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Pulsar Observations in China – Status and Results

Na Wang[1], Jin Zhang[1], and Xin-Ji Wu,[2]

[1]*National Astronomical Observatories, CAS, China*

[2]*Astronomy Department, Peking University, China*

Abstract. We present the status and results of pulsar observations in China. Pulsar observations at Urumqi Observatory over more than two years have resulted in updated rotation parameters for 74 pulsars. Comparison with earlier observations shows that long-term period and period-derivative fluctuations are probably dominated by unseen glitches. We also monitored the variation of pulsar scintillation dynamic spectra for a few strong pulsars. The data show major variations in the scintillation parameters. A new system at a lower frequency is planned to allow investigation of the frequency dependence of pulsar properties. A 50-m telescope for millisecond pulsar timing is also being planned at the National Astronomical Observatories, Beijing, and should be constructed within three years.

1. Introduction

Long-term pulsar timing and scintillation studies require large amount of telescope time for regular observations. This paper introduces such observations and results obtained with a 25-m radio telescope operated by Urumqi Observatory.

The results discussed in this paper were obtained between 2000 January and 2002 June with the room-temperature receiver operating in the 18-cm band (center frequency 1540 MHz). De-dispersion is provided by a $2 \times 128 \times 2.5$ MHz filterbank/digitizer system. This system allowed us to observe pulsars with a flux density greater than about 4 mJy, so we monitored 74 detectable pulsars to study their timing properties. Also using the timing system we started regular scintillation observations for five pulsars from January 2001. We report these results in following sections.

2. Timing Observations

2.1. Updated Parameters and the Unseen Glitch Model

Frequent observations of 74 pulsars resulted in updated periods and period derivatives, as discussed in detail by Wang et al. (2001). The accuracy of the period measurements was generally better than 0.1 ns. By comparing the new measurements with the best previous observation, we obtained the variations in periods and period derivatives, i.e., ΔP and $\Delta \dot{P}$ respectively, over long

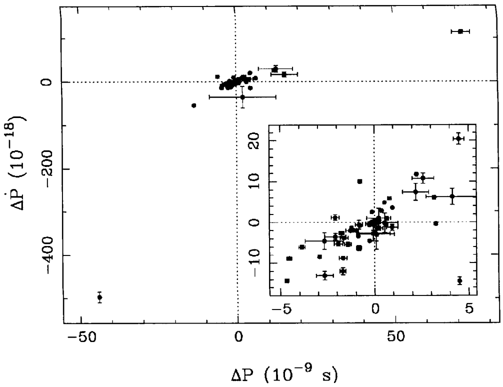

Figure 1. Difference between observed and predicted period derivative $\Delta\dot{P}$, plotted against difference in period, ΔP. The inset is an expanded version of the central region.

time intervals, up to 30 years. We found a correlation between the period and period-derivative changes which is shown in Figure 1. The period and period-derivative changes tend to have the same sign and to be correlated in amplitude. This correlation is improved when more recent data is included, compared to that shown in Wang et al. (2001).

We assume that the present results or the catalog values are contaminated by an exponentially decaying unseen glitch, and use the glitch functions to model the period and period derivative changes caused by the glitch relaxation process. This model agrees well with the observational results, in which the amplitude and sign in ΔP and $\Delta\dot{P}$ are correlated. The model also works for the very special Crab pulsar glitches, in which both ΔP and $\Delta\dot{P}_{\mathrm{p}}$ are positive after the glitch. This agreement suggests that long-term period and period derivative changes are dominated by decay from unseen glitches.

2.2. Glitches

Frequent observations at Urumqi have revealed six glitches up to June 2002. Table 1 lists the glitch pulsars and glitch epochs in the first two columns, and the glitch sizes are given in the third column. Columns four and five list the jump in frequency derivative at the glitch, $\Delta\dot{\nu}$, and the permanent jump in frequency derivative, $\Delta\dot{\nu}_{\mathrm{p}}$, respectively. The decaying part of the frequency jump, $\Delta\nu_{\mathrm{d}}$, is given in column six, and the decay time constant τ_{d} and fractional decay Q are given in the last two columns. Both of the Crab pulsar glitches have a permanent jump in $\Delta\dot{\nu}_{\mathrm{p}}$, consistent with its well-known glitch features. PSR B1737−30 was quite stable for about 700 days, and then suddenly glitched three times in about 120 days, with two small glitches followed by a larger one. PSR J1835−1106 is a young pulsar which has no previously reported glitch.

Table 1. Glitches detected by Urumqi 25m radio telescope.

PSR	Epoch (MJD)	$\Delta\nu/\nu$	$\Delta\dot{\nu}$ (10^{-9})	$\Delta\dot{\nu}_{\rm p}$ $(10^{-15}{\rm s}^{-2})$	$\Delta\nu_{\rm d}$ $(10^{-6}{\rm s}^{-1})$	$\tau_{\rm d}$ (d)	Q
B0531+21	51740.8	23(15)		−37(17)	0.5(4)	4	0.8(8)
	52082(2)	10.5(1)		−62(2)			
B1737−30	52234(2)	5.3(9)					
	52268(2)	13.2(9)					
	52347.4	152.8(5)	−1.32(14)				
1835−1106	52224(2)	23(5)			0.020(6)	100	0.21(6)

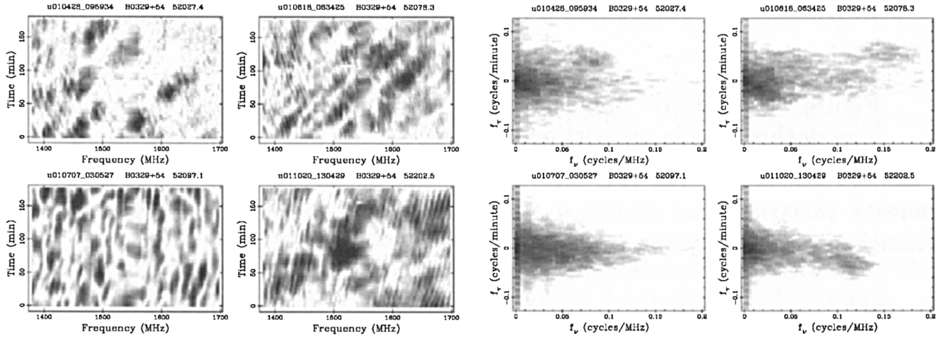

Figure 2. Scintillation dynamic spectra (left) and secondary spectra (right) for PSR B0329+54.

3. Scintillation Observations

Regular scintillation observations for five pulsars started in January 2001 with one observation about every 10 days on average. These pulsars are PSRs B0329+54, B0823+26, B1929+10, B2020+28 and B2021+51. The 18 months of data have shown major variations in the scintillation dynamic spectra for each of these pulsars. The left side of Figure 2 shows such changes for PSR B0329+54. Systematic drifts of the pattern are observed frequently for this pulsar, showing the effects of refractive scintillation (RISS). The right side of Figure 2 is the secondary spectrum – the two-dimensional Fourier transform of the scintillation dynamic spectrum. The extra power at higher frequencies shown in observations at MJDs 52027.4, 52078.3, 52202.5 are due to the finer fringes in their dynamic spectra.

4. Flux Density Variations

We consider the flux density of each timing observations and their modulation index m or r.m.s. variation/mean here. Figure 3 shows a plot of modulation index versus the logarithm of dispersion measure (DM). For nearby pulsars where the DISS is the main effect, the modulation is weak with $m < 1$. For the larger DM pulsars, the DISS effect is weaker and RISS is stronger. The observed relationship of $m \propto {\rm DM}^{-1/3}$ is expected from RISS theory, so the observed flux

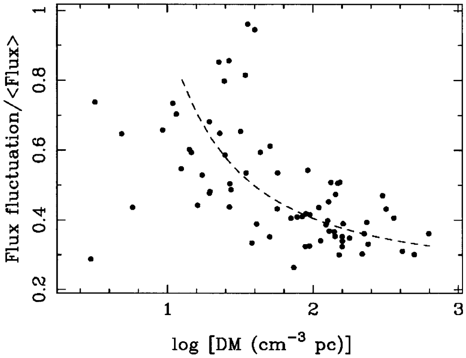

Figure 3. Relative flux density fluctuation versus dispersion measure. The dashed line is proportional to $DM^{-1/3}$.

density variations are dominated by propagation effects rather than intrinsic changes in the pulse emission.

5. Summary

These observations have proved that the present pulsar observing system is efficient for pulsar study. Plans have been made for future development. The first is a new cryogenic receiver for the 18-cm band which was designed and built at ATNF. It was installed on the 25-m telescope in July, 2002 and gives a system temperature of about 22 K, allowing us to detect pulsars as weak as 1 mJy. The second is the digital de-dispersing system at a lower frequency such as 660 MHz. This system will be based on the Jodrell Bank Observatory COBRA system. The third is to develop a pulsar searching system based on the new 18-cm receiver. Investigation of the associations of unidentified gamma-ray sources with pulsars was the initial motivation for this project.

Two planned radio telescopes in China are closely related to pulsar observations. The first project is to build a 50-m radio telescope at Miyun near Beijing within three years. The main science objective for it is to observe millisecond pulsars to detect the gravitational wave background and to use pulsars as frequency standards. For the FAST project it is proposed to build the biggest telescope in the world with an aperture of 500 meters in Gui Zhou province. Pulsar observation is one of its main science goals.

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References

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