The long-period “pulsars”

A new cosmic enigma

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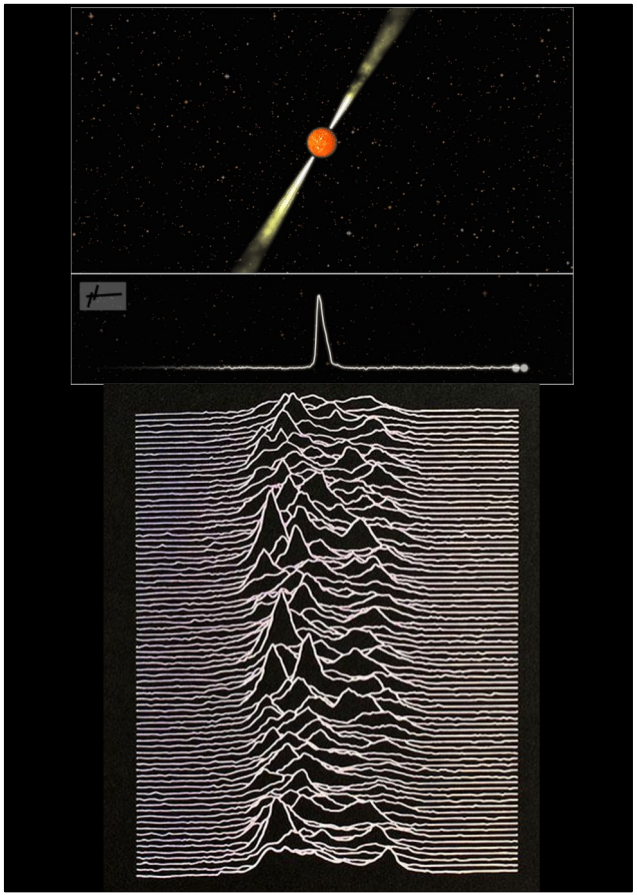
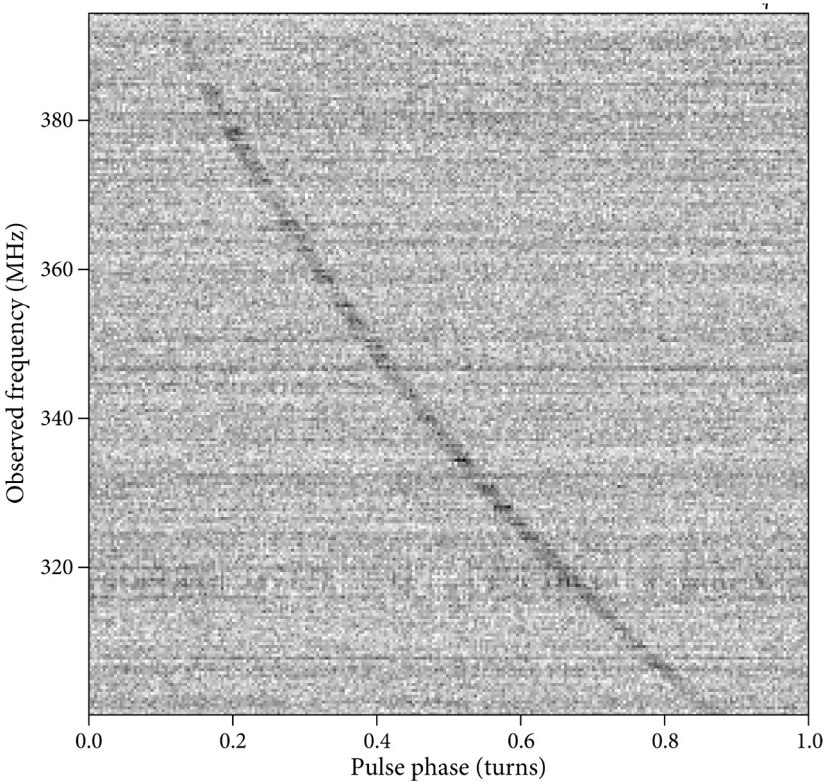
Gemma Anderson, Arash Bahramian, Matthew Bailes, Ewan Barr, Ramesh Bhat, Manisha Caleb, Tracy Clarke, Massimo Dall’Ora, Domitilla De Martino, Tim Galvin, Simona Giacintucci, Paul Hancock, Ian Heywood, Csanad Horvath, Scott Hyman, Emil Lenc, Sam McSweeney, Yunpeng Men, Bradley Meyers, John Morgan, Tyrone O’Doherty, Danny Price, Kaustubh Rajwade, **Nanda Rea**, Ben Stappers, Andrew Williams, **Francesco Coti Zelati**

Pulsars



Dynamic spectrum of a typical pulsar

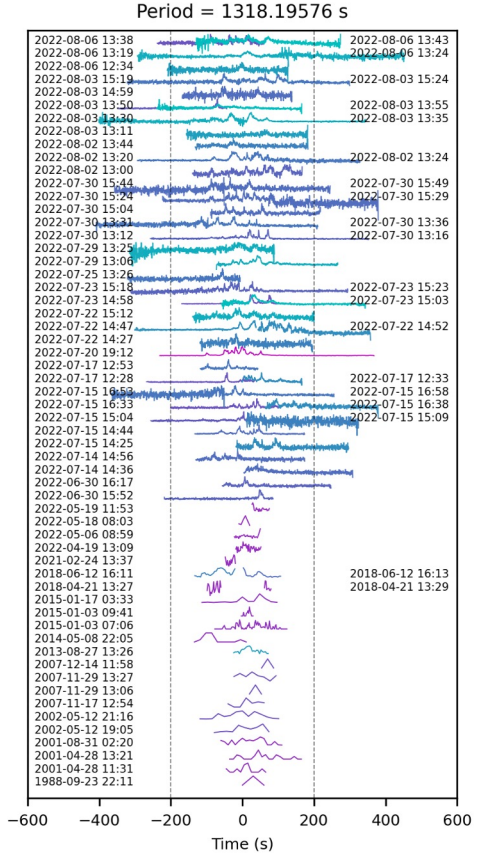


millseconds to seconds

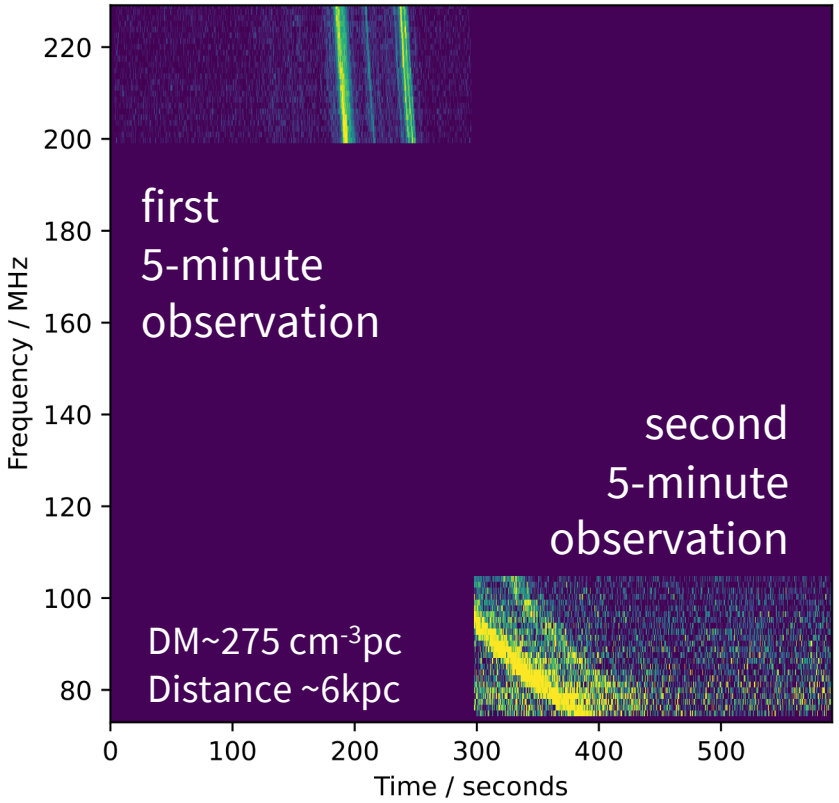
The long-period “pulsars”

today

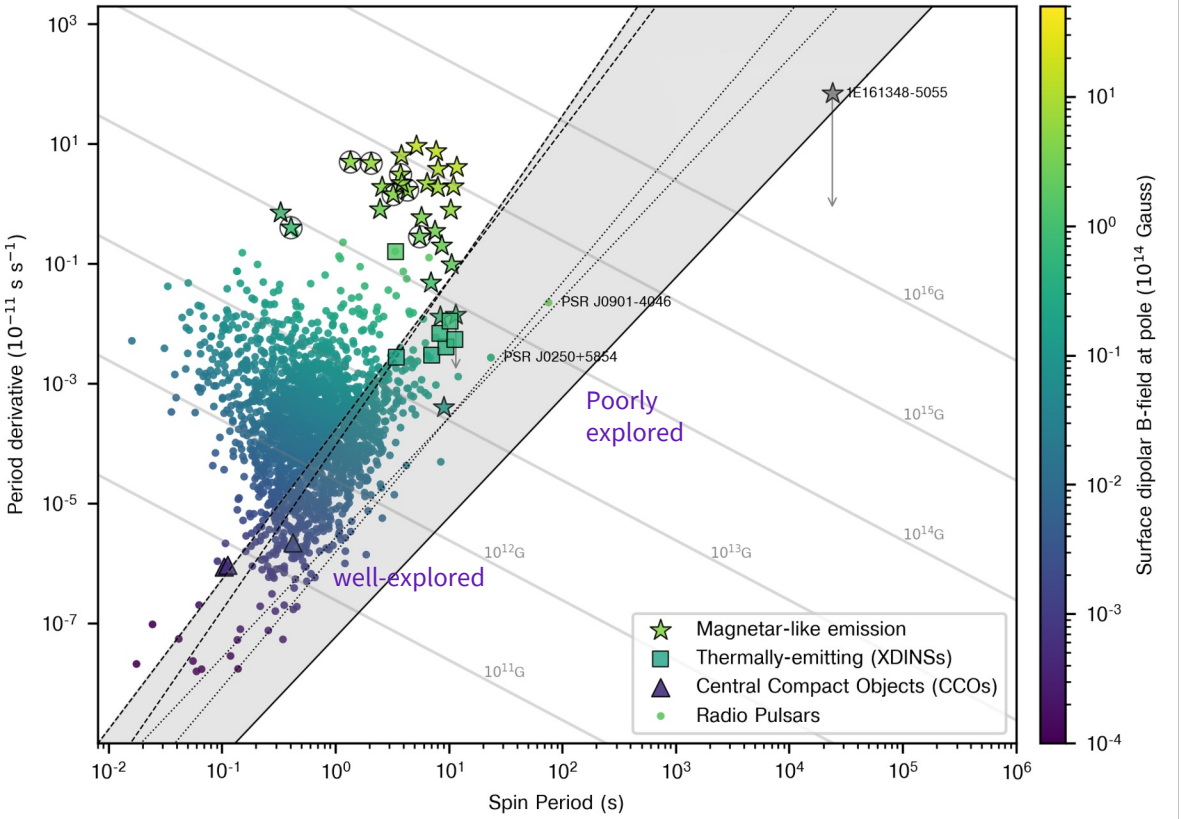
1988



Dynamic spectrum of GPM J1839-10

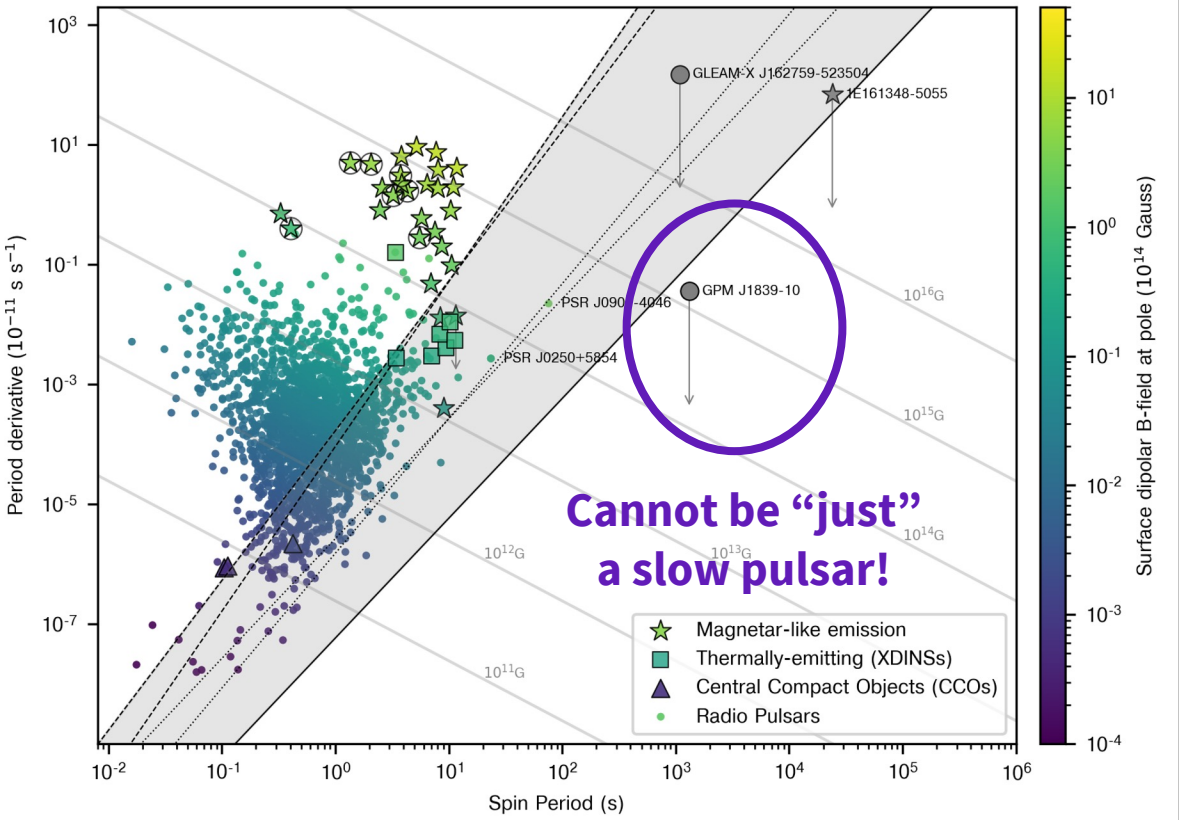


Spin-down



Hurley-Walker et al. 2023, *Nature*

Spin-down



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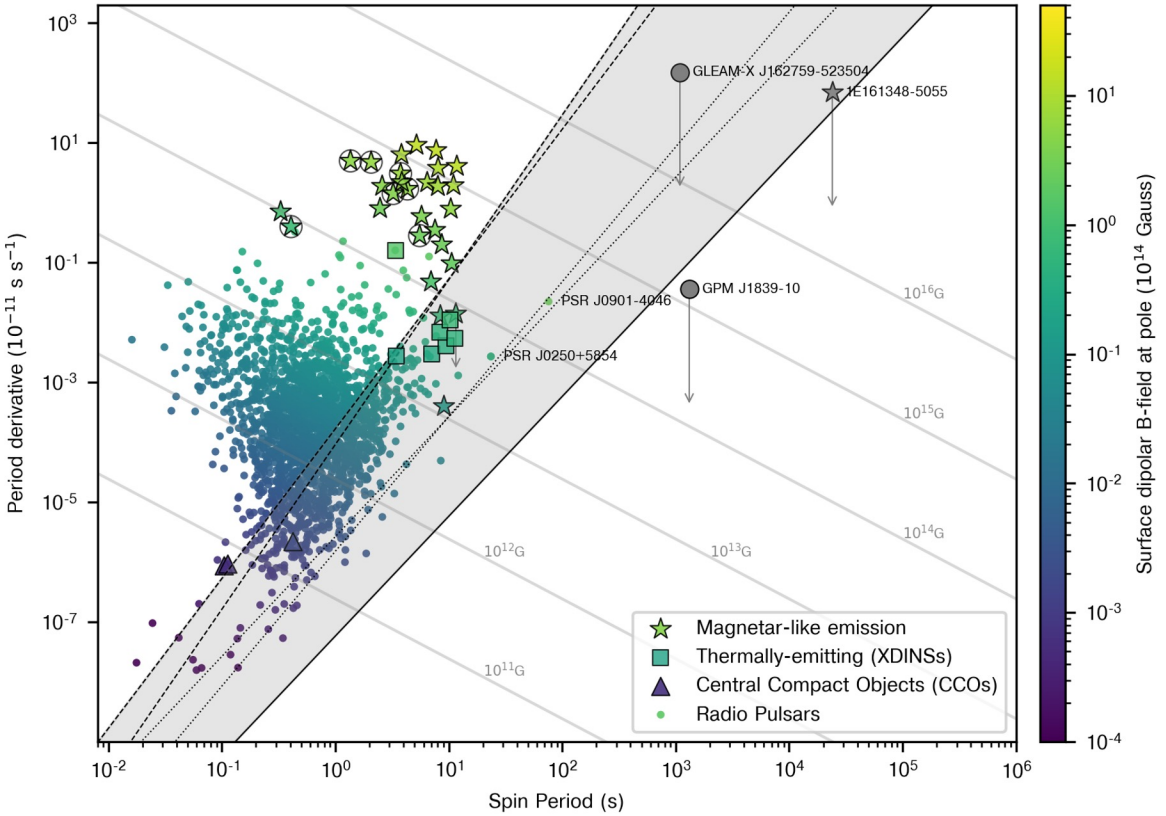
Spin-down



Hurley-Walker et al. 2023, *Nature*

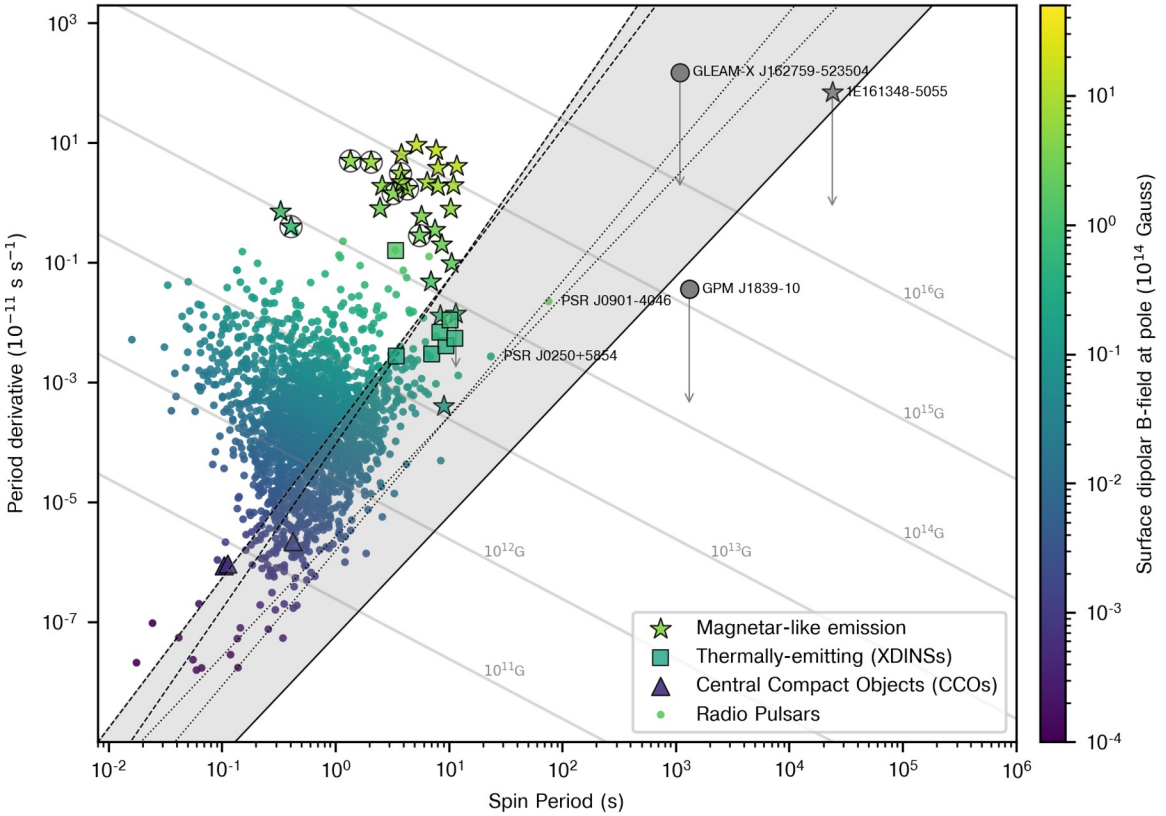
Also: what drives the differing activity windows?

Radio pulsars and GPMJ1839-10 are active for decades

GLEAM-X J1627 and many radio magnetars are only active for months

Is there more than one progenitor type?

Spin-down



Hurley-Walker et al. 2023, *Nature*

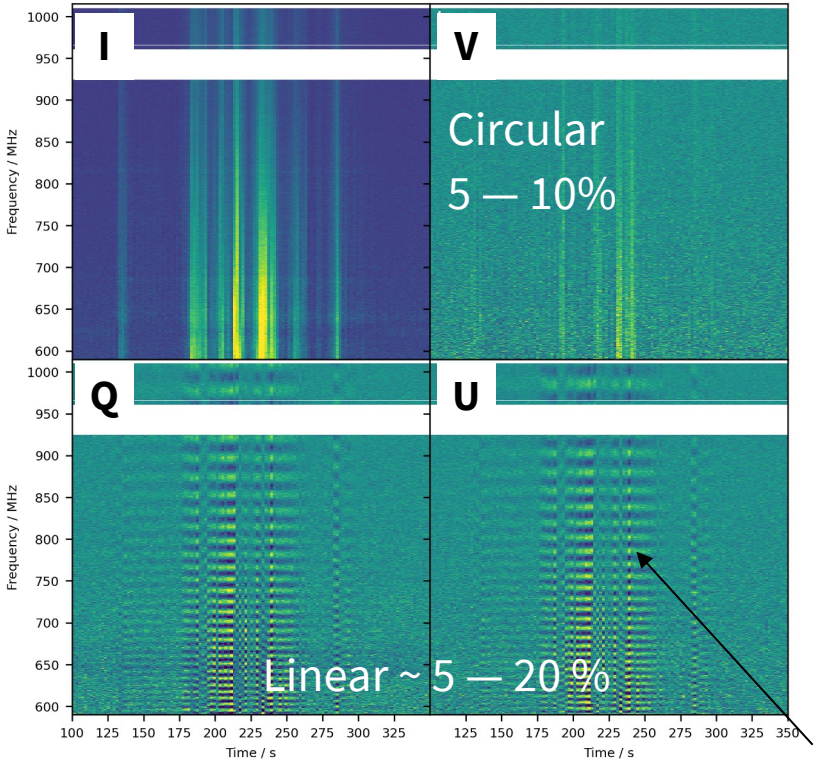
Also: How are these sources so luminous?

Rotating 10^3 — 10^4 times more slowly than pulsars yet at least as luminous

$L_{radio} \sim 10^{28}$ erg/s

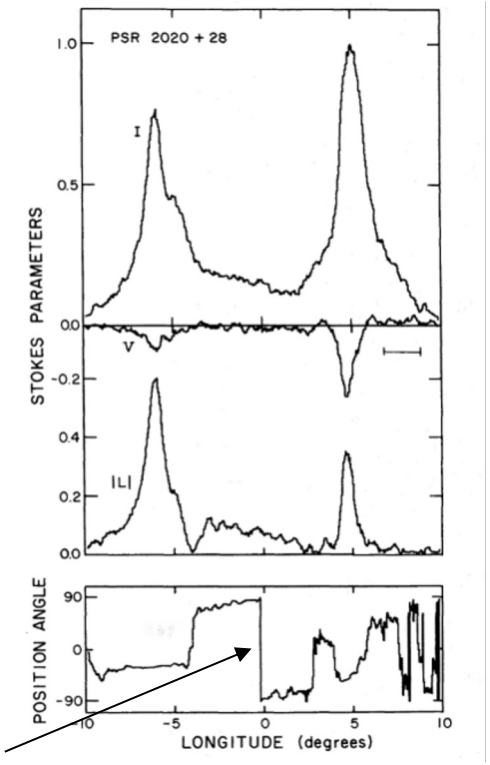
$L_{spin} \sim 10^{24}$ erg/s

Polarisation ~ some pulsars (& magnetars, FRBs)



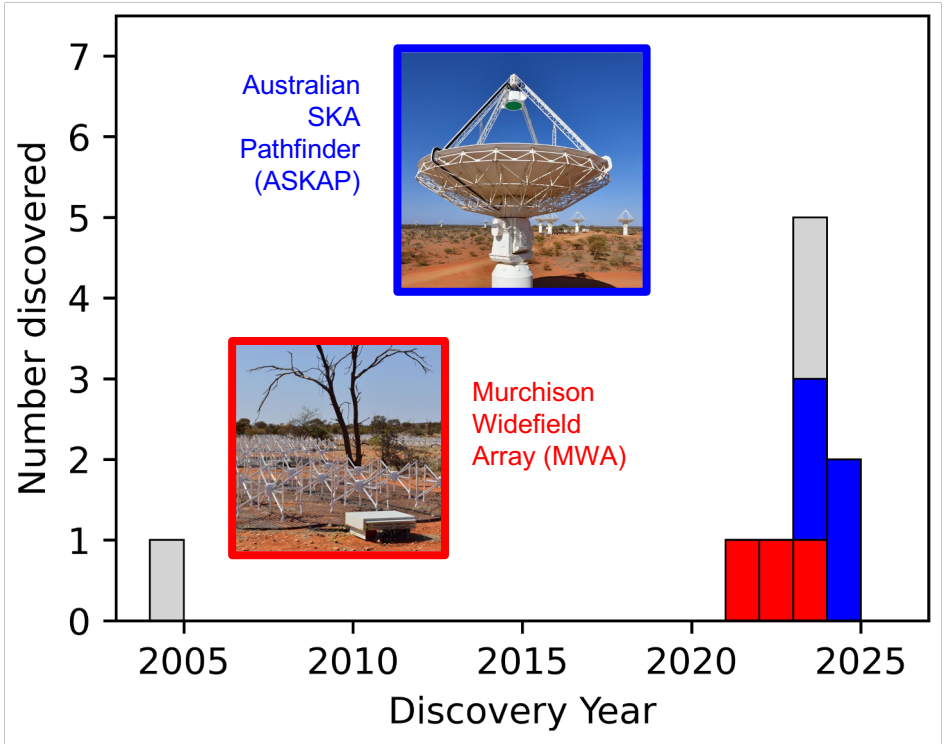
De-dispersed dynamic spectrum of one pulse from GPMJ1839-10

Flat polarisation angle with orthogonal modes

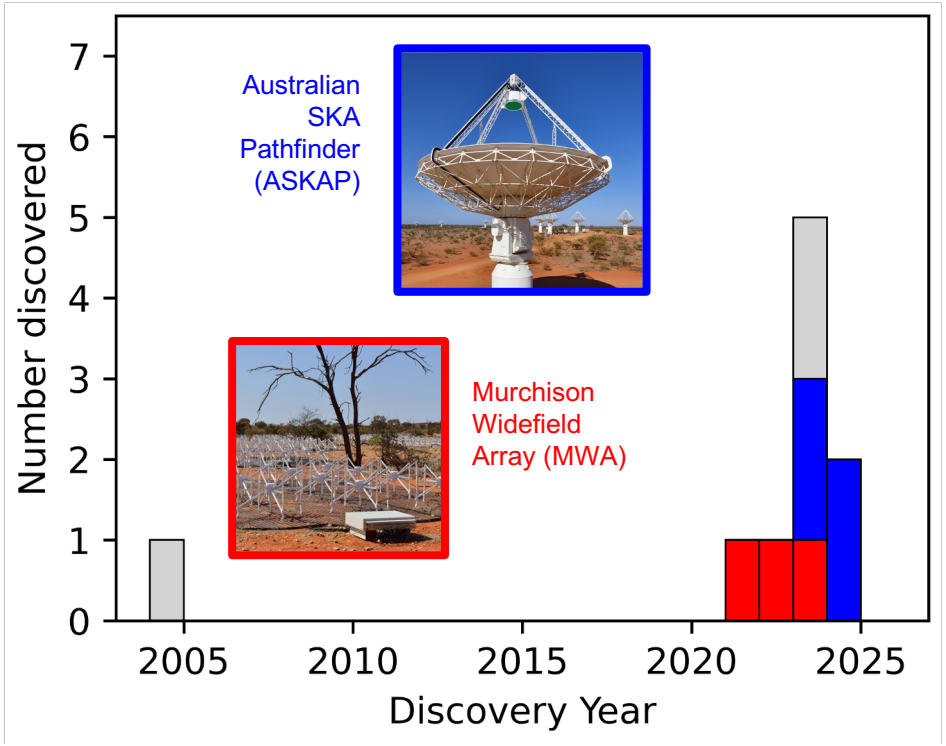


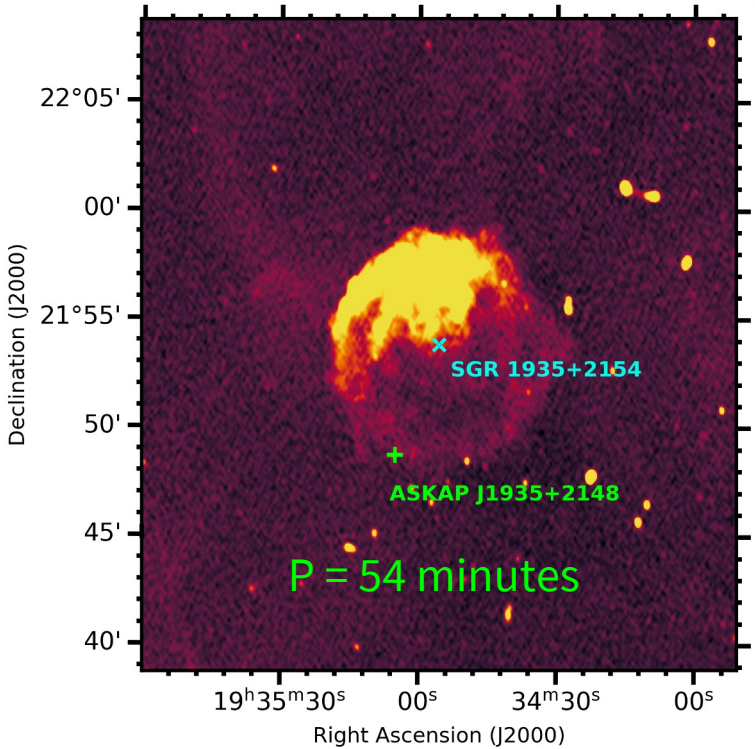
Cordes et al. 1978

Accelerating discoveries…



Accelerating discoveries… of even longer periods!





Caleb et al. 2024; available here from 11AM: https://www.nature.com/articles/s41550-024-02277-w

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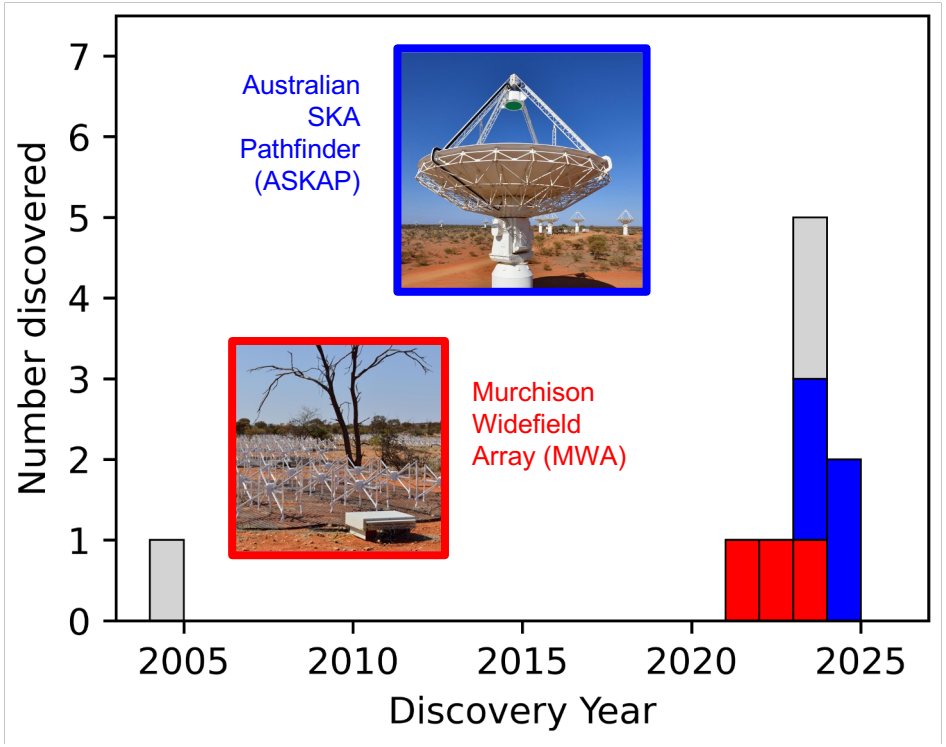

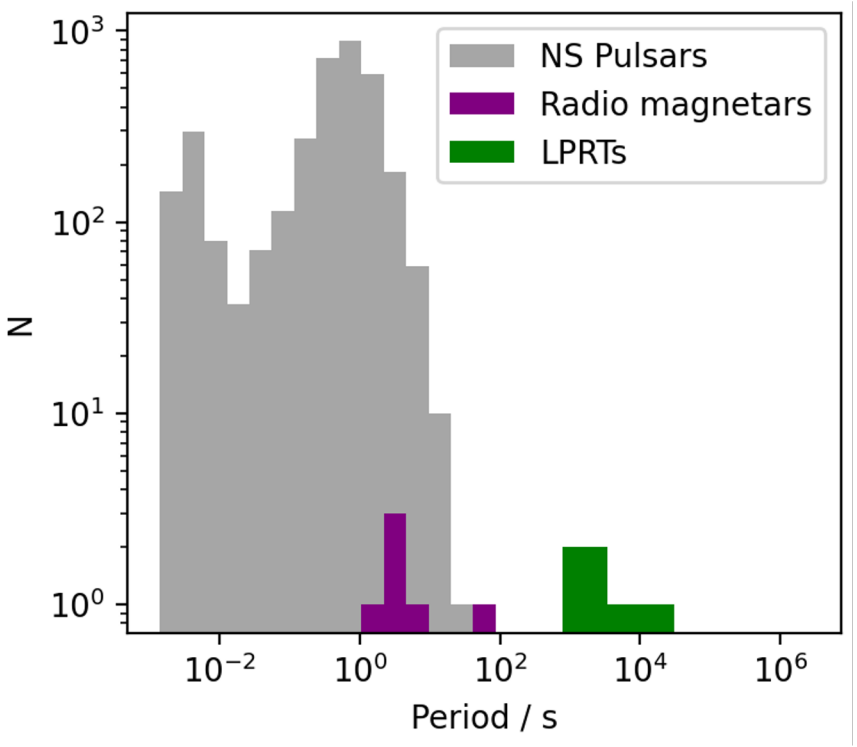

Distances 1 — 8 kpc

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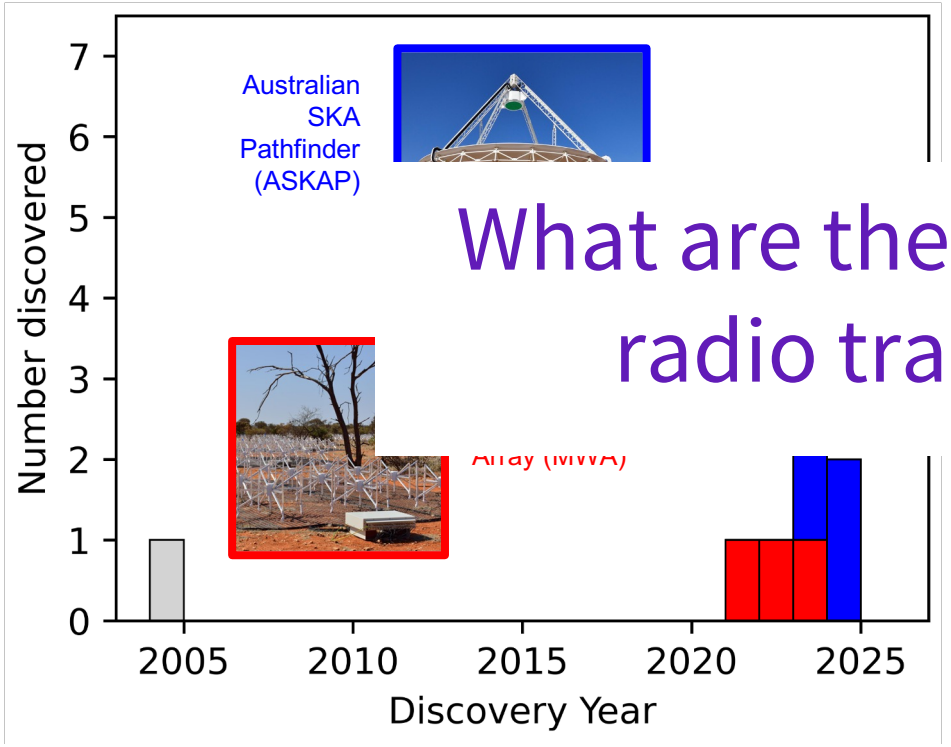
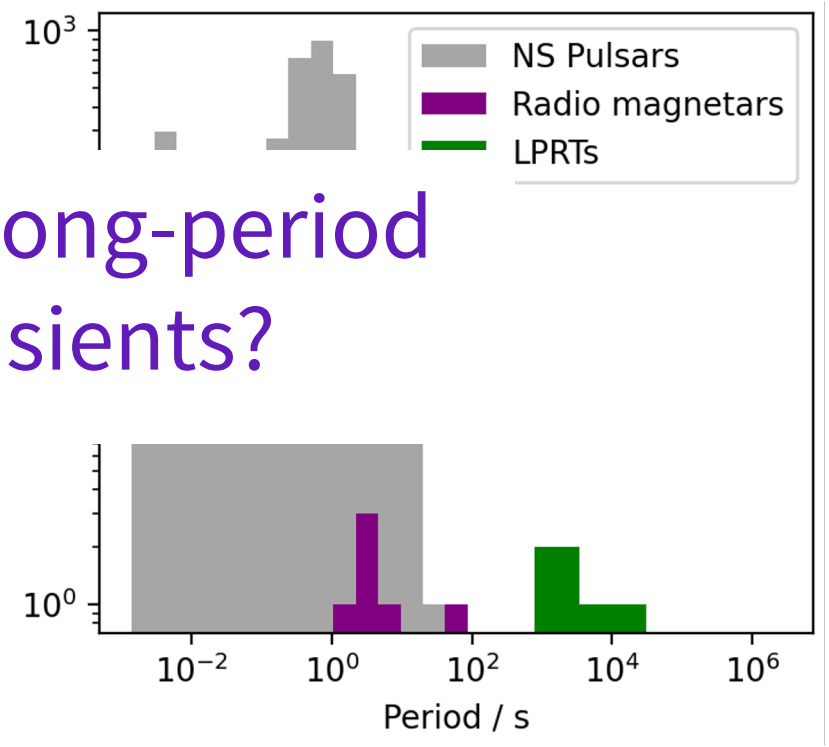


What are the long-period radio transients?

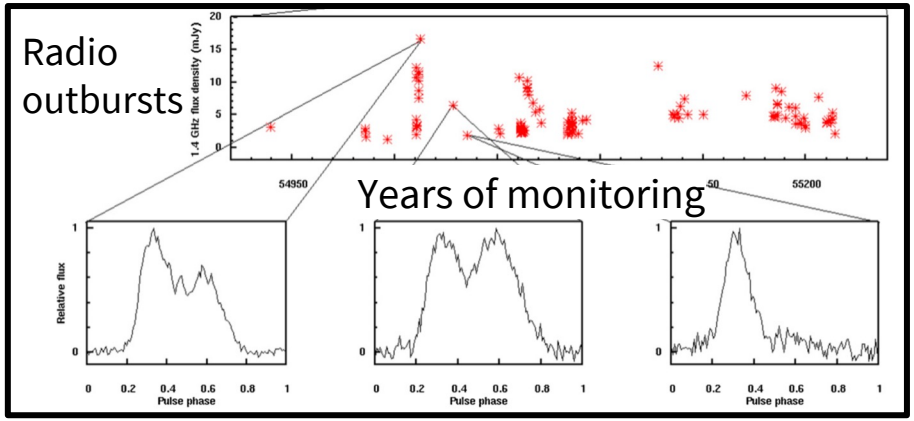


Distances 1 — 8 kpc

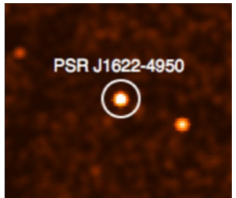
Ultra-long period magnetars

Canonical magnetars:

- Persistent X-ray luminosities ~ 10^{30} — 10^{35} erg/s
- Burst X-ray luminosities ~ 10^{37} — 10^{41} erg/s
- Visible >5 kpc away



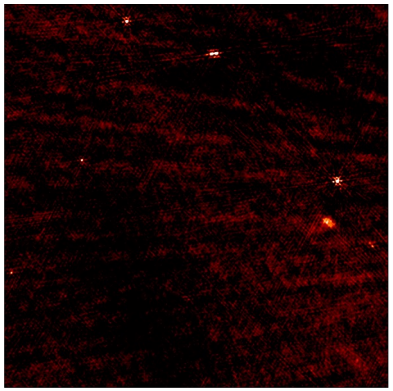
Levin et al. (2010)



Chandra
20ks

Simultaneous XMM-Newton/ASKAP observations of GPMJ1839-10 during radio burst

- Persistent $L_x < 10^{32}$ erg/s
- "Burst" $L_x < 10^{33}$ erg/s



ASKAP radio pulse of GPMJ1839
Credit: Emil Lenc

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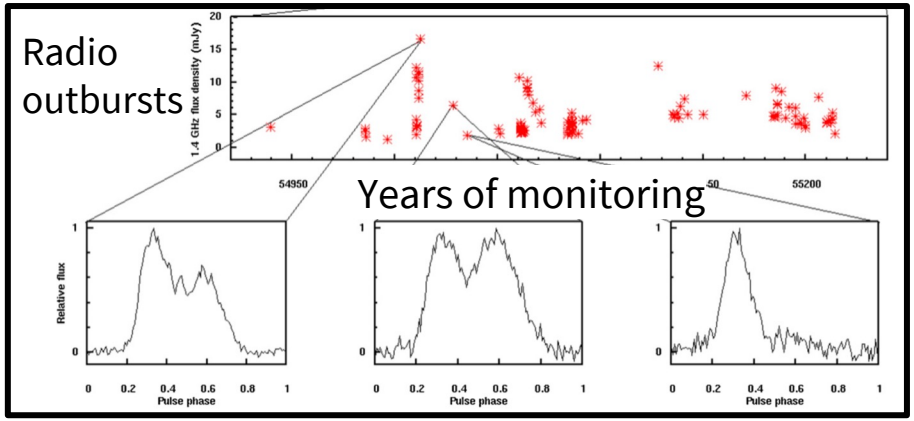

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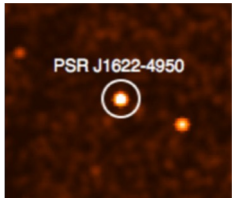

Chandra 20ks

Simultaneous XMM-Newton/ASKAP observations of GPMJ1839-10 during radio burst

- Persistent $L_x < 10^{32}$ erg/s
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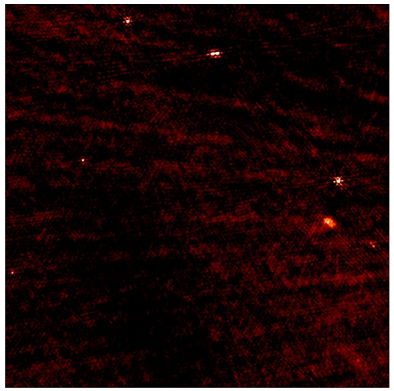
Could our sources be much older?

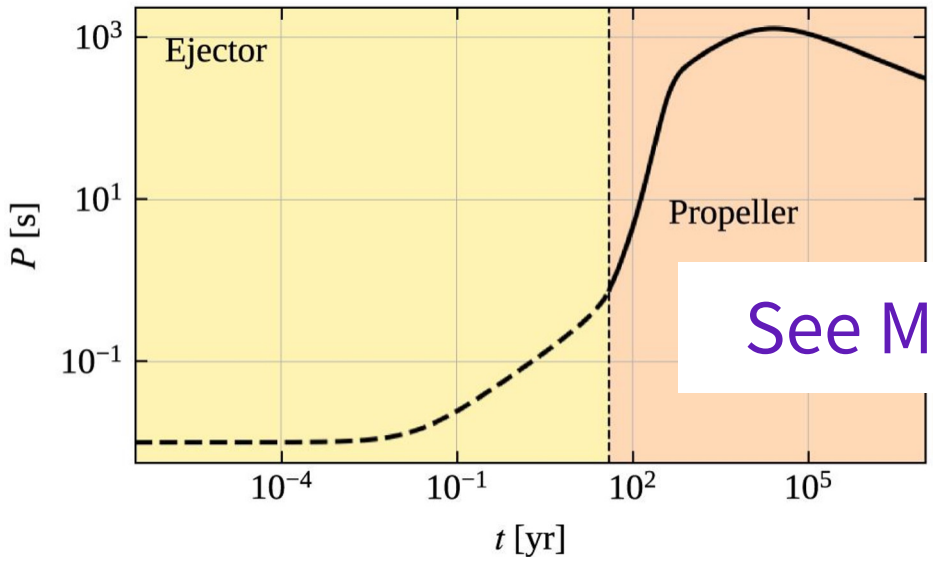
How are the magnetic fields maintained?

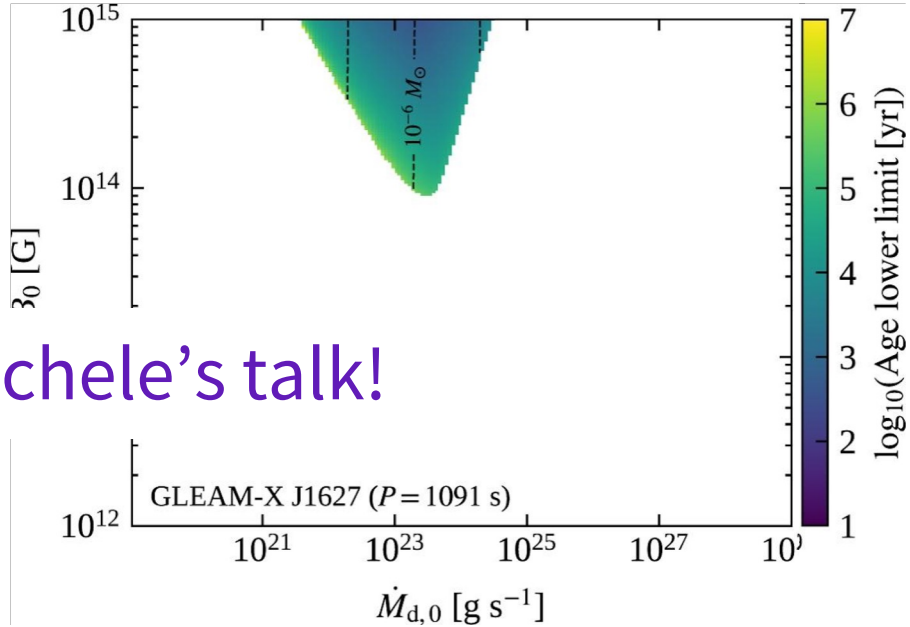


ASKAP radio pulse of GPMJ1839
Credit: Emil Lenc

Ultra-long period magnetars

Neutron stars slowed down by fall-back accretion?



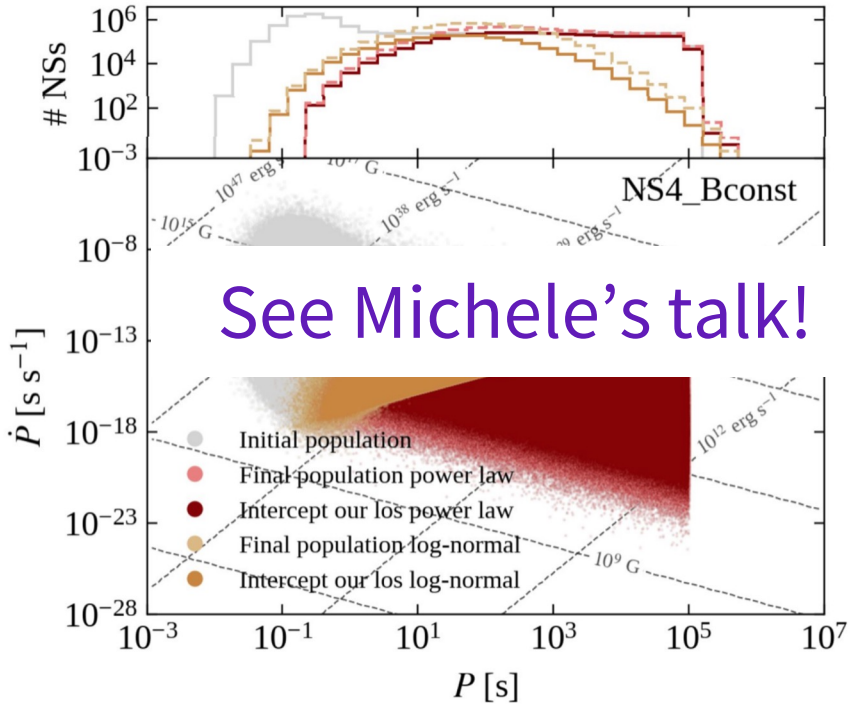


See Michele's talk!

But: no obvious supernova remnant associations yet discovered

Ronchi et al. (2022)

Ultra-long period magnetars: evolutionary model



Rea et al. 2024

Necessary assumptions to produce visible population:

- no magnetic field decay
- beam opening angles of 20%

c/f real sources:

GPMJ1839-10
pulse width 400s, P 1387s → beam angle > 28%

ASKAP J1935
pulse width 50s, P 3255 s → beam angle > 1.5%

But spin-down energies are still too low to explain the high radio luminosity

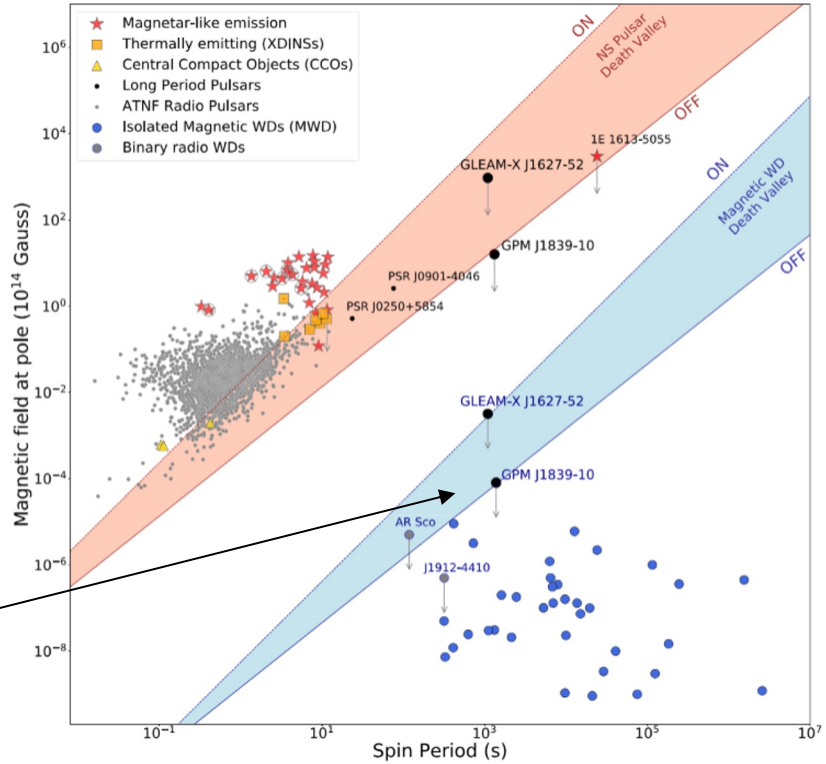
Isolated white dwarf pulsars

White dwarfs have 10^5 higher moment of inertia ***I***

Could explain 10^4 difference in spin-down and radio luminosities

$$L_{\rm spin} = \frac{4\pi^2 I \dot{P}}{P^3}$$

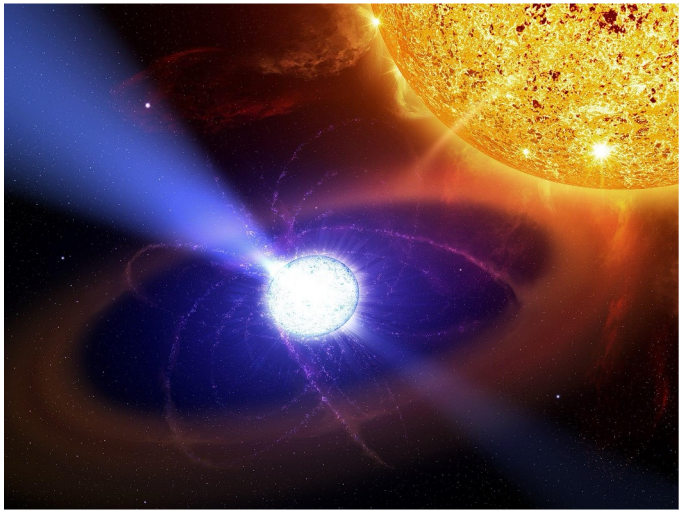
But the death lines rescale…



Rea et al. 2024

Main sequence / WD pulsar binaries

AE Aquarii: P_{spin} ~ 33s: “propellor” accelerates accreting material from companion K dwarf via magnetospheric interactions



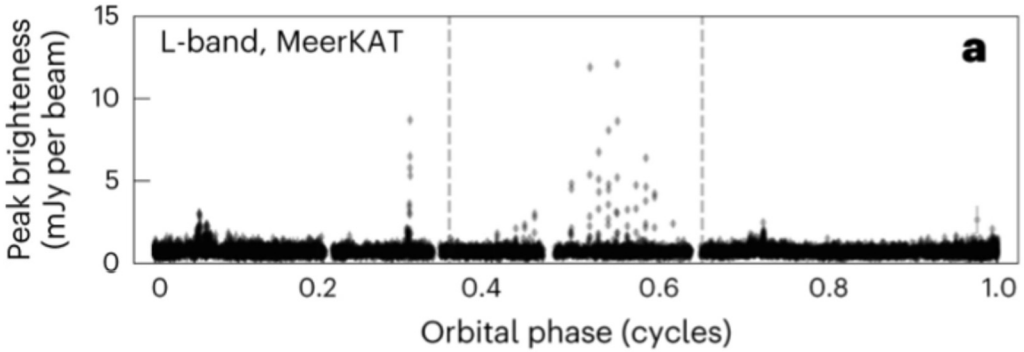
See e.g. Ikhsanov et al. 1998

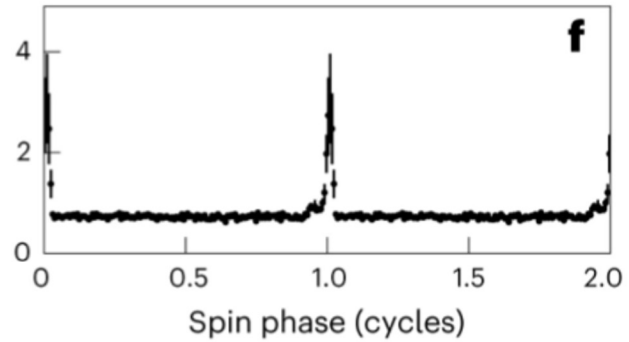
AR Scorpii: P_{spin} ~ 117s: WD pulsar beams interact with M dwarf causing pulsations on the orbital & spin beat period

Marsh et al. 2016

Main sequence / WD pulsar binaries

J1912-44: P_{spin} ~ 319s:
WD pulsar beam crosses our line of sight!





Pelisoli et al. 2023

System is 1000x less radio-luminous than the LPRTs
but selection effects could be strong
(AE Aq, AR Sco, J1912 distances < 1kpc, optically-selected)

Main sequence / WD pulsar binaries

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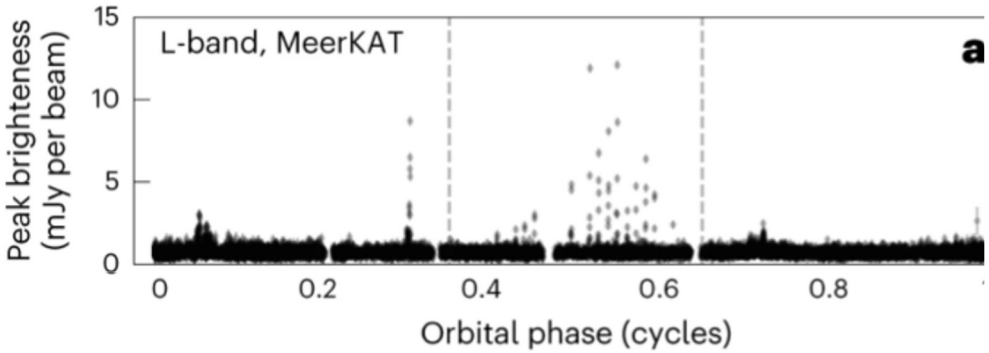
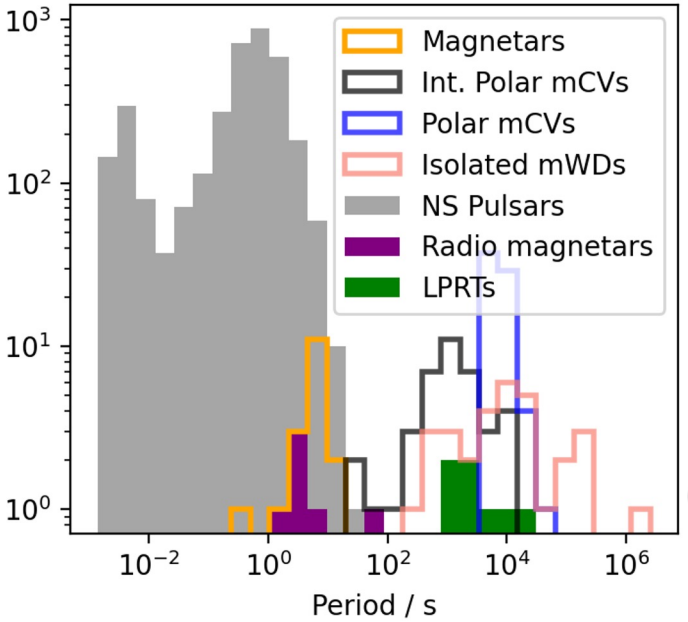


Pelisoli et al. 2023



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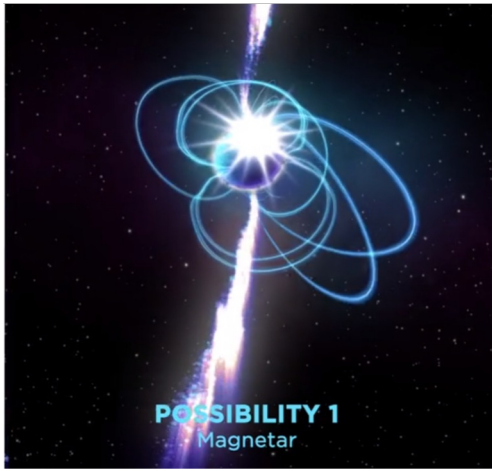
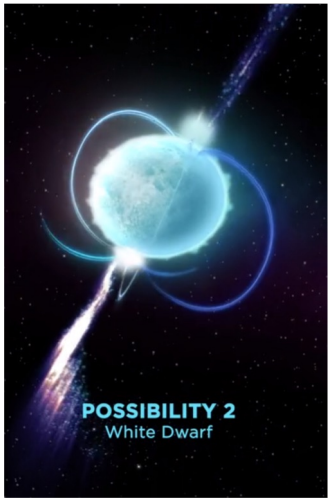
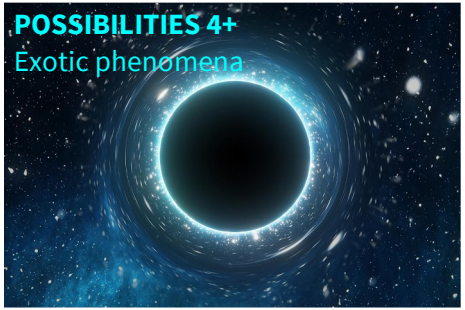
I would love to discuss at this conference — please reach out!

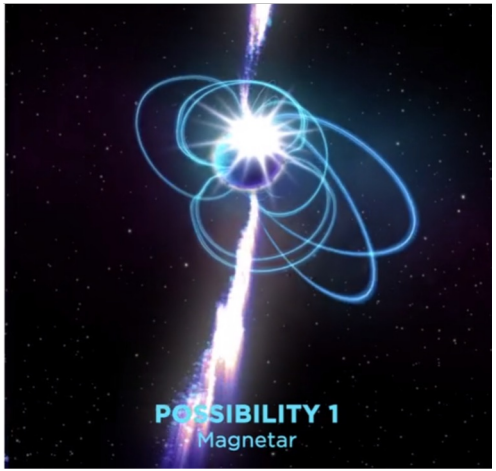
Solving the puzzle: some options

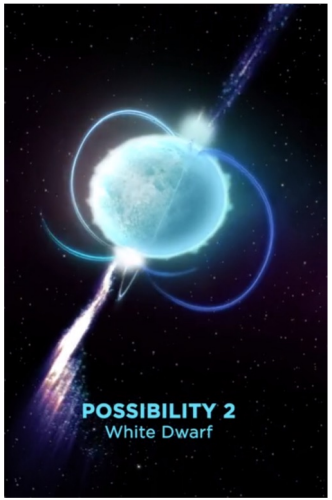


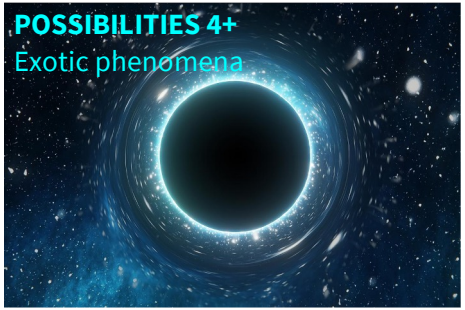




Solving the puzzle: 1) More detections

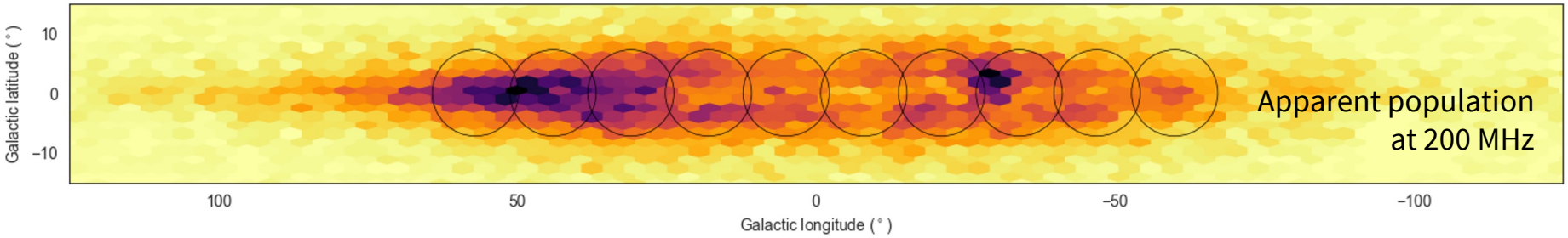






- Extreme cases rule out or support theories
- Population studies: spatial distribution, luminosities
- Can search decades of archival data
- Or use targeted transient imaging campaigns…

Galactic Plane Monitoring (GPM)



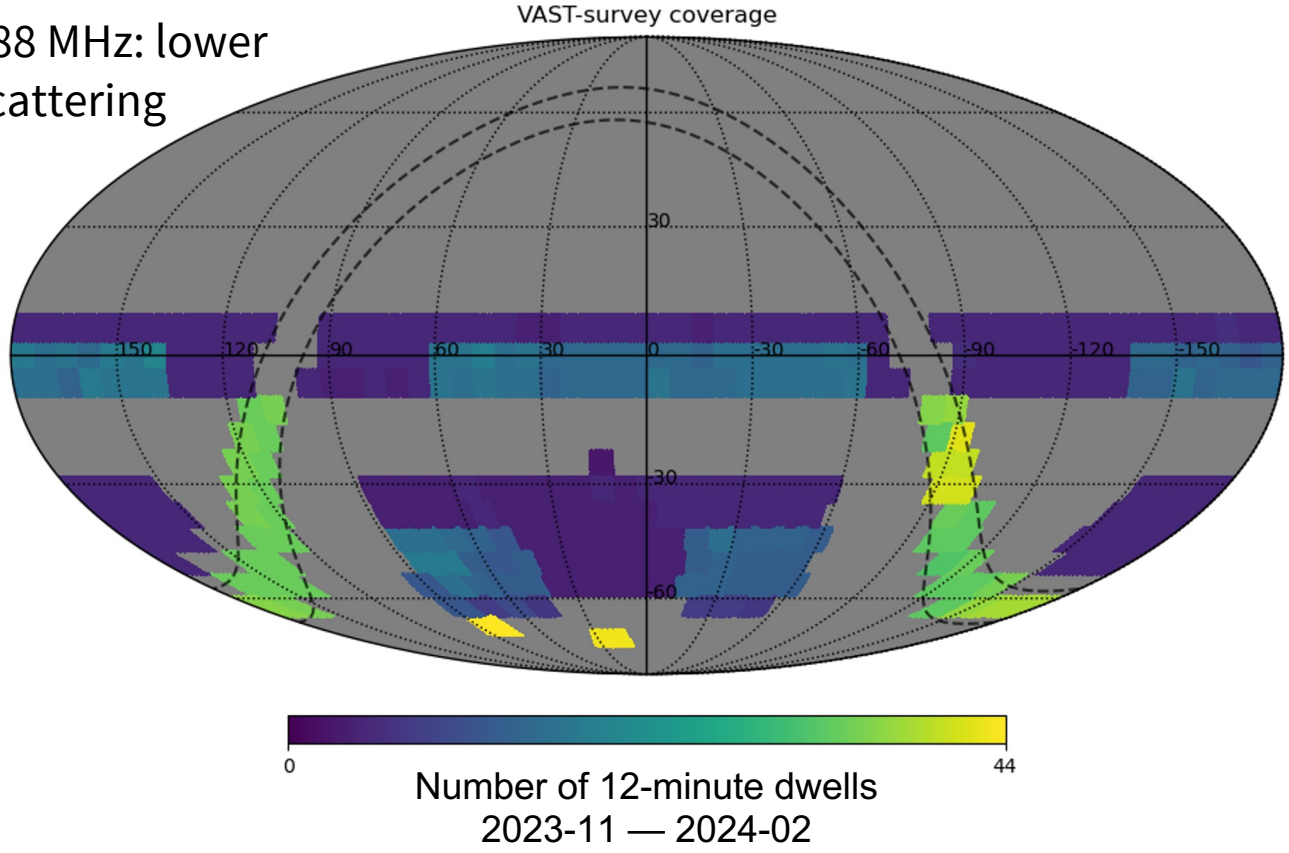
10x 30-minute pointings

Revisit every 3 days

June to September 2022
June to September 2024 (just started!)

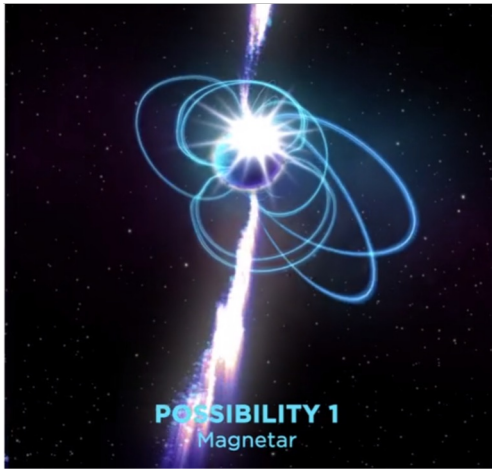
ASKAP Variables and Slow Transients (VAST) survey

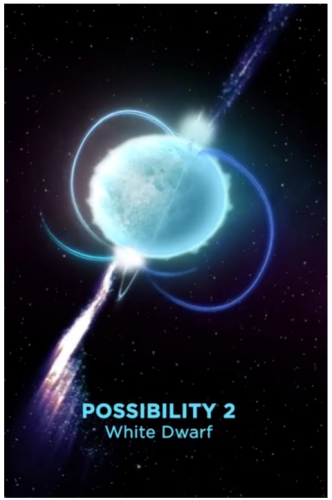
888 MHz: lower scattering

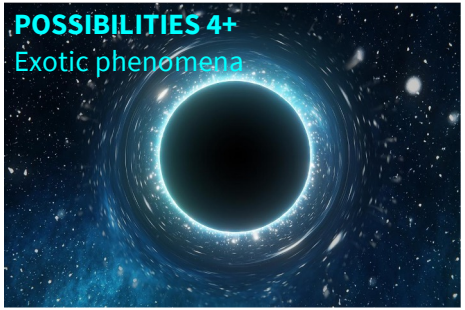


Soon: routine 10s imaging via "VASTER"
Yuanming Wang (Swinburne U.)

Solving the puzzle: 2) Further radio analysis

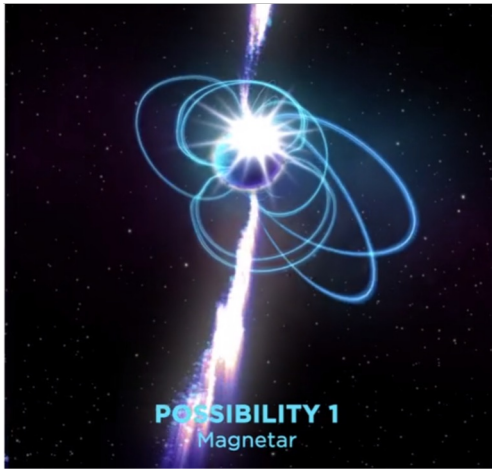


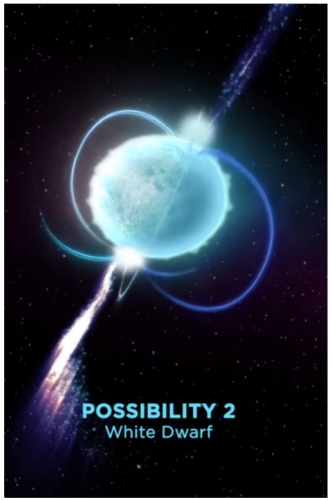


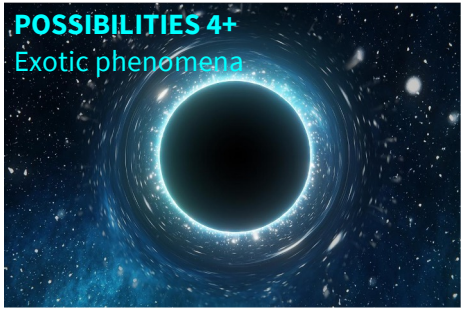


- Fine time resolution data

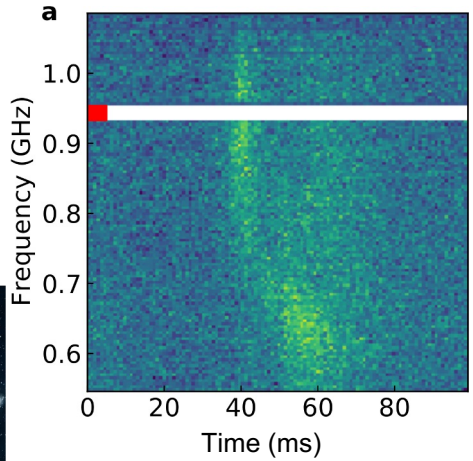
Solving the puzzle: 2) Further radio analysis



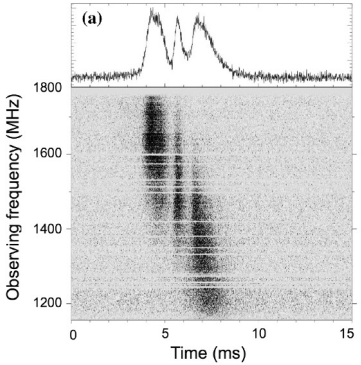




- Fine time resolution data (FRBs??)



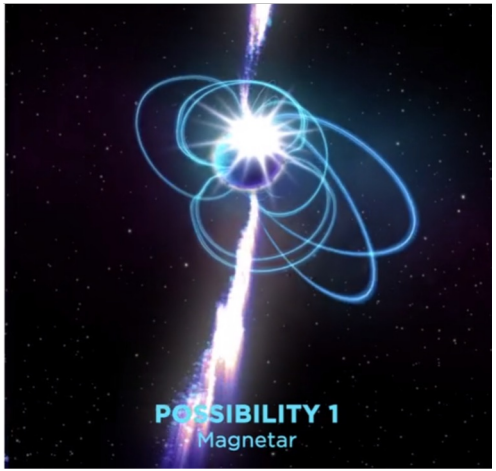
Men, Y et al. in review with *Science Advances*

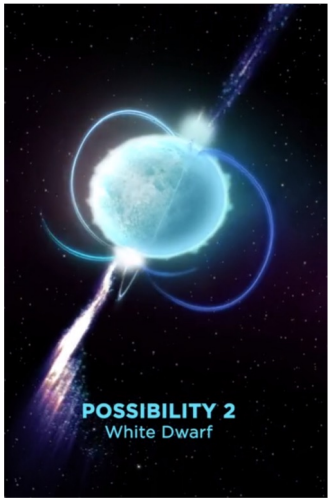


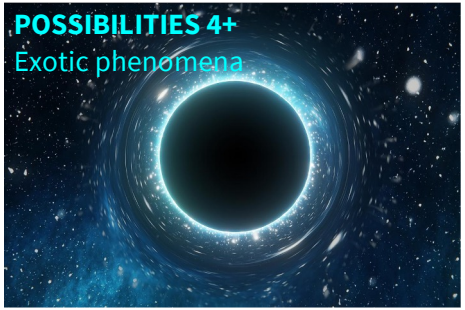
Repeating FRB 121102

Hessels et al. (2018)

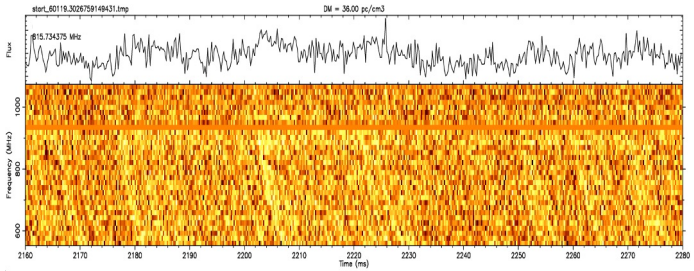
Solving the puzzle: 2) Further radio analysis







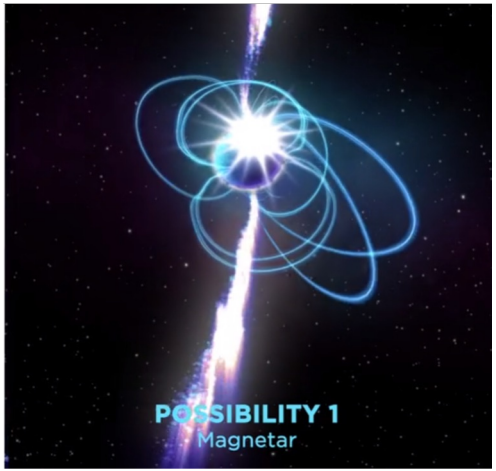
- Fine time resolution data

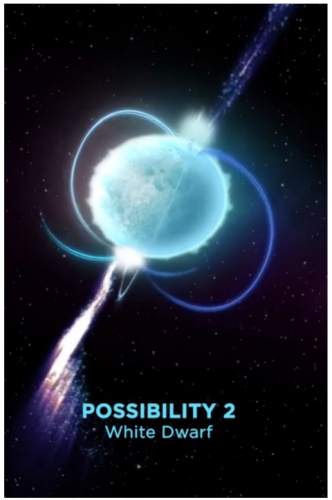


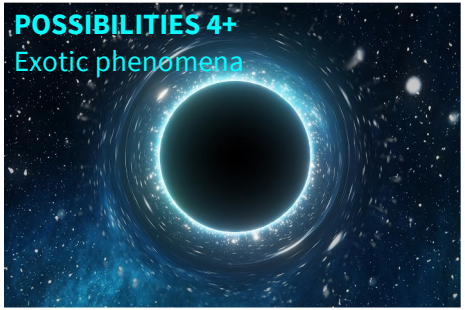
~40ms substructure in newly-discovered long-period radio transient from GLEAM-X

What does this tell us about the scale size of the radio-generating region — more like a NS or a WD?

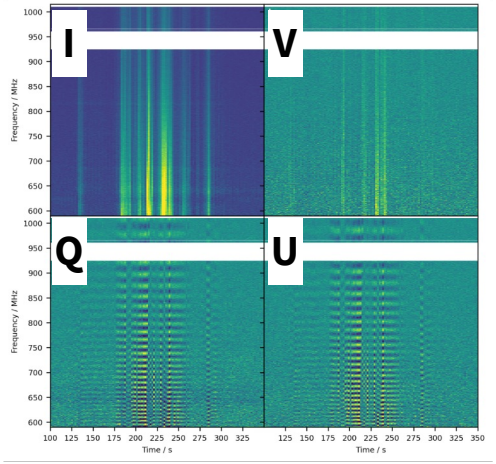
Solving the puzzle: 2) Further radio analysis





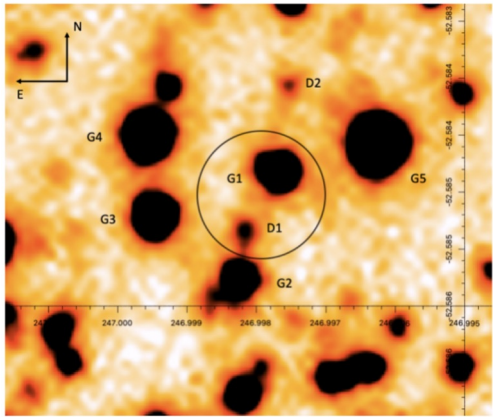


- Polarisation
  PA → magnetic field configuration;
  Faraday conversion → environment

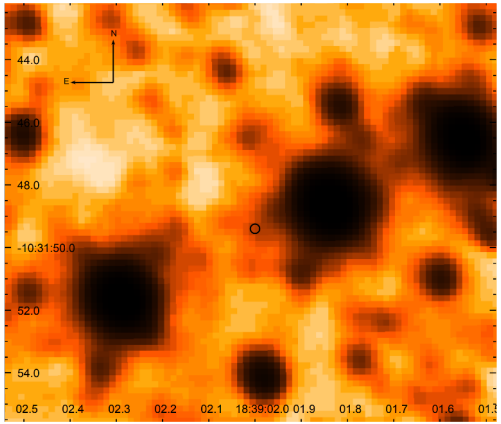


Solving the puzzle: 3) Multiwavelength counterparts

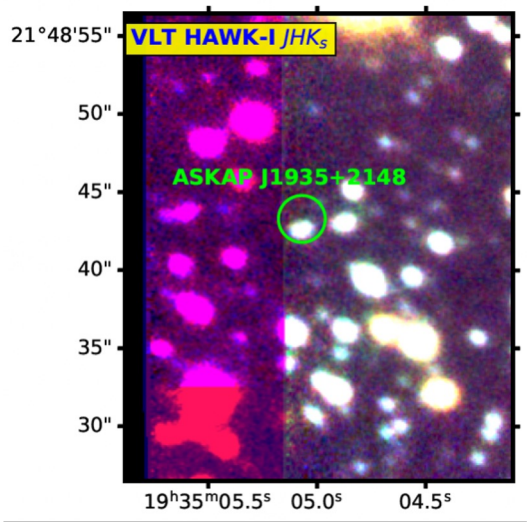
GTC K-band imaging



GLEAM-X J1627; d ~ 1.2kpc
Hurley-Walker et al. 2022



GPM J1839-10; d ~ 5.8kpc
Hurley-Walker et al. 2023



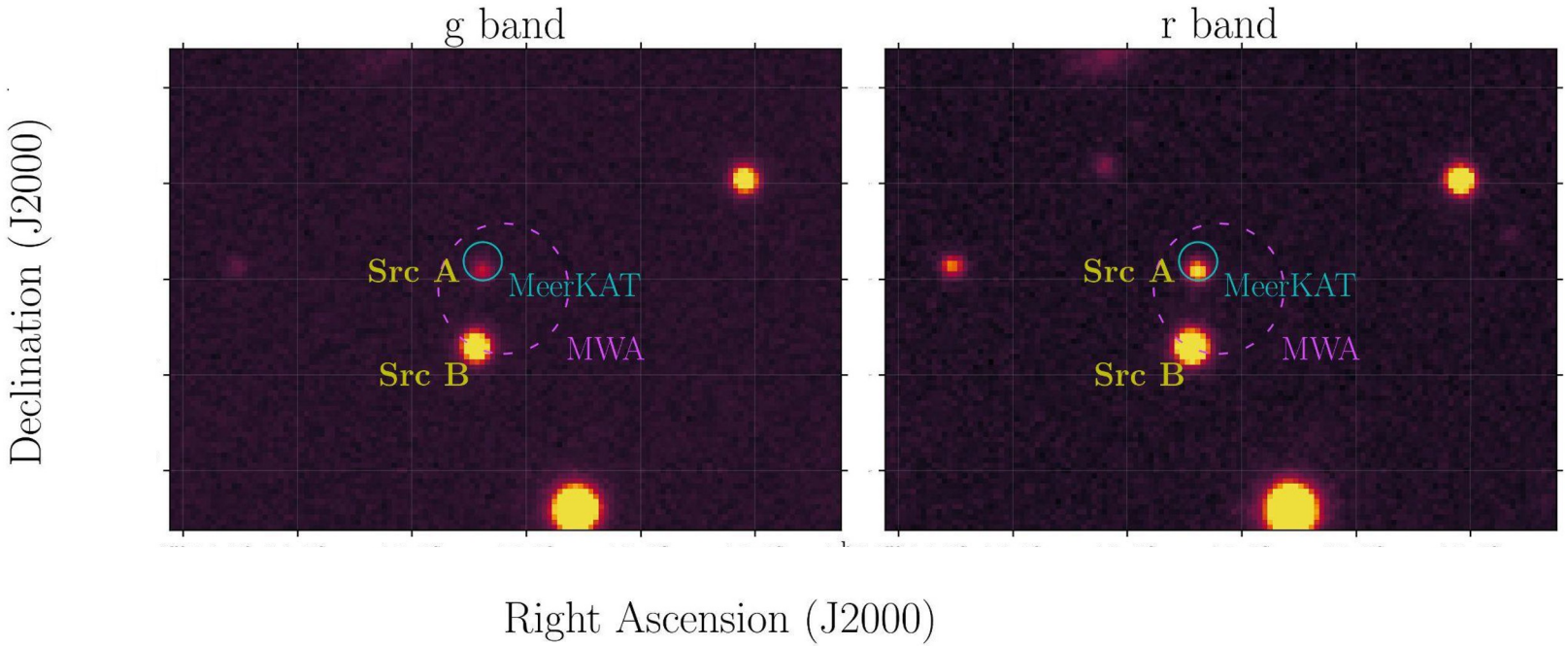
d ~ 4.9kpc
Caleb et al. 2024

Low Galactic latitudes → crowded fields → high false association chance
No X-ray counterparts detected so far…

Solving the puzzle: with a new system?

GLEAM-X J07 — detected using MWA survey data at 150 MHz

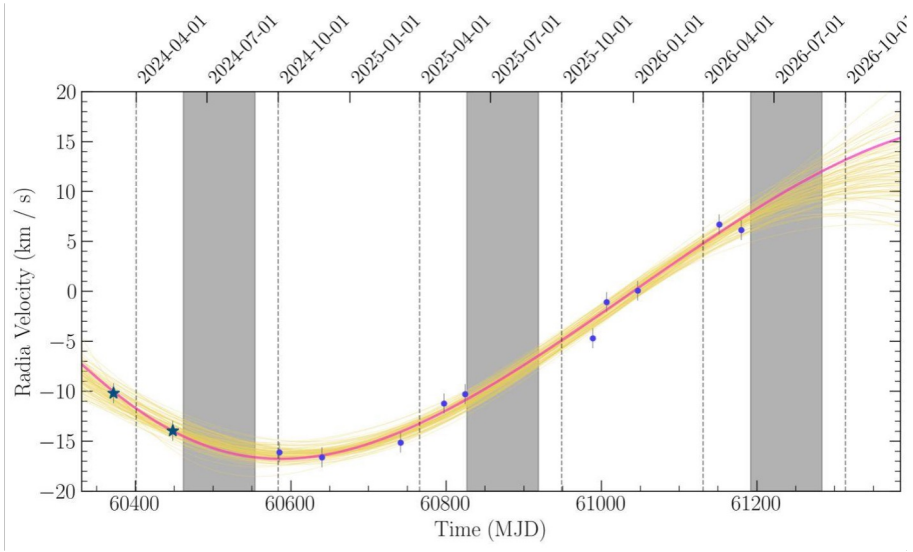
P ~ 10^4 s!



Credit: Arash Bahramian

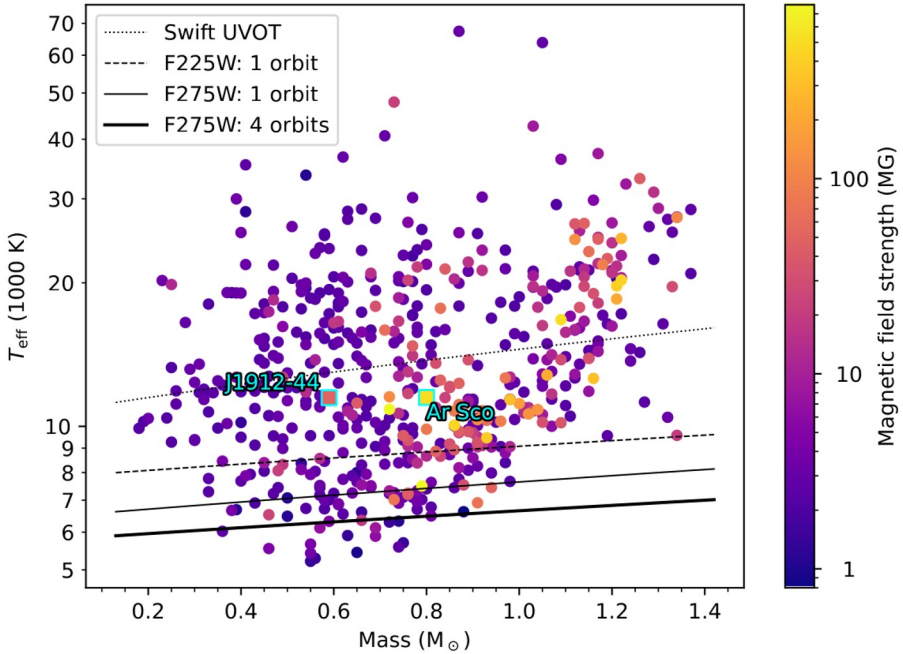
Optical follow-up now possible!

VLT: Spectral line imaging to test orbits



Credit: Arash Bahramian

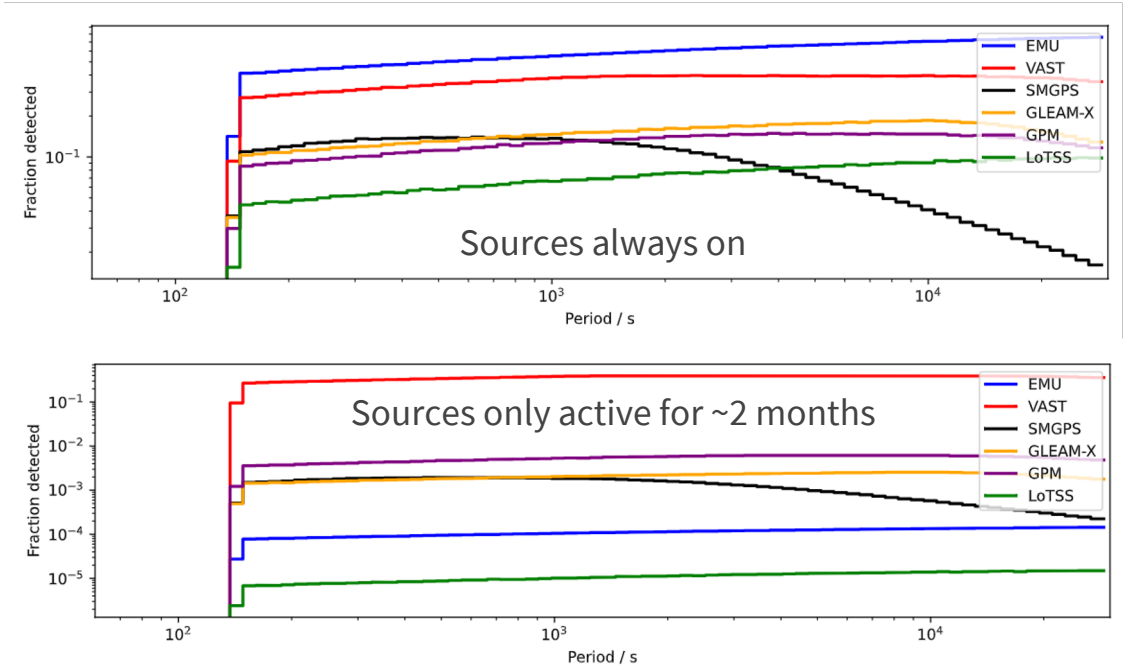
Hubble Space Telescope: UV imaging to search for white dwarf to test AR Sco hypothesis

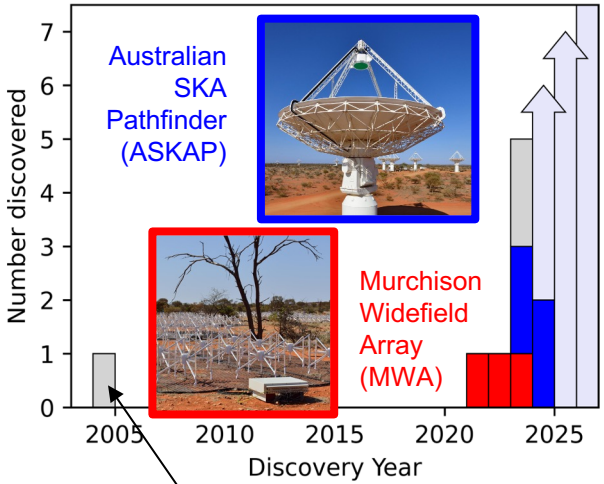


Conclusions

A new* class of astrophysical transient challenging models of radio emission and evolution of compact stellar remnants and potentially generating FRBs

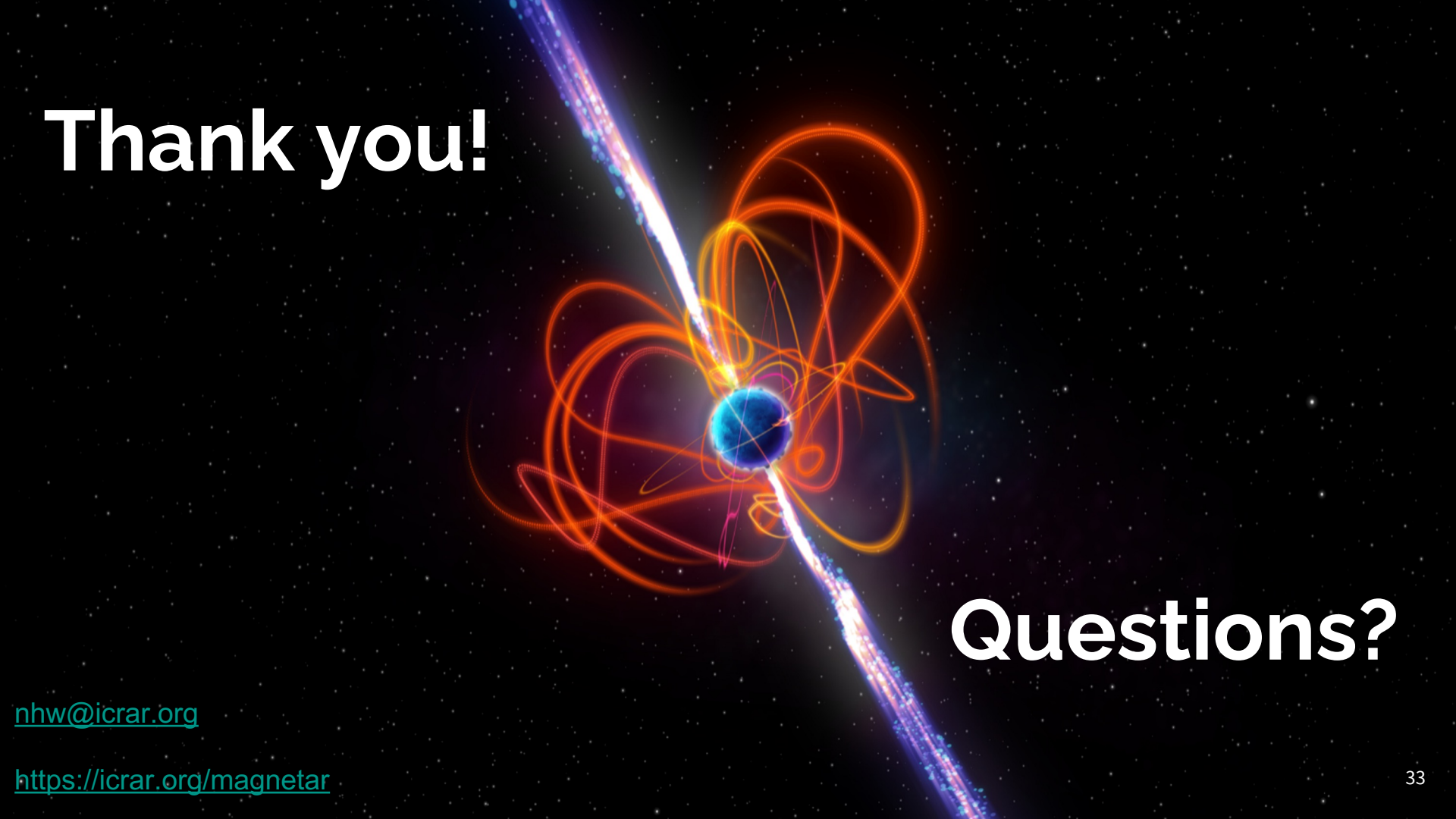
Wide field-of-view SKA precursors set to discover multitudes!





*Hyman et al. 2005

Thank you!



Questions?

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