

## Three New Binary Pulsars Discovered With Parkes

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**Abstract.** We present three new binary pulsars discovered during a search for pulsations in 56 unidentified mid-latitude EGRET  $\gamma$ -ray error boxes with the Parkes multibeam receiver. Timing observations of these sources is on-going with both the Parkes and the Green Bank telescopes. We discuss the place of these new systems in the population of binary pulsars and suggest that they are all somewhat atypical systems.

### 1. Introduction

We have recently completed a search of 56 unidentified mid-latitude EGRET  $\gamma$ -ray sources for pulsations using the Parkes telescope and the multibeam receiver. This survey covered  $\sim 140$  square degrees of sky at Galactic latitudes  $> 5^\circ$  and revealed six new pulsars, three of which are in binary systems. Here we present initial timing results for the three binaries.

### 2. The Pulsars

The properties of the three new binaries are summarized in Table 1 and their pulse profiles are shown in Figure 1.

#### 2.1. PSR J1614–2230

PSR J1614–2230 is a recycled millisecond pulsar with a very low inferred magnetic field ( $B = 1.8 \times 10^8$  G). It has the highest minimum companion mass of the  $\sim 50$  binary pulsars with spin periods lower than 8 ms, suggesting a possible non-standard evolution. Compared with the orbital period versus companion mass relationship of Rappaport et al. (1995), the orbital period of PSR J1614–2230 is short by a factor  $> 10$  for its companion mass. The companion may be a CNO white dwarf or a low-mass degenerate dwarf. The spin-down rate of

Table 1. Newly Discovered Binaries

Pulsar	$P_{psr}$ (ms)	$P_{orbit}$ (days)	$a_1 \sin(i)/c$ (lt-s)	Min $M_2^a$ ( $M_\odot$ )	DM (pc cm $^{-3}$ )	Distance $^b$ (kpc)
J1614–2230	3.151	8.7	11.3	0.40	34.5	1.3
J1614–2318	33.50	3.2	1.33	0.080	52.4	1.8
J1744–3922	172.4	0.19	0.212	0.083	148	3.1

<sup>a</sup> Assuming a pulsar mass ( $M_1$ ) of  $1.4 M_\odot$ .

<sup>b</sup> DM distance from the NE2001 electron density model of the Galaxy (Cordes & Lazio 2002).

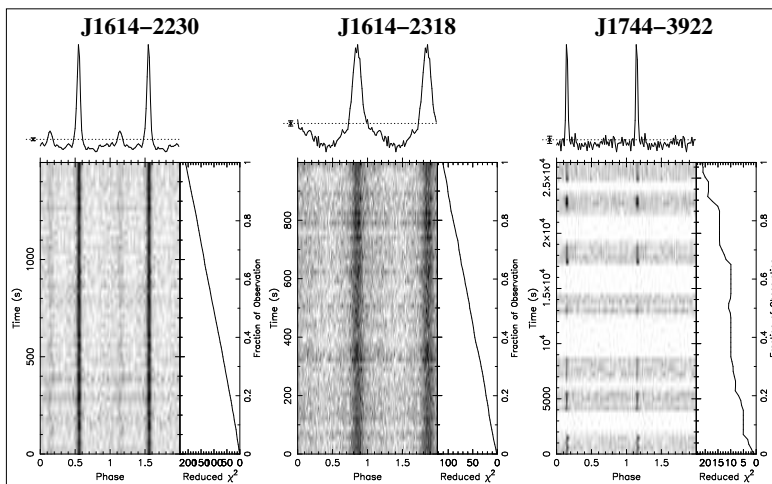


Figure 1. Best detections of the pulsars. The grey scale shows the consistency of the pulsations as a function of time during the observation and effects due to interference. *Left*: PSR J1614–2230 with the GBT using the BCPM at 1.4 GHz. *Middle*: PSR J1614–2318 with the GBT using the BCPM at 350 MHz. *Right*: PSR J1744–3922 with Parkes using the multibeam filterbank at 1.4 GHz. The profile is made up of numerous closely spaced observations, covering  $\sim 1.5$  orbits of the pulsar, with padding in between.

PSR J1614–2230 gives an  $\dot{E} \sim 1.3 \times 10^{34}$  erg s $^{-1}$ , which is just barely consistent with the flux measured from the  $\gamma$ -ray source in whose error box this pulsar was found. If the pulsar is the counterpart it would demand a very high  $\gamma$ -ray efficiency, or a significantly closer distance than what is inferred from the DM.

## 2.2. PSR J1614–2318

PSR J1614–2318 is likely partially recycled ( $B \sim 3 \times 10^9$  G). It has the lowest minimum companion mass of any binary pulsar with spin period between 10 and 100 ms. The pulse profile is relatively wide at 1.4 GHz ( $\sim 30\%$  of the pulse

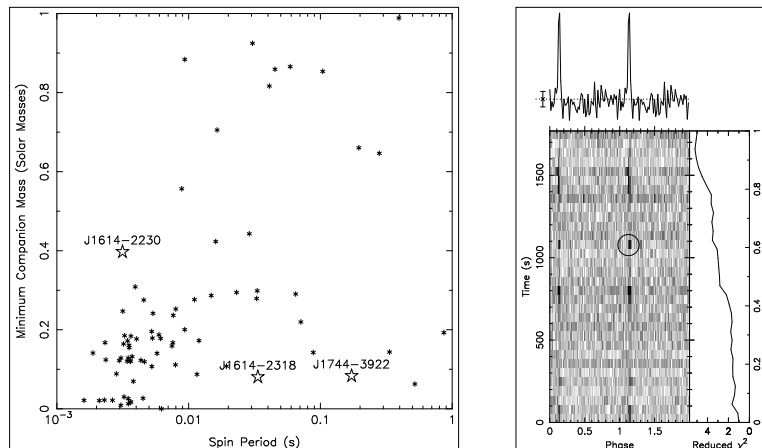


Figure 2. *Left:* A plot of minimum companion mass versus spin period for the known binary pulsars (from the ATNF catalog, available at <http://www.atnf.csiro.au/research/pulsar/psrcat/>). The three binaries presented here are marked with a star and their name. *Right:* A Parkes observation of PSR J1744–3922 at  $\sim 1.4$  GHz showing the intermittent nature of the pulsations from this source. A particularly short episode ( $< 70$  s) of relatively bright pulsations is circled.

period at FWHM). At  $\sim 350$  MHz the higher signal-to-noise ratio of the profile shows that there are wings on either side of the main pulse (see Figure 1). It is possible that we are seeing emission from the core and cone of the beam.

### 2.3. PSR J1744–3922

PSR J1744–3922 was also independently discovered by the Parkes Multibeam Galactic Plane Survey (A. Lyne, private communication). It is possibly partially recycled ( $B \leq 7 \times 10^{10}$  G) and is one of only  $\sim 16$  binary pulsars with spin periods greater than 50 ms (of these it has the shortest orbital period and the third smallest minimum companion mass). It is difficult to detect at times, as it seems to shut off and turn on on timescales as short as a few tens of seconds (see Figure 2). Since its DM is relatively high, it is unlikely that scintillation is responsible for the many non-detections of the pulsar. PSR J1744–3922 has also been very difficult to detect at wavelengths other than  $\sim 1.4$  GHz. Observations with the GBT have improved the detection rate of this strange pulsar.

## 3. Future Work

We have applied for exploratory observations of all three pulsars presented here with the 8-m Gemini-South optical telescope in order to determine the magnitudes and colors of their binary companions and to see if they are consistent with being white dwarfs. These observations may lead to future spectroscopic observations of the companions, which could allow us to determine the neutron

star masses and distances to the systems. With a clearer picture of the nature of the companion stars we would also be in a better position to comment on how these systems fit in with theories of binary evolution.

## **References**

- Cordes & Lazio 2002, astro-ph/0207156.  
Rappaport et al. 1995, MNRAS, 273, 731