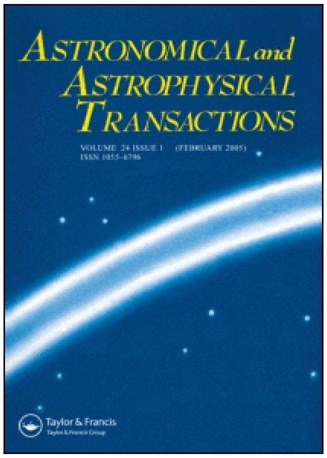

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INTERSTELLAR TURBULENT PLASMA SPECTRUM IN THE WIDE REGION OF TURBULENCE SCALES FROM OBSERVATIONS OF PULSARS

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$\rangle$

$$S = (\lambda r_e) \int_0^R \mathrm{d}r N_e = \alpha_s \left(\frac{f_0}{f}\right) DM \tag{2}$$

where $\alpha_s = 2,526 \cdot 10^7 \text{ pc}^{-1} \text{ cm}^3$, ρ is a two-dimensional vector between two points in the plane normal to the line of sight, DM – is a dispersion measure. For a power law spectrum $D_S(\rho)$ is described by the equation (Smirnova *et al.*, 1998):

$$D_S(\vec{\rho}) = A(n)(\lambda r_e)^2 C_{N_e}^2 |\vec{\rho}|^{n-2}, \tag{3}$$

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where $A(n)$ – the numerical coefficient, λ is the wavelength, r_e the classical electron radius. $D_S(\rho)$ describes the turbulence spectrum $\Phi_{N_e}(q)$ for the spatial frequency region near $q = 1/\rho$. The temporal structure function, $D_S(t)$, can be measured directly using pulsar timing data (Cognard and Lestrade, 1997) and it gives us the information about spectrum on a large spatial frequency q. The structure function (SF) of the variations of the time residuals $\delta\tau$ due to propagation in the turbulent medium, $D_{\delta\tau,\mathrm{turb}}(t)$, is reduced to $D_S(t)$ by the relation $D_S(t) = (2\pi f)^2 D_{\delta\tau,\mathrm{turb}}(t)$.

$D_S(t)$ can be measured for small values of t using data on intensity variations in the saturated scintillation regime. We will define the characteristic time scale of scintillation, t_{dif}, as $D_S(t_{\mathrm{dif}}) = 1/2$. The spatial scale of diffractive scintillation in the case of statistically homogeneous medium is connected with t_{dif} by a simple relation: $\rho = 2^{(n-2)} V_\perp t_{\mathrm{dif}}$.

Information about the structure function in the region of spatial scale of refractive scintillation can be obtained from measuring of modulation index, m_{ref}, and time scale of flux variations of pulsars, T_{ref}. There $\rho = V_\perp T_{\mathrm{ref}}$. Electron density inhomogeneities in the line of sight can be characterized by structure function:

$$D_{DM}(\rho) = \langle [DM(\rho_1 + \rho) - DM(\rho_1)]^2 \rangle \tag{4}$$

$D_S(\rho)$ is connected with $D_{DM}(\rho)$ by a linear relation $D_S(\rho) = 6.38 \cdot 10^{14} D_{DM}(\rho)$, where DM is measuring in pc/cm^3.

For construction of structure function in the wide range of scales we have to convert observations at different frequencies to a given frequency f_0: $D_S(\rho) = (f/f_0)^2 D_S(\rho)$.

Another thing that we have to do is to convert data to the same physical conditions: to the same effective thickness of medium causing scintillation, R_0, and to the same electron density, N_e. It is well known that ISM consists of two main components: A and B (Cordes *et al.*, 1985). Component A belongs to an outer arm homogeneous media. For it $DM < DM_0 \cong 30\,\mathrm{pc/cm^{-3}}$ and the main factor of scattering parameters variations in different directions is variation of distance and so, $DM \propto R$. As a standard we will use DM_0, $R_0 \cong 1$ kpc. For component A we have:

$$D_{S,0,A}(\rho) = D_S(\rho)(DM_0/DM) \tag{5}$$

Component B ($R > 1$ kpc) belongs to the spiral arms, it is inhomogeneous and the main factor of DM and scattering parameters variations is electron density variations (Punzar' and Shishov, 1997; Smirnova *et al.*, 1998). So to convert SF for pulsars with $DM > DM_0$ to the standard condition we will use:

$$D_{S,0,B}(\rho) = D_{S,B}(\rho)(DM_0/DM)^\alpha \cdot (R_{0,B}/R_{0,A})^{\alpha-1} \tag{6}$$

For construction of SF we choosed only pulsars with $DM \geq 30\,\mathrm{pc/cm^3}$ and known from literature measurements of diffractive time scales at different frequencies. We got $\alpha = 4.1$ from fitting the line in log-log scale to data of $D_S(DM)$.

In Figure 1 we show the composite structure function obtained from different kinds of observations which we converted to the same physical conditions using Eqs. 5 and 6. The open circles correspond to data from diffractive scintillation; stars are from scattering angle measurements at 326 MHz (Gwinn *et al.*, 1993); crusts are from flux variations of pulsars – refractive scintillations (Stinebring *et al.*, 2000); filled circles at scales less than 10^{15} m are from timing of PSR 1821–24 (Cognard and Lestrade, 1997) and PSR 0329 + 54 (Shabanova, 1995). To get the evaluation of structure function at the largest spatial scales

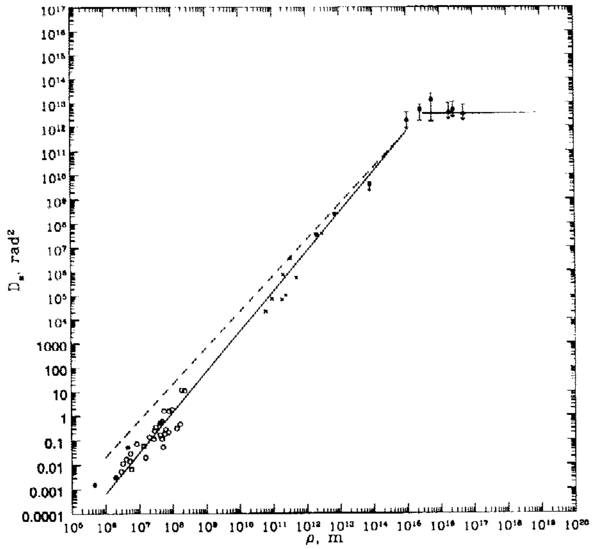

FIGURE 1 The complicated structure function versus spatial scale of ISM inhomogeneities. Solid line corresponds to Kolmogorov spectrum; dash line – for spectrum with $n = 3.5$.

we did analysis of DM variations of close pulsar pairs with the angular separation of $\Delta l \leq 0.1^\circ$ located in Globular Clusters. The spatial scale we defined as $\rho = R_0 \cdot \sin(\Delta l)/\sin(b)$, where $R_0 \cong 1\,\text{kpc}$ and b is a pulsar galactic latitude. Filled circles at scales $\rho > 10^{14}$ m correspond to mean values of SF inside of interval of ρ with the number of points not less than 6. As we can see from Figure 1 all data for distant pulsars can be described quite well by a simple Kolmogorov spectrum (solid line) in the very wide range of spatial scales: $(10^6 \div 10^{17})$ m and for $\rho \approx (0.05 - 2)$ pc structure function doesn't grow up and goes to the saturation level about $3.5 \cdot 10^{12}$. The outer scale defined as 1/2 of saturation level is 10^{15} m.

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References

Armstrong, J. W., Rickett, B. J. and Spangler, S. R. (1995). *Ap. J.*, **443**, 209.
Cognard, J. and Lestrade, J.-F. (1997). *A&A*, **323**, 211.
Cordes, J. M., Weisberg, J. M. and Boriakoff, V. (1985). *Ap. J.*, **288**, 221.
Gwinn, C. R., Bartel, N. and Cordes, J. M. (1993). *Ap. J.*, **410**, 673.
Punzar', A. V. and Shishov, V. I. (1997). *Astron. Zh.*, **74**, 663.
Shabanova, T. V. (1995). *Ap. J.*, **453**, 779.
Sieber, W. (1982). *A&A*, **113**(2), 311.
Smirnova, T. V., Shishov, V. I. and Stinebring, D. (1998). *Astronomy Reports*, **42**(6), 766.
Stinebring, D. R., Smirnova, T. V., Hankins, T. H., *et al.* (2000). *Ap. J.*, **539**, 300.