28th Texas Symposium on Relativistic Astrophysics

New recycled binary pulsars from the High Time Resolution Universe Pulsar Survey (HTRU) - the North

Marina Berezina

on behalf of the HTRU-North consortium

Max-Planck-Institut für Radioastronomie

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Overview

HTRU: North and South

HTRU-North: discoveries and mass measurements

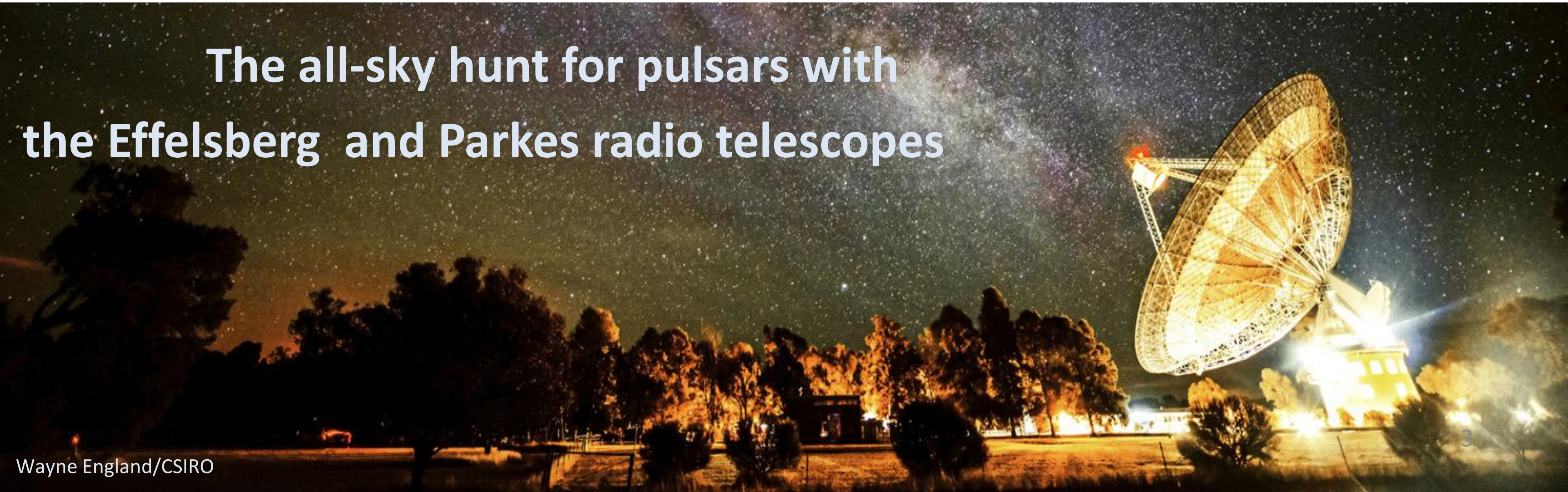
- **PSR J1946+3417**
- **PSR J2045+3633**
- **PSR J2053+4650**

Prospects

MPIfR

THE HIGH TIME RESOLUTION UNIVERSE SURVEY

The all-sky hunt for pulsars with the Effelsberg and Parkes radio telescopes



Wayne England/CSIRO

HTRU - The Deepest All-Sky Pulsar Survey Ever: Motivation

New pulsars are always welcome!

(especially binaries ⟶ especially double neutron star binaries and pulsar-black hole ("holy Grail") binaries)

Magnetars

Fast radio bursts (FRBs)

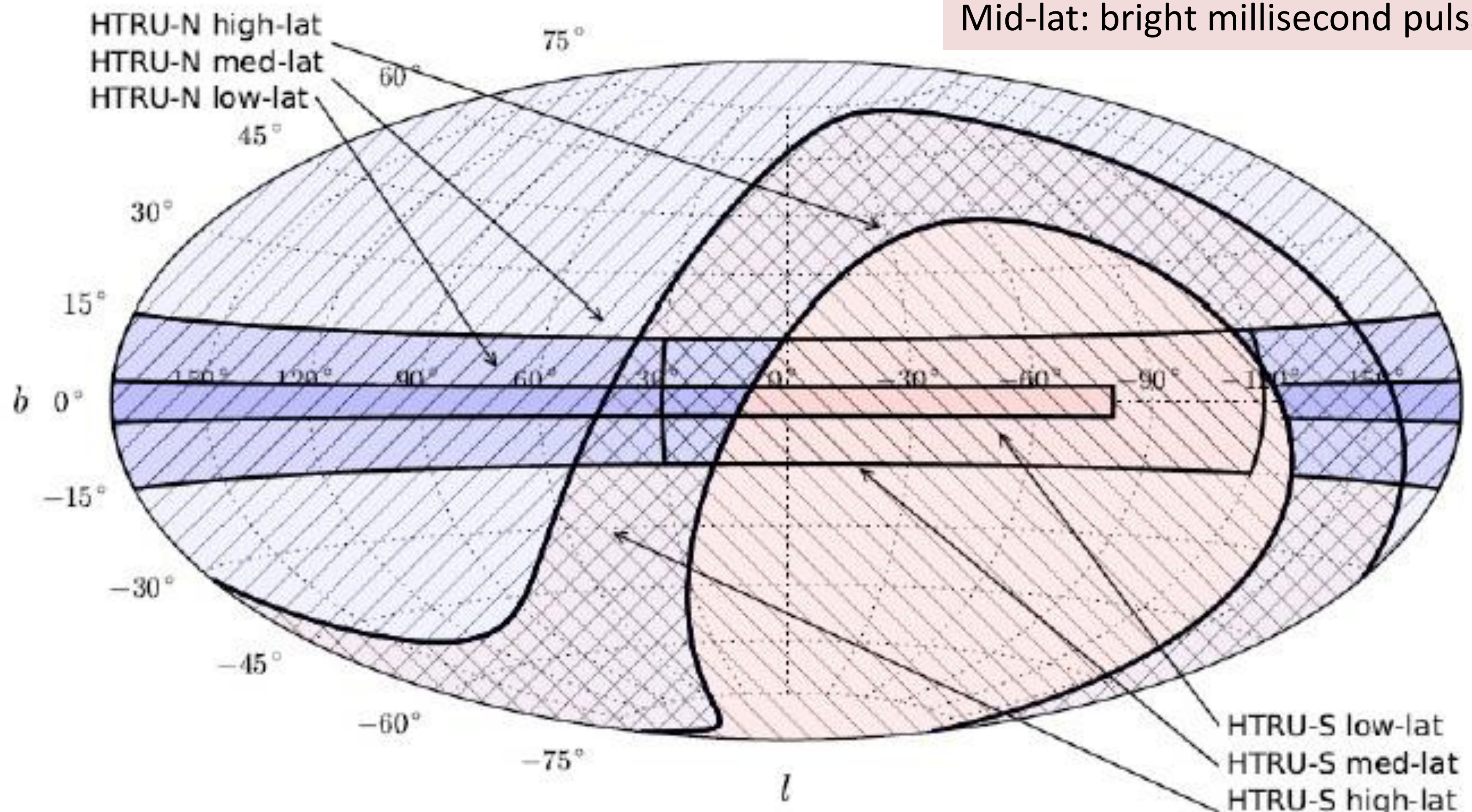
- **North: The first all-northern-sky survey in more than 20 years!**
- **South: Find what has not been found in previous surveys**

- Much higher time and frequency resolution allow us to probe deeper into the Galactic plane for short duration signals
- High-performing processing tools are available

The HTRU sky

High-lat: bright pulsars and both Galactic and extragalactic transients

Mid-lat: bright millisecond pulsars



Low-lat: double neutron stars and others exotic objects

Credit: Cherry Ng

HTRU: Setups

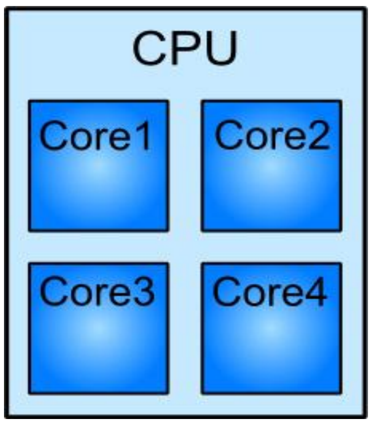
	Northern survey	Southern Survey
Start date	Summer 2010	Early 2008
Telescope	Effelsberg-100 m	Parkes-64 m
Sky coverage	$\delta > -20°$	$\delta < +10°$
Integration time	Low-lat: 1500 s Mid-lat: 180 s High-lat: 90 s	Low-lat: 4300 s Mid-lat: 540 s High-lat: 270 s
Receiver	7-beam 1.4-GHz receiver	13-beam 1.35-GHz receiver
Backend	Pulsar Fast Fourier Transform Spectrometer (PFFTS)	Berkeley-Parkes-Swinburne Recorder (BPSR)
Bandwidth	240 MHz	340 MHz
No. of channels	512	1024
Freq. resolution	**0.58 MHz**	**0.39 MHz**
Time resolution	**54 µs**	**64 µs**
No. of sky pointings	~180 000	~43 000
Data size	~2.5 petabytes	~1 petabyte

High time and frequency resolution!

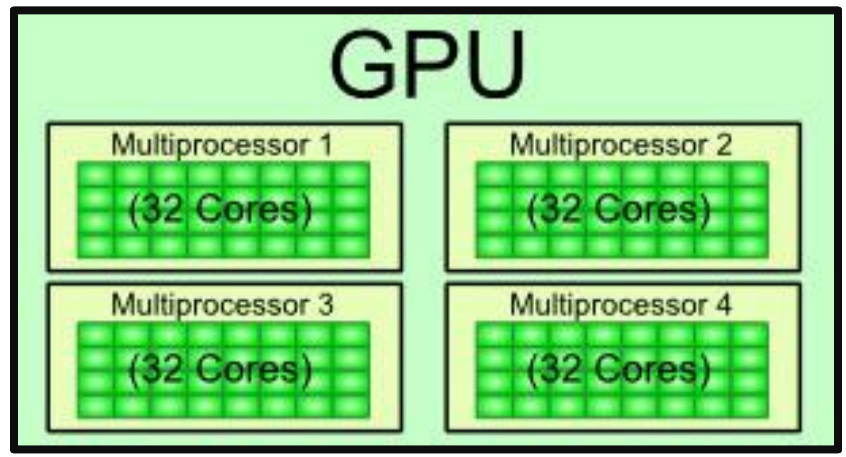
Credit: Cherry Ng, MPIfR,CSIRO

Searching

Single-pulse search (pulsars, transients, FRBs) → Periodicity search (normal pulsars, MSPs) → Acceleration search (most exotic systems)



Tools



SIGPROC
(sigproc.sourceforge.net)

HEIMDALL (Barsdell et al. 2012)

PRESTO
(http://www.cv.nrao.edu/~sransom/presto/)

PEASOUP (E.Barr)

Credit:NVIDIA

Status, discoveries

HTRU-North

Mid-lat: 38% observed, 37% processed*

Low-lat (3-min pointings): 68% observed, 65% processed*

19 new pulsars

HTRU-South

Mid-lat: 100% completed

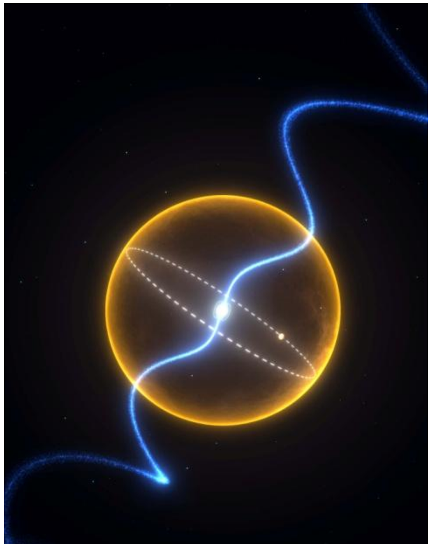
Low-lat : 100% observed, 60% processed

High-lat: 100% observed, 42% processed

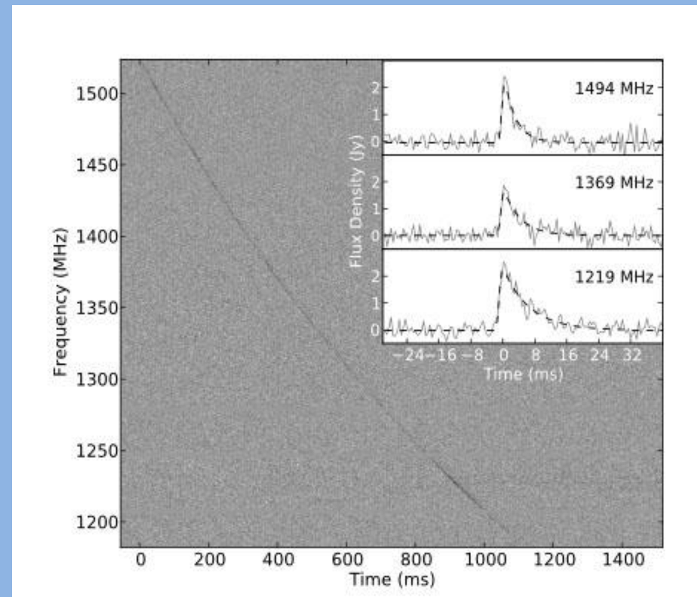
~190 new pulsars, 9 FRBs

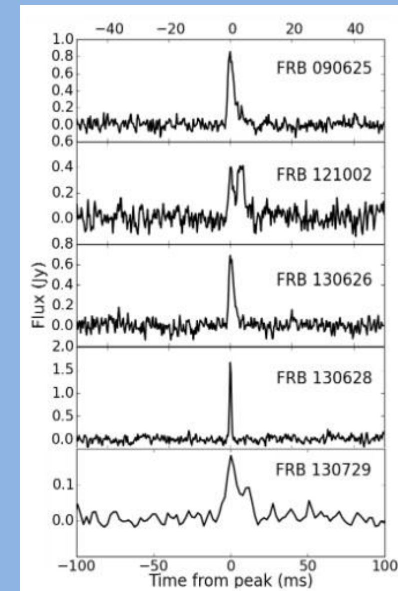
* in the FAST PIPELINE (downsampled version of the data, without acceleration search)

A few HTRU highlights …

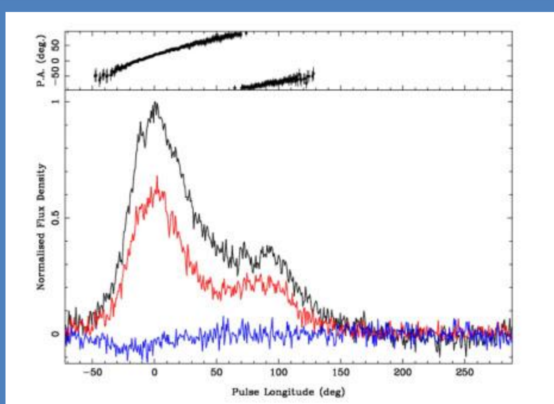


“Diamond planet” pulsar
(Bailes et al. 2011)

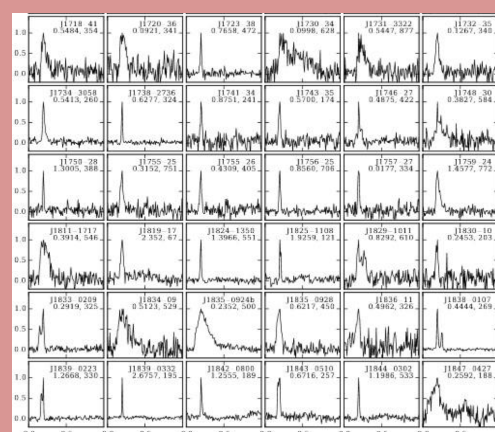


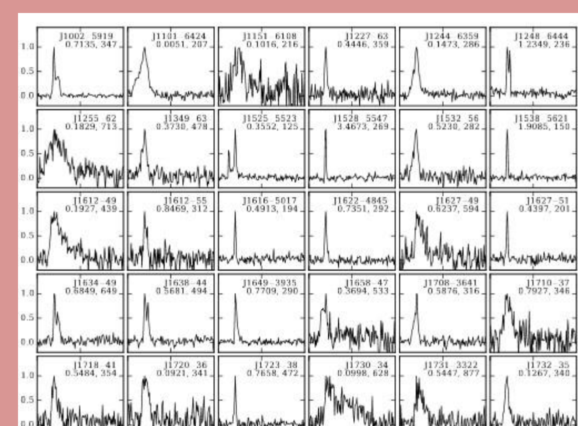


9 FRBs (Thornton et al. 2013, Champion et al. 2015)



Radio-loud magnetar
J1622–4950
(Levin et al 2010, 2011)

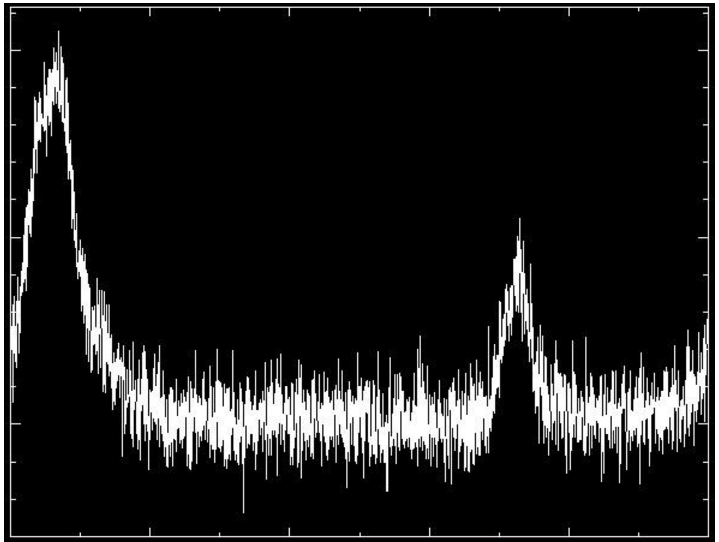




60 new pulsars (Ng et al. 2015)


HTRU-North: most promising discoveries

PSR J1946+3417: a massive eccentric MSP with a low-mass helium white dwarf companion



P=3.17 ms

Eccentricity	~0.134
Orbital period	~27 days
Companion mass	~0.27 solar

Formation mechanism

1. Hierarchical triple system?
   (Barr et al. 2013)
2. Rotationally-delayed accretion induced collapse (RD-AIC)?
   (Freire & Tauris 2014)
3. Eccentricity growth through interaction with a circumbinary disk?
   (Antoniadis 2014)
4. A strange star scenario?
   (Jiang et al. 2015)
5. *Something else…*
   (Barr, Freire, Berezina 2016, in prep.)

Barr, Freire, Berezina (2016, in prep.)

J1946+3417: Mass measurement

3 years of Effelsberg timing + Arecibo campaign

$$f(m_p, m_c) = \frac{(m_c \sin i)^3}{(m_p+m_c)^2} = \frac{4\pi^2}{G}\,\frac{(a_p \sin i)^3}{P_b^2}$$

For GR:

$$\dot{\omega} = 3T_\odot^{2/3}\,\left(\frac{P_b}{2\pi}\right)^{-5/3}\,\frac{1}{1-e^2}\,(m_p+m_c)^{2/3}$$

$$\gamma = T_\odot^{2/3}\,\left(\frac{P_b}{2\pi}\right)^{1/3}\,e\,\frac{m_c(m_p+2m_c)}{(m_p+m_c)^{4/3}}$$

$$r = T_\odot m_c$$

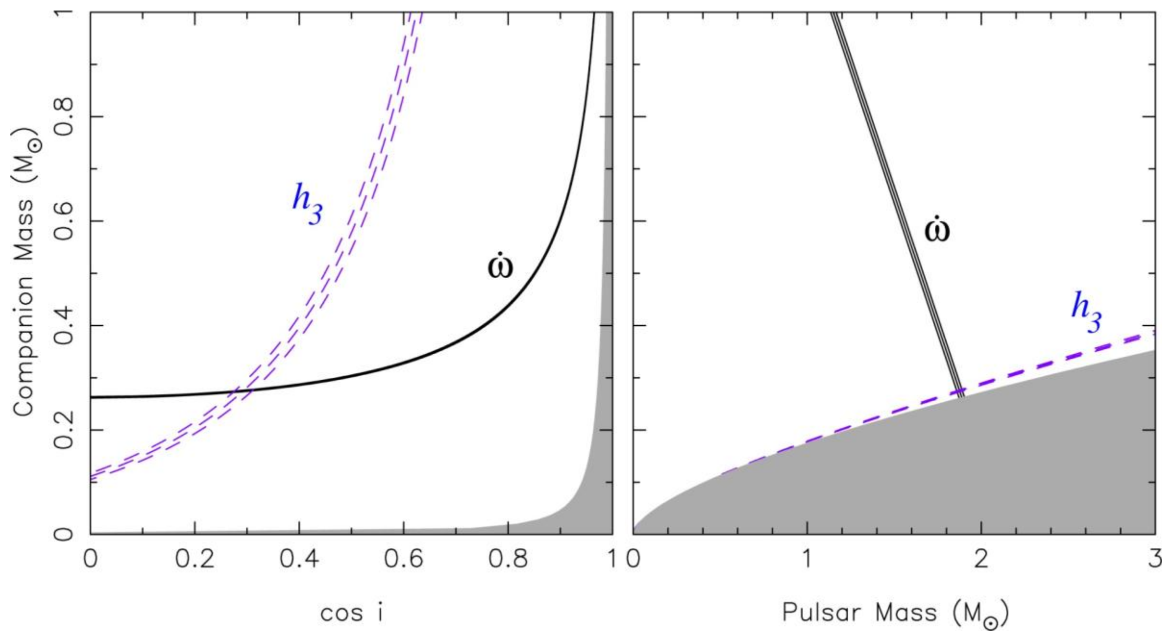
$$s = \sin i = T_\odot^{-1/3}\,\left(\frac{P_b}{2\pi}\right)^{-5/3}\,x\,\frac{(mp+m_c)^{2/3}}{m_c}$$

$$\dot{P}_b = -\frac{192\pi}{5}\,T_\odot^{5/3}\,\left(\frac{P_b}{2\pi}\right)^{-5/3}\,f(e)\,\frac{m_p m_c}{(m_p+m_c)^{1/3}}$$

$$\Omega_{\rm geod} = \left(\frac{2\pi}{P_b}\right)^{5/3}\,T_\odot^{2/3}\,\frac{m_c(4m_p+3m_c)}{2(m_p+m_c)^{4/3}}\,\frac{1}{1-e^2}$$

$$T_\odot = GM_\odot/c^3 = 4.9254909\mu\text{s}$$

(Damour &Deruelle 1982)

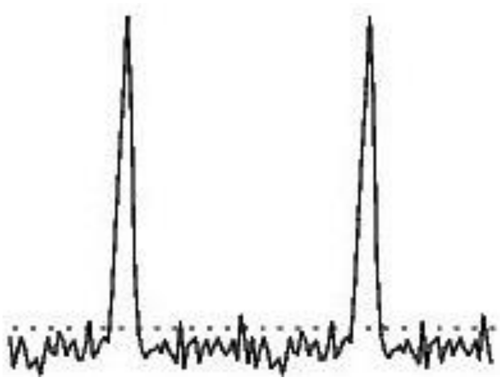


h_3 (r,s) – “Orthometric “amplitude of the Shapiro delay (Freire &Wex, 2010)

M1: 1.8840915 +- 0.0277536

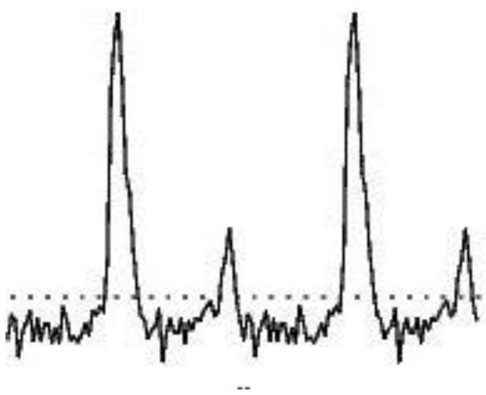
Two **new** bright recycled pulsars!!!

PSR J2045+3633



Spin period: 31.68 ms

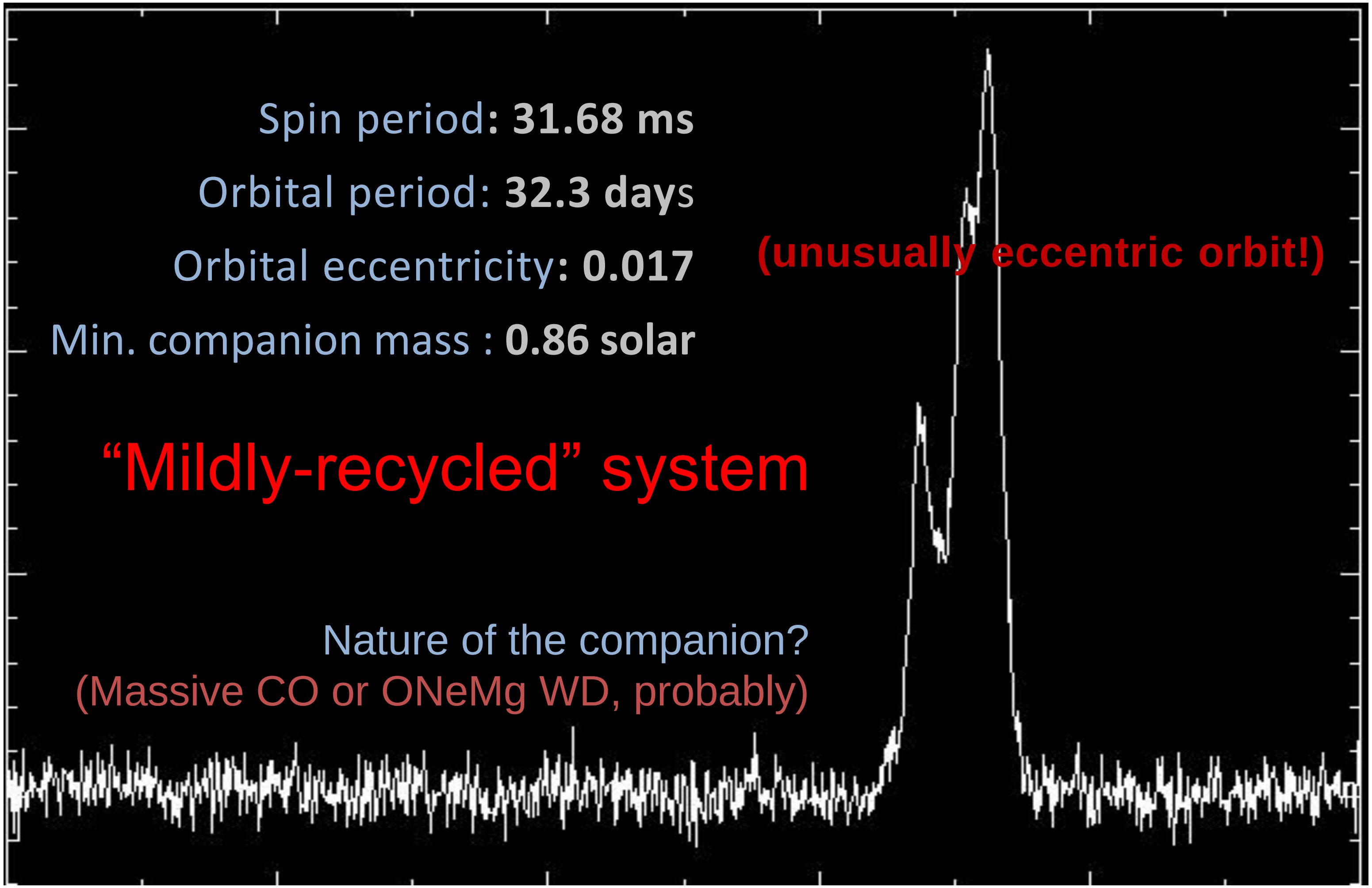
PSR J2053+4650



Spin period: 12.58 ms

Berezina et al. (2016, in prep)

PSR J2045+3633



Spin period: **31.68 ms**

Orbital period: **32.3 days**

Orbital eccentricity: **0.017**

(unusually eccentric orbit!)

Min. companion mass : **0.86 solar**

“Mildly-recycled” system

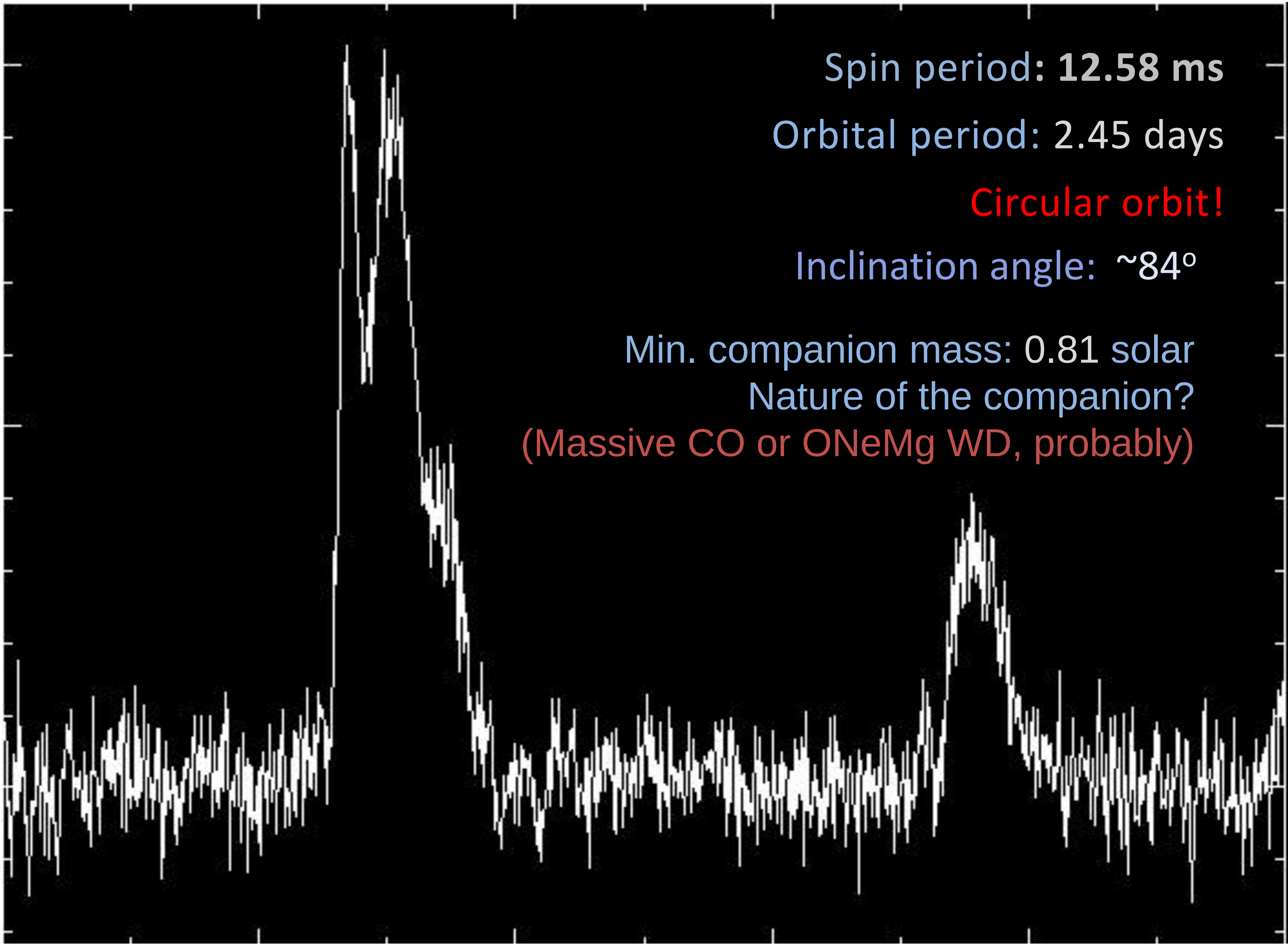
Nature of the companion?
(Massive CO or ONeMg WD, probably)

Effelsberg, Jodrell Bank, Nançay, Arecibo

Shapiro delay, Omega dot?

Pulsar mass: 1.67 (+/- 0.35) solar
Companion mass: 0.97 (+/- 0.11) solar

PSR J2053+4650



Spin period: **12.58 ms**

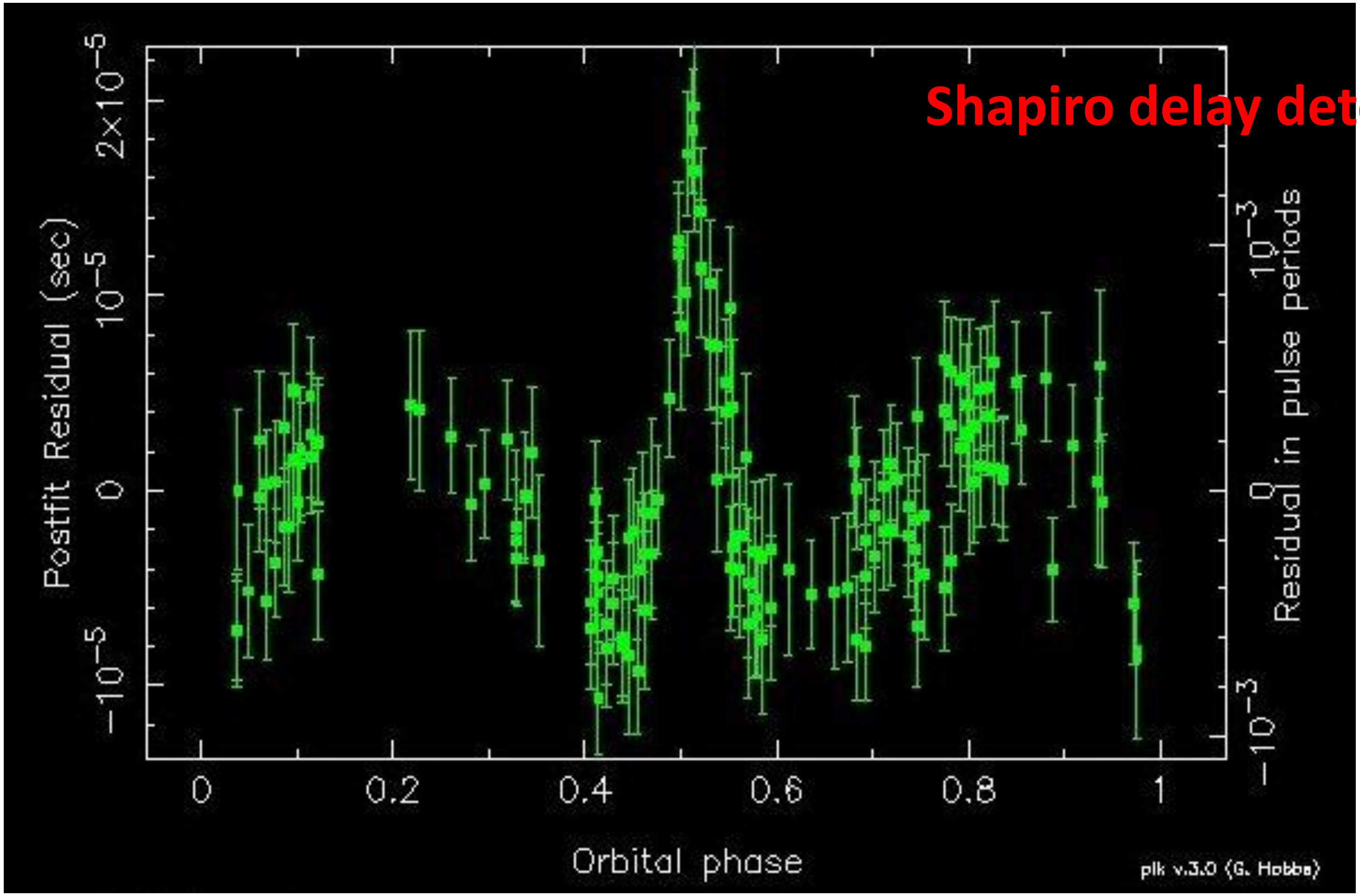
Orbital period: 2.45 days

Circular orbit!

Inclination angle: ~84°

Min. companion mass: 0.81 solar
Nature of the companion?
(Massive CO or ONeMg WD, probably)

PSR J2053+4650: Mass measurement



Effelsberg, Jodrell Bank, Nançay

Pulsar mass: 1.52 (+/- 0.25) solar
Companion mass: 0.89 (+/- 0.08) solar

Summary: Prospects for PSR J2045+3633 and PSR J2053+4650

- Future precise mass measurements
- Identification of the companions
- Evolutionary scenarios
- Release to IPTA, NanoGRAV

Thank you for attention!