Pulsars : Problems & Progress
ASP Conference Series, Vol. 105, 1996
S. Johnston, M. A. Walker and M. Bailes, eds.

Investigation of pulsar diffractive scintillation at 4.75 and 10.55 GHz

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Many papers were in the past devoted to the investigation of the interstellar medium (ISM) with the help of pulsars, most of them studying the time and frequency structure of pulsar flux variations in the strong scintillation regime. Weak scintillation is typically found at cm- and dcm-wavelengths, but depends on distance so that the critical frequency (ν_c) increases with distance. Pulsar intensities weaken, however, at high frequencies, since as a rule pulsar spectra have spectral indices steeper than -1.5. This explains why there are practically no measurements of pulsars in the weak scintillation regime.

We report in this paper on first measurements of the correlation function of pulsar intensity fluctuations, of the decorrelation time $\tau_{\rm d}$ and of the scintillation index $m_{\rm d}$ at high frequencies, i.e. at 4.75 and 10.55 GHz in the weak scintillation regime. The detail data analysis, theoretical relations and comparison with theory will presented by Malofeev et al. (1996).

Weak scintillation is expected at high frequencies for pulsars with low dispersion measures. We selected for our observations therefore pulsars, which show strong emission at 4.75 and 10.55 GHz with dispersion measures in the range from 2 to 100 $\rm cm^{-3}$ pc, The observations were performed using the 100-m radio telescope of the MPIfR. The signals represented finally total intensity. We integrated individual pulses in the data logger over 16 seconds to obtain a better signal-to-noise ratio. To check the amount of noise we calculated the flux "off-pulse".

These two sequences of flux values were then analyzed in a second step of data reduction: (1) To increase the signal-to-noise ratio all data points were averaged over 4 or 12 blocks. It gives the possibility to smooth out intrinsic pulsar fluctuations. (2) The autocorrelation function (ACF), (3) the structure function, (4) and finally the power spectrum were computed . Most important for a meaningful analysis of the ISM properties is a clear separation between intrinsic pulsar emission fluctuations and variations imposed by the ISM. The following criteria were applied: a) An insight into the inherent time scales may be obtained from the ratios $b_{\rm s} = \sigma_{\rm s}/\sigma_{\bar{\rm s}}$ and $b_{\rm n} = \sigma_{\rm n}/\sigma_{\bar{\rm n}}$, where $\sigma_{\rm s}$ and $\sigma_{\rm n}$ denote the *rms* fluctuations of the signal and noise before averaging, and $\sigma_{\bar{\rm s}}$ and $\sigma_{\bar{\rm n}}$ after averaging. The distribution of $b_{\rm n}$ is close to normal as expected, with a mean value of $b_{\rm n} = 3.5$. The $b_{\rm s}$ histogram shows two maxima. The first one is near $b_s = 1.7$ and the second one between 3 and 3.5. b) We took as another criterion to ISM induced flux variations a value of the autocorrelation function ≥ 0.3 for lags greater than 3 minutes. c) Our third criterion was a power law form of the structure function. d) Our last criterion was the shape of the power spectrum, which is typically different for pulsars with and without scintillation.

Existing long-term flux variations as evident for example for PSRs 0355+54, 0329+54, 1929+10 are detected with high reliability by all four criteria. Most pulsars, however, show rather a mixture of intrinsic short-term fluctuations and those caused by interstellar scintillation. Measured values of the scintillation index ($m_{\rm d}$) and of the correlation time $\tau_{\rm d}$ (defined as half of the ACF at half the maximum value) were determined using 3 minutes averages.

Inspection of the $m_d(\nu)$ diagrams shows that the scintillation index decreases at frequencies higher than ν_c according to a power law. τ_d begins to decrease near this frequency as well and it is possible for some pulsars to fit a power law to the observed τ_d values below and above ν_c. Mean derived values of the indices α_1 and α_2 with $m_d \propto \nu^{\alpha_1}$ and $\tau_d \propto \nu^{\alpha_2}$ in the weak scintillation regime are given in Table 1. We will compare the measured scintillation parameters $m_{\rm d}$ and $\tau_{\rm d}$ with two kinds of models of the ISM: There exist models which are based on a Kolmogorov spectrum of the density irregularities of the ISM and there are models which are based on the assumption of a spectrum which may be approximated by more than one power law (broken power law form) (Shishov 1993). The relations between $m_{\rm d}$ and $\tau_{\rm d}$ and both frequency and distance will be analyzed as well as the relations between $\nu_{\rm c}$ and $\tau_{\rm c}$ and distance. The comparison of m_d, τ_d, ν_c and τ_c with distance are shown in Table 1. Analysis indicate that the three-dimentional spectrum of the electron dencity fluctuations may be approximated by a power law with an index $n \geq 4$ on a spatial scale of $10^9 - 10^{11}$ cm.

Table 1. Comparison between theory and observation

Rel.	$m_d \sim \nu^{\alpha_1}$	$\tau_d \sim \nu^{\alpha_2}$	$m_d \sim R^{\beta_1}$	$\tau_d \sim R^{\beta_2}$	$\nu_c \sim R^{\beta_3}$	$\tau_c \sim R^{\beta_4}$
Ind.	α_1	α_2	β_1	β_2	β_3	β_4
M.K	-1.17	-0.5	0.92	-0.5	0.65	0.18
M.B	-1.55	-0.5	1.05	-0.5	0.68	0.16
Obs.	-1.4 ± 0.3	-0.5 ± 0.2	1.3 ± 0.3	-0.14 ± 0.1	~0.76	≥-0.3

Acknowledgments. We acknowledge support from INTAS, project 94-3097. VMM and VIS acknowledge also support from the Russian grant RFFI N 94-02-06490a.

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https://doi.org/10.1017/S0252921100042172 Published online by Cambridge University Press