SCINTILLATION OBSERVATIONS OF STRONG NORTHERN PULSARS

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Abstract. Scintillation of pulsar radio emission provides information about the interstellar medium along the path to the pulsar and the velocities of pulsars. It also affects the precision of pulse timing observations. Using a pulsar timing system developed at the Urumqi Astronomical Observatory 25 m telescope, we observed diffractive scintillation dynamic spectra for several strong northern pulsars. This paper introduces the observing system and discusses the observational results.

1. Introduction

Fluctuations in the refractive index of the interstellar medium introduce two types of scintillation into observed pulsar signals. The first type, diffractive interstellar scintillation (DISS), causes variations on short time-scales and with narrow frequency structure (Cordes *et al.*, 1986). The second type, refractive interstellar scintillation (RISS) has longer timescales and larger bandwidths. Early observations of long-term variations in pulsar mean flux density (e.g. Helfand *et al.*, 1977) were thought to be intrinsic until 1982, when Sieber found that these fluctuations are slower for pulsars of higher dispersion measure. DISS is only seen in sources of very small angular size, whereas RISS can also be seen in larger sources, for example, extragalactic continuum sources (Rickett *et al.*, 1984).

Based on neutral gas turbulence theory, the density fluctuations in the ionized interstellar medium can be described by a power-law spectrum $P_{3n} = C_n^2 q^{-\beta}$, where β is thought to be in the range $3 < \beta < 5$ and $\beta = 11/3$ for a Kolmogorov spectrum, $q = 2\pi/L$ is the wavenumber associated with the spatial scale of turbulence L. In the Kolmogorov case, the decorrelation bandwidth $\Delta\nu_d$ of diffractive scintillation is proportional to $\nu^{22/5} z_s^{11/5}$, where ν is the observing frequency, and z_s, the distance of the screen. Due to the relative motions of pulsar, the scattering screen and the Earth, the scintillation pattern moves across the observer with a time scale $\tau_d \propto \nu z_s^{-1/2}$, that is, more rapid fluctuations for more distant pulsars and at lower frequencies. Refractive scintillation, caused by larger scale fluctuations in the phase front, is of much longer time scale τ_r and is proportional to $z_s^{8/5}/\nu^{11/5}$ with

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TABLE I

Time scale and decorrelation frequency band of diffractive scintillation for the pulsars observed at Nanshan, Urumqi

Pulsar name	DM pc cm^{-3}	τ_d min	$\Delta\nu_d$ MHz	Pulsar name	DM pc cm^{-3}	τ_d min	$\Delta\nu_d$ MHz
B0950+08	3.0	20	80	B2021+51	22.6	20	40
B1929+10	3.2	30	60	B2020+28	24.6	20	50
B1133+16	4.8	20	50	B0329+54	26.8	14	15
B0823+26	19.9	16	40	B1642–03	35.7	5	40

a Kolmogorov spectrum. Kaspi and Stinebring (1992) found that the observations are in good agreement with the Kolmogorov prediction. In this paper, we report observations of diffractive scintillation for eight strong northern pulsars made at Nanshan, Urumqi. Our results are consistent with previous observations and with theoretical predictions.

2. Observational Results

We use the 25 m radio telescope at Nanshan operated by Urumqi Astronomical Observatory. Observations were made mostly from March to May, 2000, using a pulsar timing system at 18 cm built in mid-1999. The telescope has cassegrain optics and uses a horn feed receiving orthogonal circular polarizations. The receiver has dual-channel room-temperature pre-amplifiers with a system noise of approximately 100 K. After conversion, the signals are fed to a filter-bank system which has 128 2.5-MHz channels for each polarization. Signals from each channel are then one-bit digitized and recorded by a data acquisition system based on a PC operating under Windows NT.

Each observation lasted from 2 to 6 hours with sub-integration time 2 or 4 minutes to ensure enough signal to noise ratio. All together for eight pulsars we obtained the dynamic spectrum of diffractive scintillation at several different epochs. Figure 1 shows typical scintillation dynamic spectra and contours of the two-dimensional intensity auto-correlation function for pulsar PSR B0329+54 (J0332+5434) and PSR B2021+51 (J2022+5434).

The plots of normalized auto-correlation function show a spike at zero time lag and zero frequency lag, except for pulsar B0329+54, the strongest pulsar in the northern sky. This can be caused by interference or sky and receiver noise, and also possibly by intrinsic pulsar processes (Cordes, 1986). Thus we take the bottom of the spike for the estimation of decorrelation frequency scale. Following convention, the scintillation time scale τ_d is the half width at $1/e$ along the time

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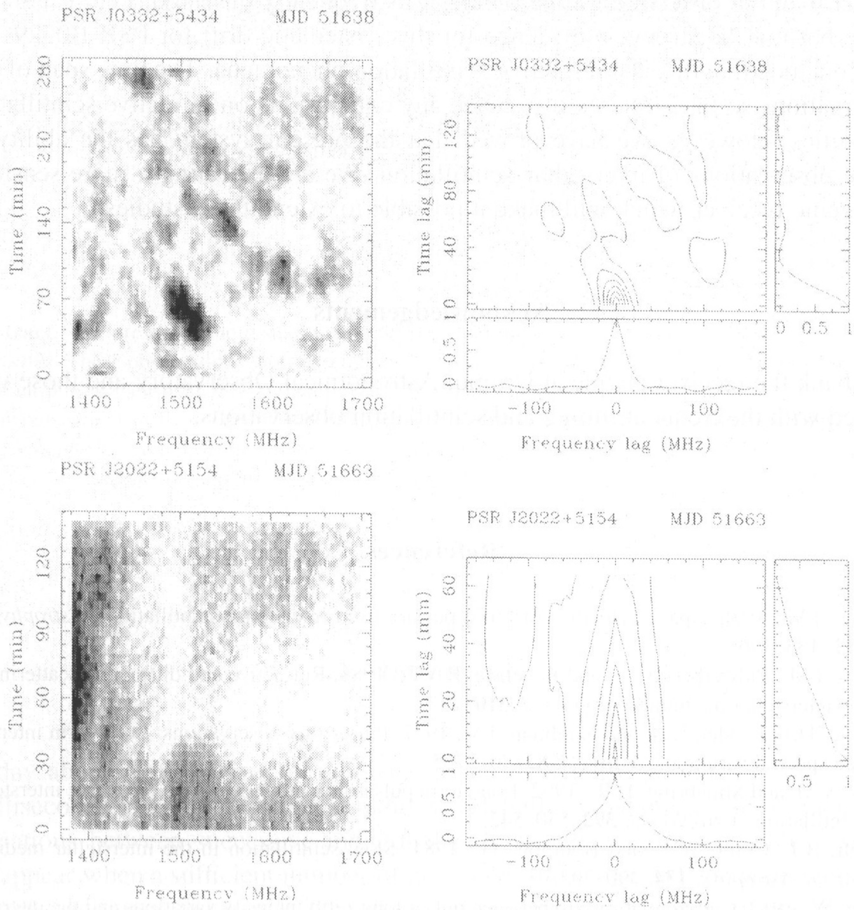

Figure 1. Dynamic spectrum and contours of the two dimensional intensity auto-correlation function of the diffractive scintillation for PSR B0329+54 & PSR B2021+51 observed at Nanshan, Urumqi.

lag axis, and decorrelation frequency scale $\Delta\nu_d$ is the half-width at half-maximum along the frequency lag axis. The averaged scintillation time scale and frequency scale of the observed pulsars are given in Table I. The time scale and decorrelation frequency scale are generally consistent with the trends that scintillation is faster at low frequency for distant pulsars or conversely.

3. Discussion

The dynamic spectrum obtained at different epochs usually show basically random variations with the expected 'scintle' size. However for PSR B0329+54, in addition to the diffractive scintillation, drift of the images over a broad band with time scale

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longer than our observation time (hours) was frequently observed. Figure 1 shows some but not the strongest evidence for this systematic drift for PSR B0329+54. We conclude that this is a refractive scintillation phenomena. The time span of our observations so far is too short to reach any conclusions on refractive scintillation properties. However, we have proved that the present system has the ability to make observations of interstellar scintillation. We are expecting a more sensitive cryogenic receiver which will make it possible to extend these studies.

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