

FRB overview



Cherry Ng-Guihéneuf (LPC2E/CNRS) || Atelier FRB et Neutrinos @IAP (Nov 27-28, 2023)

- Intenses ($< 10^{44}$ erg s $^{-1}$)
- Extra-galactiques ($\sim 0.03 > z > 1$)
- Abondants ($\sim 5,000$ /ciel/jour)

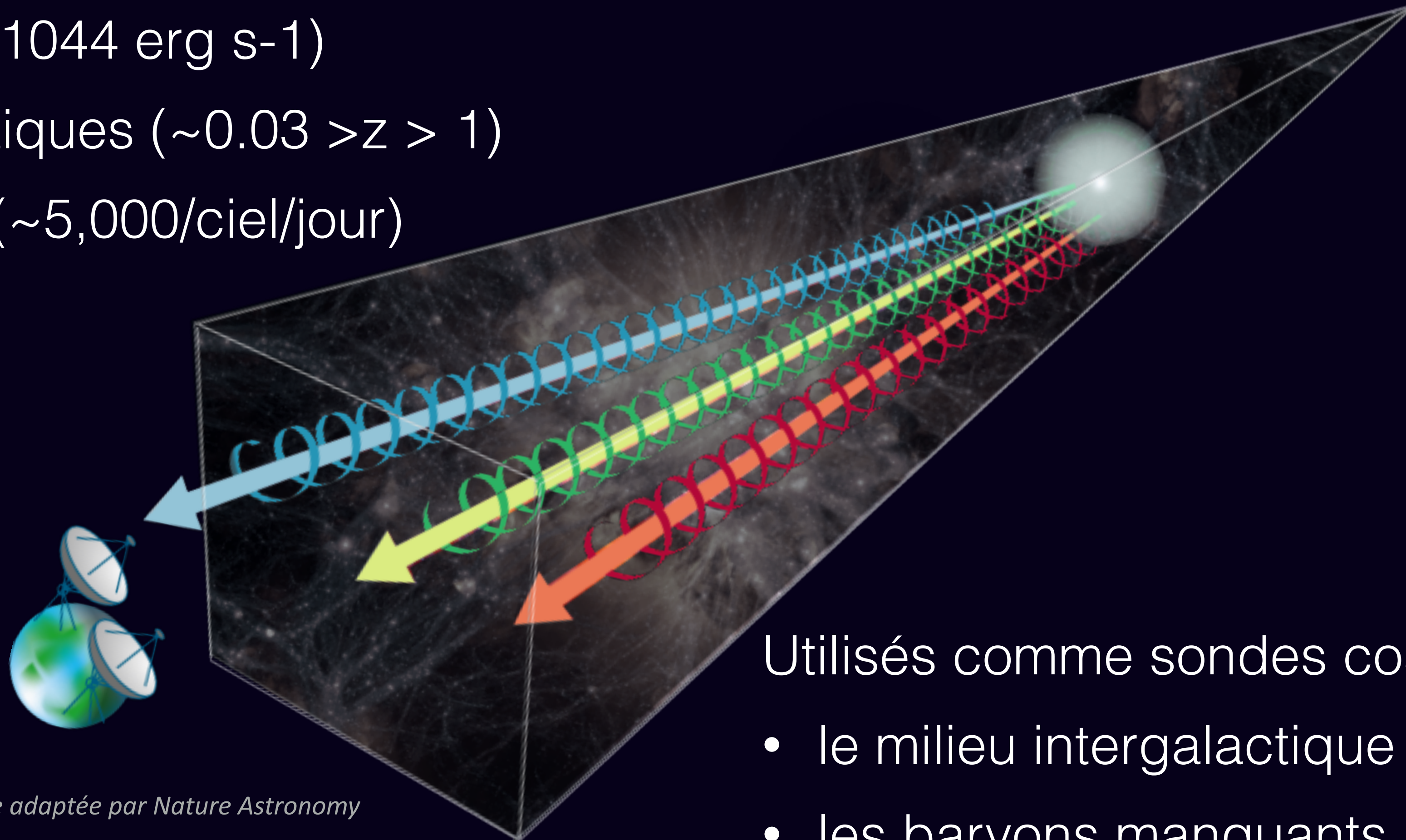


Image adaptée par Nature Astronomy

Utilisés comme sondes cosmologiques pour:

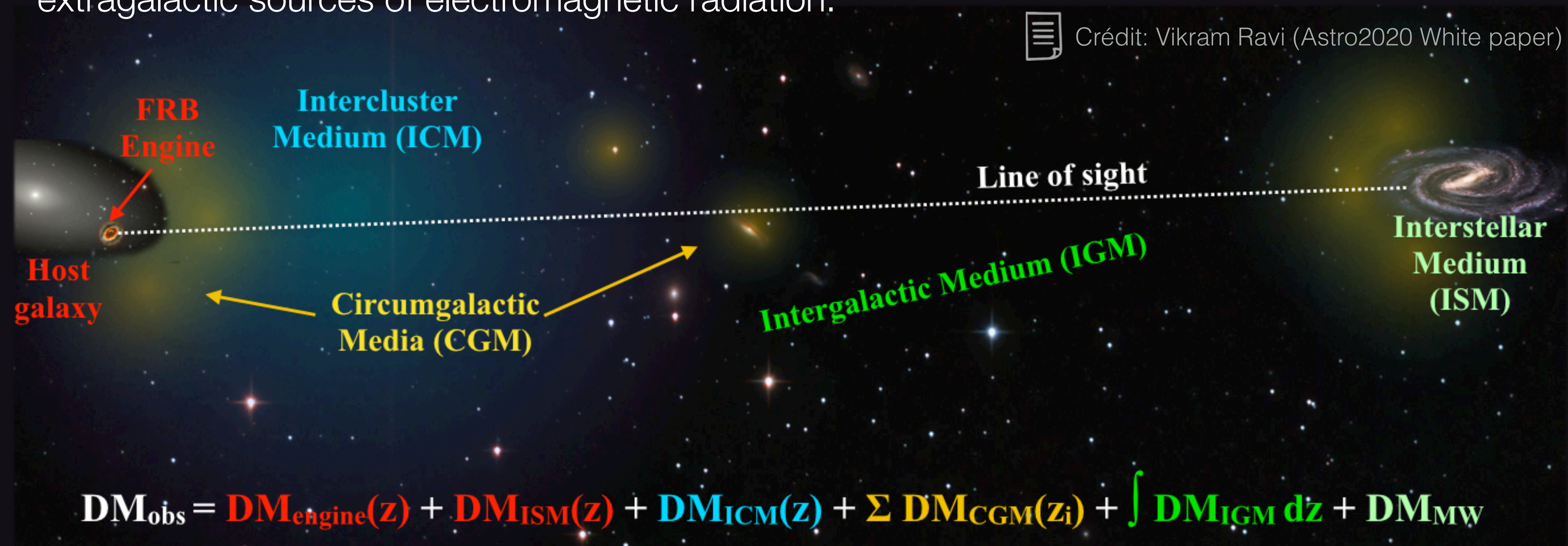
- le milieu intergalactique
- les baryons manquants

FRB as a probe for the Universe

FRBs are the shortest-duration extragalactic transients, and the most compact known extragalactic sources of electromagnetic radiation.



Crédit: Vikram Ravi (Astro2020 White paper)



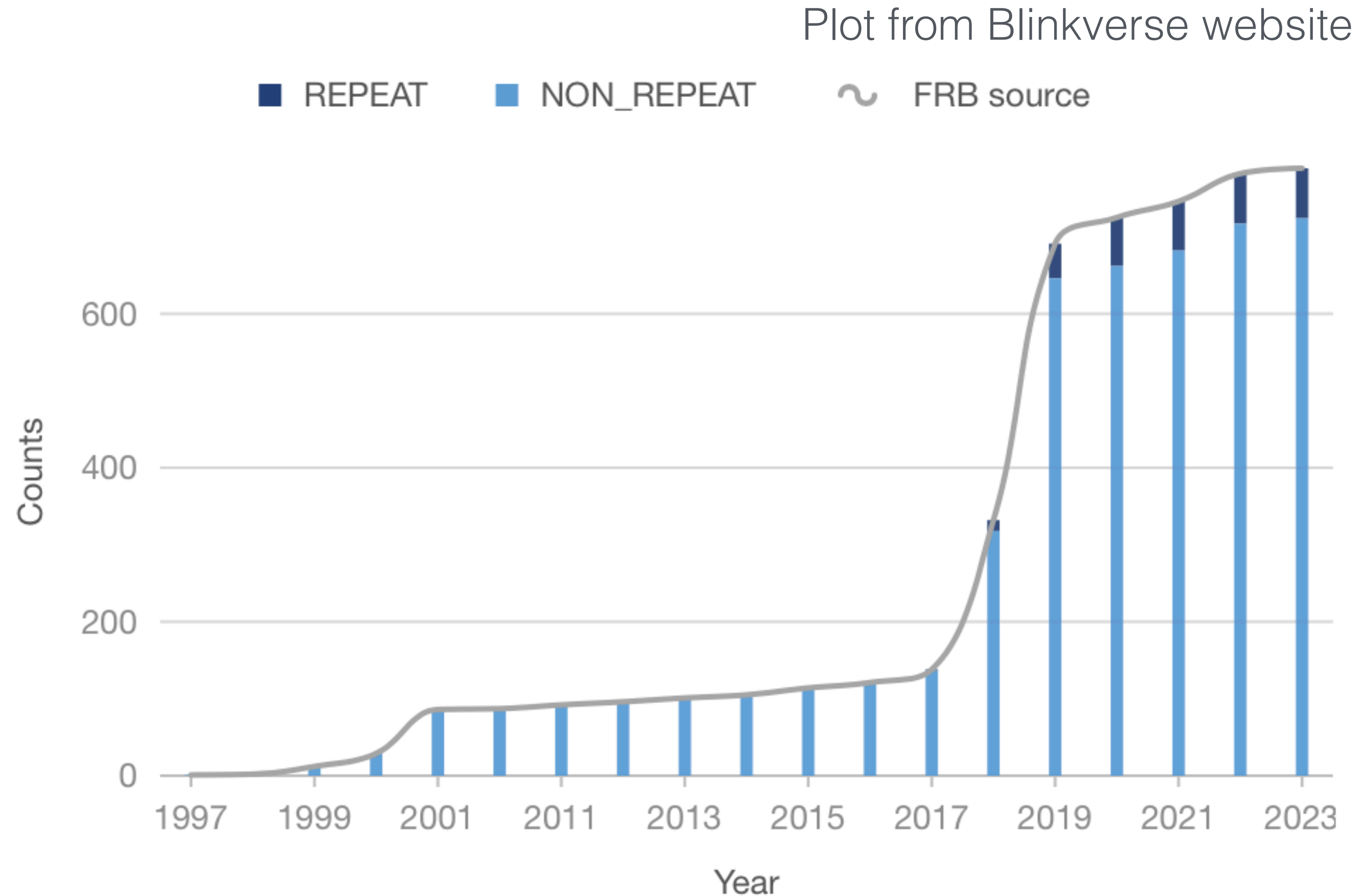
—> FRB provides a clean signal to study these otherwise very hard to probe components

Observational parameters

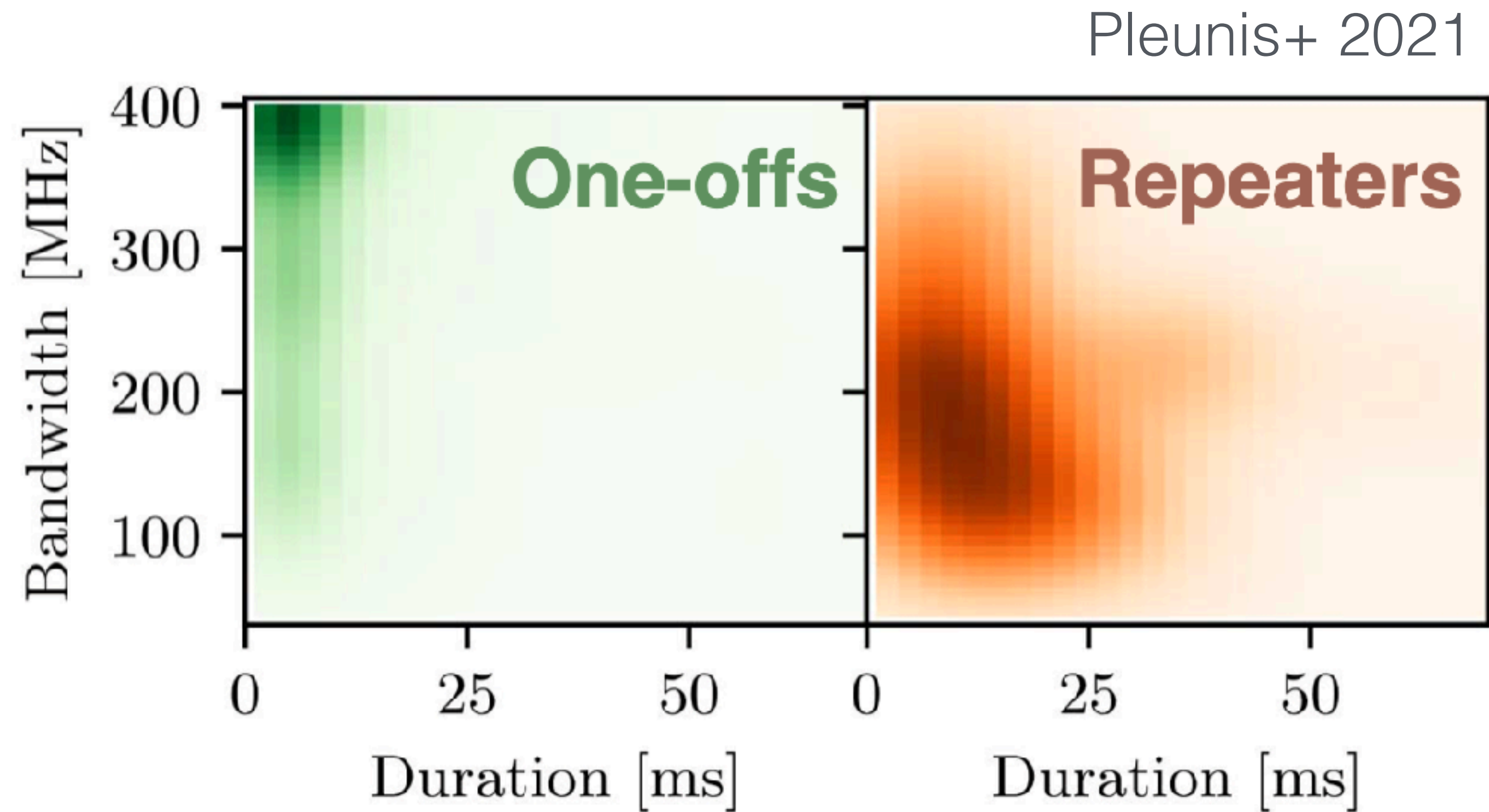
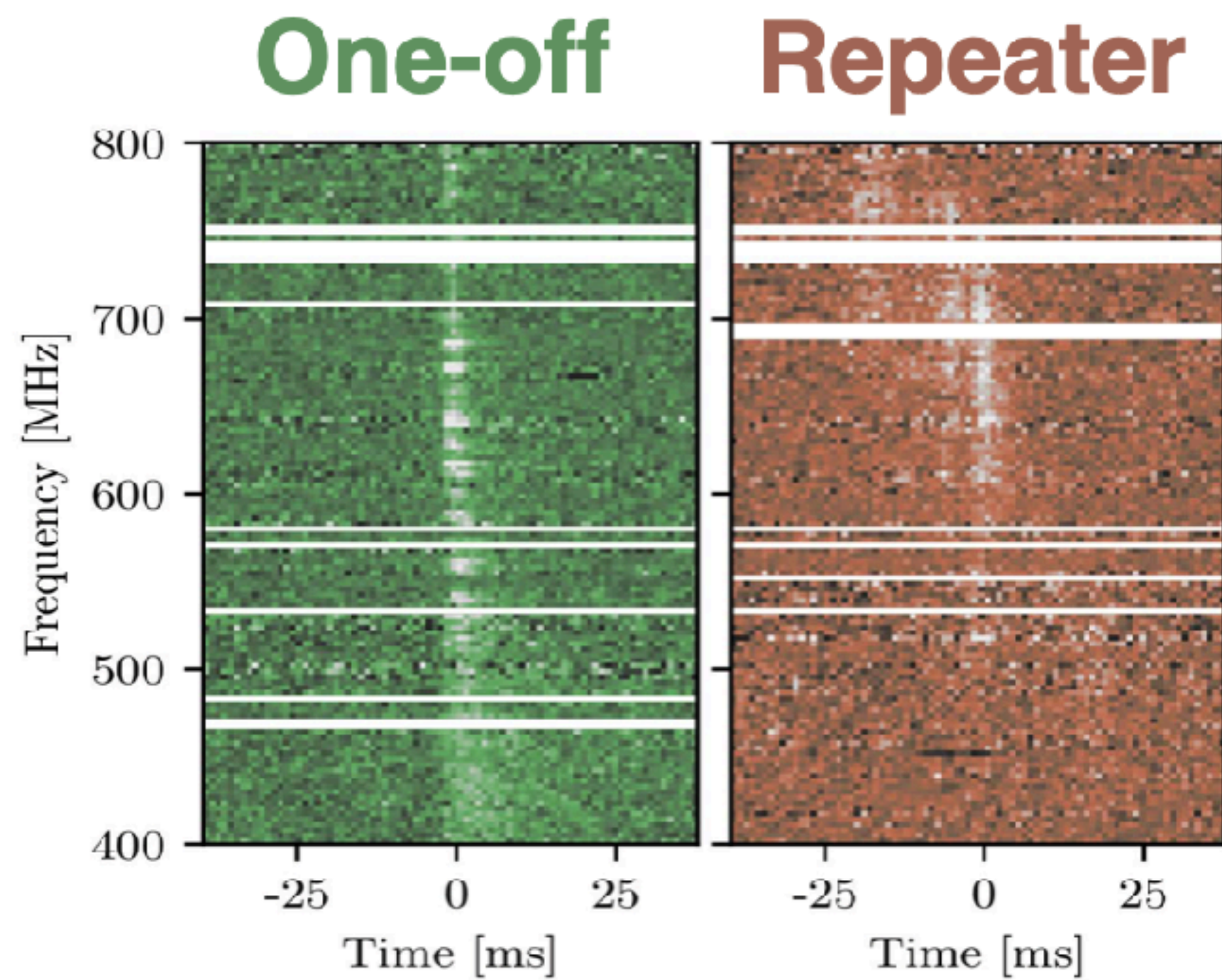
Repetition, periodicity, timescale, luminosity, emission
frequency range, polarization

Source count

- Published FRBs = 789
 - 724 non-repeaters
 - 65 repeaters (~8%)
- Plus over 4000 not-yet published

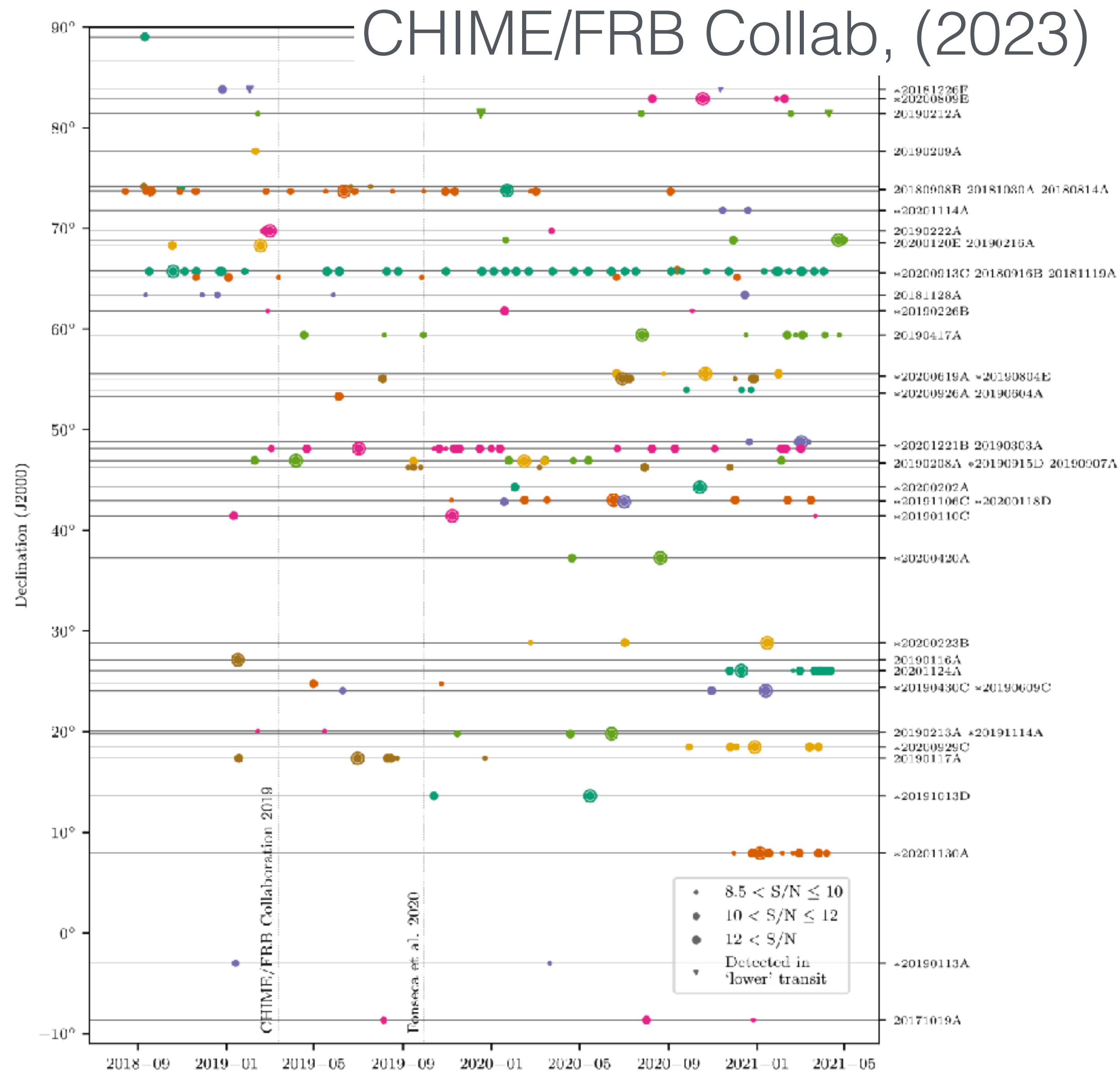


Multiple population



- Repeaters tend to have wider burst width and a narrow emission band compared to one-off FRBs.

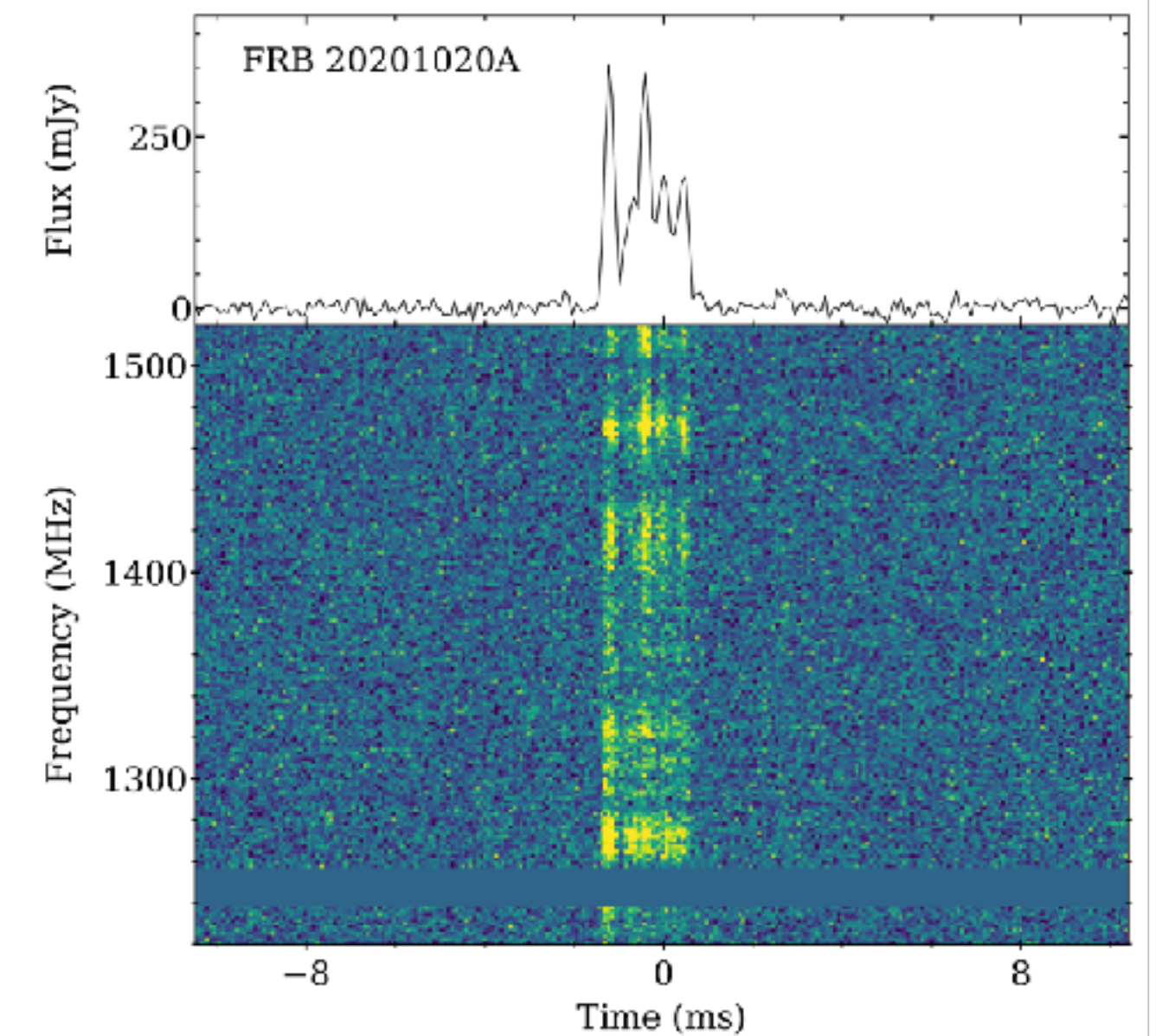
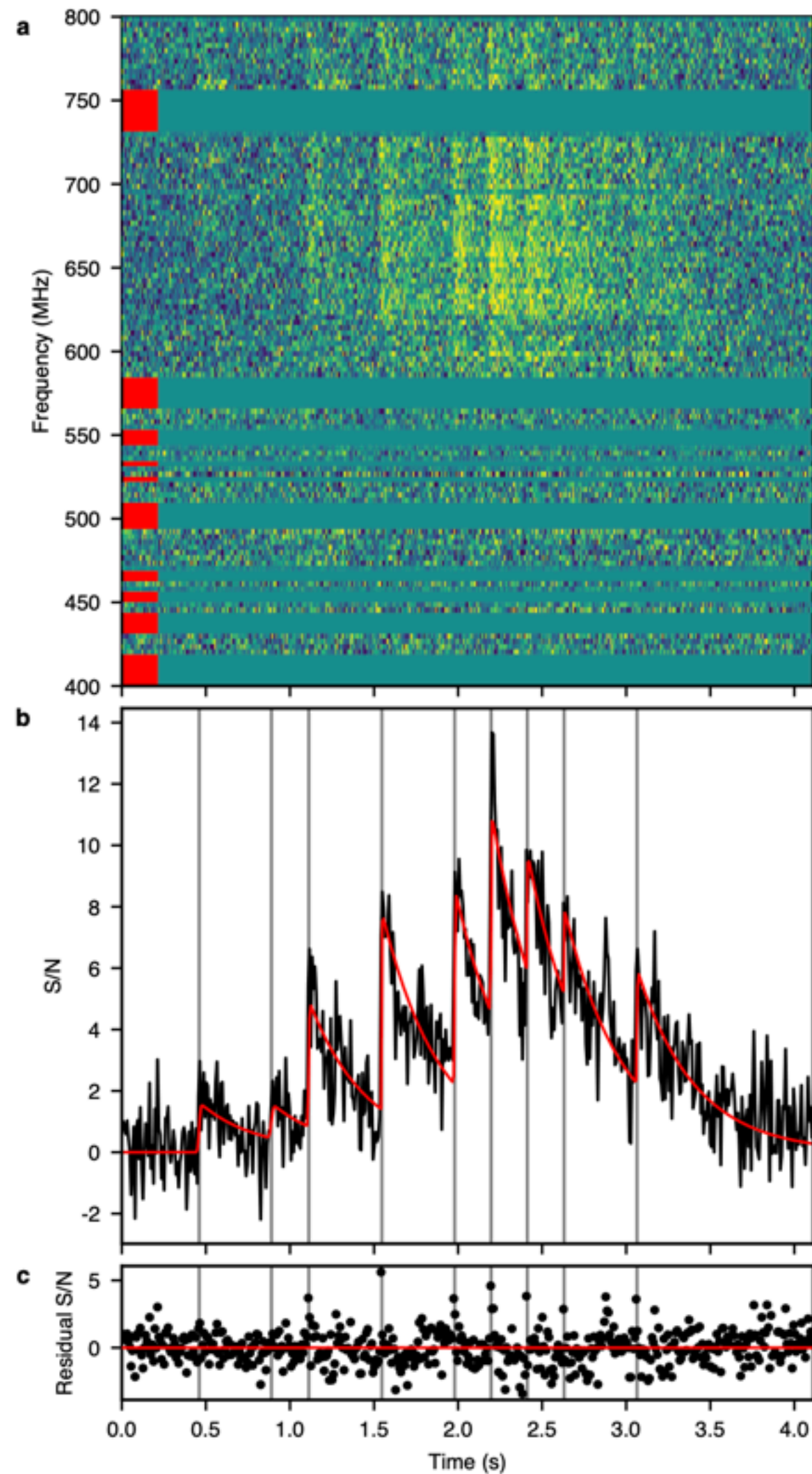
Repeating FRBs



- CHIME repeater database: <https://www.chime-frb.ca/repeaters>
- Clustering in time and energy distribution
- Periodicity:
 - 16 days for FRB 20180916 (CHIME/FRB Collab, 2020, Pastor-Marazuela+, 2021)
 - ~160 days for FRB 20121102A (Rajwade+2020, Cruces+2020)
 - ~50 days for FRB 20190417A but disappearing (FAST team, in prep)

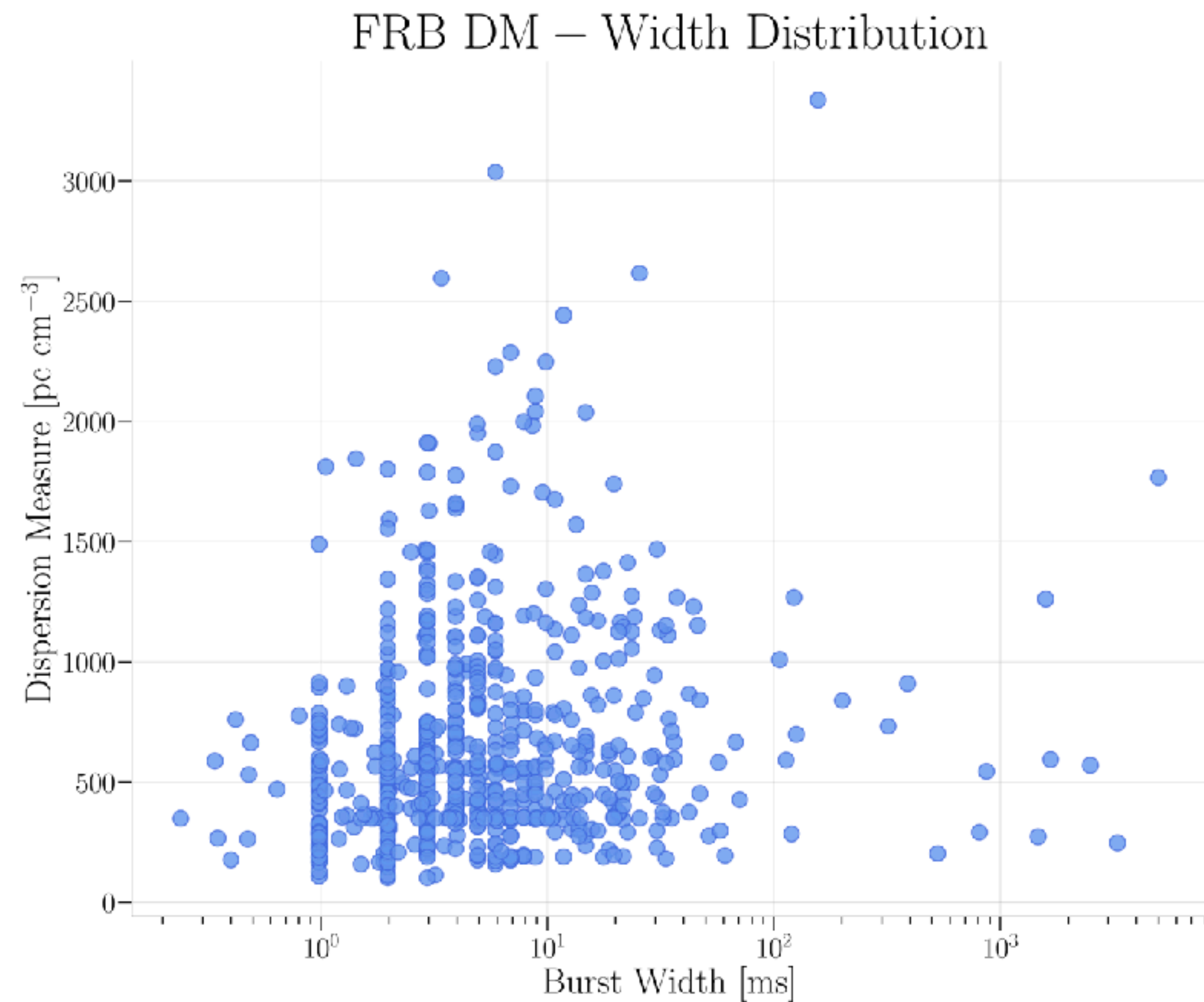
Sub-second periodicity

- CHIME: FRB 20191221A with 216.8(1) ms periodicity in ~3 s long burst
—> suggest NS magnetosphere?
- Apertif: FRB 20201020A with 0.411 ms periodicity
- ASKAP: 7.28ms (Dial+, in prep)

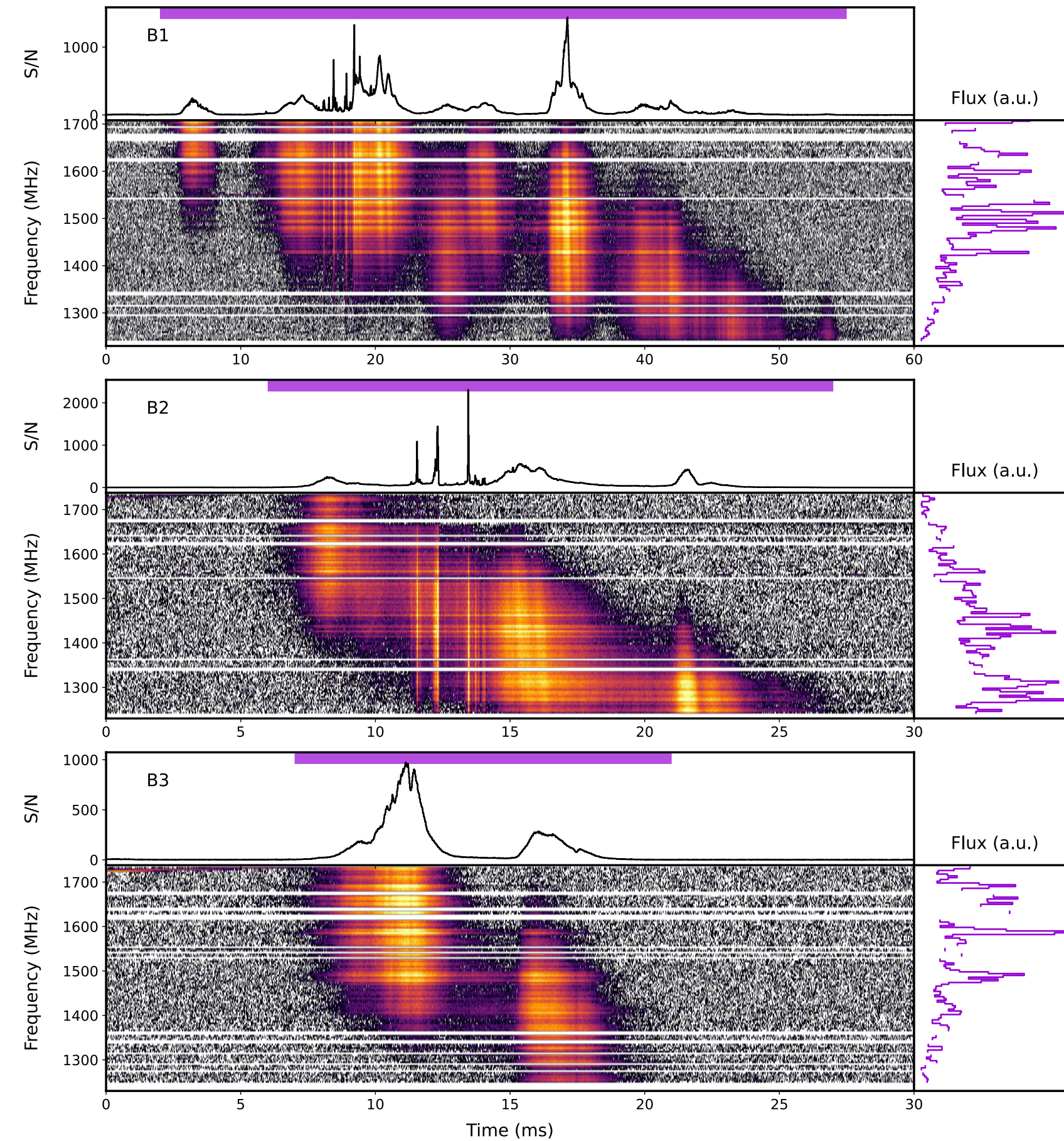


Burst width range

Plot from frbstats website



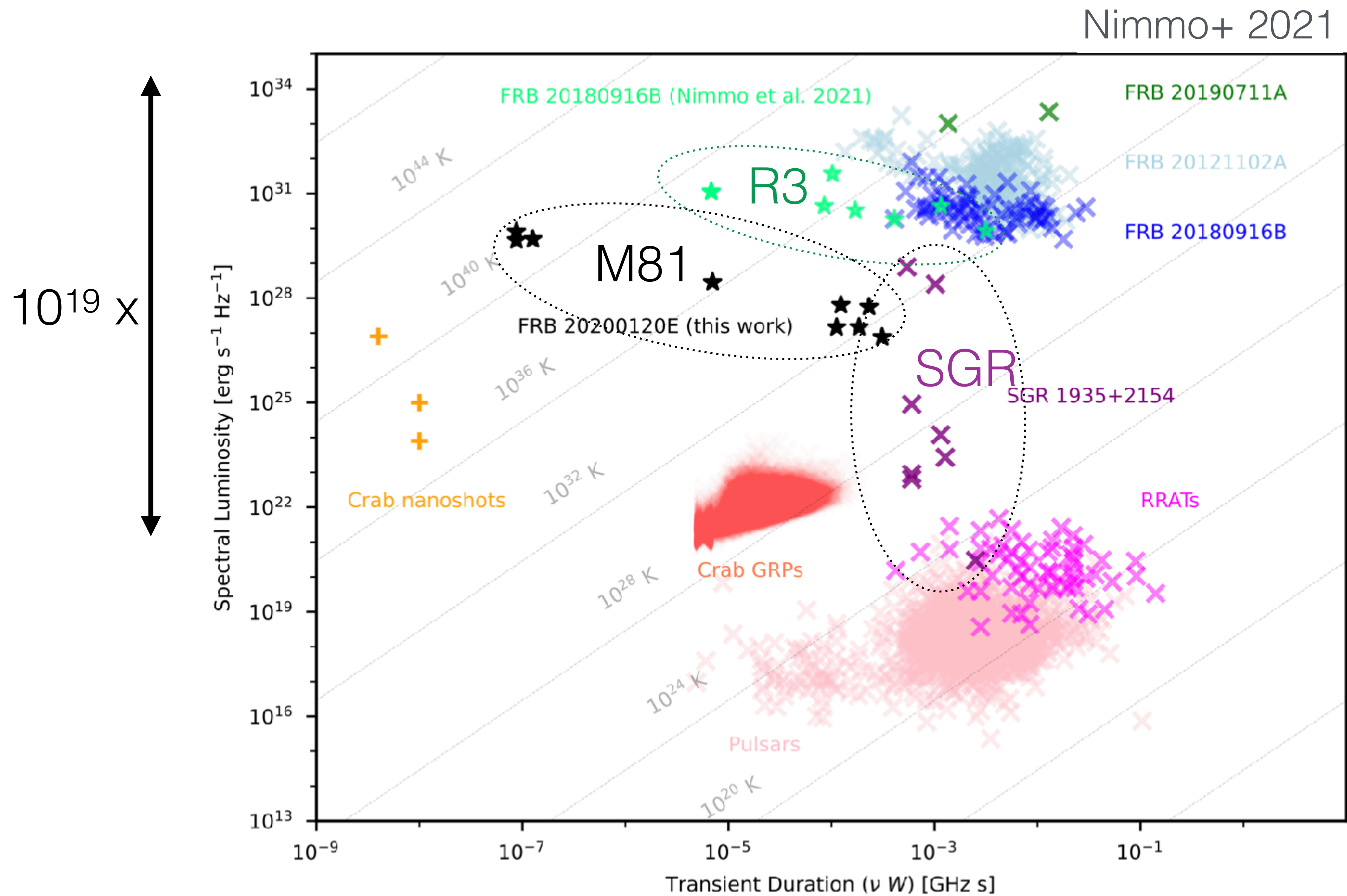
- Burst width range from sub-ms to few seconds



Hewitt+Cognard+
2023

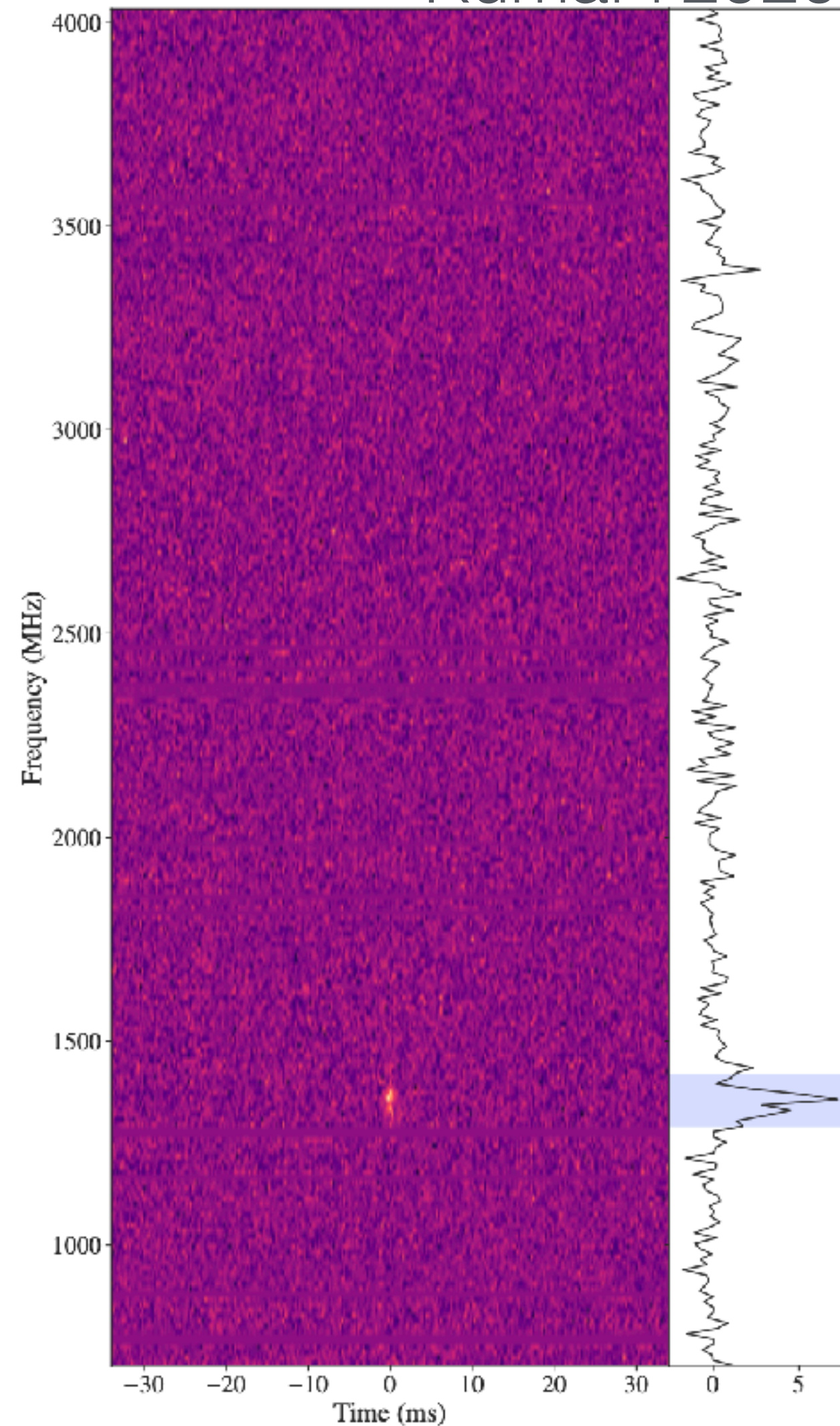
- Microshots of tens of μs seen in FRB 20220912A with the Nançay radio telescope, similar to solar flare?

Spectral luminosity



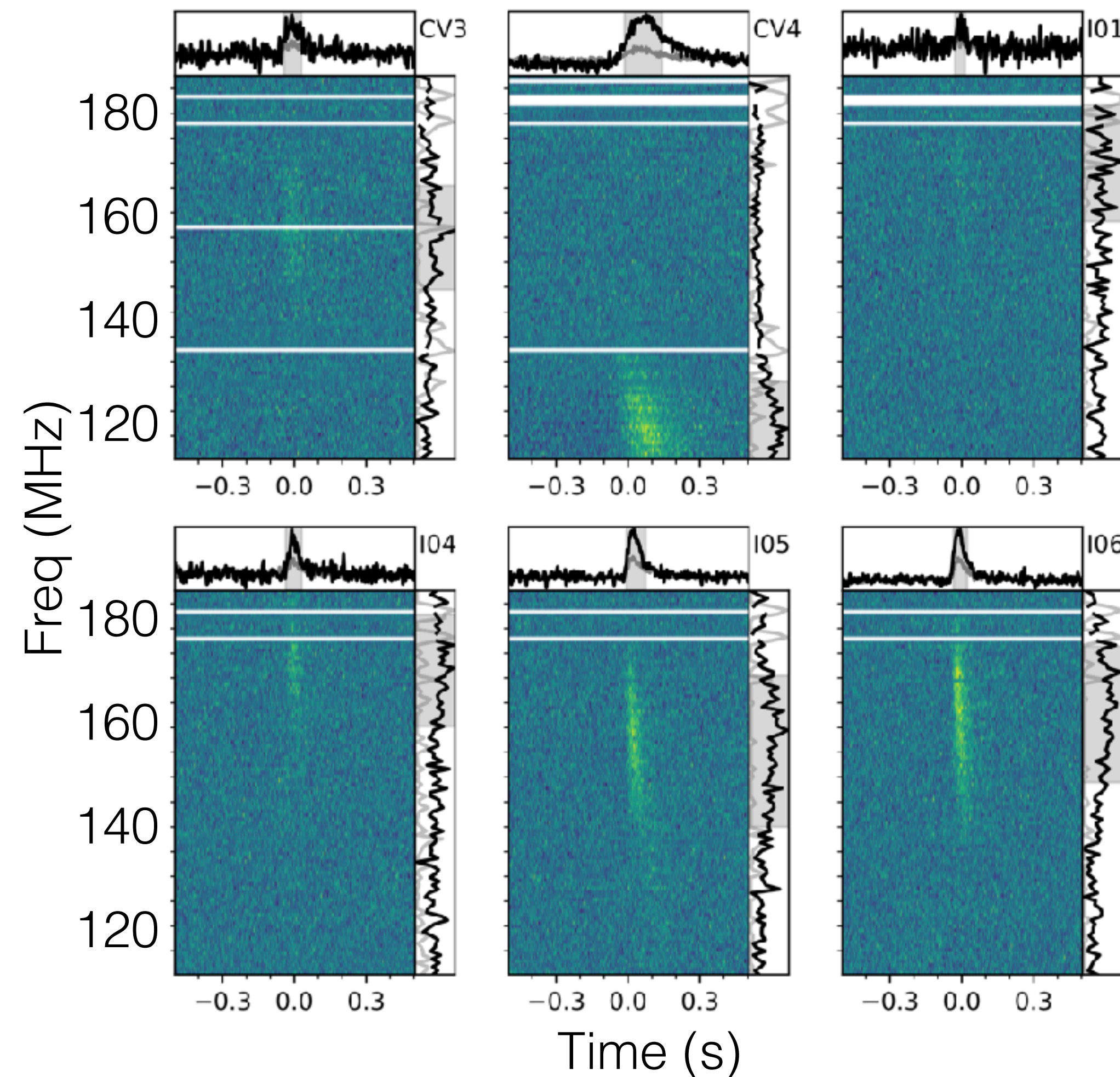
Narrow band emission

Kumar+2020



Repeater FRB20190711A

Pleunis+ (2021)

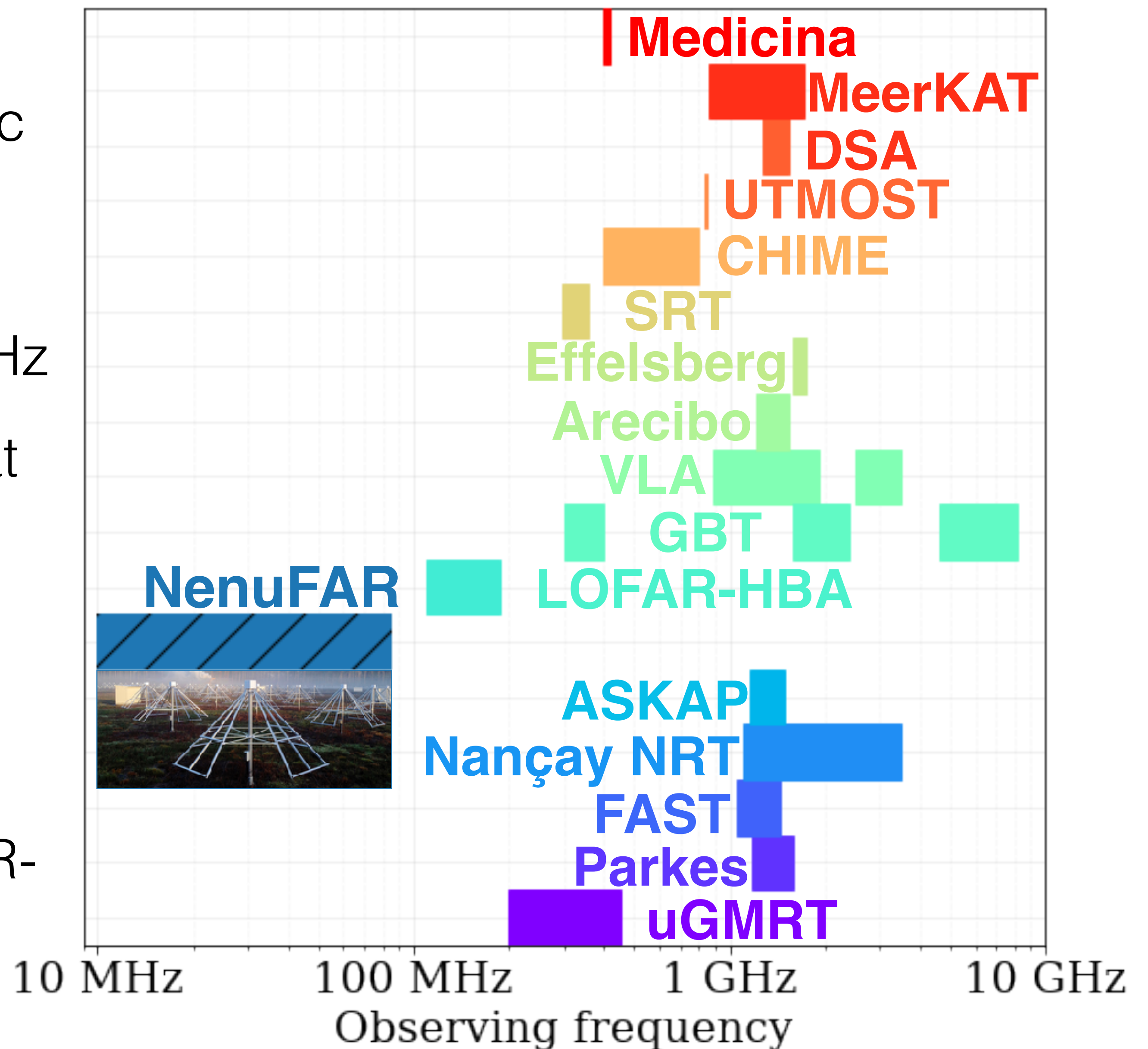


Repeater FRB20180916B



- FRB can be extremely band limited, e.g. UWL receiver detection from Parkes of FRB20190711A.
- Also repeaters seen with LOFAR and CHIME.
- Apparently the second FRB detected by LOFAR was only found in ~ 20 MHz subtended search (Gopinath+, in prep)
- Good to have broad-band receiver but might want to also search with limited band

FRB emission frequencies

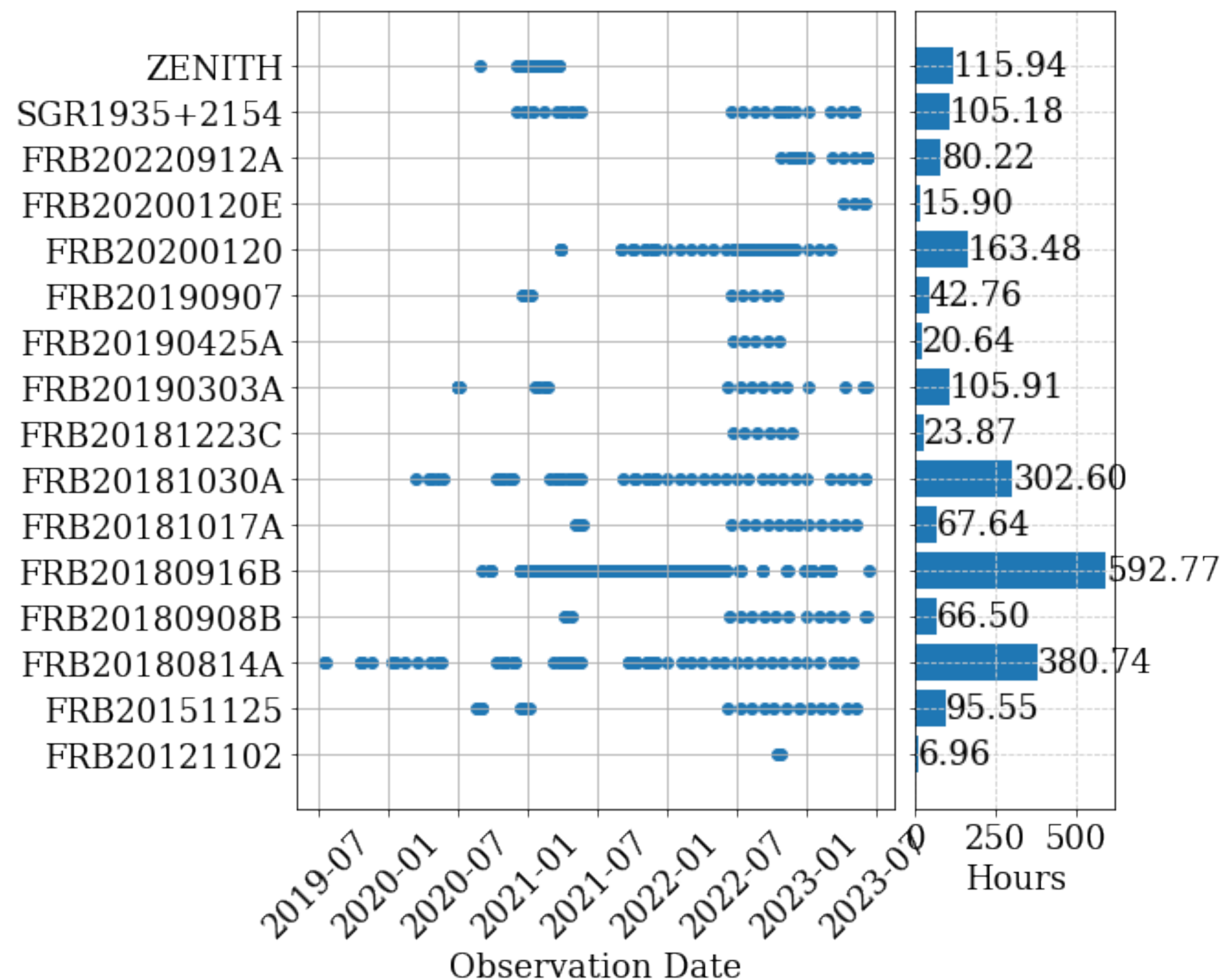
- no conclusive multi-wavelength counterparts yet, except the Galactic magnetar FRB
- So far detected by 16+ radio telescopes between 110 MHz - 8 GHz
- NenuFAR can open a new window at low frequencies — study emission mechanisms
- Low freq detection particularly good for cosmology (clean)
- But seems quite challenging: LOFAR-HBA only detected 2 FRBs so far



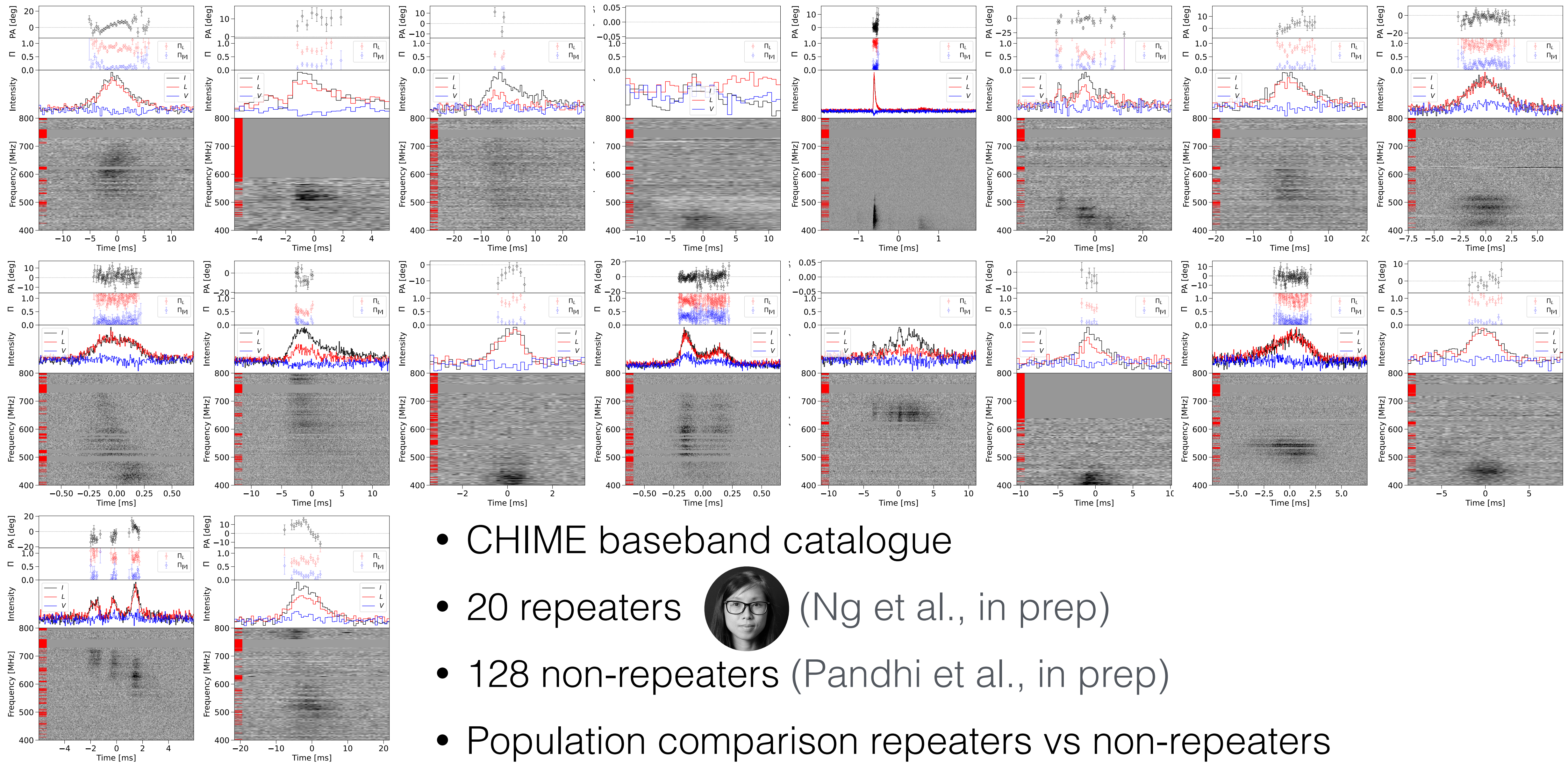
Campaign with NenuFAR

- Program led by  Valentin Decoene with collaboration from  Philippe Zarka and the Orléans team
- Monitoring 11 repeaters
- >500 observation (>200 hours)
- Initial analysis did not find anything
- Next: sub-band search and ML
- Possibility of triggered observations?
Low-frequency emissions arrive systematically some days after higher frequencies

Summer student Gaspari
+ Ng+ Griessmeier



CHIME polarization study

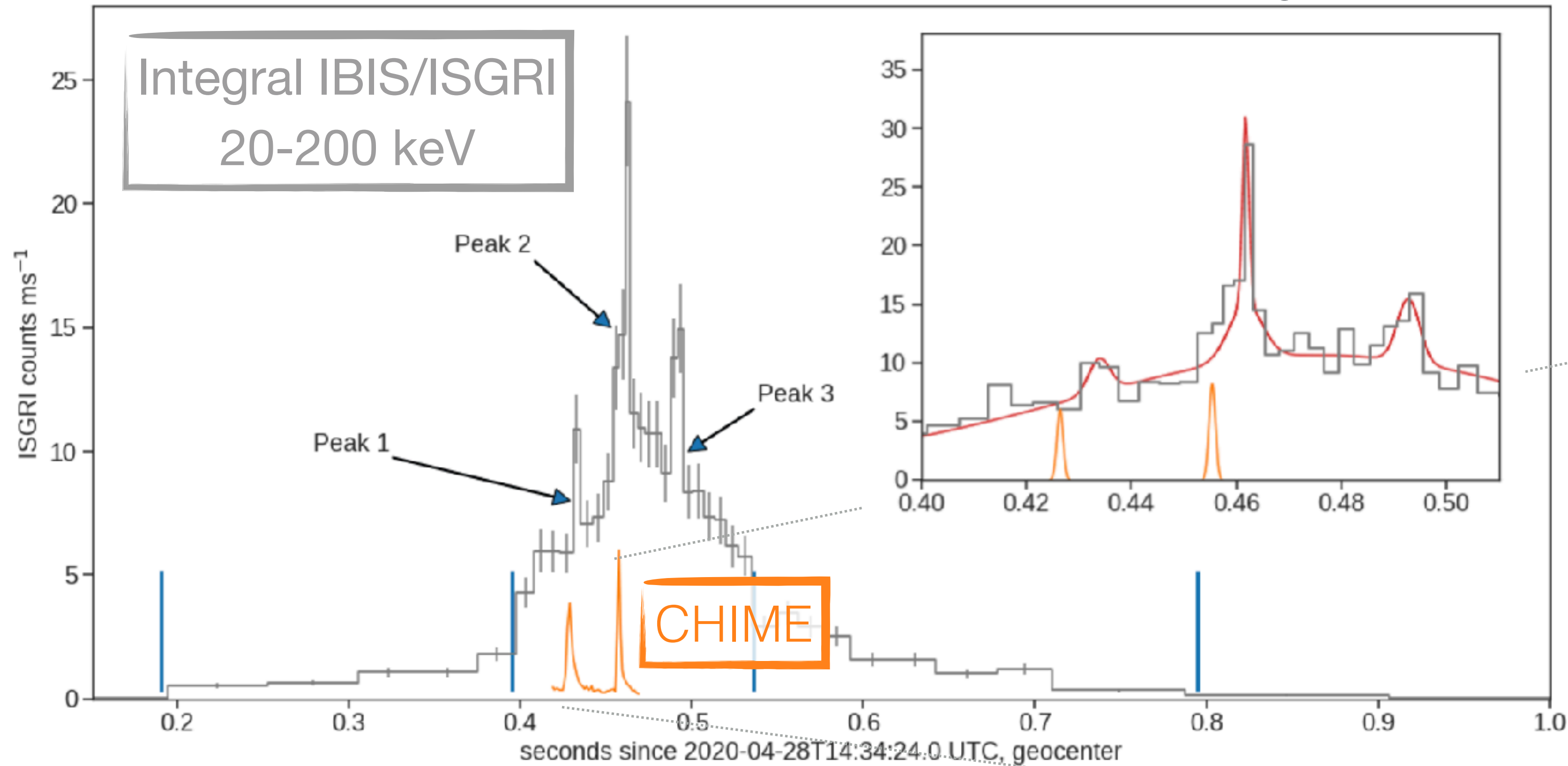


Origin of FRBs

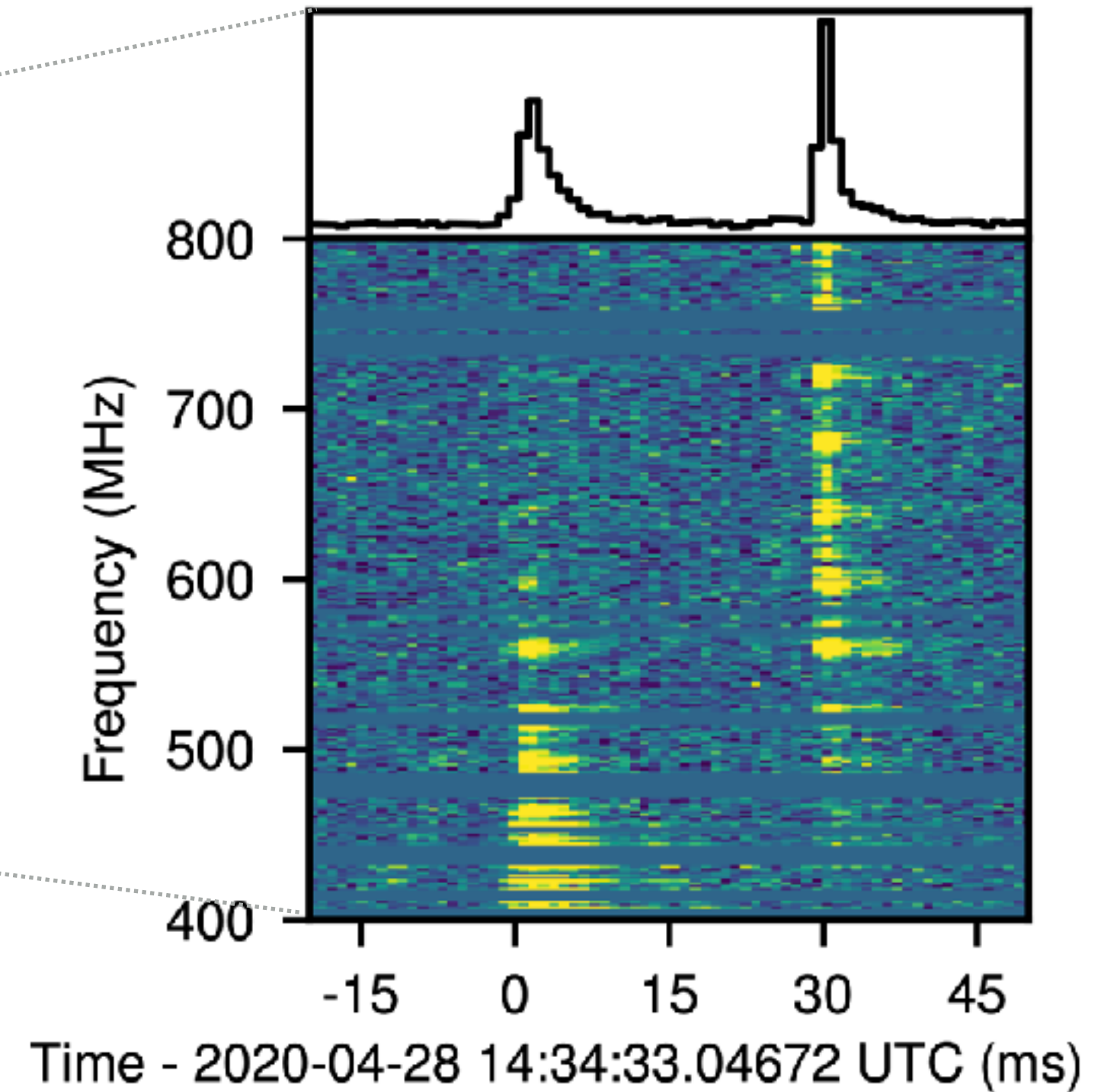
Multi-wavelength observations, Host galaxy and local environments

Magnetar SGR 1935

Mereghetti et al. 2020






collab. CHIME/FRB, 2020



- Également détecté par NICER, Chandra, XMM, Swift XRT (rayons X), Swift BAT, Fermi, NuSTAR, Integral (rayons Gamma)
- Le pic de rayons X survient 6,5 ms après le pic radio

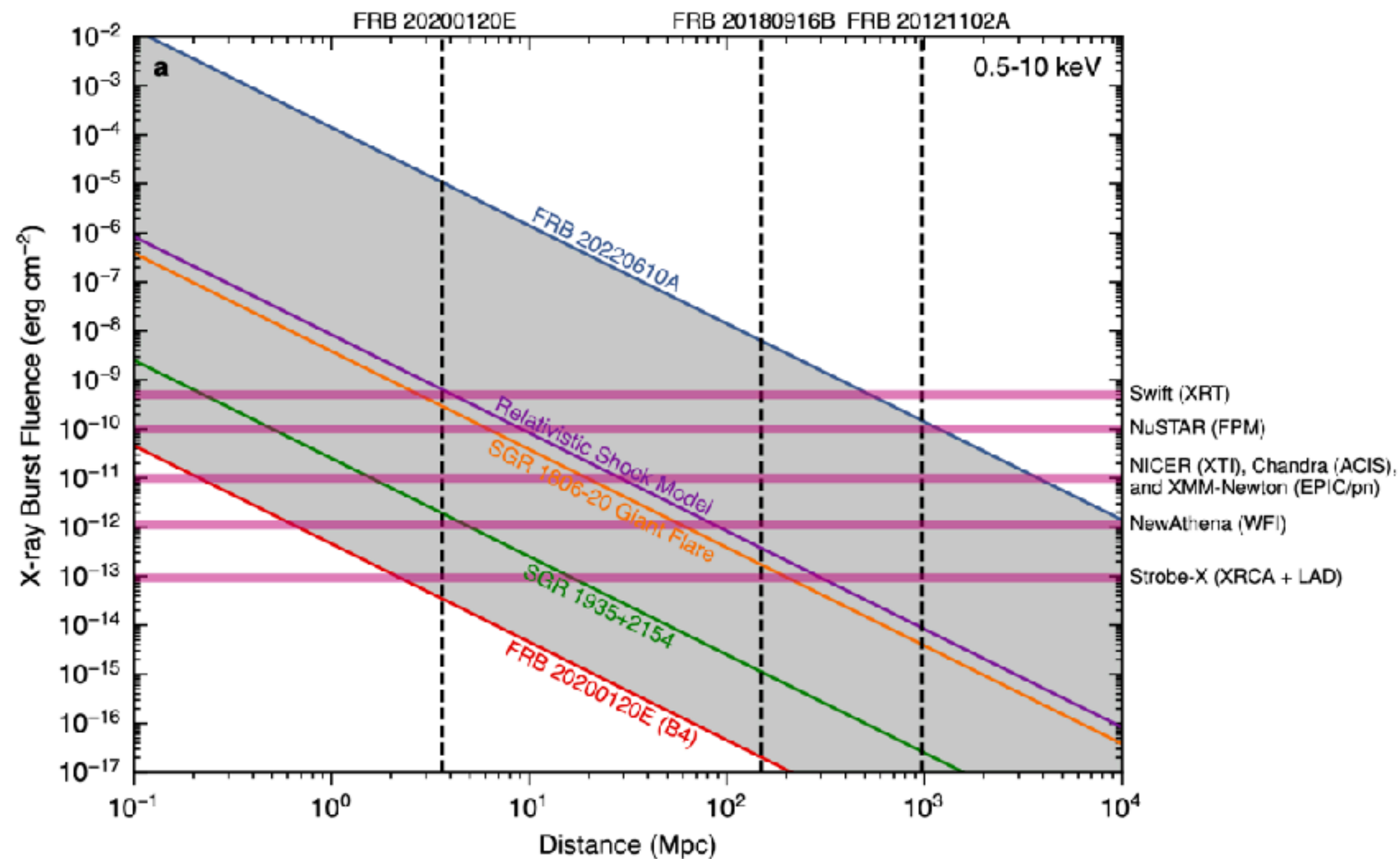
Multi-wavelength campaigns (non-exhaustive list)

- Multi-telescope campaign for bona-fide (prompt) counterparts
 - Shadow a radio telescope, e.g. MeerKAT + MeerLITCH ← first simultaneous observation (no positive detection)
 - FRB121102 campaign (NRT, Integral, OHP...) by Christian Gouiffes,  Michel,  Ismaël,  Cherry...
 - X-ray campaign (see next page)
 - Look for coincident CHIME and past GRB detections (Curtin+2022) — no positive detections
 - Deeper Wider Faster: over 50 facilities, targeting transients « proactively », not only FRBs
- Coordinated photometric and spectroscopic follow-up for host galaxy study → F4 collaboration (Keck, Gemini, VLT, Hubble, ALMA, Chandra, VLA, Magellan)

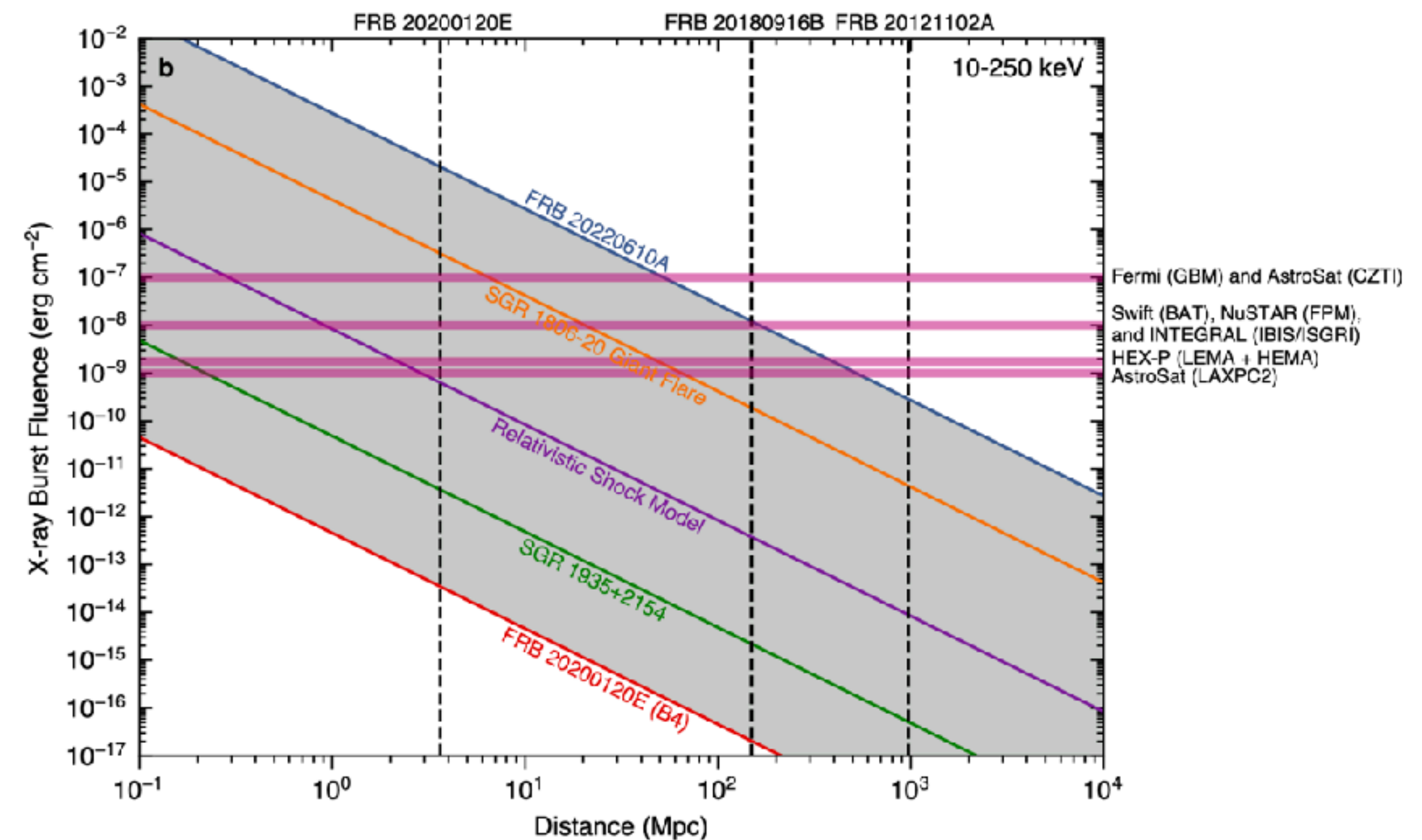


Low DM, nearby FRBs

- 18 FRBs with $z < 0.1$ \leftarrow most promising candidates for MW detections?
- Pearman+2023 conducted deep x-ray campaign on FRB 20200120E in Globular cluster (no positive detection)
 - \rightarrow current and future soft X-ray telescopes are promising for detecting FRB < 10 Mpc, hard X-ray is probably too weak



predicted X-ray burst fluences in the soft energy band (0.5–10 keV)



predicted X-ray burst fluences in the hard X-ray band (10–250 keV)

FRBs host galaxy associations

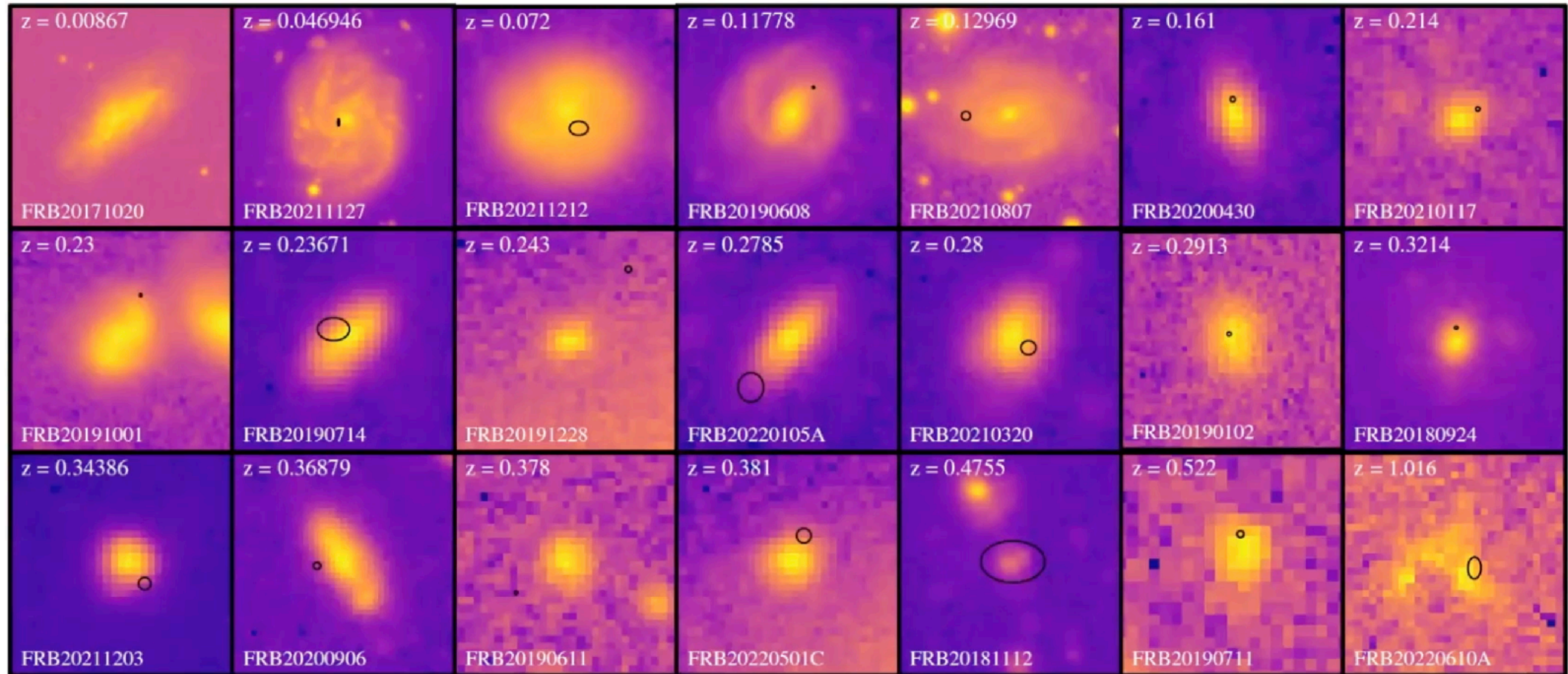
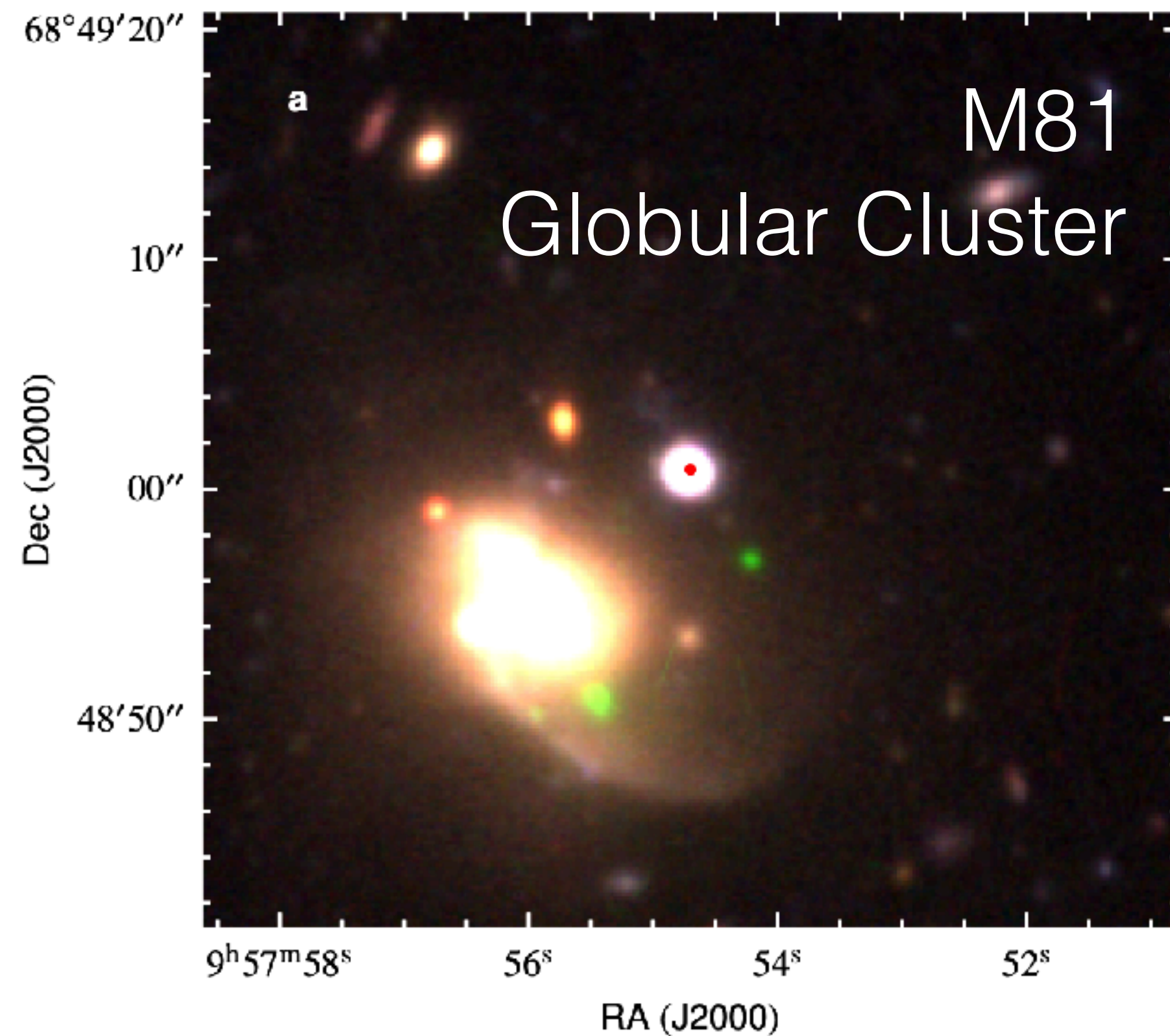


Image de Lachlan Marnoch

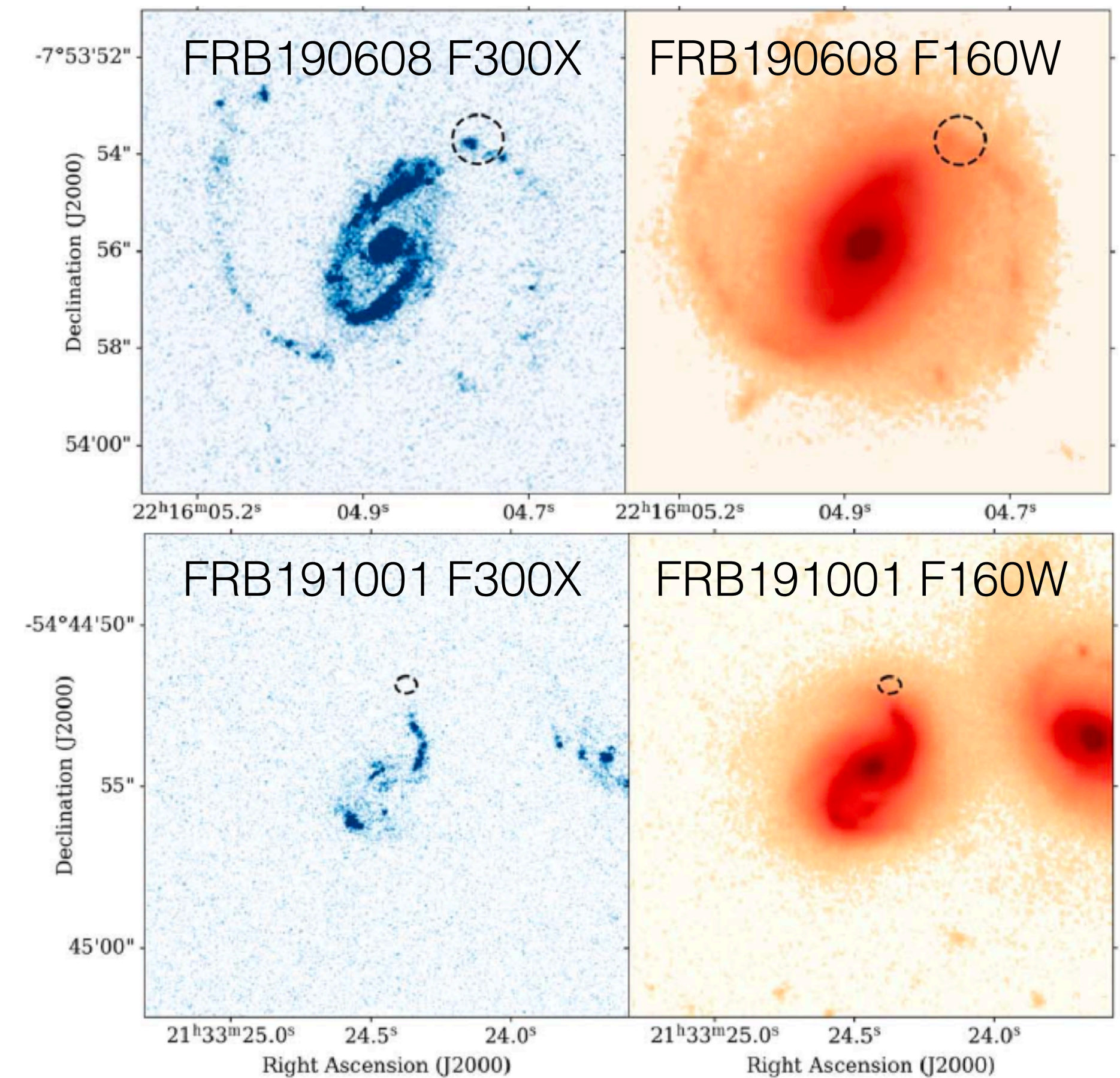
- >40 associations de galaxies hôtes
- Principalement des galaxies en spirales (star forming galaxies), mais aussi des galaxies lenticulaires

Local environment

Kirsten et al., 2021

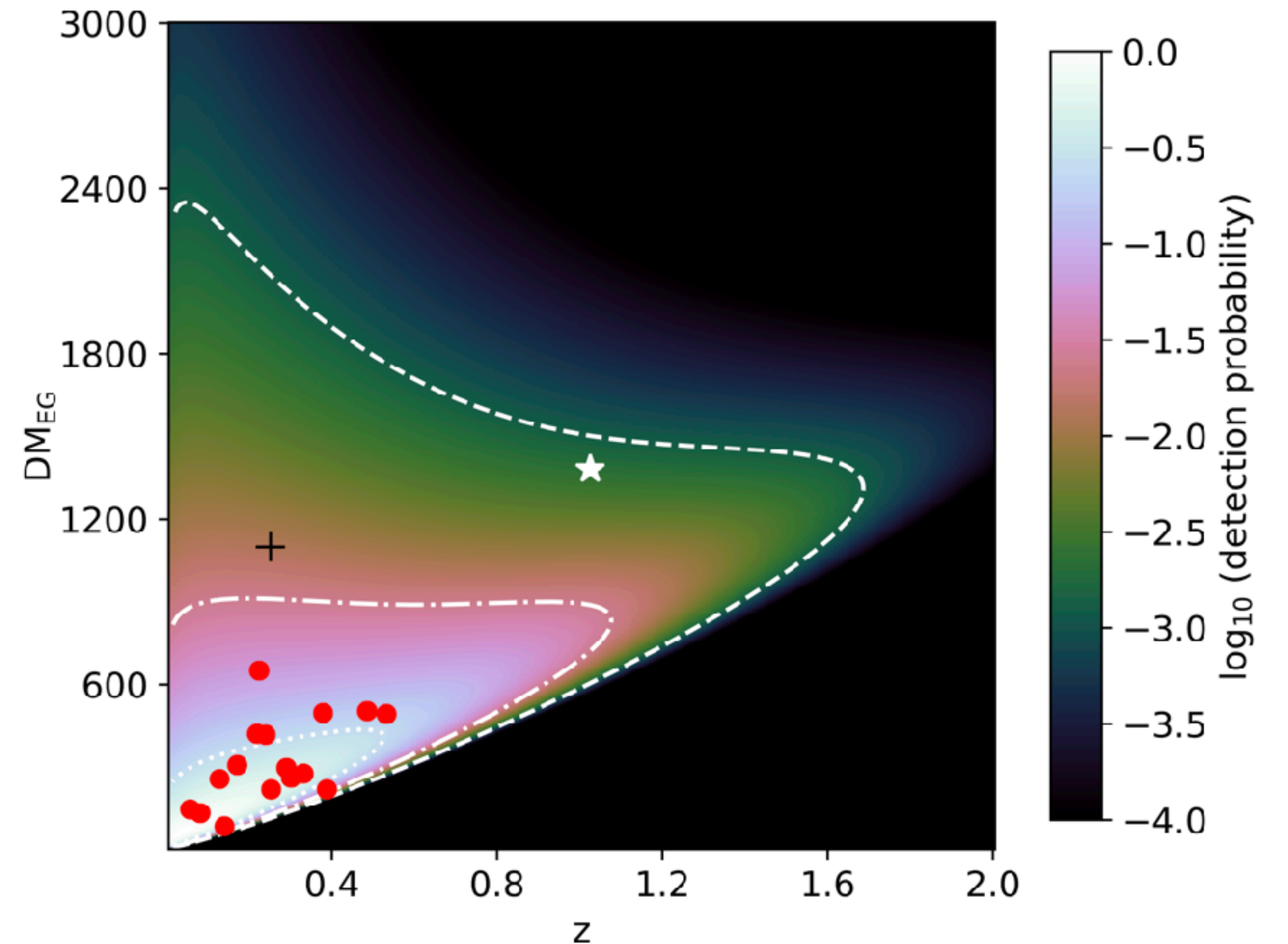
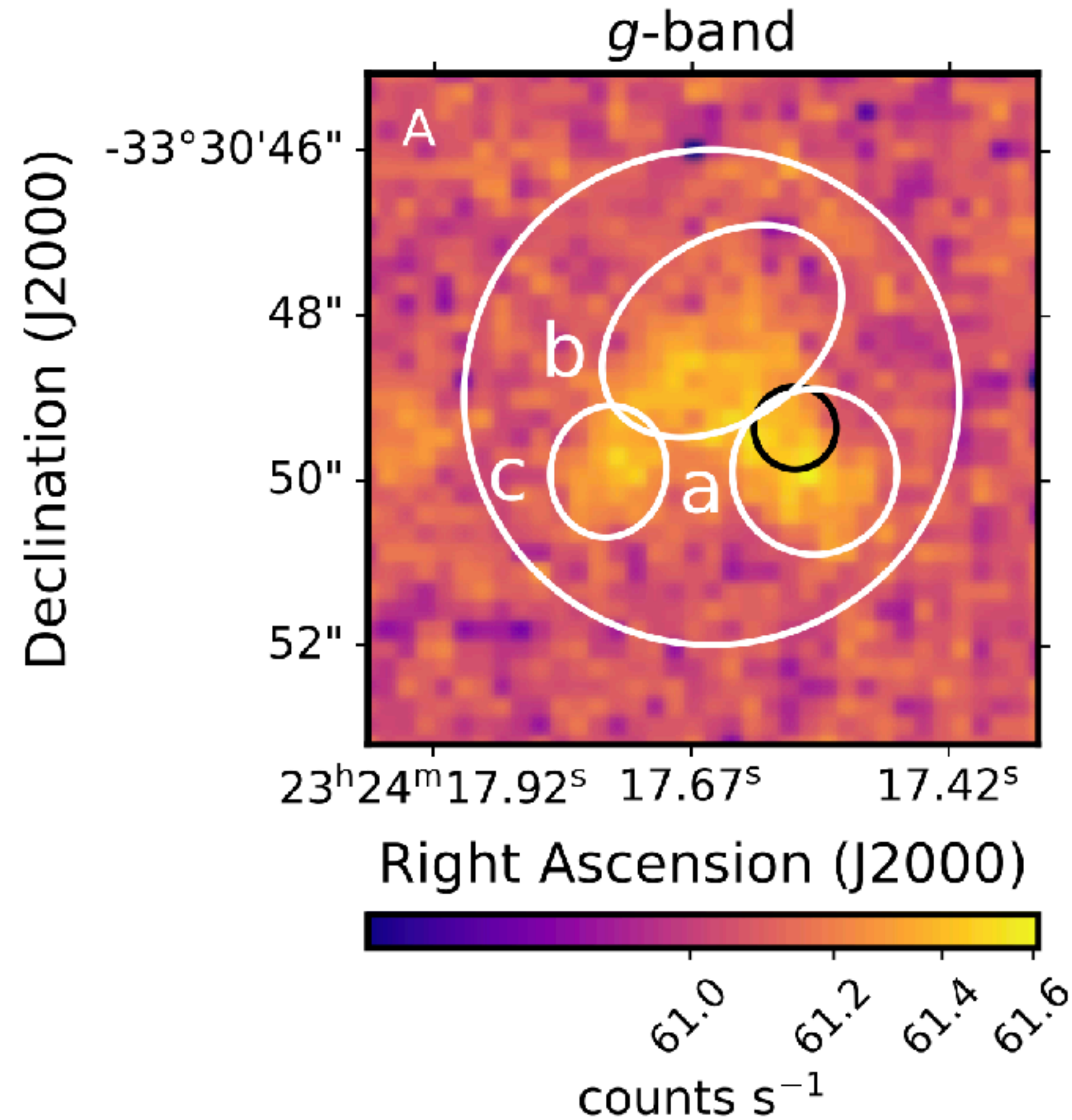


Mannings et al., 2021



Les FRBs proviennent de divers environnements locaux au sein des galaxies hôtes, et pas toujours au centre.

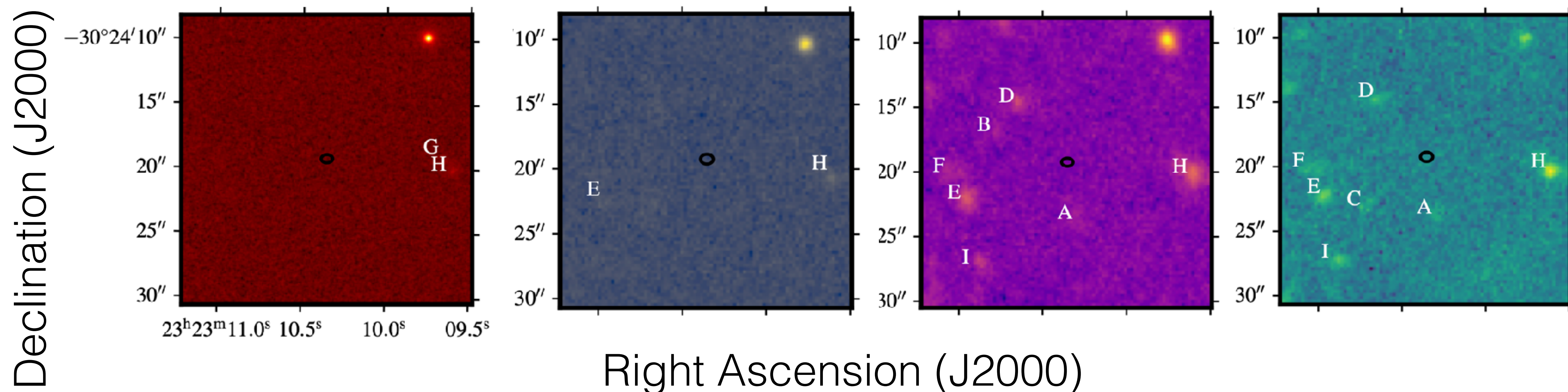
FRB 20220610A at $z=1$



- ASKAP discovery: morphologically complex host galaxy system with possible signs of interaction (Stuart+ 2023, Gordon+ 2023)
- But also a few $z > 1.6$ FRBs from MeerKAT announced at FRB2023 conference

FRB with no host

- ASKAP FRB20210912A - unseen host galaxy despite deep optical ($R > 26.7$ mag) and near-infrared ($K_s > 24.9$ mag) VLT imaging
—> high DM (1233.7) suggests high-redshift ($z > 0.7$) origin (Marnoch+ 2023)
- Could be a problem for cosmology studies if many similar cases



Useful links

Databases:

- CHIME FRB repeaters (<https://www.chime-frb.ca/repeaters>)
- CHIME VOEvents (<https://www.chime-frb.ca/voevents>)
- Blinkverse database (<https://blinkverse.alkaidos.cn/>)
- TNS Database (www.wis-tns.org)
- FRBSTATS (<https://www.herta-experiment.org/frbstats/>)

Conferences:

- FRB2023 (<https://www.youtube.com/watch?v=AyvXSKjk0lw&list=PLDTm-GculgCkdkEM2X8SJ2jj7ifNLU2zE>)