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Searching for pulsars in the Galactic centre with MeerKAT Band 5B

Federico Abbate

INAF - Osservatorio Astronomico di Cagliari
Max Planck Institut für Radioastronomie Bonn

Bologna, 27 November 2025

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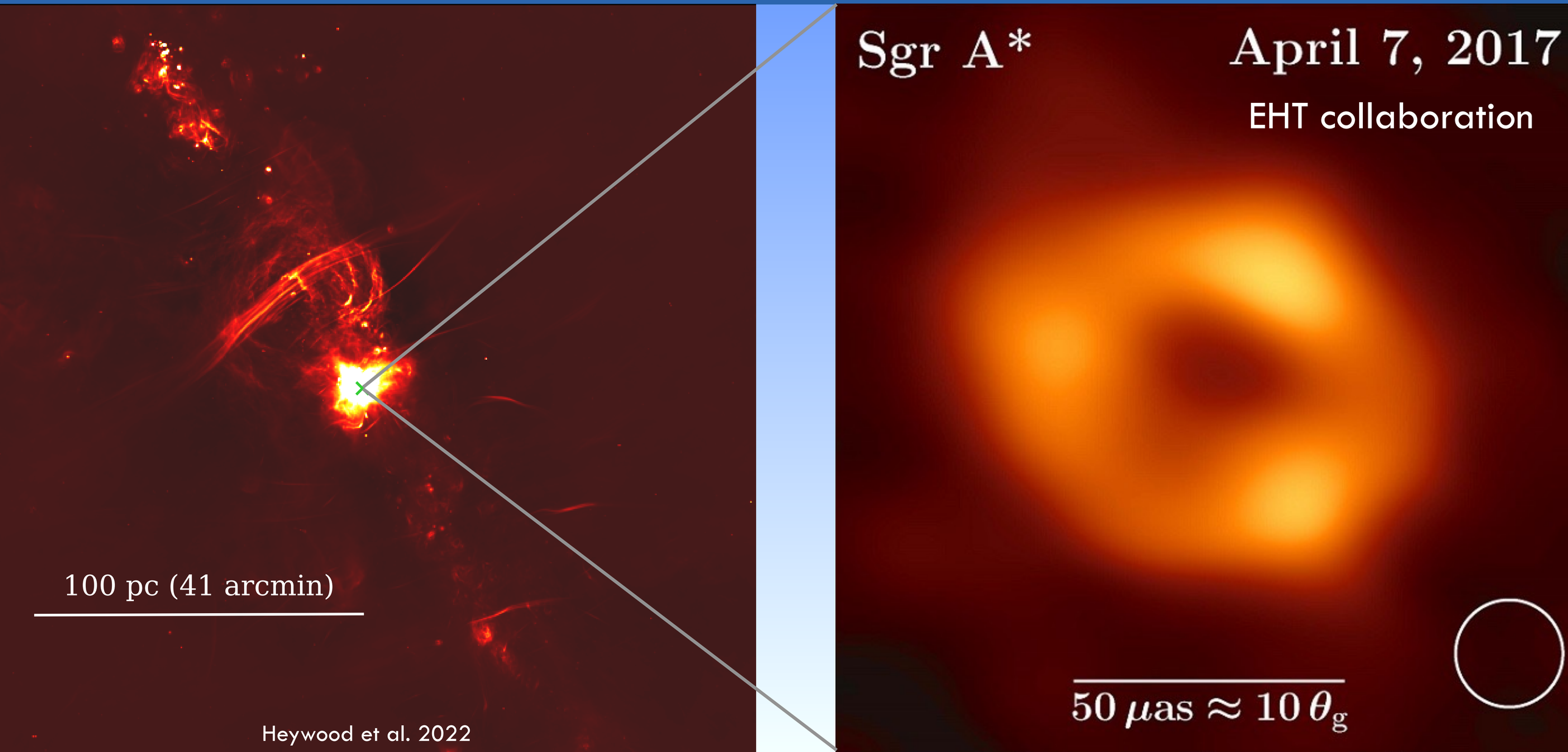

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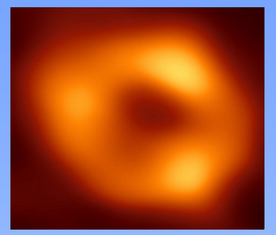

Tests of gravity

Pulsar in 1 yr orbit around Sgr A*

(Liu et al. 2012)
(Psaltis et al. 2016)
(Hu et al. 2023)

Large number of Post-Keplerian effects can be measured as time delays in the arrival of pulses.

PK effects in double neutron star systems

$$\sim 1 - 10\,\mu s$$

PK effects in pulsar - Sgr A* binary

$$\sim 10 - 100\,s$$

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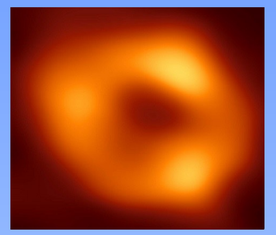

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BH spin measurable with precision <<1%

BH quadrupole mass moment measurable with precision ~1%

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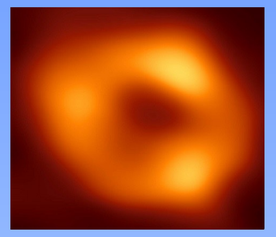

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Test of cosmic censorship conjecture

Test of "no-hair" theorem

Tests for alternative theories of gravity like:
Yukawa gravity or bumblebee gravity
(Massive graviton) (Vector-tensor theory)

(Dong et al. 2022)
(Della Monica et al. 2023)
(Hu et al. 2024)

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Additional science cases

ISM studies

Measure the ISM densities and magnetic fields around Sgr A*

Probe the scattering along different lines of sight

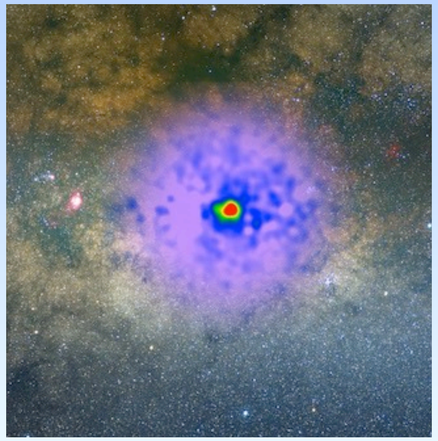
Trace the elusive Galactic wind at small scales

Nuclear Star Cluster

Study star formation

Provide insights into the formation of the NSC

Credits: NASA, ESA, and the Hubble Heritage Team (STScI/AURA



Credits: Nasa Goddard/A. Mellinger (Central Michigan Univ.) and T. Linden (Univ. of Chicago)

Synergies with GWs

Pulsar in very tight orbit around Sgr A* could emit gravitational waves in the LISA band

Dark Matter

Test universality of free fall towards Dark Matter with binary pulsars

Emission lines from Axions in the pulsar magnetospheres

Gamma-ray excess

Solve the nature of the Gamma-ray excess in the Galactic Centre

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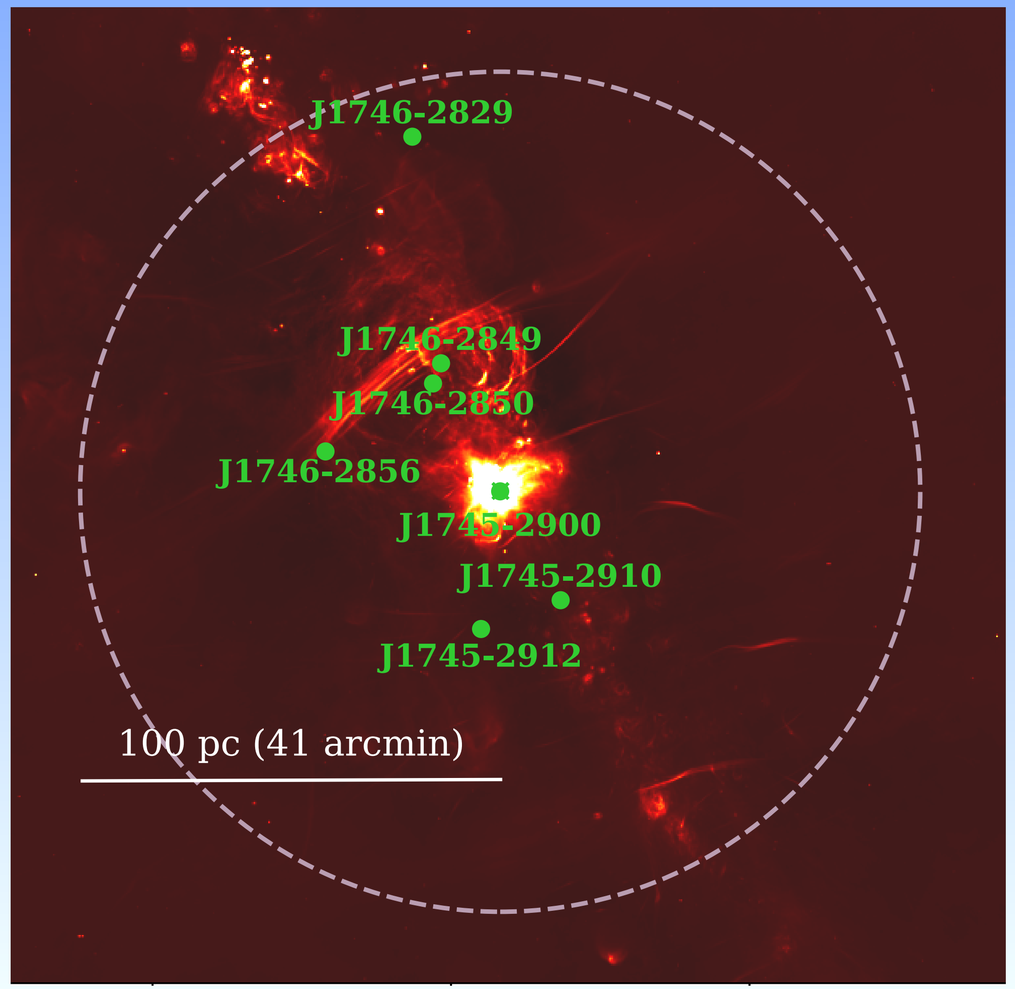
Known pulsars in the Galactic Centre



Pulsar Name PSR	P (s)	DM (pc cm^{-3})	RM (rad m^{-2})	Sgr A* offset (arcmin / pc)	τ_{sc} (ms)	Remarks
J1746–2849	1.48	1360	10, 104(100)	12.3 / 29	266 (1.5 GHz)	-
J1746–2850	1.08	941	−12, 363(40)	11.3 / 27	-	magnetar-like
J1746–2856	0.95	1155	13, 253(50)	15.6 / 37	450 (1 GHz)	-
J1745–2900	3.76	1778	−66, 960(50)	0.04 / 0.1	1300 (1 GHz)	magnetar
J1745–2912	0.19	1106	−535(100)	14.5 / 34	750 (1 GHz)	-
J1745–2910	0.98	1088	-	12.9 / 31	-	-
J1746–2829	1.89	1309	−743(14)	31.8 / 76.0	67 (1 GHz)	magnetar-like

(Abbate et al. 2025)

4 more discoveries in the region using the MeerKAT S-band (unpublished)

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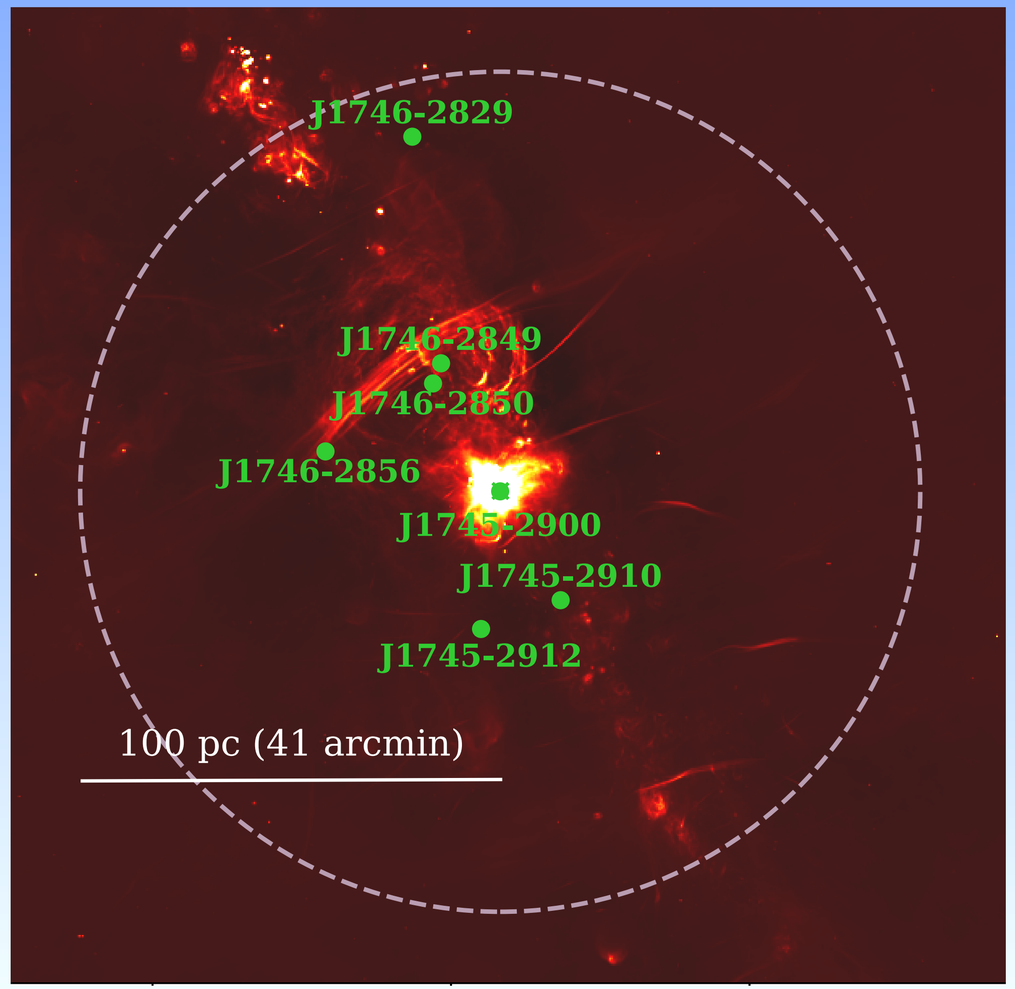

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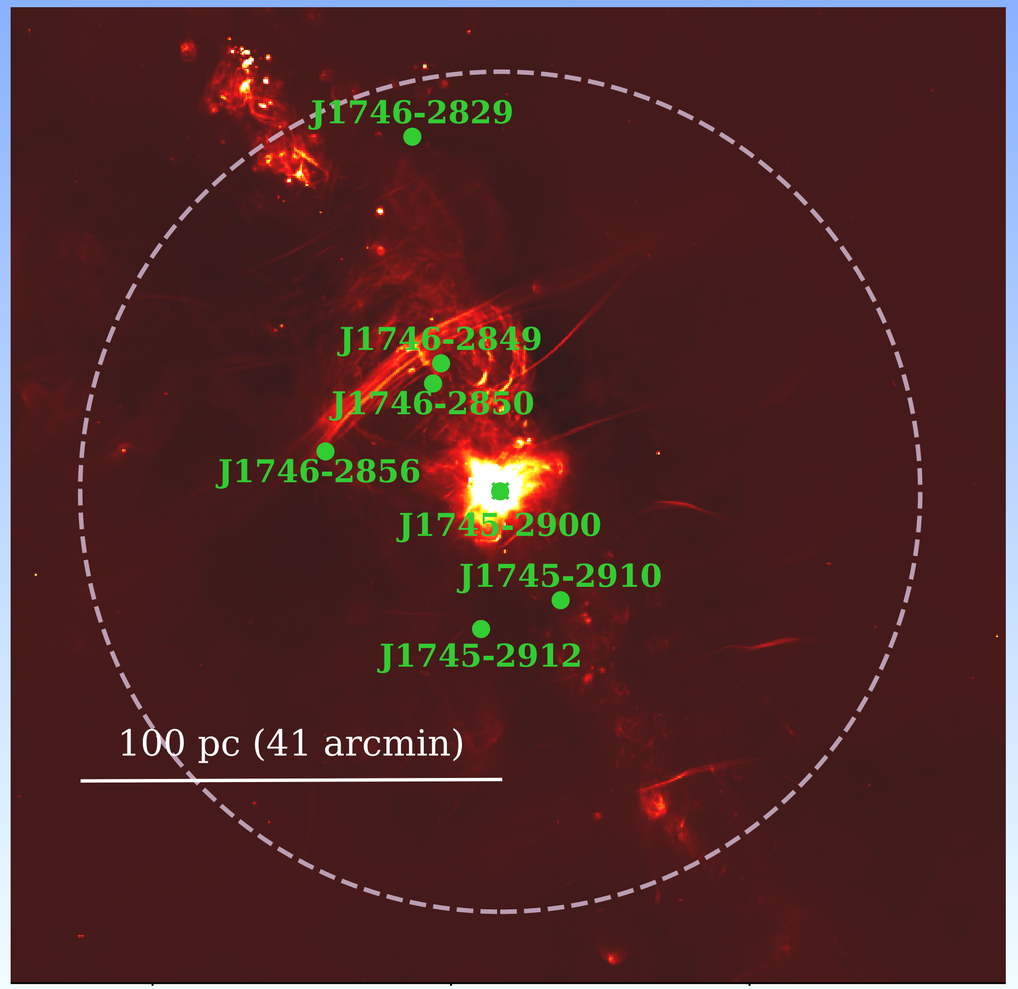

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We need MeerKAT Band 5B

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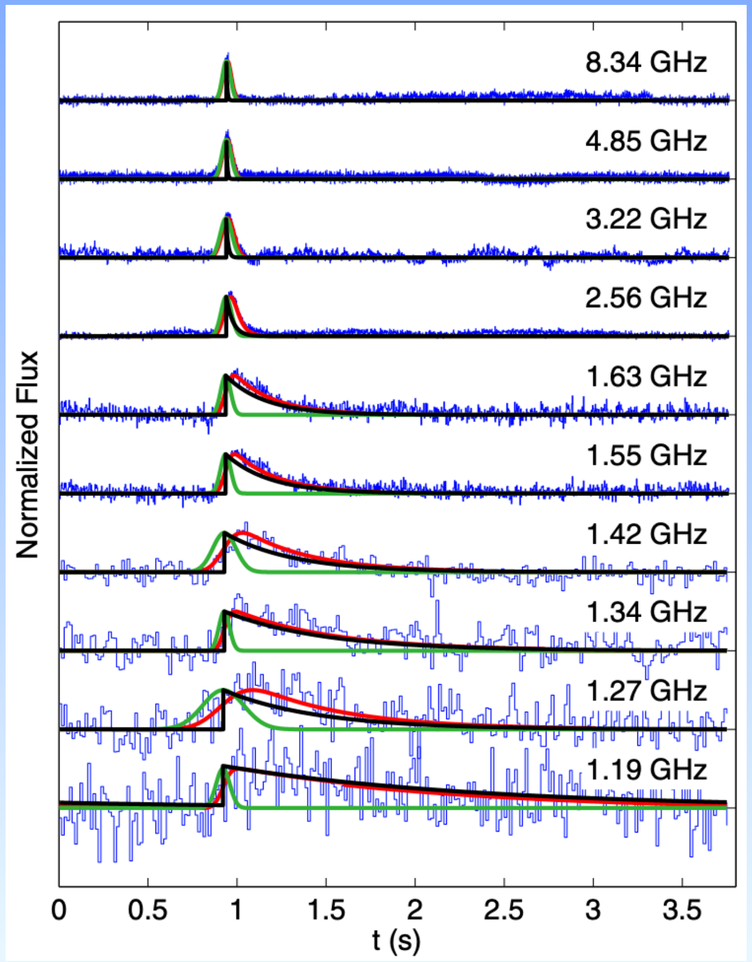
Why go to high frequencies? The scattering problem

The biggest adversary of new pulsar discoveries in the very central region is the scattering:

$$t_{\rm scat} = \tau_{\rm sc,\,1\,GHz} \left(\frac{f}{\rm GHz} \right)^{-\alpha}$$



Scattering tail of the Galactic Centre Magnetar, J1745-2900 (Spitler et al. 2014)

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From measurements of the angular broadening of Sgr A* the scattering is expected to be:

$$\tau_{\mathrm{sc,\,1\,GHz}} \sim 210\,s \qquad \alpha = -4$$

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The situation is thought to be patchy with areas of weaker scattering and areas of stronger scattering

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$$\tau \sim 46\,\mathrm{ms}$$

Scattering at 9 GHz:

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We need to look at high frequency to detect pulsars

Keep in mind that the emission of pulsars is weaker at high frequencies

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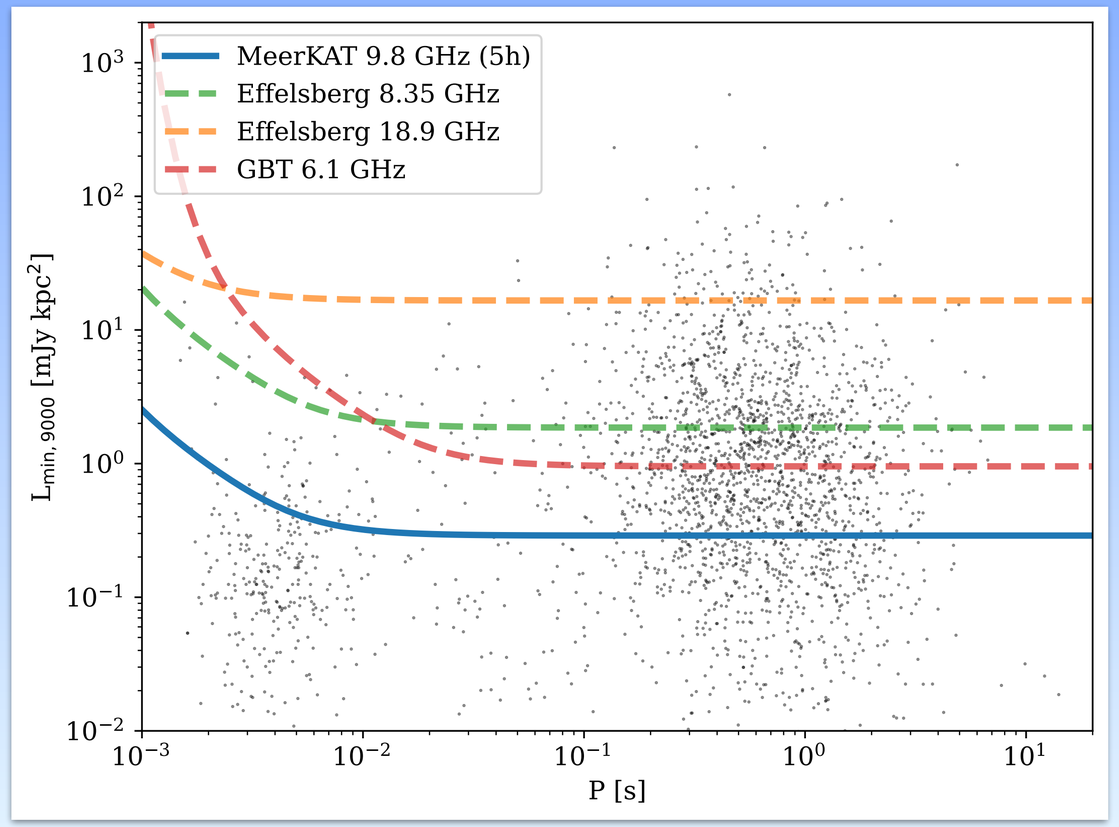
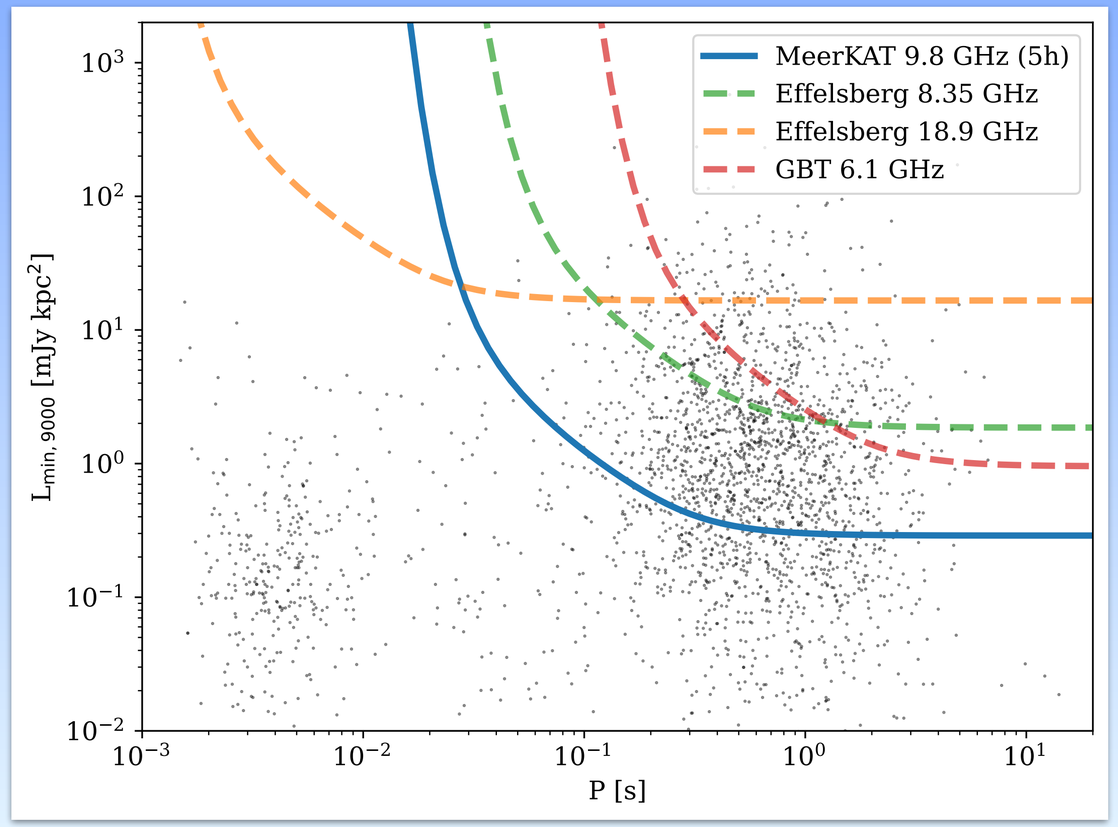
Sensitivity curves

Magnetar-like scattering



Scattering from angular broadening of Sgr A*



(Eatough et al. 2021) (Suresh et al. 2022)

Considering 5h of integration and a bandwidth of 2.5 GHz at the bottom of band 5B

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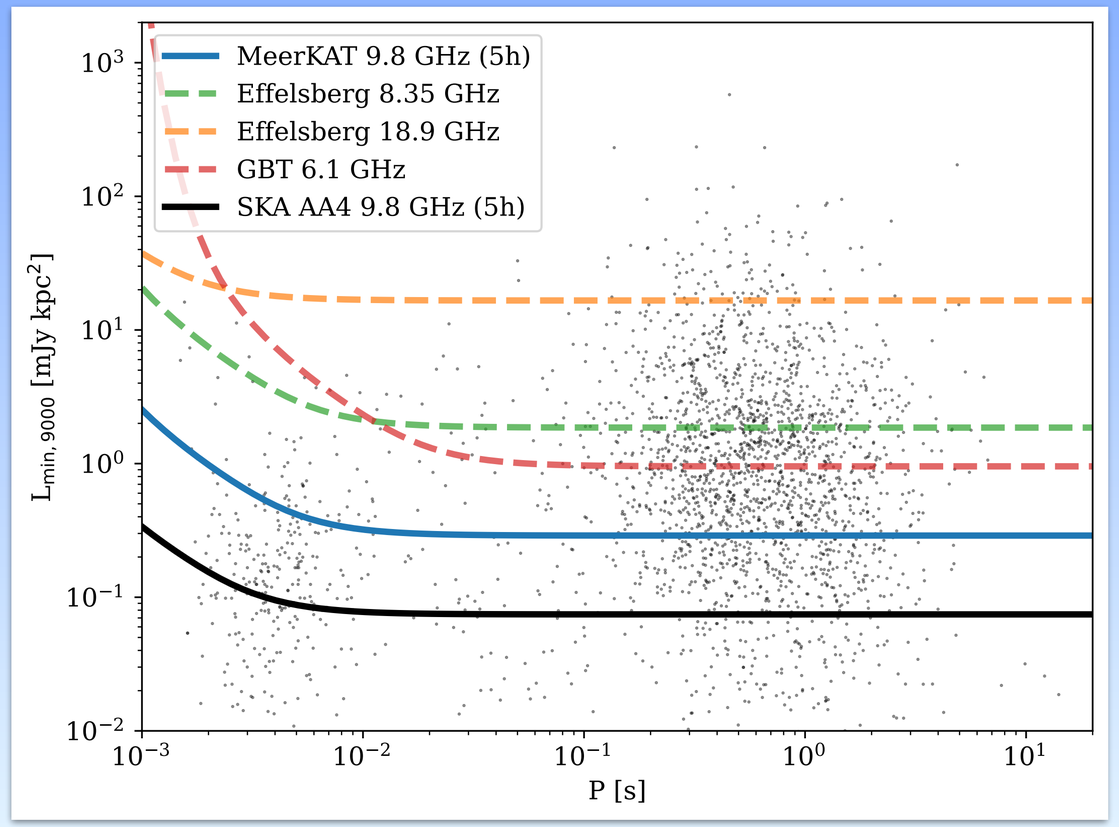

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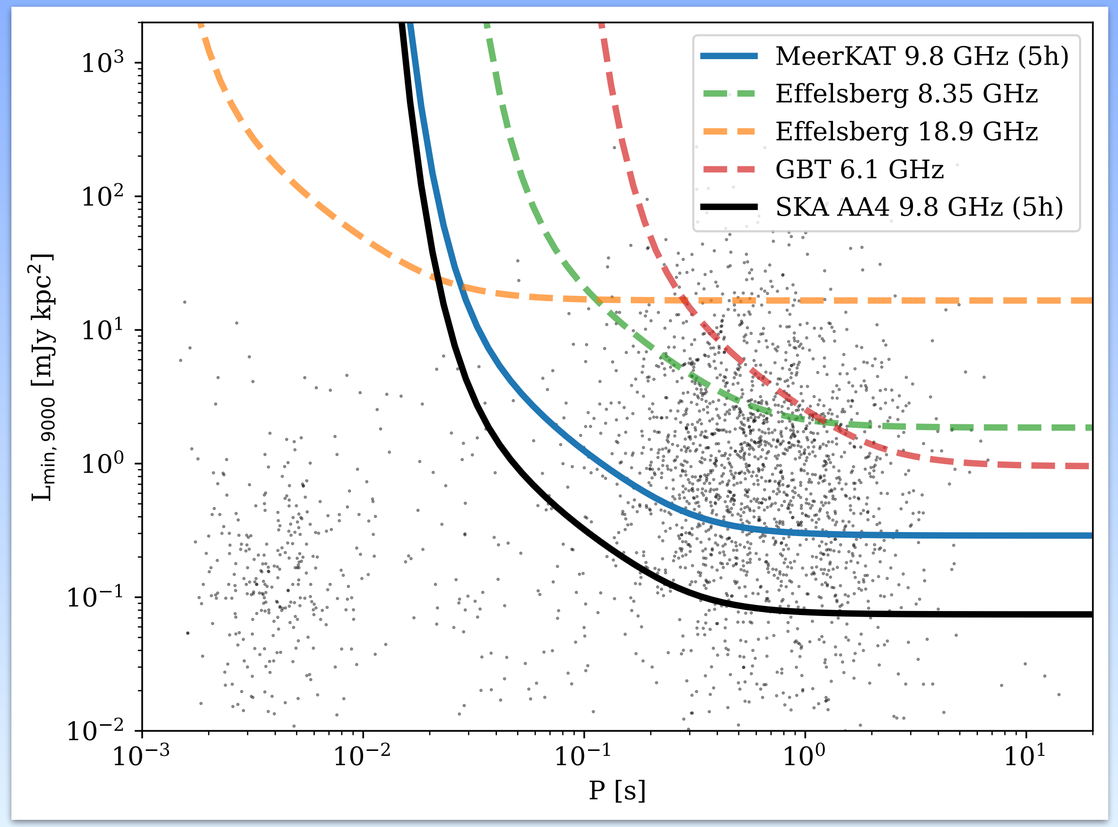

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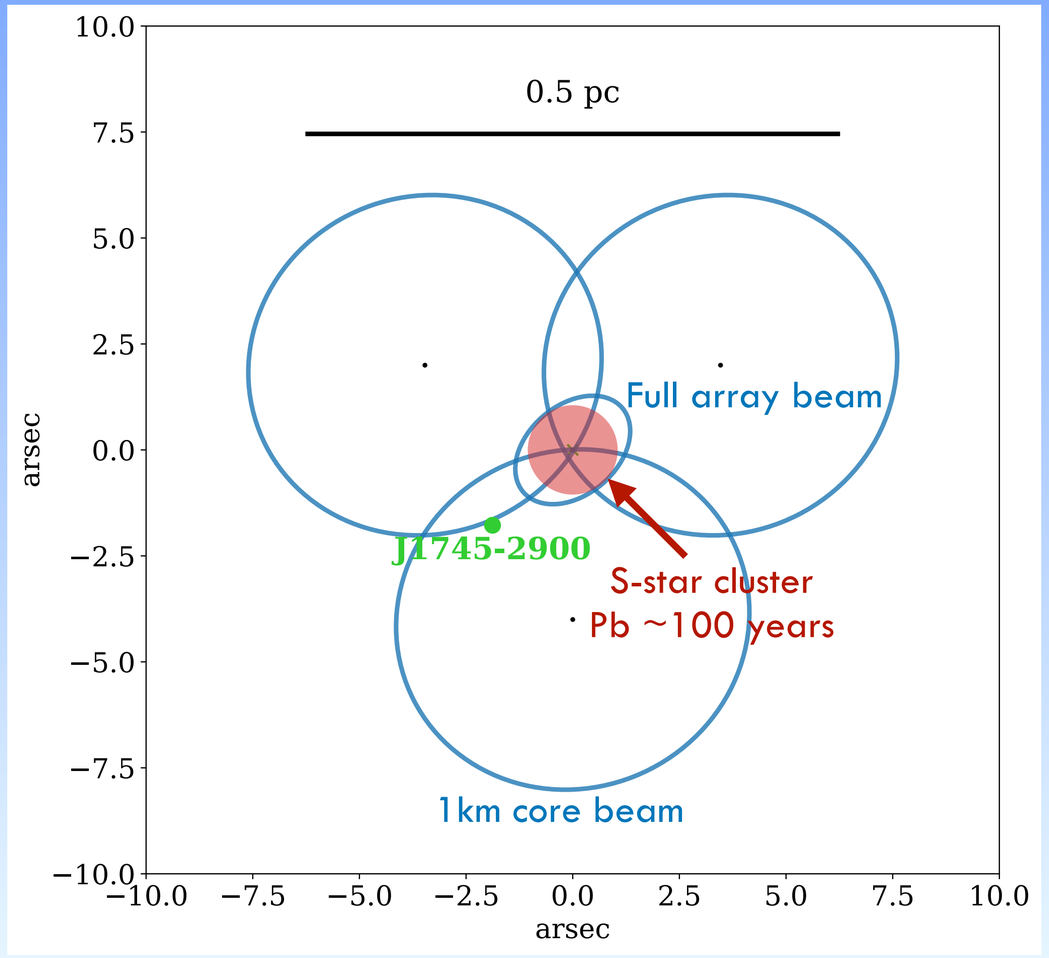
Possible observation set-up

Will be using the PTUSE system capable of forming up to four simultaneous beams

Each beam can have a different sky position and use a different number of antennas

Will be necessary for confirmation of the candidate and improved sky localisation

Using the full array we can cover all of the pulsars in orbit around Sgr A* with orbital period less than 100 years.



Beam sizes for an example configuration of the four PTUSE beams at 9 GHz

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Conclusions

- The Galactic Centre is likely to contain a large number of pulsars still undetected
- The scattering is one of the biggest problem preventing further detections
- Band 5B best frequency range to detect highly scattered pulsars close to Sgr A*
- MeerKAT band 5B will have the highest chance of detecting pulsars in close orbit around Sgr A* and MSPs in the 100 pc region
- Necessary step that will inform searches with the SKA-Mid surveys

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