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INTERSTELLAR SCINTILLOMETRY OF THE PSR B0329+54 AT 1650 MHZ

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Abstract. VLBI observations of the pulsar PSR B0329+54 allowed to measure velocity of diffractive pattern at 1.6 GHz. Scintillations of the pulsar were found to have two typical periods: about 20 min and 1 min. Scintillation spots move independently, and no regular motion of the scintillation pattern has been distinguished. We believe that the thin screen model is inapplicable in this case.

Key words: pulsars – interstellar matter – interstellar scintillations

1. INTRODUCTION

Interstellar scattering distorts the signal of a source (pulsar) so that its radio spectrum shows maxima and minima. An observer moves through the diffractive pattern and registers scintillations. The characteristic velocity of the scintillations $V_{\rm iss}$ depends on respective velocities of the source, medium and observer.

In the paper we discuss the results of measurement of the velocity of scintillation pattern from pulsar PSR B0329+54 obtained by a "direct" method when the data of simultaneous observations with serveral antennas are correlated between antenna pairs and then the shift of the cross-correlation (CCF) with respect to zero is measured. The shift reflects the motion of scintillation pattern, and $V_{\rm iss}$ can be calculated from the data.

Let us consider a model when the scintillation spot has an axial symmetry (for instanse, an elliptical spot). Let $\mathbf{v}$ be a constant velocity of the scintillation patern, $\mathbf{l}$ is the axis of symmetry, $\mathbf{r}_{ij}$, $\mathbf{r}_{jk}$ and $\mathbf{r}_{ki}$ are the bases between antennas i, j and k. Then

$$\begin{aligned} \tau_{mn} &= \frac{\mathbf{r}_{mn}\mathbf{v}_{\rm eff}}{v_{\rm eff}^2} \\ \mathbf{v}_{\rm eff} &= \mathbf{v} - \mathbf{l}(\mathbf{vl}) \end{aligned} \qquad (1)$$

The delay τ_{mn} is a measured shift of the CCF, $\mathbf{v}_{\rm eff}$ is an effective velocity of the scintillation pattern, $(\cdot)$ means a scalar product. Formula (1) shows we measure only the effective value of the velocity.

2. OBSERVATIONS AND DATA REDUCTION

We used the data of VLBI observations that had been carried out on 1998 August 22 and had involved up to 10 ground-based antennas around the world.

The wavelength of observations was 18 cm, the total duration of the experiment was 12 hours. The data were recorded at two intermediate frequencies, 1634 and 1650 MHz, each band had a width of 16 MHz. The correlation was performed at the VLBA correlator, both gated and non-gated data were produced. The fact we have data correlated both with and without gate regime allowed us to extract the pulsar intensity at each site from the VLBI data (see Semenkov et al. 2003 for details).

After that we selected 14 scintillation spots and correlated data between all the antennas in every spot. Two time scales are found in the cross-correlations (CCFs): a large scale of about 20 min and a small scale of about 1 min. We have determined the delay for each scale independently by fitting a sum of two Gaussians in a CCF.

3. RESULTS

Equations (1) were solved in the UV coordinate frame widely used in VLBI. A "synthetic" least squares (LSQ) method was applied to the system. It is evident (see Equation (1)) that the sum of delays around any closed contour should be equal to zero. So in every spot we: solved (1) using the common LSQ method (denoting the solution as $V_{\rm iss}^{\rm LSQ}$); solved (1) for every set of three antennas (denoting the solutions as $\{V_{\rm iss}^{\Delta}\}$) where the sum of delays did not exceed ± 5 s; plotted the angular distribution of $\{V_{\rm iss}^{\Delta}\}$.

If there was a distinct direction in the distribution of $\{V_{\rm iss}^{\Delta}\}$ and angle between $V_{\rm iss}^{\rm LSQ}$ and $V_{\rm iss}^{\Delta}$ did not exceed 20° then $V_{\rm iss}^{\rm LSQ}$ was supposed to be true and otherwise false. The results are presented in Figure 1.

A regular motion of the scintillation pattern is not present although every spot has a constant speed and diffractive spots do not dissolve during observations. The average velocity $V_{\rm iss} = \{-3 \pm 14, -22 \pm 12\}$ km/s, rms of the velocity is $\{19, 27\}$ km/s. The average module of the scintillation velocity is 39 ± 15 km/s. Therefore we suggest that the hypothesis about uniform motion of the scintillation pattern is wrong.

Let us compare our results with the predictions of thin screen model. According to the formula C15 from Gupta et al. (1994) and using proper motion by Brisken et al. (2002) we obtain that the expected value is $V_{\rm iss} = |\{80, -92.6\}|$ km/s = 122 km/s, what disagrees with our measurements.

We also built a spatial flux distribution in the strongest diffractive spot (since $13^{\rm h}41^{\rm m}$ till $14^{\rm h}5^{\rm m}$). The typical size of the spot is about 60 000 km.

4. CONCLUSIONS

The paper deals with measurement of scintillation pattern velocity from pulsar PSR B0329+54 at 1.6 GHz during 12 hours. A special method of amplitude calibratin allows to obtain light curves at all ground-based sites participating in the space VLBI experiment. The data analysis shows that the scintillation of the pulsar has two typical temporal scales (about 20 min and 1 min). We obtained the scintillation velocity by measuring shifts of the cross-correlation maxima. Scintillation spots are found to move independently, and a regular motion of the scintillation pattern is absent. The measured values of the drift velocity lie in the range

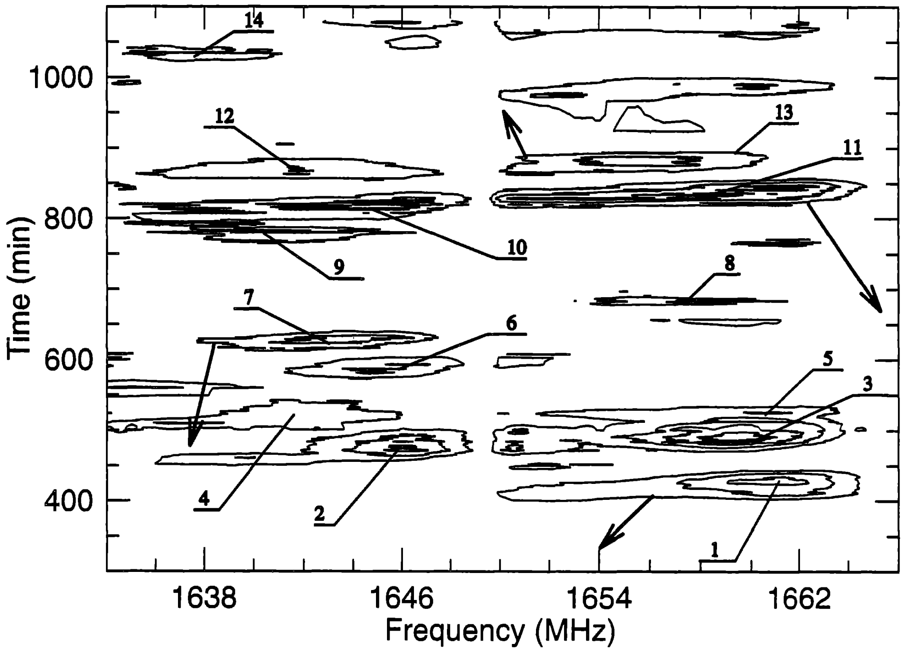

Fig. 1. Dynamical cross-spectrum (i.e., cross-spectrum versus time) of the pulsar during the observations. The interval of averaging over time is 1 min, over frequency – 500 kHz. Numerals on the picture are numbers of the spots, arrows represent valid $V_{\rm iss}^{\rm LSQ}$, the u axis is along the abscissa, the v axis is along the ordinate.

25–50 km/s, the average velocity is 39 ± 15 km/s whereas *a priori* value based on thin screen model and measurements of pulsar proper motion is 122 km/s. We believe thin the screen model is inapplicable in this case.

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REFERENCES

Brisken W. F., Benson J. M., Goss W. M., Thorsett S. E. 2002, ApJ, 571, 906

Gupta Y, Rickett B. J., Lyne A. G., 1994, MNRAS, 269, 1035

Semenkov K. V., Popov M. V., Soglasnov V. A., Hirabayashi H. 2003, Astronomy Letters, 29, 96