Searching for Radio and Gamma-ray Millisecond Pulsars with MeerKAT

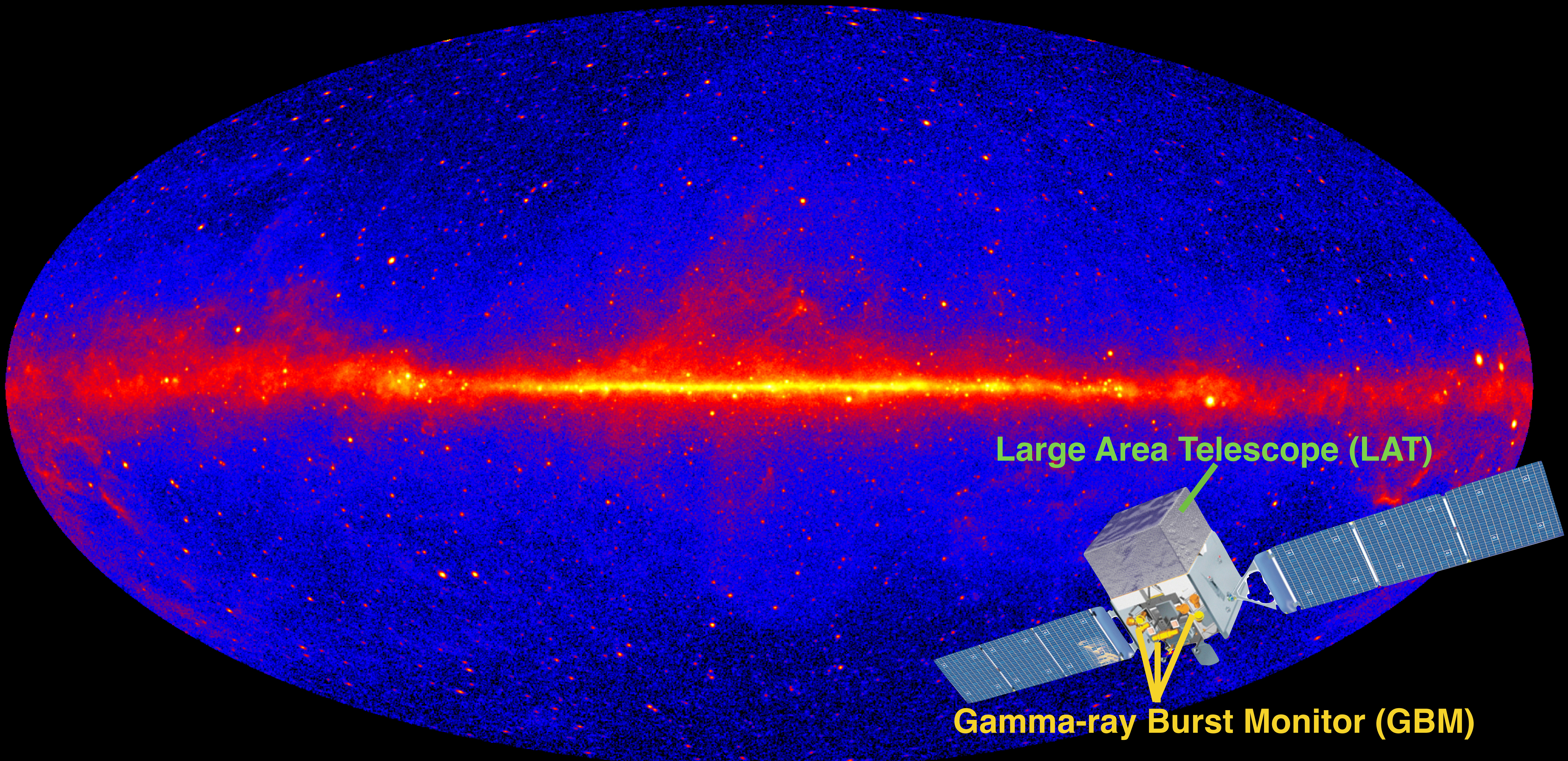
Colin J. Clark, on behalf of the TRAPUM and *Fermi*-LAT collaborations

GEMMA2 - Sapienza University, Rome
18/09/2024

Fermi Gamma-ray Space Telescope

TRAPUM Transients and Pulsars with MeerKAT

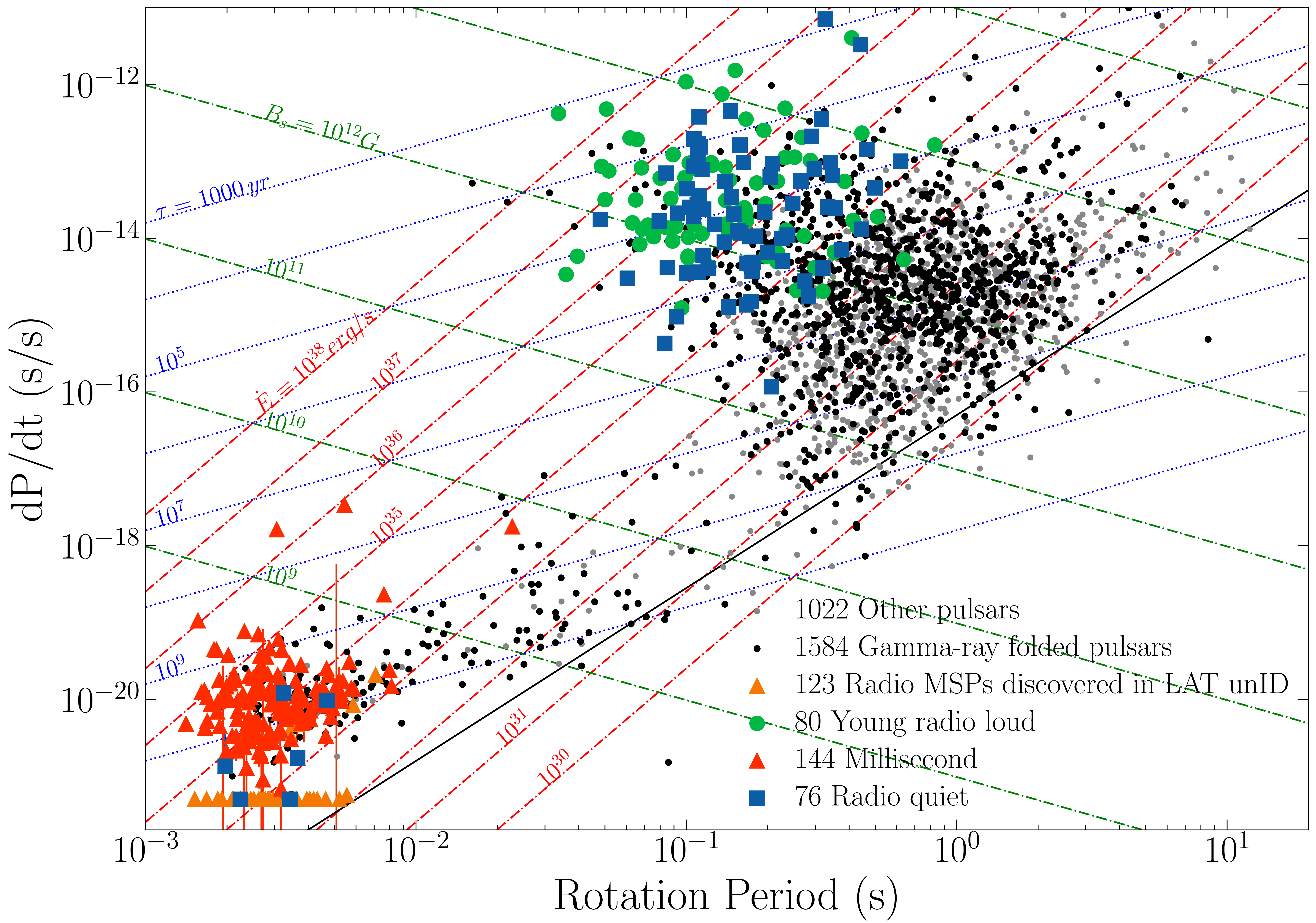
Fermi Gamma-ray Space Telescope



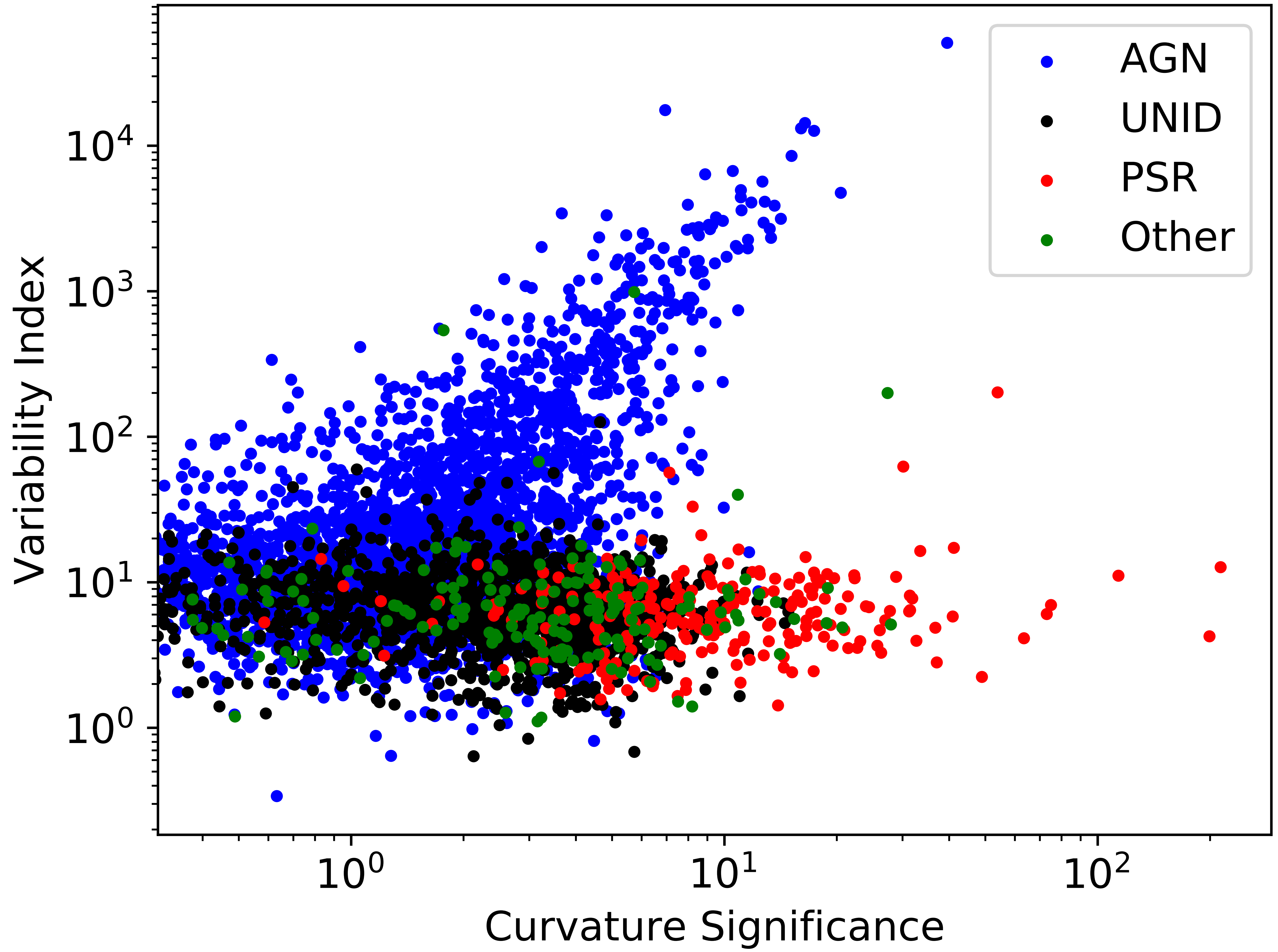
Fermi Image credit: NASA/Sonoma State University/Aurore Simonnet, LAT data courtesy of the Fermi-LAT collaboration

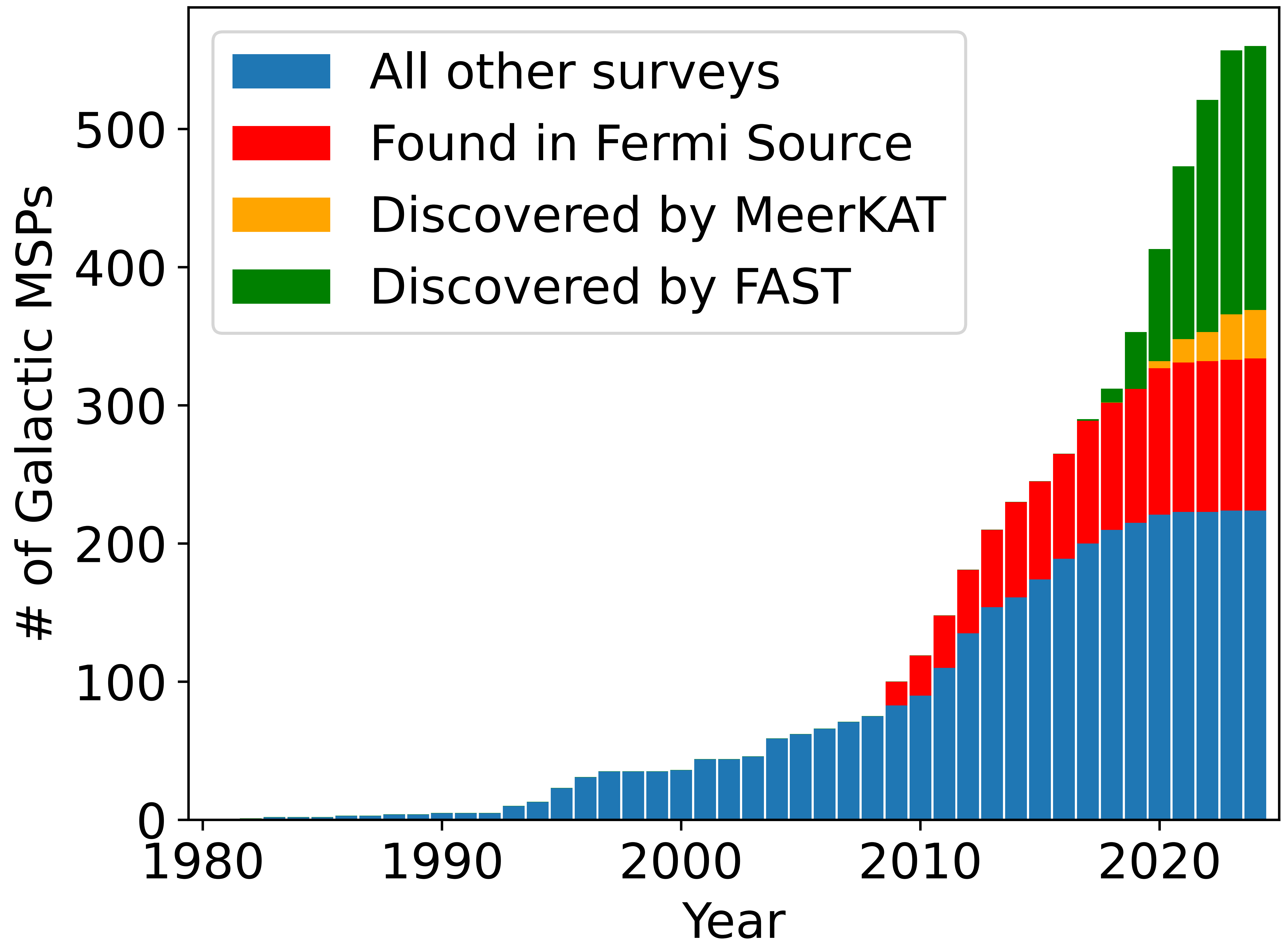
The 3rd Fermi-LAT Catalogue of Gamma-ray Pulsars

Smith, D., et al., 2023, ApJS, 958, 191



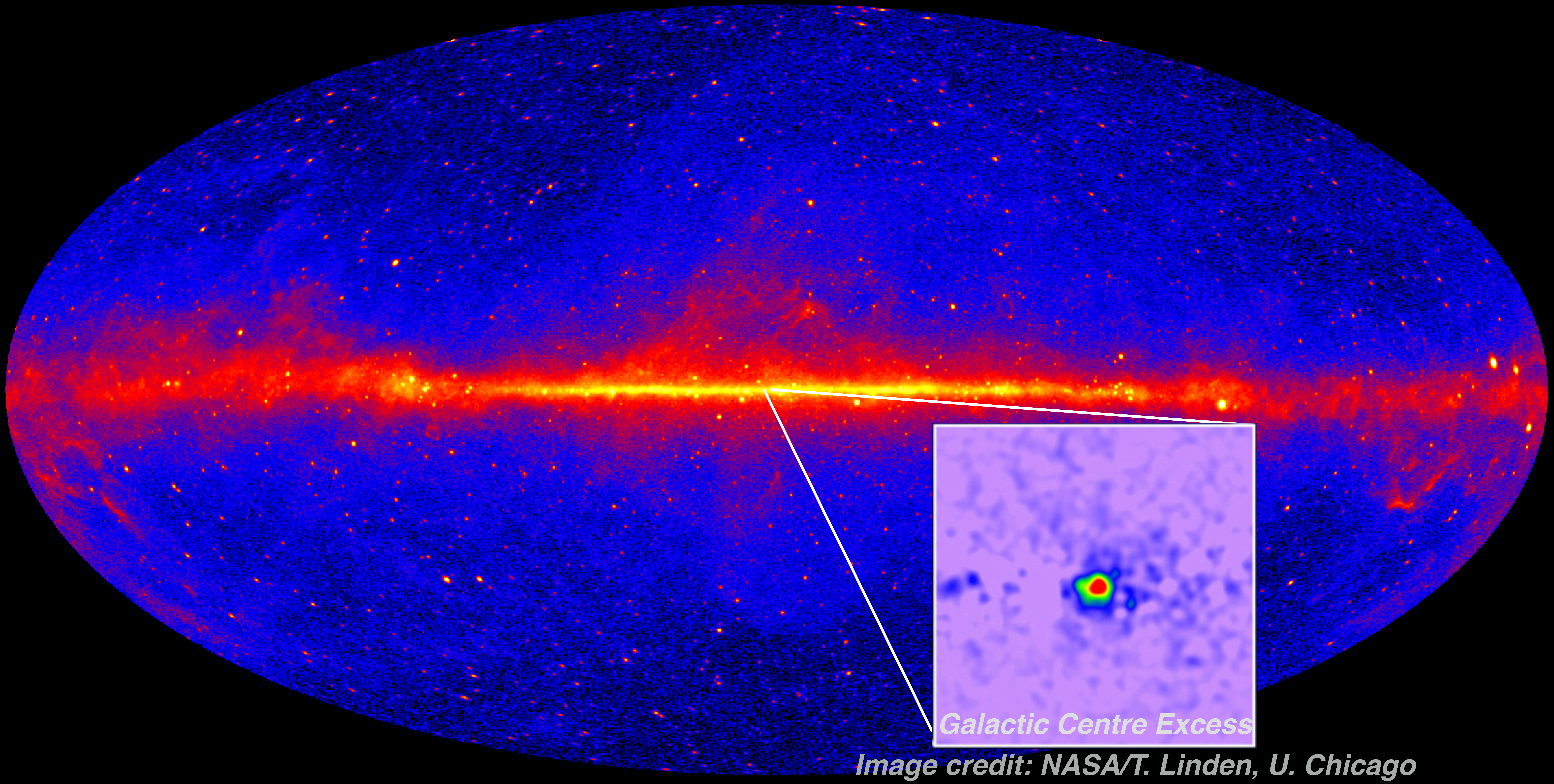
The Fermi “Treasure Trove”





> 120 new MSPs found in Fermi sources by the Pulsar Search Consortium (See Ray et al. 2012, arXiv:1205.3089) + FAST + TRAPUM

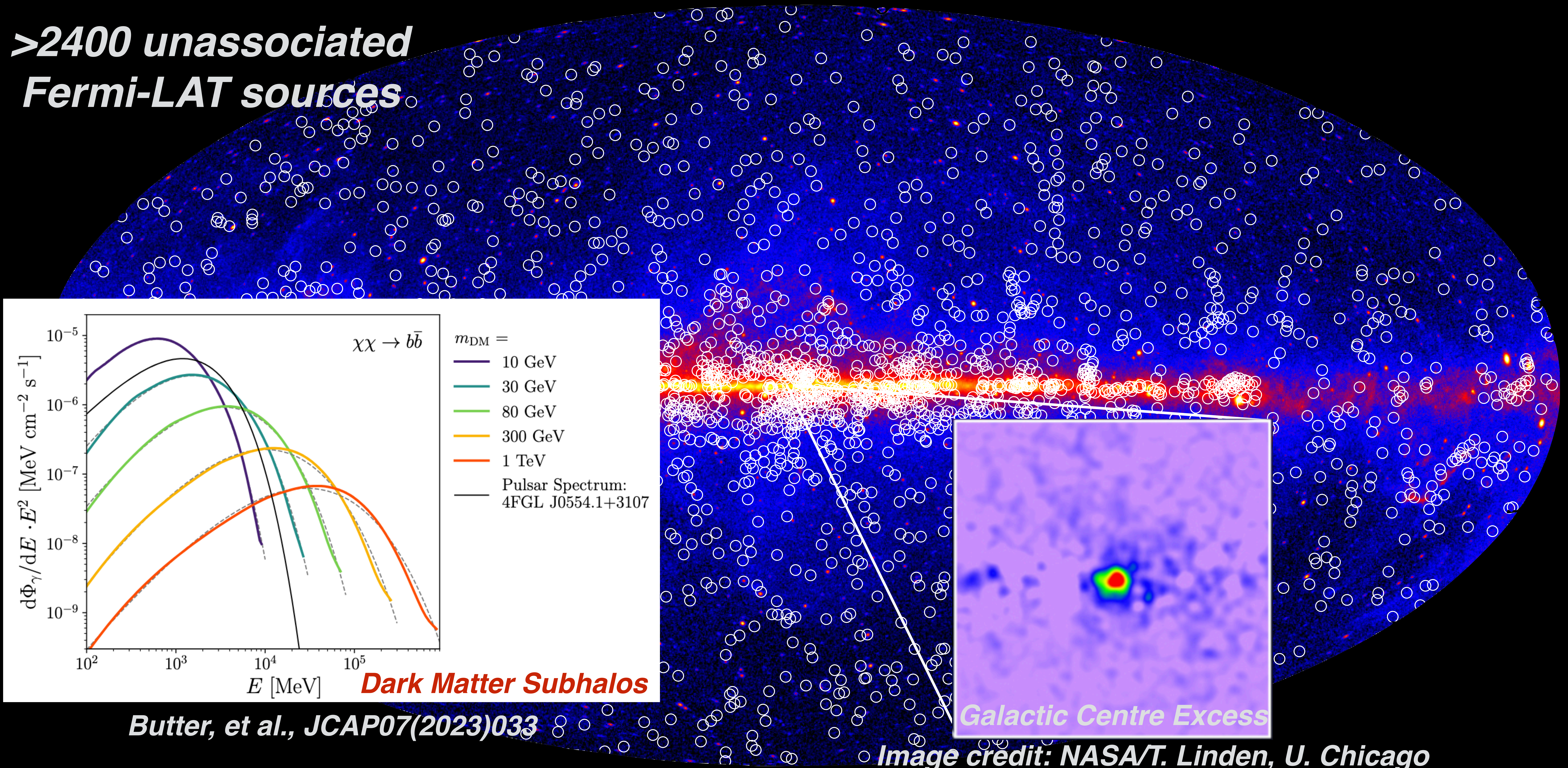
Gamma-ray MSPs and Dark Matter



Gamma-ray MSPs and Dark Matter

Gamma-ray MSPs and Dark Matter

>2400 unassociated Fermi-LAT sources

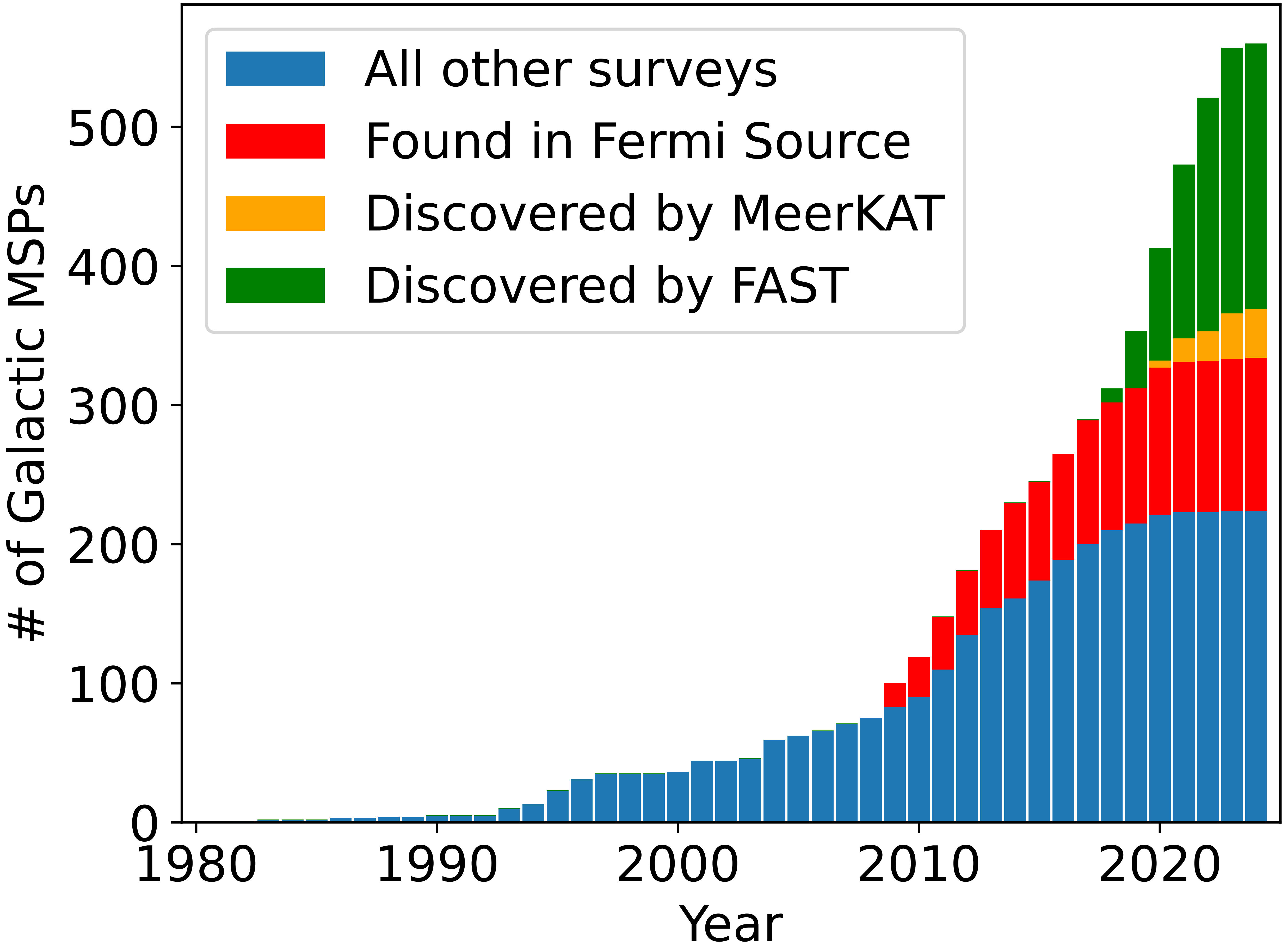


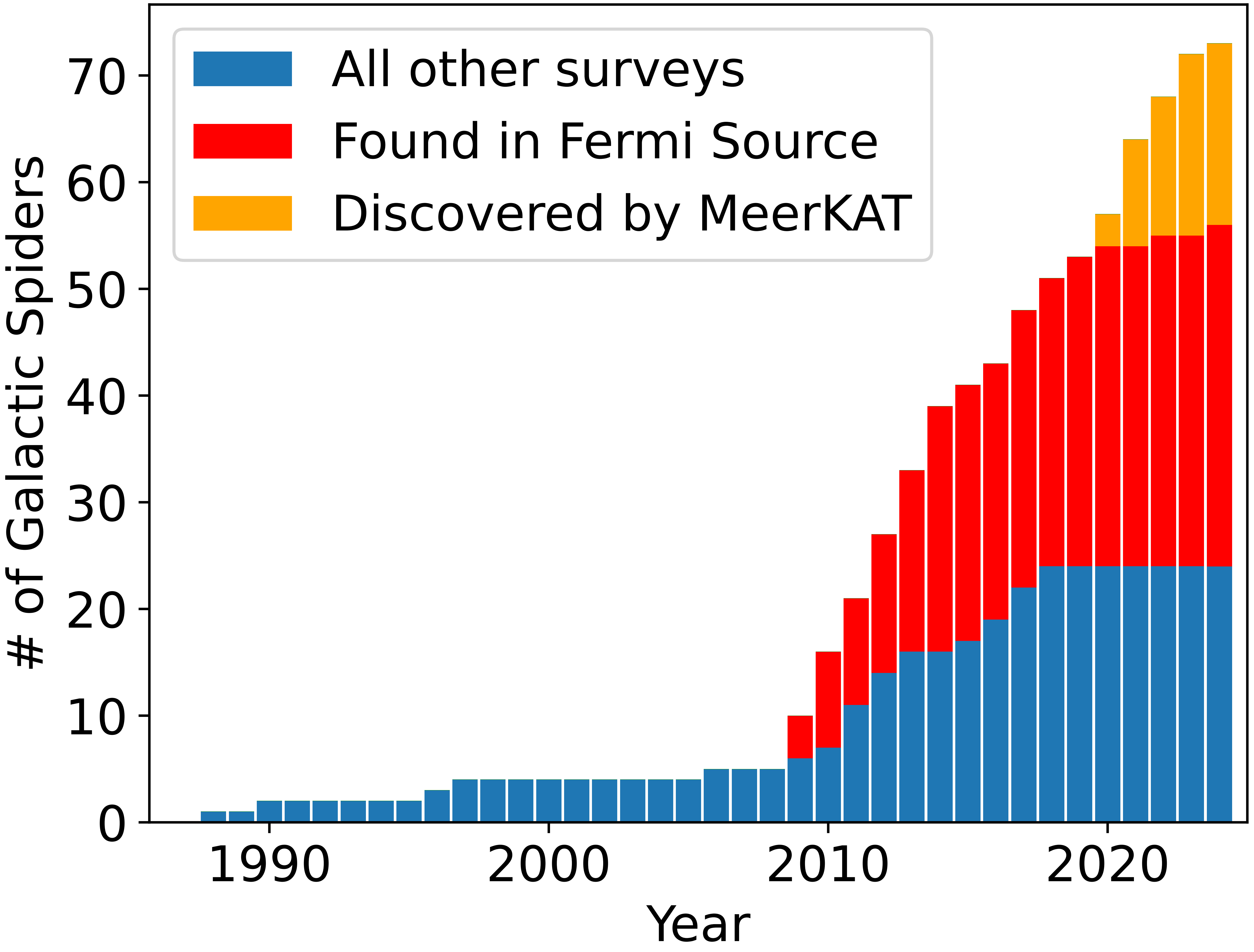
Butter, et al., JCAP07(2023)033

Image credit: NASA/T. Linden, U. Chicago


Artwork by Soheb Mandhai (JBCA)
@TheAstroPhoenix

The Fermi "Treasure Trove"

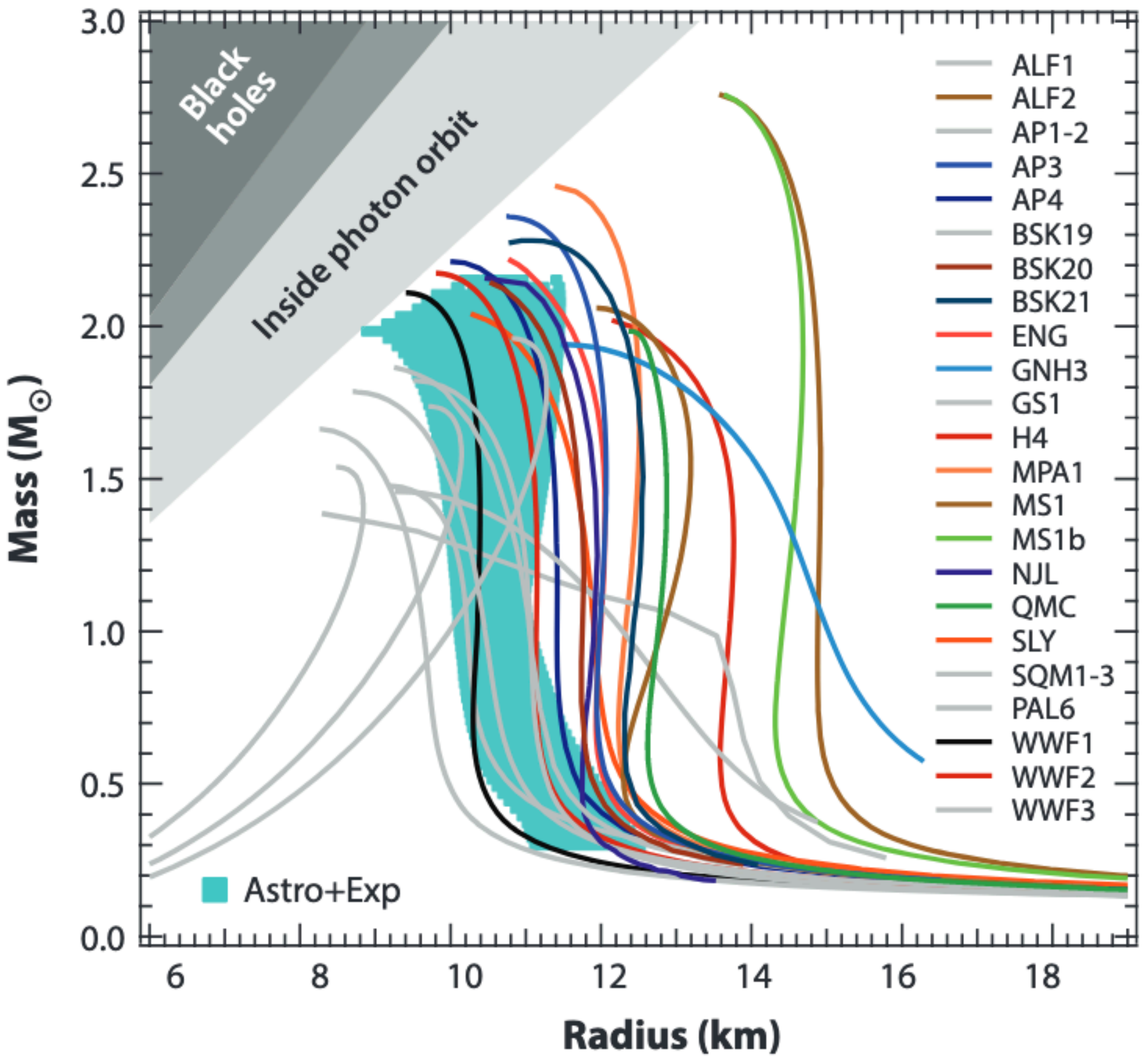




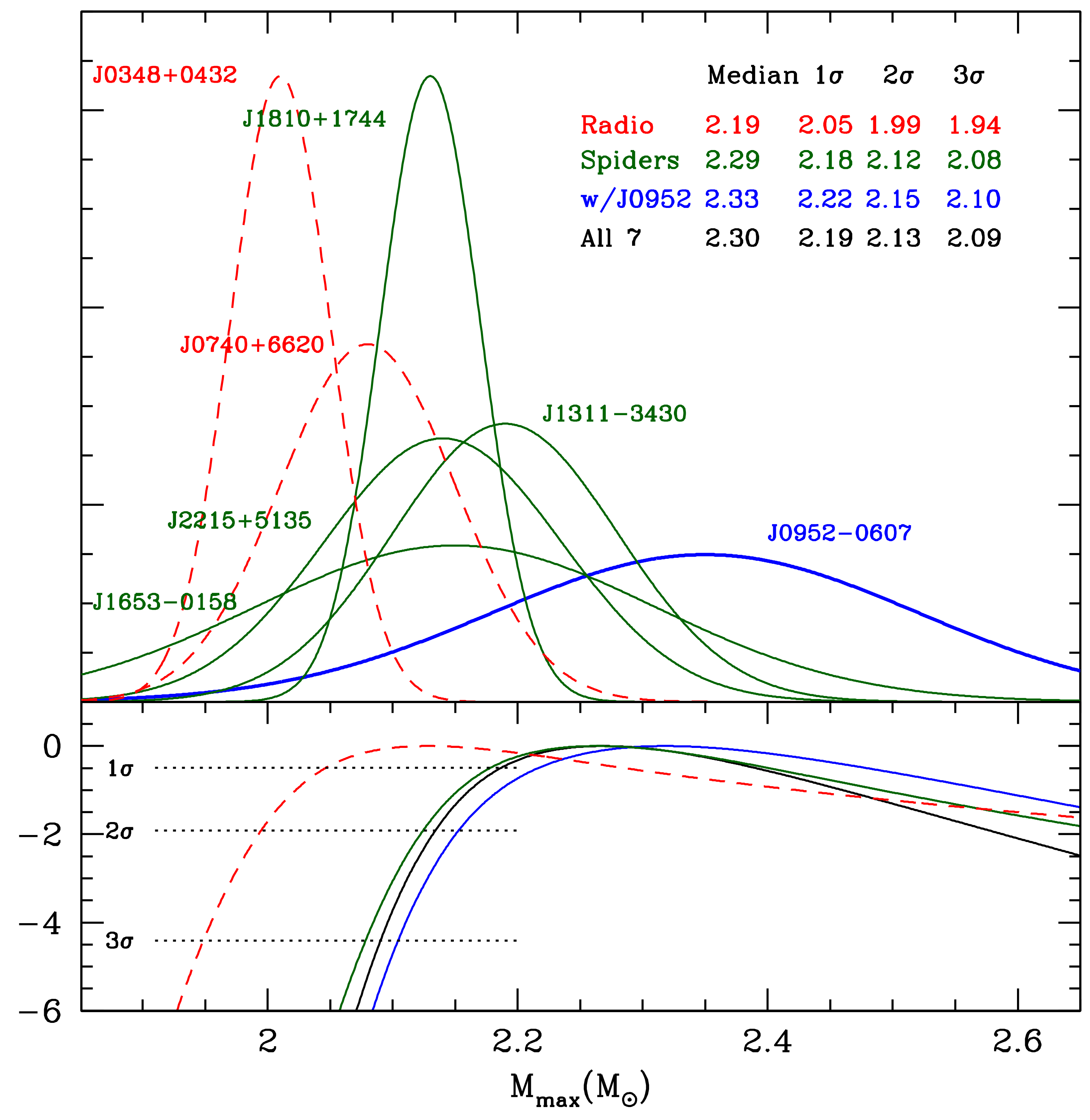
Spider Pulsar Masses and the EoS

Are spider pulsars heavier than other types of neutron star?

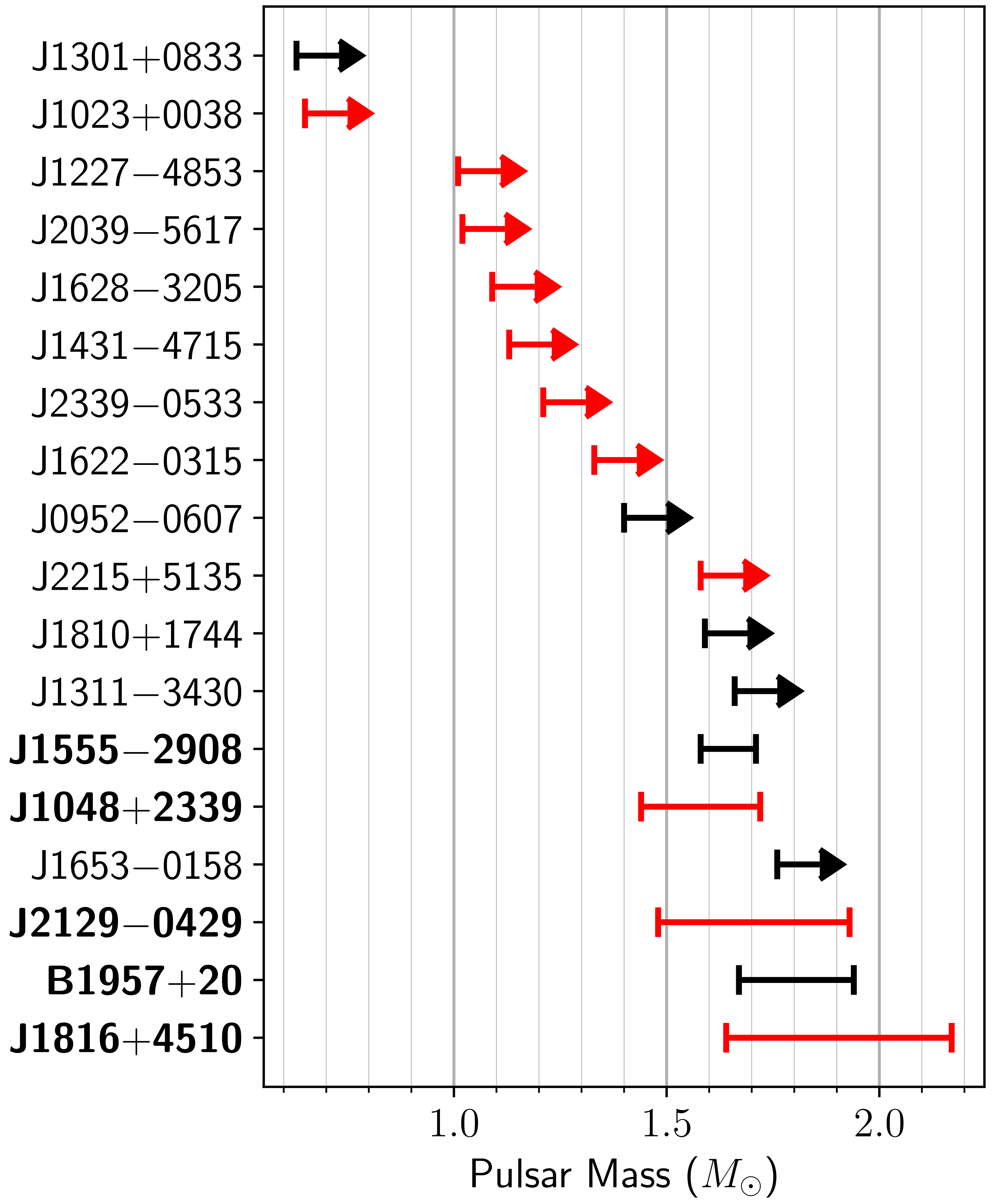
Özel & Freire, 2016, ANA&A, 54, 401



Romani, R.W. et al., 2022, ApJL, 934, L17

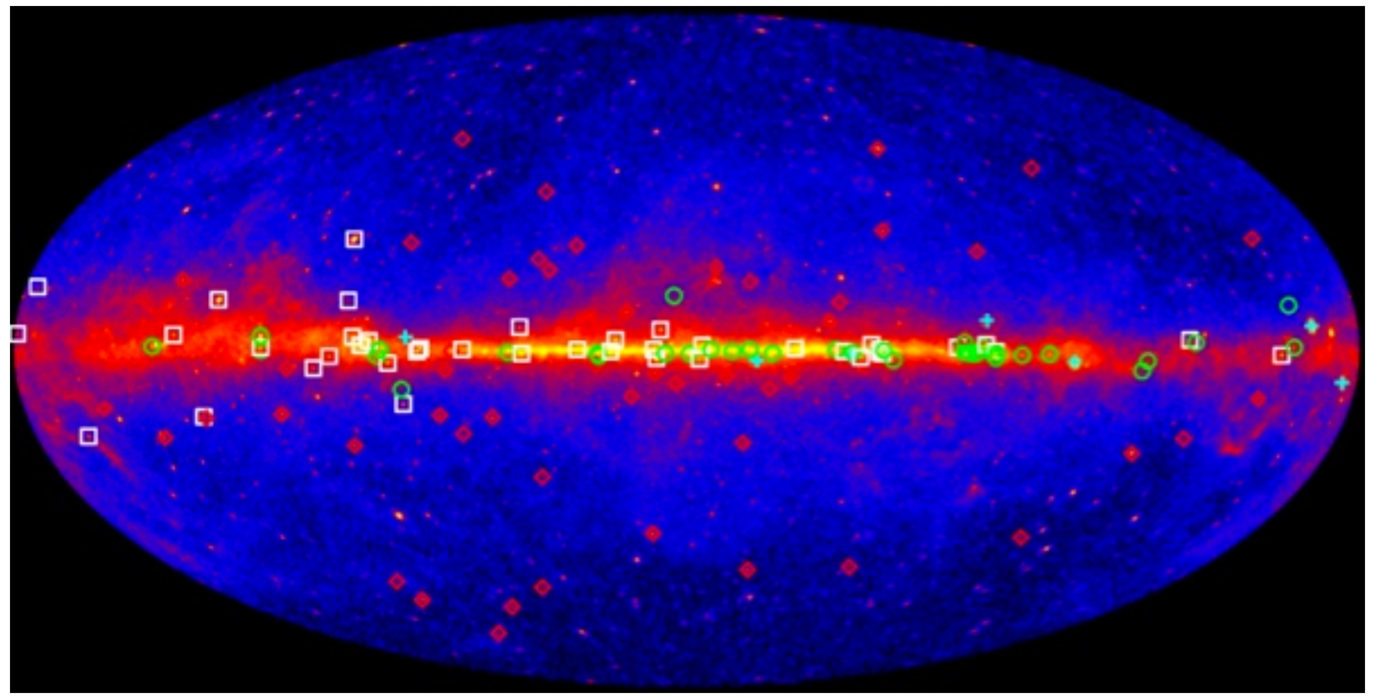


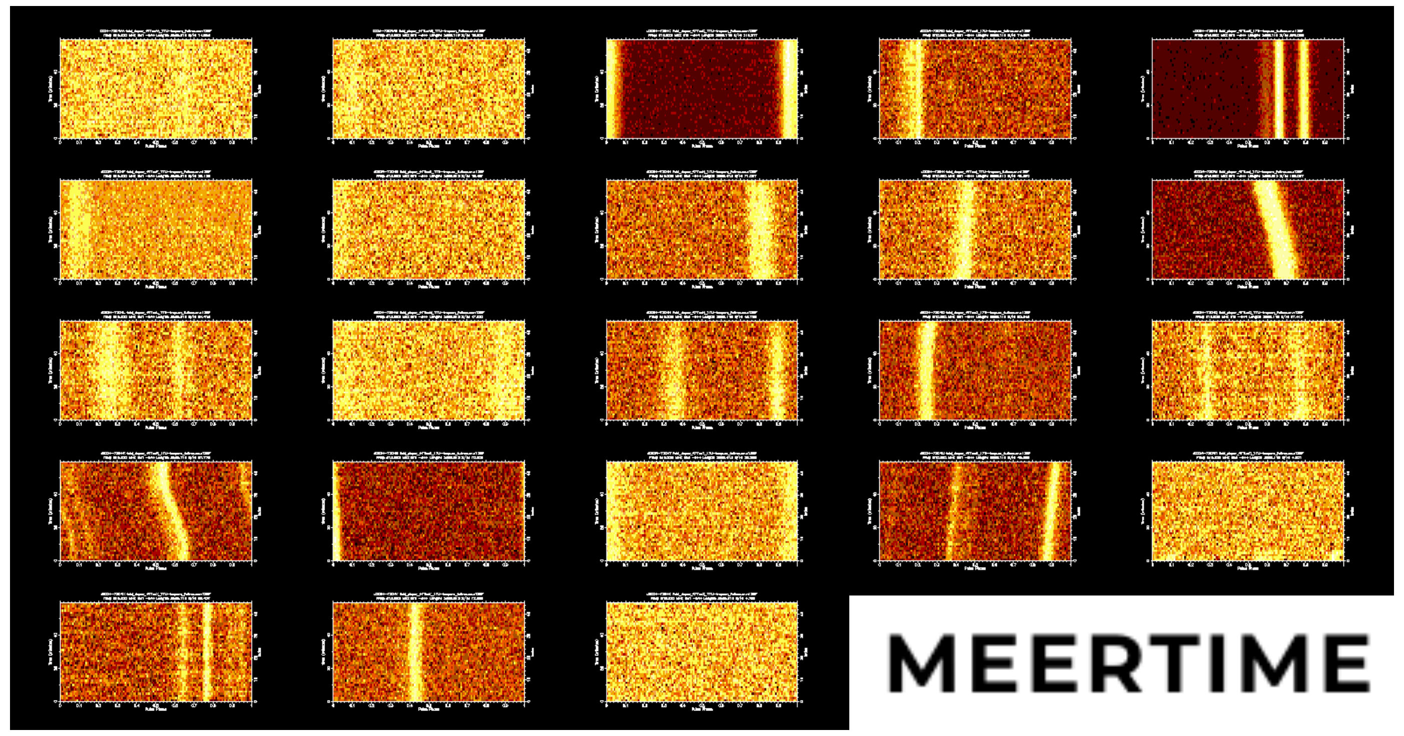
C.J.C., et al., 2023, Nature Astronomy, 7, 451



Unidentified Fermi LAT sources
Chairs: C.J.C. & R. Breton

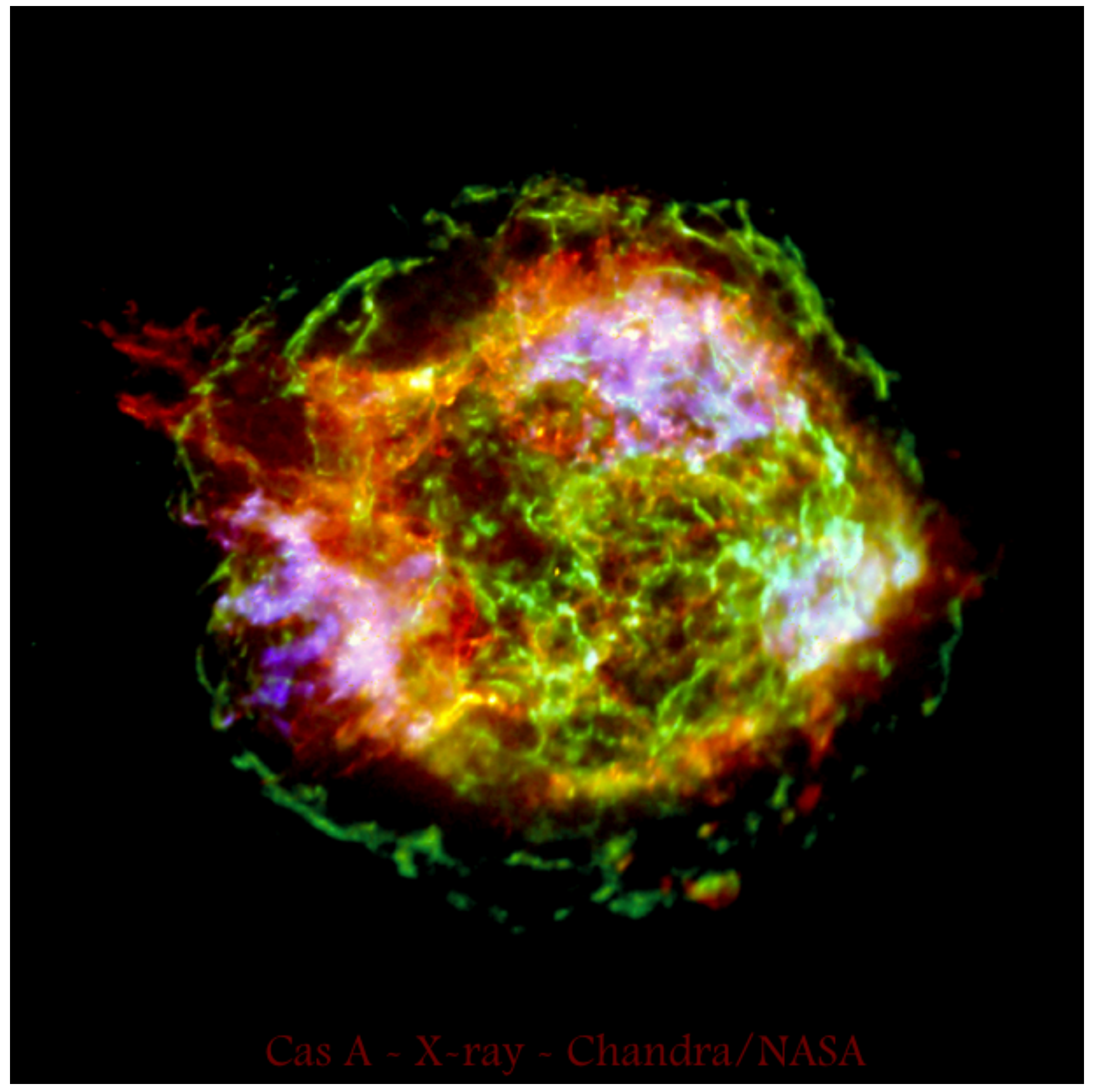
Credit: *FERMI*/NASA





Globular clusters
Chair: A. Ridolfi

Credit: *Chandra*/NASA



SNR/PWNe/TeV sources
Chair: B. W. Stappers

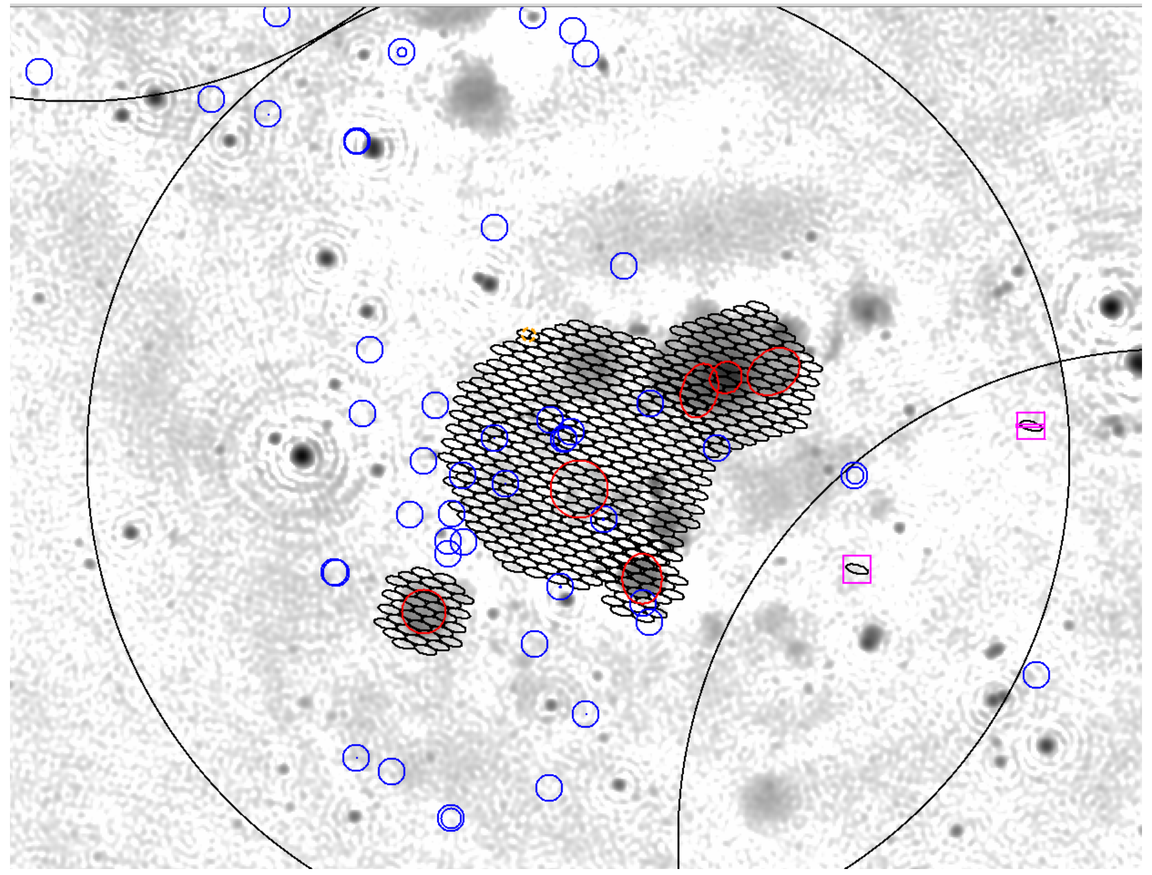
TRAPUM

Transients and **Pu**lsars with **M**eerKAT

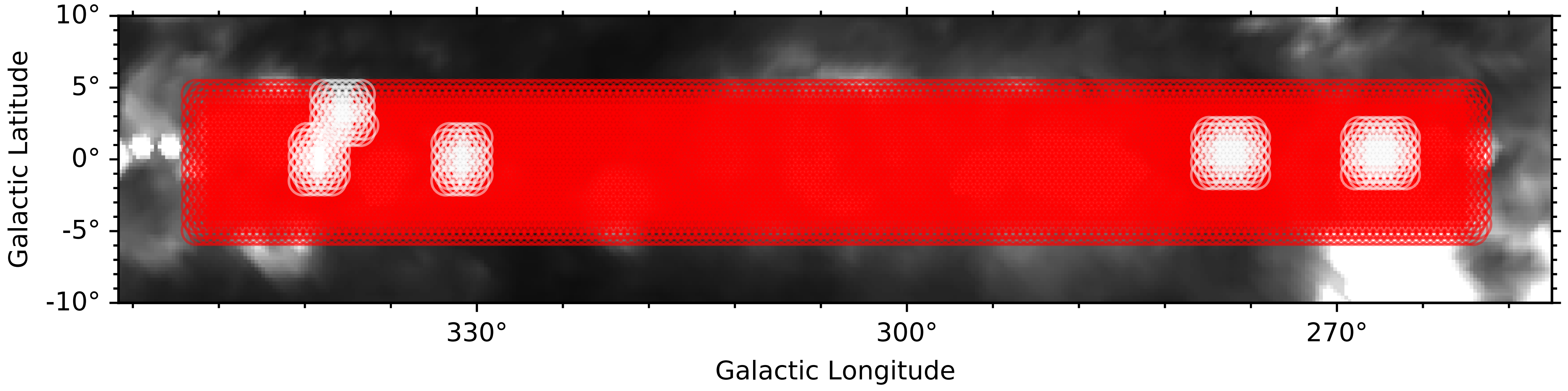
Principal Investigators: M Kramer & B. W. Stappers

Project Scientist: E. Barr

Follow-up Coordinator: M. Burgay



Nearby galaxies
Chair: L. Levin-Preston

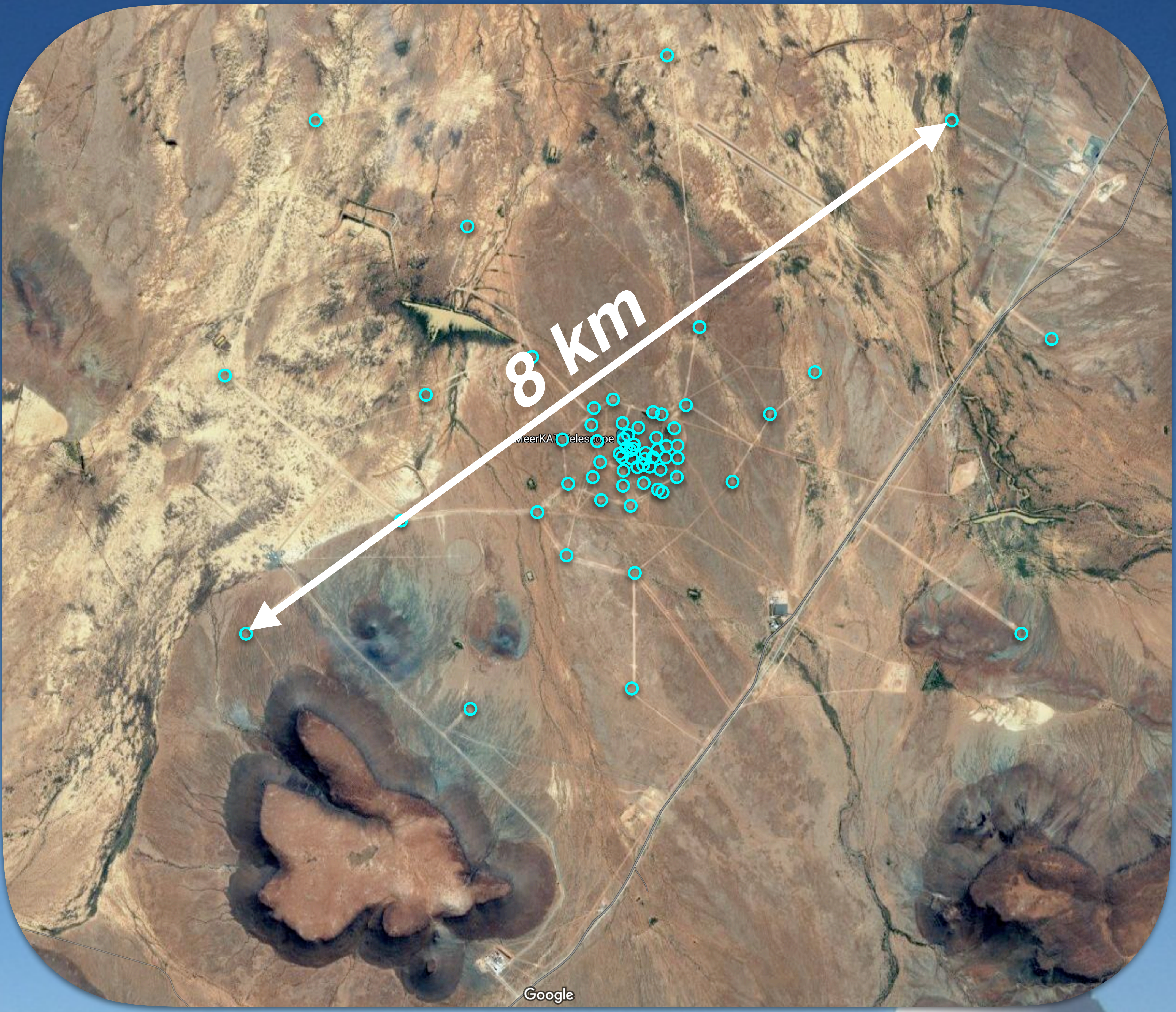


MPIfR MeerKAT Galactic Plane Survey (MMGPS)

https://www.trapum.org/discoveries/

MeerKAT

Number of antennas	64
Dish diameter	13.5 m
Minimum baseline	29 m
Maximum baseline	8 km
Frequency bands	544 – 1088 MHz (U-band) 856 –1712 MHz (L-band) 1.75 – 3.5 GHz (S-band)
Instantaneous bandwidth	856 MHz
Sensitivity (0.58 - 1.67GHz)	220 m^2/K



Slide credit: E. Barr (MPIfR)

TRAPUM Pulsar Searches

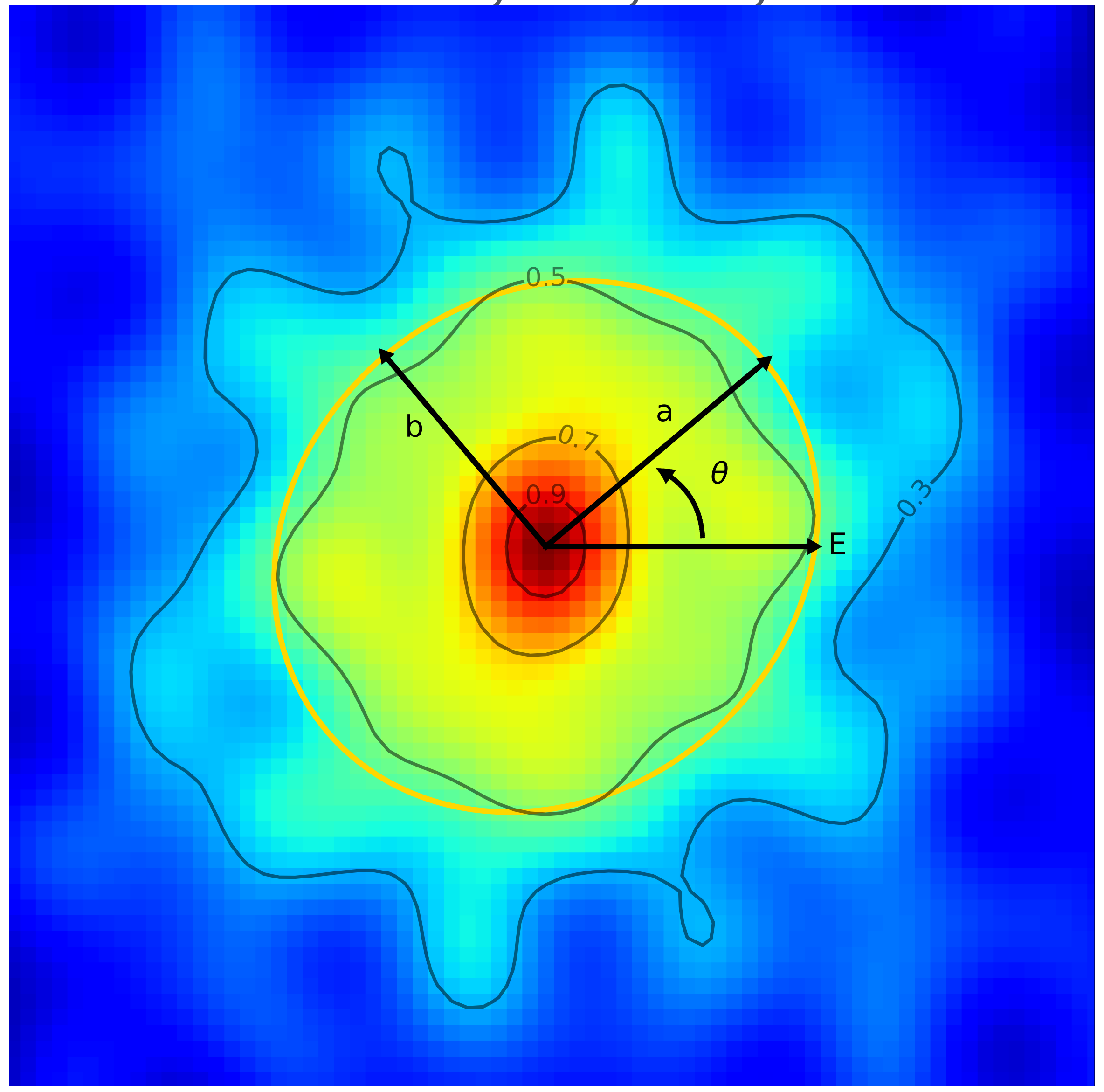
FBFUSE
Multi-beam
beamformer

↓ ***480 coherent beams***

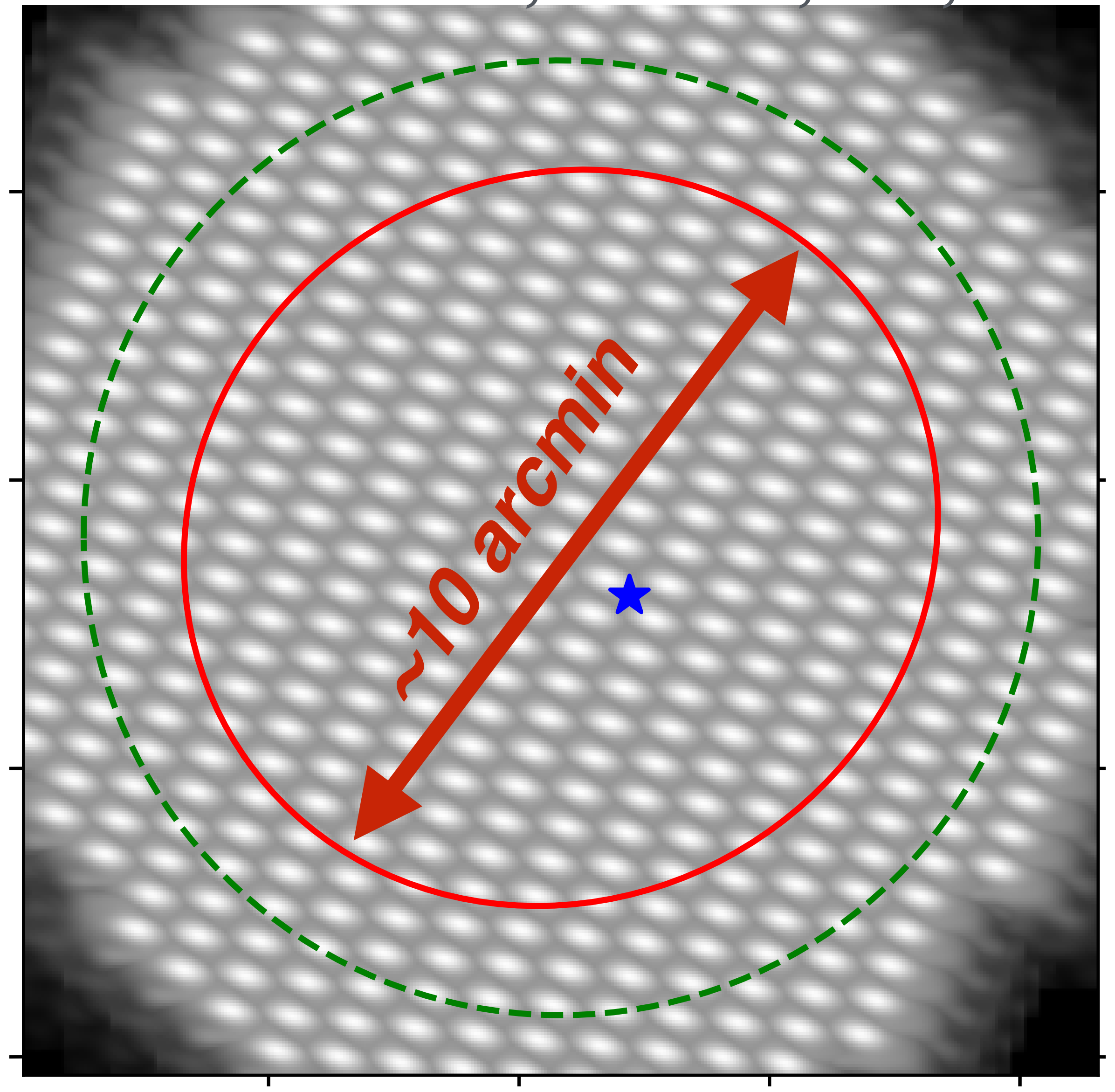
APSUSE
Binary pulsar search

↓ ***Folded candidates ranked by ML classifier***

Chen et al. 2021, JAI, 10, 2150013



C.J.C. et al. 2023, MNRAS, 519, 5590



Wide field-of-view (~2° at UHF)
x high angular resolution (~few arcsec)
= lots of data!

Project	Beams	Typical integration time (s)	Data volume (per hour)	Acceleration range (m/s/s)	Real-time ratio
Fermi	480	600	46 - 71 TB	+/- 50	x39
Nearby Galaxies	480	1800/7200	46 TB	+/- 50	x54
MGPS-L	480	600	46 TB	+/- 15	x24

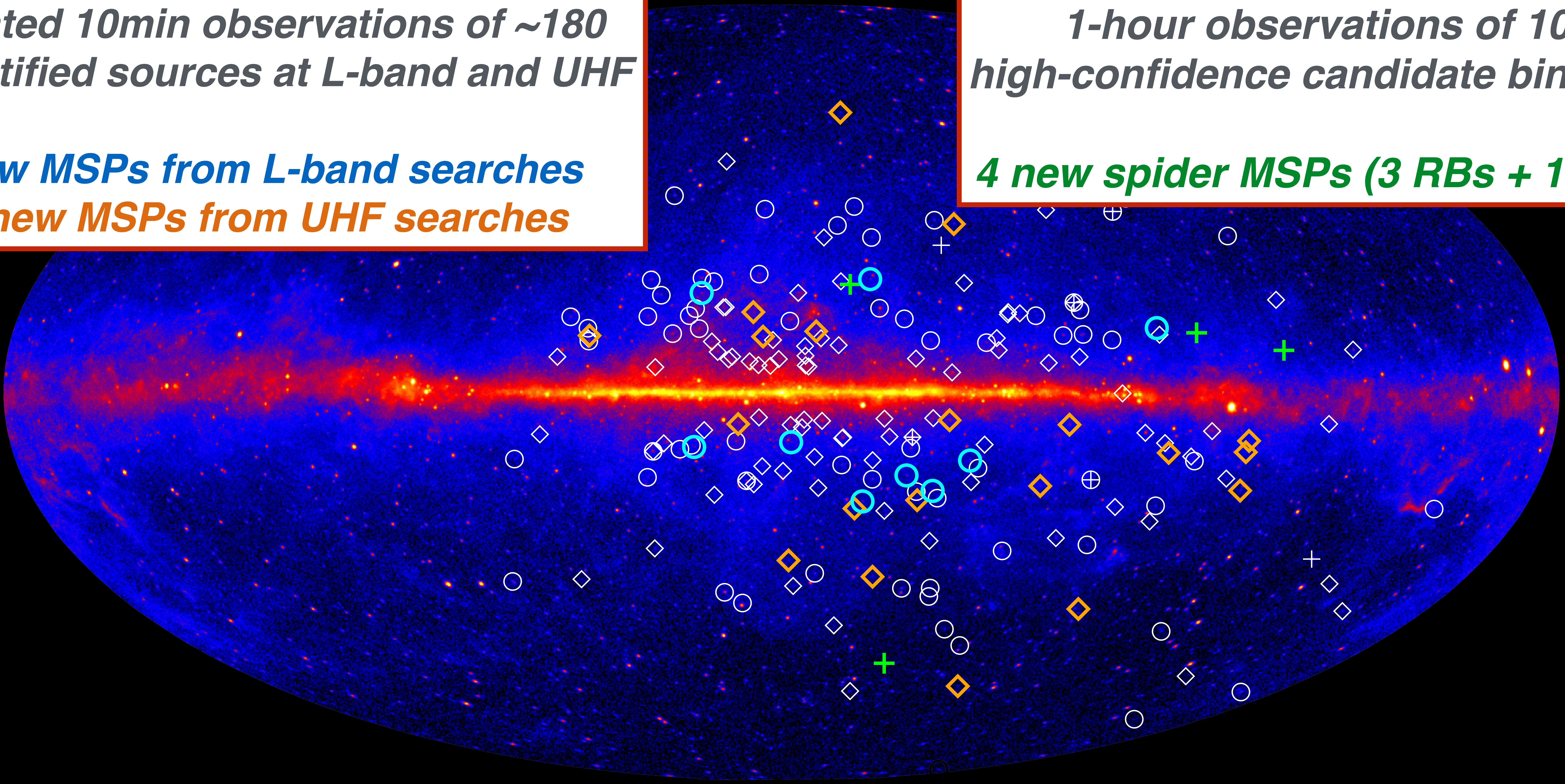
TRAPUM+Fermi Pulsar Searches

"Shallow" survey:
repeated 10min observations of ~180 unidentified sources at L-band and UHF

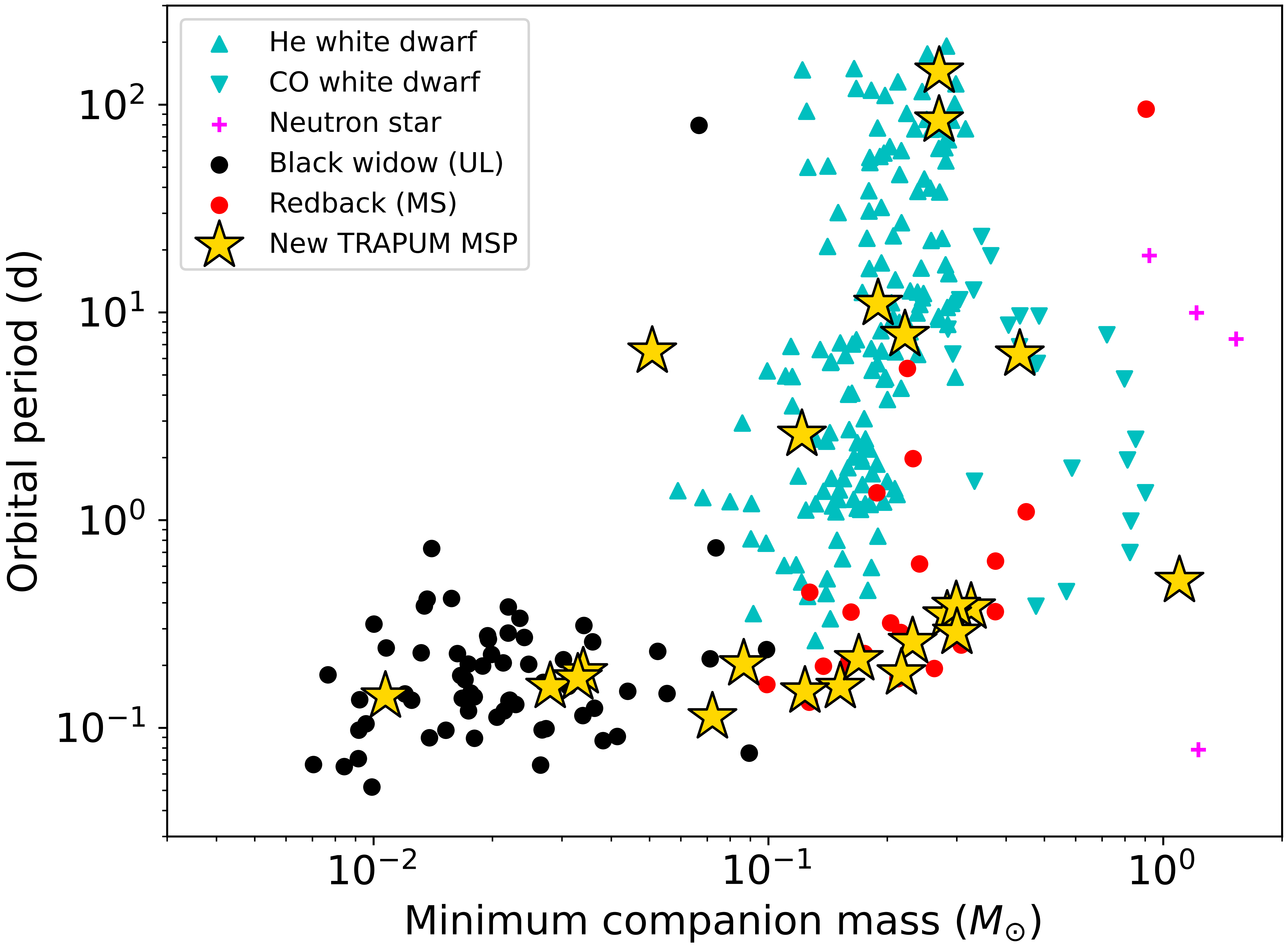
9 new MSPs from L-band searches
21 new MSPs from UHF searches

"Targeted" survey:
1-hour observations of 10 high-confidence candidate binaries

4 new spider MSPs (3 RBs + 1 BW)

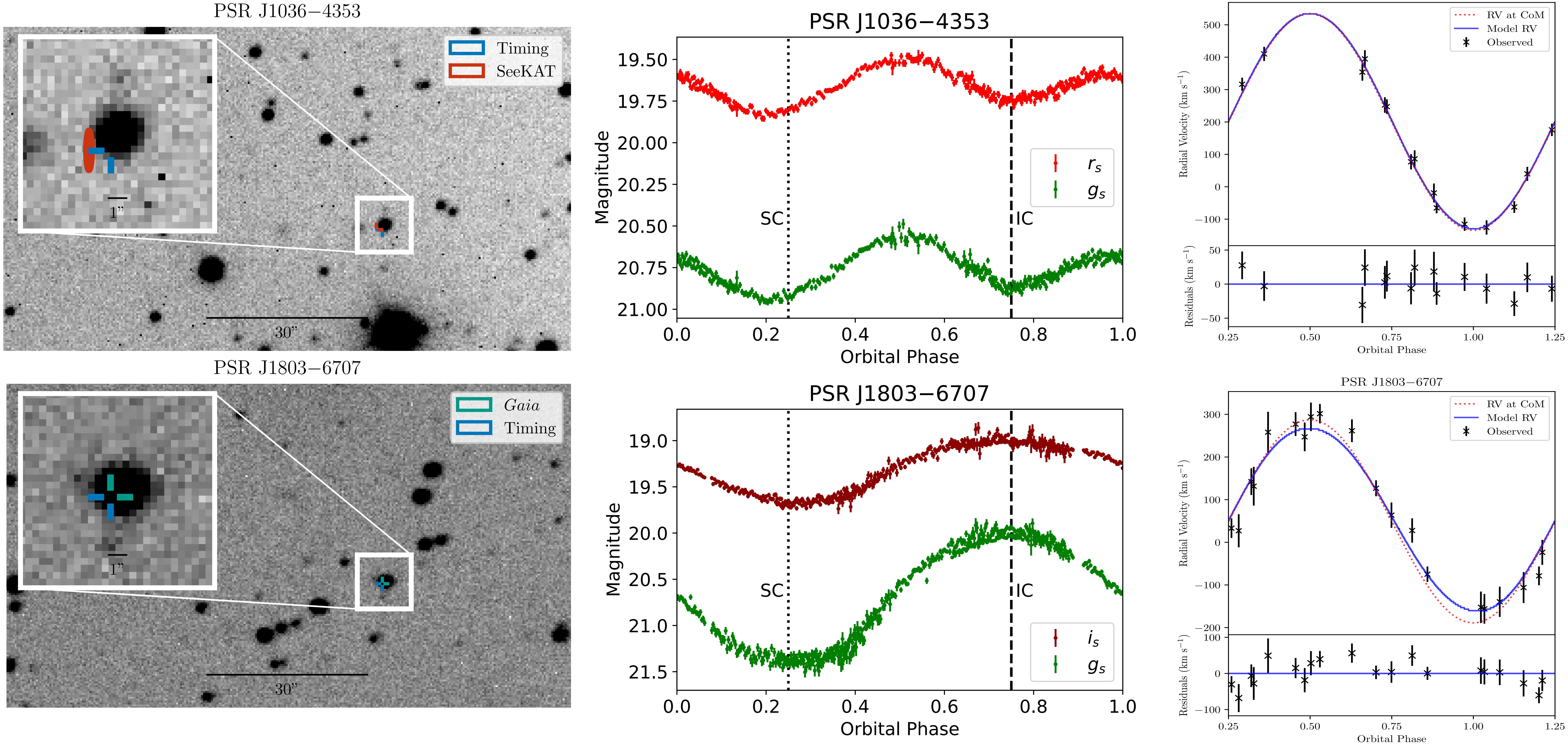


TRAPUM+Fermi discoveries



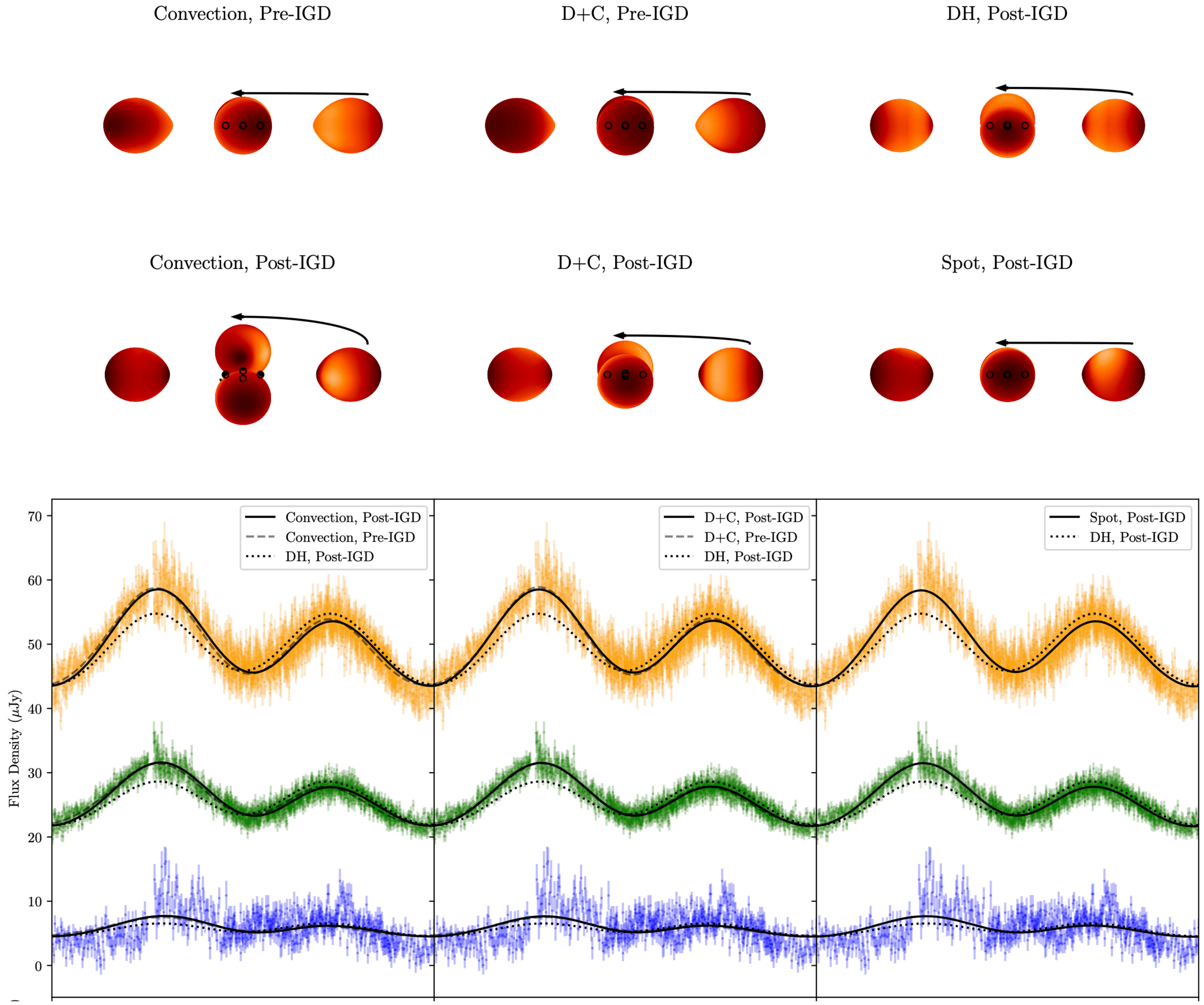
Multi-wavelength Follow-up

Phosrisom, A. et al., in prep

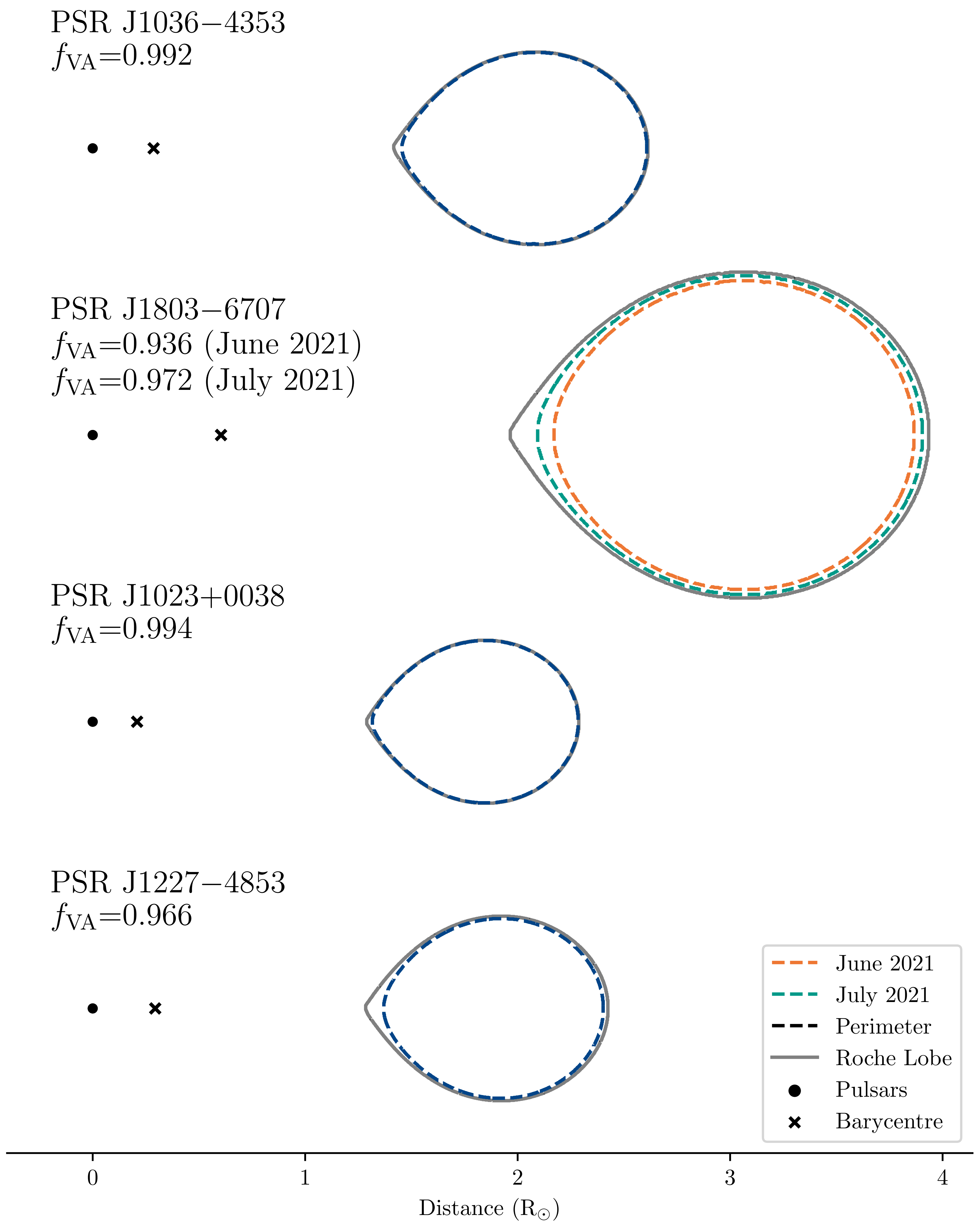


Redback Optical Modelling

Phosrisom, A. et al., in prep

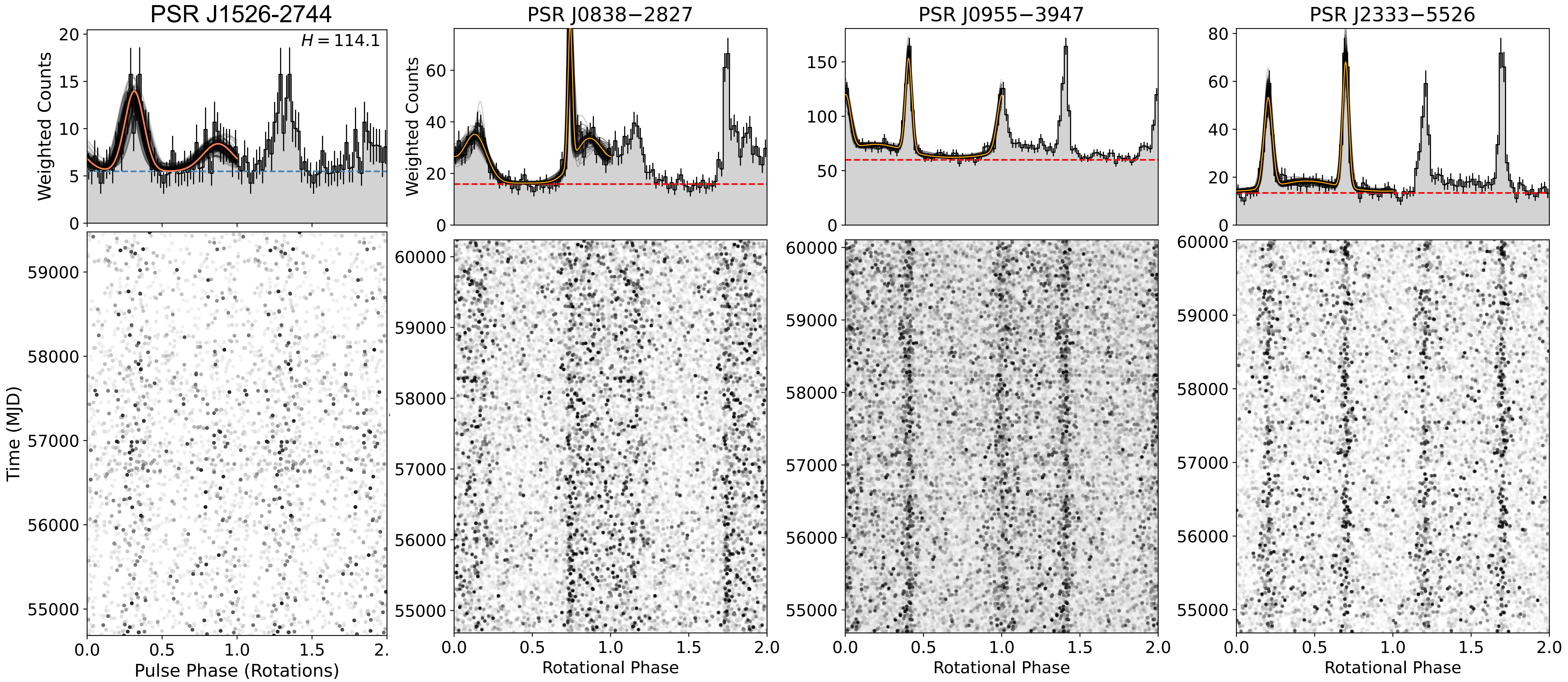


Radius variations, a "failed" tMSP?

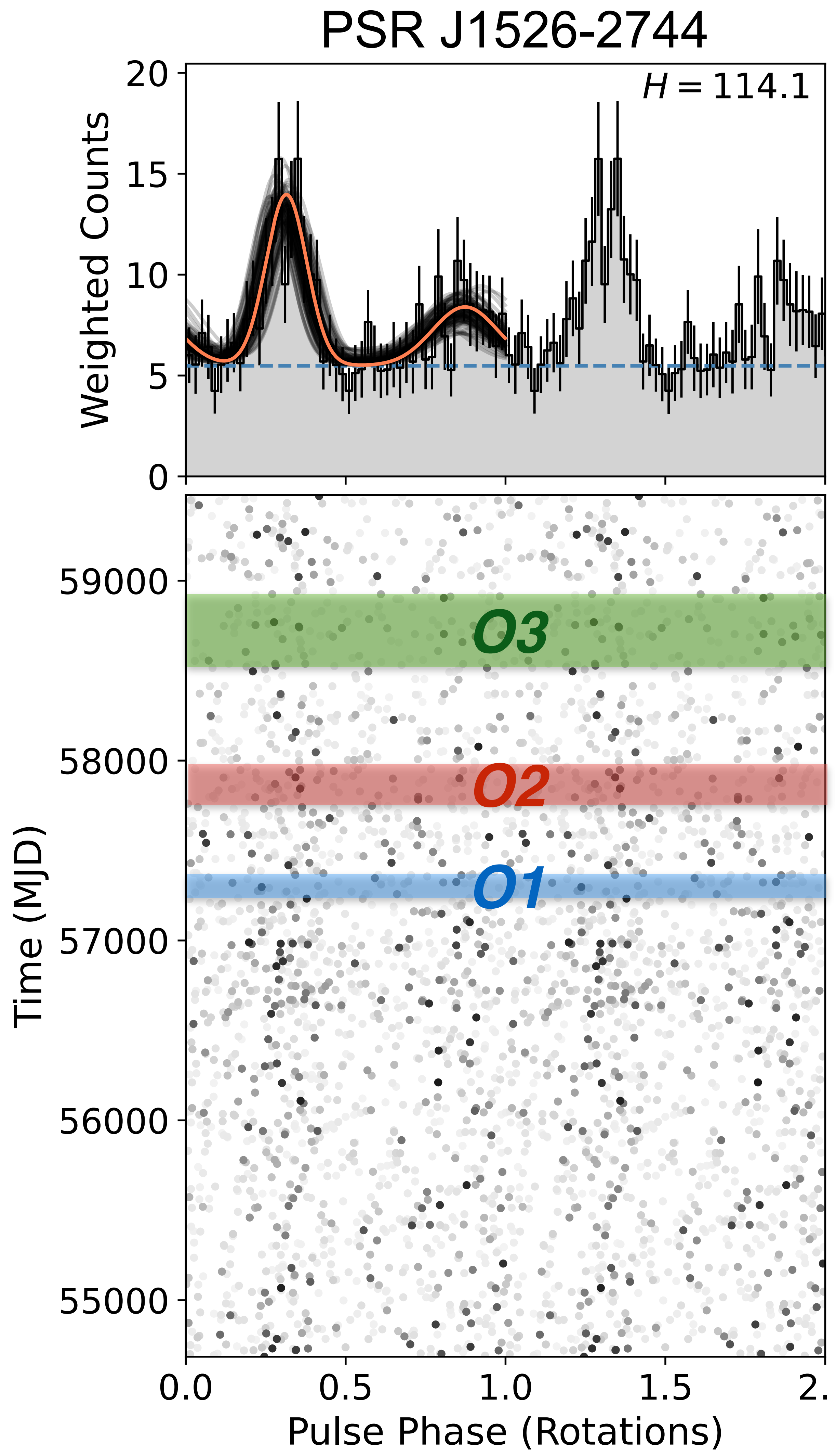


Gamma-ray Pulsar Timing

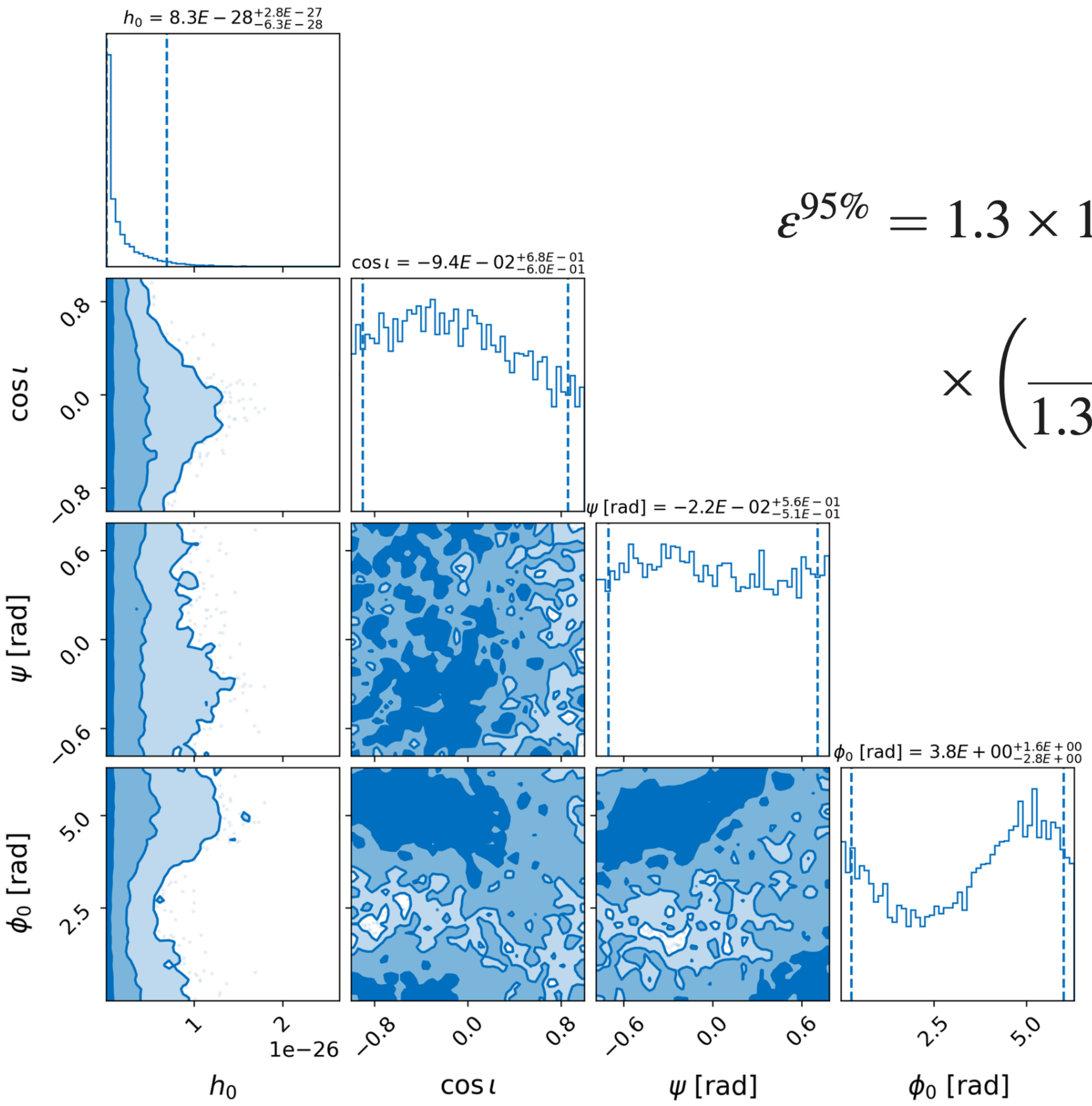
16-year Fermi-LAT all-sky data provides long-term timing solutions



Gamma-ray Pulsar Timing



Retrospective gamma-ray timing solutions enable searches for continuous gravitational waves in public LIGO data



$$\varepsilon^{95\%} = 1.3 \times 10^{-8} \left(\frac{h_0^{95\%}}{6.7 \times 10^{-27}} \right) \times \left(\frac{d}{1.3\ \mathrm{kpc}} \right) \left(\frac{803.5\ \mathrm{Hz}}{f} \right)^2 \left(\frac{10^{38}\ \mathrm{kg\,m^2}}{I_{zz}} \right)$$

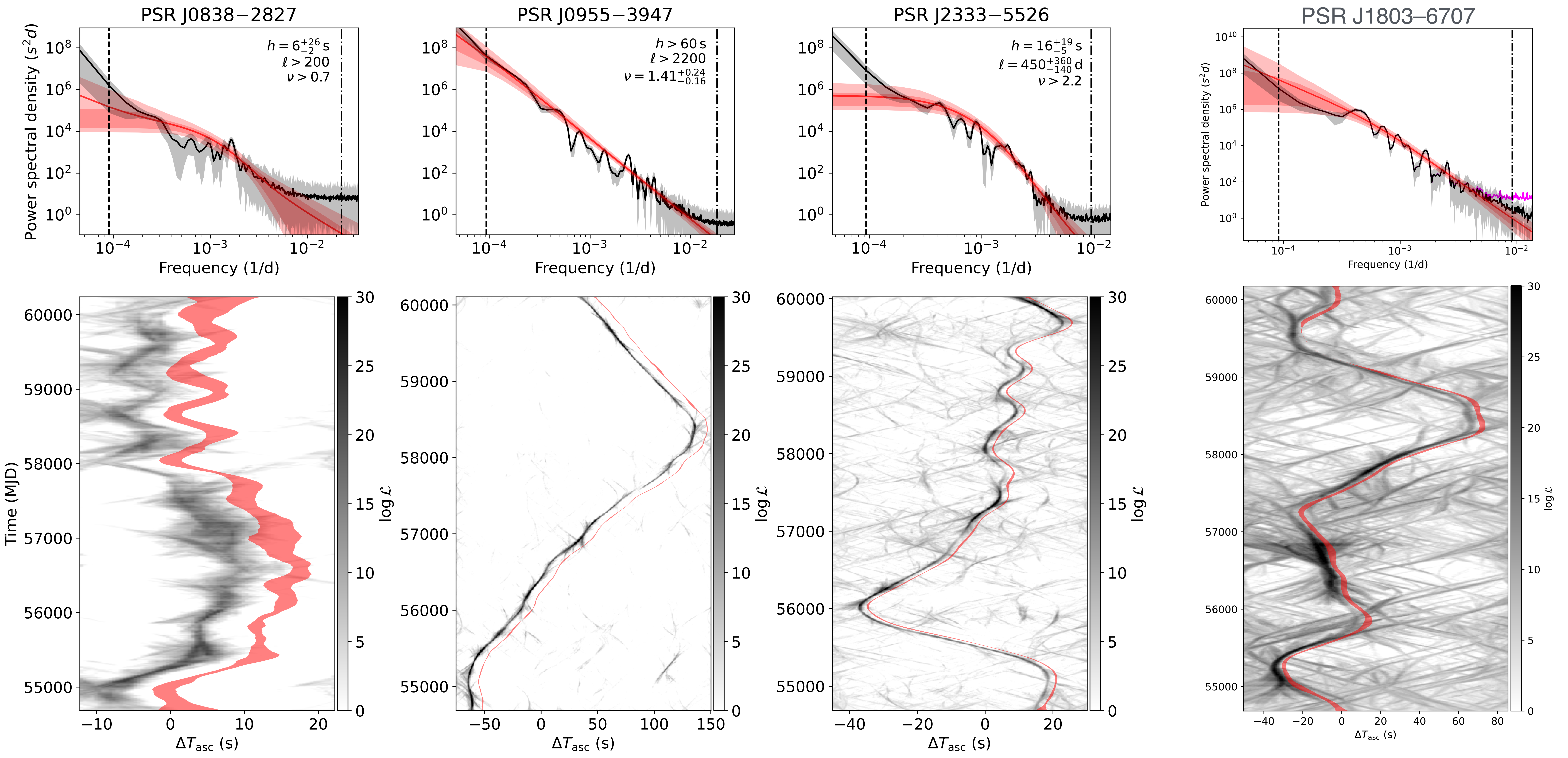
$$h_0^{95\%} \approx 9.2 \times h_0^{\mathrm{sd}}$$

Ashok, A. et al. 2024, Phys. Rev. D 109, 104002

Redback Orbital Period Variations

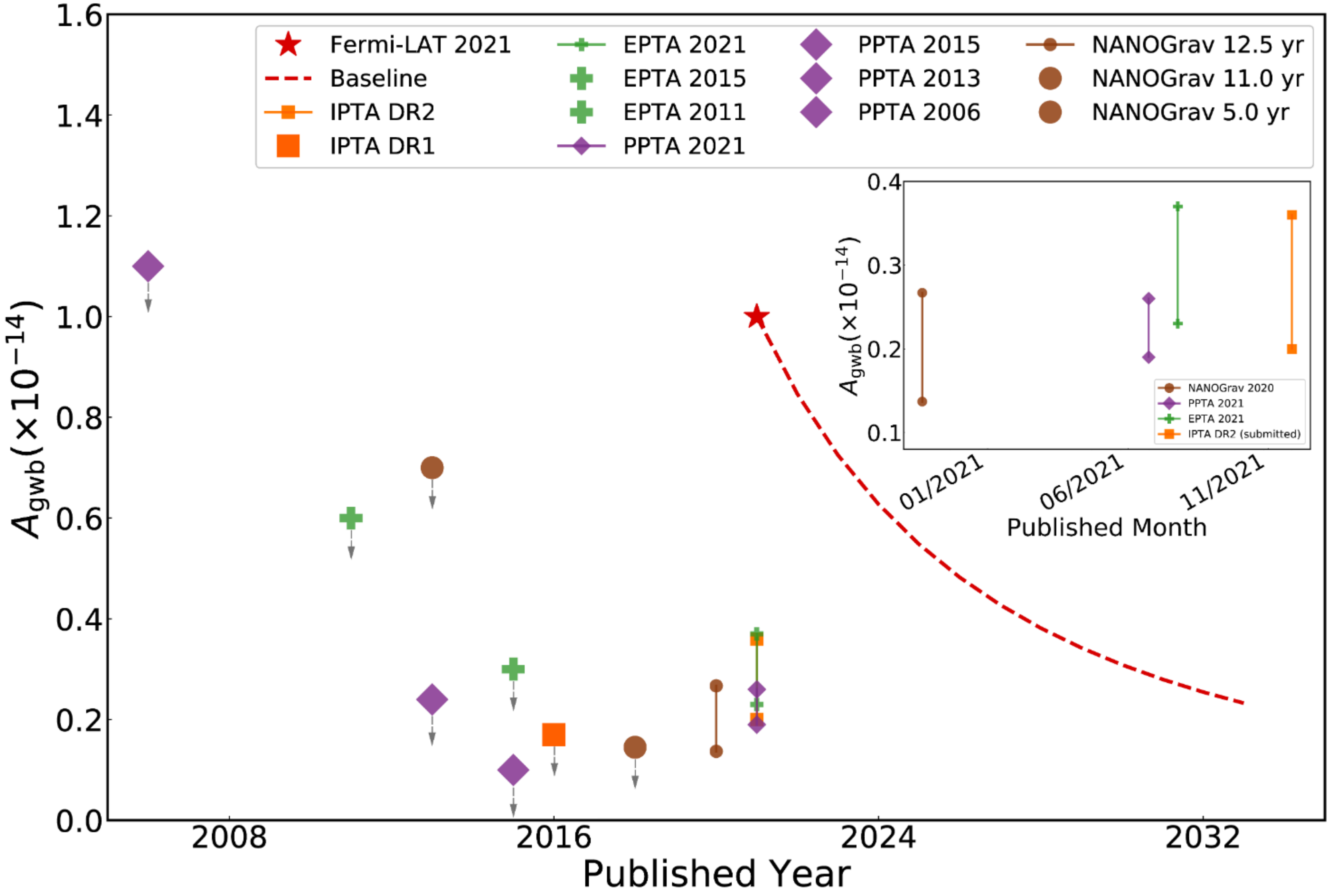
Thongmeearkom, T. et al., 2024, MNRAS, 530, 4676

Burgay, M. et al., A&A, submitted

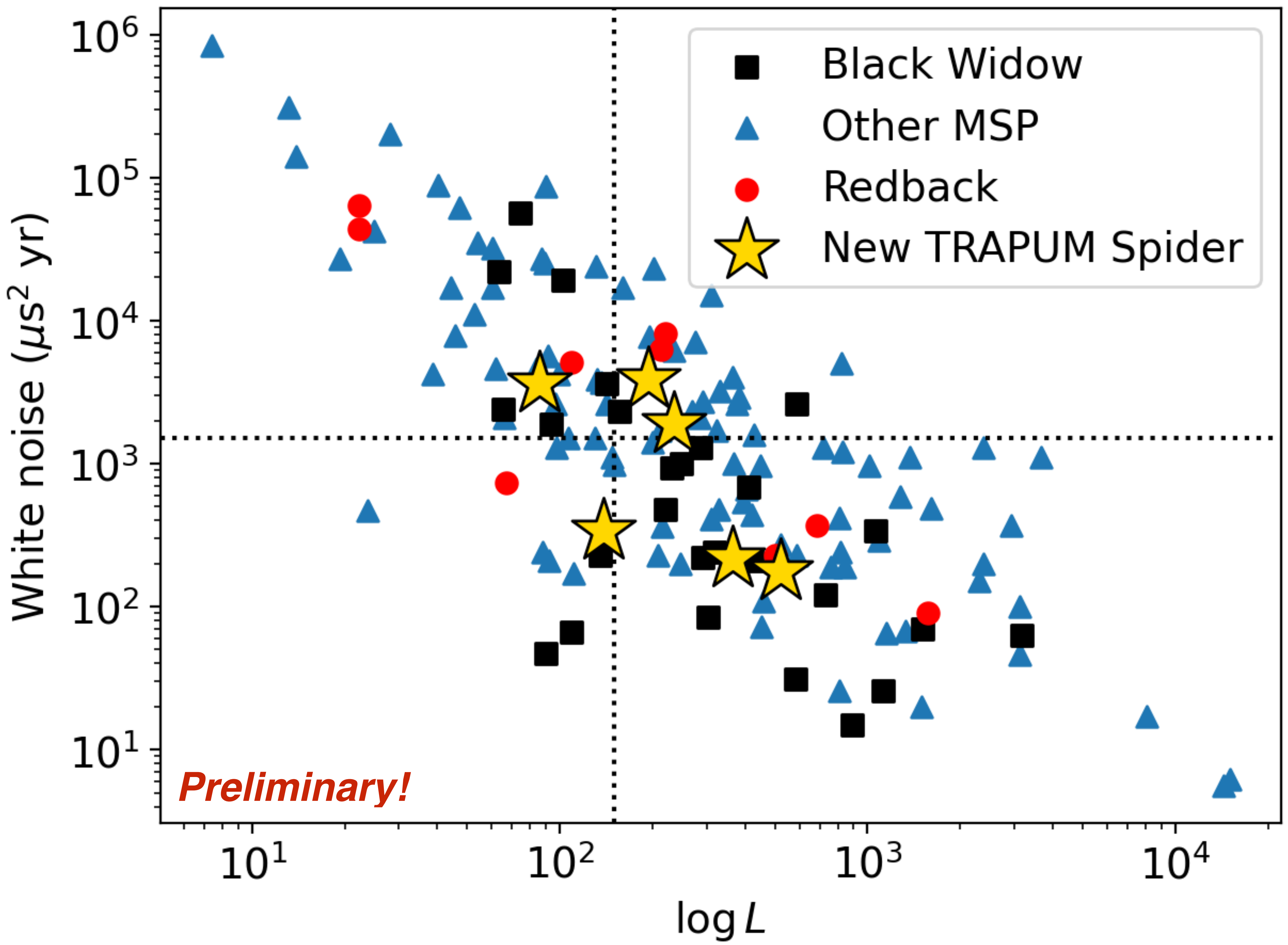


The Gamma-ray Pulsar Timing Array

The Fermi-LAT collaboration, 2022, Science, 376, 521



GPTA DR2, in prep!



Summary

- Fermi-LAT gamma-ray data provides a treasure map for new MSPs

- 34 new MSPs from TRAPUM searches of Fermi-LAT sources
  — Many new spiders, mass estimates for 6 new redbacks
  C.J.C. et al. 2023, MNRAS, 519, 5590
  Dodge, O. et al., 2024, MNRAS, 528, 4337
  Thongmeearkom, T., et al. 2024, MNRAS, 530, 4676

- Radio + gamma-ray MSP discoveries enable lots of NS science:
  — Targeted CW searches, even in old LIGO data, for new MSPs
  — Equation-of-state constraints from new pulsar mass measurements
  — Pulsar timing array projects to constrain the nano-Hertz GWB

Thank you for listening!