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Intermediate-Mass Binary Pulsars: a New Class of Objects?

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Approximately 4/5 of the $\sim$ 35 millisecond pulsars known in the disk of the Galaxy are in binary systems. The vast majority of these binary pulsars have (presumed) helium white dwarf companions with masses $m_2 < 0.45\,\mathrm{M}_\odot$, spin periods $P < 10$ ms, and all are in extremely circular orbits (Fig. 1). In a search for millisecond pulsars with the Arecibo radio telescope, we have recently discovered PSR J1022+1001, a 16.45 ms pulsar in a 7.8 d orbit with a companion that is at least $0.73\,\mathrm{M}_\odot$, and is more likely as massive as 0.8–$1.0\,\mathrm{M}_\odot$; and PSR J0621+1002, a 28.85 ms pulsar in an 8.3 d orbit with a companion at least $0.45\,\mathrm{M}_\odot$, and more likely with $m_2 \approx 0.54\,\mathrm{M}_\odot$. One other system, PSR J2145−0750, has $P = 16.05$ ms, orbital period $P_b = 6.8$ d, and $m_2 \approx 0.50\,\mathrm{M}_\odot$ (see Table 1).

Table 1. Parameters of PSRs J0621+1002 and J1022+1001 (Camilo et al. 1996), and J2145−0750 (Bailes et al. 1994).

	PSR J0621+1002	PSR J1022+1001	PSR J2145−0750
α (J2000)	$06^h21^m22\overset{s}{.}1103(6)$	$10^h22^m58\overset{s}{.}06(6)$	$21^h45^m50\overset{s}{.}468(2)$
δ (J2000)	$+10°02'38\overset{''}{.}79(4)$	$+10°01'54''(3)$	$-07°50'18\overset{''}{.}29(8)$
P (ms).......	28.85386072615(4)	16.452929681440(7)	16.05242365500(8)
$\dot{P}$...........	$< 8 \times 10^{-20}$	$4.2(3) \times 10^{-20}$	$2.9(2) \times 10^{-20}$
Epoch (MJD)	49950.0	49780.0	48978.65730
DM ($\mathrm{cm^{-3}\,pc}$)	36.60(1)	10.25(1)	9.043(2)
P_b (d)........	8.31867514(4)	7.80513015(1)	6.83890247(4)
$a_1 \sin i/c$ (s)..	12.032077(5)	16.765411(2)	10.16409(2)
e.............	$2.4575(6) \times 10^{-3}$	$9.76(2) \times 10^{-5}$	$1.8(4) \times 10^{-5}$
ω	$188\overset{\circ}{.}769(16)$	$97\overset{\circ}{.}54(15)$	$206(12)°$
T_0 (MJD)....	49954.8334(4)	49778.4057(30)	48932.3(2)

It is worth noting that among the group of millisecond pulsars the three systems with the largest companion masses also have the largest spin periods. Interestingly they also have very similar orbital periods of about 7.5 d. The pulsar B0655+64, although slower with $P = 196$ ms, and with shorter orbital period $P_b = 1.0$ d, also has an unusually massive companion, and may have had a similar history. The companion stars to PSRs J0621+1002, J1022+1001, J2145−0750, and B0655+64 are probably carbon-oxygen white dwarfs, based on the large masses and binary eccentricities small compared to those of neutron

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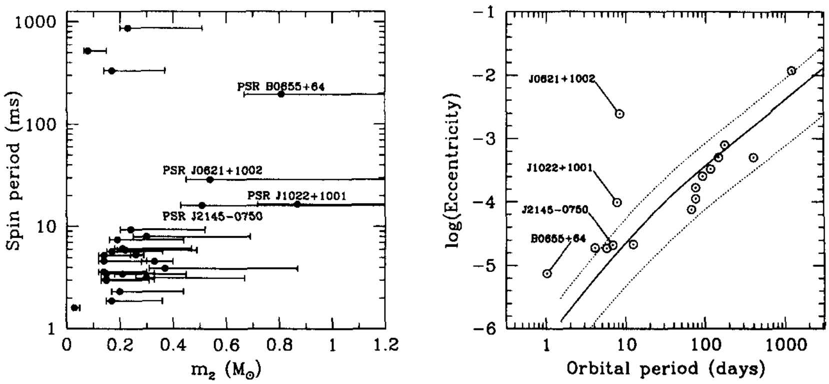

Figure 1. Parameters of binary pulsars in the disk of the Galaxy with measured orbital eccentricities $e < 0.1$. Data are from Taylor et al. (1995) and Camilo et al. (1996). *Left:* eccentricity versus orbital period. Solid line is the median eccentricity predicted by Phinney & Kulkarni (1994); dotted lines should contain 95% of systems for which this model holds. *Right:* Pulse period versus companion mass, inferred from mass function with assumed pulsar mass $1.4\,M_{\odot}$ and inclination angle $i = 60°$. Uncertainty in m_2 is given by the range $0 < \cos i < 0.9$.

star–neutron star binaries (see also contributions by van Kerkwijk and Lundgren et al., this volume). These systems almost surely underwent deep common-envelope evolution, possibly when the companions were on the asymptotic giant branch (van den Heuvel 1994).

Another fact hints at the likely different origin of these systems, compared to the usual low-mass systems. Phinney (1992) derived a relation between the expectation value of the eccentricity and the orbital period for systems where the pulsars were spun up via stable mass transfer by a Roche lobe–overflowing companion star. The two exceptions to this relation are PSR J1022+1001 and, in particular, PSR J0621+1002, which is at least two orders of magnitude more eccentric than would be expected (see Fig. 1).

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