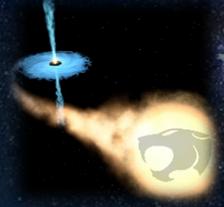




Science Highlights: MeerTRAP & TRAPUM and a brief look ahead to the SKAO.

Thanks to MeerTRAP and TRAPUM teams for slides.

Ben Stappers, DARA Lectures 2026



Background Image Credit: Danielle Futselaar

MAX-PLANCK-GESellschaft

AIMS TO REVEAL NUMEROUS NEW RADIO EMITTING NEUTRON STARS AND FAST RADIO TRANSIENTS



- ▶ Initially an ERC funded collaboration (PI: Stappers) to discover radio transients and pulsars
- ▶ **Fully commensal** high time resolution survey that piggybacks on all the MeerKAT Large Survey projects (MLSPs) + Most Open Time.
- ▶ It allows a large sky coverage, multiple visits to the same field to search for repeats, and variable cadence observations.
- ▶ **Simultaneous optical data** as MeerLICHT optical telescope co-points during night time observations



MeerTRAP and Friends



MAX-PLANCK-GESELLSCHAFT



- Ben Stappers
- Tiaan Bezuidenhout*
- Manisha Caleb*
- Laura Driessen*
- Fabian Jankowski*
- Mateusz Malenta*
- Vincent Morello*
- Inés Pastor-Marazuela*
- Kaustubh Rajwade*
- Sotiris Sanidas*
- Kavya Shaji
- Mayuresh Surnis*
- Jun Tian

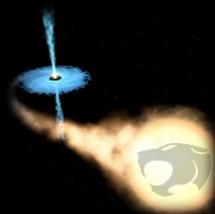
- Ewan Barr
- Marina Berezina
- Weiwei Chen
- Michael Kramer
- Jason Wu

- Aris Karastergiou
- Chris Williams



- Karel Adamek
- Wes Armour
- Cees Carels
- Jan Novotny

- Thomas Abbott
- Sarah Buchner
- Fernando Camilo
- David Horn
- Anton Joubert
- Jason Manley
- Simon Ratcliffe
- Maciej Serylak
- Lance Williams



Thanks SARA0/MeerKAT Observers



Image credit: SARA0

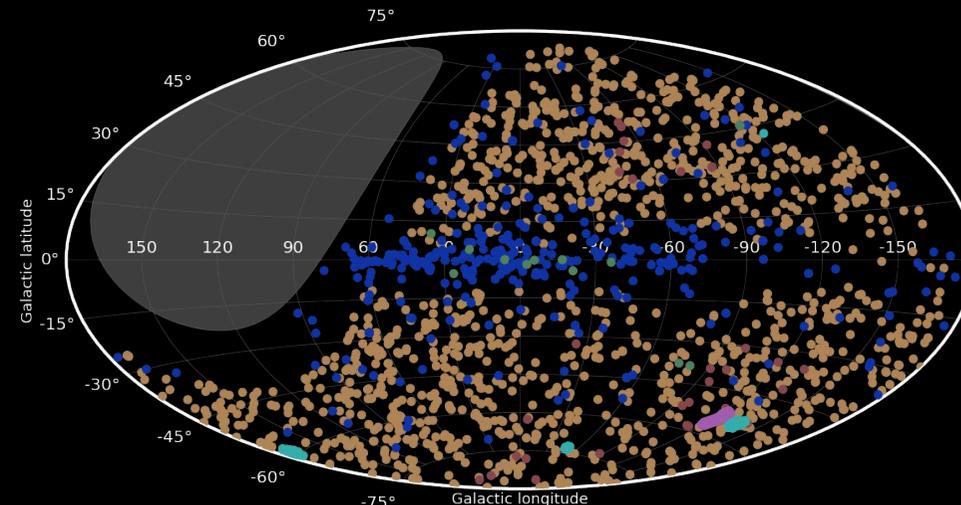
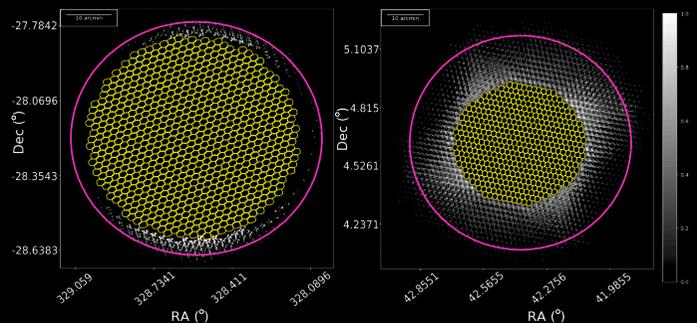


Image credit: L. Driessen

& MPIfR



OBSERVING MODES

Incoherent mode

- Total FoV: 1.27 sq.deg
- Using 64 dishes, a factor of 5-7 less sensitive compared to coherent mode
- Sensitivity comparable to Parkes radio telescope (0.7 Jy).

Coherent mode

- Total FoV: 0.4 sq deg at zenith (25% overlap)
- 768 tied-array beams in collaboration with MPIfR
- Use 40 core dishes
- Higher sensitivity and better localisation (<45")
- Sensitivity comparable to Green Bank Telescope (0.1 Jy)

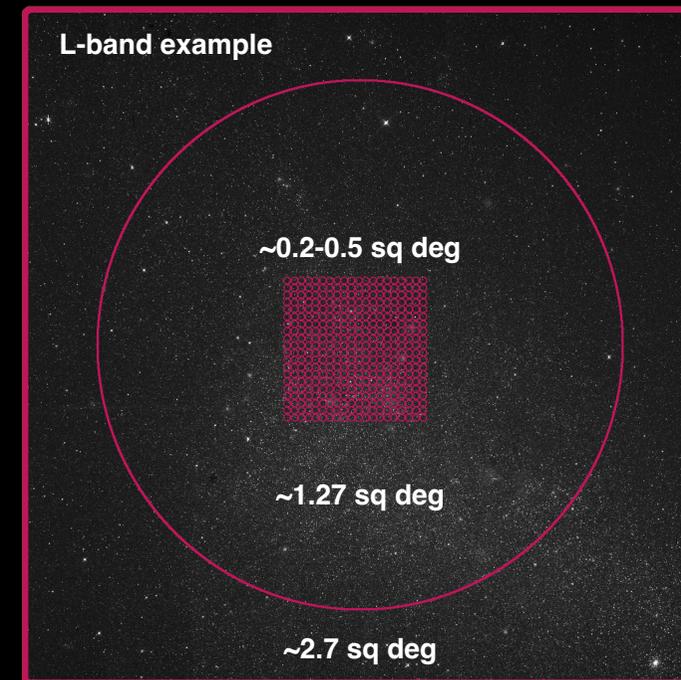
Processing

- UHF (544—1088 MHz), L-band (856—1712 MHz) and S-band (~3GHz/0.97)
- DMranges: U < 2200, L < 3600, S < 5000)

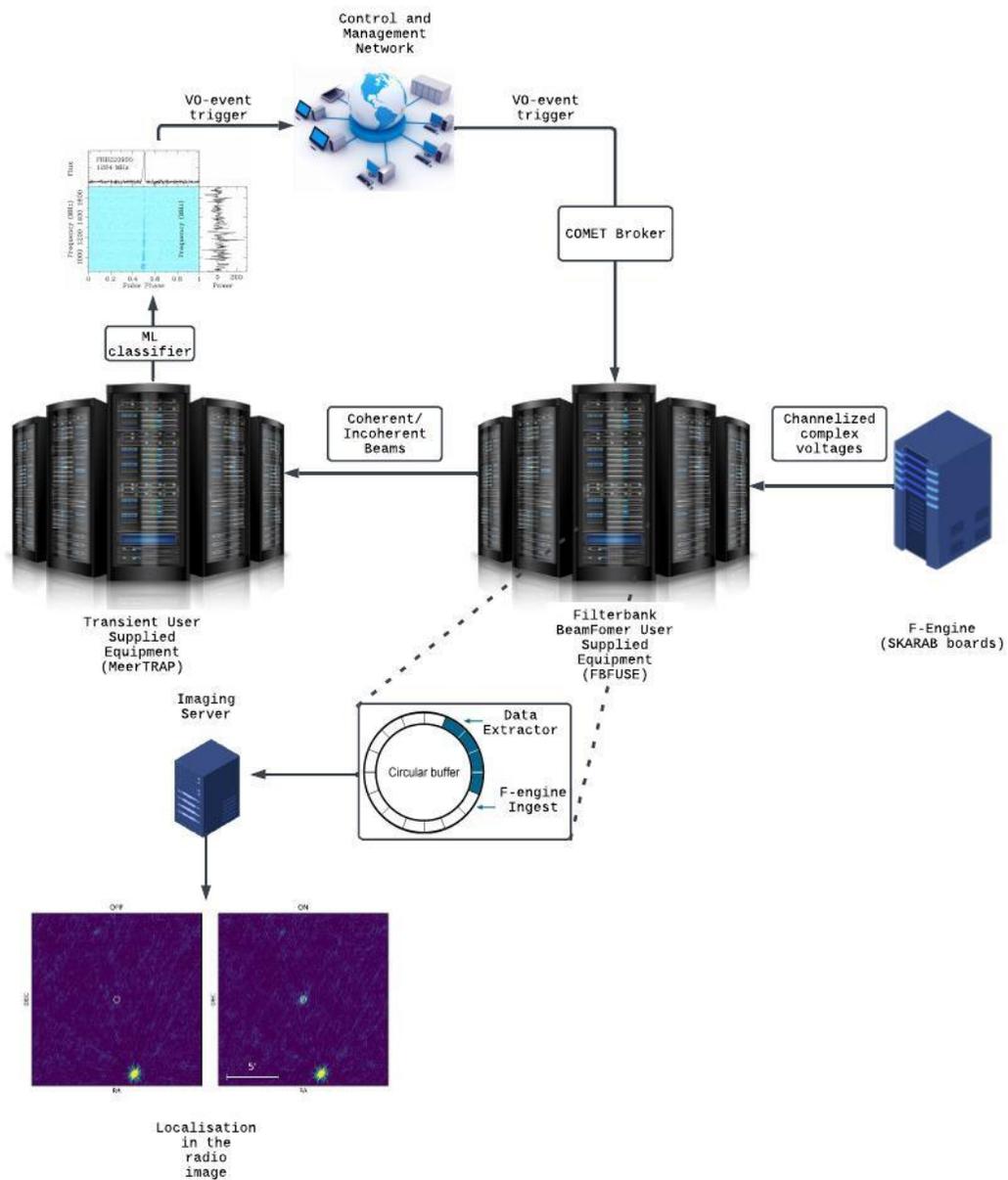
Transient buffer

- Store voltage data around the detected burst to perform fast imaging
- This mode useful for sub-arc second localisation (combined with beamforming post-facto).

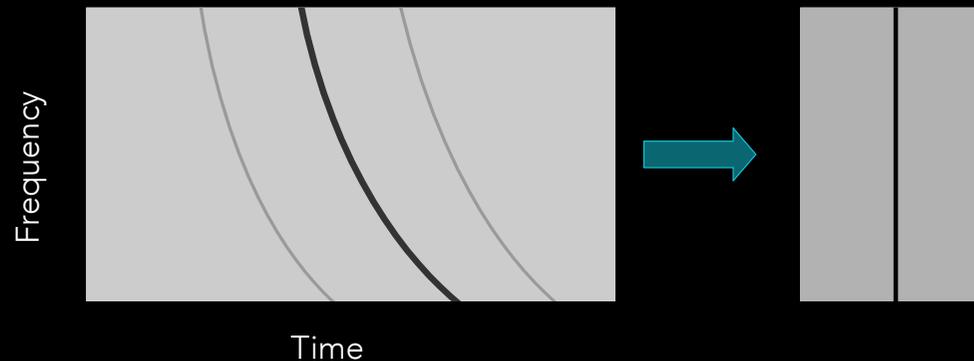
All beams are searched in realtime for pulsars and fast transients



SMC image from MeerLICHT



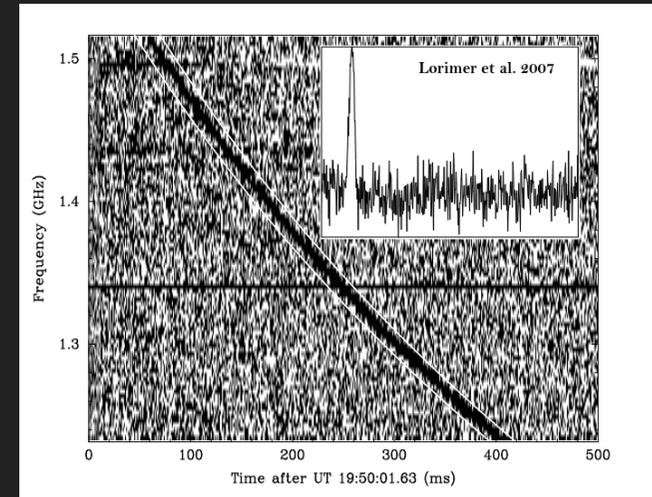
TRANSIENT BUFFER



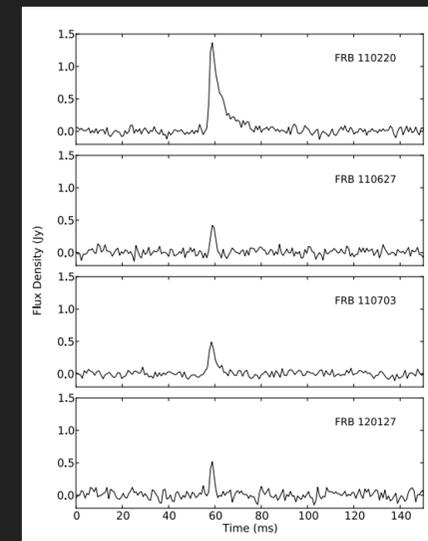
- Channelized voltage data capture on FBFUSE
- Can do a maximum of ~57 seconds of data capture (12 TB)
- Buffer dump accounts for the dispersion sweep of the burst (total stored is 0.3s)
- Get full array data — S/N boost typically factor of 1.5 — 5.
- Been in regular operation since Sept. 2022
- Not yet catching all FRBs.
- Imaging performed offline using custom scripts, DIFx and xGPU.

FRBS: THE ESSENCE

- ▶ Short Duration bursts of radio emission
- ▶ Extremely energetic events ($< 10^{44}$ erg s^{-1}) from $z_{\text{spec}} \sim 0.03$ to > 1 galaxies
- ▶ $\sim 5,000$ events/sky/day
- ▶ Some repeat! – No strict periodicity (??)
- ▶ Some show very long term (days) periodicities – binarity?
- ▶ Detected from 110 MHz to 8 GHz (observed)
- ▶ Not yet definitively seen at wavelengths other than radio (extragalactic).
- ▶ No statistically significant counterpart yet



Lorimer et al. 2007

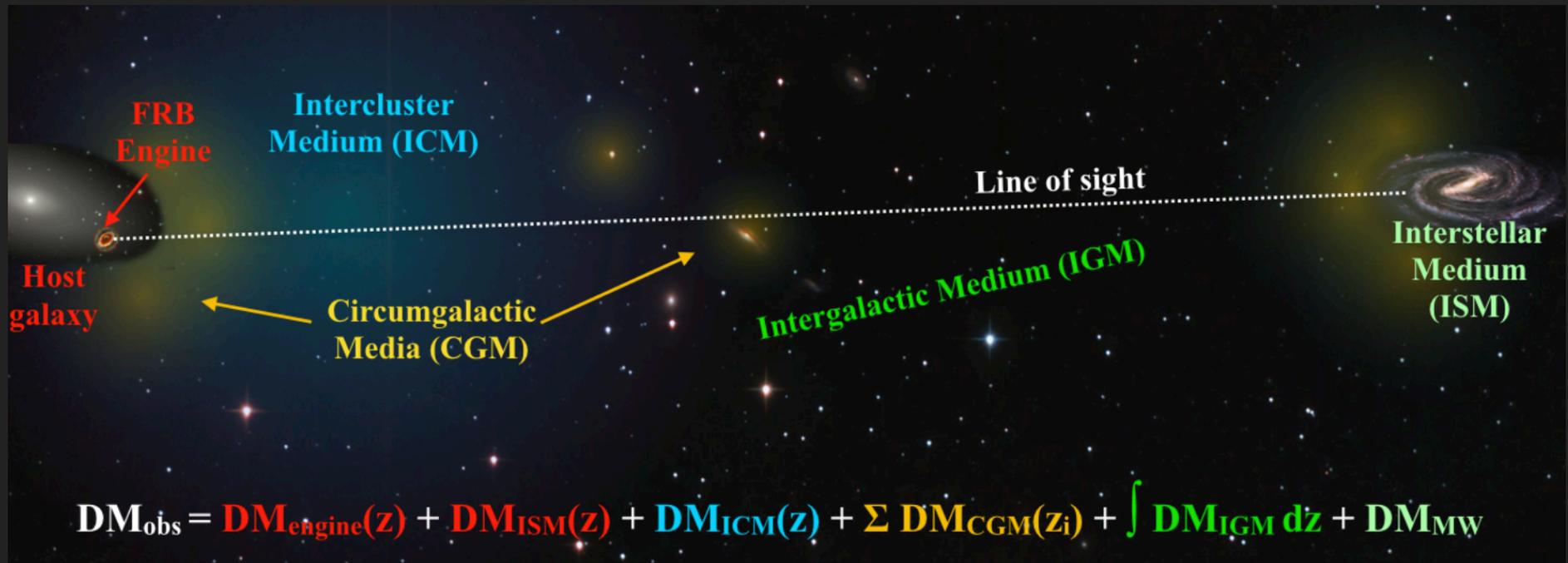


Thornton et al. 2013

DISENTANGLING THE DM DISTRIBUTION

- ▶ FRB signal bears the imprint of the propagation medium
- ▶ Magnetic field strength, inhomogeneities and turbulence
- ▶ Information about the source circum-burst region, host galaxy ISM, IGM, halos of intervening host galaxies, MW halo and ISM

Credit: Ravi et al. 2020



FRB MODELS

- ▶ Magnetospheric origin
- ▶ Shock wave models

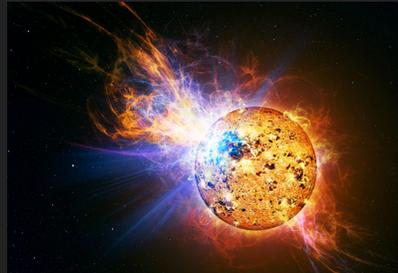
Magnetars:

- ▶ Young magnetar from SLSN
- ▶ Magnetar from CCSN
- ▶ Magnetar from DNS merger



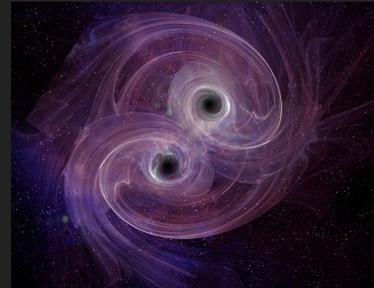
Pulsars:

- ▶ Pulsar giant flares
- ▶ Young SNR pulsars



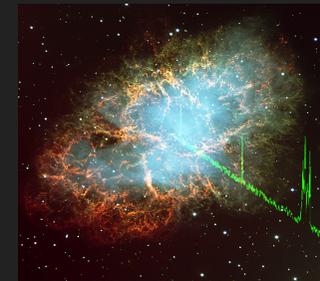
White dwarfs:

- ▶ WD from WD-WD merger
- ▶ White dwarf collapse (AIC)



Compact-object mergers:

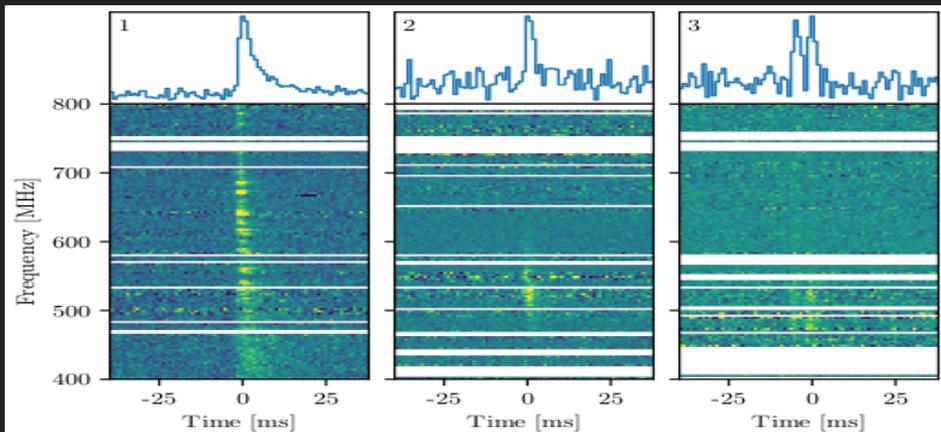
- ▶ NS-NS merger
- ▶ WD-WD merger
- ▶ NS-BH merger
- ▶ BH-BH merger



FRB CLASSES

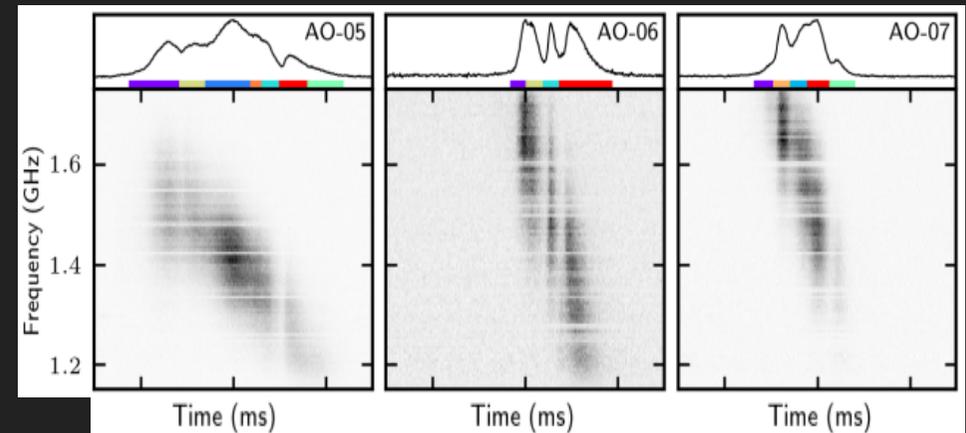
One-offs

- ▶ Thousands detected [TNS, CHIME/FRB+2021]
- ▶ Discovered in 2007 [Lorimer+2007]
- **Morphologies:** single broadband, single narrowband, multicomponent. [Pleunis+2021]
- **At least 30% complex bursts.** [e.g. Pastor-Marazuela+2023,2025]



Repeaters

- >60 published.
- Discovered in 2016 (FRB20121102A) [Spitler+2016]
- Two(++) are known to be periodically active [CHIME+2020, Rajwade+2020, Cruces+2021, Pastor-Marazuela+2021]
- **Morphology:** multicomponent, downward drift in frequency (sad trombone effect) [Hessels+2019]



UNVEILING AND UTILIZING FRBS

Production site

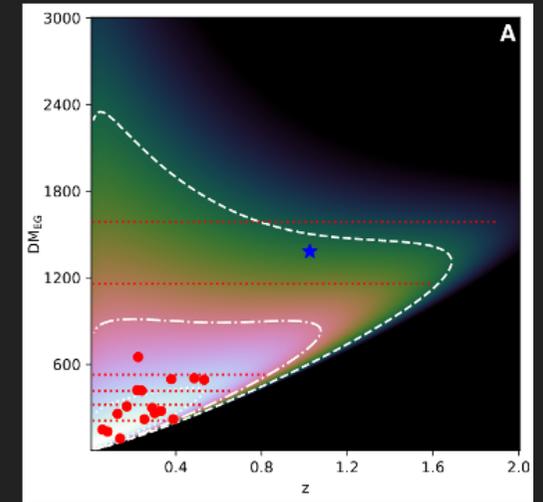
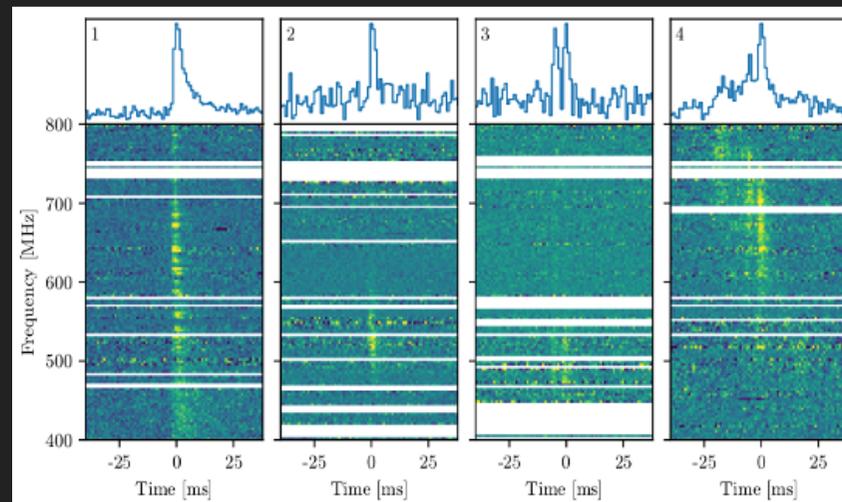
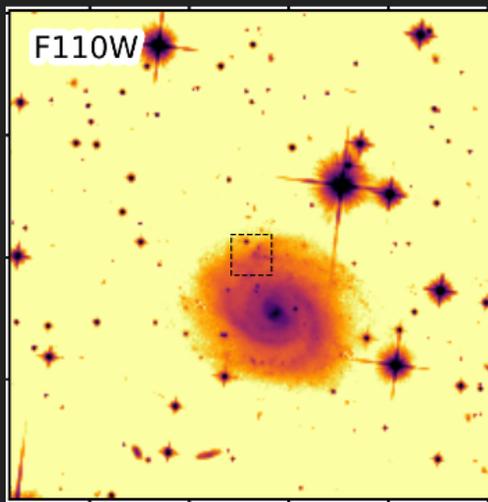
- How do the progenitors of FRBs form and evolve?
- What is their origin?

Emission process

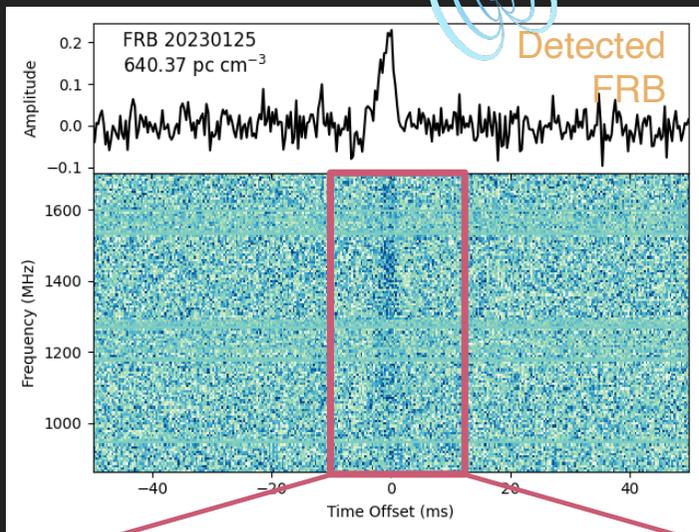
- What is the underlying physics of these energetic bursts?
- What is the influence of site and propagation?

Cosmological probes

- What do they reveal about the matter distribution in, and structure of the Universe?
- What can they tell us about the state and history of the Universe.



TRANSIENT BUFFER DATA



Example: FRB20230125D

DM = 640 pc cm⁻³

Detected in the L-band, IB + 1 CB

Localisation with often less than 1'' accuracy:

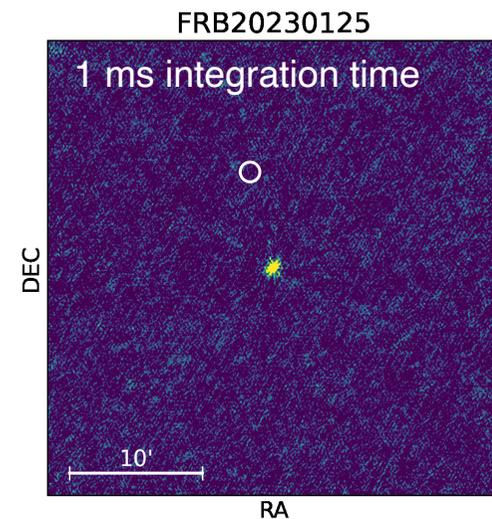
Host galaxy identification in optical data.

Follow up spectroscopy: $z = 0.3265$,
cf: $z_{\text{Macquart}} = 0.62(+0.14-0.34)$.

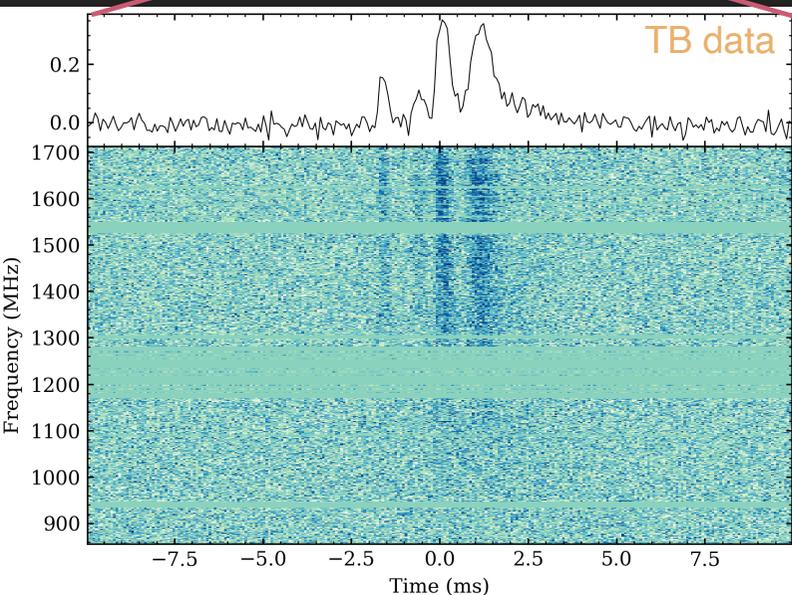
Coherently dedispersed TB data with μs time resolution:
Resolving complex morphological structures.

[Pastor-Marazuela et al. in prep]

Radio data



Optical data

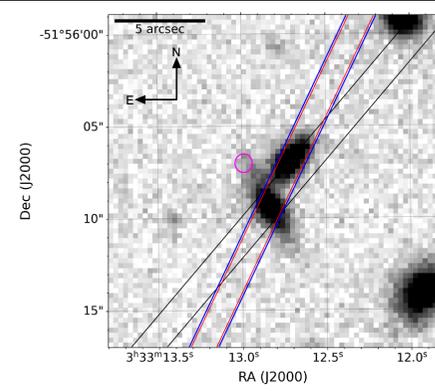
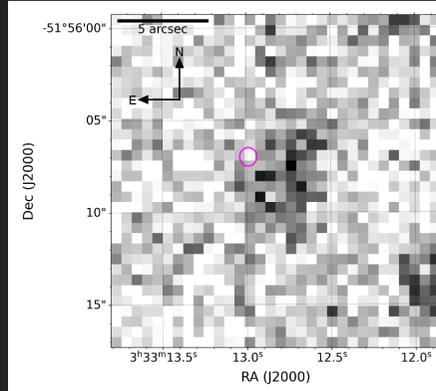
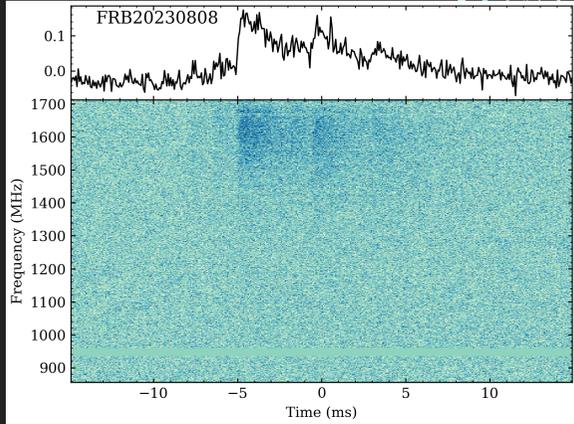


MEERLICHT



Image credit: SAAO

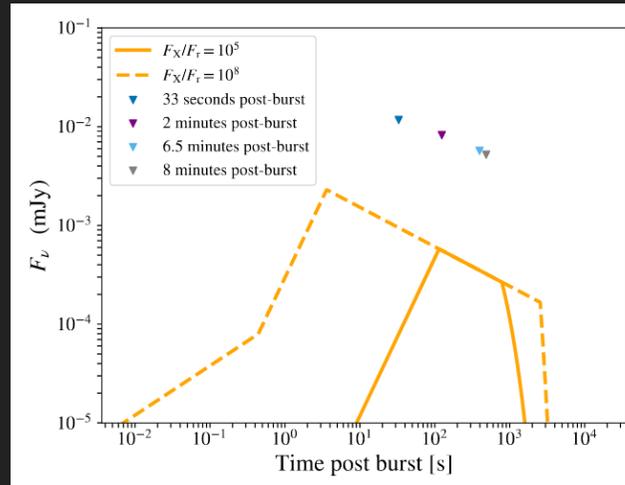
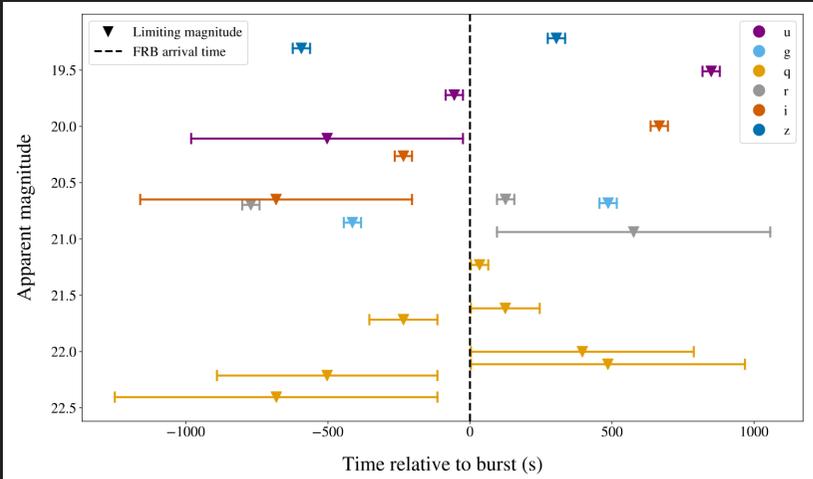
- MeerLICHT: 65-cm fully robotic optical telescope that can co-point with MeerKAT for simultaneous optical.
- Integration time of 1 minute (can reach limiting magnitude of 20.5 at g-band with 1" seeing)
- Regularly tracking MeerKAT since September 2022
- UCT Masters student — Kira Hanmer — regularly cross checked — simultaneity is proving to be hard!



Flux limit $f_{AB,q} < 11.7 \mu\text{Jy}$ for 60 s exposure ~ 3.4 s after the burst

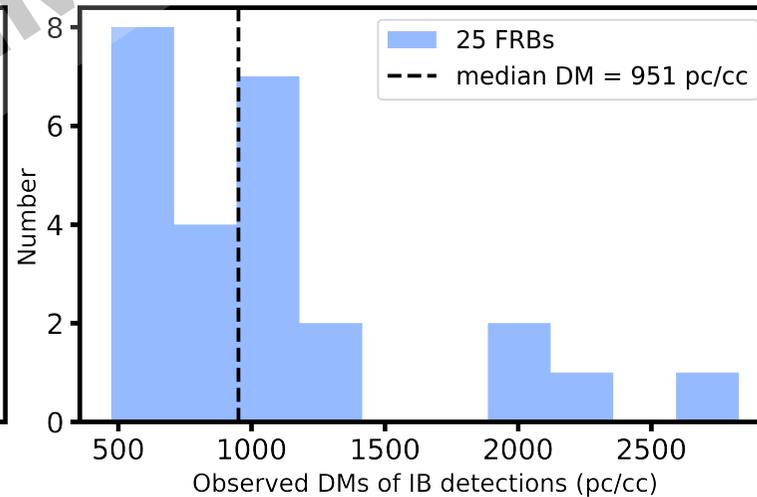
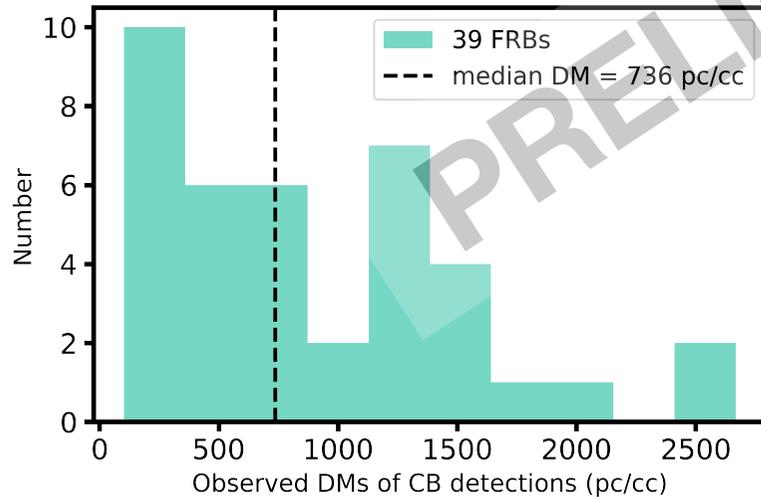
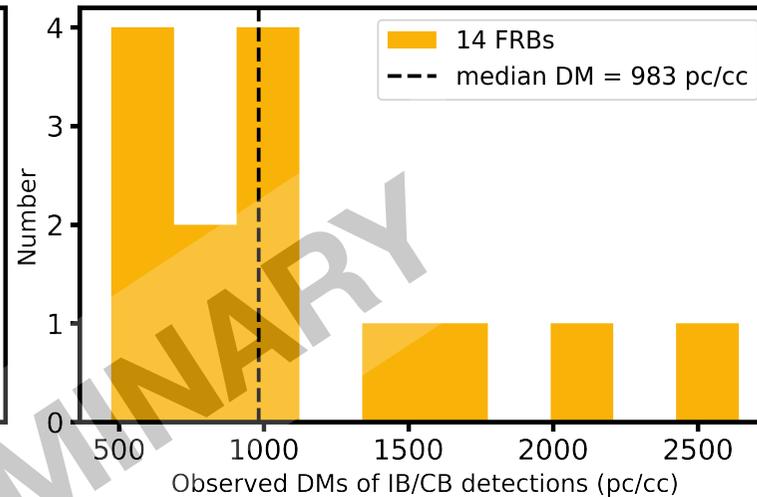
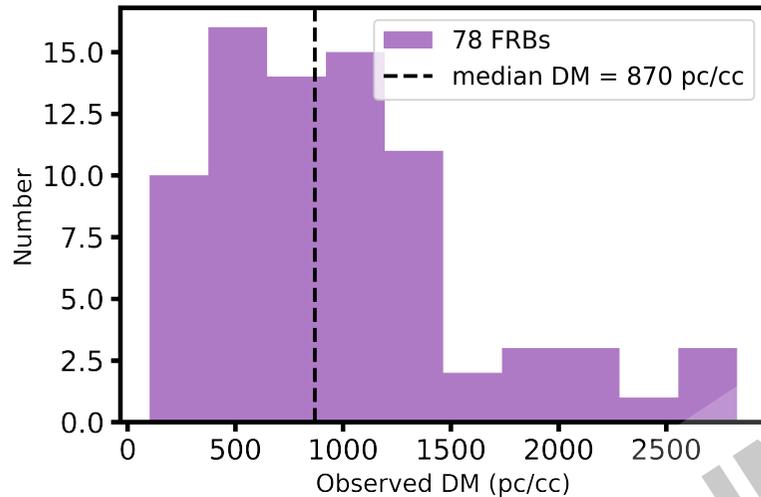
Luminosity limit of $\nu L\nu \sim 1.3 \times 10^{43} \text{ erg s}^{-1}$: $F_{\text{opt}}/F_{\text{radio}} \lesssim 0.023$

Shortest optical follow-up delay and deepest optical constraints for one-off FRBs.



Comparison to optical afterglow predictions for the synchrotron maser model [Margalit+2020, Cooper±2022] using F_x/F_r of 10^5 and 10^8 :

- ▶ CB & IB detection
- ▶ $DM_{\text{obs}} \sim 654 \text{ pc/cc}$
- ▶ $DM_{\text{Gal}} \sim 30 \text{ pc/cc}$
- ▶ $RM = 169.36 \pm 0.20 \text{ rad m}^{-2}$
- ▶ $t_{\text{scat}} = 3.10 \pm 0.13 \text{ ms}$
- ▶ Triggered
- ▶ Close galaxy pair
- ▶ $z_{\text{spec}} = 0.3472$
- ▶ MeerLICHT image just 3.4s after burst.
- ▶ Nothing seen in months after either.
- ▶ Unfortunately too far away to be constraining for models.



- Median DMs of ASKAP, CHIME, DSA 400-500.
- We have 31 voltage dump triggers so far.
- Total localisations ~35, so host galaxy studies possible.
- So far have redshifts for ~14 of those hosts.

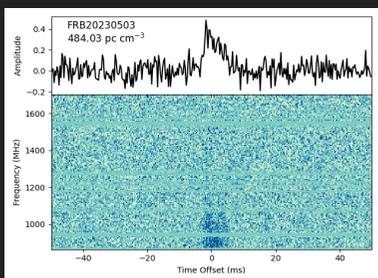


A COLLECTION OF FRBS

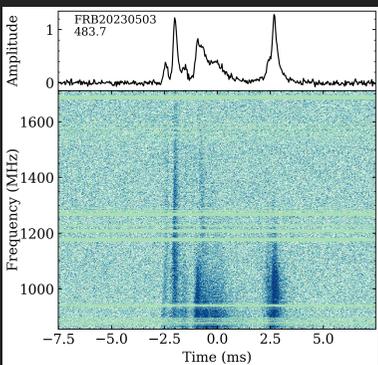
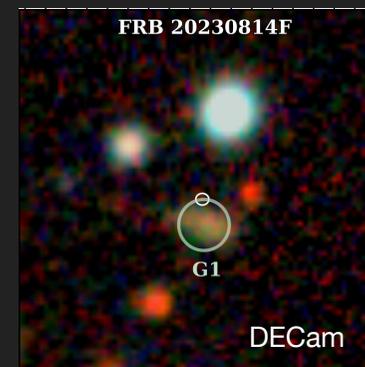
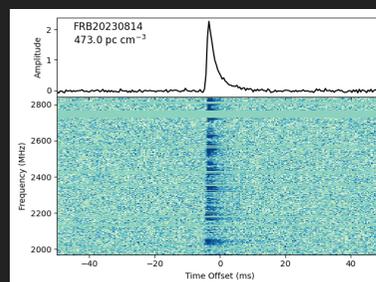
Pastor-Marazuela et al. in prep X 2.

- ▶ A collection of 15 (currently) one-off FRBs.
- ▶ Includes 11 localisations
- ▶ 9 have host galaxies with > 90% confidence
- ▶ 6 have redshifts in the range 0.33 – 0.85

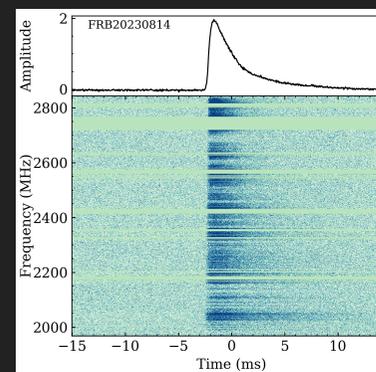
Please do not photograph, post or use this material



- Localised in 8s images
- DM = 1145 pc cm⁻³
- $z_{\text{spec}}=0.627$ (Keck)
- $z_{\text{macquart}}=1.27 + 0.28 - 0.62$



- $z_{\text{phot}}=0.32 \pm 0.15$
- $z_{\text{macquart}} = 0.42(+0.12-0.24)$

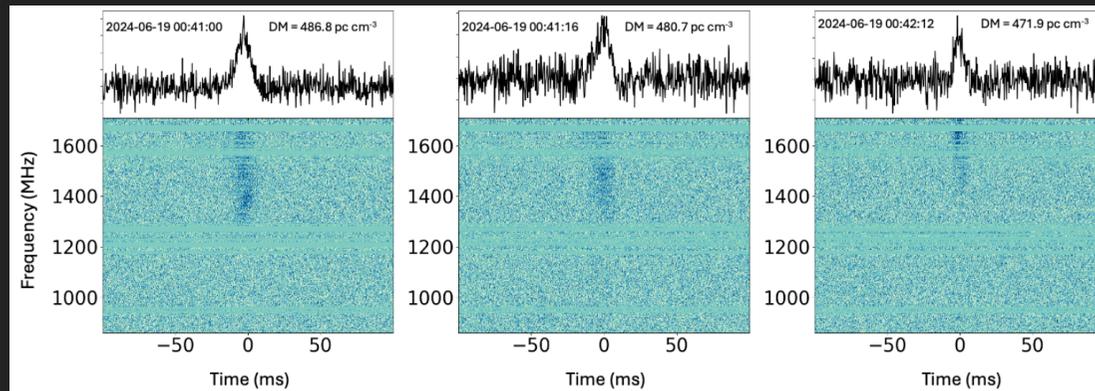


- First one-off FRB discovered in the S-band.
- Redshift incoming.



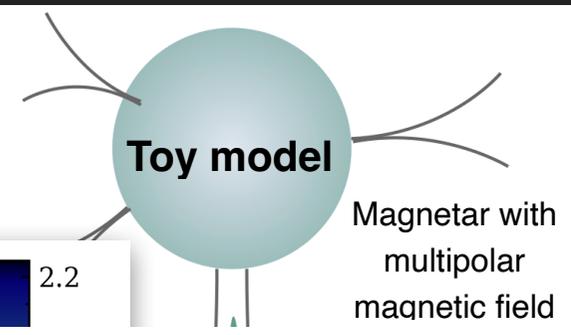
FRB 20240619D – FIRST REPEATER

- ▶ Discovery: 3 bursts detected by MeerKAT within 2 minutes on 2024 June 19 (MeerTRAP ATel #16690)

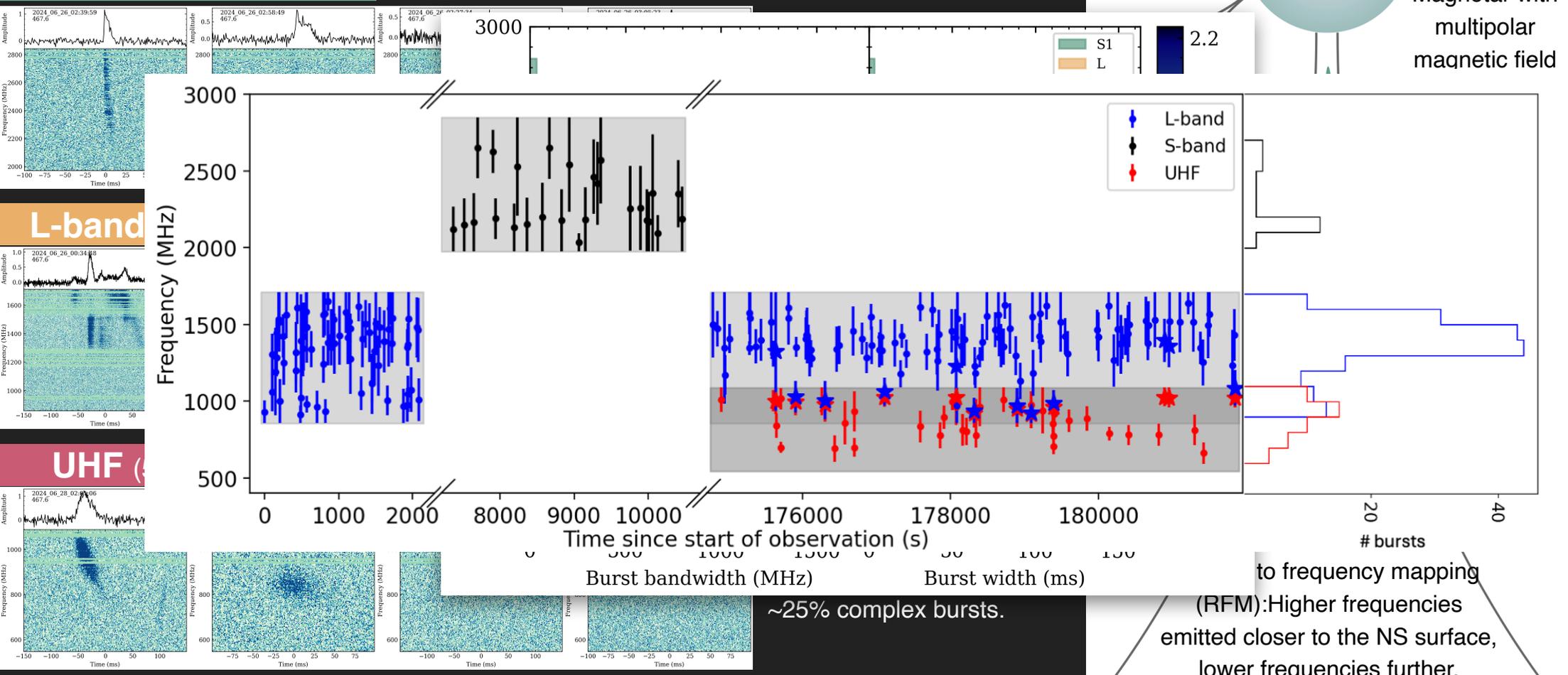


- ▶ MeerKAT DDT follow-up: 1 hr L-band + 1 hr S-band on 2024 June 26,
2 hr L-band + 2 hr UHF simultaneous sub-array on 2024 June 28
- No detections in ~ 4000 s (>1 h) of previous observations of the same field.
- → Sudden activation, reminiscent of magnetar outbursts (X/ γ -rays).
- During one of the DDT follow-up sessions we observed with MeerLICHT – but no emission seen coincident with a single burst and relatively strong upper limit from the stacked images (but integration time a bit too long).

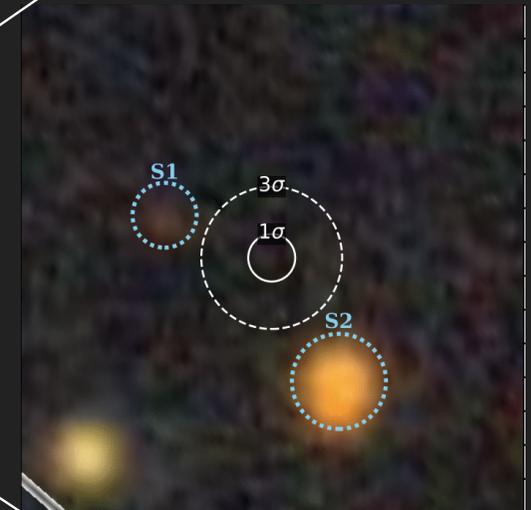
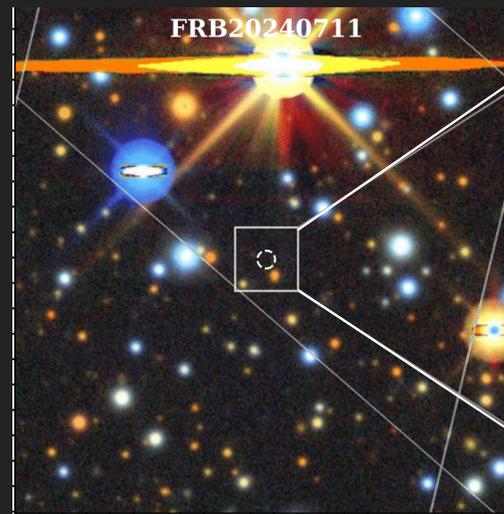
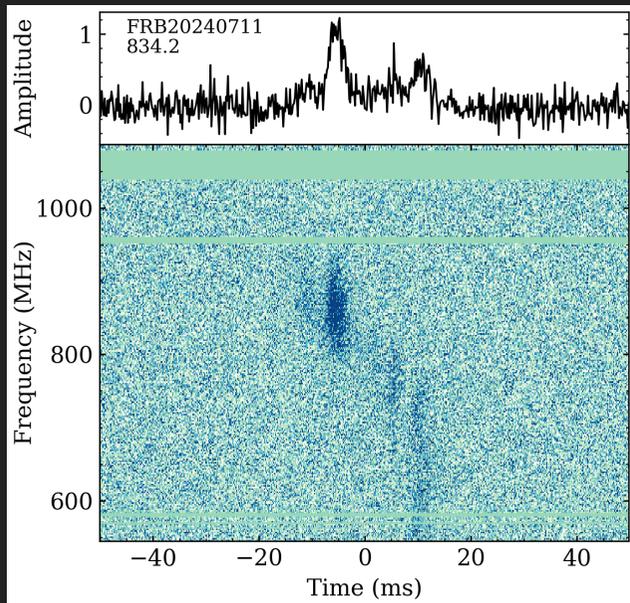
MEERTRAP FRB20240619D - BURST MORPHOLOGIES



S1-band (1968 - 2843 MHz)



to frequency mapping (RFM): Higher frequencies emitted closer to the NS surface, lower frequencies further.



Single burst detected during a 1h observation of PSR J1902-5105 (often targeted with MeerKAT).

- Downward drifting structure (sad trombone effect): repeater?
- Found in the UHF (544-1088 MHz)
- DM = 834.75 pc cm⁻³, no visible host in DESI-DR10.
- Low RM = 4.2 \pm 0.2 rad m⁻²; L~97%, V~3%
- Deeper images being undertaken — hampered by bright star nearby.

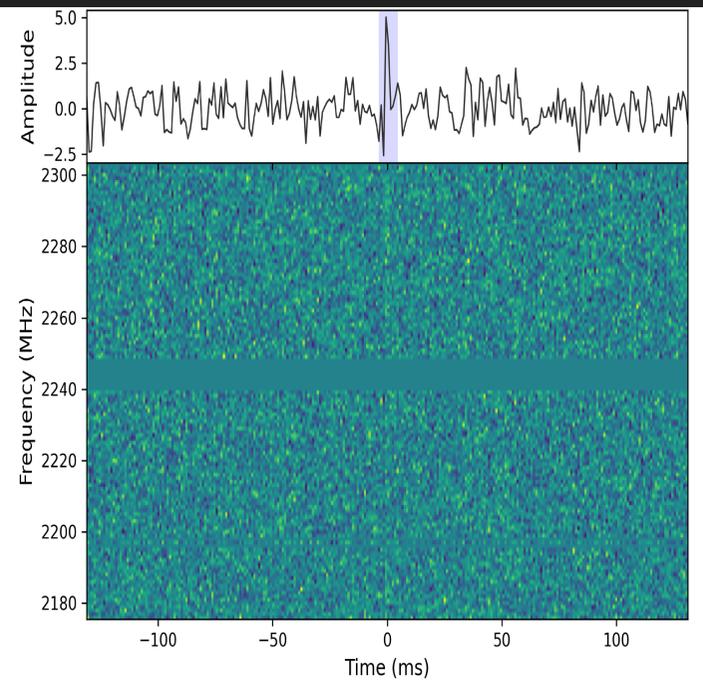
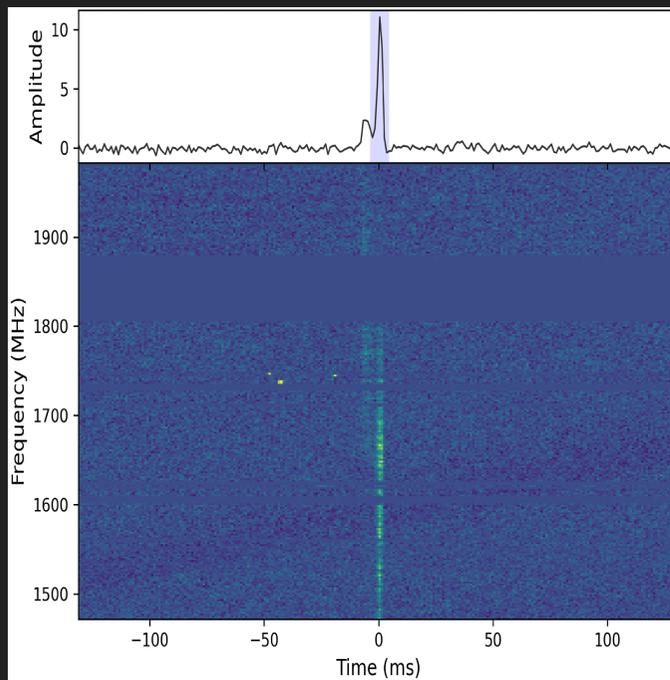
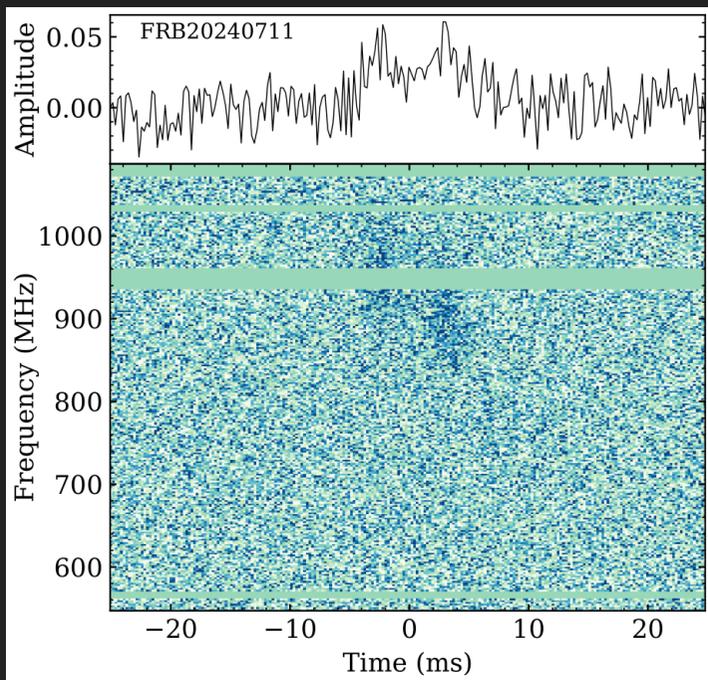


FRB20240711A: CONFIRMED NEW REPEATER

18/01/2025: burst detection, same location (within $\sim 6''$), same DM $\pm 2 \text{ pc cm}^{-3}$

Follow up with Parkes Murriyang on January 25 and 30 with UWL receiver (704-4032 MHz), led by Kavya Shaji see her again for latest results!
→ 5 new burst detections

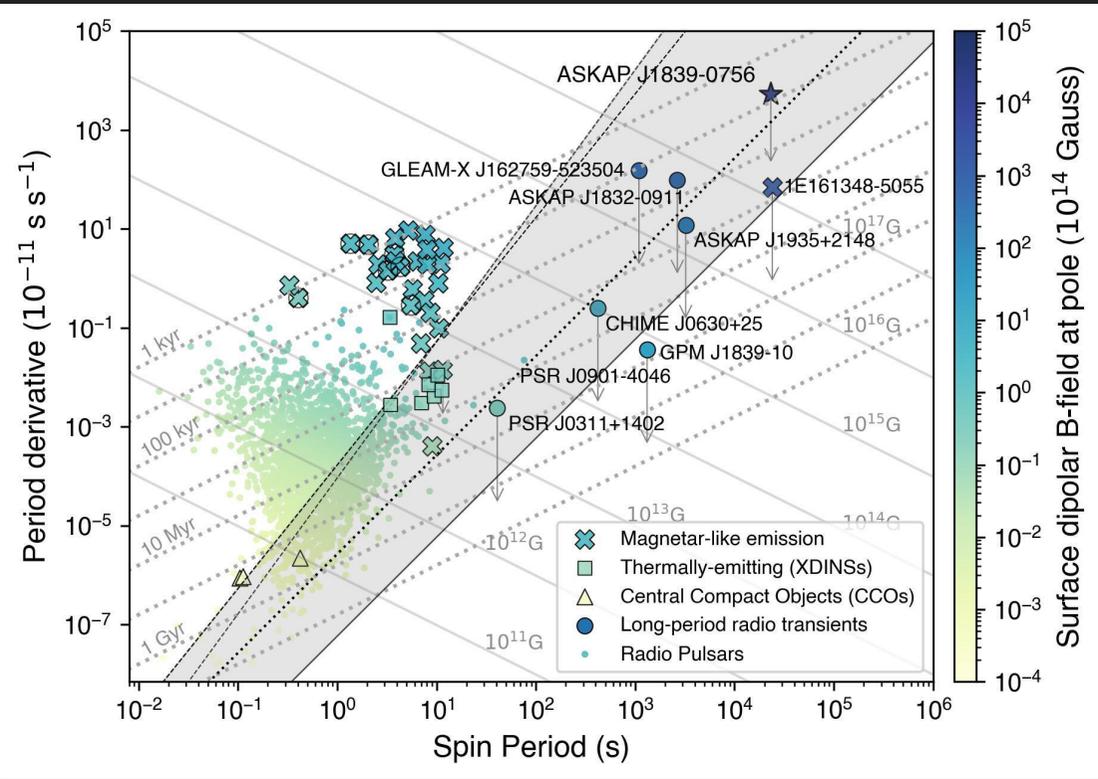
→ Confirmation of new repeater



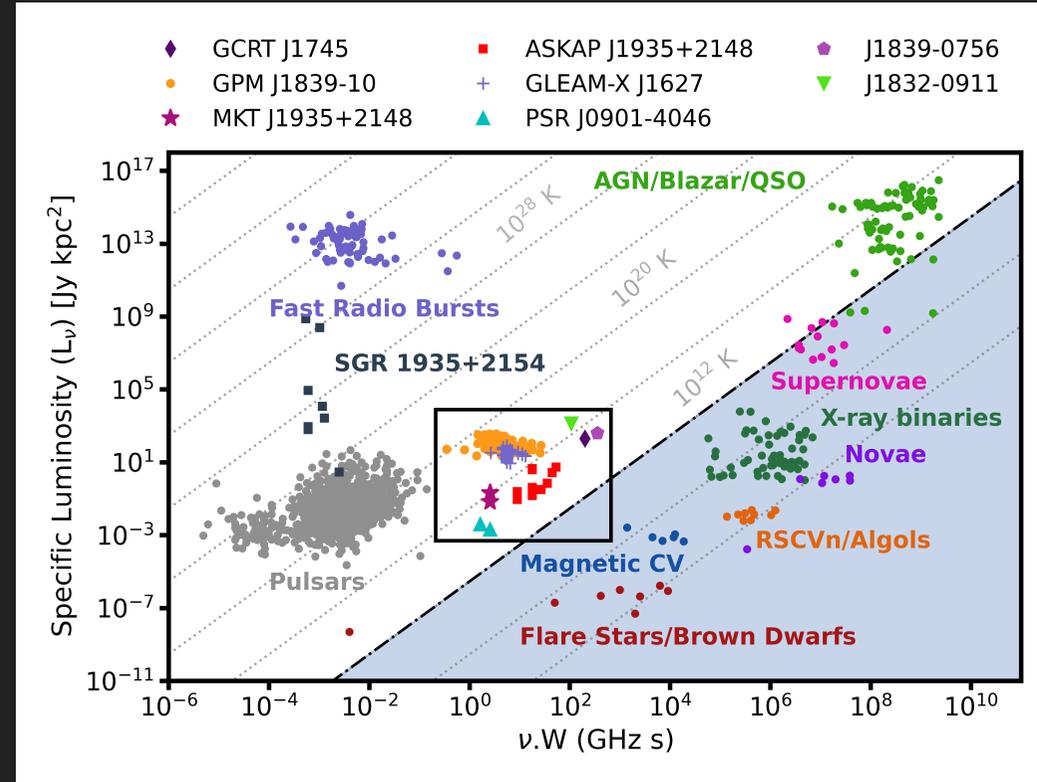
Link between sad trombone effect and repetition confirmed (again).

FRB20240711A is much less active than e.g. FRB20240619D, but activity spans larger date range.

SEARCHING FOR NEW GALACTIC TRANSIENTS.

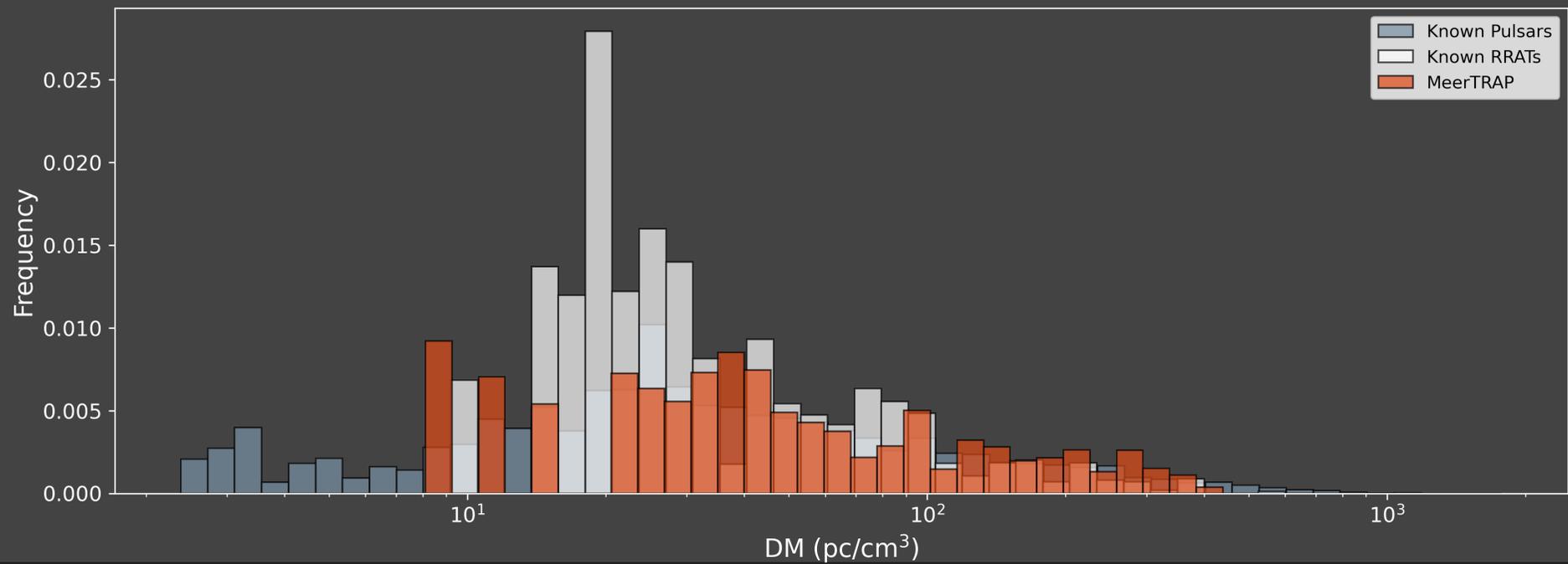


Credit: Lee





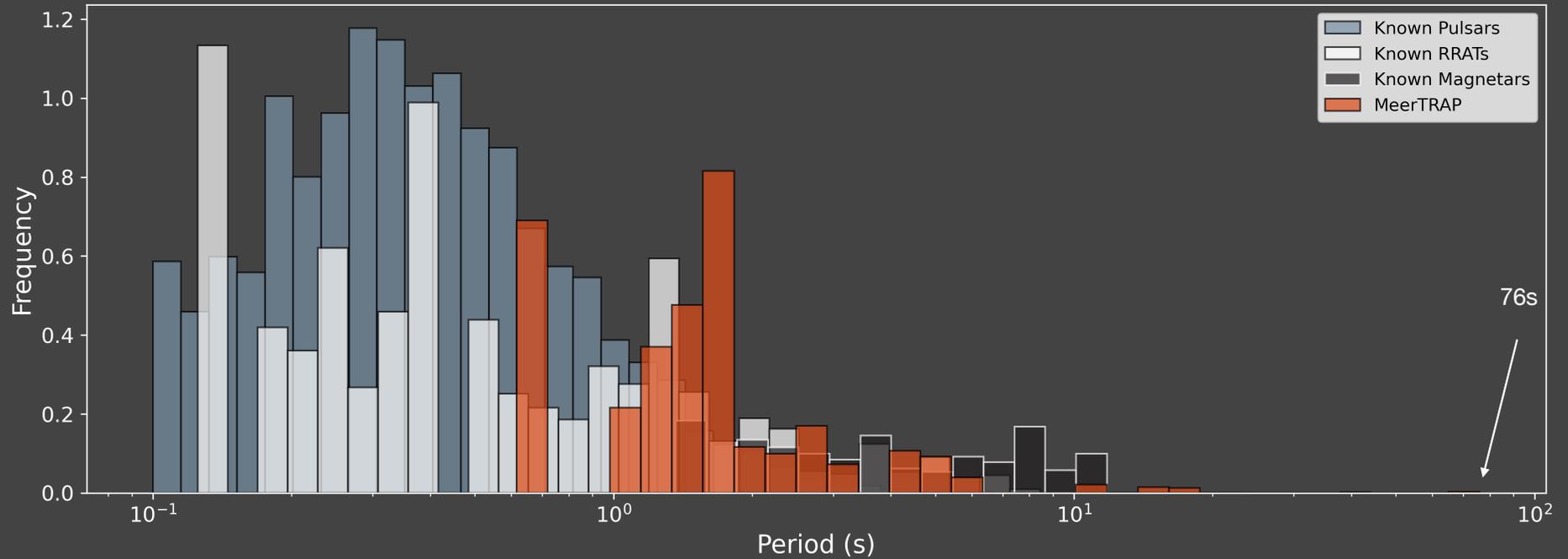
MEERTRAP > 100 NEW GALACTIC SOURCES



Bezuidenhout et al. 2022, Caleb et al. 2022, Surnis & Rajwade et al. 2023, Turner et al. 2025, Tian et al 2026, Singh et al. 2026.



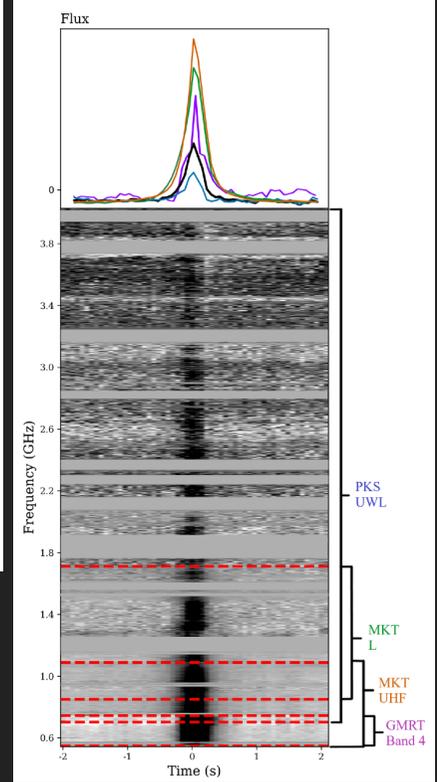
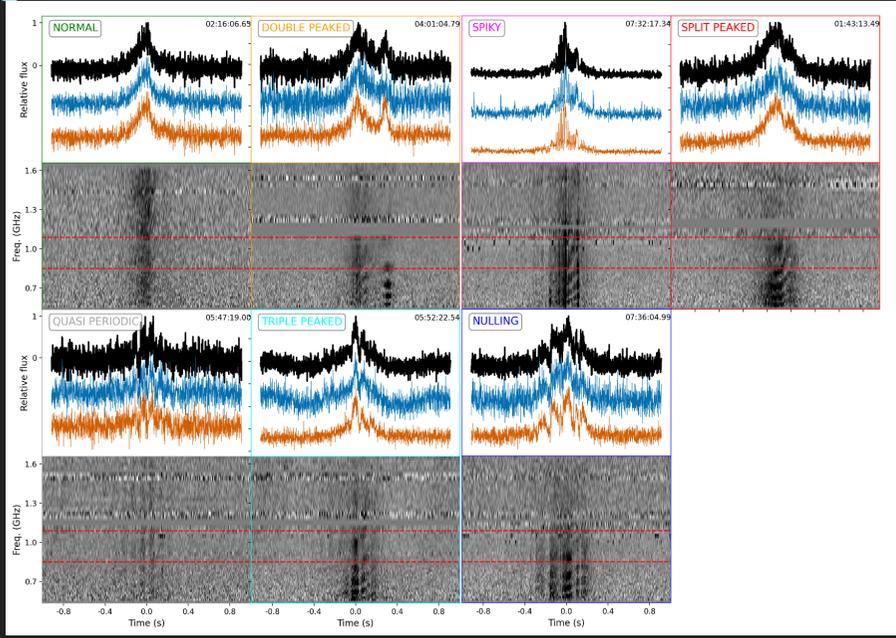
MEERTRAP > 100 NEW GALACTIC SOURCES



Bezuidenhout et al. 2022, Caleb et al. 2022, Surnis & Rajwade et al. 2023, Turner et al. 2025, Tiaan et al in prep.

MEERTRAP PSR J0901-4046 (AKA MTP0013)

- ▶ Spin period = 75.883 seconds
- ▶ DM = 52.6 pc cm⁻³
- ▶ Distance ~327 pc
- ▶ Periodic microstructure seen at ~/ 1000th of period.
- ▶ Seen all the way down to ~320 MHz and up to ~4 GHz.
- ▶ L-band ~ 90 mJy ; UHF-band ~ 170 mJy
- ▶ Most recent timing shows timing (1/10000th) precision still Pdot holding steady.



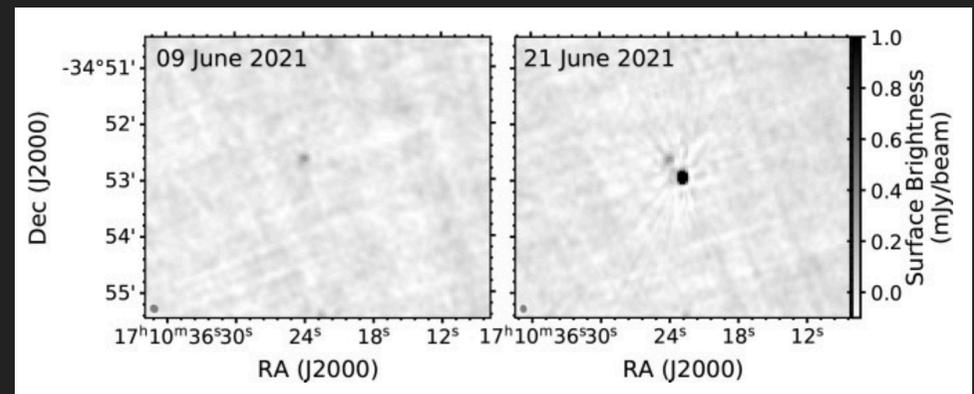
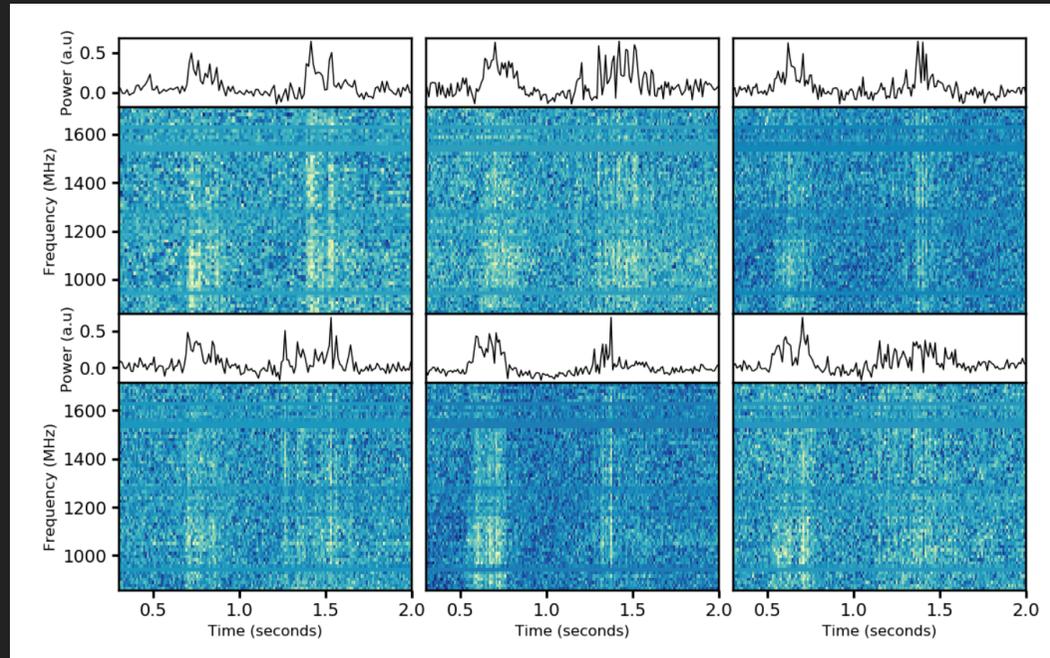
Shape type	Caleb et al. (2022)		This work	
	Number	Proportion	Number	Proportion
Split peaked	65	33%	25	17%
Normal	53	27%	102	68%
Spiky	12	6%	8	5%
Quasi-periodic			5	3%
Double peaked			5	3%
Triple peaked			3	2%
Nulling			3	2%
	196		151	

Caleb et al. 2022, Bezuidenhout et al. 2025.



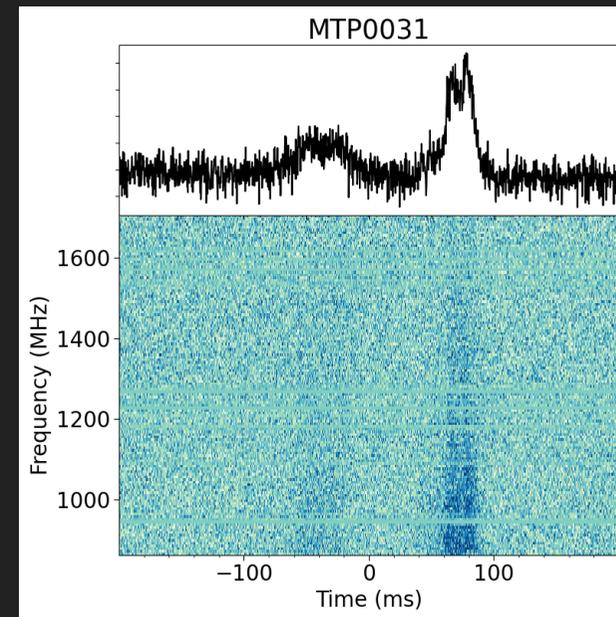
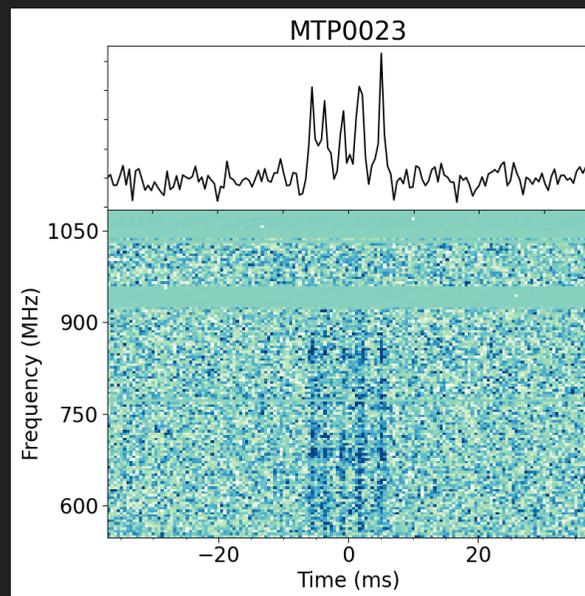
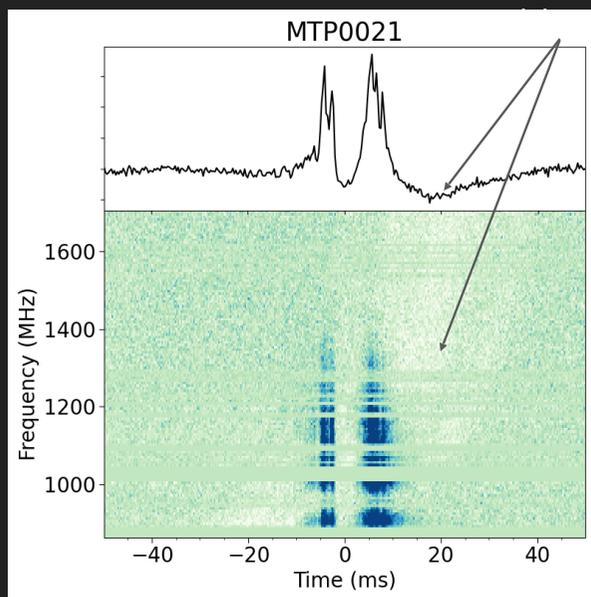
PSR J1710–3452 (AKA MTP0027)

- ▶ Spin period = 10.4 seconds
- ▶ Discovered through the detection of 97 bright radio pulses in only one out of 66 epochs of observations spanning almost three years. Total: 1320 min.
- ▶ We observed the source location with the Swift X-ray telescope but did not detect any significant X-ray emission (bursts or steady).
- ▶ No evidence for any extended emission, which MeerKAT is very sensitive to.
- ▶ The long period and the microstructure in the single-pulses resembles the emission of radio-loud magnetars.
- ▶ At a relatively high Galactic latitude (2.9°), making it potentially one of the oldest and the most intermittent magnetars known in the Galaxy.
- ▶ The very short activity window of this object is unique and may point towards a yet undetected population of long period, highly transient radio emitting neutron stars



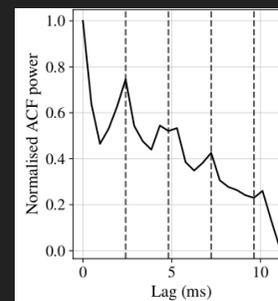
MEERTRAP SOME SHOW VERY INTERESTING PULSE PROFILE SUBSTRUCTURE

zero-DM RFI



- DM = 8.46 pc cm⁻³ from optimising structure
- Bright, S/N > 130!

- Microstructure has periodicity $P_{\text{rot}} / 1000$

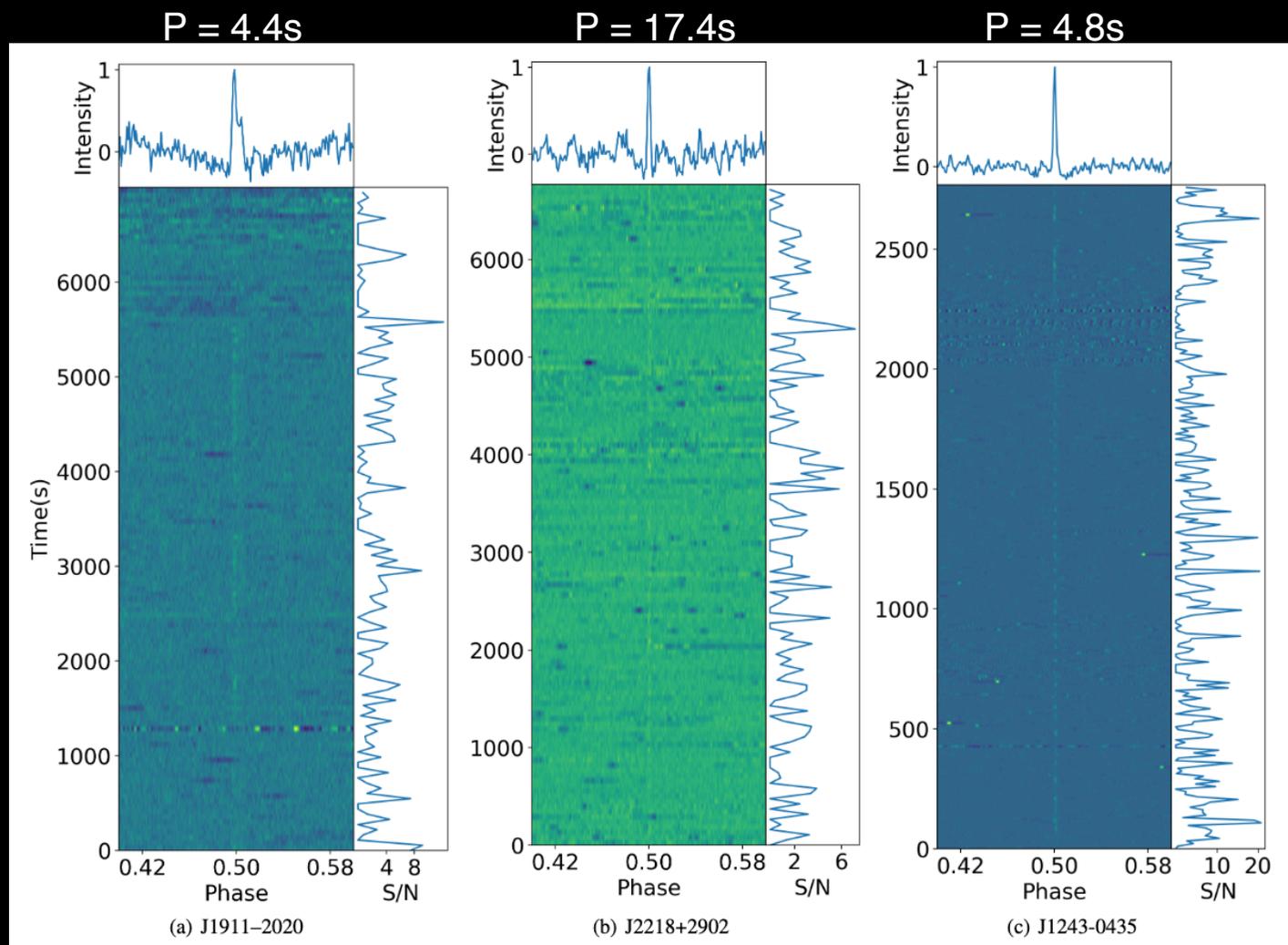


- $P = 2.55$ s with a wide pulse
- Occasional substructure

For data, scripts & more, see Turner+2025: [arxiv.2501.08224](https://arxiv.org/abs/2501.08224)

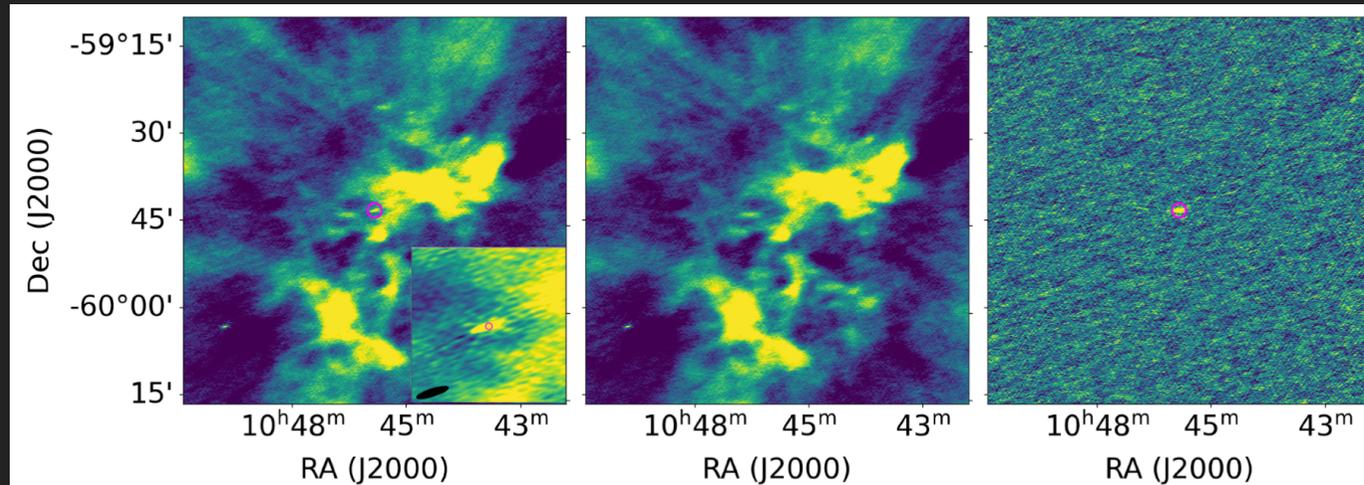
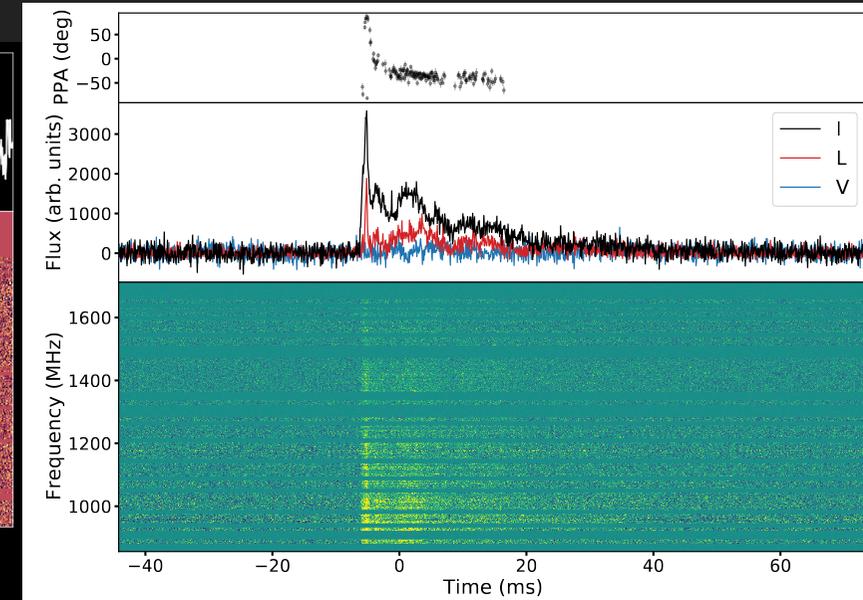
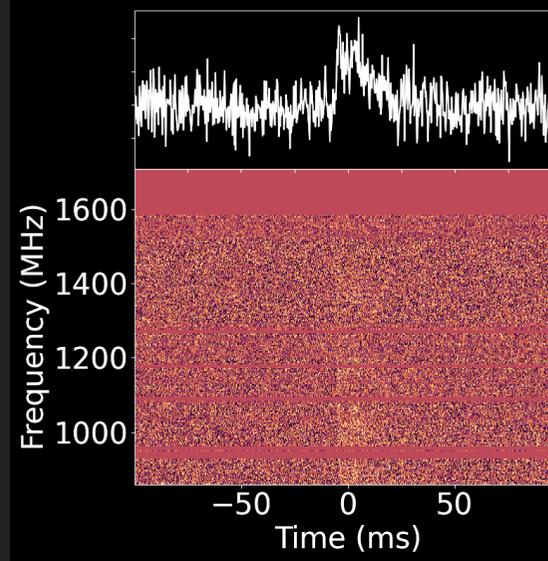
MEERTRAP RRATS: IN THE EYE OF THE TELESCOPE OR EPOCH(?)

Effelsberg follow-up: periodic but somewhat variable signals are detected from 3 sources.

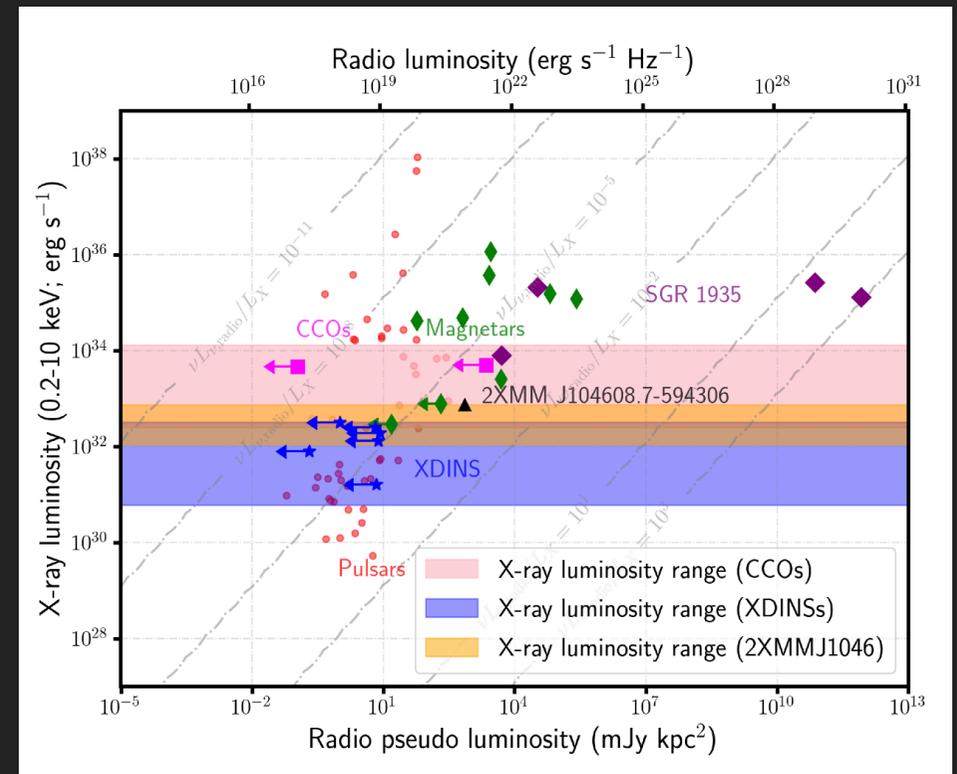


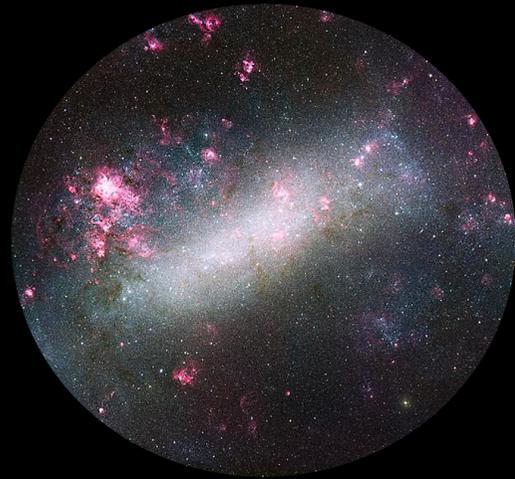
- ▶ Single pulse detected in the incoherent beam.
- ▶ $DM = 98.6 \pm 3 \text{ pc cm}^{-3}$
- ▶ Distance of 1.5-2.3 kpc
- ▶ Burst rise time just 1.1 ms.
- ▶ Best fit with 8 components. No periodicity.
- ▶ Triggered our TB so we could localise and also beam form.
- ▶ Located at the edge of the Carina Nebula
- ▶ No pulses/periodic signal seen in an hour follow up with Murriyang.

Discovery Pulse

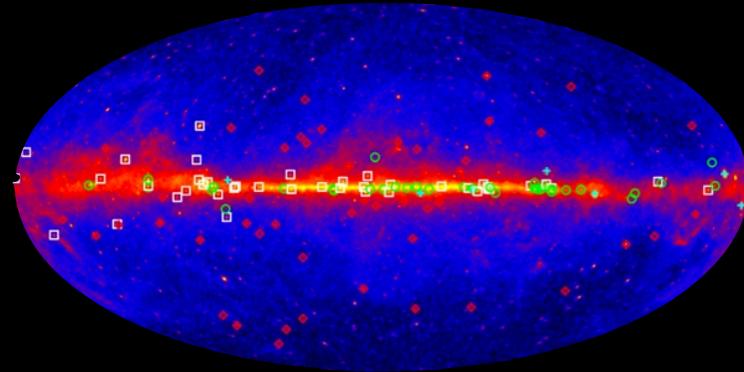


- ▶ Associated with XMM J104608.7-594306 in the Carina Nebula region (1").
- ▶ Considered to share characteristics with XDINSs and CCOs (Pires et al. 2015). – radio quiet!!!
- ▶ 3.9-sigma period of 18 ms in XMM (Pires et al. 2015). But radio pulse is wider!
- ▶ We checked many instruments and no high-energy bursts seen at the time, nor previously. Also no periodicity found.
- ▶ Isolated burst of radio emission could be akin to the bursts seen from the magnetar SGR J1935+2154
- ▶ 2XMM J104608.7-594306 may represent a unique evolutionary phase whereby the neutron stars are transitioning from being magnetically (magnetars) or thermally (CCOs/ XDINS) powered to rotationally powered neutron stars and may point to the onset of coherent radio emission commonly seen in pulsars.

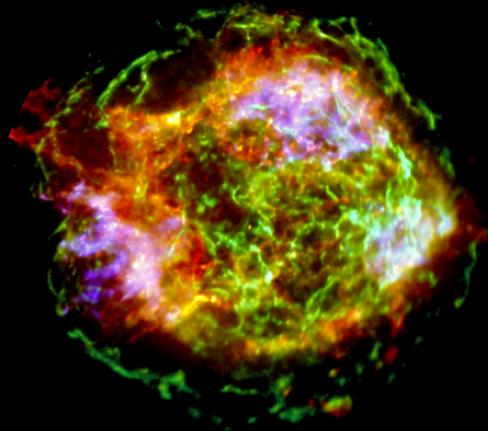




Nearby galaxies



Fermi sources



TRAPUM

Transients and Pulsars with MeerKAT



Globular clusters

WHO ARE WE?



Prof. Michael Kramer

PIs



Prof. Ben Stappers

Working group chairs

SNR/PWN/TeV

Fermi

Nearby galaxies

Globular clusters

Follow up

Project scientist



Prof. Rene Breton & Dr Colin Clark



Dr Lina Levin-Preston



Dr Alessandro Ridolfi



Dr Marta Burgay



Dr Ewan Barr

>64 members from 20+ institutes, 27 Masters and PhD students (10 graduations so far)



TRAPUM

Transients and Pulsars with MeerKAT

TOTAL DISCOVERIES: 281

GC: 106

MMGPS-L:
78

FERMI: 46

MMGPS-S: 8

TEV/SNR/PWNE:
2

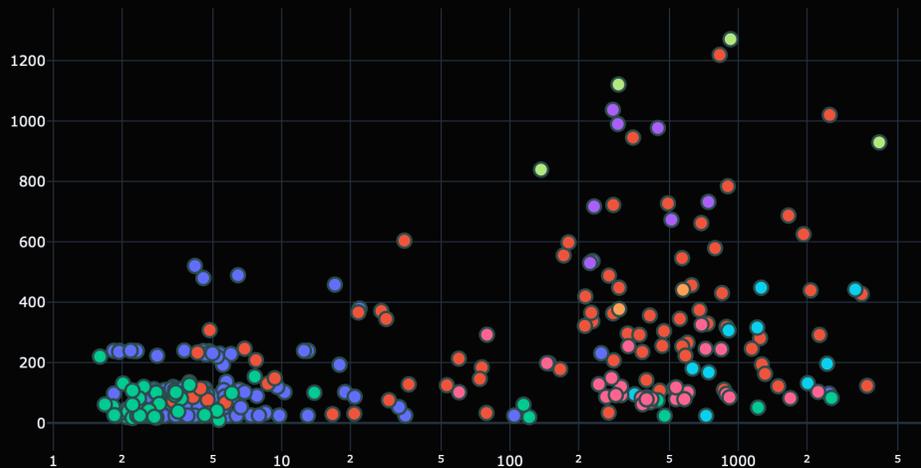
MMGPS-
UHF: 10

EXGAL: 27

MMGPS-
SGRA: 4

LAST UPDATED: 2025-10-03 16:58

Graph Table



- GC
- MMGPS-L
- FERMI
- MMGPS-S
- TEV/SNR/PWNE
- MMGPS-UHF
- EXGAL
- MMGPS-SGRA

X-axis: Period (ms)

y-axis: DM (pc cm⁻³)

Z-axis: Project

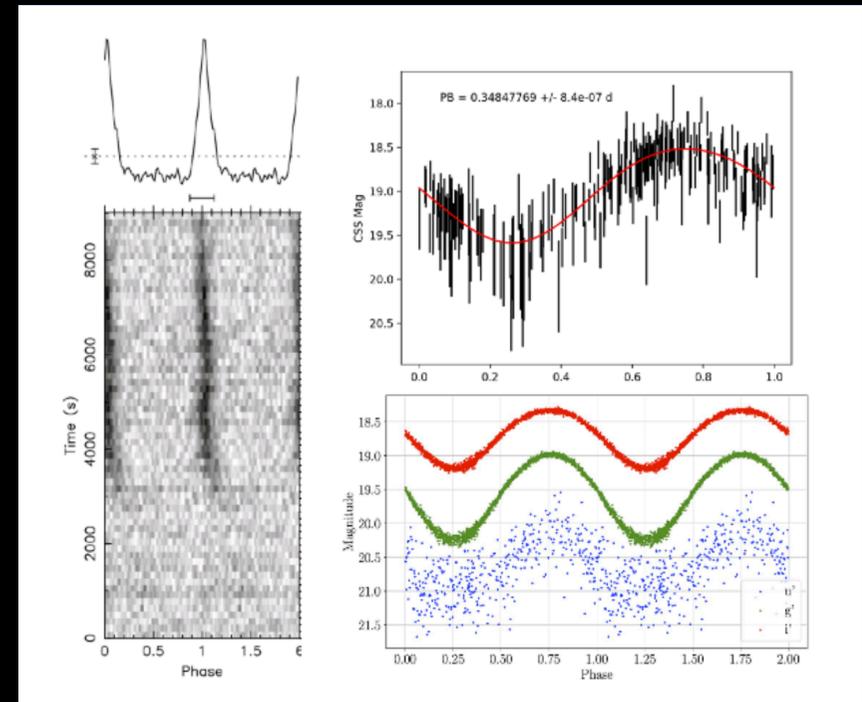
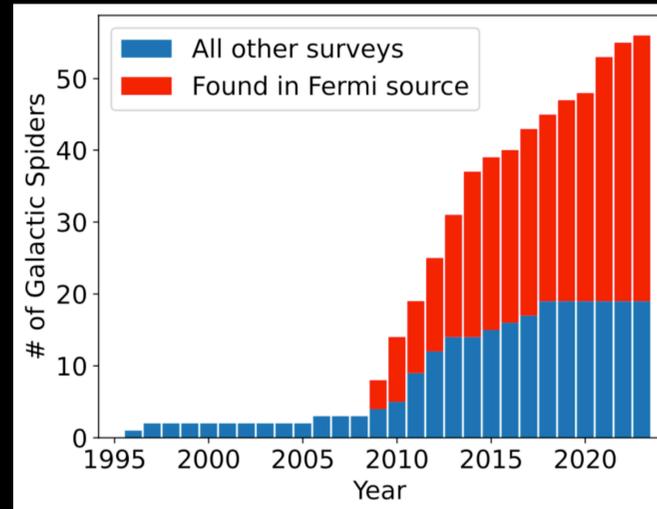
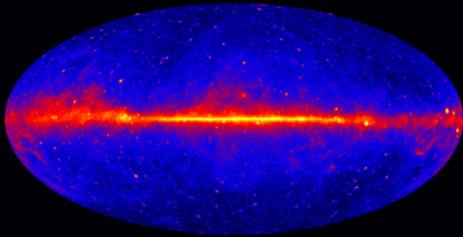
log-x

log-y

Update

trapum.org/discoveries

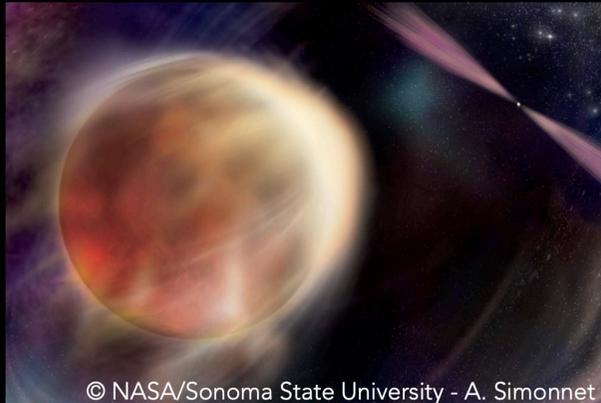
FERMI UNIDENTIFIED SOURCES



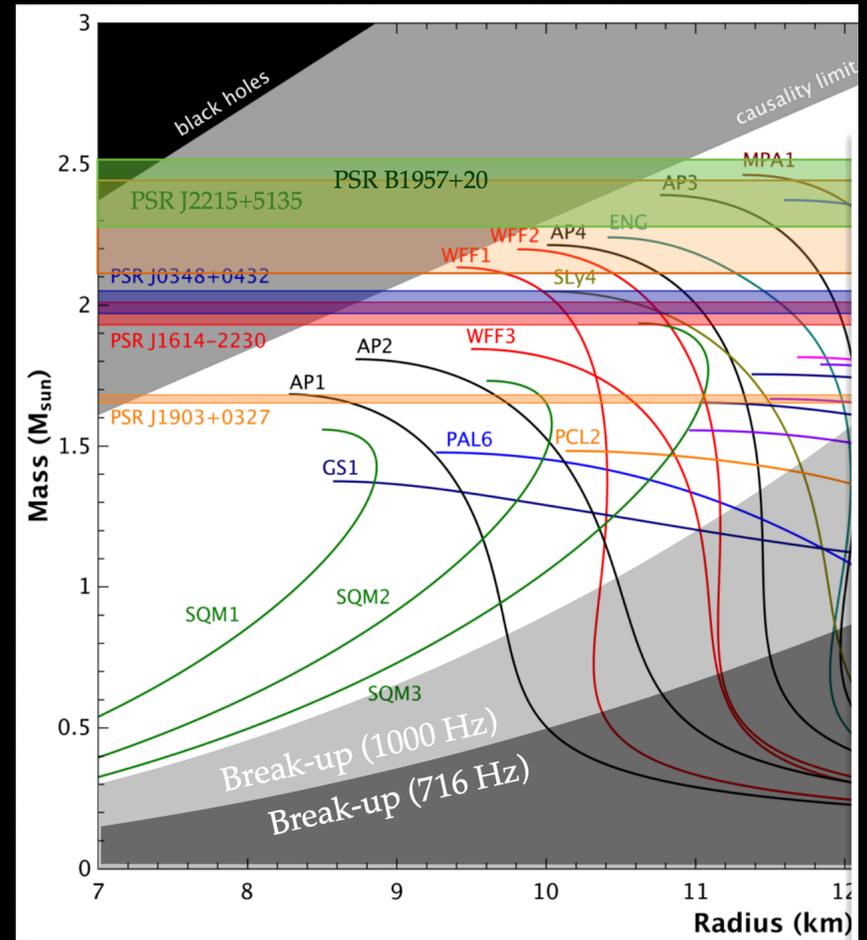
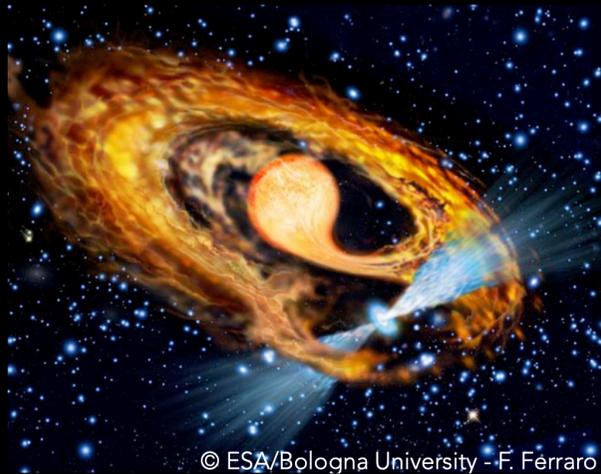
TRAPUM already discovered more than 46 new MSPs

"SPIDER" BINARIES

Black Widows ($\sim 0.02 M_{\odot}$)

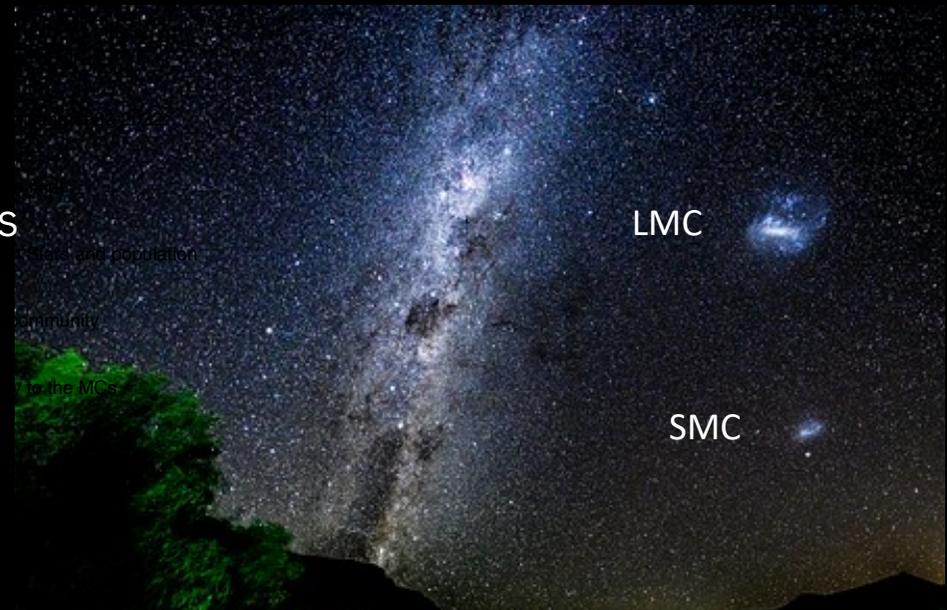


Redbacks ($\sim 0.2-0.4 M_{\odot}$)



EXTRAGALACTIC PULSARS

- Rare: Of 3k pulsars discovered, 31 are extragalactic
- All in the Magellanic Clouds, radio discoveries with Murriyang 1983-2022
- New observatory with better sensitivity : more pulsars to find!
- Different galaxy: properties impact pathways to Neutron Stars and population
- Extragalactic NS merger rate update: interest to GW community
- FRBs are linked to NS, one repeater in a similar galaxy to the MCs



DISCOVERIES IN THE SMC — DOUBLED THE POPULATION.

New pulsars !

Young X-ray pulsar in PWN
Radio upper limit (Carli et al.2022)

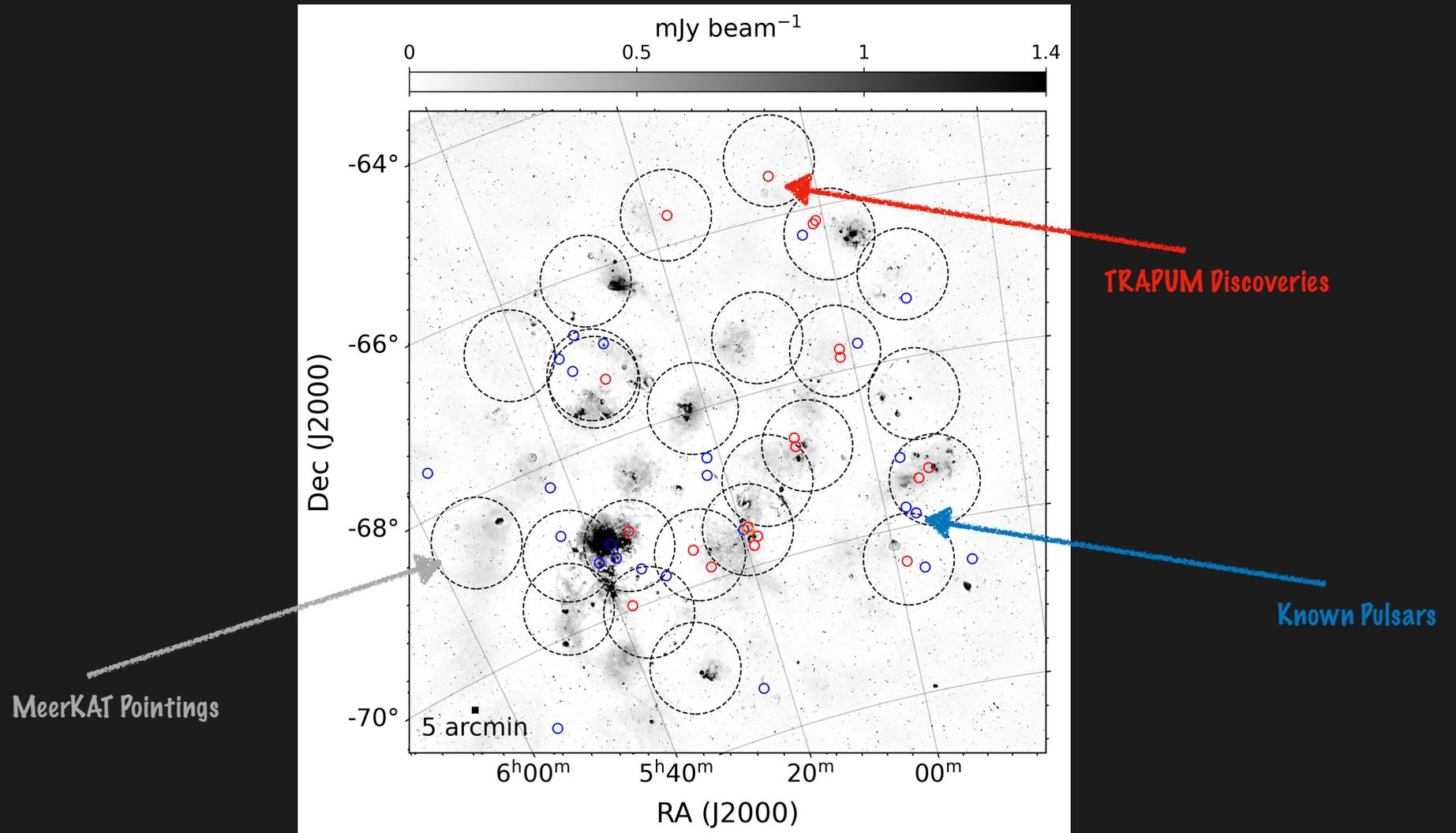
New PWN identified!

young big glitcher

young glitcher

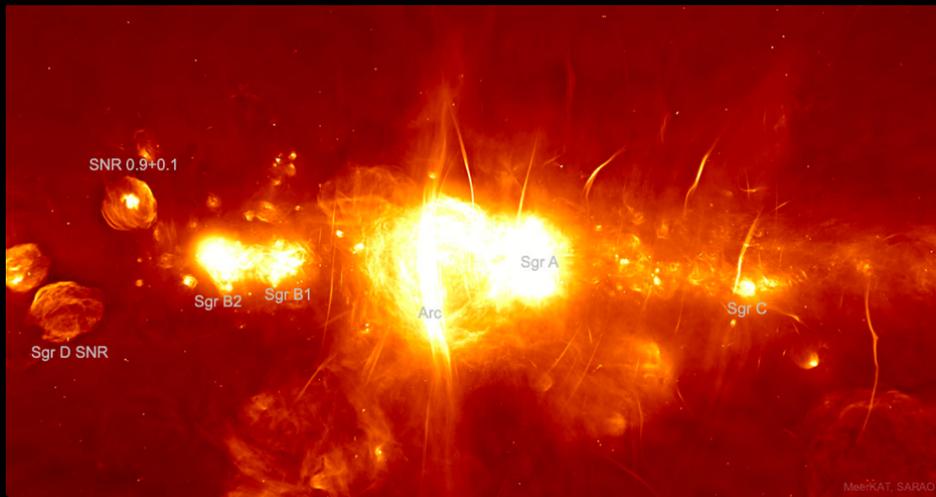
PWN pulsar found ! Too faint in X-rays
young big glitcher

MORE THAN 20 DISCOVERIES IN THE LMC

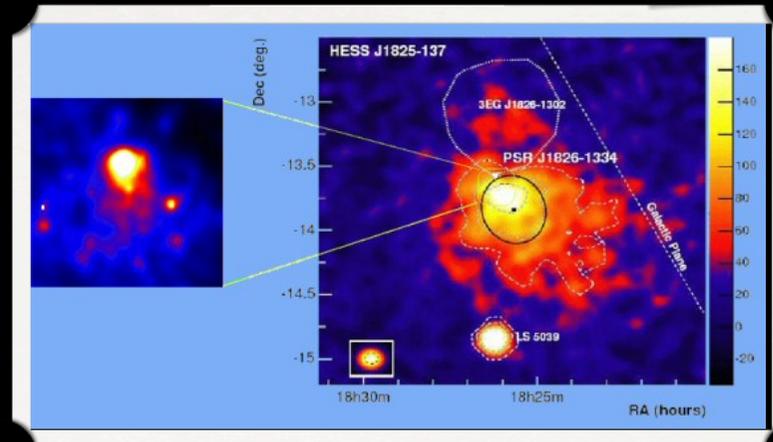
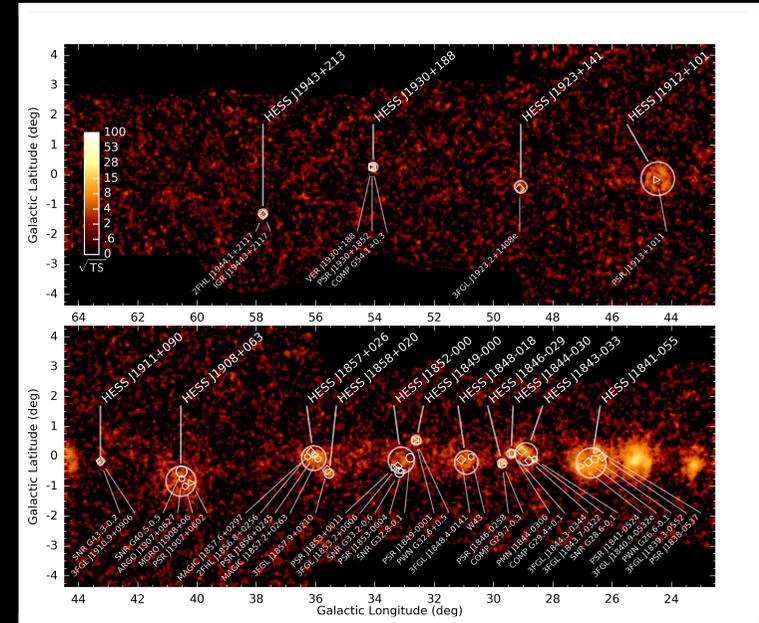


INCLUDING FIRST LMC PULSAR BINARY SYSTEM

PULSAR WIND NEBULAE, SUPERNOVA REMNANTS AND TEV SOURCES

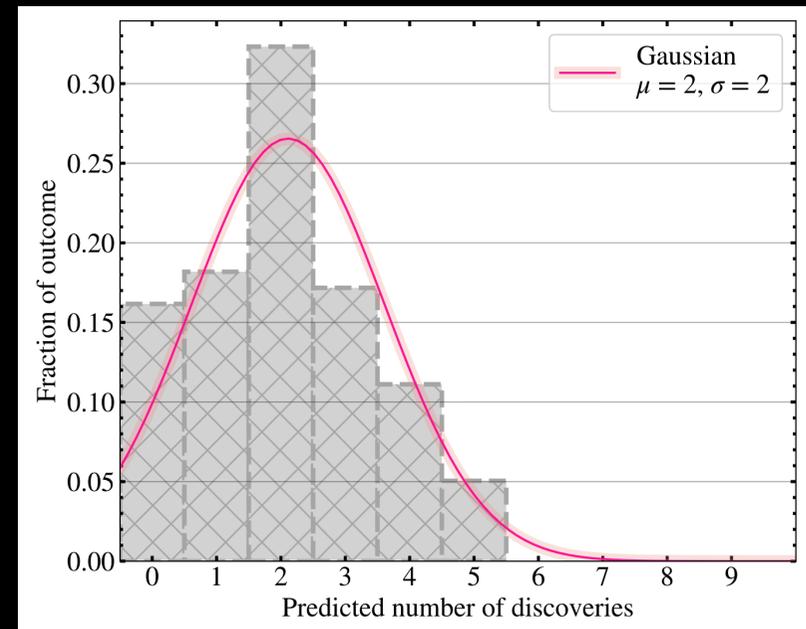
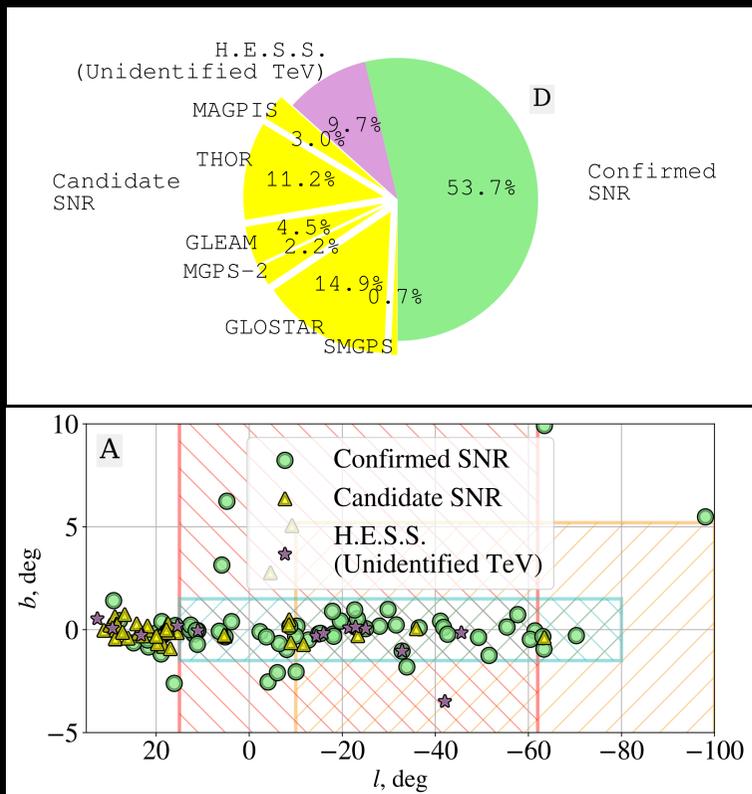


MeerKAT image of the Galactic Centre Region
Credit: SARAO



WHERE DID ALL THE ASSOCIATIONS GO?

- Surveyed 134 targets, and found 1 new pulsar associated with a SNR.
- Extremely unexpectedly low yield.
- Sophisticated set of simulations shows broadly consistent with simulations.



- Pulsars are too faint or too scattered to be found
- Best bet is to survey deeper at frequencies ~ 2.5 GHz.

GLOBULAR CLUSTERS

About 50% of all the known MSPs are found in globular clusters (GCs)

Spherical, gravitationally bound groups of $10^4 - 10^6$ stars, confined within a volume a few light-years across.

Among the oldest structures known in the universe (ages billions of years)

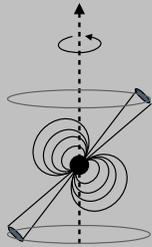
Extreme stellar densities, several orders of magnitude higher than those found in the Galaxy, favouring the formation and disruption of binaries.



GCs are extremely efficient factories of MSPs and exotic pulsars!

EXCITING PULSARS

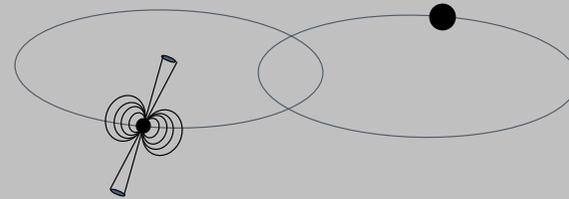
Extremely recycled pulsars



e.g.: Ter 5 ad (Hessels et al. 2006)



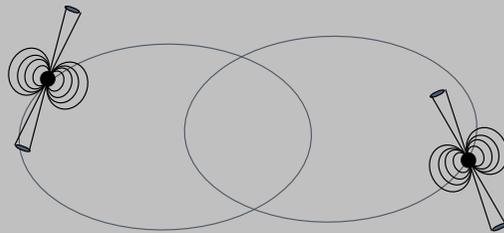
Extremely eccentric binaries



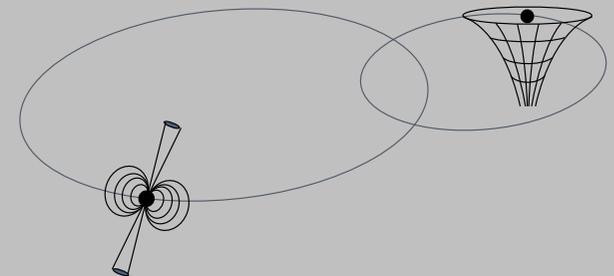
e.g.: NGC 6652 A (DeCesar et al. 2015)



MSP - MSP

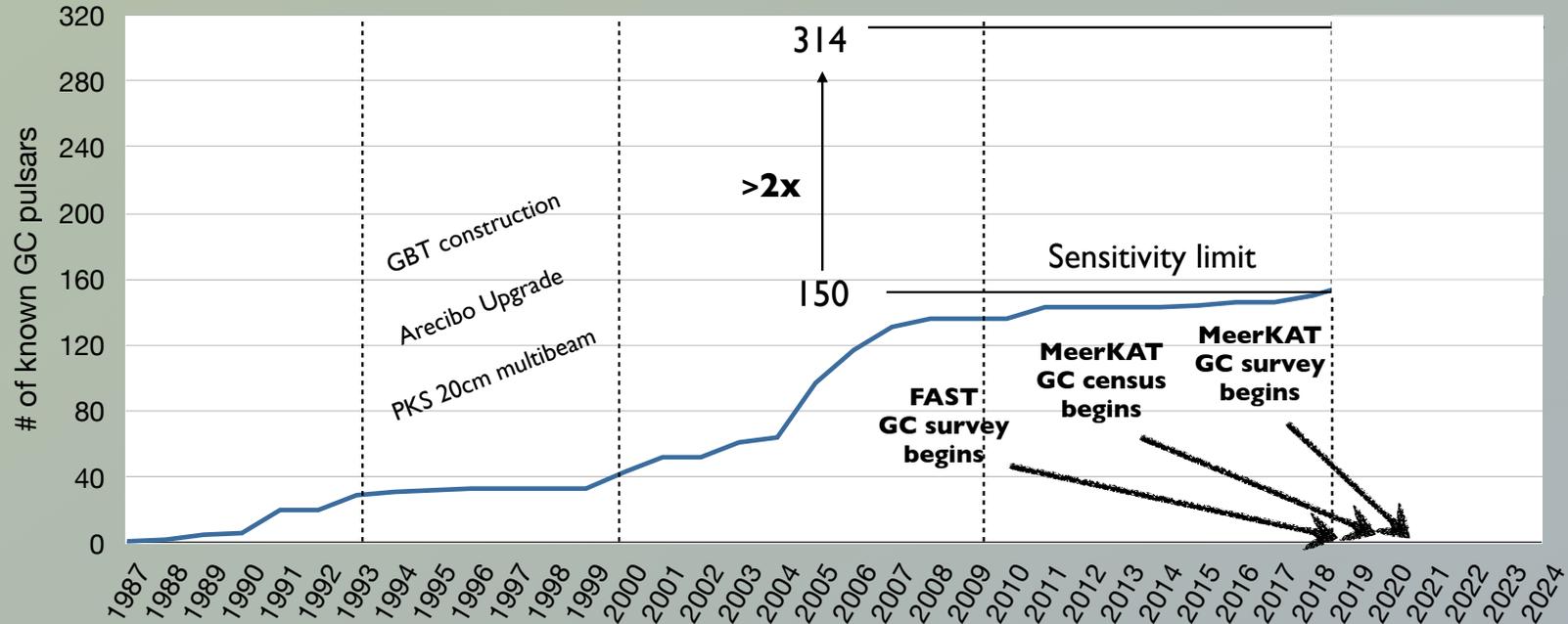


Pulsar - BH



Where are we now?

GC pulsar population over time



MeerKAT
>106

Ridolfi et al. (2021)
Vleeschouer et al. (2022)
Douglas et al. (2022)
Ridolfi et al. (2022)
Abbate et al. (2022)
++++...

FAST
>51

Pan et al. (2020)
Wang et al. (2020)
Pan et al. (2021a, b)
Qian & Pan (2021)
Yan et al. (2021)
Pan et al. (2023)

GBT
>8

De Cesar et al. 2024

Parkes
>8

Dai et al. (2020)
Zhang et al. (2022)

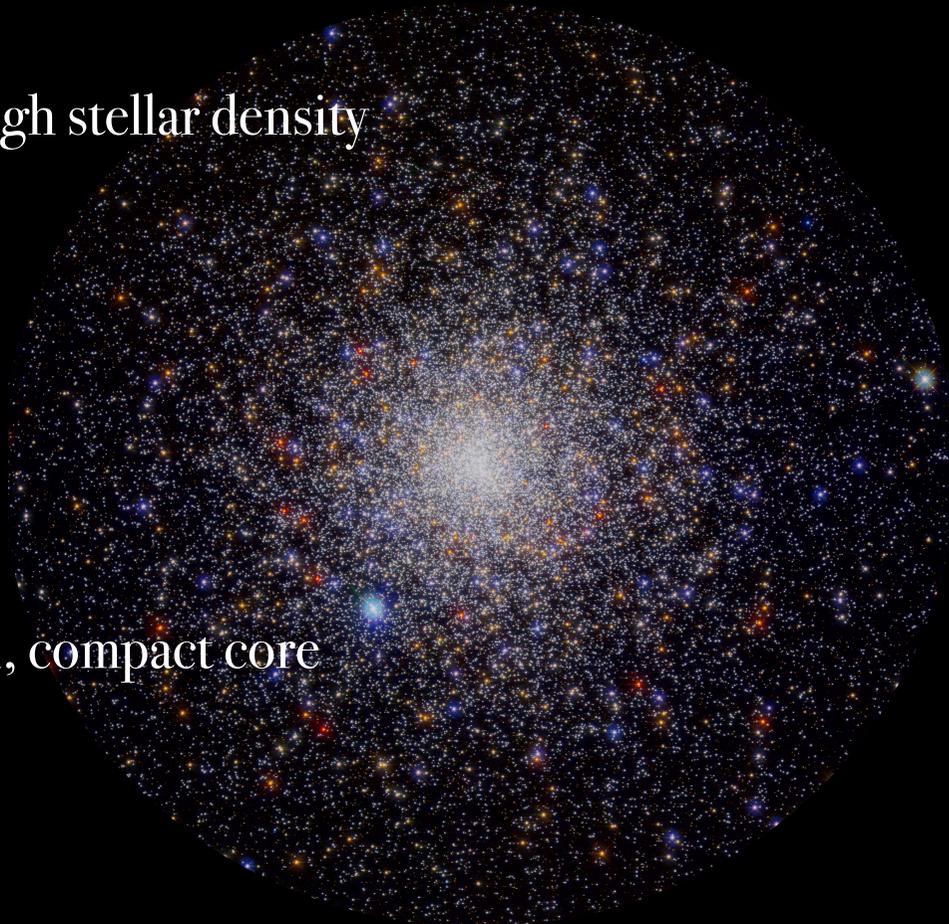
GMRT
>3

Gautam et al. (2022)

NGC 1851

High stellar density

Small, compact core



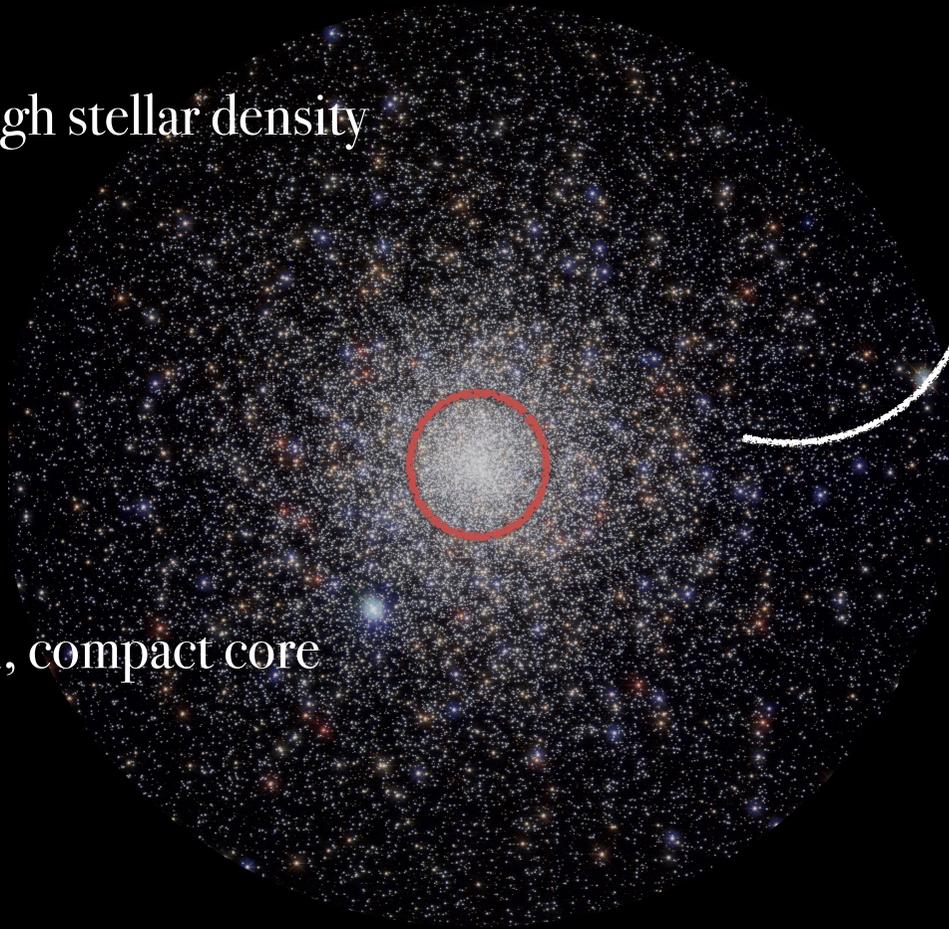
Source: Hubble

- Southern constellation of Columba
- Distance ~ 11.6 kpc
- Age ~ 9 Gyr
- Stellar density $\sim 3 \times 10^6 M_{\odot}/\text{pc}^3$
(Libralato+22)

NGC 1851

High stellar density

Small, compact core



Multiple stellar
interactions/ binary



Forms **exotic** systems:
Fully recycled pulsars, highly eccentric binaries

NGC 1851



One known pulsar NGC 1851A

Discovered with GMRT (Freire+2004)

MSP - heavy WD eccentric binary

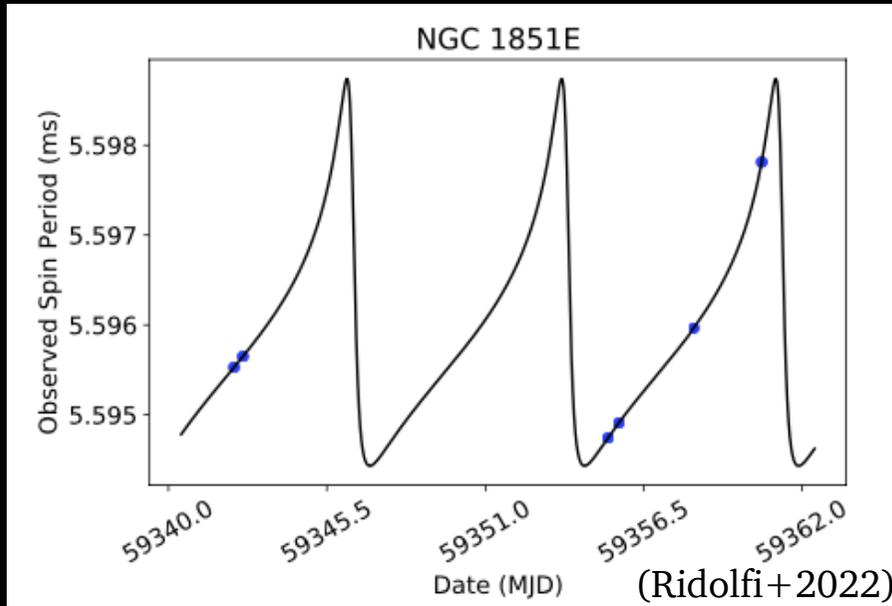
MeerKAT & TRAPUM

13 new pulsars
8 in binaries



3 eccentric binaries:
MSP - heavy companions

NGC 1851E



What did we know?

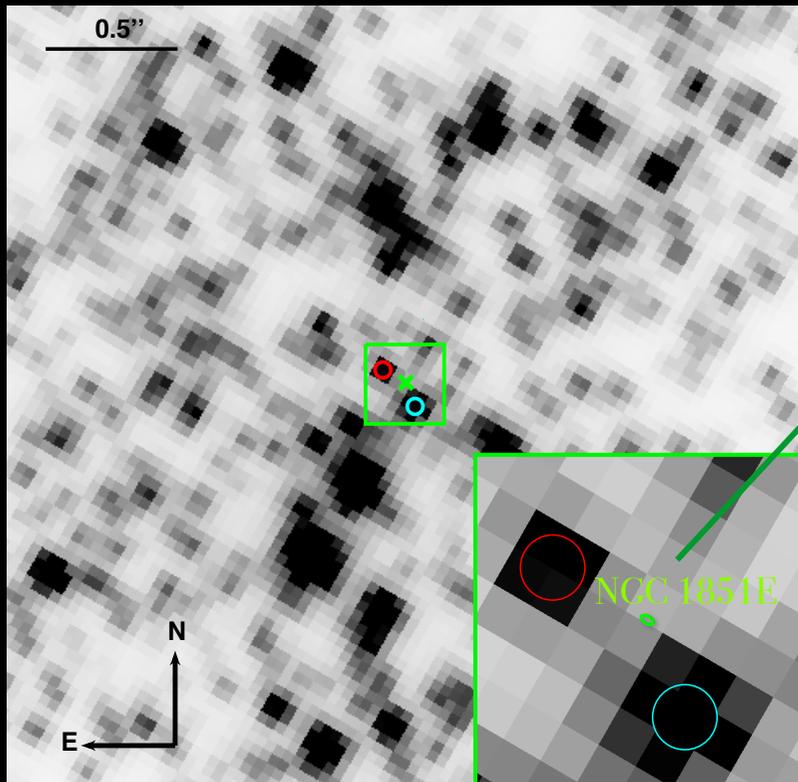
5.6 ms pulsar in NGC 1851

Eccentric binary: 7.4 day orbit, $e = 0.7$

High mass function \longrightarrow **Massive companion**

For $M_p = 1.17 M_\odot$ and edge-on orbit, $M_{c,\min} = 1.4 M_\odot$

Compact companion – possible with accurate position



(Barr, Dutta et al., Science, 2024)

No optical companion detected in HST images
(Closest source offset by $> 6\sigma$)

No evidence of plasma from companion



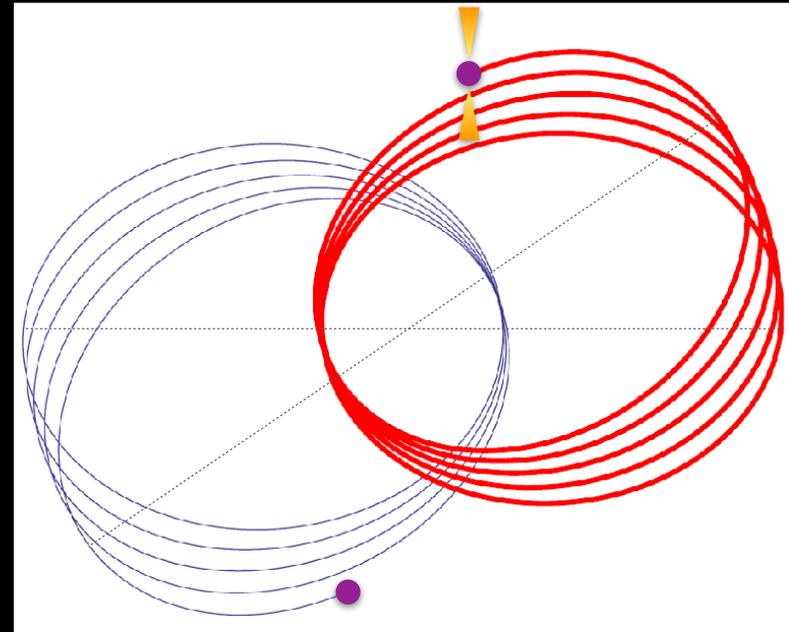
Compact companion

Advance of periastron: possible with precision timing

Post Keplerian Effect

Rate of advance of periastron

$$\dot{\omega}_{\text{obs}} = 0.03468 \pm 0.00003 \text{ deg yr}^{-1}$$



Credit: N.Wex

Advance of periastron

$$\dot{\omega}_{\text{GR}} = \left(\frac{3}{c^2(1-e^2)} \right) \left(\frac{P_b}{2\pi} \right)^{-5/3} (GM)^{2/3} \rightarrow 3.887 \pm 0.004 M_{\odot}$$

Total mass of Most massive Galactic DNS

$$2.8887 \pm 0.0006 M_{\odot} \text{ (Ferdman+ 2020)}$$

Total mass of Heaviest LIGO-Virgo
NS-NS Merger GW190425

$$3.4^{+0.3}_{-0.1} M_{\odot} \text{ (Abbott+ 2020)}$$

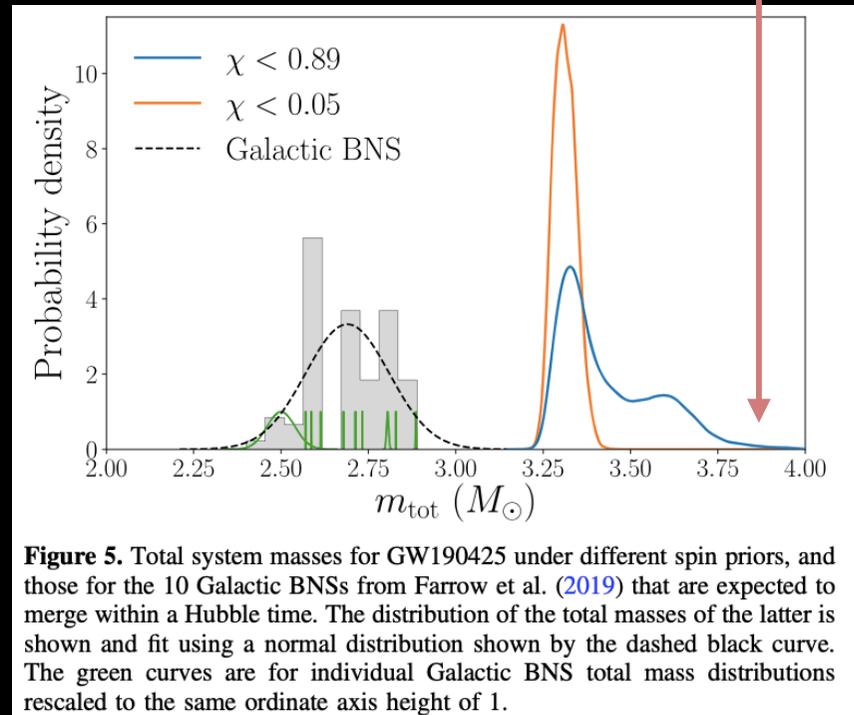


Figure 5. Total system masses for GW190425 under different spin priors, and those for the 10 Galactic BNSs from Farrow et al. (2019) that are expected to merge within a Hubble time. The distribution of the total masses of the latter is shown and fit using a normal distribution shown by the dashed black curve. The green curves are for individual Galactic BNS total mass distributions rescaled to the same ordinate axis height of 1.

(Abbott+ 2020)

Mass measurements

Mass function \leftrightarrow total system mass

$$M_p \leq 2.04 M_\odot, M_c \geq 1.84 M_\odot$$

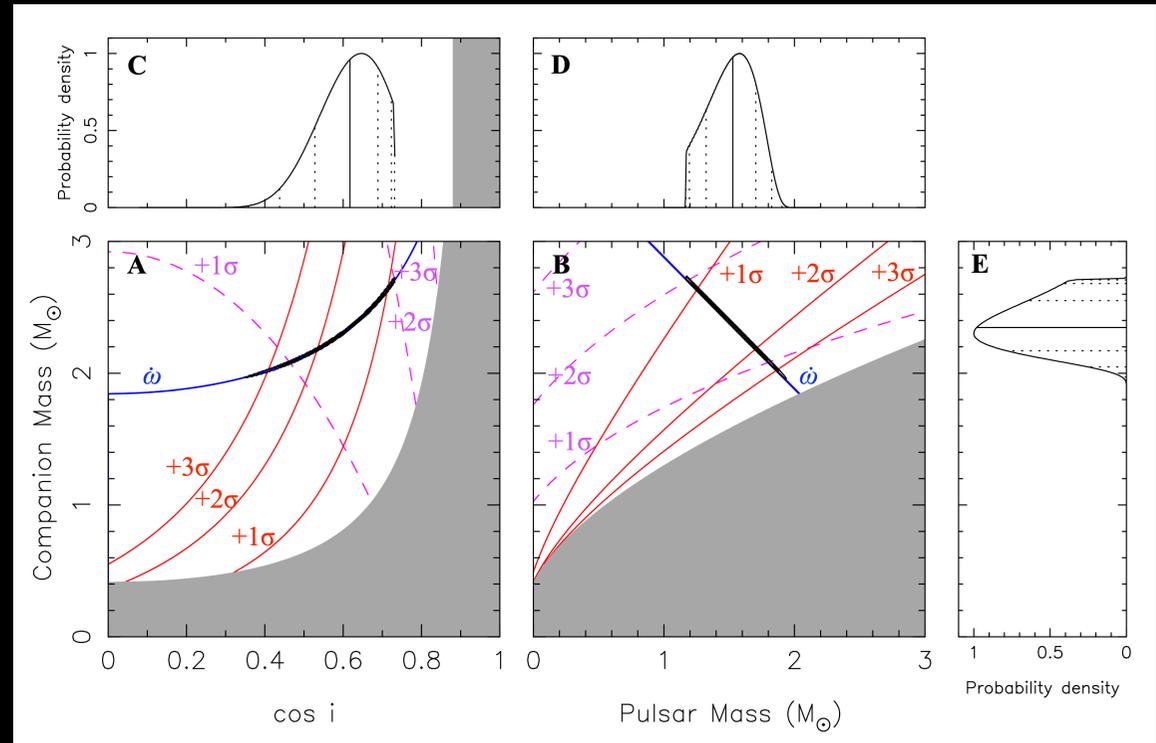
$$(i = 90^\circ)$$

Einstein delay (2σ upper-limit)

$$\gamma = 27.96 \text{ ms}$$

Shapiro delay (2σ upper-limit)

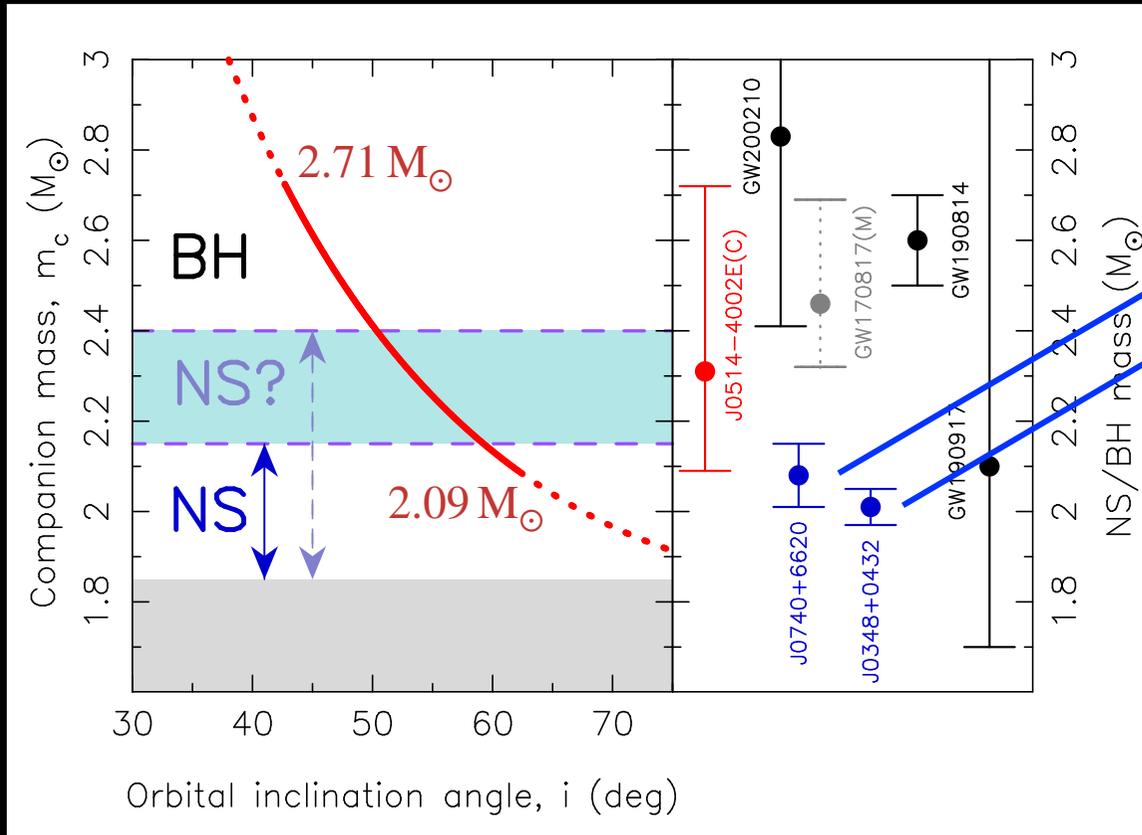
$$h_3 = 1.8 \mu\text{s}$$



(Barr, Dutta et al., Science, 2024)

$$M_c > 2.09 M_\odot, i < 62^\circ \text{ (95\% probability)}$$

NGC 1851E: Companion



(Barr, Dutta et al., Science, 2024)

Too massive to be a white dwarf

$M_p = 2.08(7) M_\odot$ (Fonseca+ 2021)

$M_p = 2.01(4) M_\odot$ (Antoniadis+ 2013)

In the LIGO-Virgo
compact object “mass gap”

No radio pulsations detected

Massive NS / Light BH

Prospects

Continued timing in progress

Upgraded facilities: MeerKAT+, SKA

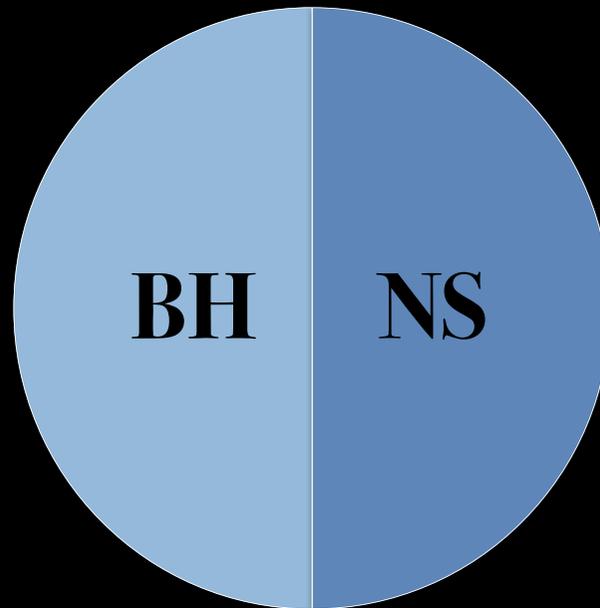
Improved masses with Einstein delay measurement (in $\sim 5-6$ years)

Change in projected semi-major axis of binary

Spin of companion > 0.6

First pulsar-black hole binary

Tests of BH properties



Most stringent mass constraints on NS EoS

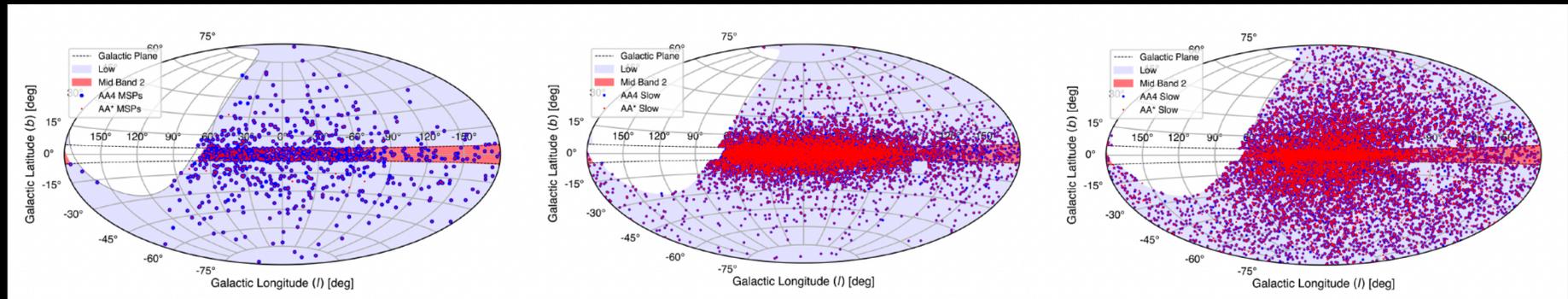
WE ARE CURRENTLY BUILDING THE WORLD'S LARGEST RADIO TELESCOPES!

SKAO



Credit: SKAO (skao.int)

SKAO PULSAR YIELDS...An example only... survey can be done in multiple ways

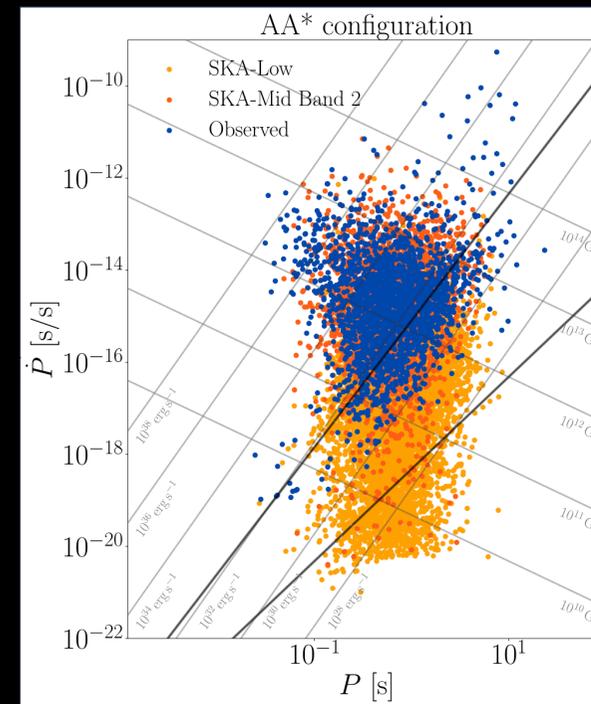


Keane et al. 2025

Band		Latitude Range	
Low		$ b > 5$ deg	
Mid Band 1		N/A	
Mid Band 2		$ b < 5$ deg	

Band	Slow PSRs	MSPs	Band	full count above DL
AA*			AA*	
Low	4990(170)	440(20)	Low	8050(30) 7110(20)
Mid Band 1	-	-	Mid Band 1	- -
Mid Band 2	5400(150)	380(20)	Mid Band 2	2570(10) 2540(10)
TOTAL	10390	820	TOTAL	10620 9650

Keane et al. (2025)



These are detections and so correspond to factors of a couple to a few in discovery space.

SKAO

Transients.. hard to quantify improvement in numbers as populations are less well known so far.

- Enhanced sensitivity: ($> \sim 2$ x MeerKAT and ~ 4 x LOFAR)
- Excellent frequency coverage
- Real-time commensal searches for millisecond duration transients
- Excellent FoV (especially for SKA-Low).
- Transient Buffer trigger for further analysis (20-40 seconds for SKA-MID and 900 seconds for SKA-LOW)

Much more detail across all source classes in the upcoming science book!

SKAO

Look out for upcoming chapters/papers on SKAO science with/of transients and pulsars that will be part of the next SKAO science book.

PULSARS

- Pulsar Timing Array Science with the SKA
- Understanding pulsar magnetospheres with the SKA
- Understanding the Neutron Star Population with the SKA
- A Cosmic Census of Radio Pulsars with the SKA
- Three-dimensional Tomography of the Galactic and Extragalactic Magnetoionic Medium with the SKA
- Probing the neutron star interior and the Equation of State of cold dense matter with the SKA
- Testing Gravity with Binary Pulsars in the SKA Era
- Observing Radio Pulsars in the Galactic Centre with the Square Kilometre Array
- Pulsar Wind Nebulae in the SKA era
- Pulsars in Globular Clusters with the SKA
- Pulsars as probes of Galactic magnetic field

TRANSIENTS

- A Fresh View on the Transient Universe with the SKA
- Gamma-ray Bursts and Kilonovae from Gravitational Wave Events
- Interacting Compact Object Binaries
- Tidal Disruption Events and Transients from the Centres of Galaxies
- Fast Radio Bursts as Astrophysical Probes
- Fast Radio Bursts as Cosmological Probes
- Time Domain Studies of Active Galactic Nuclei with the SKA
- Supernovae with the Square Kilometre Array
- Novae and Symbiotics with the Square Kilometre Array
- Long period transients with the SKA
- The variability of radio stars
- Rapid response triggering for radio transients with the SKA
- Commensal transient searches with the SKA
- SKA and the unknown unknowns

Summary — FRBs

- MeerTRAP has found over 75 new FRBs over a wide range of Dispersion Measures.
- Probes the high end region of the DM space probed by current instruments.
- Localisation with the Transient Buffer allows one to get redshifts and host galaxy properties.
- High redshift hosts tell us something about the origin of these systems, e.g. time and environment of formation.
- These sources also pave the way for cosmology with FRBs.
- So far 2 repeaters seen with interesting characteristics, some FRB locations have many hours of follow up time.
- Future work includes population of FRBs in the Laduma field, and those with interesting sightline
- The sensitivity and step up in resolution of the SKAO telescopes will allow us to make a significant step forward, in particular for the most distant FRBs with MID and the nearerby systems with LOW.

Summary — Galactic Sources

- MeerTRAP has found over 100 new radio emitting neutron stars through their single pulse emission
- Of those it has also been able to get period derivatives for a handful.
- There are some sources that emit very rarely!
- A population of long period sources is becoming evident, and most show variability within pulse shapes but also in timescales of activity.
- In some cases the complexity of the pulses resembles FRBs...
- Helping improve theories of radio emission by finding pulsars in the death valley regions.
- It seems like NSs will always find a way to emit radio! — e.g. 2XMM J104608.7-594306 / MTP0096.
- Potentially challenging for the total number of neutron stars in the Galaxy.
- Still finding new galactic transients all over the sky.
- Commensal observing is great for finding new sources, but need that follow up time for characterisation.