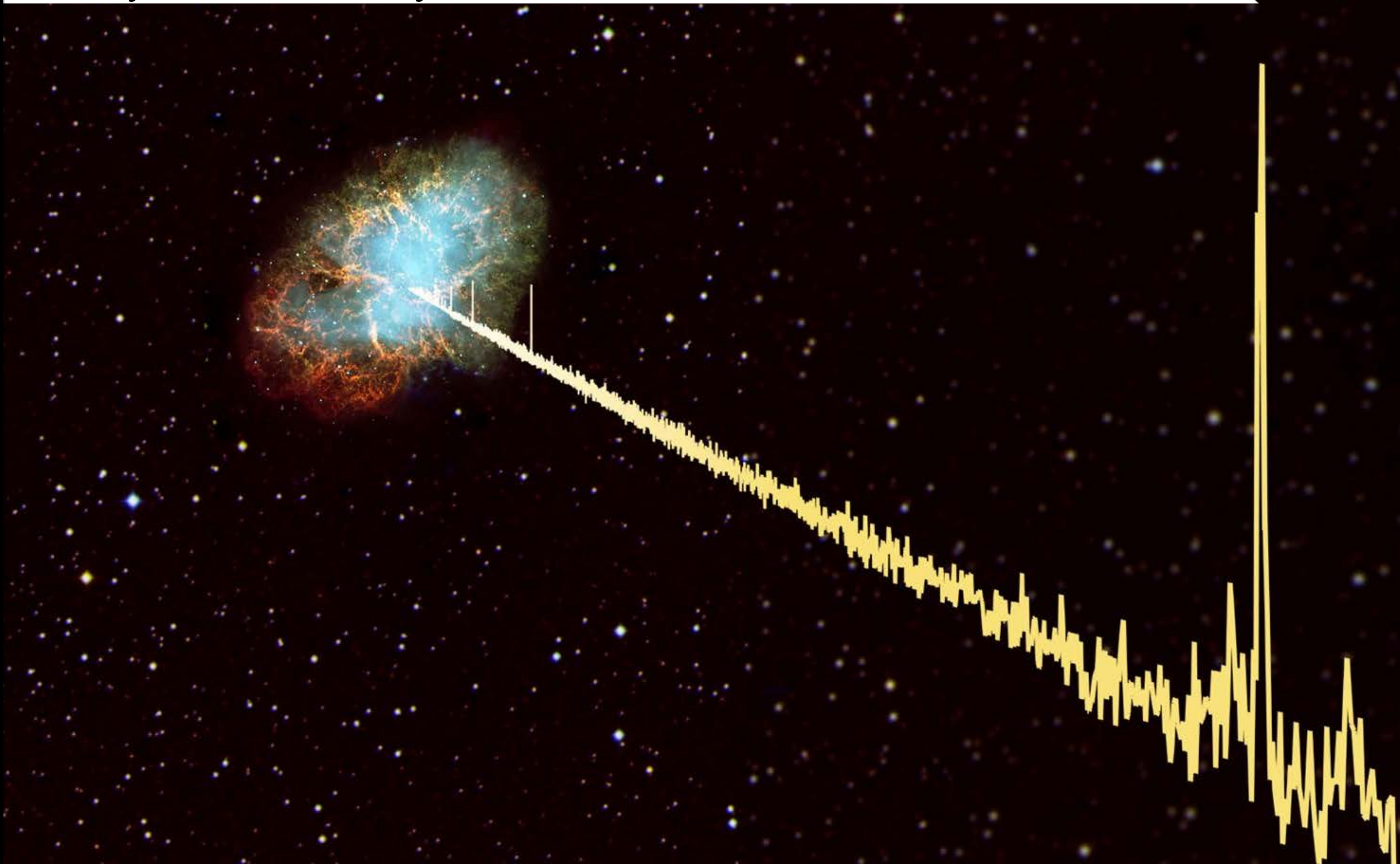
Joeri van Leeuwen

The dynamic radio sky: Pulsars



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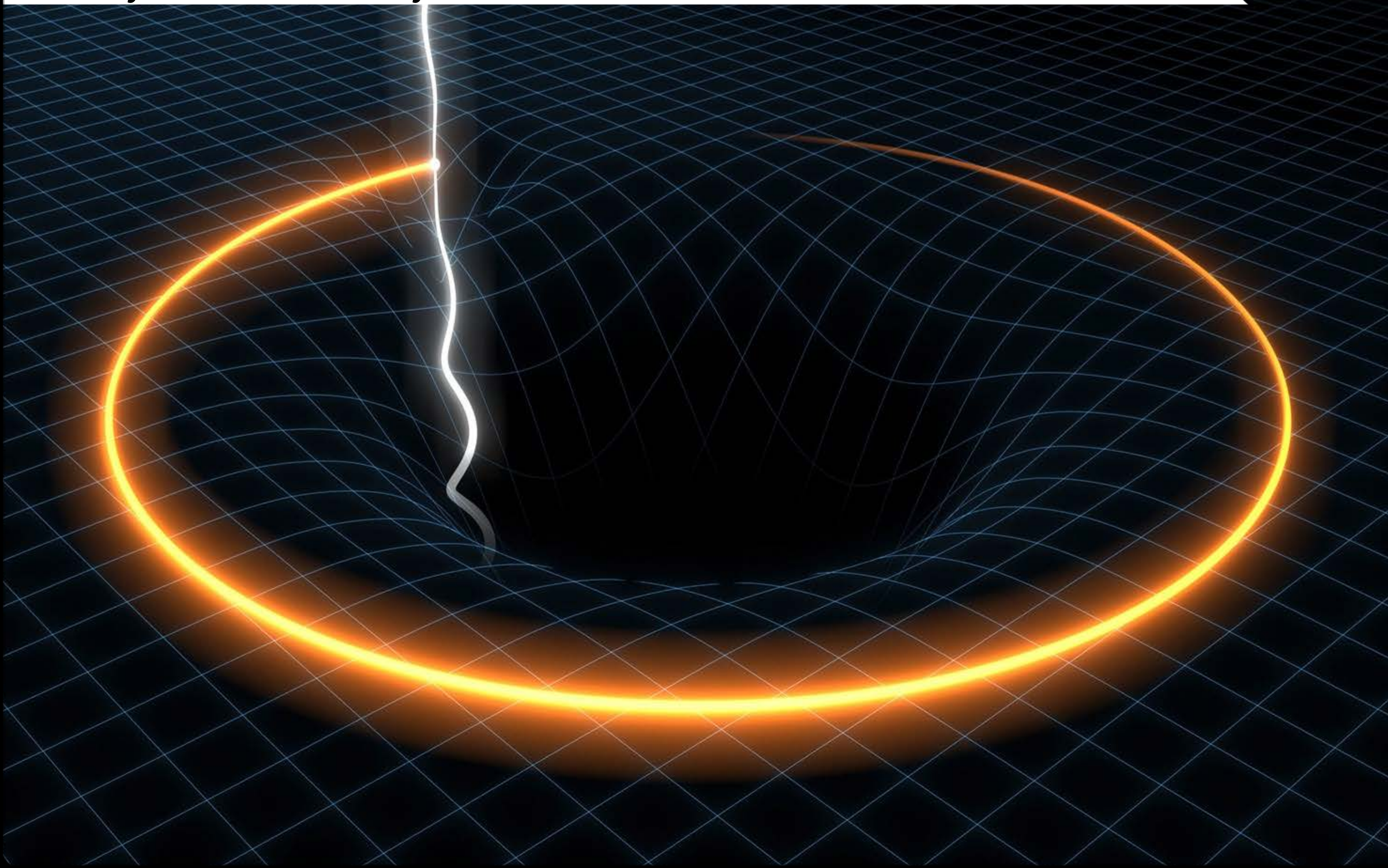

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The dynamic radio sky: Pulsars

SKA2-MID(AA)

Assuming

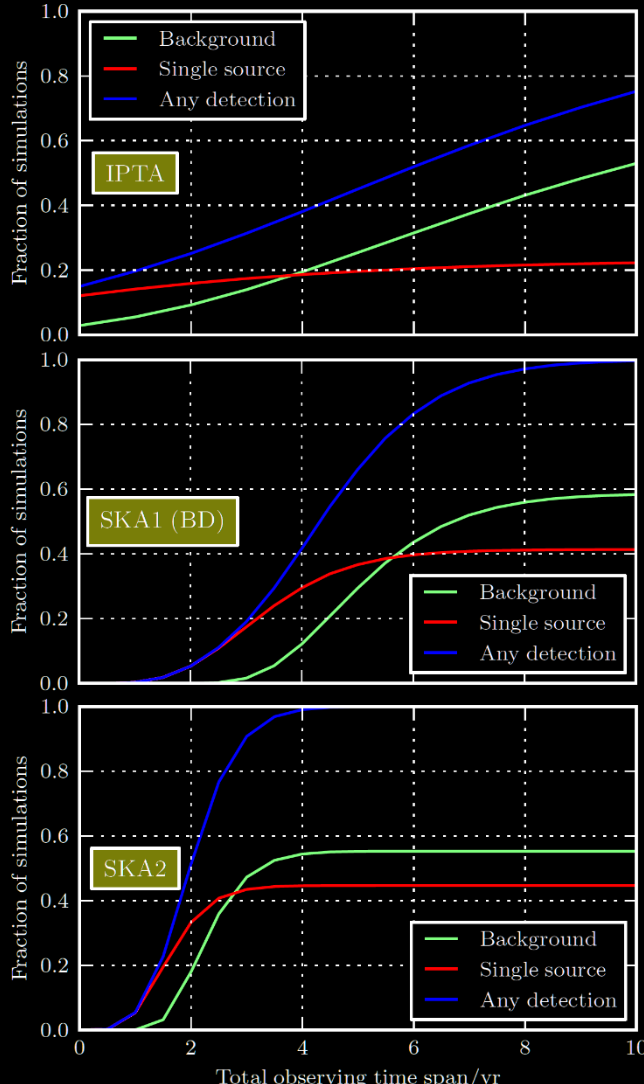
1. $A/T = 10{,}000\ \mathrm{m^2/K}$ ($A = 300{,}000\ \mathrm{m^2}$; $T_{rec} = 30$ K)
2. Frequency = ~300-1500 MHz
3. Bandwidth = 0.5 GHz

SKA2-MID(AA) pulsar science: Pulsar Timing

Pulsar Timing Arrays:

First direct-GW PTA detection: SKA1/IPTA

Increased sensitivity of SKA2-MID(AA)/(DISH) gravitational wave astronomy will become a reality, study detailed properties of GWs.

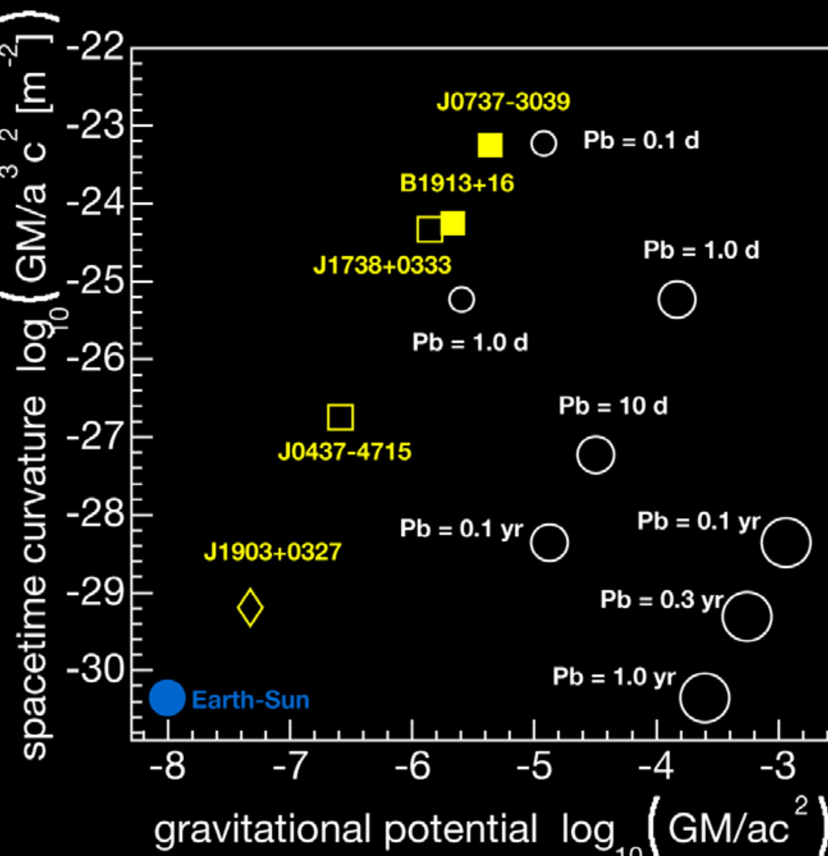


Janssen et al. 2015

SKA2-MID(AA) pulsar science: Pulsar Timing

Testing Gravity:

Simulations for SKA2-MID(AA) predict sub-us timing variance for Double Pulsar -- allows highly precise measurements of "higher-order Post-Newtonian" parameters.



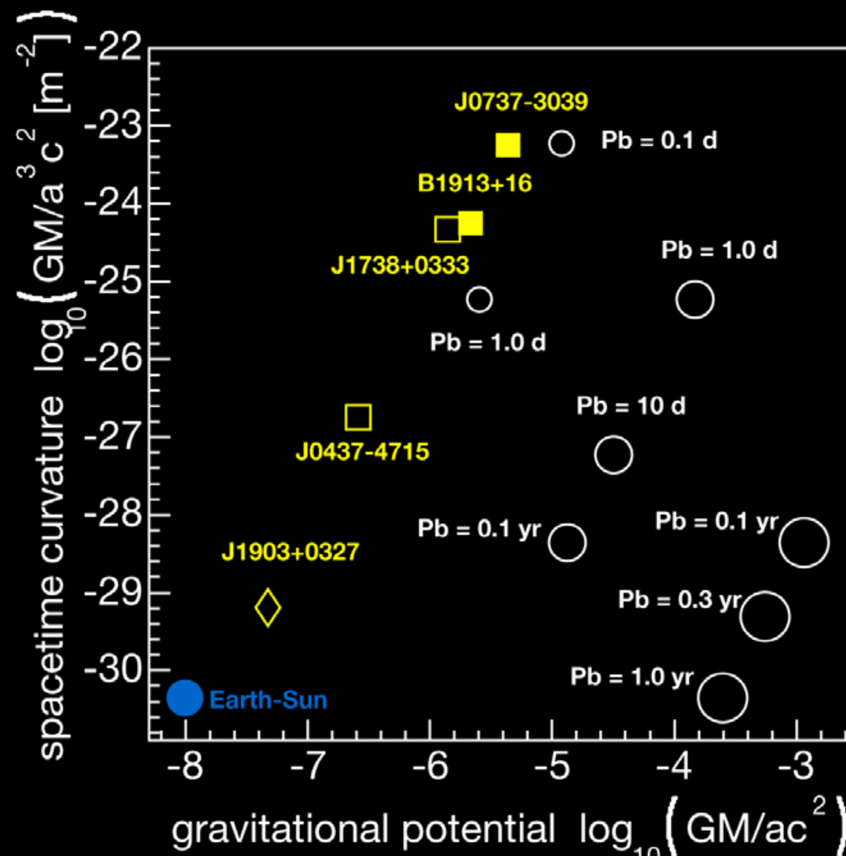
Shao, Stairs et al. 2015

SKA2-MID(AA) pulsar science: Pulsar Timing

Testing Gravity:

The SKA2 survey FoV and sensitivity can help find pulsar – black hole (PSR-BH) binaries.

Discovery of even single PSR-BH system opens study of BH physics with great precision, including possible tests of the "cosmic censorship conjecture" and the "no-hair theorem".



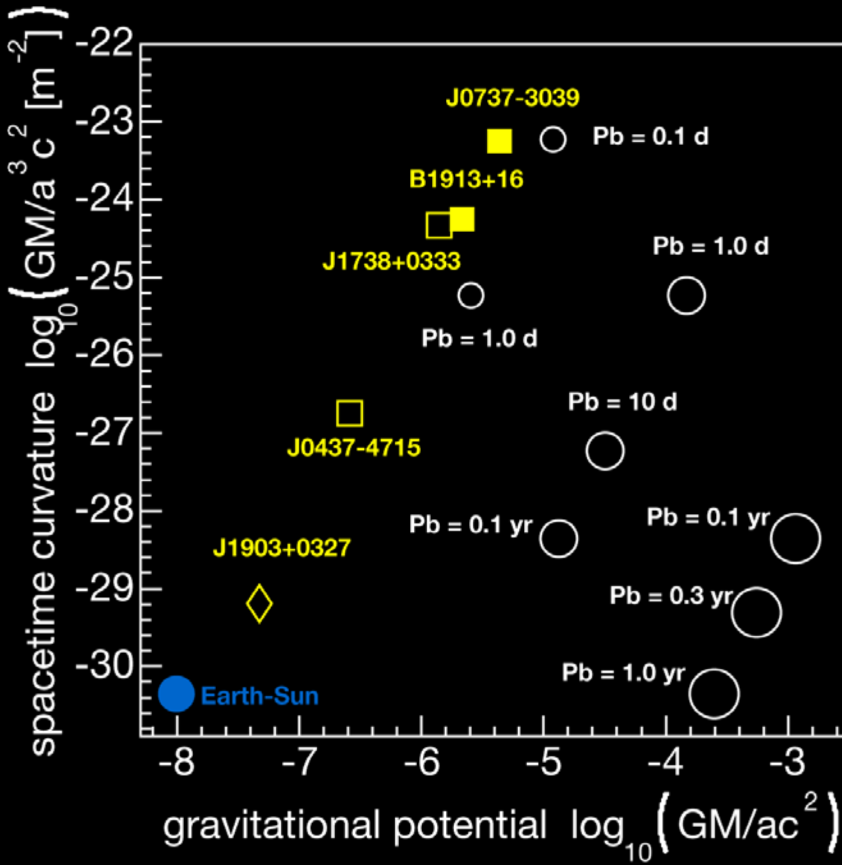
Shao, Stairs et al. 2015

SKA2-MID(AA) pulsar science: Pulsar Timing

Testing Gravity:

The SKA2 "Galactic Census" will discover ~200 double neutron stars (Keane et al. 2015).

Some will have orbits that allows for measurement of "spin-orbit coupling", or "frame-dragging" effect.



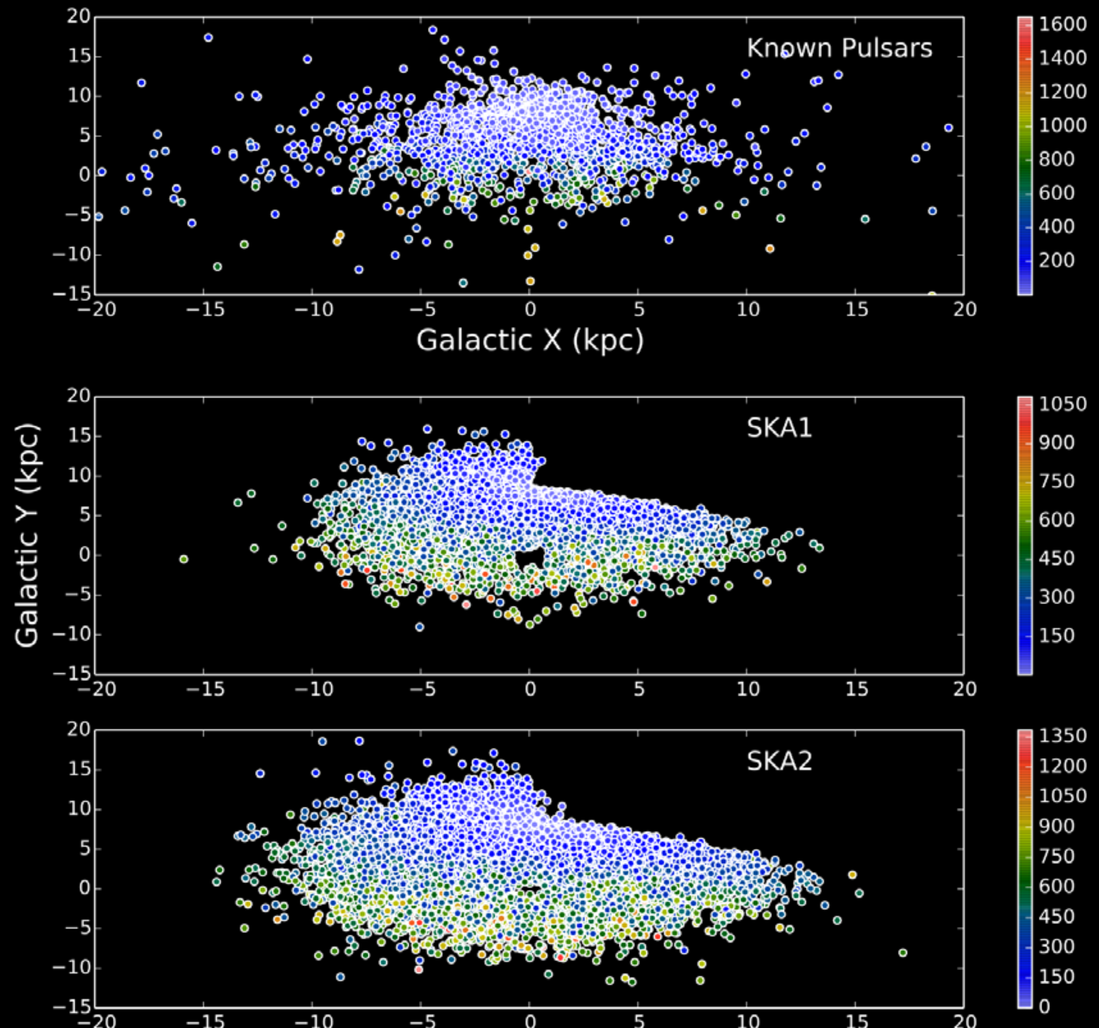
Shao, Stairs et al. 2015

SKA2-MID(AA) pulsar science: Surveys

Simulations show a pulsar survey with a SKA-MID(AA) at 750 MHz would detect around 27,000 normal pulsars and 3000 MSPs (Keane, .. vL., et al. 2015)

In some regions of the sky this corresponds *to detecting the entire population of pulsars* that are beamed in our direction.

SKA2-MID(AA) pulsar science: Surveys



Keane, .., vL, et al. 2015

SKA2-MID(AA) pulsar science: Follow-up Timing

Telescope with “front-end beams” (dish beams, analog/digital station beams, etc.) small enough to fully sample with “back-end beams” (e.g. tied-array beams)?

Then follow-up timing of a successful survey takes about as long as survey itself.

This is where large FoV has huge benefit, *without* high back-end costs. Ability to make even e.g. 100 TABs anywhere in > 100 sq. deg. would create high-speed bulk timing machine.

→ This is the part that creates 95% of the survey science value

SKA2-MID(AA) pulsar science: Processing

Processing is done to make Tied Array Beams (TABs) and next search these.

LOFAR:	200 TABs
Apertif:	500 TABs
SKA1:	2,000 TABs
SKA2:	10,000 TABs

Demonstrator science

Assuming

1. A/T = 40
2. Frequency = ~300-1500 MHz
3. 50 % compact (within 100m)
4. Half-power zenith-angle = ~45 degrees
5. Located in SA

Demonstrator science

Strengths:

1. Location, location. Excellent for Galactic Centre / Plane science
2. Multi beaming
3. Wide field of view

Weaknesses:

1. Moderate sensitivity (equal to one 50-m dish @ 30K; 2/3rd of Parkes)
2. Sensitivity falls off beyond zenith angle of 45deg

Science opportunities

1. Pulsar timing.
Multi-beaming would allow for vast improvement of on-source time.

2. Pulsar monitoring.
Glitches ("starquakes"), single-pulse variations

3. Pulsar searching.
The Big League

Pulsar timing

1. **Pulsar timing**.

Multi-beaming would allow for vast improvement of on-source time.
cf. Parkes Pulsar Timing Array producing excellent science.
30% less A/T, but perhaps 10x more on-source time!
And possibly larger bandwidth.
In contrast to MeerKAT / SKA-Mid, no detrimental dish - subarraying needed
Can use entire demonstrator area, including stations outside compact core

Around LST 17-21, there are generally *10-30 millisecond pulsars* within each 15deg FWHM beam

Pulsar monitoring

2. Pulsar monitoring.
Glitches are starquakes that uniquely probe the stellar interior.

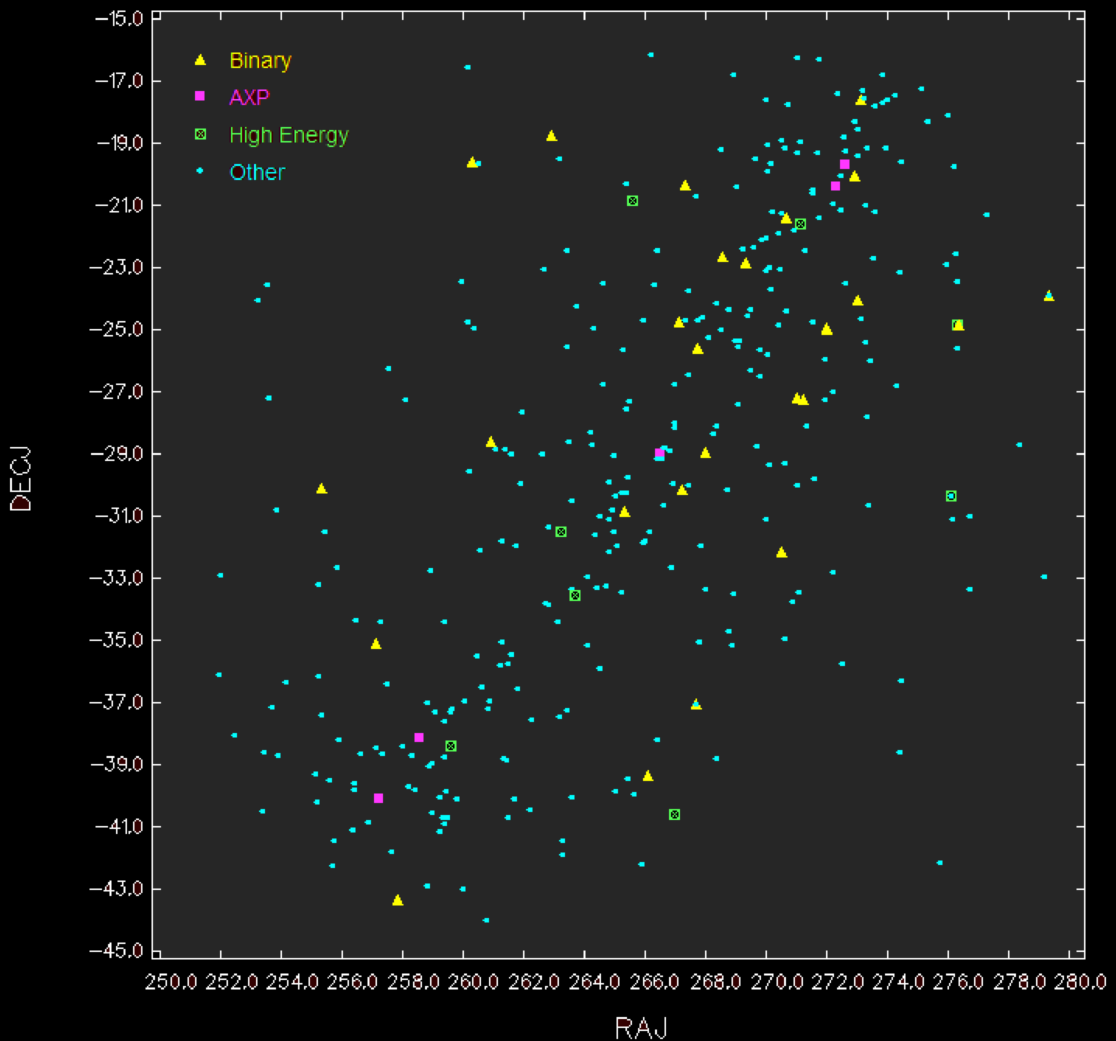
Single-pulse variations are solid low-treshold science with continuing surprising results (Lyne et al. 2010 *Science*; Hermsen et al. 2013 *Science*)

These need long dwell times, high cadence, moderate sensitivity.
40 m^2/K is $1/6^{th}$ of MeerKAT

Also allows for high-cadence wide-band monitoring of the ISM.

Around LST 17-21, there are generally *100-400 pulsars* within each 15deg FWHM beam

Pulsar monitoring



Pulsar monitoring

3. Pulsar searching.

Pulsar survey speed: $S = (A/T)^2 \times \mathrm{FoV} \times \mathrm{BW}$

Demonstrator CC / Apertif = $((40/2)/70) \times (170/9) \times (500/300) = 10$ (!)

To fill >10% of that 170 deg^2, with the tied-array beams of the 100-m Compact Core (CC) one needs of order 1,000 beams. Correlator hardware should suffice.

Next, a 1000-beam backend. Could be procured in e.g. 2018 for ~ 1 MEur. This problem is currently being solved by e.g. Apertif (500 beams).

Conclusions

There is a set of excellent pulsar science cases that is uniquely enabled by *the SKA2-MID(AA)'s wide field of view*.

An MFAA science demonstrator would be a huge draw for the global pulsar community.