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New Pulsars from Arecibo Drift Scan Search

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Abstract.
We report the discovery of 3 pulsars, PSR J0030+0451, PSR J0711+09, and PSR J1313+09 that were found in a three dimensional (DM, period, position) search at 430 MHz using the 305m Arecibo telescope. PSR J0030+0451 is a nearby 4.8-millisecond solitary pulsar. Spin and astrometric parameters are presented for the three new pulsars. We have measured significant polarization in the millisecond pulsar, PSR J0030+0451, over more than 50% of the period and use these data and also a morphological decomposition of the profile to briefly discuss magnetospheric models.

1. Introduction

From 1994 to 1995, during the time of the Gregorian Dome upgrade at the Arecibo Observatory, while the telescope had limited steerability due to construction, a joint effort by several collaborations was aimed at surveying the sky visible from Arecibo (declination range roughly -1° to 39°) in search of new pulsars. A total of 44 pulsars including 5 MSPs have been discovered so far by the other institutions (Foster et al. 1995, Camilo et al. 1996, Ray et al. 1996). Our search has an estimated sensitivity of 0.9 mJy at 7σ for long period, low DM, low zenith angle, high galactic latitude pulsars which is comparable to previous searches. In December 1997 we confirmed the presence of 3 new pulsars: J0030+0451 (4.8ms), J0711+09 (2.4s), and J1313+09 (0.85s) at the Arecibo Observatory using the Arecibo Berkeley Pulsar Processor and the Penn State Pulsar Machine (Backer et al. 1997, Foster et al. 1995). Follow up observations of the 3 new pulsars were conducted over a period of nearly 2 years from December 1997 through September 1999 at the Arecibo Observatory.

2. Analysis

The data were cross correlated with a template, and the resulting TOAs analyzed using the TEMPO program (Taylor & Weisberg 1989). Table 1 provides spin, astrometric and other parameters for each of the 3 new pulsars.

Table 1. Observed pulsar parameters.

	J0030+0451	J0711+09	J1313+09
Right Ascension (2000)	00 30 27.4339(6)	07 11 36.74(2.00)	13 13 26.5(2.0)
Declination (2000)	04 51 39.65(2)	09 31 40(30)	09 33 31(30)
Galactic longitude	113.1°	206.7°	320.4°
Galactic latitude	-57.6°	8.8°	71.7°
Period(s)	0.00486545320737(1)	1.21409045(4)	0.84893276(7)
$\dot{P}$ (10^{15}) s s^{-1}	$1.0(2)\times10^{-5}$	0.246(300)	1.947(2000)
Epoch (MJD)	50984.4	50699.5	50984.5
Dispersion Measure (pc cm^{-3})	4.3326(1)	46.15(200)	12.0(1)
Timing Data Span (MJD)	50789-51277	50789-51104	50788-51080
RMS timing residual (μs)[a]	13	4500	1400
Flux S_{400} (mJy)	7.9(1)	2.4(1)	3.5(1)
Flux S_{1400} (mJy)	0.6(1)	$>$ 0.04(1)	$>$ 0.16(1)
DM distance (pc)[b]	230	2450	780
L_{400} mJy kpc^2	0.4	14	2.1
Spectral index	$2.2 \pm .2$	< 3.5	< 2.6
Characteristic age (y)	8×10^9	7×10^7	7×10^6
Magnetic field (G)[c]	2.2×10^8	5.5×10^{11}	1.3×10^{12}
Proper motion upper limit (arcsec/yr)	.060	(none)	(none)

[a]RMS from 3 minute averages
[b]Model from Taylor & Cordes, 1993
[c]$B_o = 3.2 \times 10^{19}\sqrt{P\dot{P}}$

3. Millisecond Pulsar : PSR J0030+0451

A pulsar displaying an interpulse like PSR J0030+0451 has two distinct possible geometries: nearly aligned, with the interpulse resulting from the second crossing of a wide-angle hollow "cone" of radiation, or orthogonal, with the two emission regions coming from opposite poles. We performed a dual frequency morphological study of the intensity profile to look for clues to the geometry of the system. Figure 1 depicts the Gaussian decomposition of the profile at each frequency, with the corresponding Gaussian parameters shown in Table 2 (Kramer et al. 1994, Kramer 1994). Conal emission is suggested by the narrowness of the 1400 MHz model compared to the 430 MHz data (panel b overlays the two). In addition, the amplitudes of the Gaussian components suggest that possibly all but component 2 are steep spectral index peaks, which may indicate that component 2 is a core component, and the rest are cone components.

The polarization data do not settle the question of whether the geometry is orthogonal or nearly aligned. Figure 2 shows an example of each.

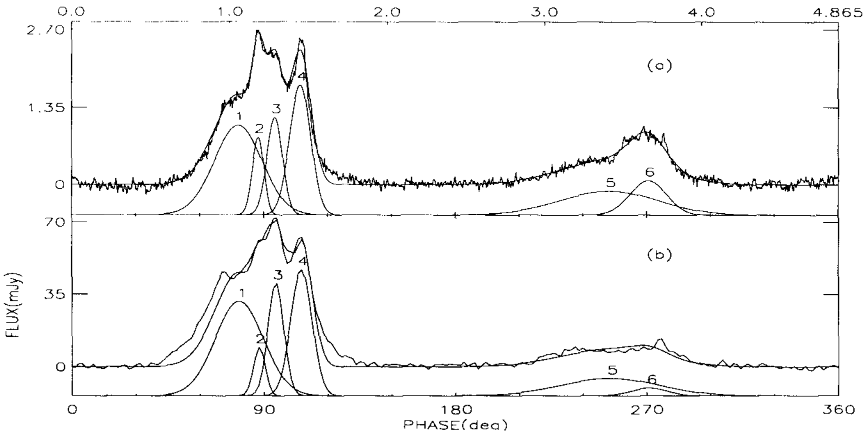

Figure 1. Decomposition of PSR J0030+0454 intensity profile into 6 components. (a) 1400 MHz (b) 430 MHz. The best-fit Gaussian components at 1400 MHz were only allowed to vary in amplitude in order to fit the 430 MHz profile. (cf. Lorimer, "A Week in Review", these proceedings)

Of the 36 known MSPs in the disk of the galaxy, PSR J0030+0451 is the 9th solitary MSP, i.e., it is not in a binary system. These objects present a unique problem in the standard evolutionary scenario of MSPs. If the neutron star is spun up via accretion by a mass transfer from a companion star, the companion must somehow be obliterated.

Table 2. Fitted Gaussian parameters for the 6 components in Figure 2. The amplitude of component 2 was arbitrarily set to 1.0 for both frequencies. All other amplitudes are relative to component 2.

Peak #	1	2	3	4	5	6
Center (deg)	78.74	88.13	95.88	107.85	253.106	271.45
Width (deg)	15.96	3.854	5.183	7.012	32.77	12.23
Amplitude (430 MHz)	1.95	1.00	2.34	2.61	0.771	1.26
Amplitude (1400 MHz)	1.15	1.00	1.25	1.67	0.473	0.442

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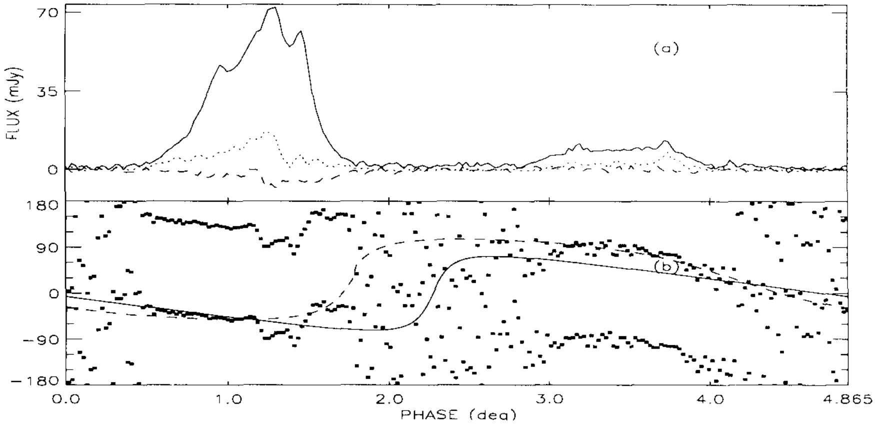

Figure 2. PSR J0030+0454 at 433 MHz. (a) The solid line shows intensity vs. phase. The dotted line shows linear polarization and the dashed line shows circular polarization. (b) Two *RVMs* are superimposed on the PPA data. The solid line demonstrates a possible nearly aligned rotator, plotted with $\alpha = 8°$ and $\beta = 1°$. The dashed line demonstrates a possible orthogonal rotator with values $\alpha = 62°$ and $\beta = 10°$.

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