The short, high-DM FRB sky in sharp view

Joeri van Leeuwen

for the ALERT and ARTS teams

arxiv:2205.12362

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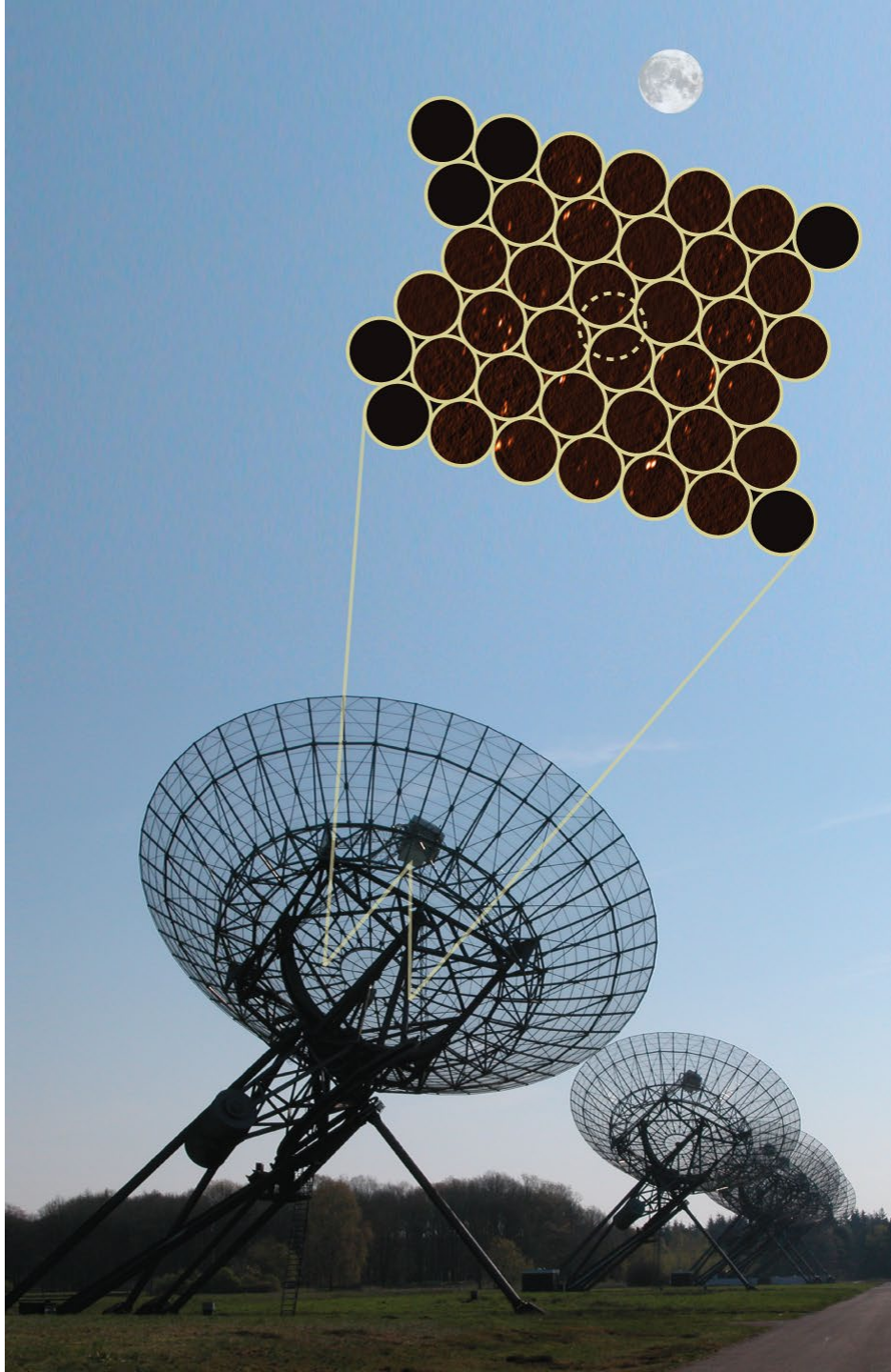
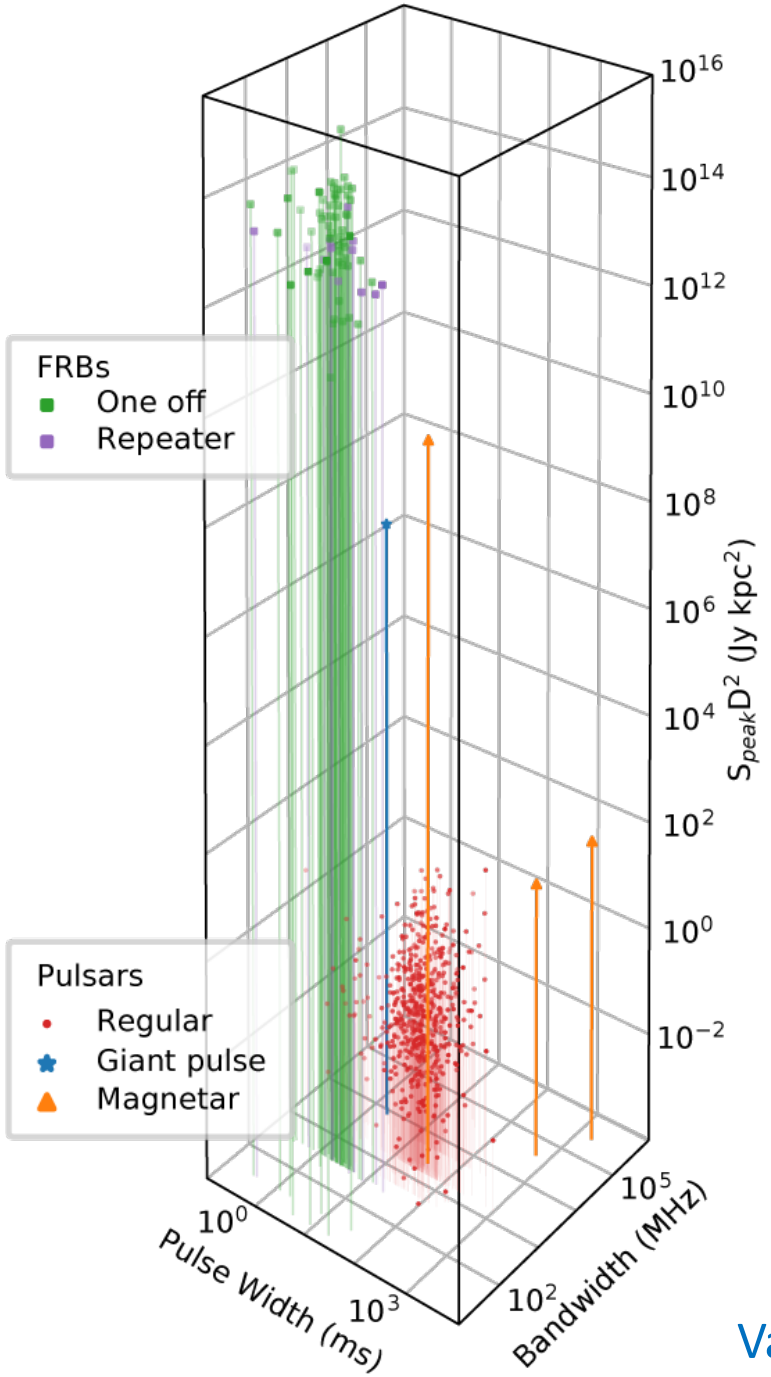




Van Leeuwen et al. 2022 (arxiv:2205.12362)

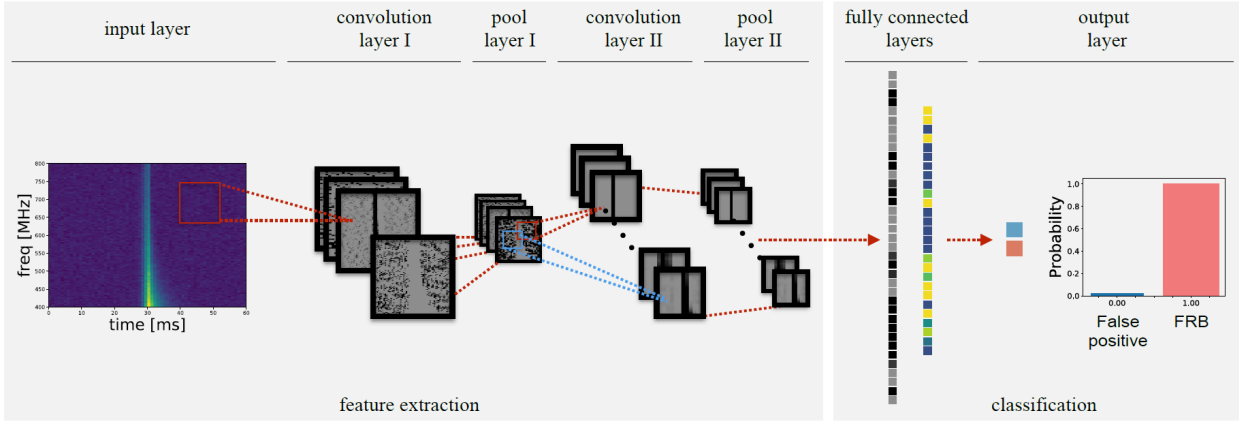
Unique to ALERT (I): ARTS backend

The Apertif Radio Transient System (ARTS) is:

Real-time system

Hybrid supercomputer of

- Two FPGA-based beam formers
- GPU cluster
- Real-time RFI excision
- AMBER search software
- Deep neural net detection



Vohl, Sclocco et al. 2016, 2020; Maan & van Leeuwen 2017, Connor & van Leeuwen 2018

amber
apertif monitor for bursts encountered in real-time

APERTIF RADIO TRANSIENT SYSTEM

APERTIF
APERture Tile In Focus

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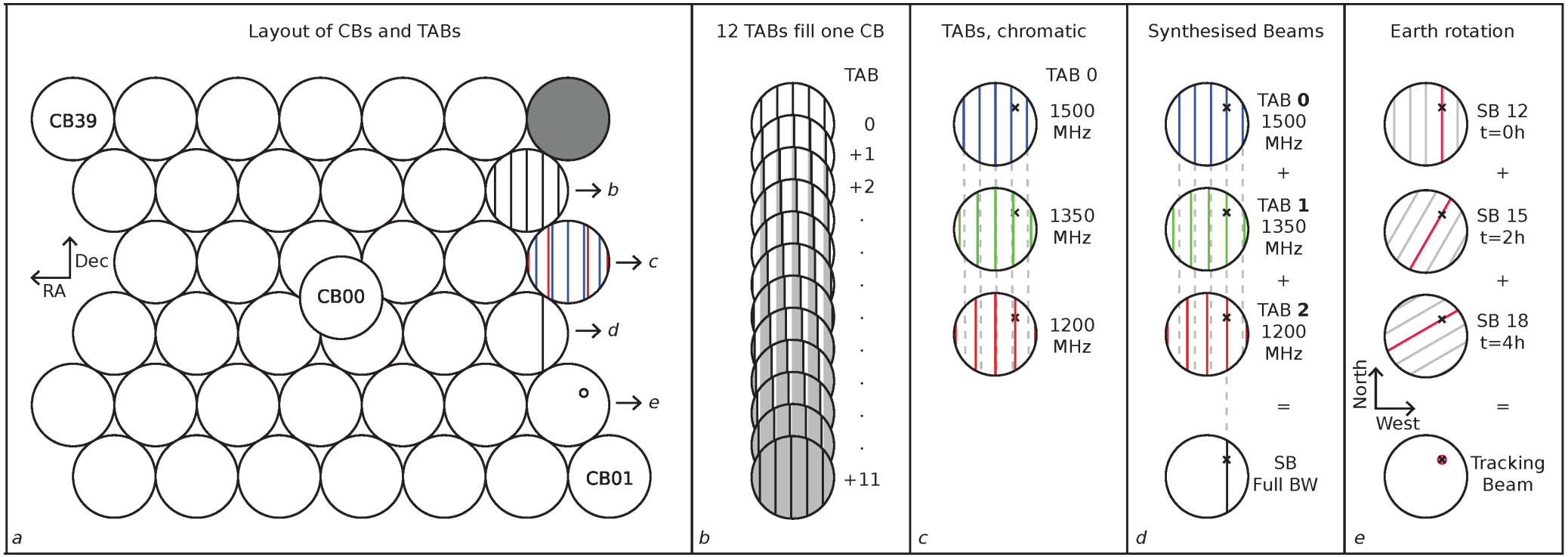
Unique to ALERT (II): hierarchical beamforming

The ALERT survey employed hierarchical beamforming



vL et al. 2022

amber
aperTif monitor for bursts encountered in real-time

APERTIF RADIO TRANSIENT SYSTEM

APERTIF
APERture Tile In Focus

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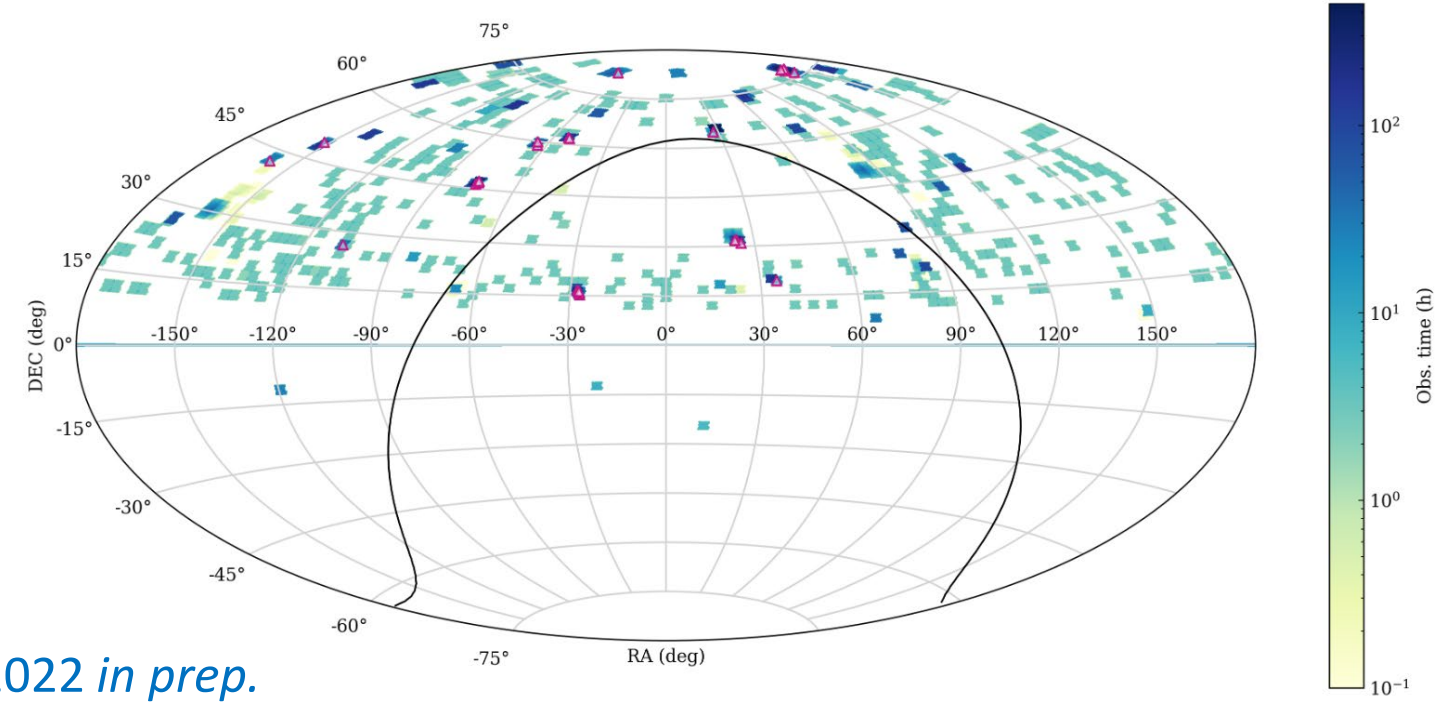
Unique to ALERT (III): steering & pointing

Field priorities *localization – characterization – detection*

1—2 weeks on, 4 weeks off ; 3 hr pointings

Operation 2.5 yrs, Jul 2019 .. Feb 2022.

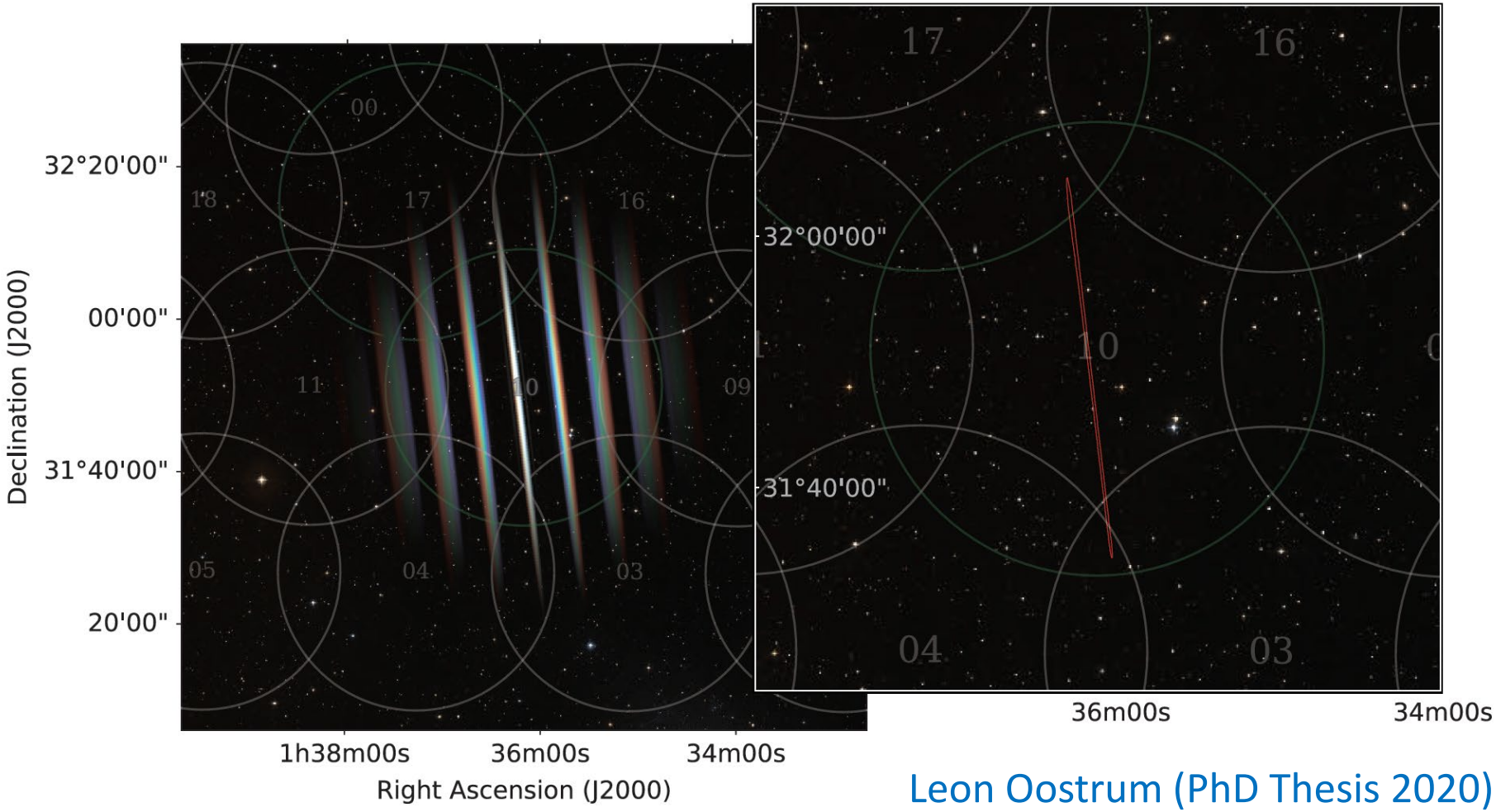


Pastor-Marazuela, vL, et al. 2022 *in prep.*

Apertif – first FRB detection

FRB 190709

DM = 663 pc/cc



Leon Oostrum (PhD Thesis 2020)

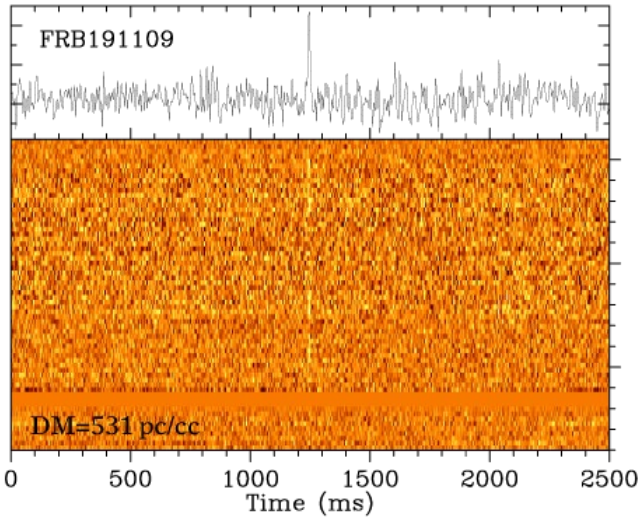
Discovered 24 new FRBs

One FRB every ~7 days of observing

One of most productive L-band surveys in the world

High DM, very narrow, quite broadband

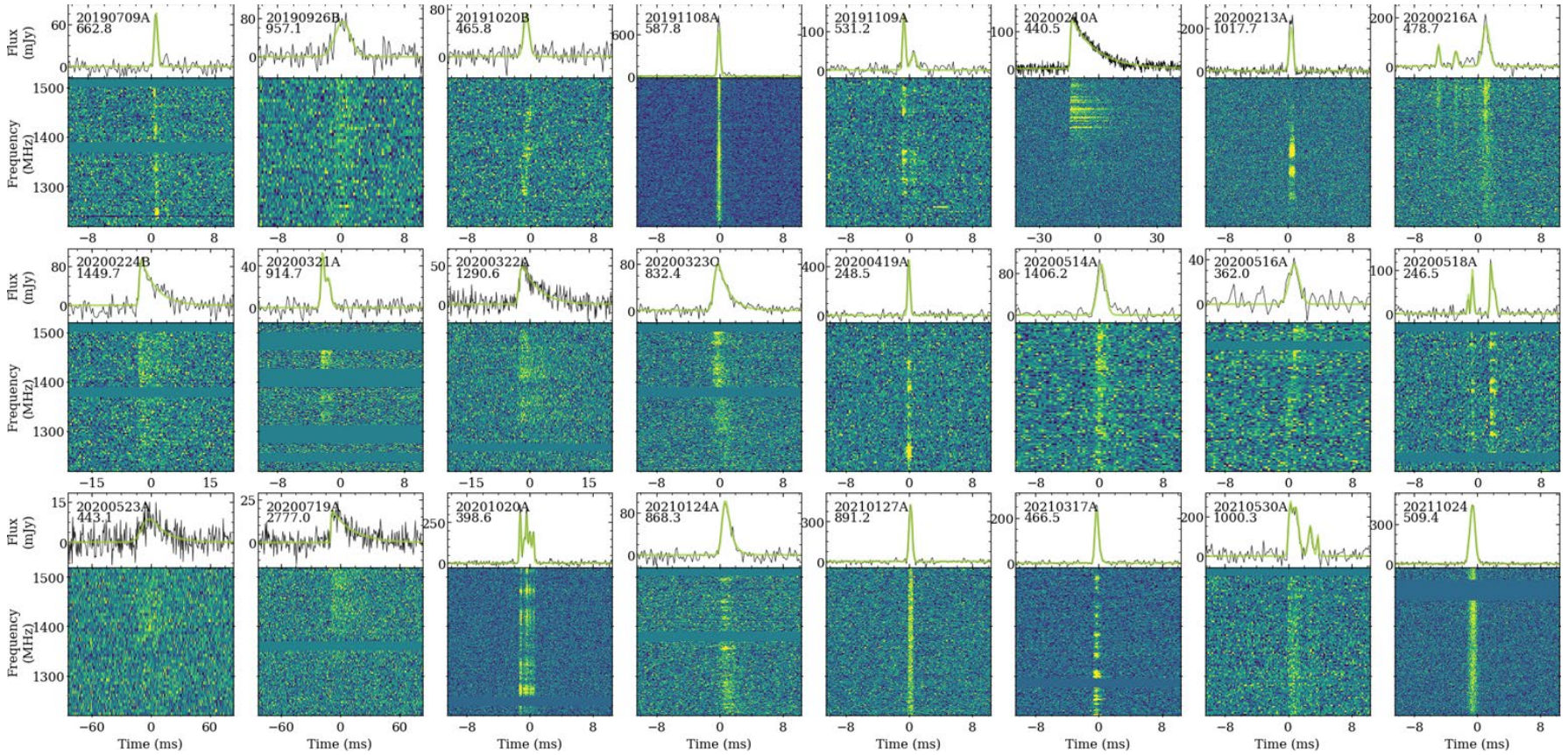
Interferometric localization



Van Leeuwen et al. 2022 (arxiv:2205.12362)

Discovered 24 new FRBs

Interesting morphologies, multi-component, scattered:

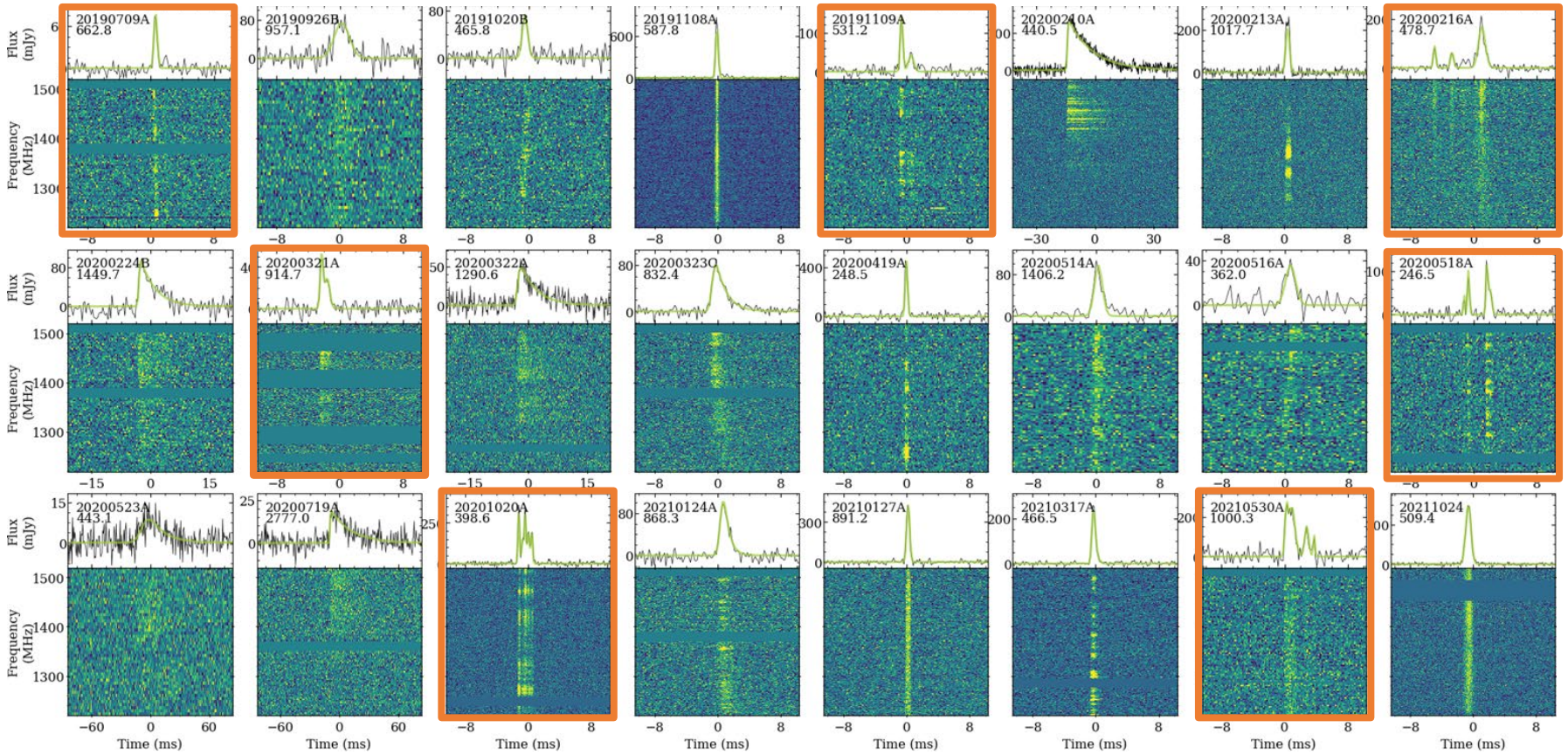


vL et al. 2022

PM, vL et al. 2022

Discovered 24 new FRBs

Higher multi-component fraction than @ CHIME

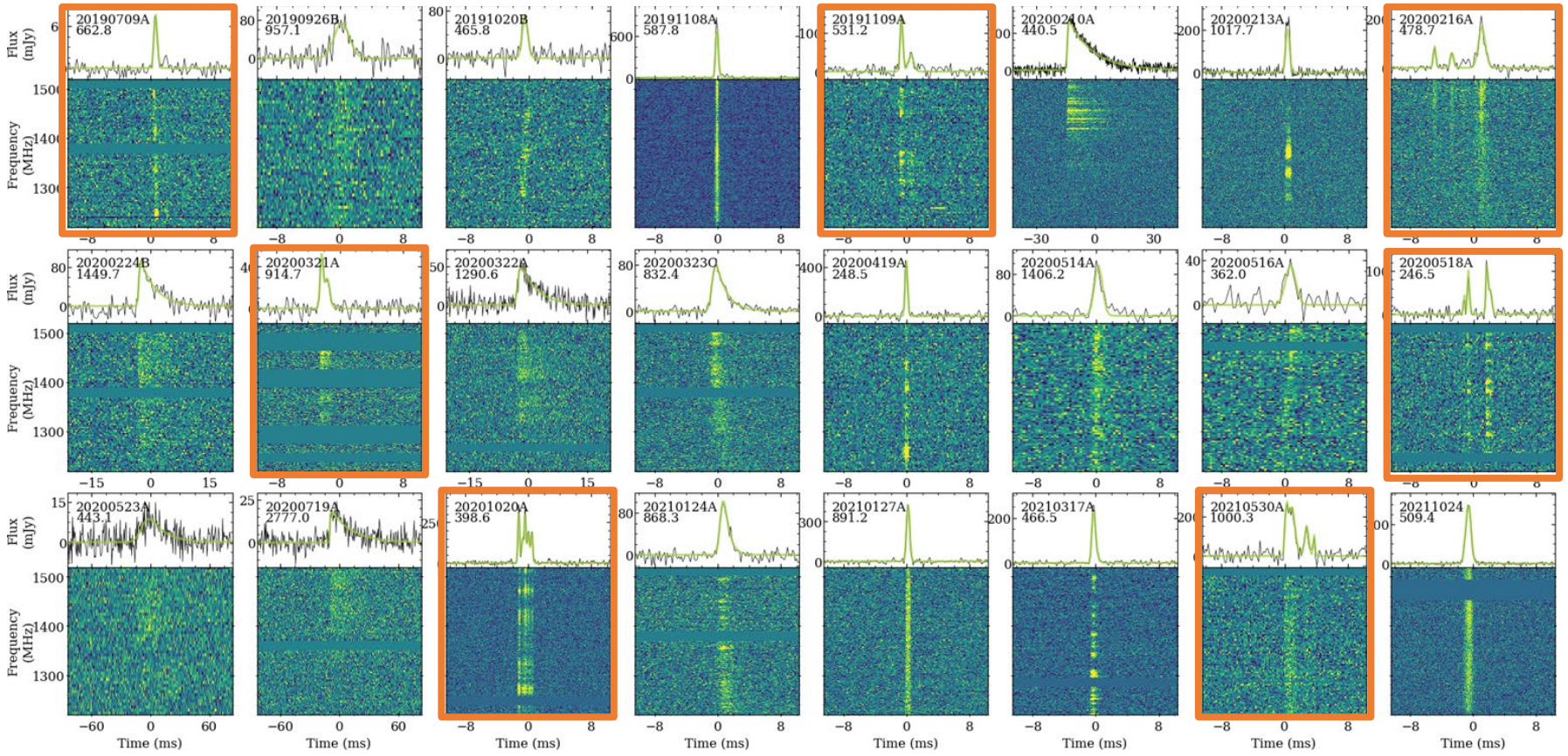


vL et al. 2022

PM, vL et al. 2022

Discovered 24 new FRBs

How can FRB morphology evolve with frequency?



vL et al. 2022

PM, vL et al. 2022

Discovered 24 new FRBs

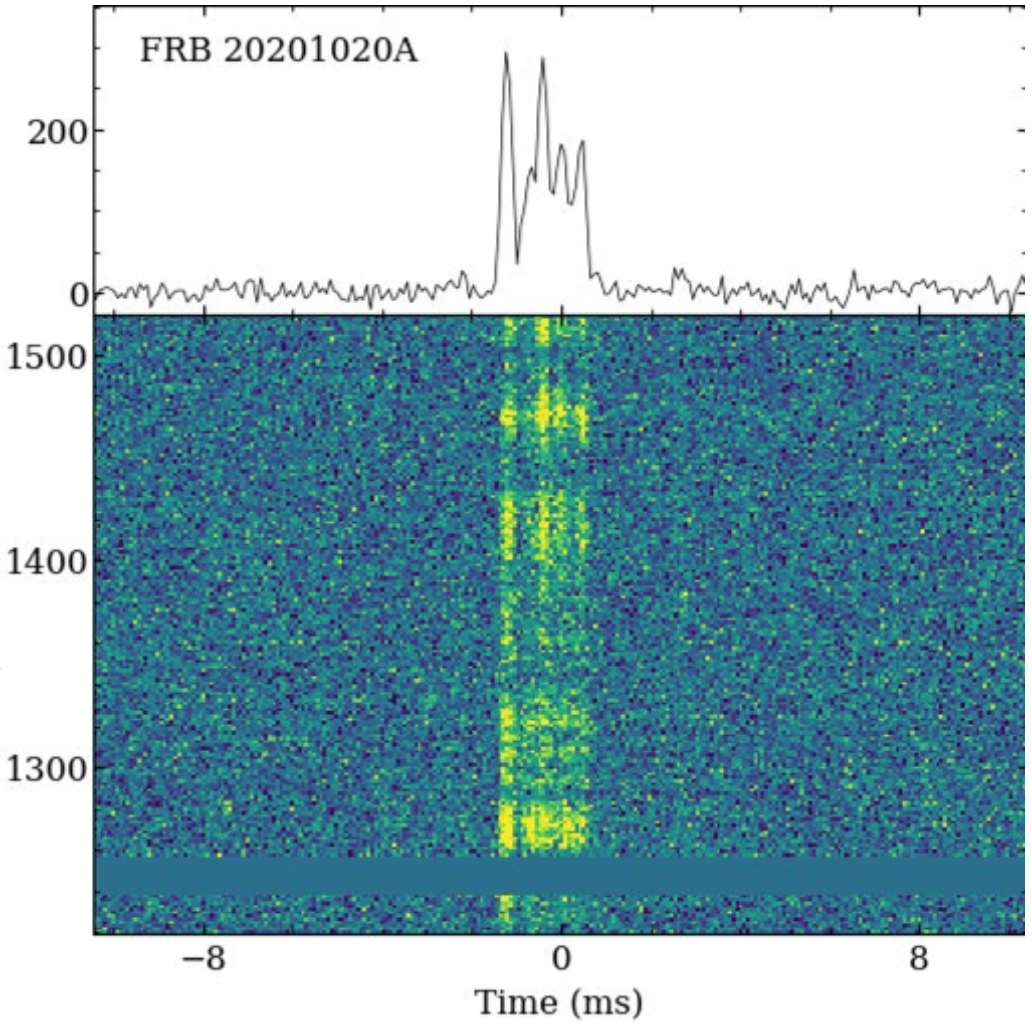
Sub-ms pseudo-periodic structure:

5 components

Spacing 0.415 ms → frequency ~2409 Hz

Periodicity significance 2.5σ

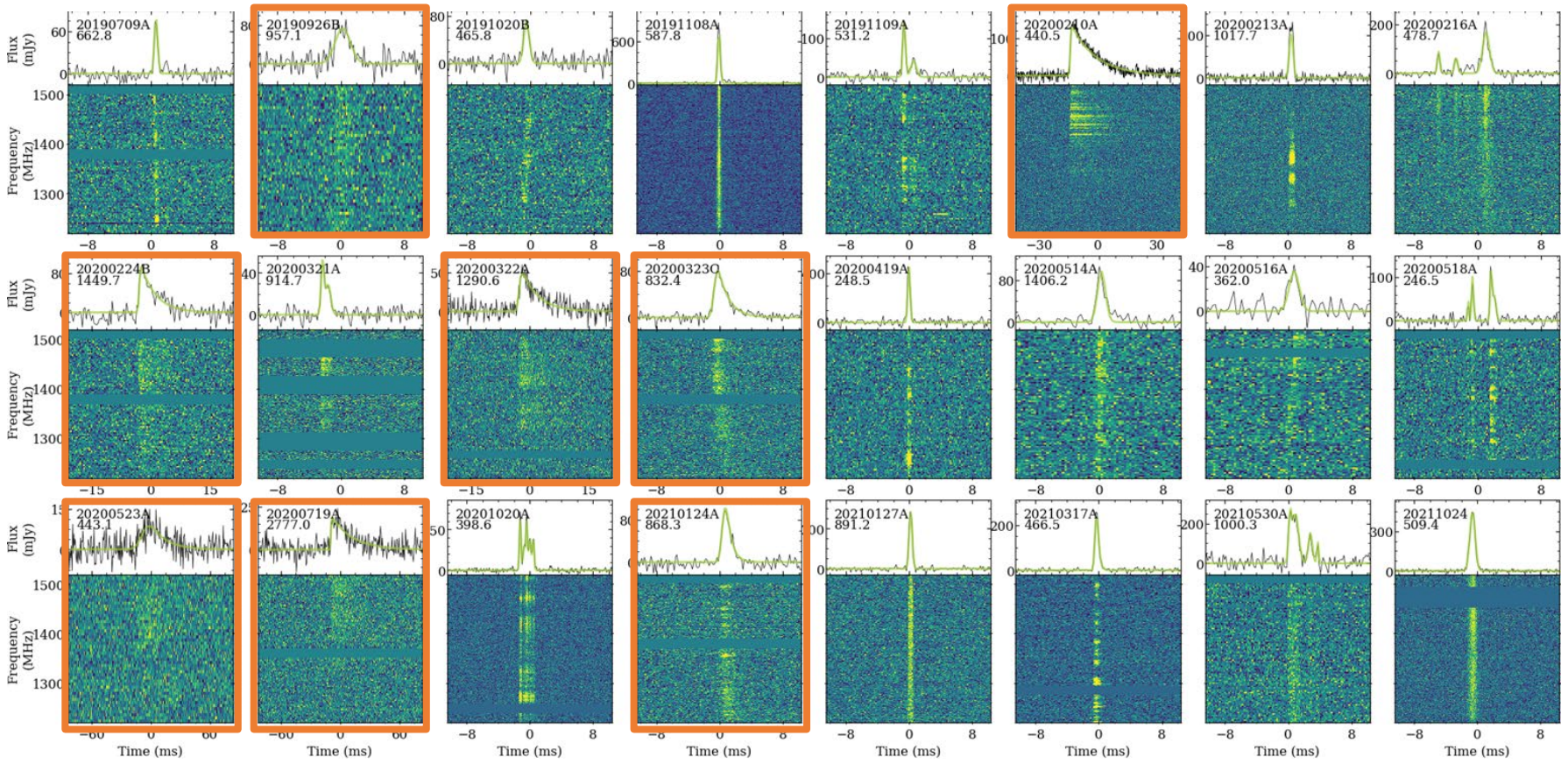
FRBs show microstructure now?



Pastor-Marazuela, vL, et al 2022 (arxiv:2202.08002)

Discovered 24 new FRBs

Scattering:



vL et al. 2022

PM, vL et al. 2022

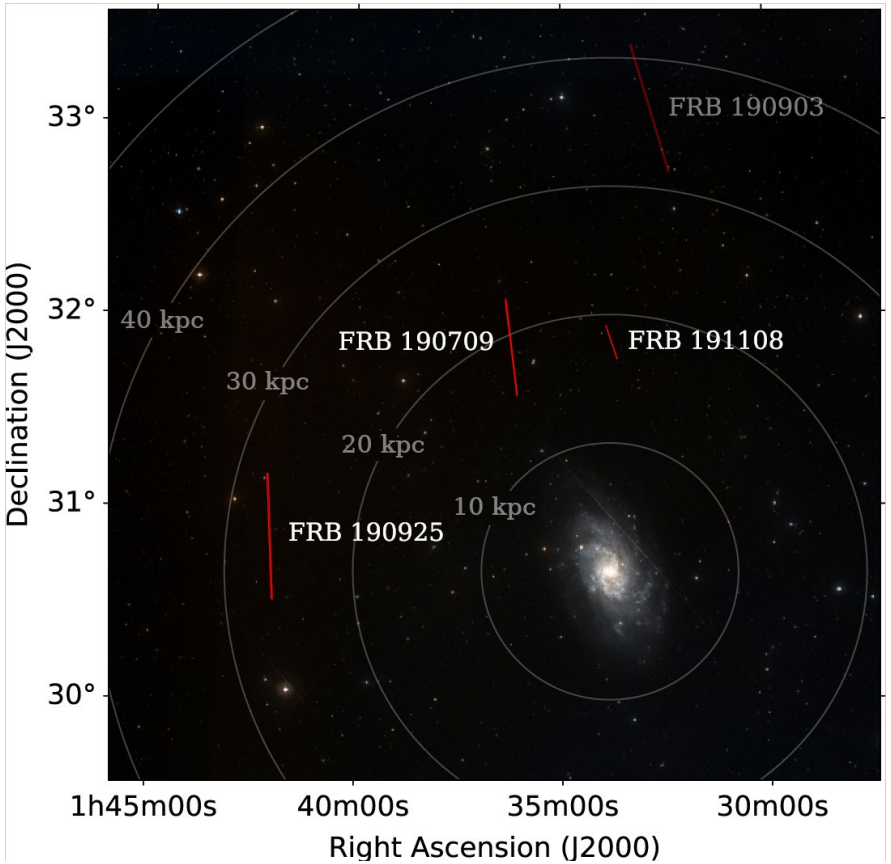
Probing the M33 halo

3 out of first 4 FRBs skewer M33/M31 halos

FRB 191108 is localised to 5” x 7’ ellipse

Cuts within a degree (~18 kpc) of M33

Probes halo + circumgalactic medium



Liam Connor + Apertif Builders (2020, MNRAS 499, 4716)

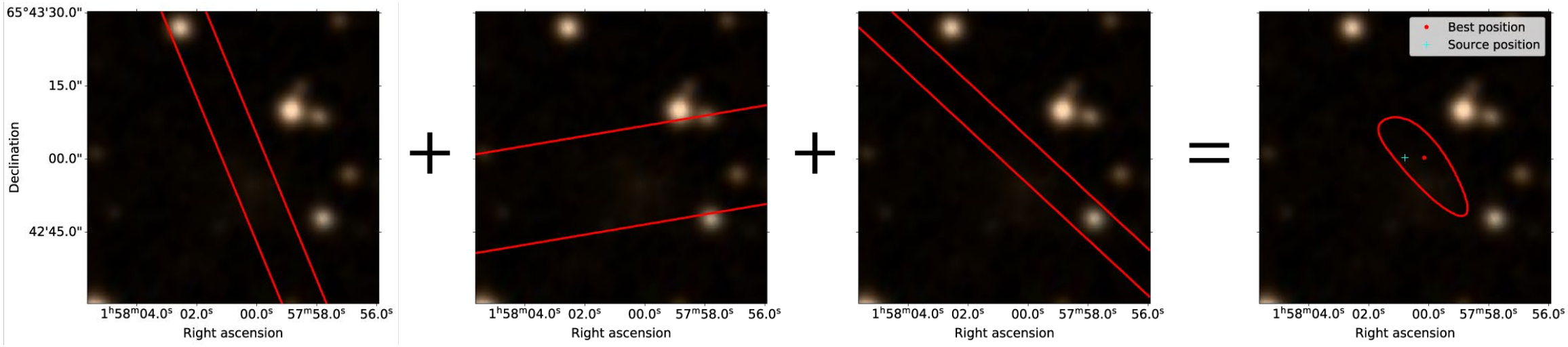
Van Leeuwen et al. 2022 (arxiv:2205.12362)

Repeater localization, study

Detecting 2 or 3 bursts from repeating FRBs
improves localization ~50x.

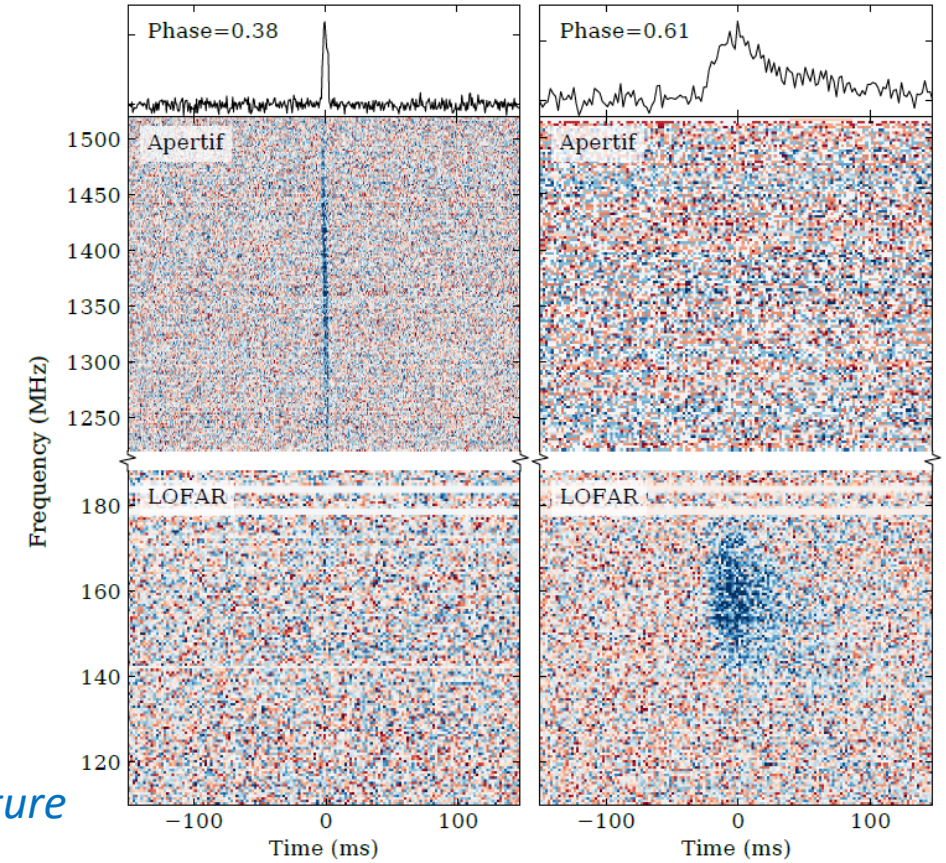
The long, 3-h tracks at WSRT are a large benefit.

About 90% of *new* FRBs are from *repeater* fields.



Repeater FRB 20180916B at Apertif + LOFAR

We detected repeating FRB 20180916B at both telescopes; but never at the same time.

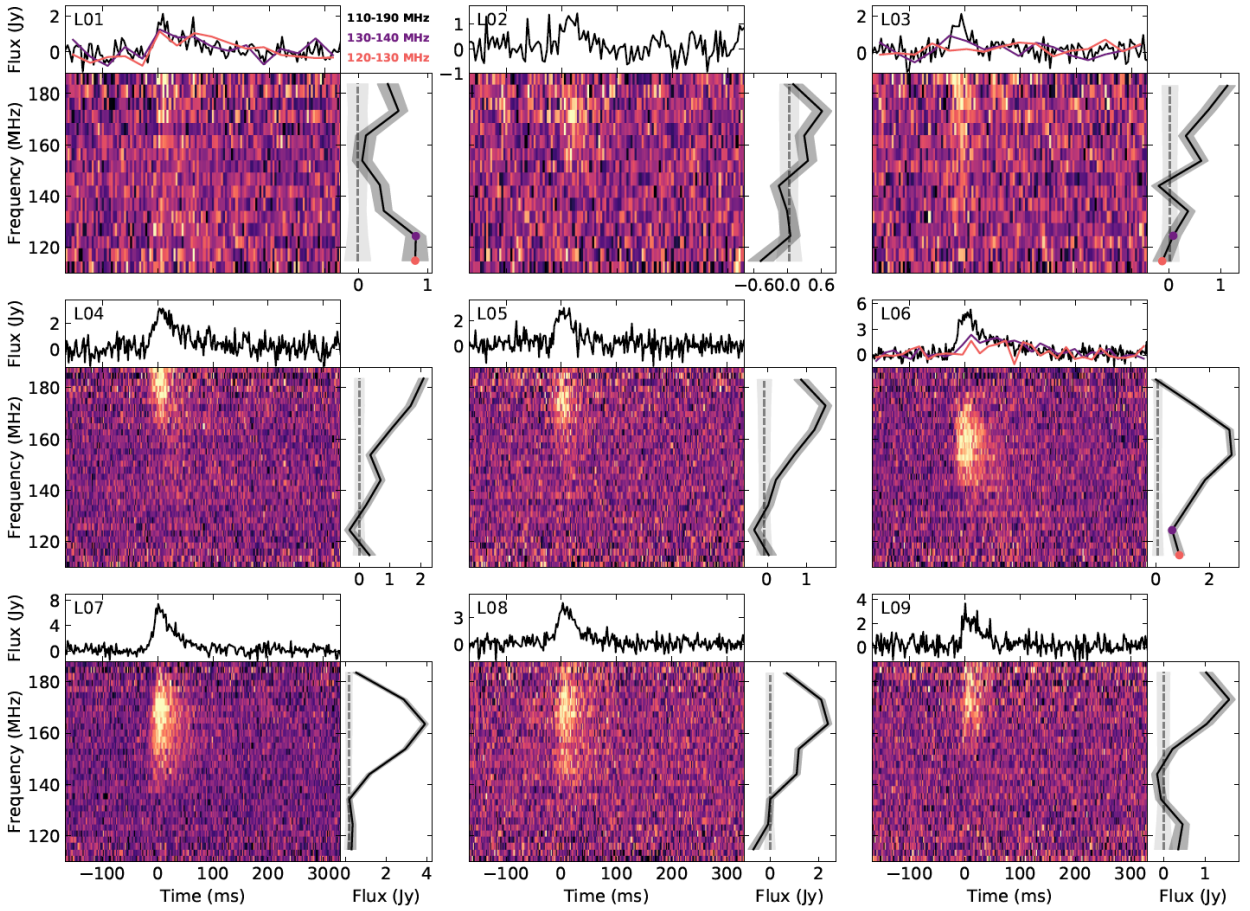


Inés Pastor-Marazuela et al. 2021, *Nature*

Repeater FRB 20180916B at Apertif + LOFAR

First FRB ever seen with LOFAR.

Low-frequency FRB emission escapes local medium – clean environment, important for cosmology applications.



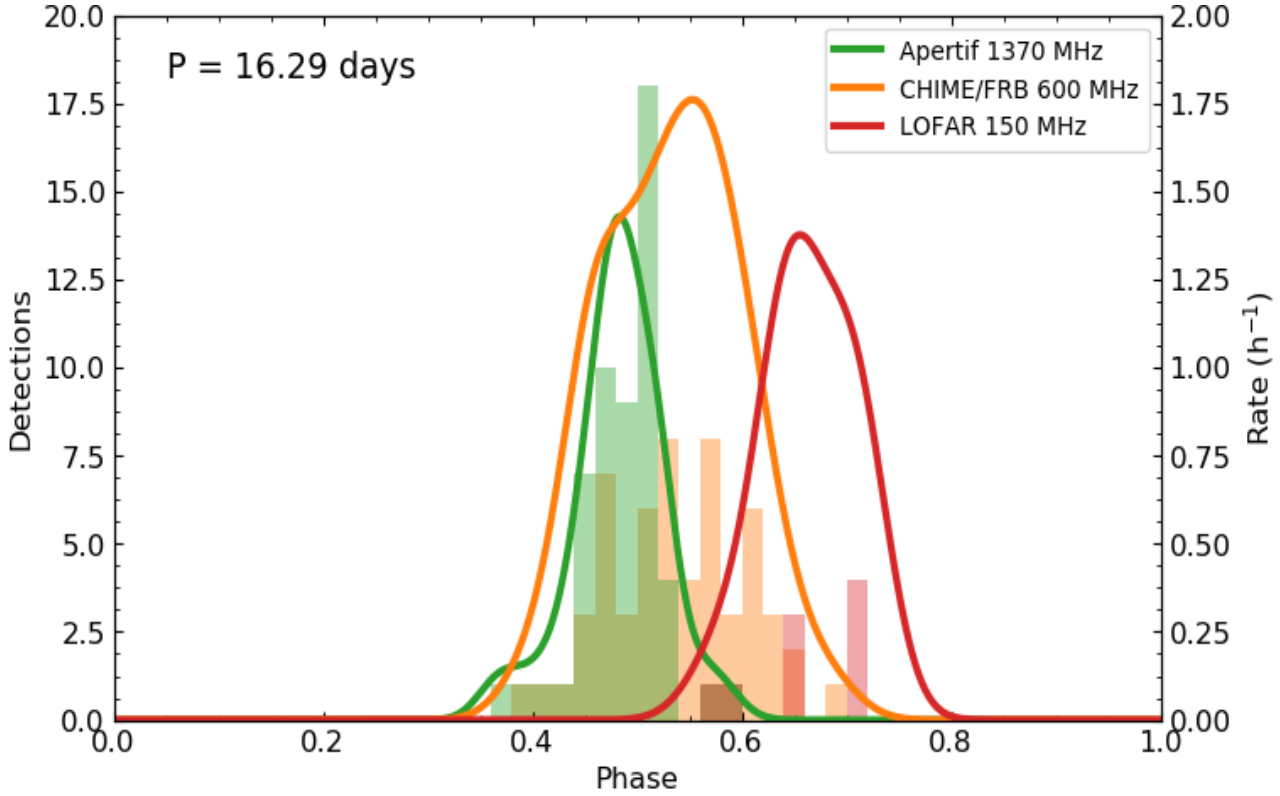
Inés Pastor-Marazuela et al. 2021, *Nature*

Repeater FRB 20180916B at Apertif + LOFAR

Activity *peaks earlier* and *is narrower* at higher frequencies than at lower frequencies.

R3 lives in a clean environment
Opposite to binary wind models
Ultra-long period magnetars work

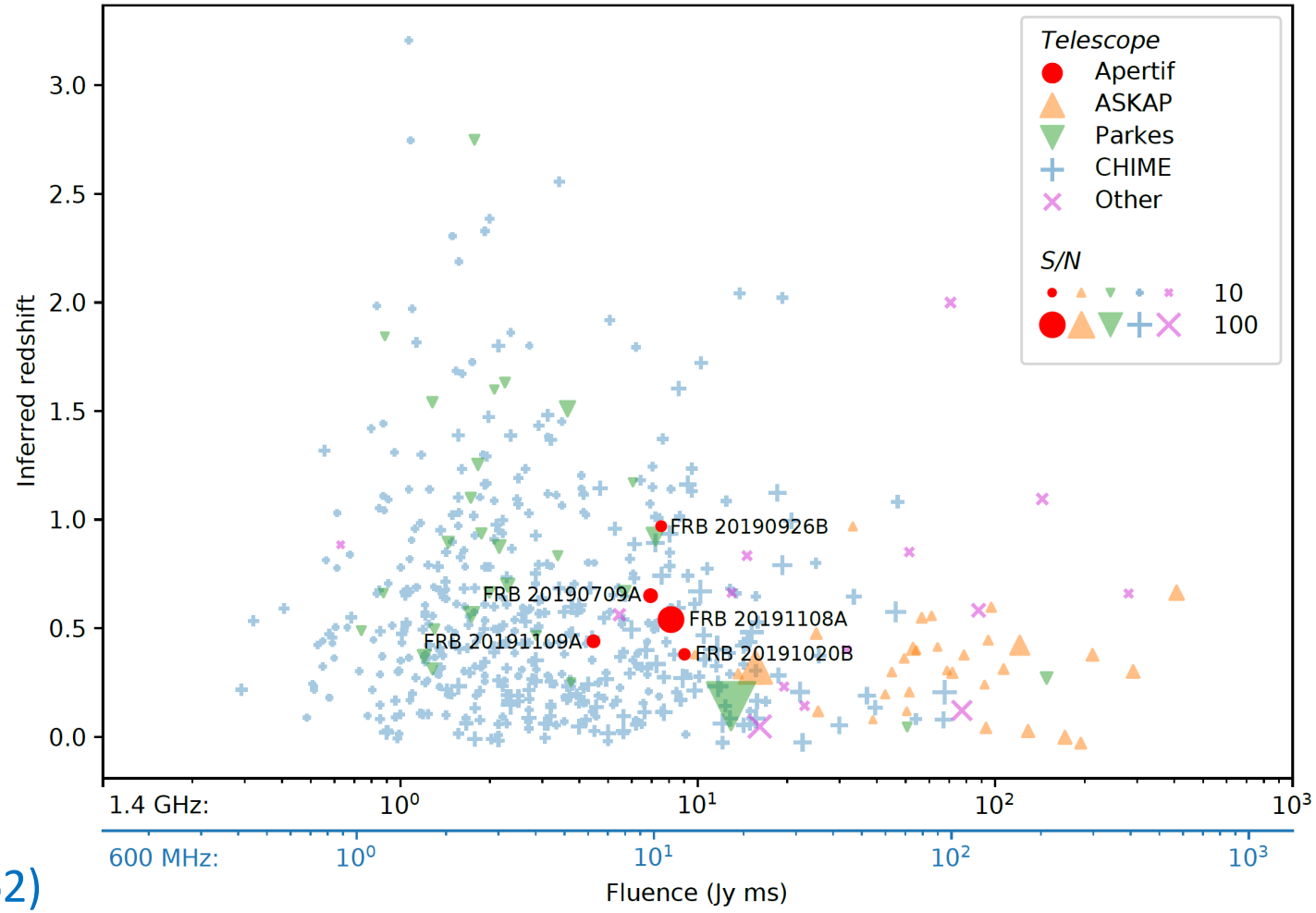
Chromatic FRBs



Inés Pastor-Marazuela et al. 2021, *Nature*
Pleunis et al. 2021 supports this trend

Characteristics of the discovered sample

Fluences of the Apertif-discovered bursts are around the median of the known fluence distribution

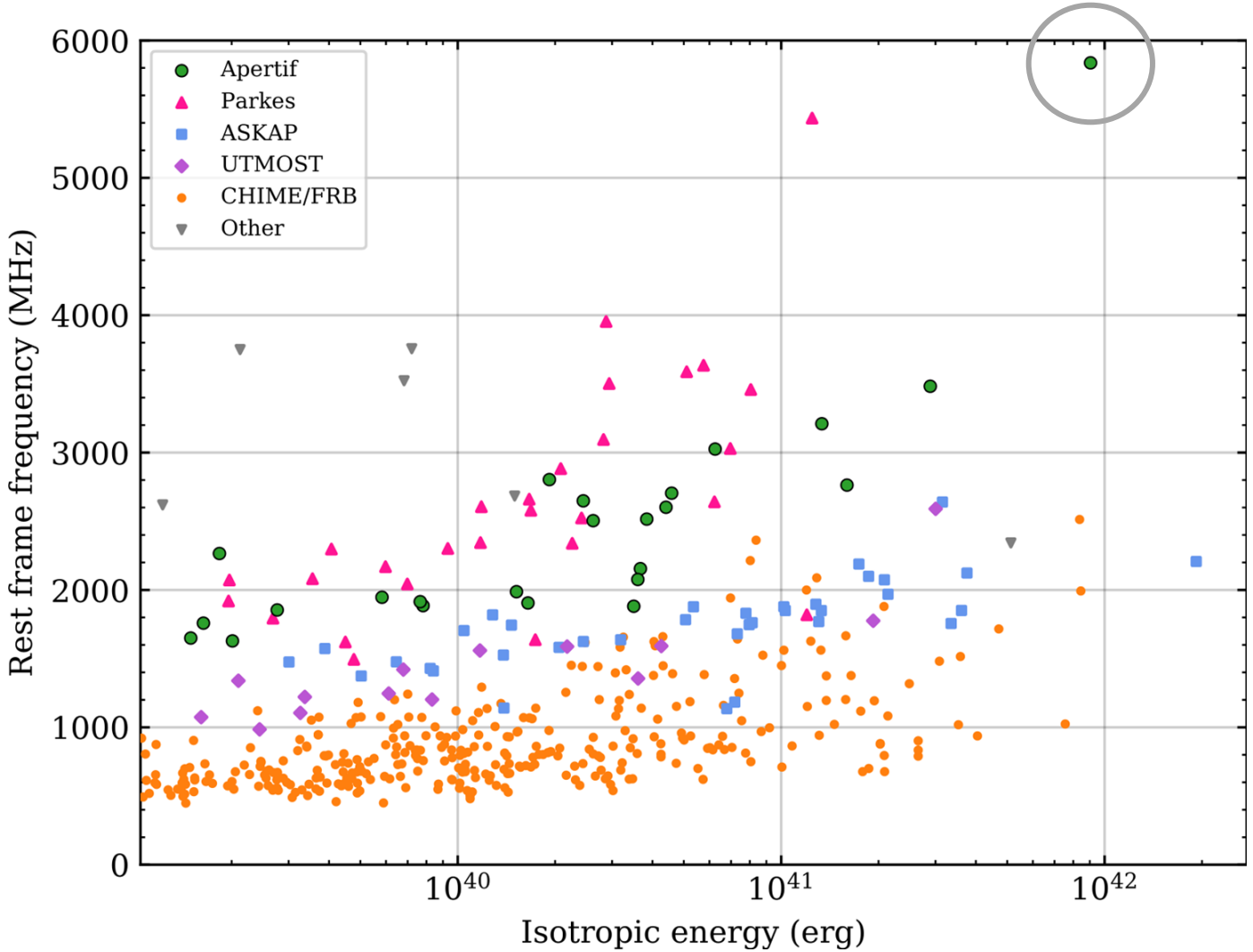


Van Leeuwen et al. 2022 (arxiv:2205.12362)

Characteristics of the discovered sample

FRB 20200719A is the 3rd most dispersed FRB known to date, and its rest frame shows FRB emission frequencies reach 6 GHz.

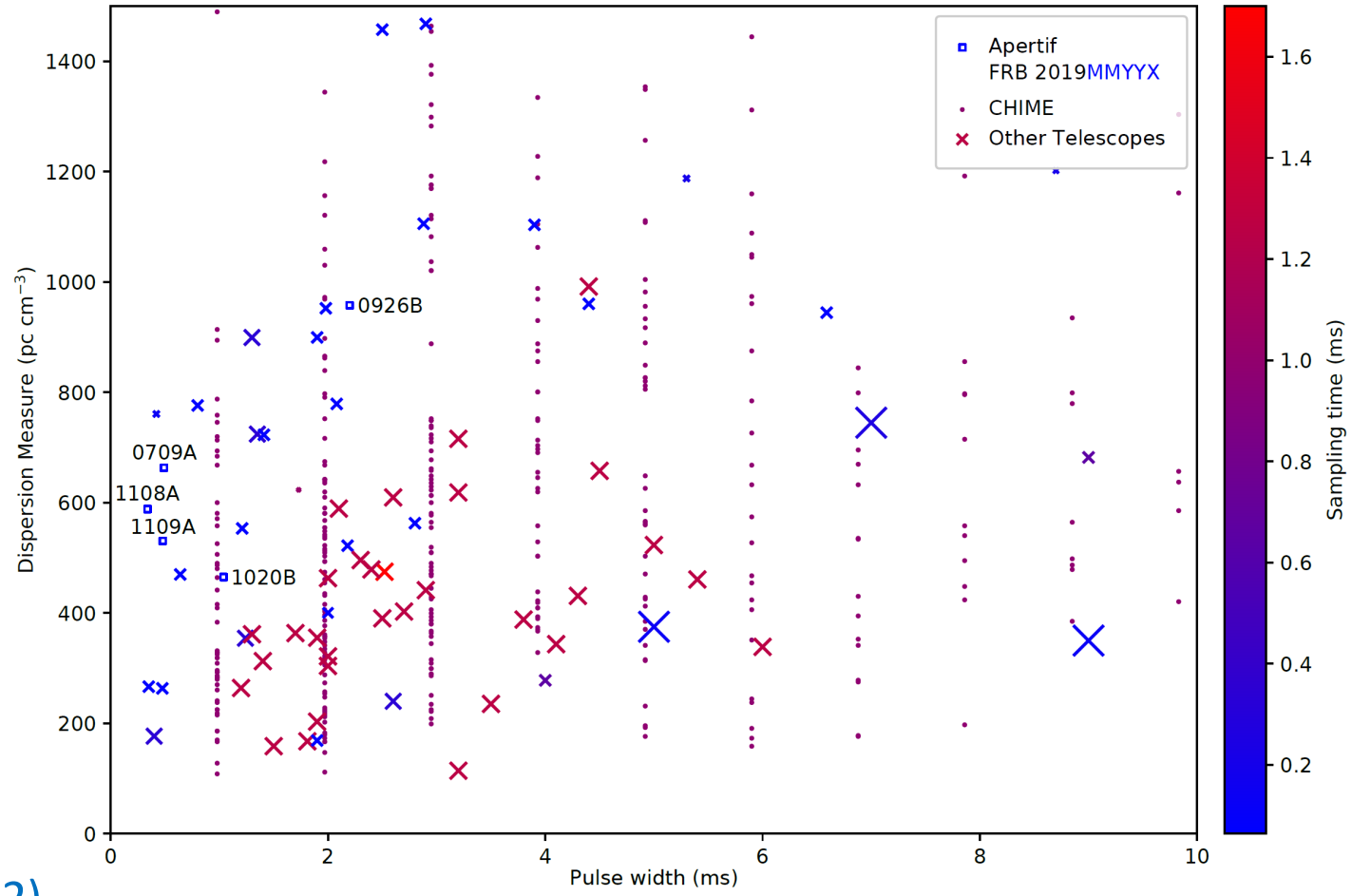
High-freq. FRB models, searches?



Pastor-Marazuela, vL, et al 2022 *in prep.*

Characteristics of the discovered sample

The Apertif FRBs are among the narrowest known, and have high dispersion measure.



Van Leeuwen et al. 2022 (arxiv:2205.12362)

Intrinsic FRB Characteristics

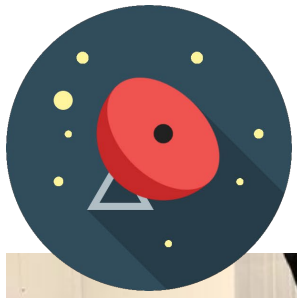
Order-of-magnitude speedup of **`frbpoppy`**

\+

National supercomputer “Snellius”

=

Full MCMC

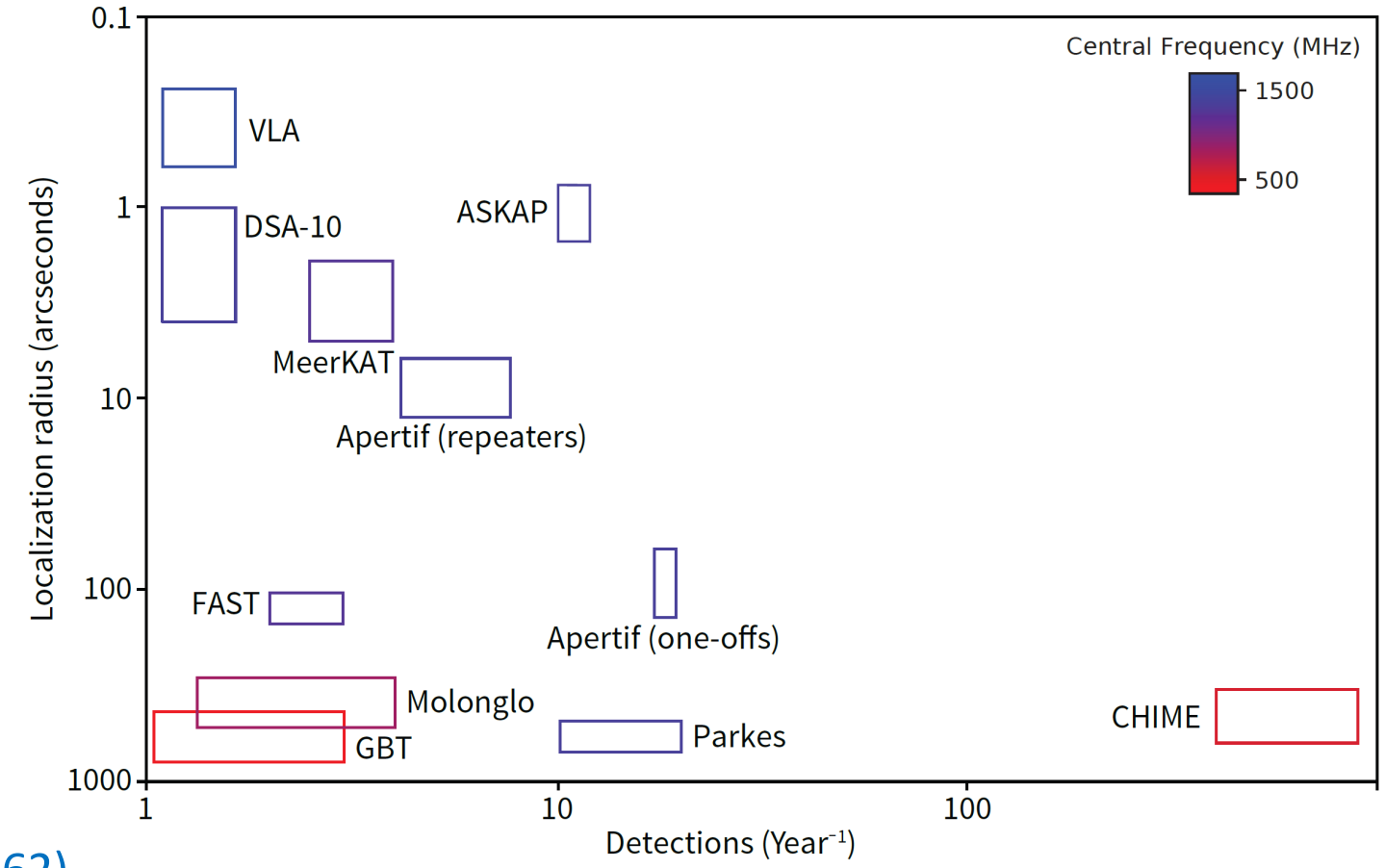


frbpoppy

Gardenier & van Leeuwen 2021
Yuyang Wang, vL, et al. *in prep*

Survey detection rate and localisation

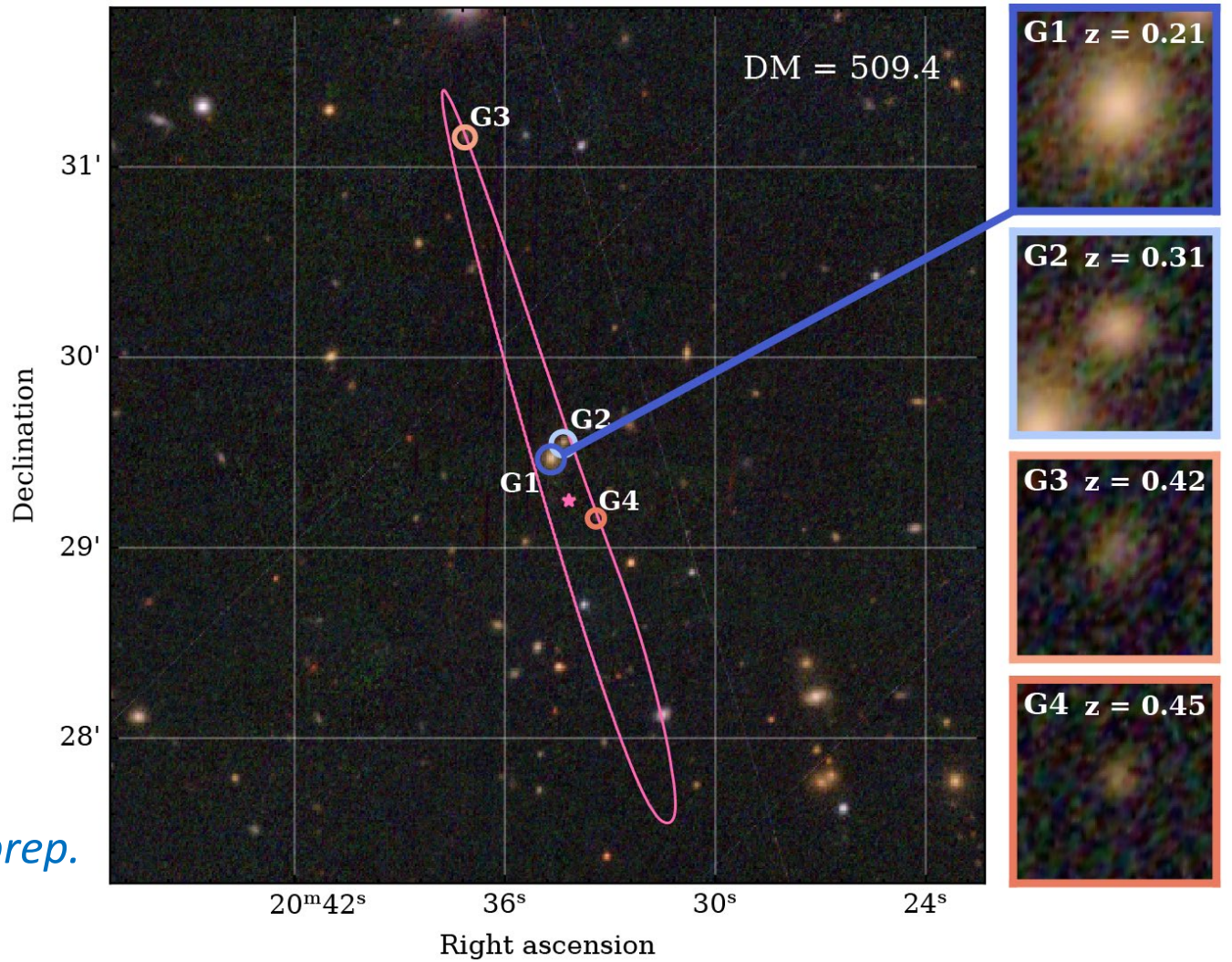
ASKAP, CHIME and Apertif each have their own trade off between rate and localisation accuracy, with Apertif providing both.



Van Leeuwen et al. 2022 (arxiv:2205.12362)

Survey detection rate and localisation

Interferometric host detection to $z = 0.21$:



Pastor-Marazuela, vL, et al. 2022 *in prep.*

Conclusions

The Era of Interferometers

Full coherent-addition sensitivity over entire Apertif field of the view.

Detecting 1 FRB every 7 days of observing.

We discovered 24 one-off FRBs, with good localization.

We found pseudo-periodic structure, from a magnetar magnetosphere?

Combination of solid rates + mapping magneto-ionic material along well-defined lines of sight.

European Research Council
Established by the European Commission
NWO
ASTRON
netherlands eScience center
NOVA

Future ?

The Era of Interferometers – Continued

Farewell Apertif Surveys 1.0. Stopped operations in March 2022.

What next, for WSRT2023+ ?

Extend array to 2D, with baseband buffer system ?
Real-time AI w/ slaved connection to LOFAR ?
..

European Research Council
Established by the European Commission