Millisecond pulsars in the HTRU survey

Dan Thornton & HTRU Collaboration

Applications of Millisecond Pulsars Aspen, CO. Jan. 2013

Outline

The HTRU pulsar and transients survey

- The survey
- Overview of discoveries
- Spiders
- Isolated MSPs
- Planets
- WD-MSP binaries
- MSP population



HTRU Survey

- 400 MHz bandwidth centered on 1.318 GHz
- 1024 * 390.625 kHz channels
- 2-bit time sampling every 64 µ.secs



- 13 adjacent beams on the sky simultaneously
- Survey split into low-, mid- and high-Galactic latitude regions



Now using configurable ROACH based digital HIPSR backend, operating as BPSR

Keith et al, 2010.

Candidates & Confirmations



J1431-4717: 1431.p

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 $\begin{array}{l} \text{BC P(ms)} = 2.011794606 \ \text{TC P(ms)} = 2.011940033 \ \text{DM} = 59.300 \ \text{RAJ} = 14.31:50.88 \ \text{DecJ} = -47:17:15.6 \\ \text{BC MUD} = 55756.295288 \ \text{Centre freq(MHz)} = 1382.000 \ \text{Bandwidth(MHz)} = -400 \ \text{I} = 320.056 \ \text{b} = 12.218 \\ \text{NBin} = 128 \ \text{NChan} = 16 \ \text{NSub} = 31 \ \text{TBin(ms)} = 0.016 \ \text{TSub(s)} = 20.000 \ \text{TSpan(s)} = 616.611 \\ \text{P(us)}: \ \text{Offset} = 0.0000, \ \text{step} = 0.00005, \ \text{range} = 0.01000 \ \text{DH}: \ \text{offset} = 0.0000, \ \text{step} = 0.0200 \\ \text{Starbox} = 0.0000, \ \text{step} = 0.00005, \ \text{range} = 0.21000 \ \text{DH}: \ \text{offset} = 0.0000, \ \text{step} = 0.0005, \ \text{range} = 0.2000 \\ \text{Starbox} = 0.0000, \ \text{step} = 0.00005, \ \text{range} = 0.21000 \ \text{DH}: \ \text{offset} = 0.0000, \ \text{step} = 0.0005, \ \text{range} = 0.20000 \\ \text{Starbox} = 0.0000, \ \text{step} = 0.0000, \ \text{step} = 0.0000 \ \text{Starbox} = 0.0000 \ \text{Starbox} = 0.0000, \ \text{step} = 0.0000 \\ \text{Starbox} = 0.0000, \ \text{step} = 0.0000, \ \text{step} = 0.0000 \ \text{Starbox} = 0.0000 \ \text{Starbox} = 0.0000, \ \text{step} = 0.0000 \ \text{Starbox} = 0.0000$





HTRU Survey Discoveries

- Approx. 130 pulsars discovered to-date
- 27 of which are MSPs
- $P_{spin} = 2.01 66 \text{ ms}$





Black Widow & Redback Systems

- J1731-1847[†] and now J1431-4717*
- Eclipsing systems which appear to be ablating a companion

$$P_{spin} = 2.01 ms; P_{B} = 10 hrs; M_{c, min} = 0.127 M_{sol}$$



 $P_{spin} = 2.34 \text{ ms; } P_{b} = 7.4 \text{ hrs;}$ $M_{c,min} = 0.037 M_{sol}$

[†]Bates *et al,* 2011



*Thornton et al, in prep.

PSR J1729-2121 — A disrupted HMXB?

- $P_{spin} = 66.29 \text{ ms}$
- dP/dt = 2 x 10⁻¹⁹, very low for a non-recycled pulsar, quite normal for an MSP





Thornton et al, in prep.

- PSR J1832-0836 A solitary fast MSP
- 2.719 ms, $DM = 28 \text{ pc.cm}^{-3}$, $rms_{toa} = 2.00 \text{ }\mu sec$
- Suitable candidate for PTA membership (along with J1545-4550)



Burgay et al, submitted.

Planets in a pulsar survey

- J1719-1438 the "diamond planet" system*
- In Hi-Lat survey a second MSP-planet system has been discovered and is timed from JBO
- Longer P_{orb} = smaller lower limit on density

	J1719-1438	"Planet-pulsar" n°2
P_{spin} (ms)	5.7	3.46
Distance (kpc)	1.2(3)	0.313
Porb (days)	0.09	0.32
a sin <i>i</i> (lt-s)	0.0018	0.002
m _{comp} (M _O)	≥0.00115	≥0.00076
	(~1.2 M _{Jovian})	(~0.8 M _{Jovian})

*Bailes et al 2011

• PSR J1226-6202 ($P_{spin} = 34 \text{ ms}$) - 6.7 day orbit with heavy WD companion (M_{comp, min} = 1.29M_{sol}) • PSR J1406-4656 ($P_{spin} = 7.6 \text{ ms}$) - 9 day orbit with WD companion (M_{comp, min} = 0.215M_{sol}) • PSR J1 431-47 17 $(P_{spin} = 2.01 \text{ ms})$ -10 hr orbit Redback system ($M_{comp, min} = 0.127 M_{sol}$) • PSR J1653-2056 ($P_{spin} = 4.12 \text{ ms}$) timed @ JB0 - 1.2 day orbit with light companion $(M_{comp, min} = 0.080 M_{sol})$ • PSR J1729-2121 ($P_{spin} = 66.29 \text{ ms}$) timed @ JBO - Solitary MSP, disrupted HMXB(?) Thornton et al, in prep.

MSP population study

- Snapshot population analysis of MSPs in Galaxy
- ~45000 Galactic MSPs $(L_{1400} > 0.1 \text{ mJy.kpc}^2)$
- Preferred scale height of 500 pc.
- Predictions: Low-Lat: 67, High-Lat: 50 (84 new)



Levin *et al,* in prep.

Finally ...

- HTRU survey is part-searched, and finding new MSPs and normal pulsars all the time
- The survey forms an enormous dataset for future processing techniques, particularly acceleration searching
- We are finding objects from a magnetar to a 2 ms MSP
- Survey is still going and many more will be found
- Outreach at JBCA; secondary school students found 350 ms pulsar!