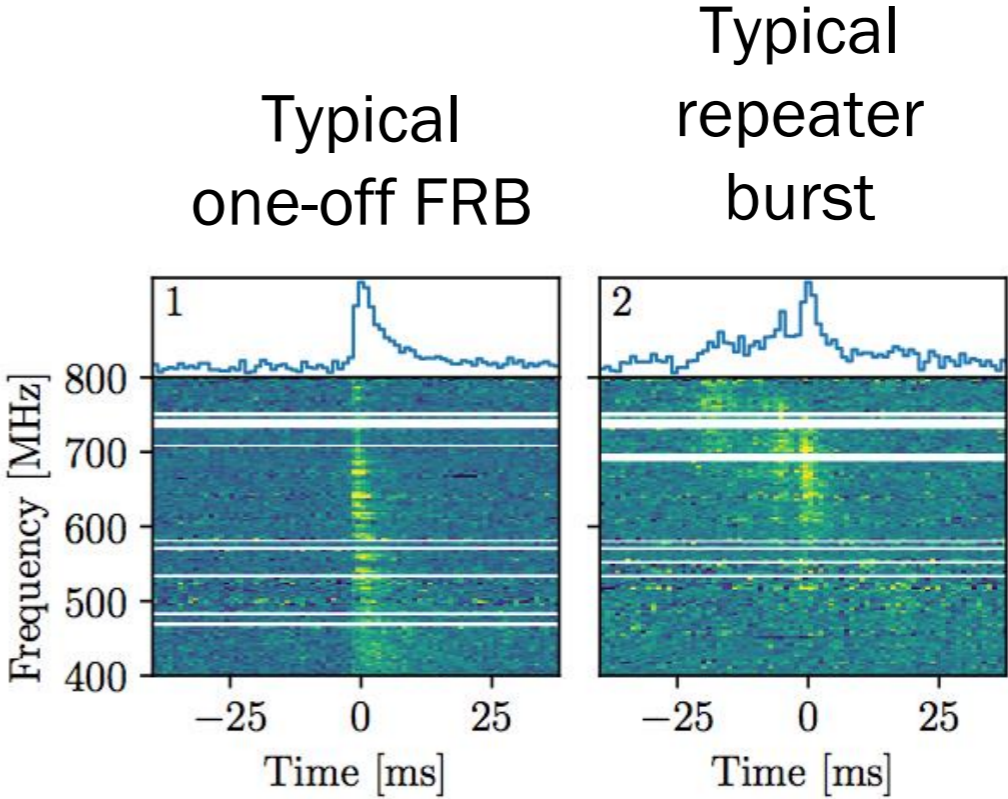CHIME/FRB Collaboration

Andre Renard
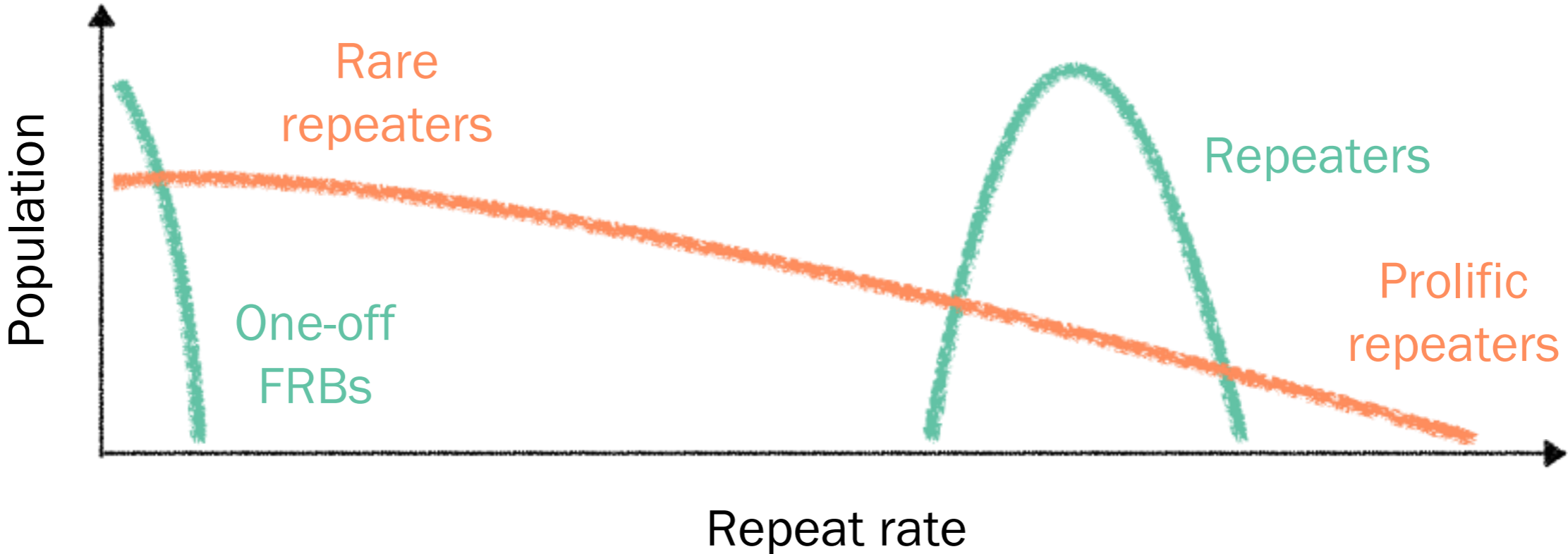
Do all FRBs repeat?

No FRB has been directly associated with a cataclysmic event

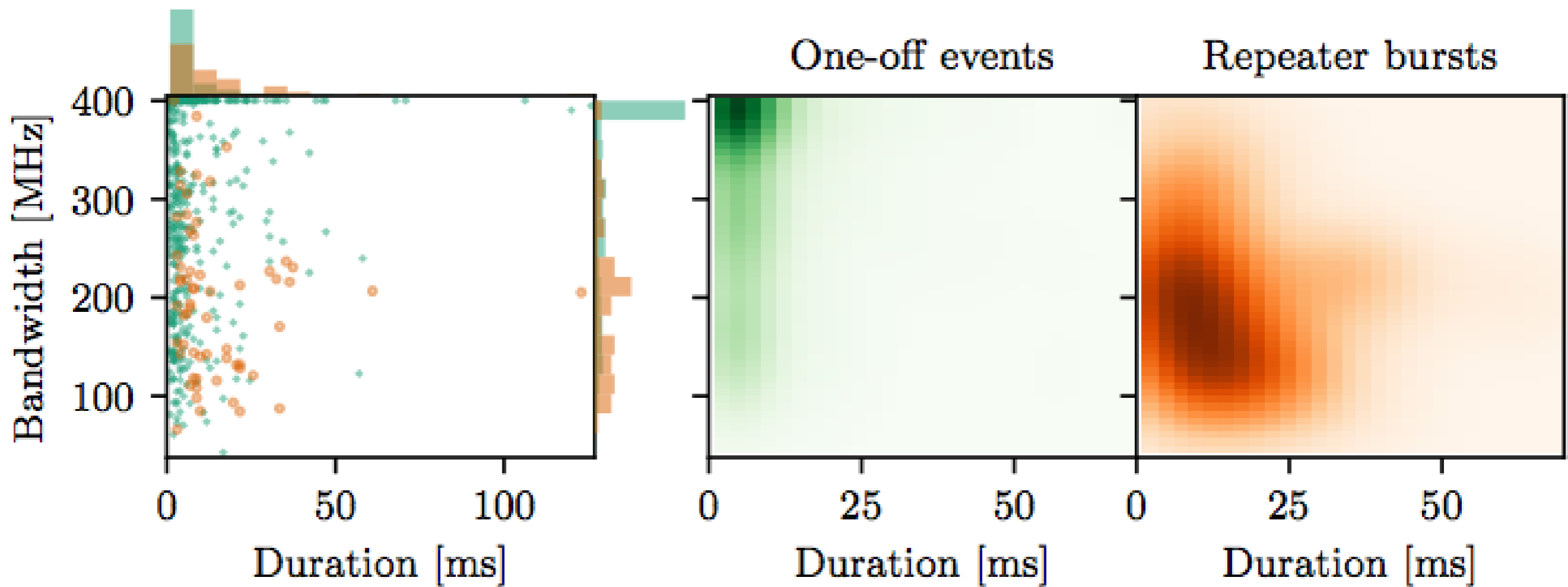Typical one-off FRB

Typical repeater burst

📄 ZP+ 2021

Note also anomalous FRBs with sub-second periodicity:
📄 CHIME/FRB Collaboration 2022 📄 Pastor-Marazuela+ 2022

The morphology dichotomy
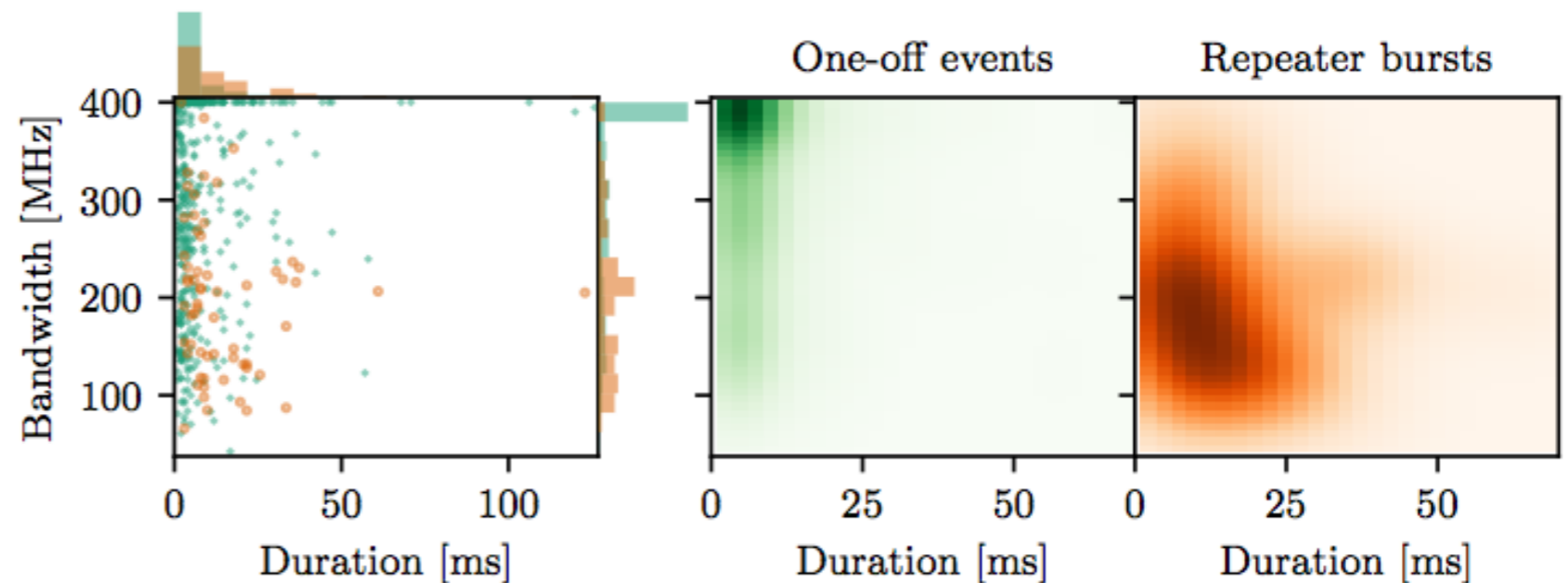

One-off events   Repeater bursts

maybe intrinsic?

repeater bursts made up of
sub-bursts?
different burst mechanism?

maybe propagation effect?

related to periodic activity?
plasma lensing?
beaming geometry? 📄 Connor+2020

The morphology dichotomy

Hard to reconcile with continuum of repetition rates, unless:

Correlation between repetition rate and burst duration and anti-correlation between repetition rate and bandwidth
- Intrinsically through the emission mechanism
- Extrinsically through a propagation effect (e.g., tied to evolutionary stage if active repeaters are young sources)

Repetition rates and nearby repeaters (M81R, R4) will help.

Searching for repeat bursts

📄 Connor & Petroff 2018

(UT) 2019/08/29 − 2019/10/29

59.5 hours in 47 days

Cumulative
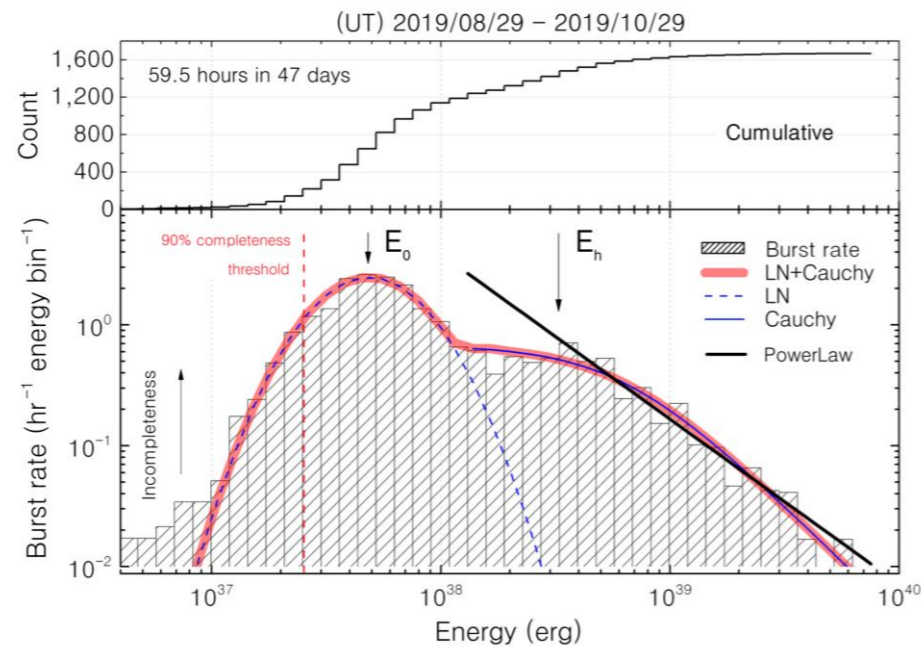
Many more dim bursts than bright bursts from the same source

e.g. 📄 Li+ 2021

Repetition statistics largely unconstrained, Poissonian or clustered?
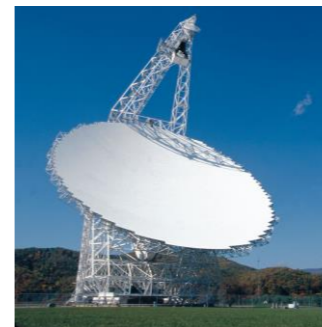
a) Revisit/monitor

This talk

b) Follow up

📄 Kumar+ 2019, 2021

📄 Luo+ 2020

Search for new repeating sources of FRBs

Database of all
CHIME/FRB events

Dispersion measure (DM)

Uncertainty ~few pc cm^{-3}

Sky position

From detection metadata (all events):
~15'

FRB 20181012B
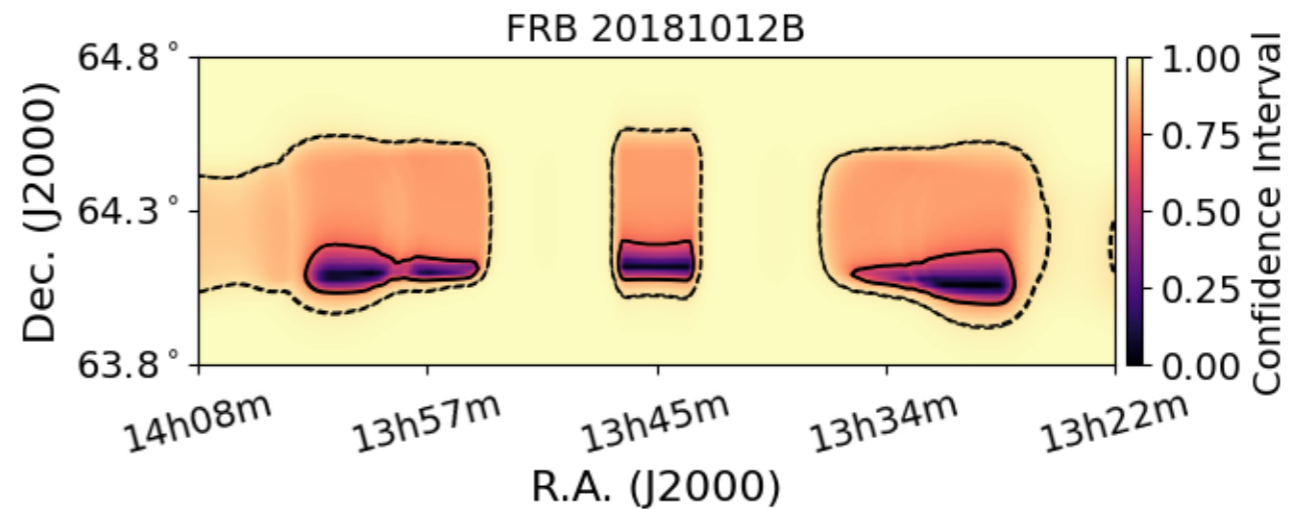
From baseband data (some events):
sub arcmin

Clustering, chance coincidences and repeater candidates

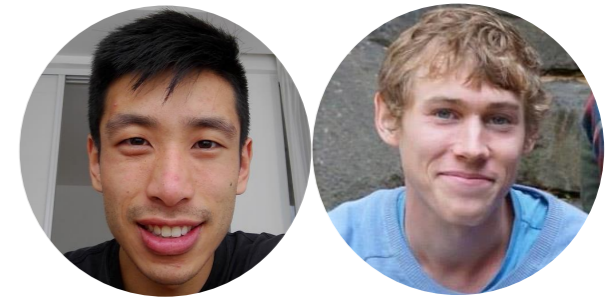Clustering analysis: 65 clusters that are not associated with known repeaters or pulsars

Chance coincidence probability calculation:
29 clusters $R_{cc} < 0.5$,
19 clusters $0.5 <= R_{cc} < 5$

Localization check:
🥇 25 clusters $R_{cc} < 0.5$,
🥈 14 clusters $0.5 <= R_{cc} < 5$
have consistent event localizations

Led by Adam Dong (UBC) and Alex Josephy (McGill)
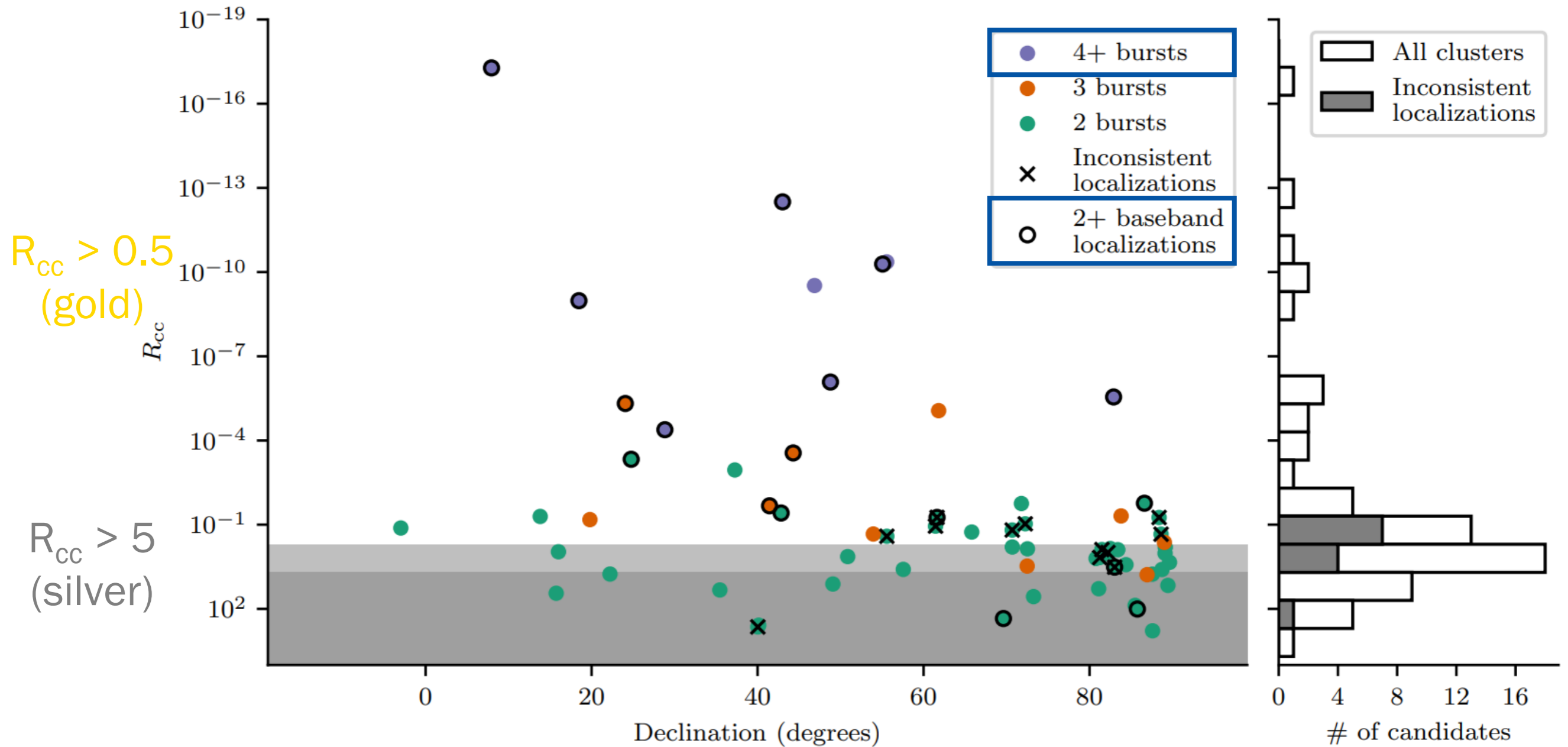
Led by Amanda Cook (UofT)

Led by Alex Josephy (McGill) and Cherry Ng (UofT)

Chance coincidence probabilities
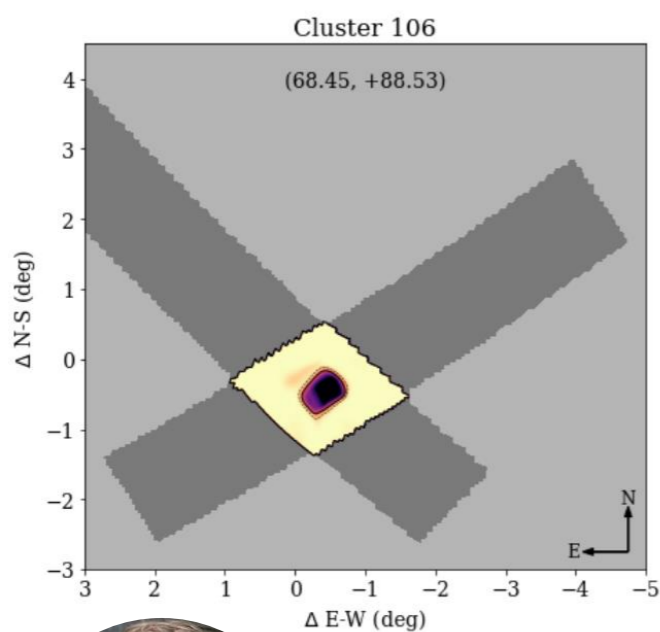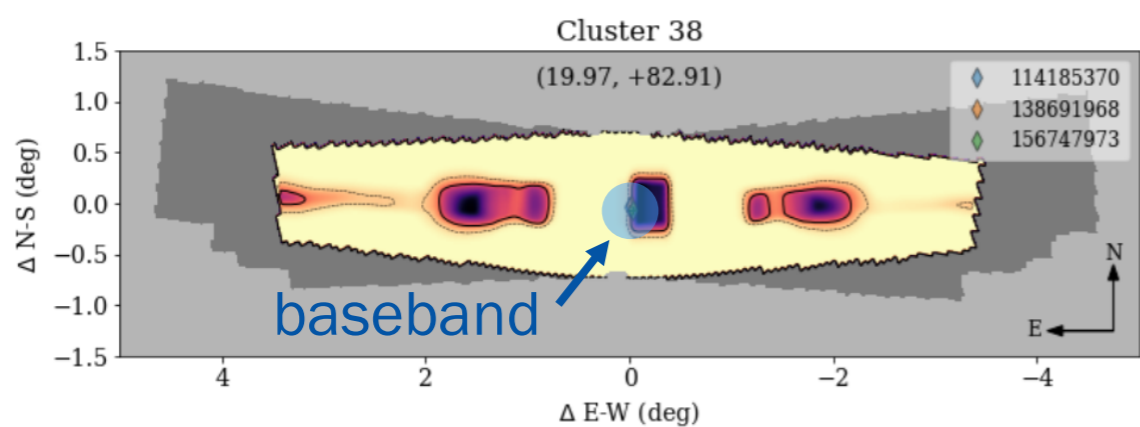
$$R_{cc} = P_{cc} \times N_{FRB}$$
(contamination rate)

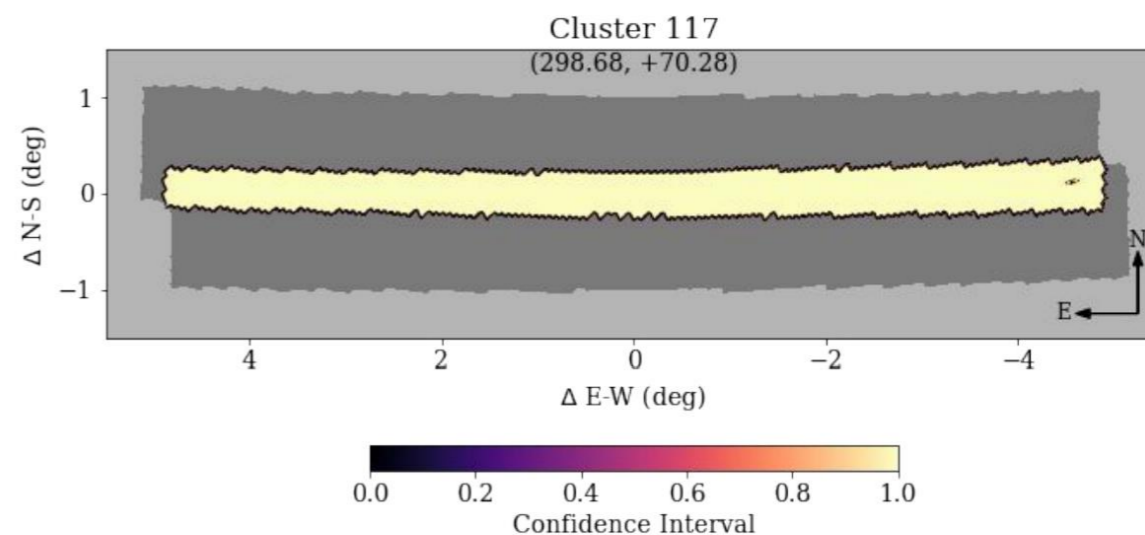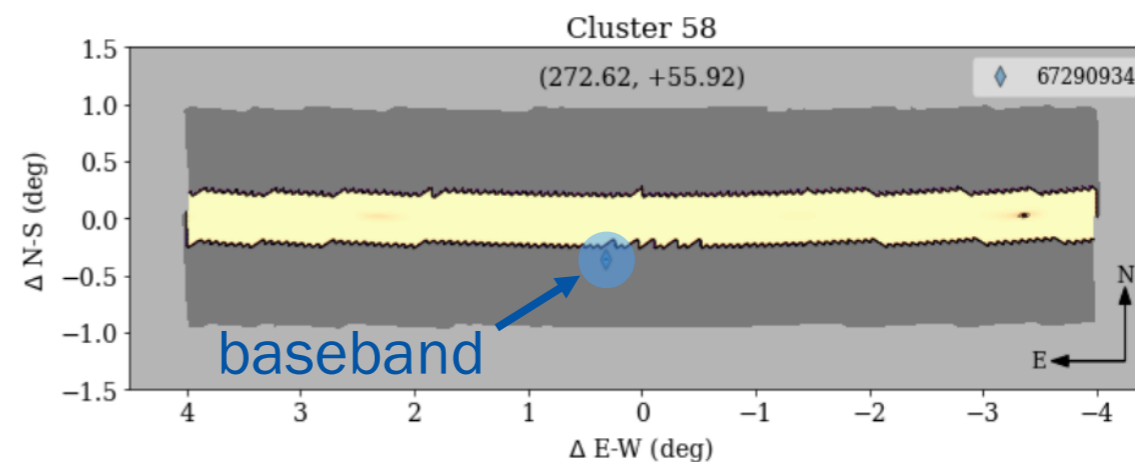

$R_{cc} > 0.5$ (gold)

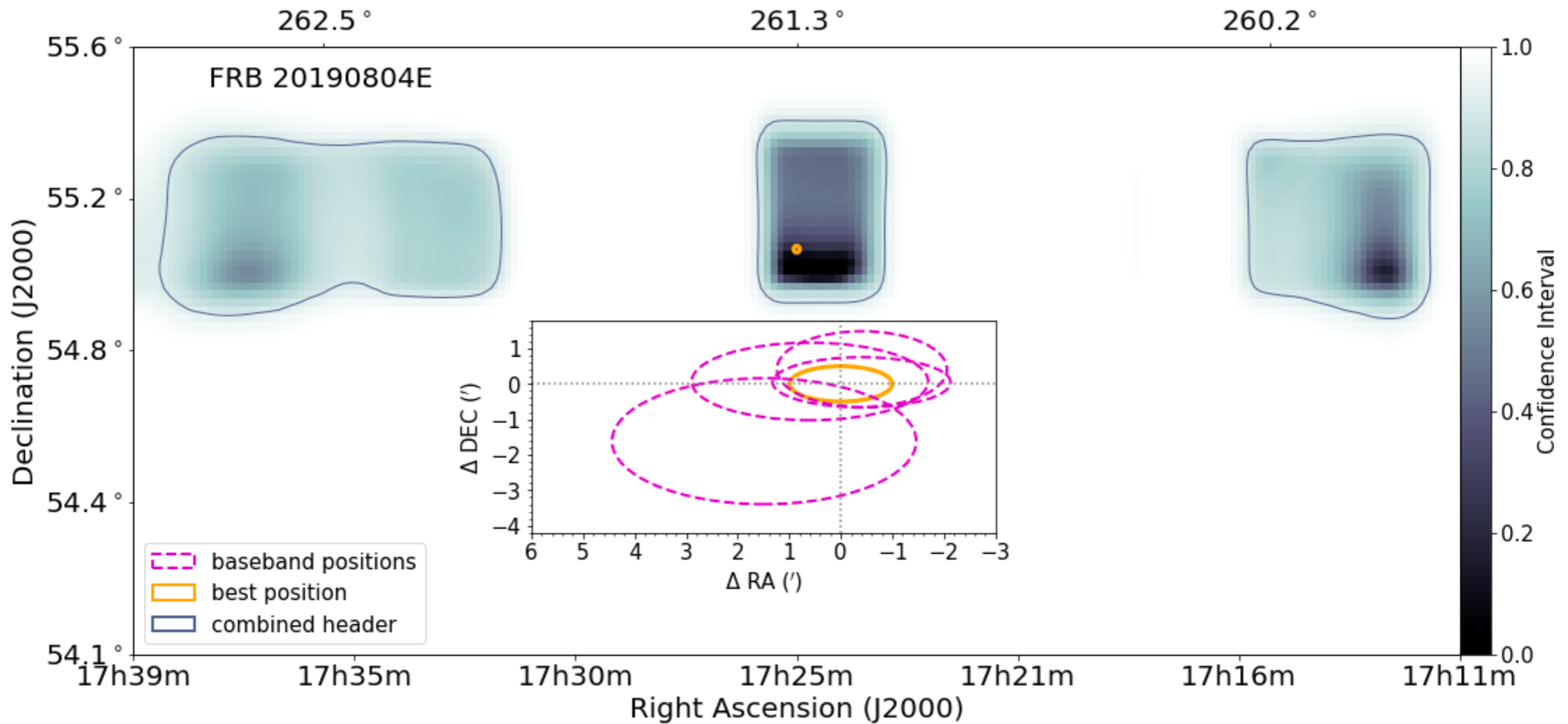$R_{cc} > 5$ (silver)

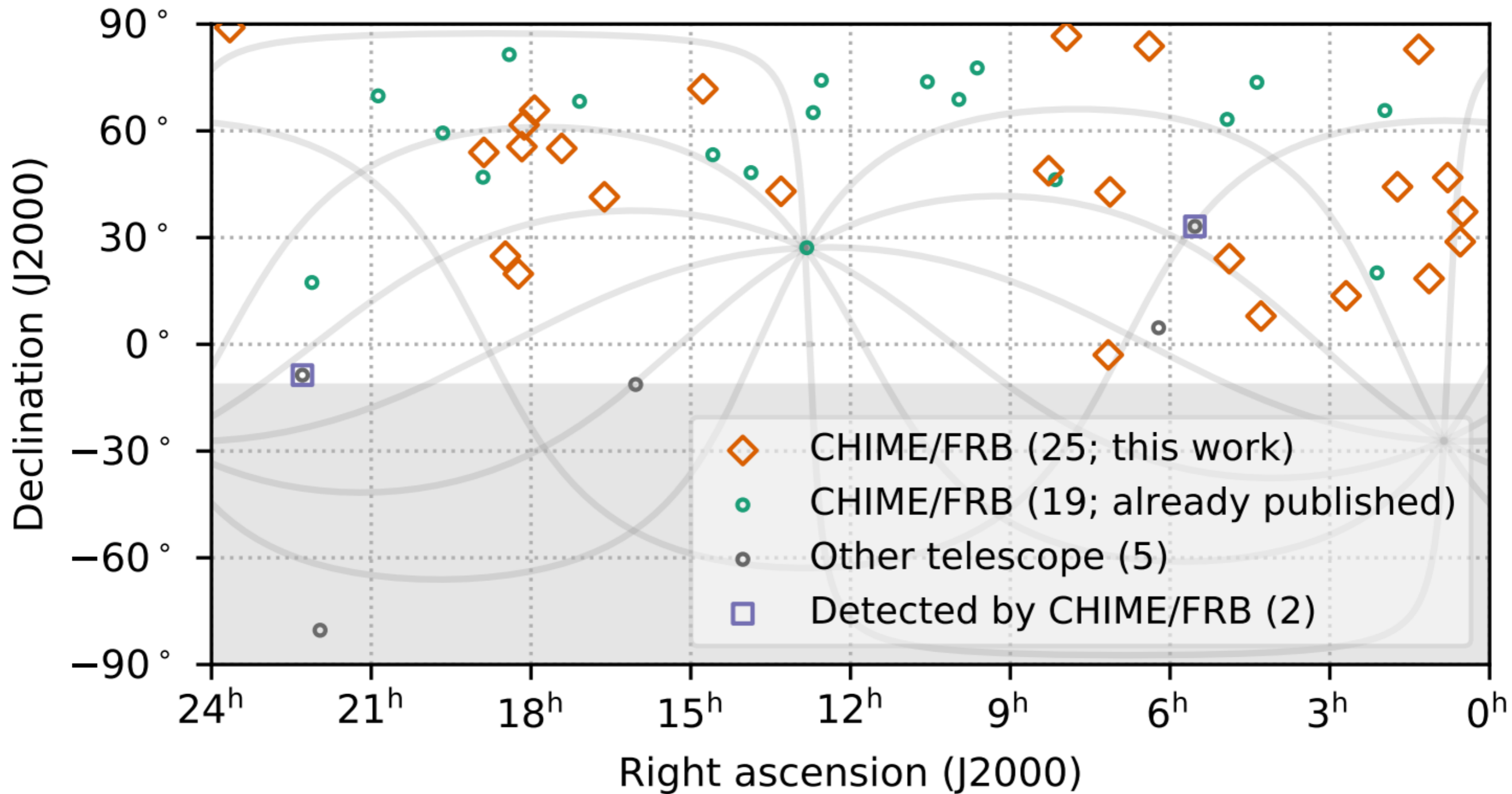# Some challenges

Localizations consistent
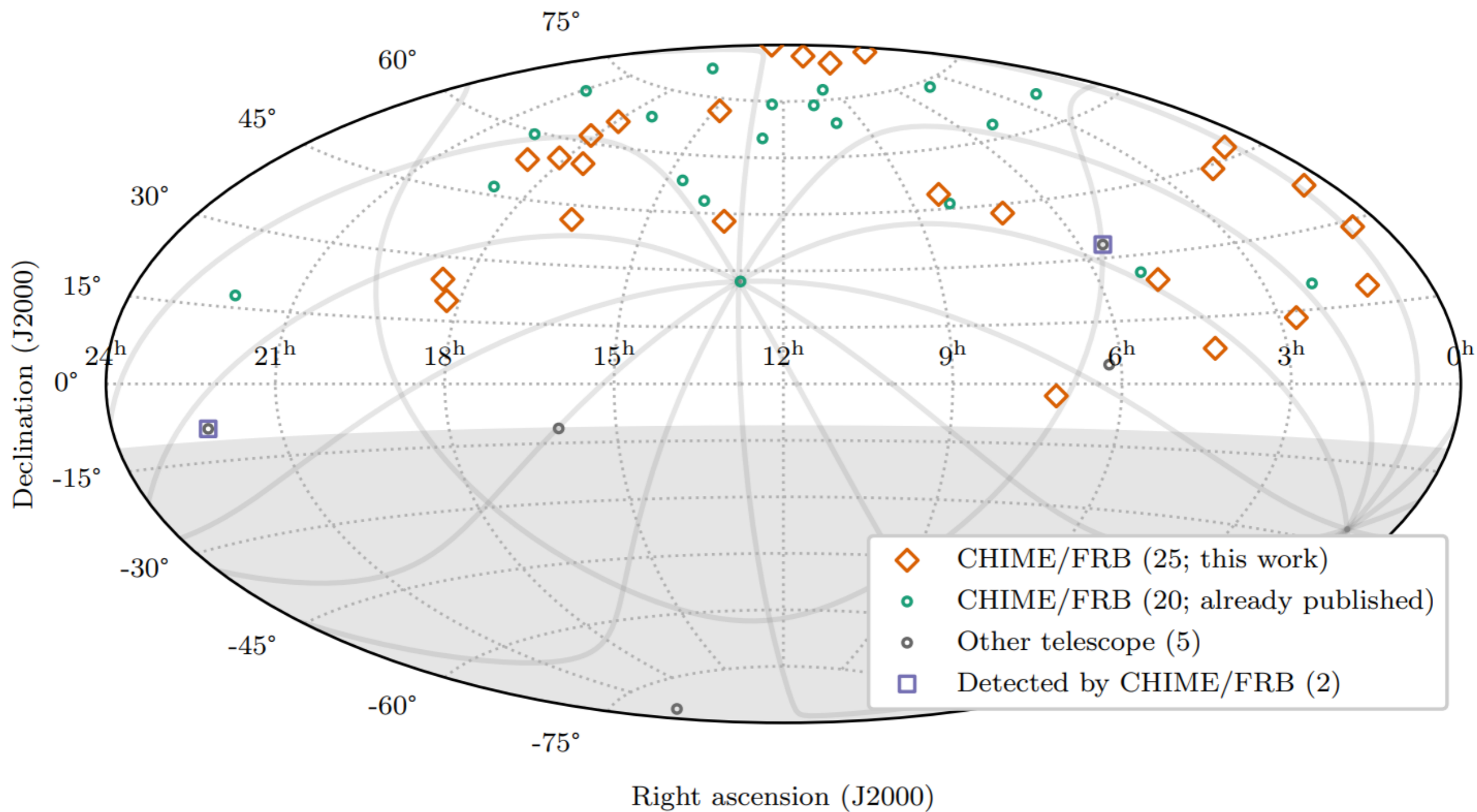

Localizations inconsistent

Some very clear new repeaters

The repeater sky

CHIME/FRB Collaboration in prep.

The repeater sky

Legend:
- ◇ CHIME/FRB (25; this work)
- ○ CHIME/FRB (20; already published)
- ○ Other telescope (5)
- □ Detected by CHIME/FRB (2)

Declination (J2000) vs Right ascension (J2000)
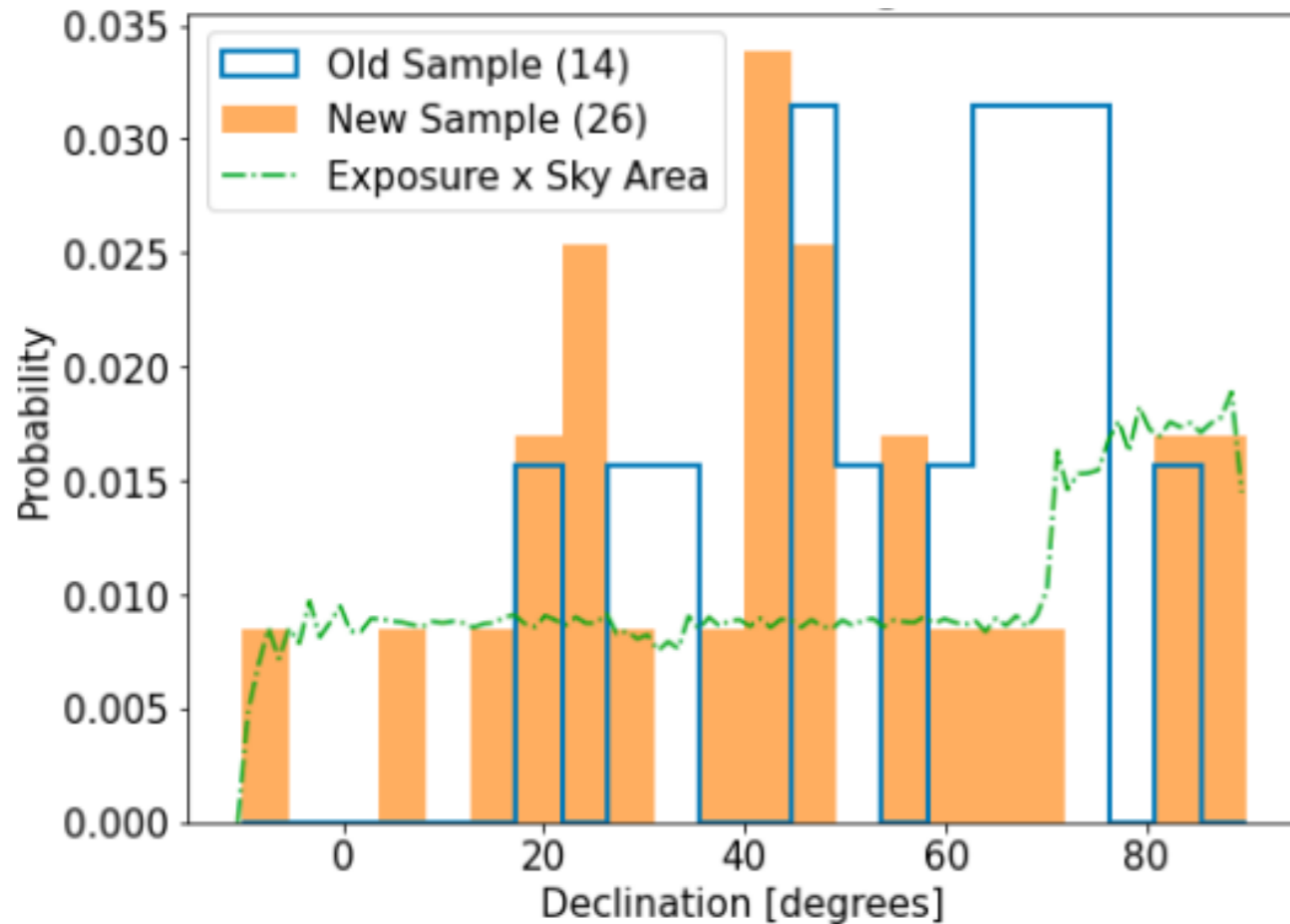
Comparing old and new repeaters

NB Slightly outdated; one source needs to be removed
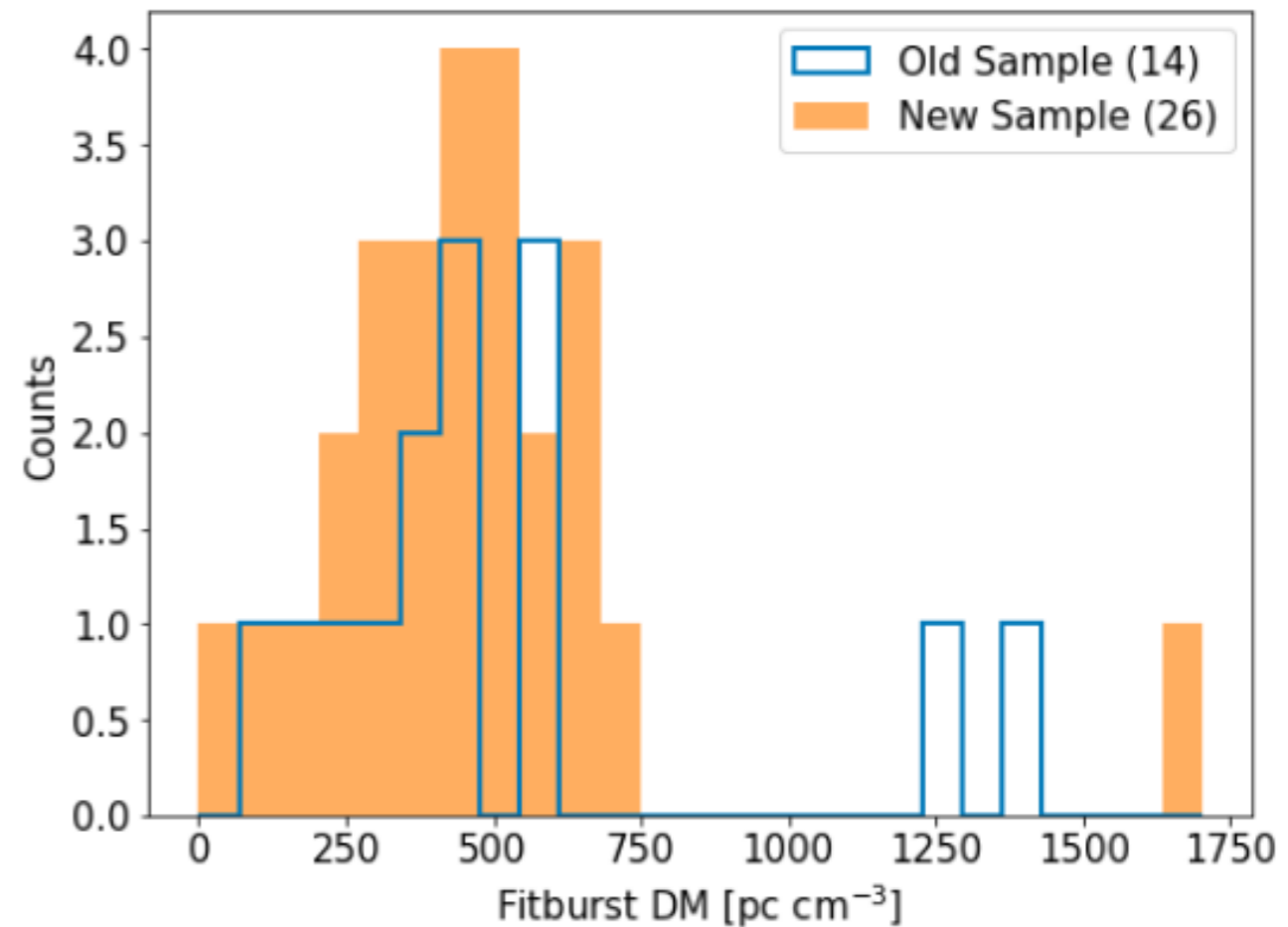
New repeaters near the pole (better localizations and more robust chance coincidence calculation) and at lower declinations (increased total exposure); DM distributions seem to match

Comparing repeaters with one-off FRBs
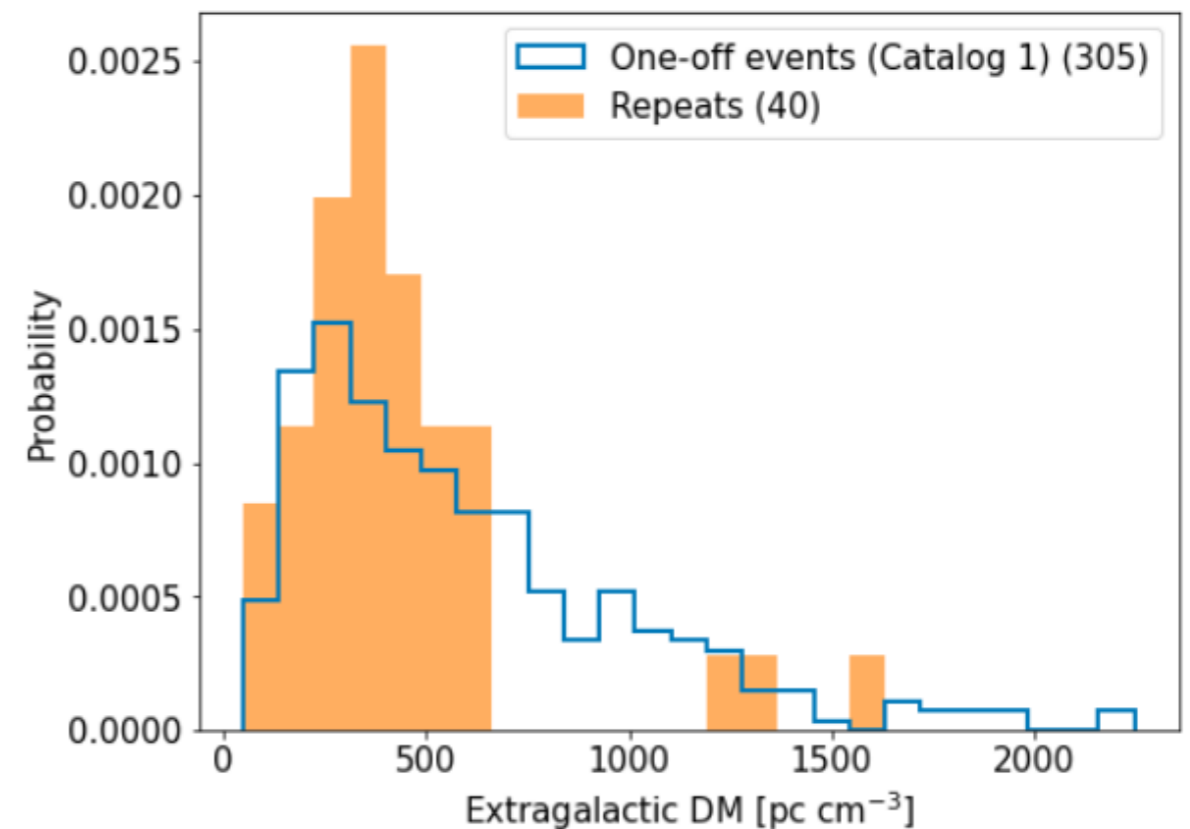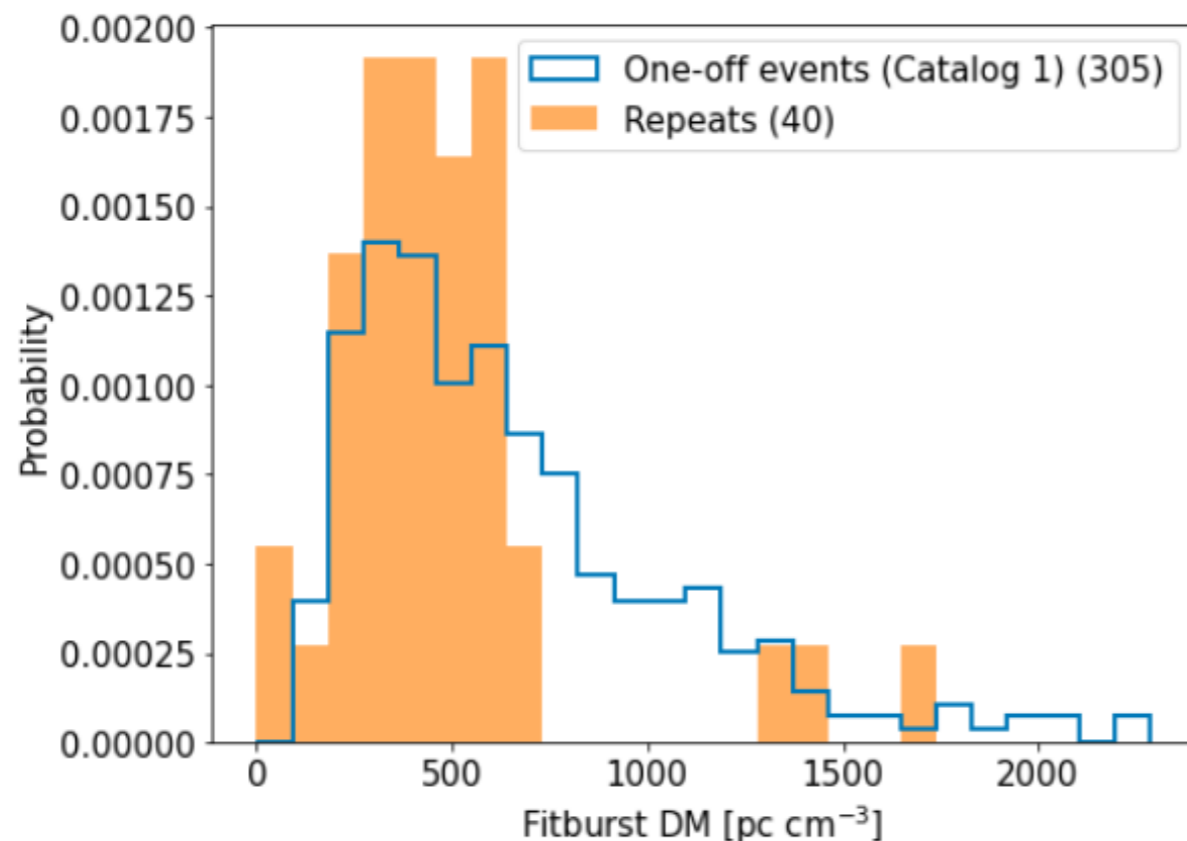
NB Slightly outdated; one source needs to be removed

DM difference between repeating sources and one-off events, which can likely be explained by luminosity/distance effects;
detailed population synthesis will help interpret

Repeater detection fraction

FRB A

FRB B

S/N

Time (from start to end of survey)

★ FRB detection
◯ Source discovery
▢ Repeater discovery
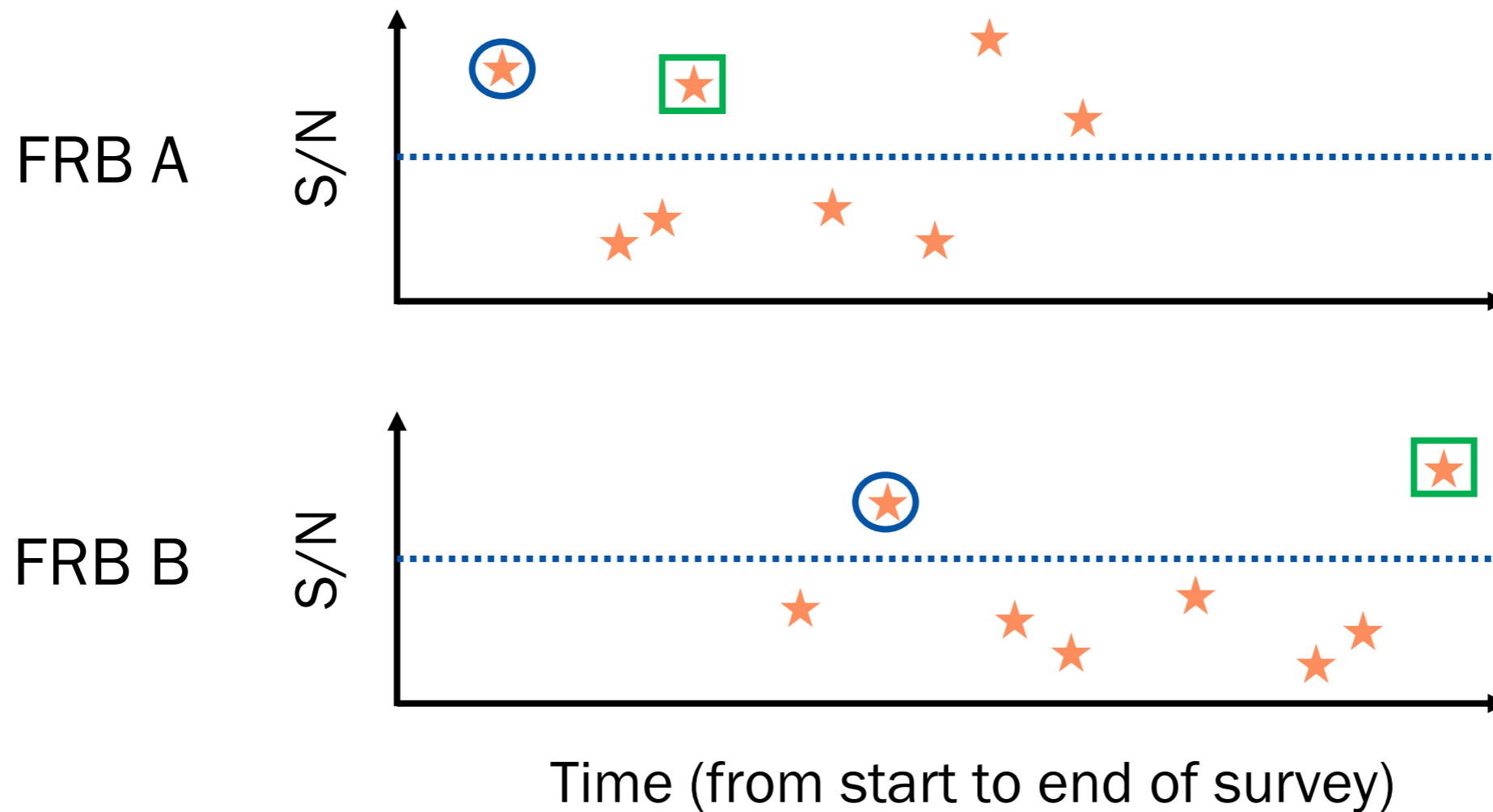
Repeater detection fraction

Sensitivity
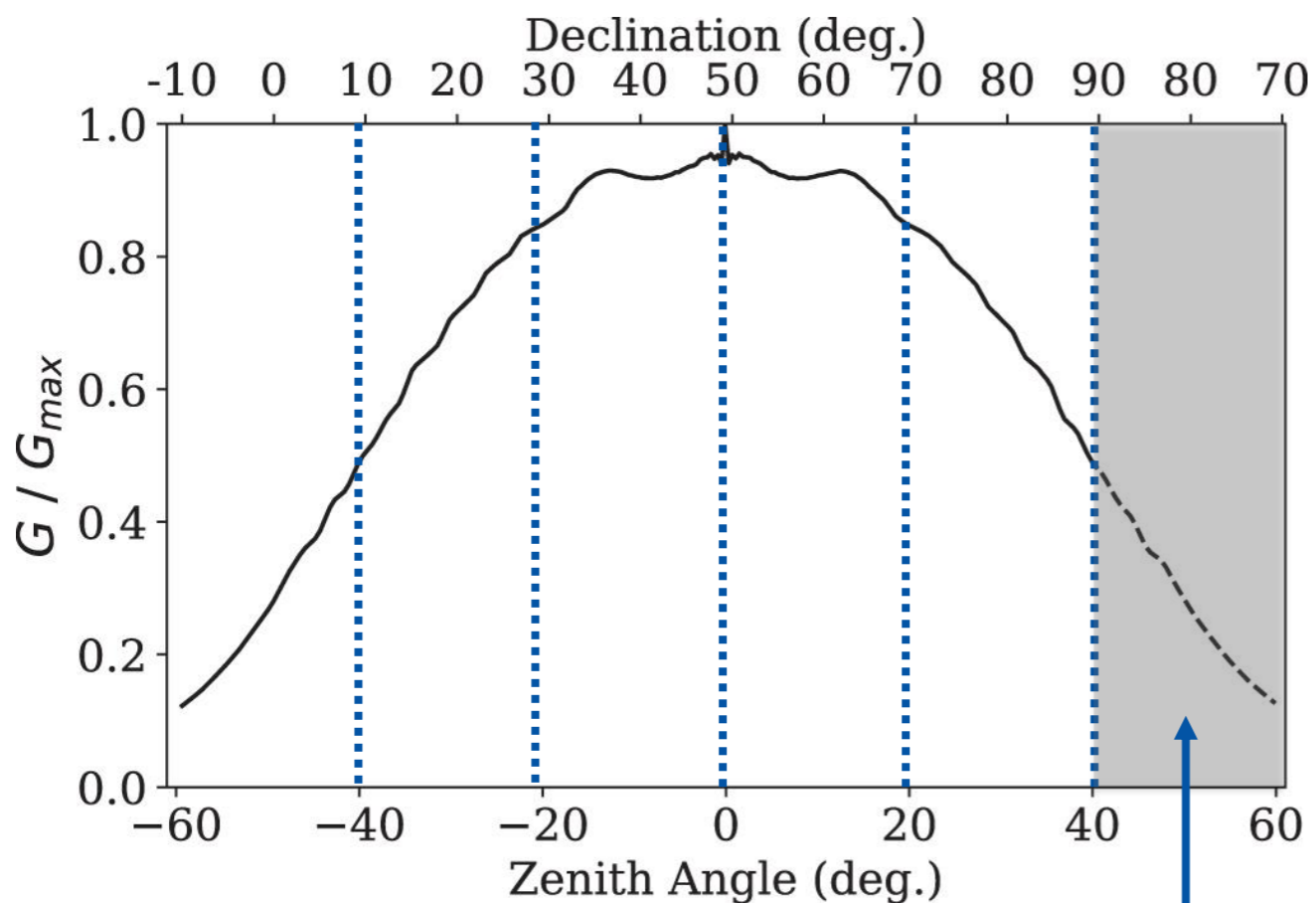
Exposure

"Upper" "Lower"
transit transit

"Upper"
+ "lower"
transit

📄 Josephy+ 2021 📄 Chawla+ 2021
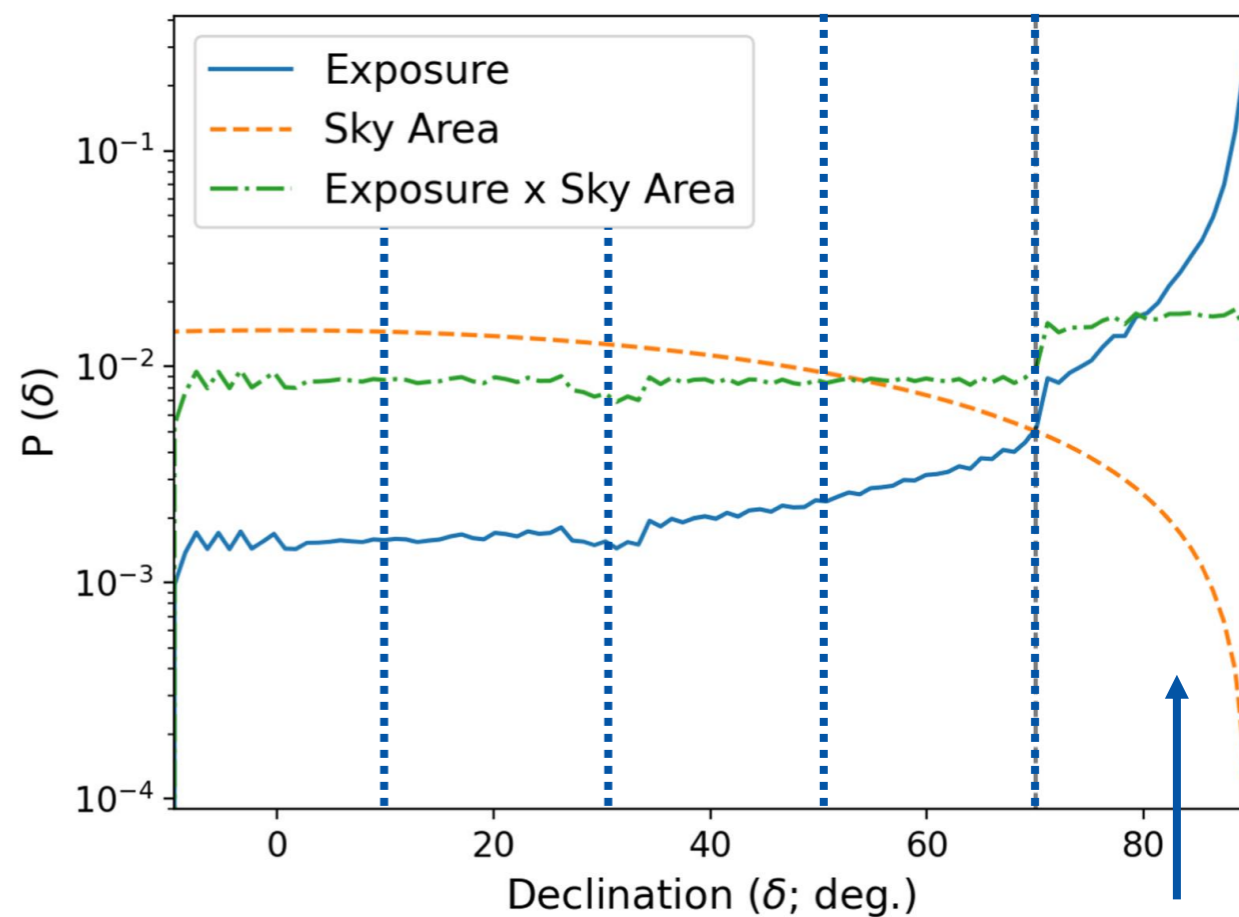
Comparing # of repeaters with # of FRBs in declination bins
with approximately equal exposure and sensitivity
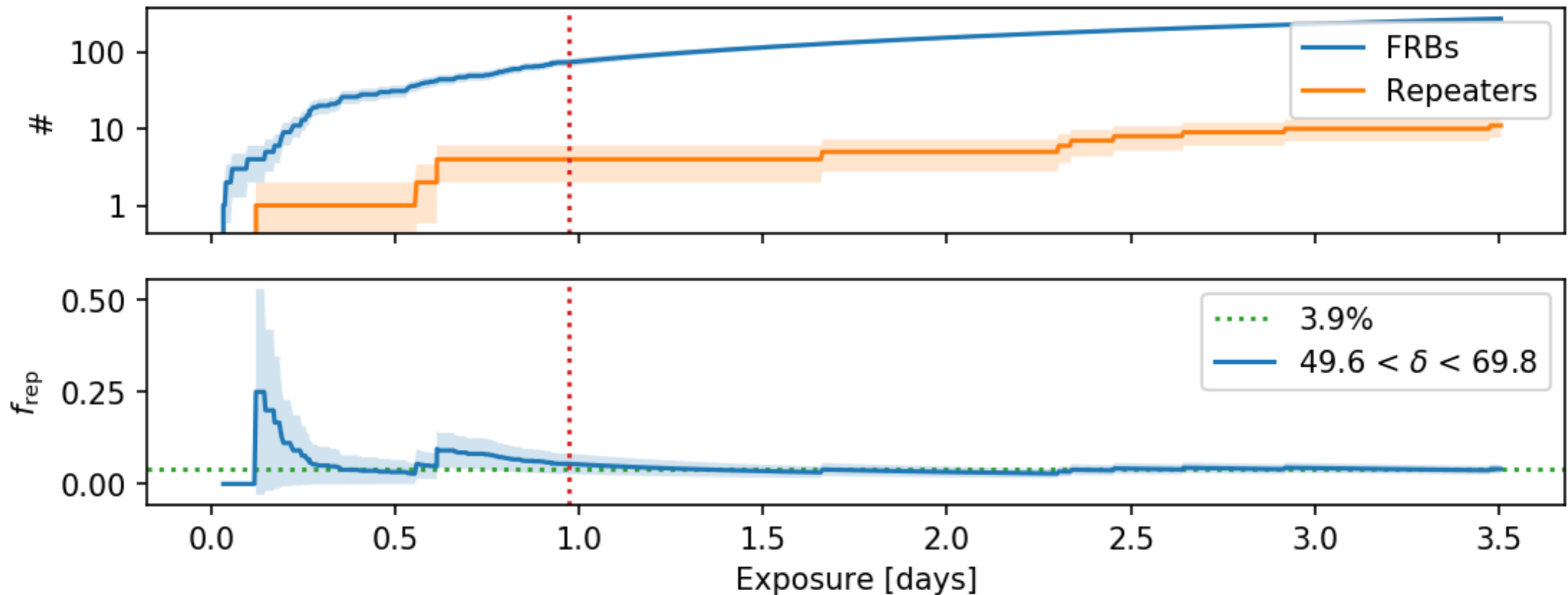
If all FRBs repeat, the repeater fraction, f_{rep},
would tend to 1 over time

Repeater detection fraction
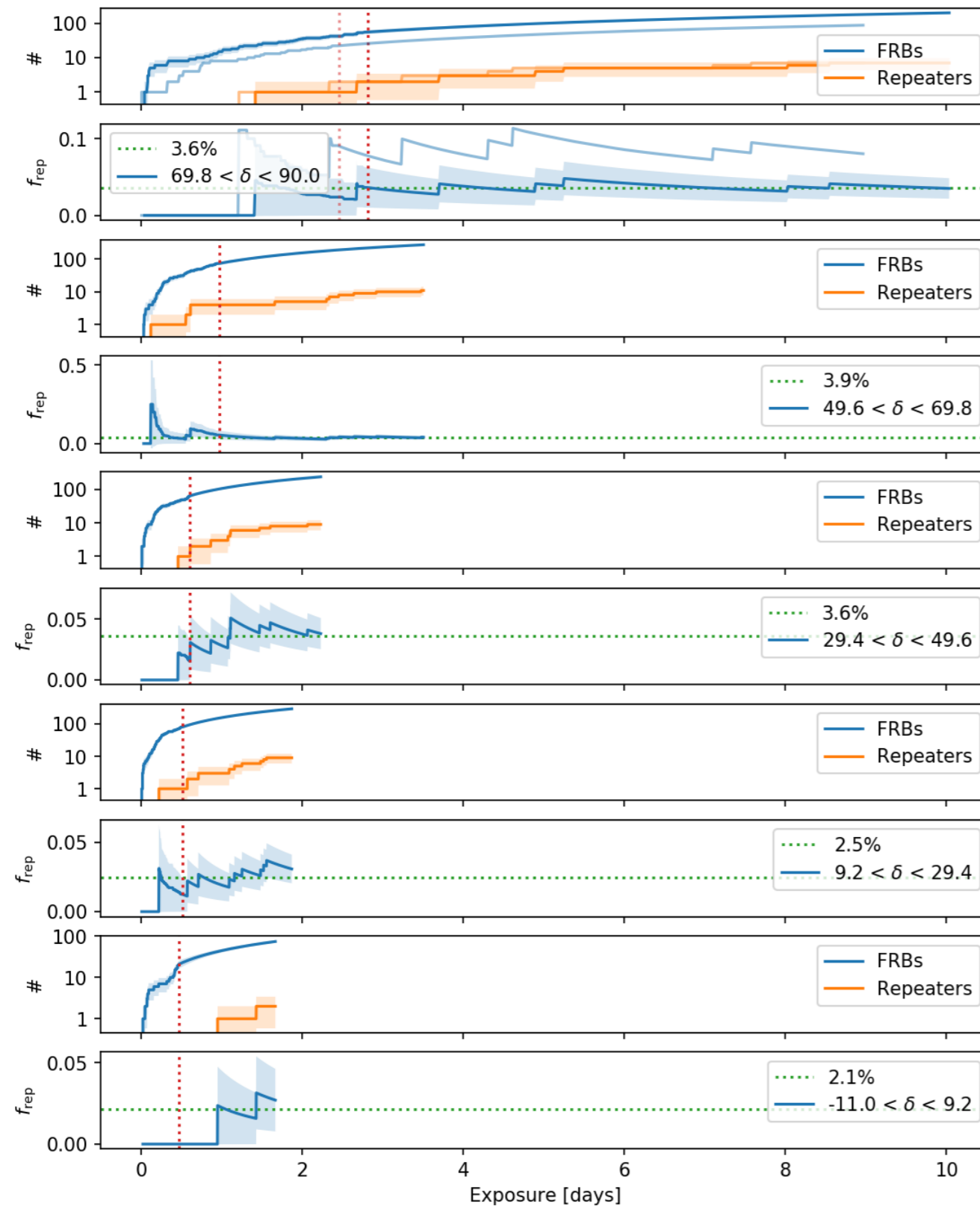
~4% of FRBs is detected to repeat

Need broad distribution of repetition rates or distinct population of one-off events

CHIME/FRB   see 📄 Gardenier+ 2021 📄 Ai+ 2021 for simulations of the effect   18

Not all FRBs repeat

Burst morphology dichotomy between one-off events and repeater bursts

25 new repeating sources of FRBs double the population
(and 14 more new sources are interesting targets for follow-up)

DM difference between repeating sources and one-off events,
which can likely be explained by luminosity/distance effects

~4% of FRBs in CHIME/FRB are detected to repeat: need broad
distribution of repetition rates or distinct population of one-off events

Repetition rate distribution under investigation is next line of inquiry

📄 CHIME/FRB Collaboration in prep.

Appendix

Clustering analysis

Led by Adam Dong (UBC)
and Alex Josephy (McGill)
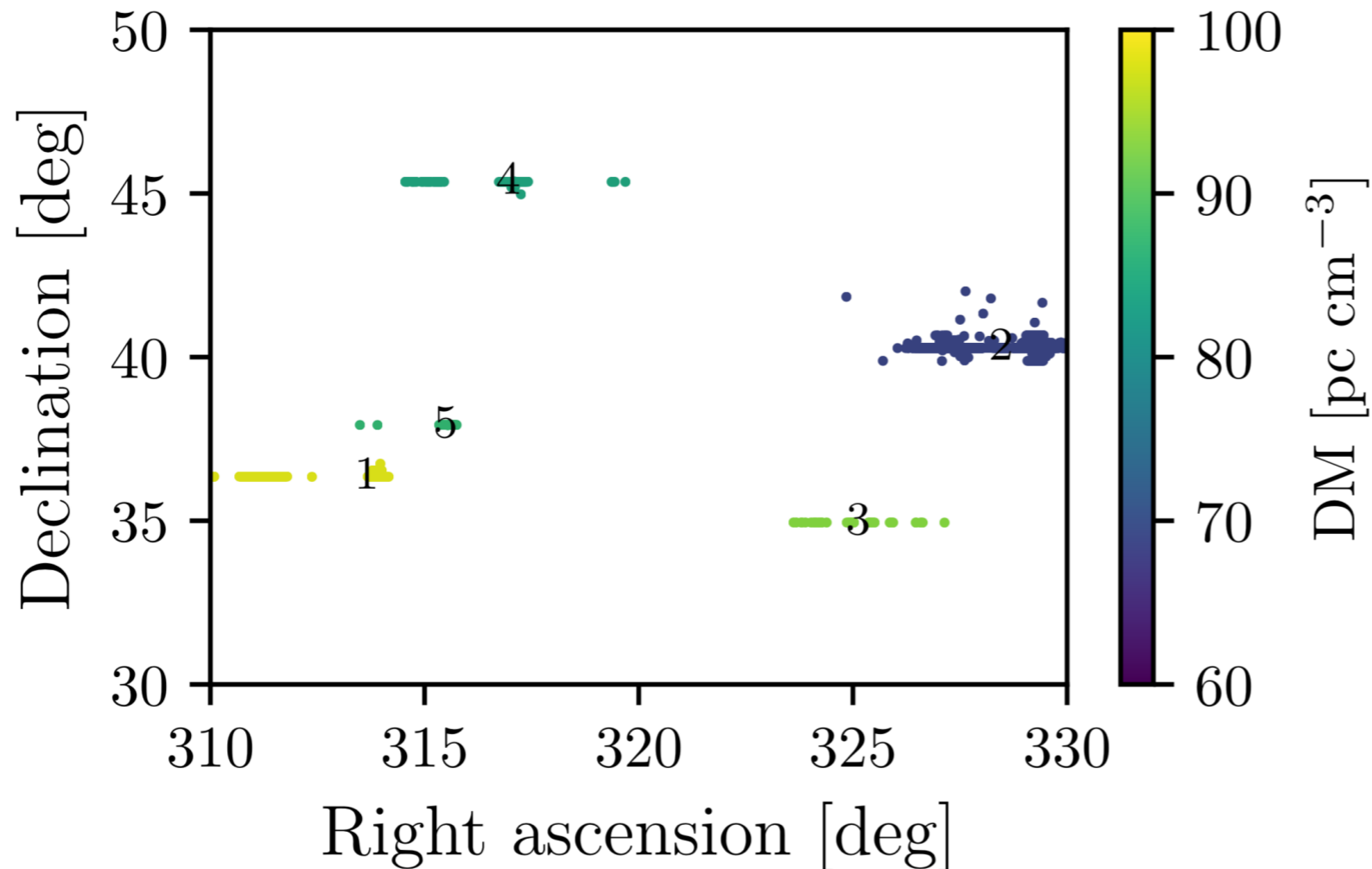
Tolerance:
~13 pc cm^{-3} in DM
~1° in Dec
~0.5 cos(Dec)° in RA

Look for clusters in sky position and DM from real-time detection metadata, taking into account CHIME/FRB systematic and statistical uncertainties using DBSCAN algorithm in CHIME/FRB database
→ Rediscovered all published CHIME/FRB sources

Localization methods

Fitting per-beam detection
S/N with a beam model
e.g. 📄 CHIME/FRB Collaboration 2021

~15'

Led by
Alex Josephy
(McGill)

Brute force repointing using
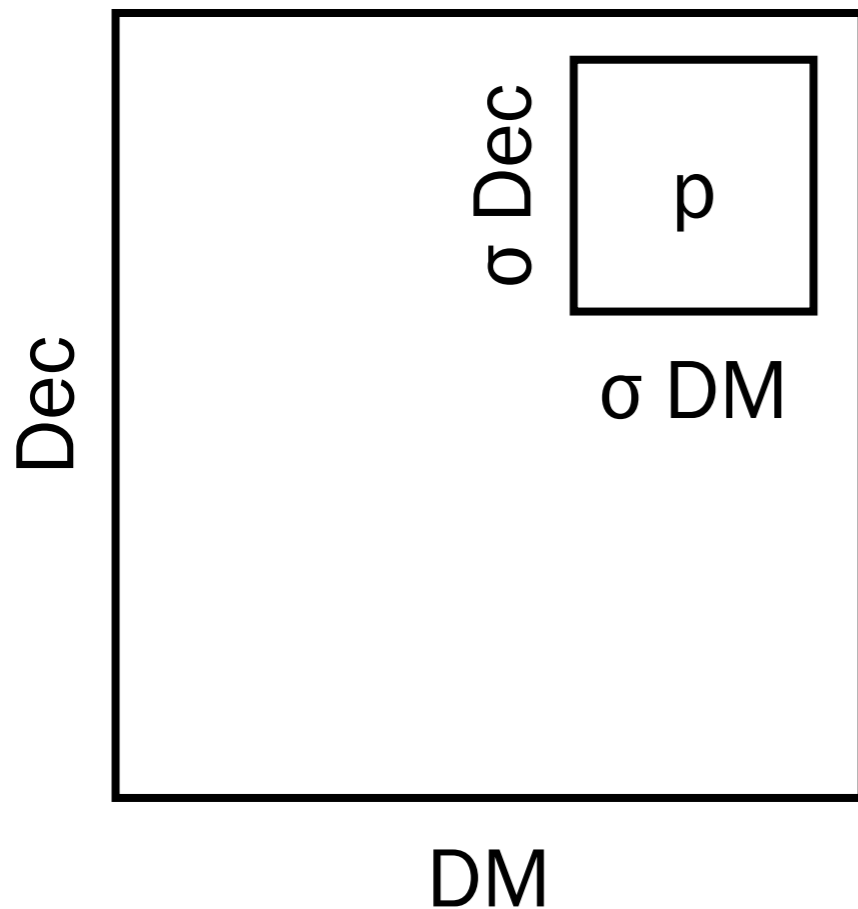the saved complex voltages
of the interferometer
📄 Michilli+ 2021

sub
arcmin

Analysis by
Cherry Ng
(UofT)

Chance coincidence probability

Dec

σ Dec

p

σ DM

DM

Led by
Amanda Cook
(UofT)

Probability of detecting two unrelated FRBs at high declination with similar DM is non-negligible

Modeling FRB detections as a set of independent Bernoulli trials

Comparing candidate repeater sources with all FRB detections

$$P_{\mathrm{cc}} = \sum_{k=x\text{-}1}^{n} \binom{n}{k} p^k (1-p)^{n-k}$$