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Millisecond Pulsars and a WSRT Search for Candidates

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Abstract. Seven millisecond pulsars (MSPs) have been identified from the NVSS by positional coincidence. Our examination of the characteristics of about 280 known pulsars and 40 MSPs has shown that they have high polarization and a steep spectrum. We identify likely MSP candidates from both the NVSS at 1.4 GHz and the WENSS at 325 MHz. The first sample of 14 candidates has been observed by the WSRT using PuMa at both 92 and 21 cm in May 1999. From our preliminary analysis of the 382 MHz data, we find no evidence for MSPs in the first sample.

Of the 40 known MSPs, the spectral characteristics of 34 (Kramer et al. 1998) are: for 32, $\alpha \leq -1.0$, while 27 have $\alpha \leq -1.5$. Of 24 MSPs for which the polarization is known, all are $\geq$ 10% polarized. For a sample of 280 normal pulsars with known linear polarizations and flux densities, we find 80% with $\alpha \leq -1.0$, and 85% are $\geq$ 10% polarized. We conclude that MSPs are somewhat more strongly polarized and have steeper spectra than normal pulsars.

The NVSS has 2×10^6 sources brighter than 2.5 mJy, and covers $\delta > -40°$. The positional accuracy for sources over 15 mJy is $\leq 1''$. Han & Tian (1999) have identified 7 MSPs from the NVSS (Table 1). WENSS includes some 2×10^5 sources brighter than $\simeq$ 18 mJy for $\delta \geq 30°$ at 92 cm. The positional accuracy for strong sources is $1.5''$.

There are 23 pulsars detected by the NVSS in the WENSS declination range, 15 of which have counterparts in WENSS (Kaplan et al., 1998). The fact that both the NVSS and WENSS detected these pulsars suggests that in the both catalogs there are probably some weak MSPs which have not been discovered, especially MSPs at high galactic latitude where fewer pulsar surveys have been done.

We have selected a sample of candidate MSPs from both the NVSS and WENSS catalogues, as follows: (A) steep spectrum, $\alpha \leq$ -1.5; (B) high linear polarization, $\geq$ 15%; (C) point source of low flux density, $\leq$ 100 mJy at 325 MHz; (D) high galactic latitude, $\geq 30°$.

Comparing the candidates with all known sources definitely classified by position using NASA's Astrophysics Data System, we are sure that none of them have been optically identified. We have also excluded obvious non-pulsar

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candidates as much as possible. Our selection criteria can distinguish MSP candidates from both radio quasars and compact steep spectrum sources.

The first sample, consisting of 14 of the best candidates, was recently observed using the WSRT at both 92 and 21 cm in combination with the new pulsar machine PuMa. All our candidates have sufficiently well determined positions to fit in the WSRT beam. We observed each one for about 215 seconds, corresponding to a 2 Mpt time series with a sampling time of 0.1 ms at both frequencies. At 92 cm we used 256 channels over a 10 MHz bandwidth, while at 21 cm we used 512 channels over 80 MHz. This is sufficient to detect each of them if the emission is 100% pulsed. Including the time for set up and calibration, the total observation times was 3.5 hours. The data analysis was done using software developed by the pulsar group in Amsterdam.

So far, we have processed the 382 MHz data for all candidates. The signal-to-noise ratio of most candidate pulsations over the range searched in period and DM is under 5, too low for any to be seen as genuine new MSPs. This result has to be seen in the light of interference at 382 MHz. Also scattering effects ($\propto \nu^{-4.4}$) at this frequency are serious. From our analysis of the data on all candidates at 382 MHz, we find no direct evidence that any of the sources is a MSP.

Table 1. Flux density, α and polarization of MSPs from the NVSS

PSR J (1)	$S_{1.4psr}$ mJy	$(L/S)_{1.4psr}$ (%)	SI_{psr} α_{psr}	$S_{1.4nvss}$ (mJy)	$(L/S)_{1.4nvss}$ (%)	SI_{nvss} α_{nvss}
1012+5307	3±1	54.8±0.7	-1.8±0.4	4.5± 0.4	43±11	-3.58
1022+1001	3.0±0.4	52.8±0.4	-1.7±0.4	3.5± 0.4	42±18	-1.50
1518+4904	4±2	21.7±1.7	-0.5±0.5	4.4± 0.4	3±11	-2.60
1713+0747	8±2	29.7±0.2	-1.5±0.1	8.0± 1.4		-1.85*
1744−1134	3±1	26.8±1.7	1.6±0.3	3.8± 0.5	79±22	-0.98
2124−3358	1.6±0.4		-1.1±0.4	3.0± 0.5	4±23	-3.46
2145−0750	8±2	45.1±0.3	-1.6±0.1	3.1± 0.5	17±19	-0.85*

Note.— Flux density, spectral and polarization data are from Kramer et al., 1998 and Xilouris et al., 1998. The spectral indices α_{nvss} are mainly from Kaplan et al., 1998. * indicates α from $S_{1.4nvss}$ and $S_{4.85psr}$.

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