

FRBs and pulsars with MeerKAT and the Nançay Radio Observatory telescopes



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FJ

Part 1: Discovery of an FRB sample with MeerKAT

On behalf of the MeerTRAP team

F. Jankowski,^{1,2*} M. C. Bezuidenhout,^{1,3} M. Caleb,^{1,4,5} L. N. Driessen,^{1,6} M. Malenta,¹ V. Morello,¹ K. M. Rajwade,^{1,7} S. Sanidas,¹ B. W. Stappers,¹ M. P. Surnis,^{1,8} E. D. Barr,⁹ W. Chen,⁹ M. Kramer,^{9,1} J. Wu,⁹ S. Buchner,¹⁰ M. Serylak,¹¹ and J. Xavier Prochaska^{12,13}



arXiv ID: 2302.10107





FJ

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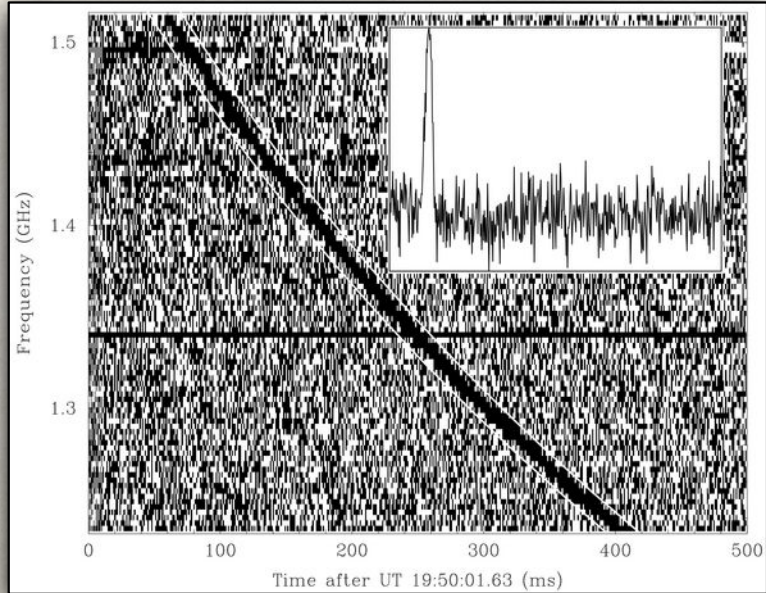
F. Jankowski,^{1,2*} M. C. Bezuidenhout,^{1,3} M. Caleb,^{1,4,5} L. N. Driessen,^{1,6} M. Malenta,¹ V. Morello,¹
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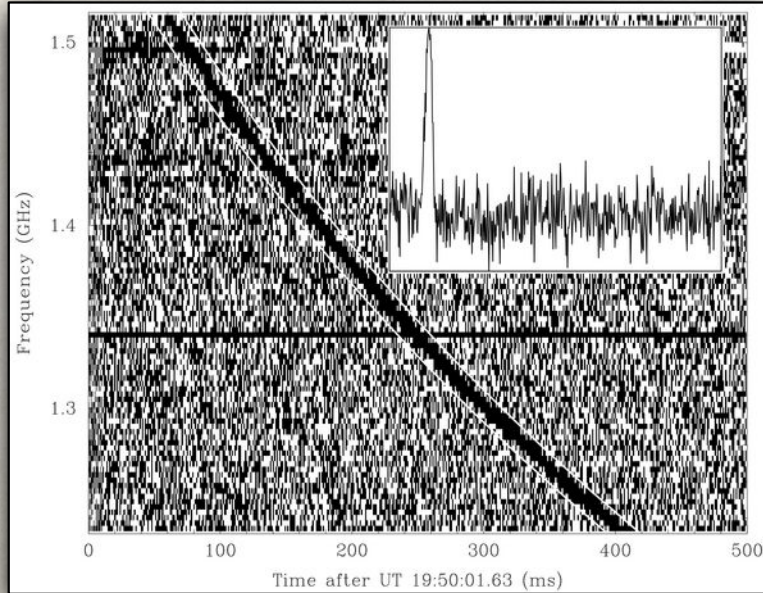
FRB open questions



Lorimer+ 2007

- What are their progenitors?
- Are there multiple classes of FRBs?
- What is the physical mechanism that generates the bursts (high brightness temperature)?
- What other applications are there for FRBs?

FRB open questions



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Shaw Prize 2023!

Bailes, Lorimer, McLaughlin

The MeerTRAP transient surveys

- Fully-commensal project at MeerKAT telescope
- Real-time data processing and transient detection
- Piggybacks on all LSPs, some open time proposals and DDTs
- Huge amount of time on sky and sky coverage ($\sim 20,000$ h over 5 yr)
- Excellent sensitivity ($T_{\text{sys}} \sim 23$ K,

$$A_e/T_{\text{sys}} \sim 6.5 \text{ m}^2/\text{K} \text{ at L-band})$$



The MeerTRAP transient surveys

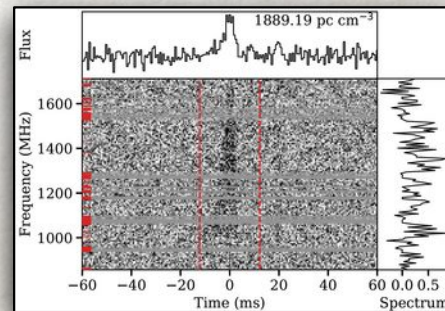
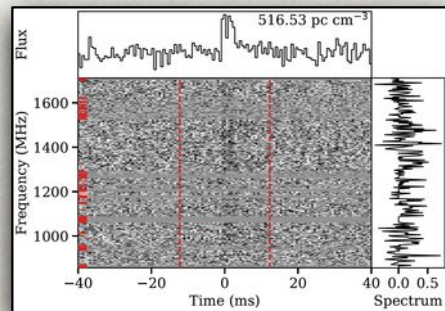
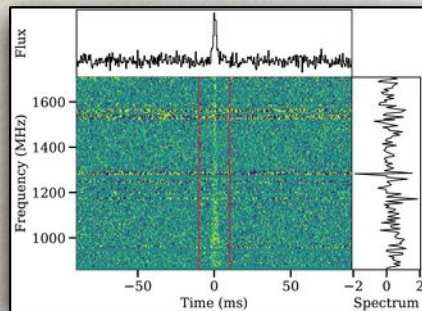
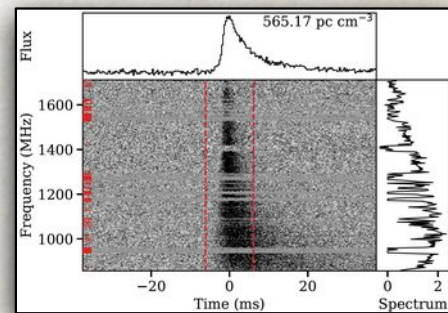
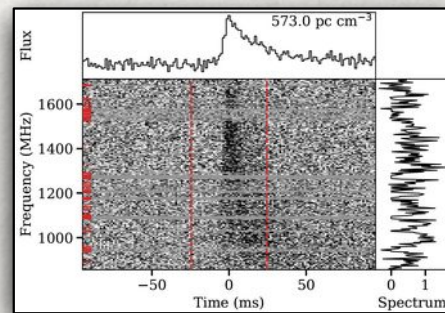
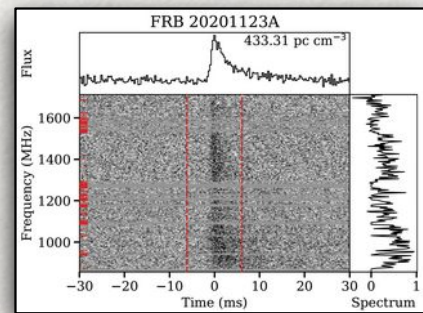
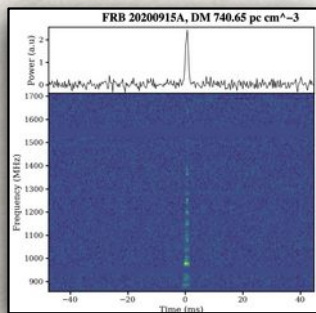
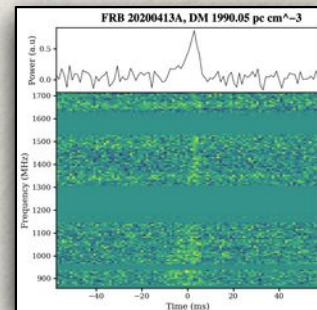
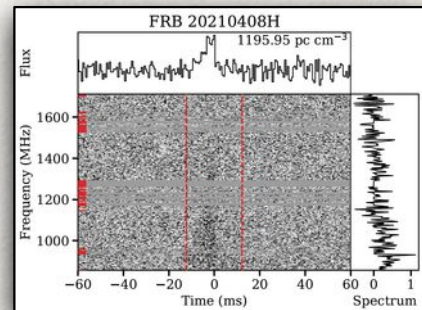
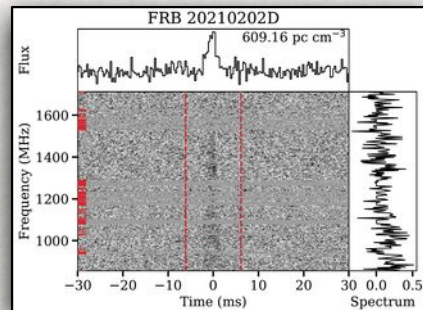
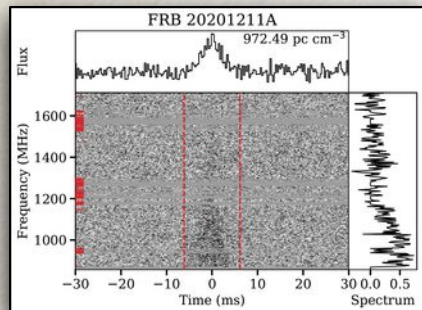
- Fully-commensal project at MeerKAT telescope
- Real-time data processing and transient detection
- Piggybacks on all LSPs, some open time proposals and DDTs
- Huge amount of time on sky and sky coverage ($\sim 20,000$ h over 5 yr)
- Two surveys at the same time
 - incoherent, wide FoV (~ 1 deg²), less sensitive
 - coherent, smaller FoV (~ 0.2 deg²), ~ 5 x more sensitive
- Operating since late 2019, in earnest since late 2020

• Excellent sensitivity ($T_{\text{sys}} \sim 23$ K,

$A_e/T_{\text{sys}} \sim 6.5$ m²/K at L-band)



The FRB sample discovered

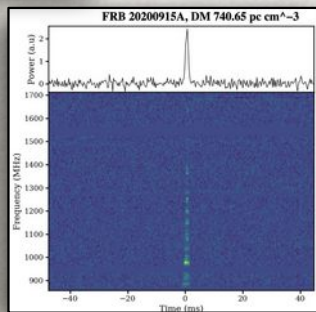
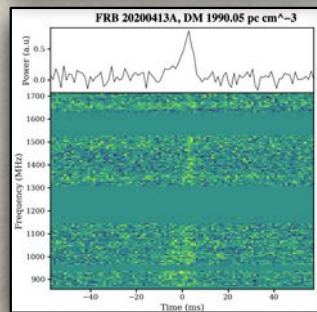
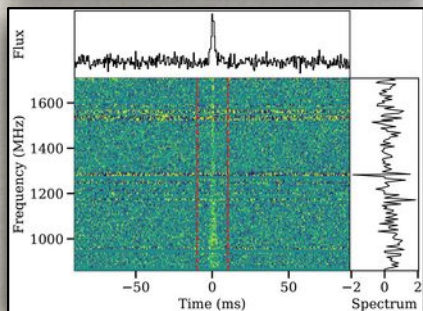
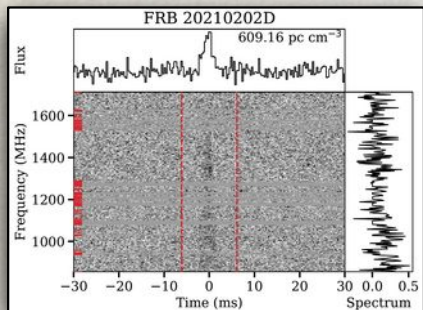


FJ+ 2023; Rajwade+
2022; Driessen+
submitted; Caleb+
2023

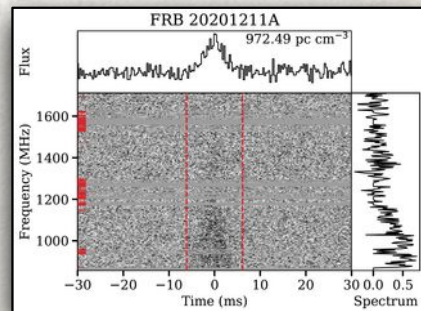
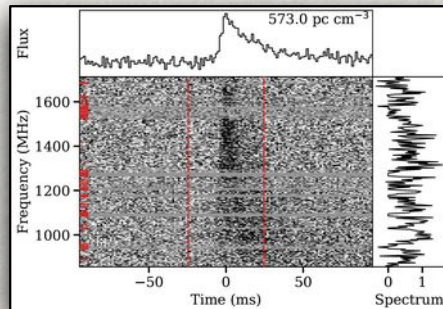
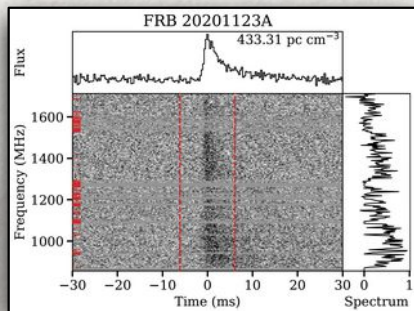
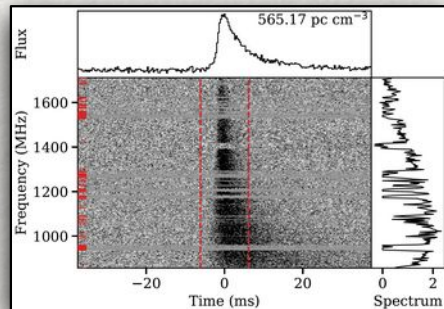
arXiv IDs: 2302.10107;
2302.09787;
2302.09754

Fast Radio Burst types

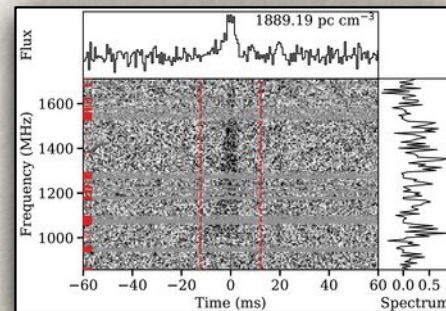
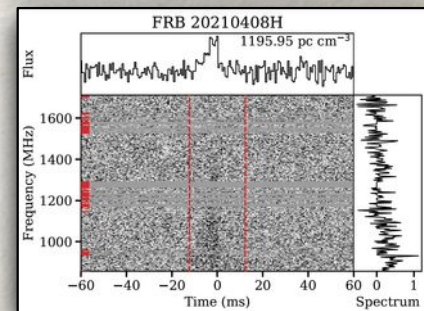
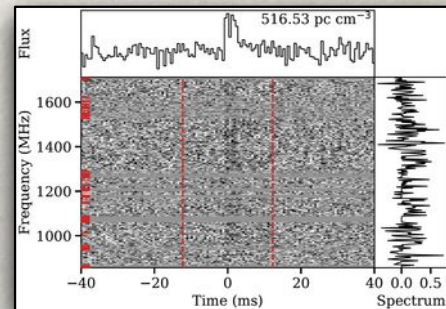
Unresolved



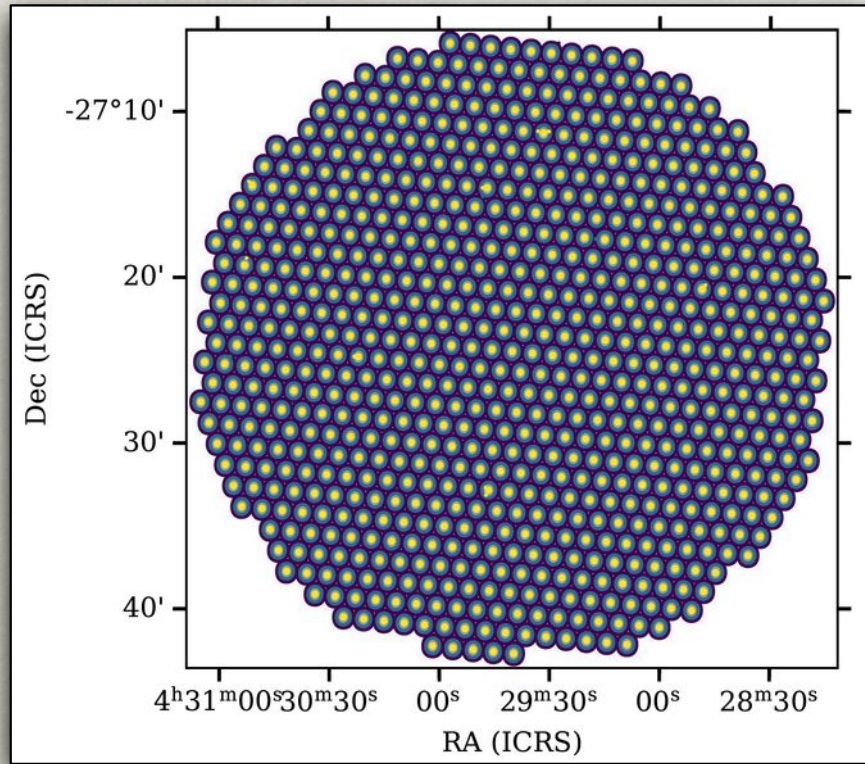
Scattered



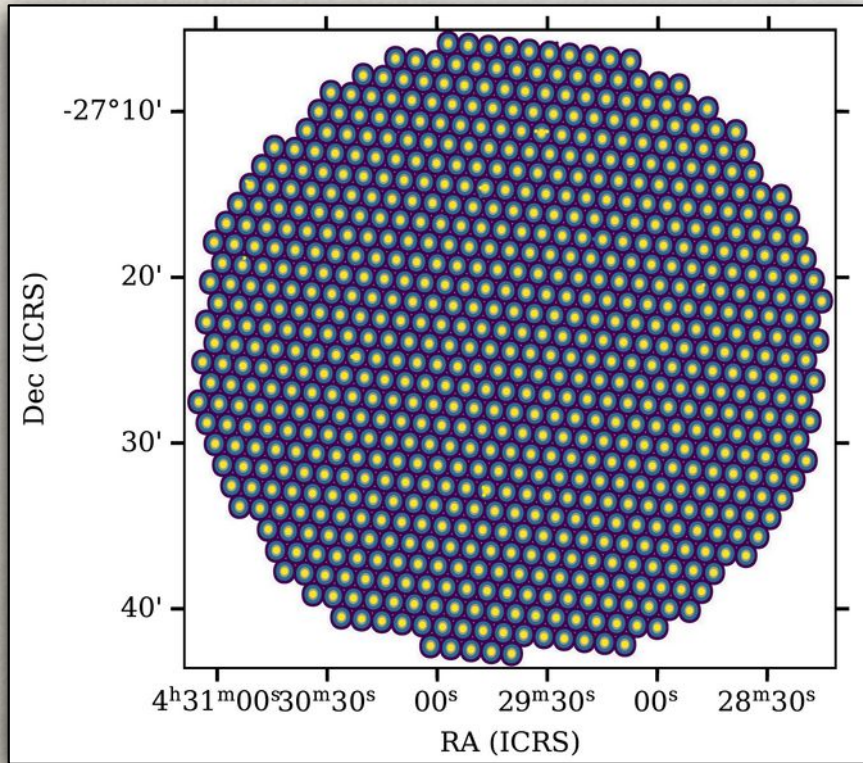
Complex



FRB localisation

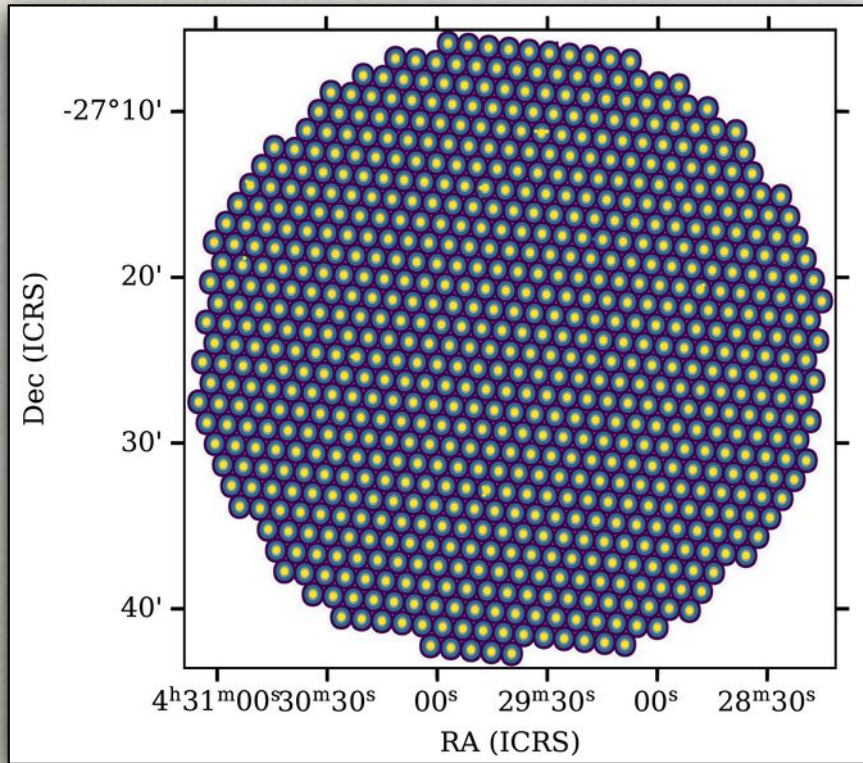


FRB localisation



- “TABLo” method implemented in “SeeKAT” software
 - Tiaan Bezuidenhout’s PhD work
- Based on (non) detection in neighbouring beams

FRB localisation



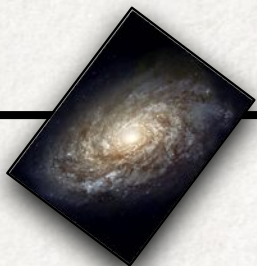
- “TABLo” method implemented in “SeeKAT” software
 - Tiaan Bezuidenhout’s PhD work
- Based on (non) detection in neighbouring beams
- Precision
 - Single-beam: $\sim 0.9 \text{ arcmin}^2$
 - Multi-beam: $O(100) \text{ arcsec}^2$
 - Synthesis image: $O(1) \text{ arcsec}^2$

Scattering



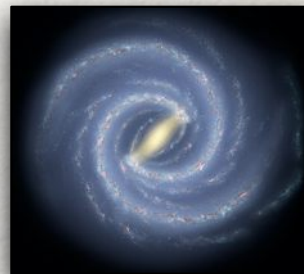
Host galaxy

IGM



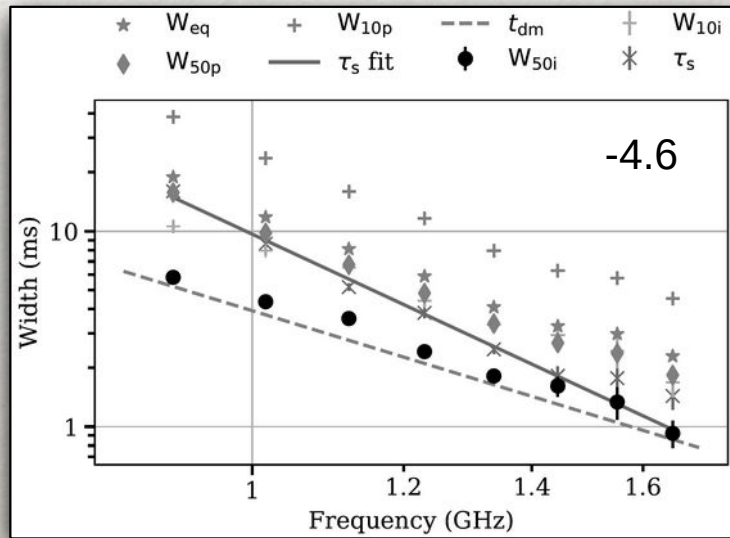
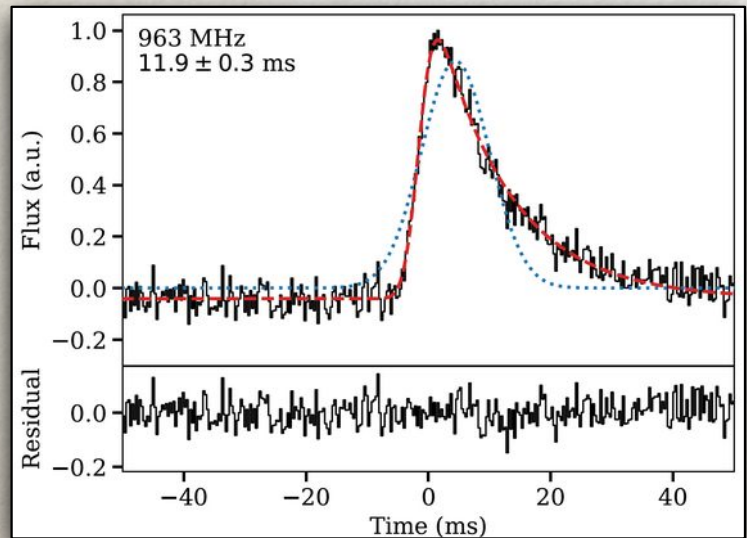
Intervening galaxy & halo

IGM

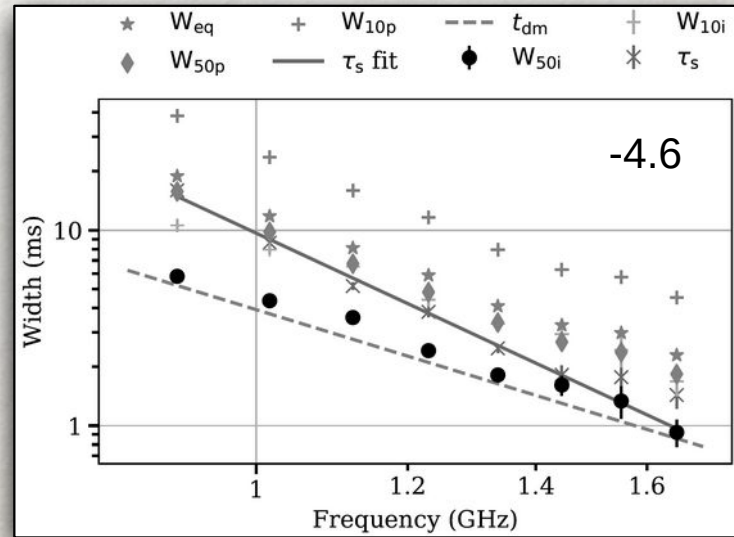
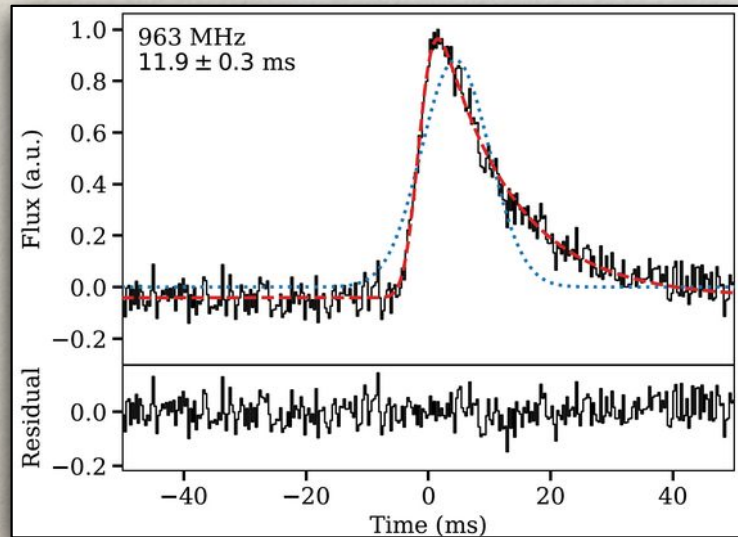
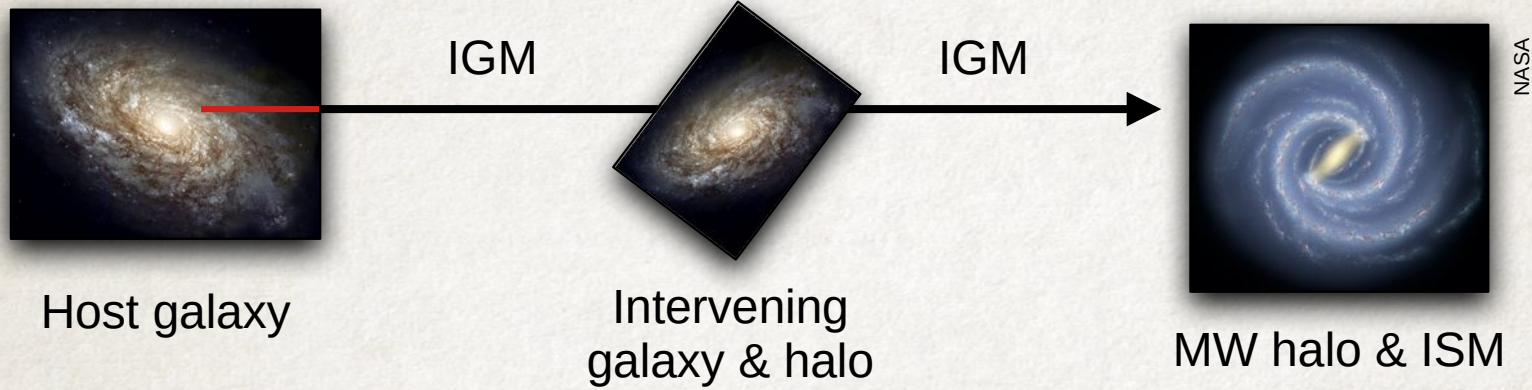


MW halo & ISM

NASA

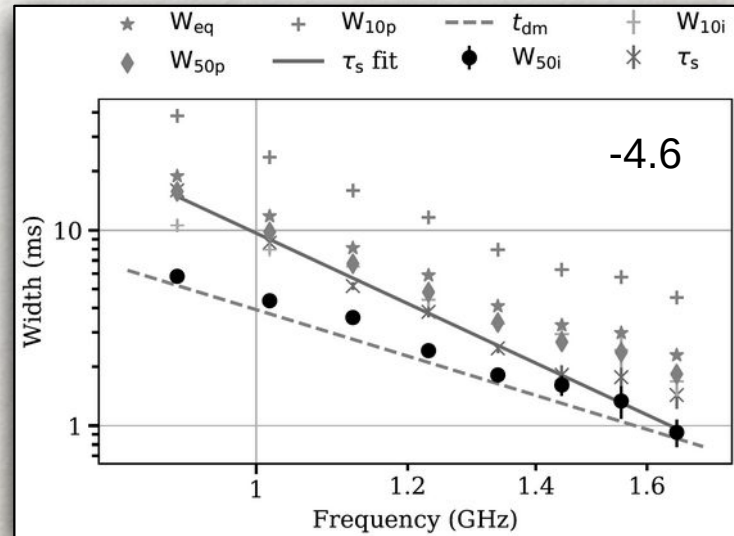
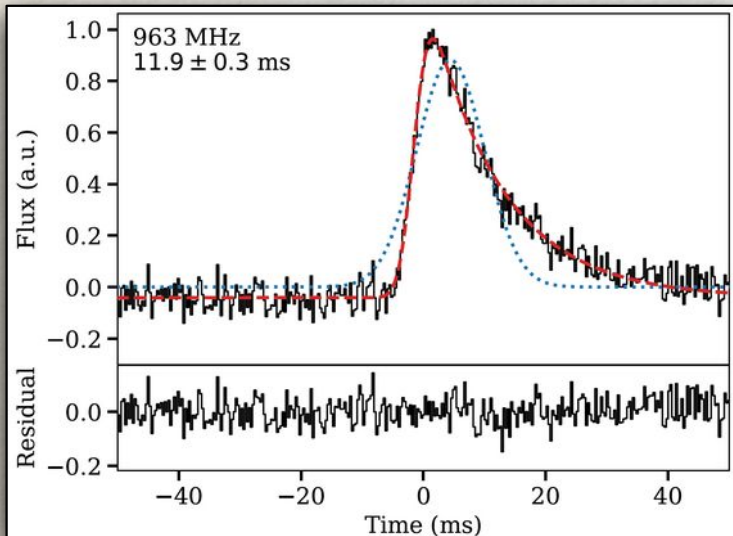
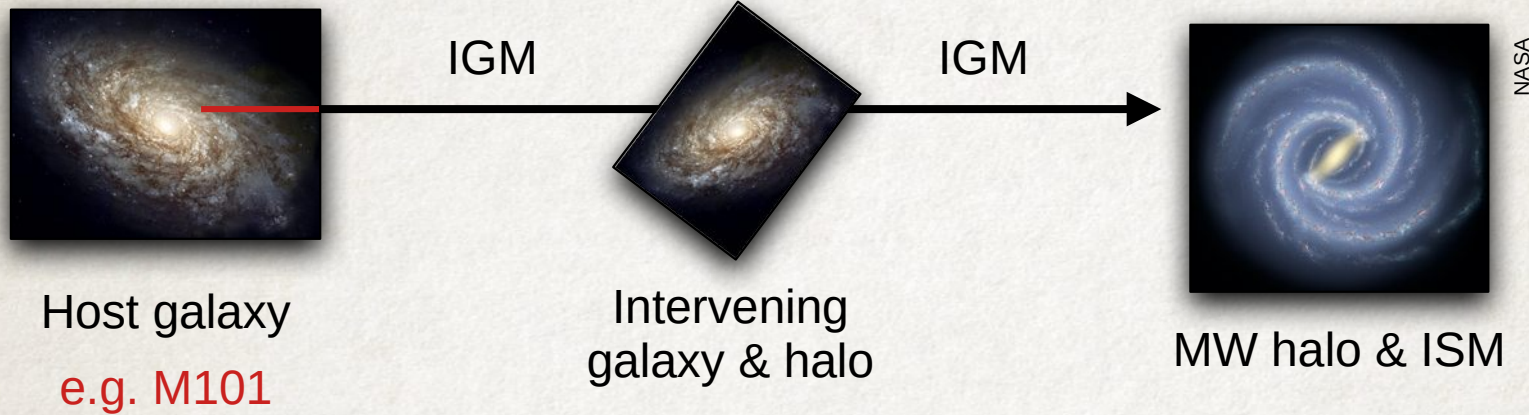


Scattering



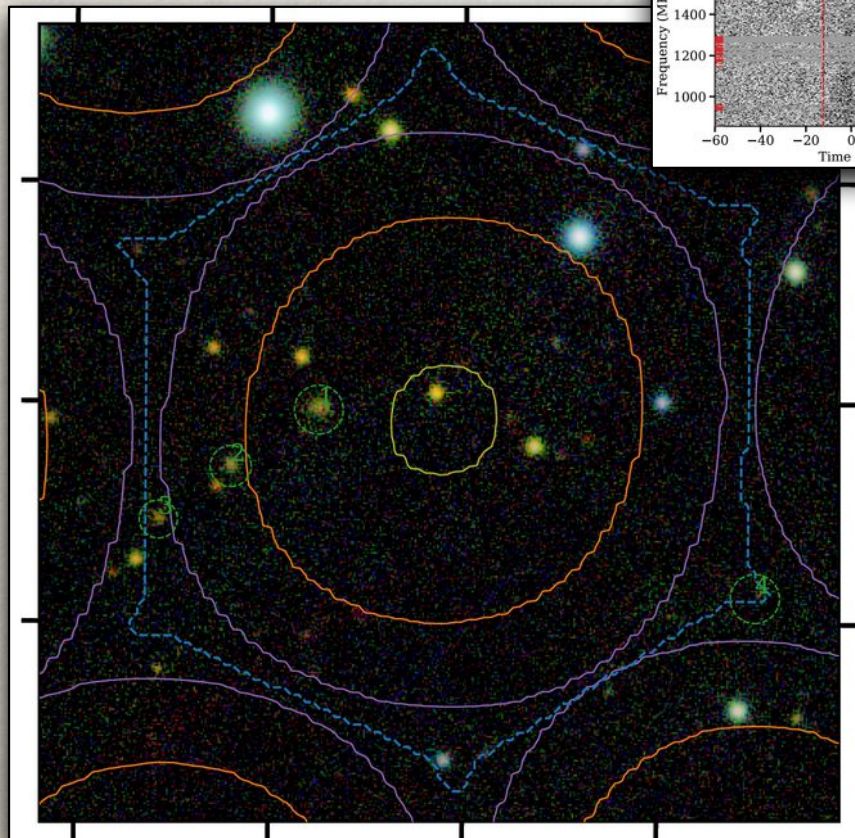
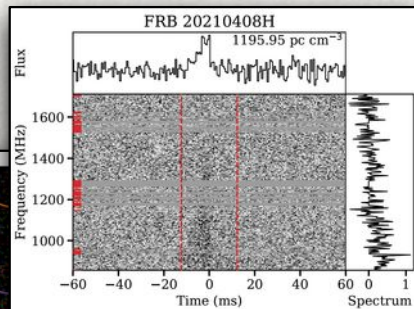
- 3 FRBs show significant scattering
- 1 shows hint
- Several limited by DM smearing
- Close to Kolmogorov

Scattering



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- 1 shows hint
- Several limited by DM smearing
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Host galaxy association



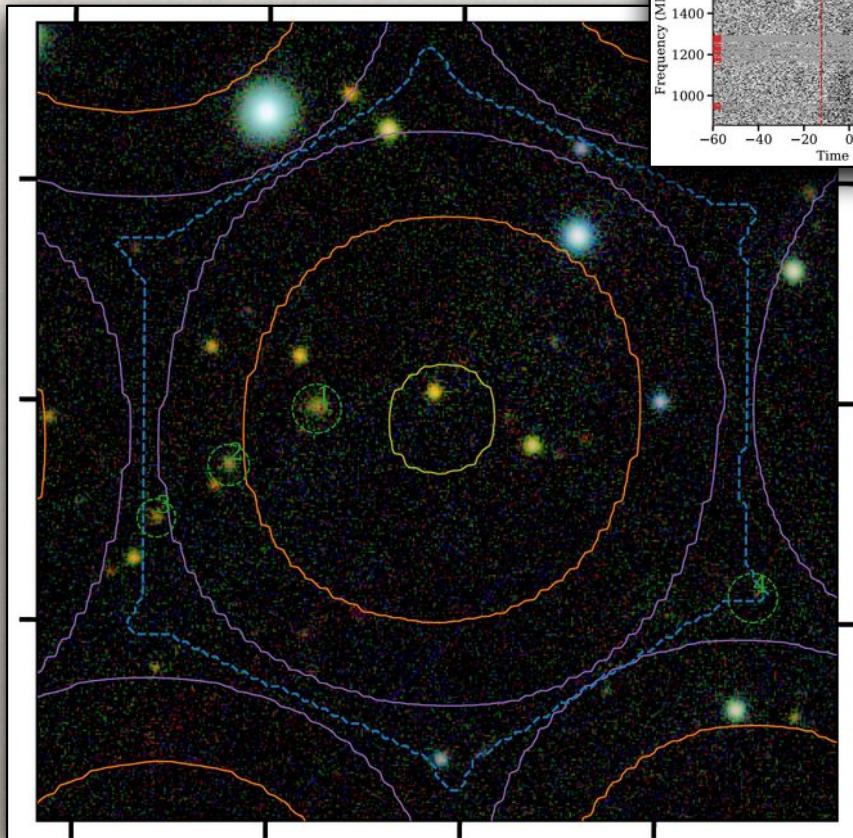
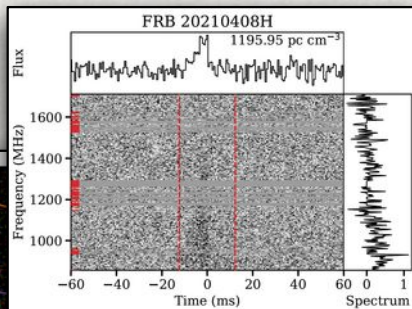
FJ+ 2023

- Aim: Host galaxy spectroscopic redshift
- Two distance measurements
- Calibrate $DM_{\text{cosmic}} - \text{redshift}$ relation
- Probabilistic Association of Transients to their Hosts (PATH) software

#	$p(O x)$	$p(O)$	m_i (mag)	r_{50} (")
1	0.35	0.31	20.1	3.3
2	0.17	0.16	20.8	2.8
3	0.09	0.11	21.2	2.6
4	0.04	0.08	21.5	3.3

$$p(M|x) = 0.34$$

Host galaxy association



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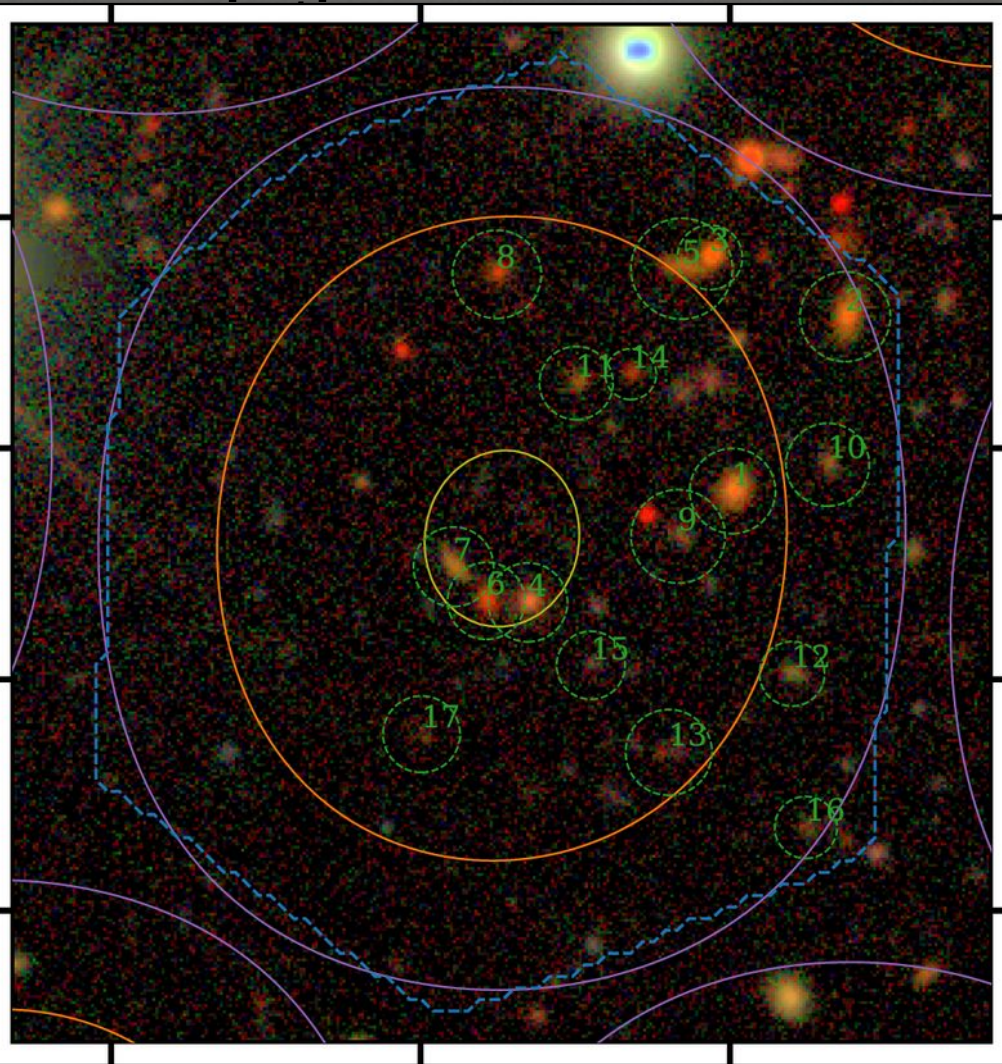
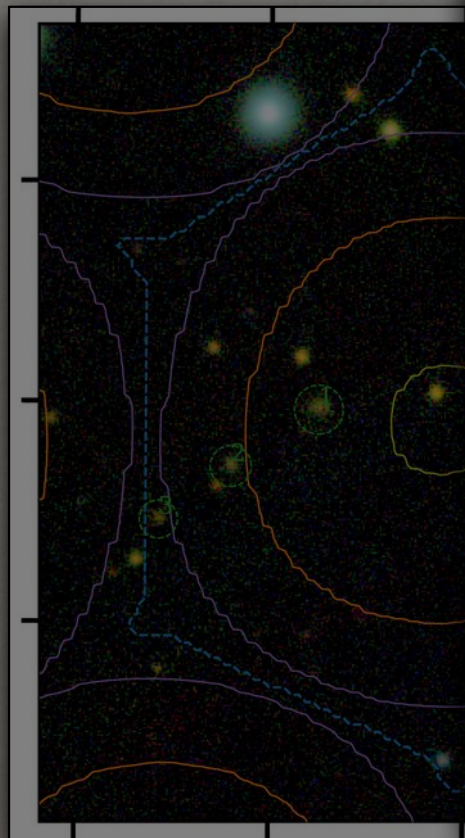
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$p(M|x) = 0.34$

For $p(M) = 0$, $p(O_1|x) = 0.53$

$z_{\text{phot}} = 0.45 \pm 0.08$

Host galaxy



$z_{\text{phot}} = 0.45 \pm 0.08$

galaxy spectroscopic

measurements

cosmic – redshift relation

(Association of Transients

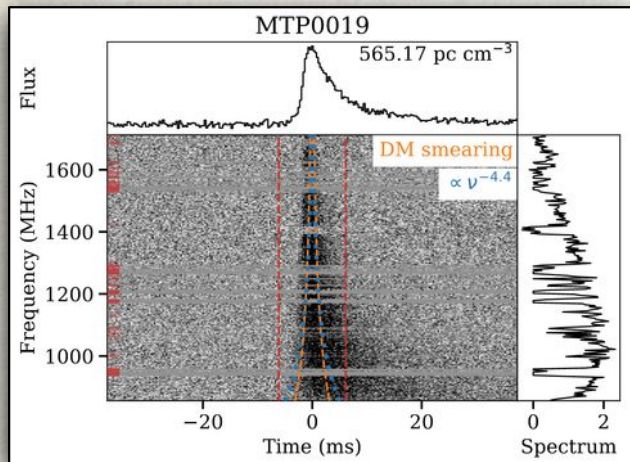
PATH) software

(O)	m_i (mag)	r_{50} (")
308	20.12	3.32
160	20.77	2.79
110	21.16	2.59
084	21.45	3.34

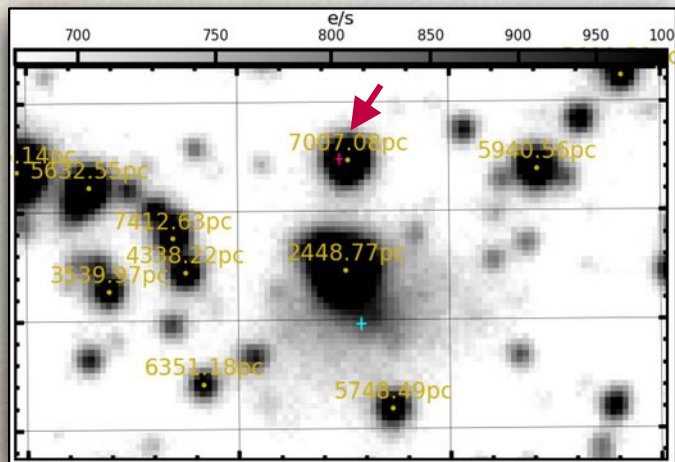
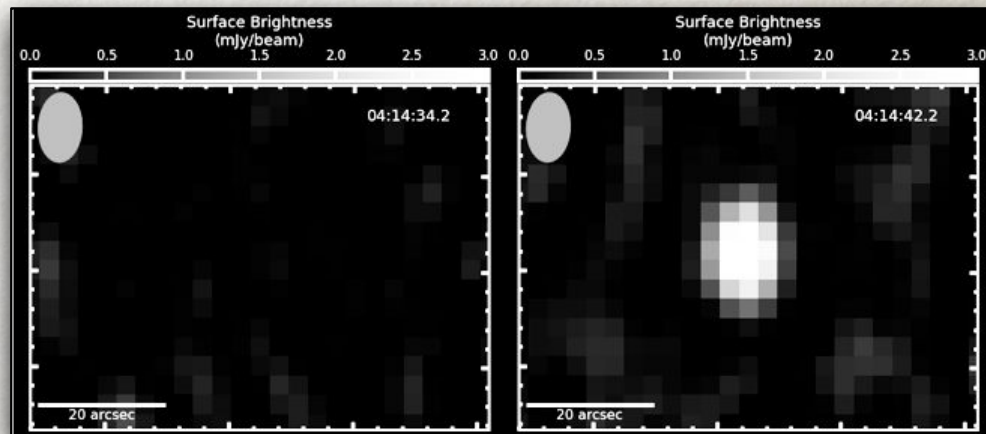
$$p(M|x) = 0.34$$

0.53

Host galaxies – MTP0019



Driessen+ in prep.

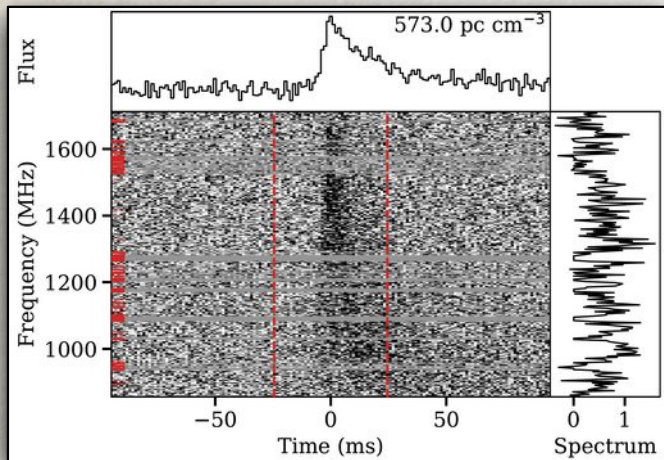


- Sub-arcsec localisation
- Galactic vs extragalactic?
- Faint optical source and persistent radio source, 7.4" offset
- Galaxy obscured by foreground star. Star-forming spiral
- $z_{\text{spec}} = 0.066$
- Host DM ~ 30 units

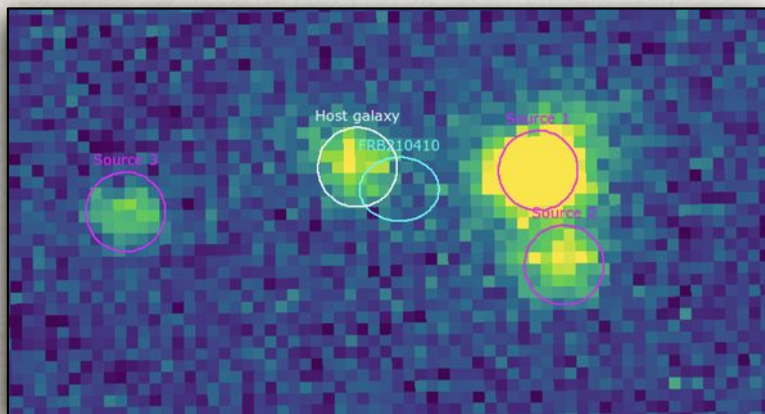
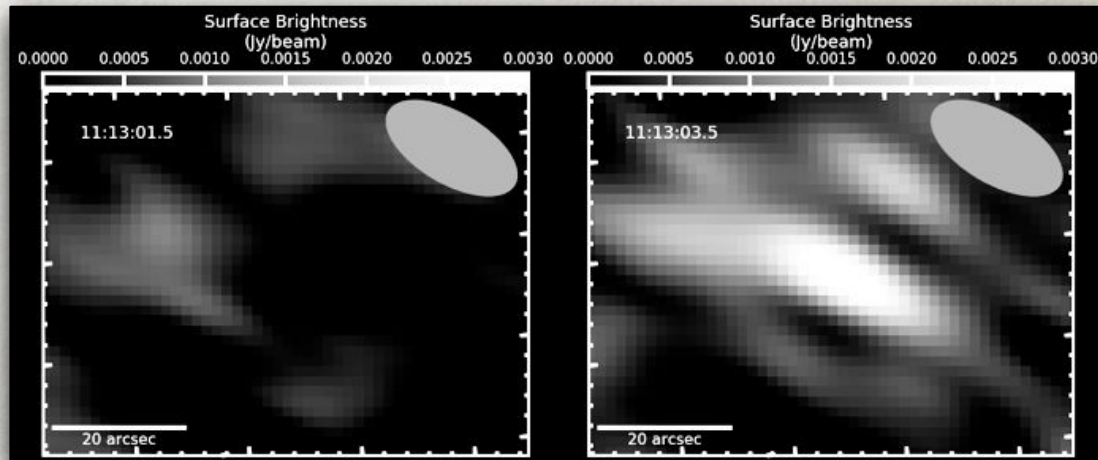


arXiv ID:
2302.09787

Host galaxies – FRB 20210410



Caleb+ 2023

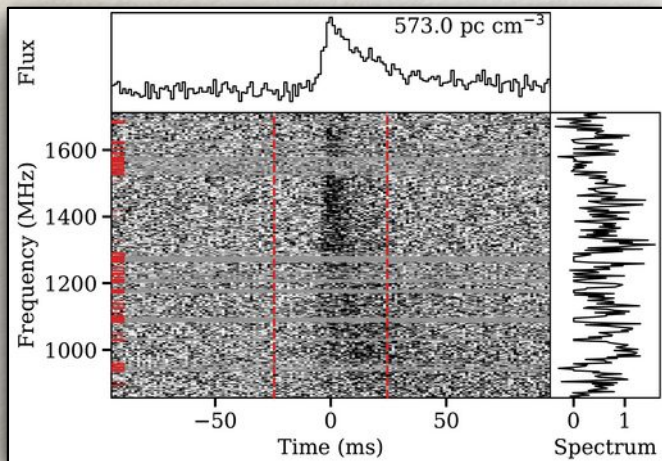


- Localised from 2-s corr. dump
- Normal galaxy
- $z_{\text{spec}} = 0.14$
- Complex field
- MUSE image

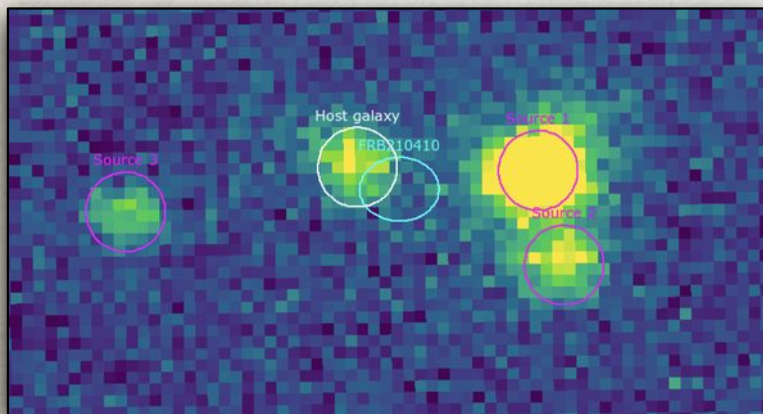
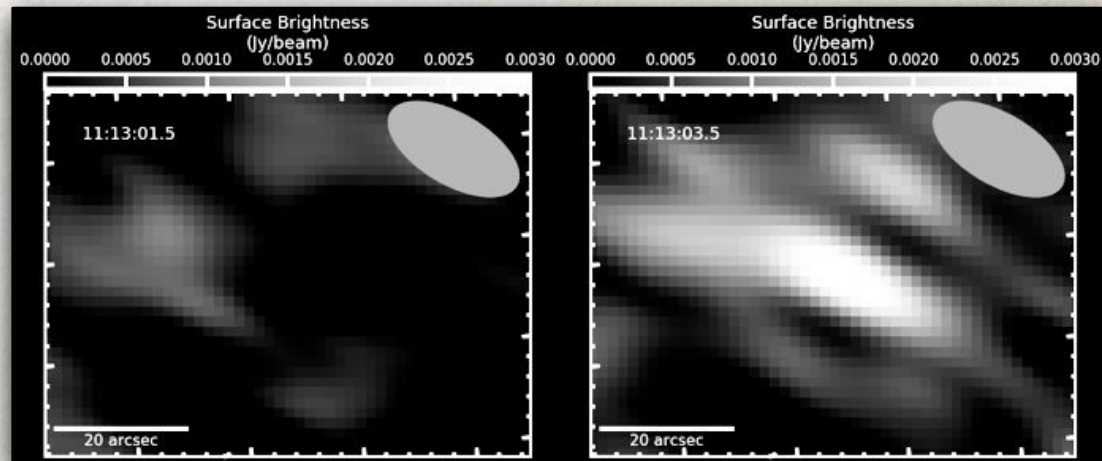


arXiv ID:
2302.09754

Host galaxies – FRB 20210410



Caleb+ 2023



- Localised from 2-s corr. dump
- Normal galaxy
- $z_{\text{spec}} = 0.14$
- Complex field
- MUSE image

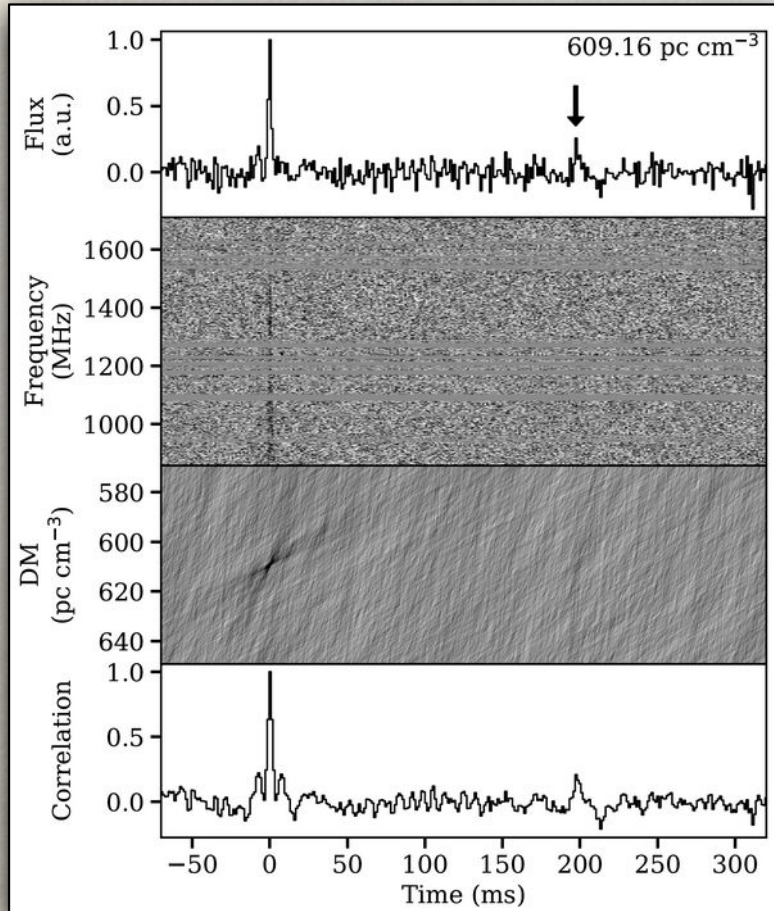
Summary

- 2 sub-arcsecond localisations → 2 host galaxies
- Another secure PATH association with $p(O|x) > 0.8$

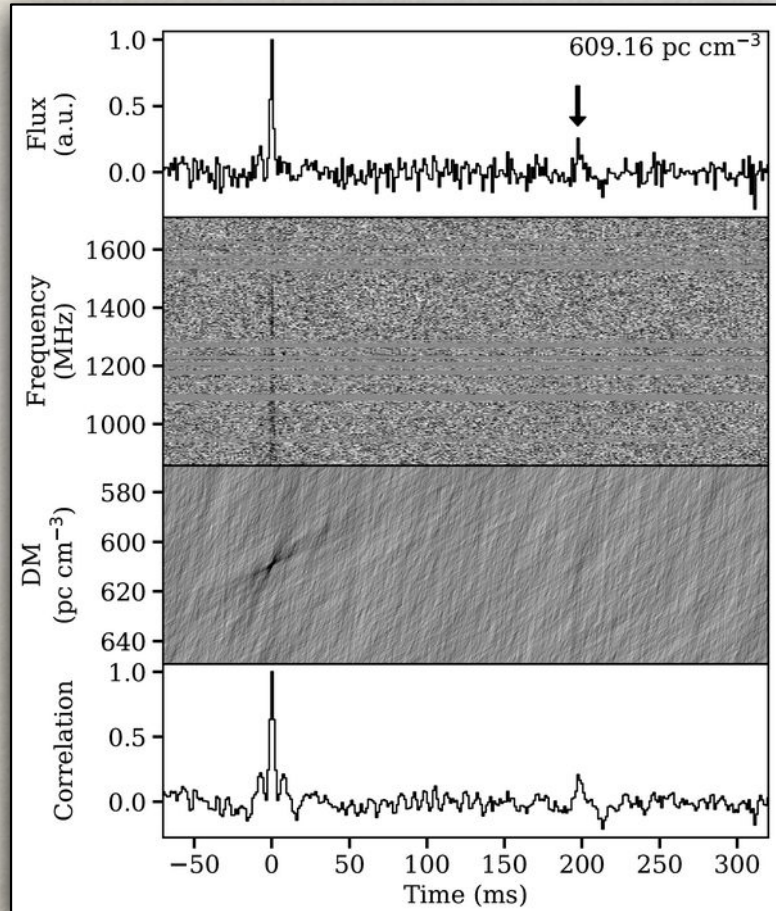


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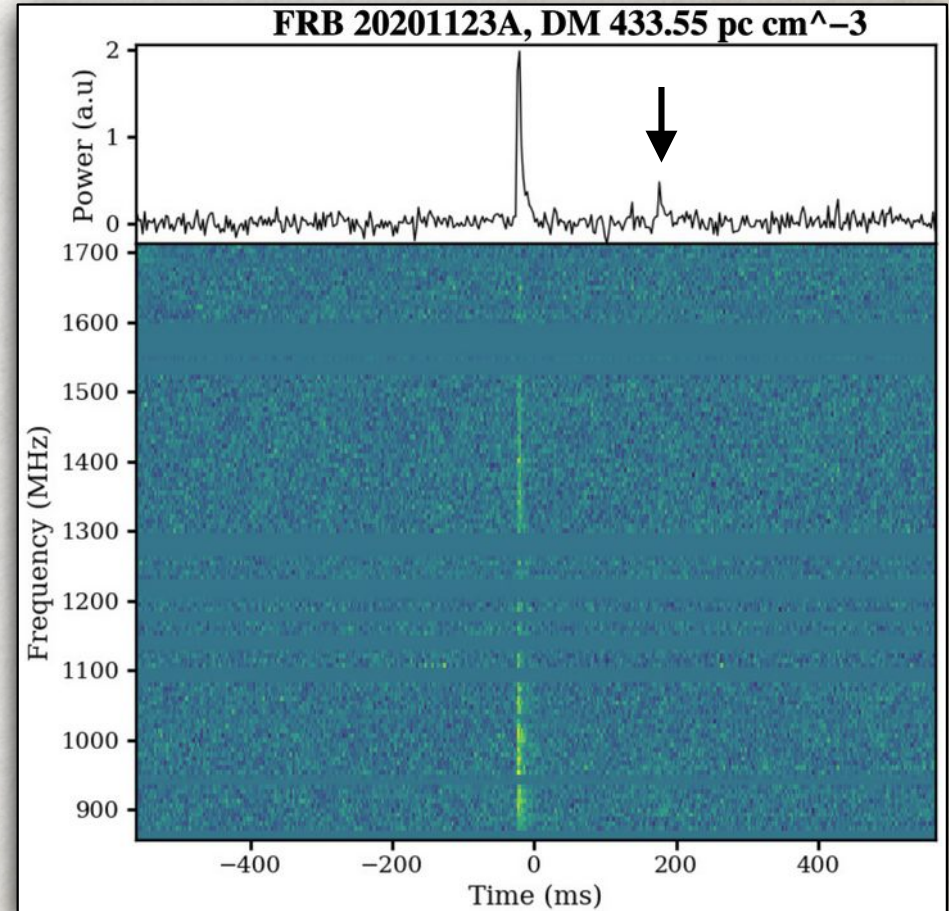
Post-cursor burst detections



Post-cursor burst detections

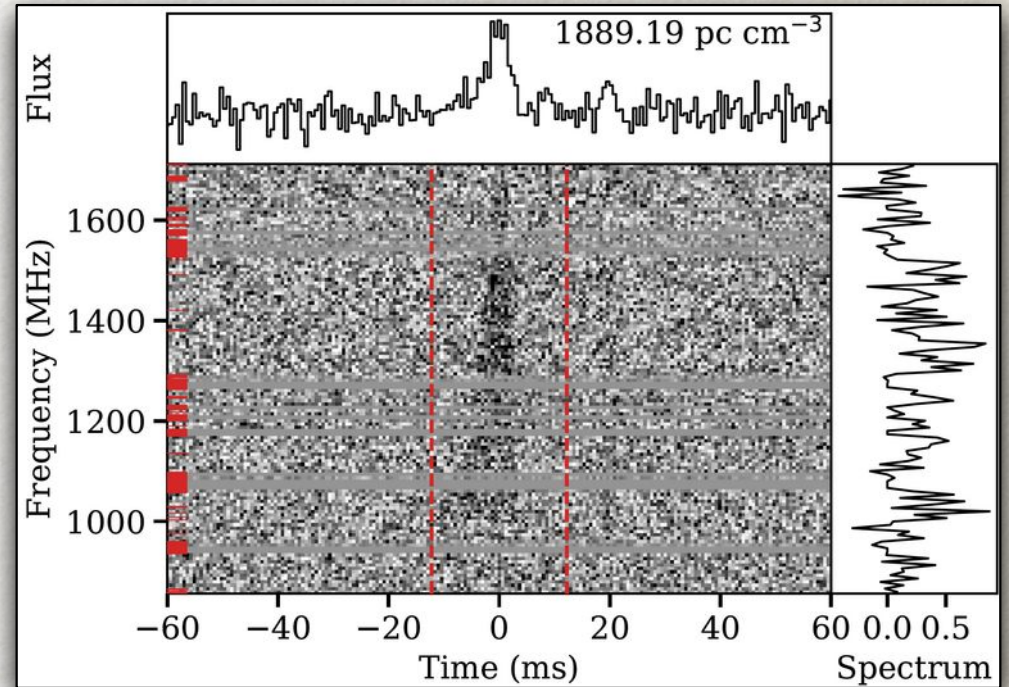
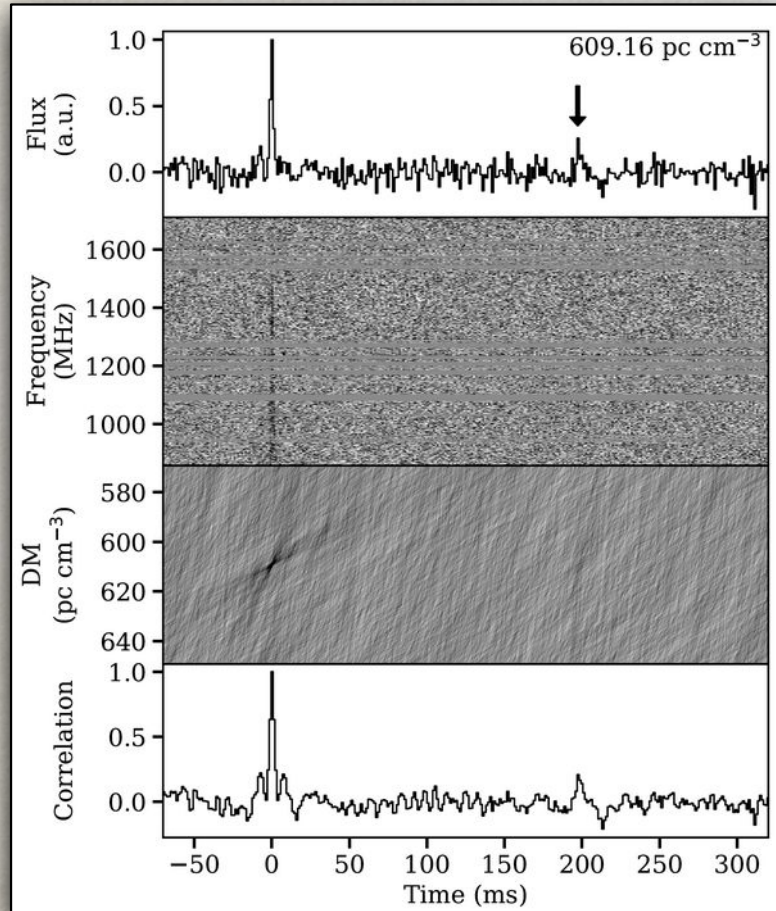


FJ+ 2023



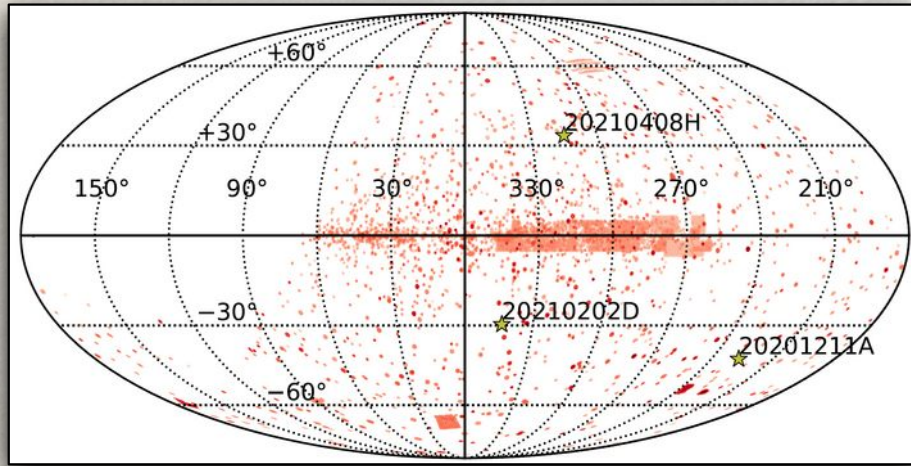
Rajwade+ 2022

Post-cursor burst detections



Understanding the MeerTRAP surveys & FRB all-sky rates

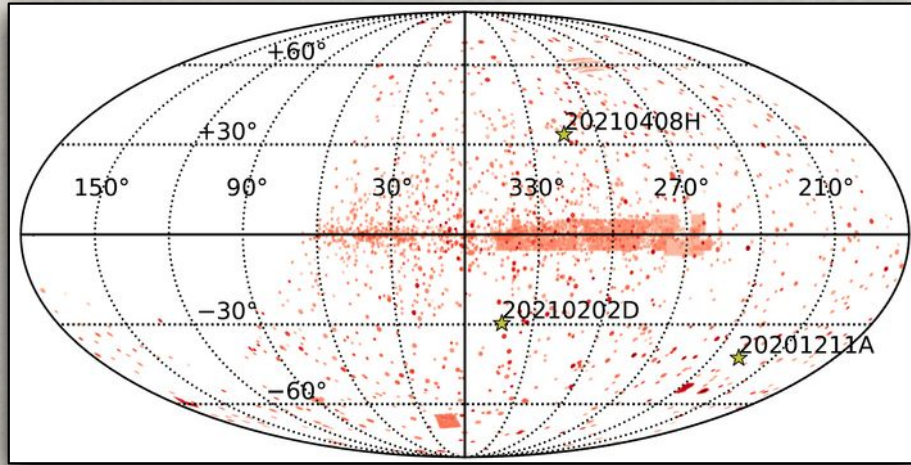
Understanding the MeerTRAP surveys & FRB all-sky rates



317.5 days on-sky time!

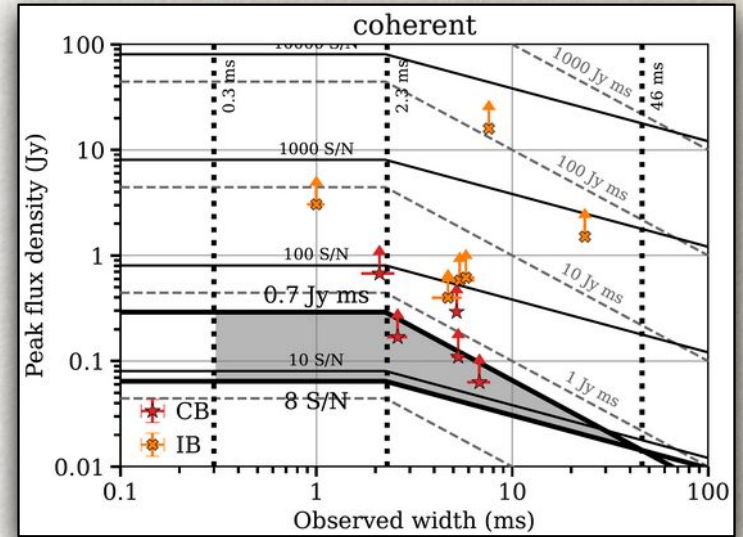
FJ+ 2023

Understanding the MeerTRAP surveys & FRB all-sky rates



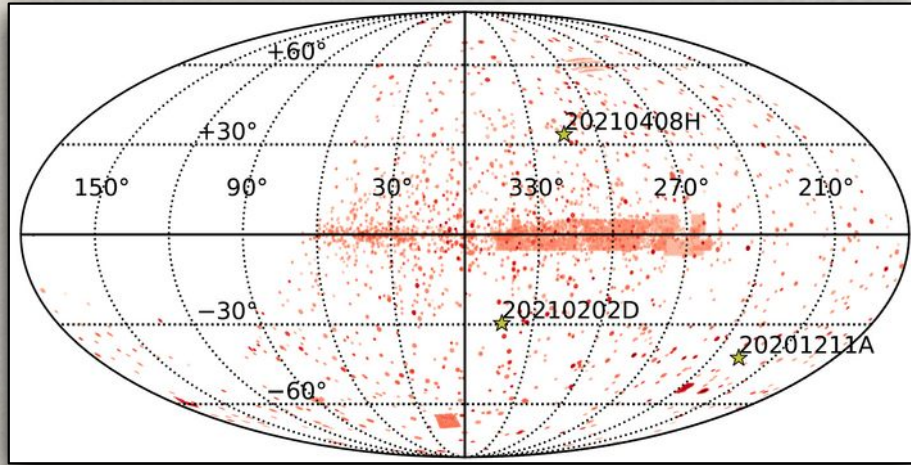
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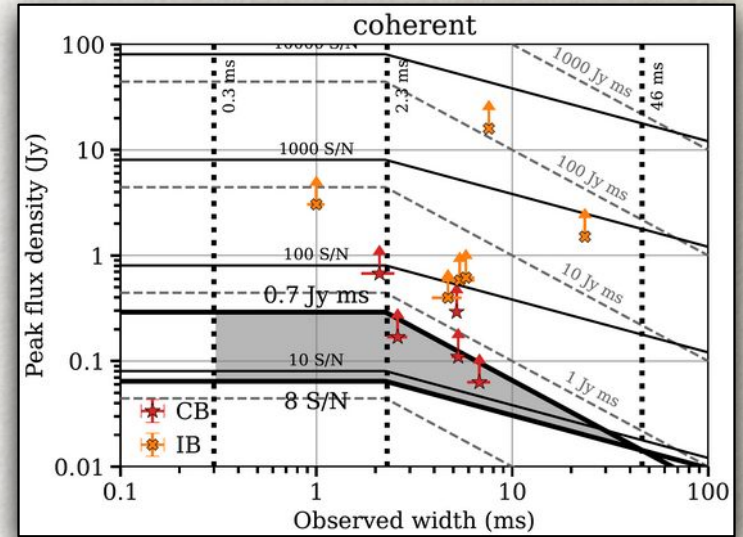
F_c : 0.7 & 3.4 Jy ms

Understanding the MeerTRAP surveys & FRB all-sky rates



317.5 days on-sky time!

FJ+ 2023



F_c : 0.7 & 3.4 Jy ms

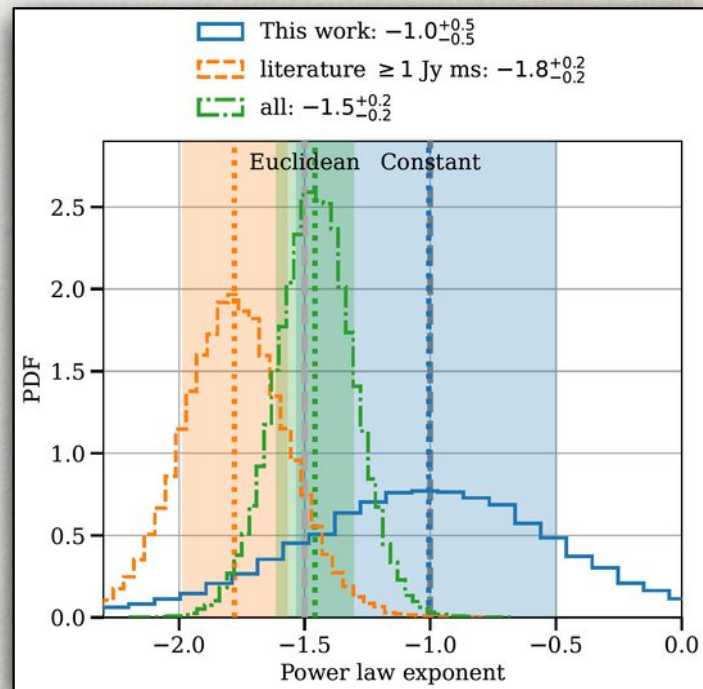
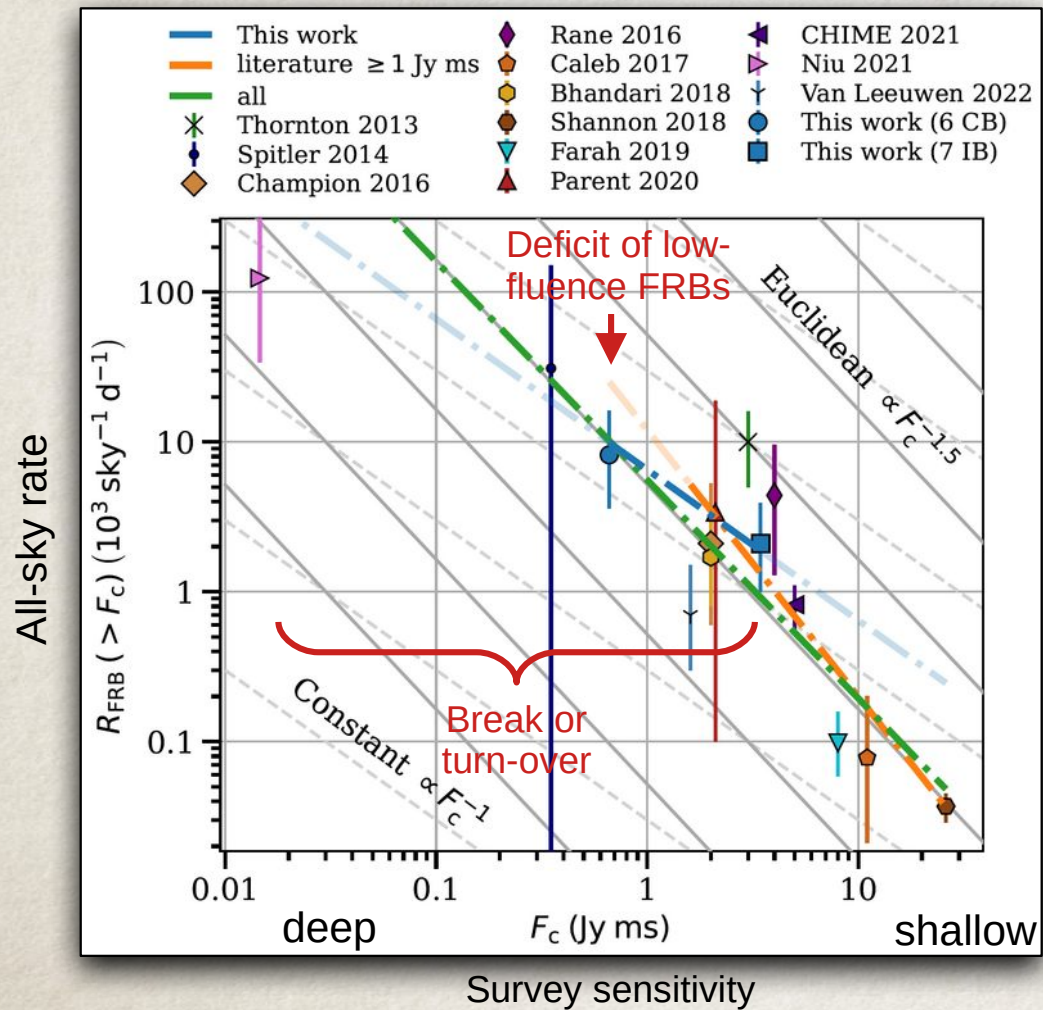
Limiting
fluence

All-sky
rate

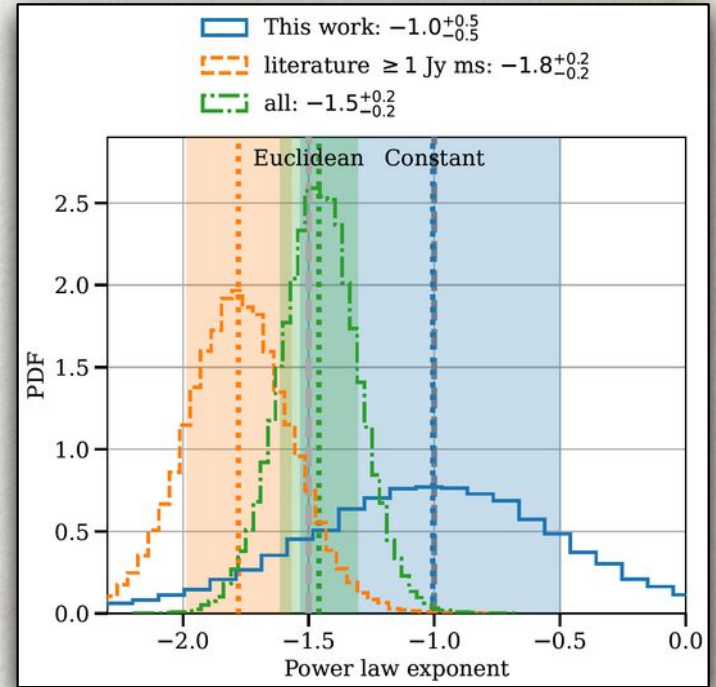
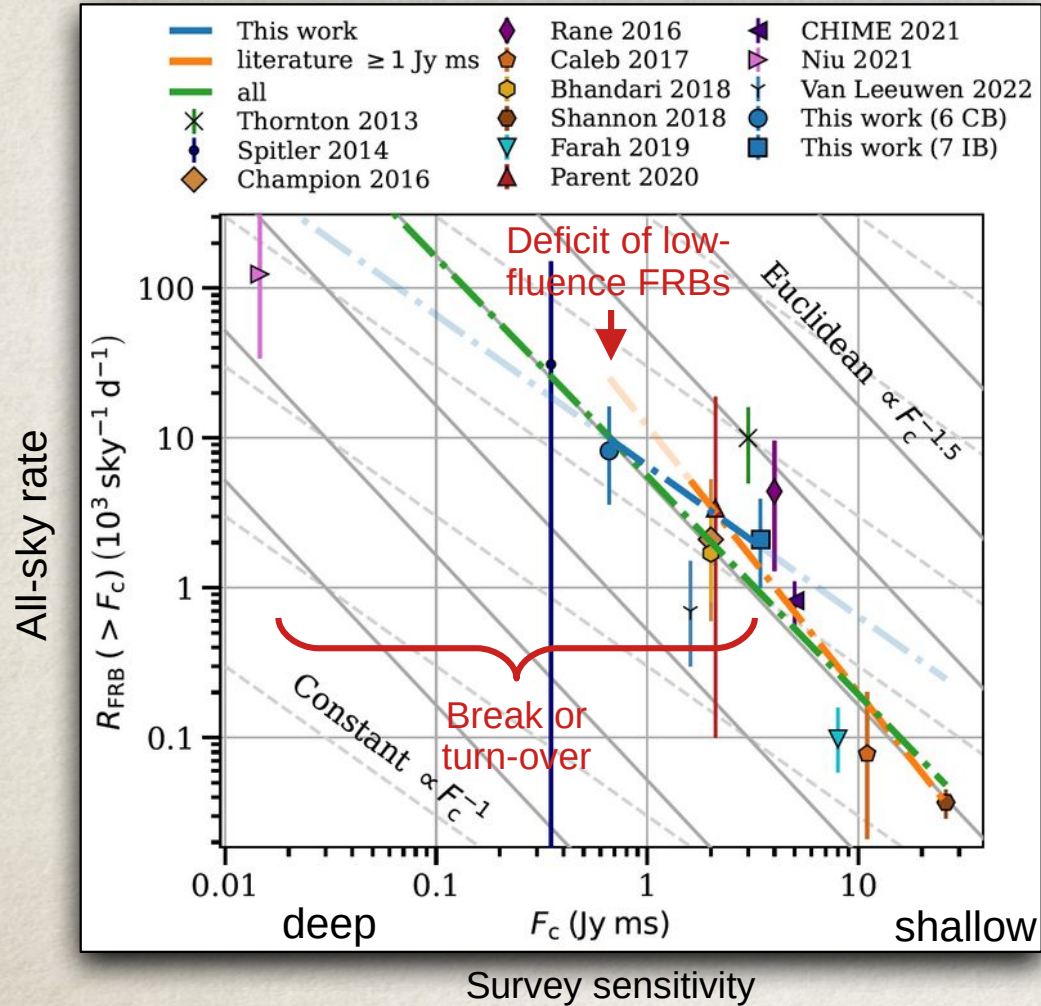
Survey	t_{obs} (d)	$\langle A_{0.5} \rangle$ (deg ²)	c_s (deg ² h)	F_c (Jy ms)	$N_{\text{FRB}} (> F_c)$	$R_{\text{FRB}} (> F_c)$ (10 ³ sky ⁻¹ d ⁻¹)
Coherent	317.5	0.19	1448	0.66	6	8.2 ^{+8.0} _{-4.6}
Incoherent (total)	317.5	0.97	6662	3.44	7	2.1 ^{+1.8}
Incoherent (subtracted)	317.5	0.78	5944	3.44	5	1.7 ^{+1.8} _{-1.0}

~2100 and 8200 FRBs
per sky per day!

FRB all-sky rates \rightarrow cosmology



FRB all-sky rates \rightarrow cosmology



- Deficit of low-fluence FRBs
- Due to cosmological effects or progenitor evolution



Part 2: A multi-telescope single-pulse campaign with the Nançay telescopes & uGMRT

On behalf of Jean-Mathias Grießmeier, Killian Lebreton,
Gilles Theureau, Mayuresh Surnis,
NenuFAR pulsar team





FJ



See Jean-Mathias Grießmeier's
talk on Friday morning!



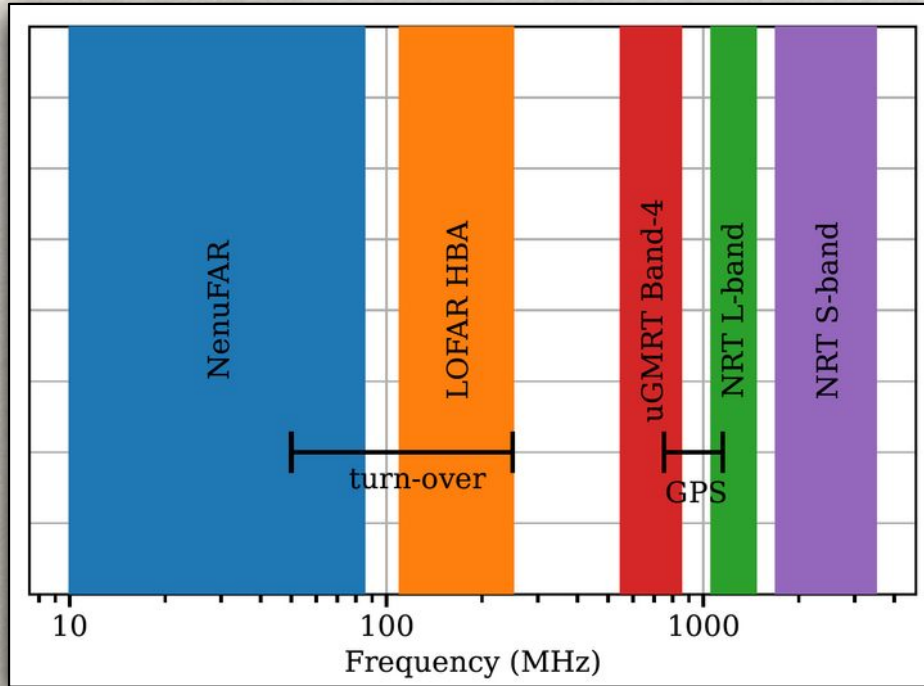
NCRA

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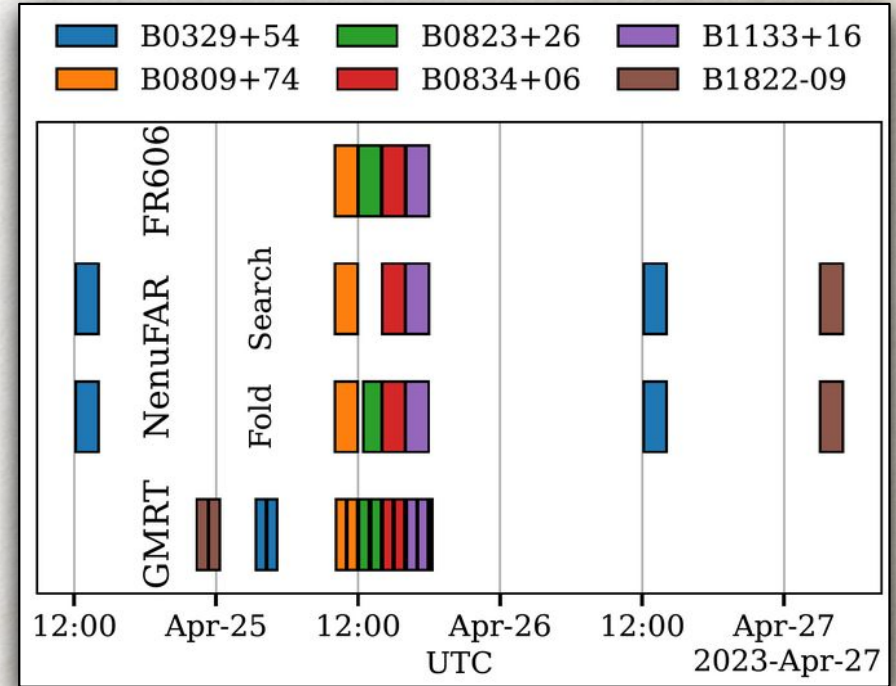
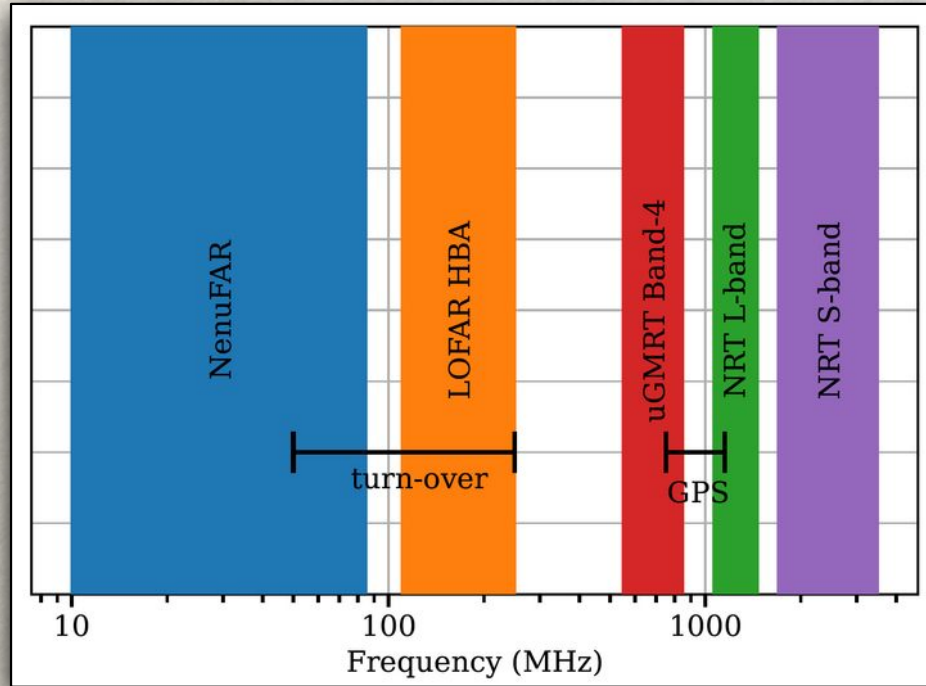


Understanding the wide-band single-pulse properties of radio pulsars



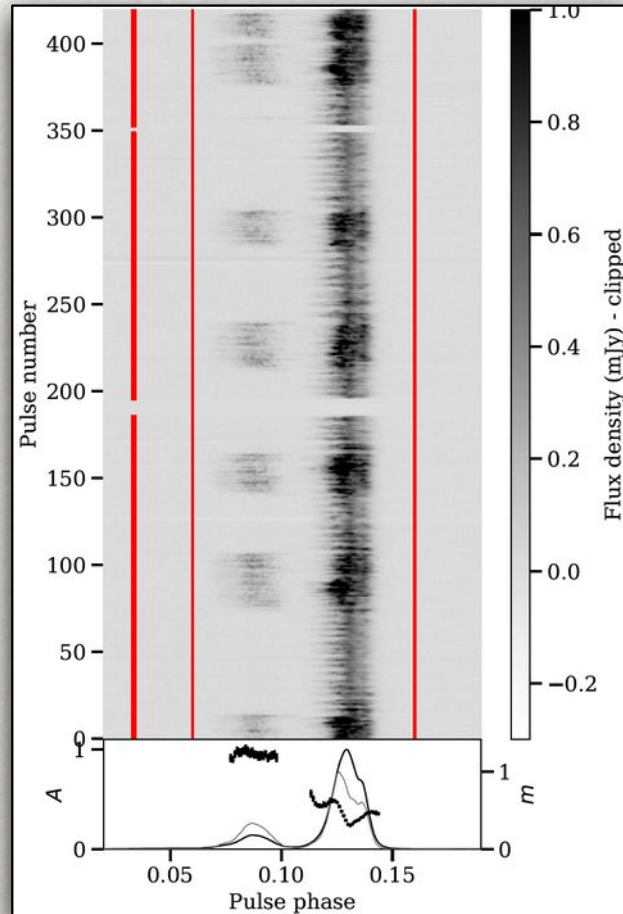
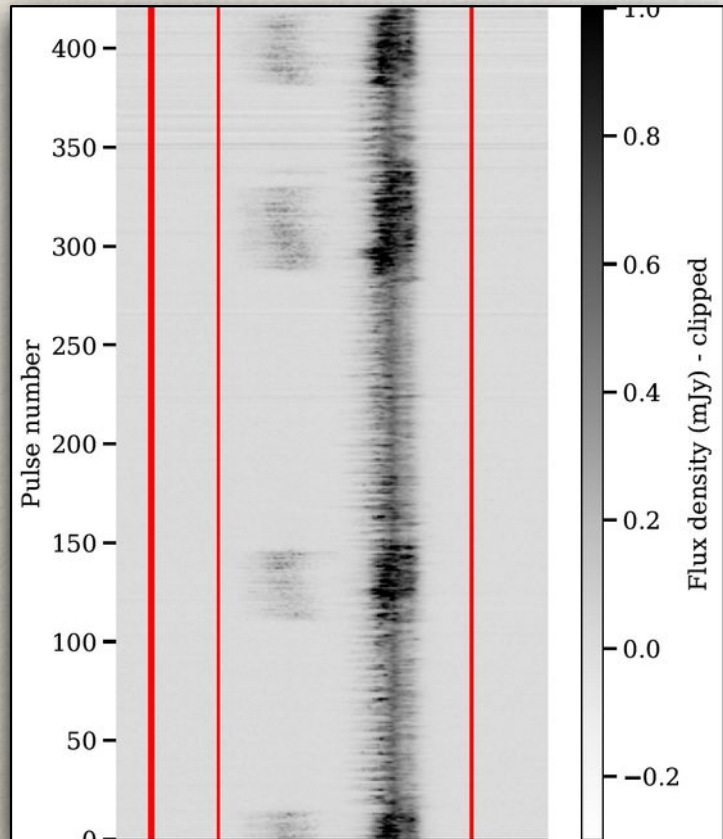
- Aims:
 - Test relationship between FRBs and pulsar single-pulses
 - Study single-pulse properties (PE distributions, modulation, SP polarimetry)
 - Others: pulse profiles, modes, RFM, flux densities, spectra
- Focus on mode-changing and sub-pulse drifting pulsars
- Master's M2 project – Killian Lebreton

A multi-telescope multi-frequency single-pulse campaign



First results – PSR B1822-09 moding

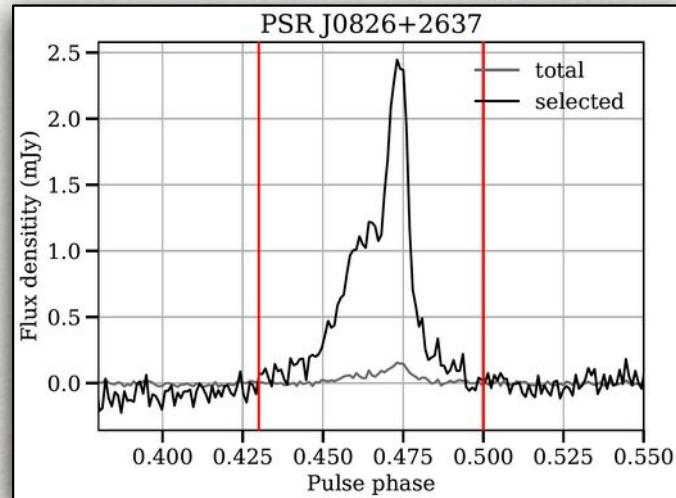
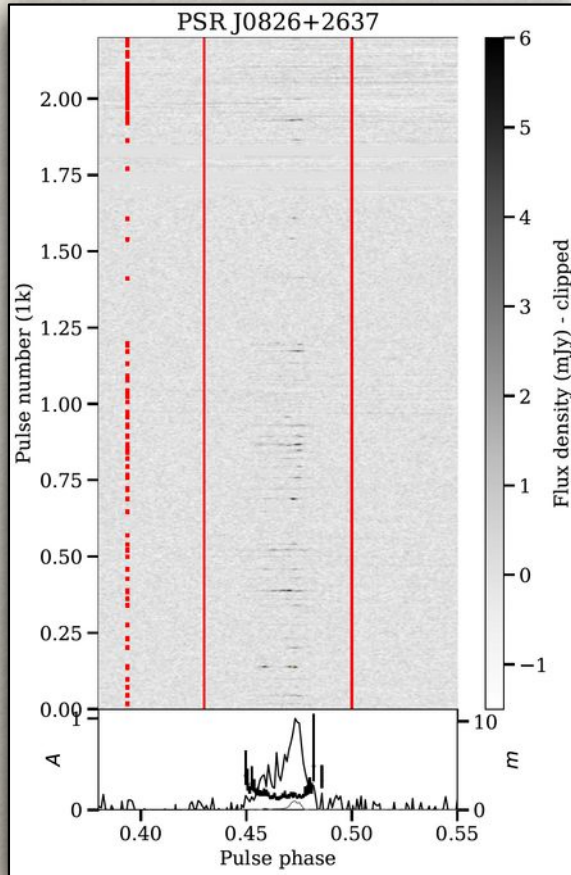
uGMRT data



- 550 – 750 MHz
- 200 MHz bw
- simple RFI excision
- S/N ~ 5000 – 10,000!

PSR B0823+26 quiet mode detection

uGMRT



- $P = 513$ ms, $DM = 19.48$, $\tau = \sim 5$ Myr, $\dot{E} = 4.5 \times 10^{32}$ erg/s
- Synchronous radio & X-ray moding (Hermsen+)
- B, Q, N modes
- Faintly detected with NenuFAR
 - Spectral index constraint

Summary

MeerKAT

- 11 new FRBs discovered
- Localised to <1 arcmin²
- Substantial DMs [400, 2000], extragalactic [100, 1900], redshifts [0.1, 2.0]
- $S_{\text{peak}} > [60, 1400]$ mJy, $F > 0.4$ Jy ms
- 3 FRBs scattered, 1 hint, limited by smearing
- Several host galaxy associations
- Post-cursor bursts (broad-band rep. pulses)
- Surveys: 317.5 days on sky, >0.7 & 3.4 Jy ms
- Rates: $2.1_{-1.1}^{+1.8}$ & $8.2_{-4.6}^{+8.0} \times 10^3$ sky⁻¹ d⁻¹

- Power law idx flatter than at higher fluences
- Deficit of low-fluence FRBs due to cosmology or progenitor evolution

Nançay telescopes & uGMRT

- B1822-09 moding
- B0823+26 quiet mode detection
- Work ongoing



arXiv ID: 2302.10107



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