АСТРОФИЗИКА

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THE RADIO LUMINOSITY OF PULSARS AND THE DISTRIBUTION OF ELECTRON DENSITY IN THE GALAXY

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Radio luminosities of pulsars are depended on their periods and periods derivatives. The parameters of that dependences and the independent distances for 288 pulsars are determined. The known dispersion measures are used for determination of the mean electron densities in the direction of pulsars. The obtained results are used for investigation of the large-scale distribution of electron concentration in the Galaxy. The maximum value of that distribution is found at the distance of 9 kpc from the galactic centre in the Sagittarius arm. In the inter arm regions electron density decreases roughly exponentially.

1. *Introduction.* The general observational parameters such as period, period derivative, etc. have been determined for most of pulsars (PSRs). This makes possible to use them in statistics.

For most PSR distances are determined by means of both the dispersion measure value (DM) and the mean electron concentration (n_e) on the line of sight.

$$DM = \int_0^R n_e dr = \bar{n}_e R. \tag{1}$$

The first parameter is defined from observations. For the second one a value of the electron concentration in solar vicinity is adopted, which is equal to $\sim 0.03 cm^{-3}$.

The distances determined in such a way could contain large sistematic errors, because of an insufficient knowledge of the electron density distribution in the Galaxy. In present paper we examine the possibility to determine the luminosities of PSRs without knowing the distances to them beforehand. It allows us to calculate the PSR distances without values DM and n_e . Having the pulsars distances, found by independent method we can calculate the mean value of electron density in the direction of each pulsar from (1) and then reconstruct its distribution in the Galaxy.

2. *The Radioluminosities of Pulsars.* It is generally accepted that pulsars emit at the expence of the rotation energy loss. Apparently the bolometric luminosity of PSRs depends on the total rotation energy and on the rate of spin up down[1], which is determined by period P and period derivative $dP/dt = \dot{P}$ of PSRs. On the other hand, if we accept, that the rotation energy of PSR spin up down due to the magnetodipol emmision, then the magnetic field of PSR be equal $B_0 - P\dot{P}$ and the energy loss rate is $W \sim B_0^2$ [2]. So one may write that the bolometric luminosity depends on P and $\dot{P}$ as

$$L = \gamma P^{\alpha} \dot{P}^{\beta} \tag{2}$$

where α, β and γ are unknown parameters.

A more complete information about PSRs is obtained at the frequency 400 MHz, therefore we shall use the radio luminosity at the same frequency determined as in [2]

$$L_{400} \sim \frac{W_e}{P} S_{400} R^2 ,$$

where R is the distance of PSR from the Sun, S_{400} is the emission flux density and W_e is the pulse equivalent width. So we have

$$\frac{W_e}{P} S_{400} R^2 = \gamma P^{\alpha} \dot{P}^{\beta}. \tag{3}$$

Taking logarithm of (3) we can obtain a linear equation concerning α, β and logγ . Such an equation one may write for each pulsar separately in the form of

$$\log\left(\frac{W_e}{P} S_{400} R^2\right) = \log\gamma + \alpha \log P_i + \beta \log P_i \tag{4}$$

where i=1,...,N (N is the PSRs number). The solution of the system (4) by the least square fit gives the values of parameters a, b and logg . It should be noted, that in the papers [3,4] the following values of parameters respectively were obtaind: a =-1.04±0.15, β=0.35±0.06 and a=-0.86±0.2, β=0.38±0.08.

In this paper we used a greater number of PSRs than in [3,4] and the obtained results are used for the study of distribution of free electrons concentration in the Galaxy. The needed parameters (W_e, P, $\dot{P}$, S_{400}, R) are known for 288 PSRs [2]. Using these data, the α, β, γ, its dispersions and the correlation coeficient (ρ) were defined from the system of linear equations (4). The obtained results are shown in Table 1.

Table 1

P(sec)	*N*	logγ	α	β	ρ
All	288	8.26 (0.0008)	-1.42 (0.19)	0.33 (0.013)	0.43
<0.7s	148	10.03 (0.0012)	-0.61 (0.41)	0.43 (0.037)	0.34
>0.7s	140	6.86 (0.0010)	-2.11 (0.49)	0.23 (0.018)	0.34

The pulsars with periods P>0.7s and P<0.7s are distinguished by the distribution of duty cycle (*We/P*)[5]. Since the value *We/P* figures in the equation (4), we have solved the system (4) for two groups separately. The calculations are shown in Table 1. Hence it is seen that the values α and β, obtained for all pulsars, are close to the results of other authors.These parameters are strongly differ from each other for isolated groups. It speaks in favour of independence both short-period and long-period pulsars and differences between them by various features. So let us write the relation (3) in the form:

$$R_i = \sqrt{\gamma \frac{P^{\alpha+1} \dot{P}^{\beta}}{S_{400} W_e}} \qquad (5)$$

Using the calculated parameters α, β and γ, obtained for two groups separately and observed values S_{400}, W_e we have defined the new distances of pulsars. How far the obtained distances are true? It will be discussed in the next section.

3. The Distribution of The Galaxy Free Electrons. The study of the large-scale distribution of free electrons in the Galaxy is of great theoretical and

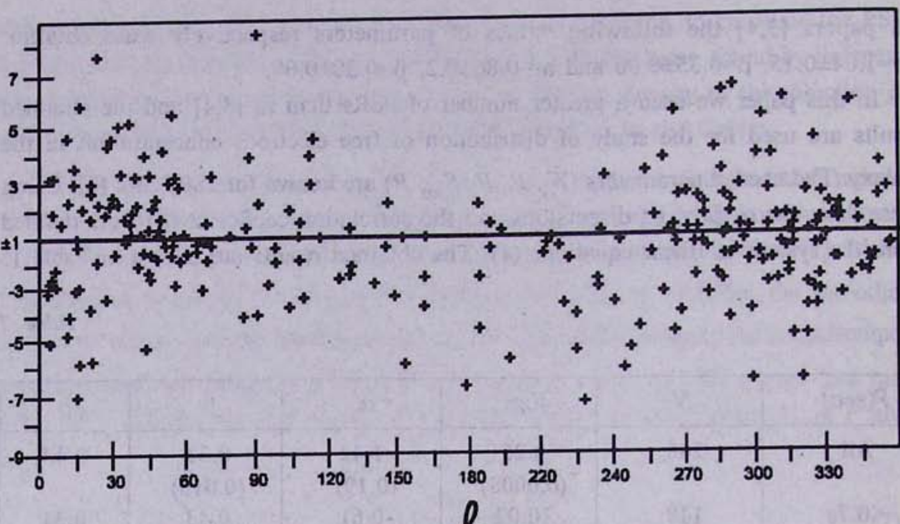

Fig. 1. The mean relative electron density as a function of Galactic longitude. In the cases when n_e>0.03 and n_e<0.03 we have taken the values n_e/0.03 and -0.03/n_e respectively.

practical importance. The values of dispersion measure and the pulsar's distances, determined by independent method are used for determination of the mean electron density in the direction of pulsars (see for example[6]). The relation between the electron density and the height of pulsars over the Galactic plane in the solar vicinity has been obtained

$$n_e(z) = n_0 e^{-z/h},$$

where n_0 =0.03 cm^{-3}, h - 1000 pc.

Now we shall use the distances obtained in preceding section for the study of the large-scale distribution of free electrons. Using the relation (1) and obtained distances R_t (5) the mean electron density has been found in the direction of 288 pulsars

$$\overline{n}_e = \frac{DM}{R_t}.$$

In Fig. 1 we plot the relative electron density as a function of Galactic longitude. We can see that the values n_e are higher, regardless of a large dispersion, than the mean electron density (~ 0.03) in directions to the Galactic centre and are well below of the value 0.03 in opposite directions($120^0 < l < 240^0$).

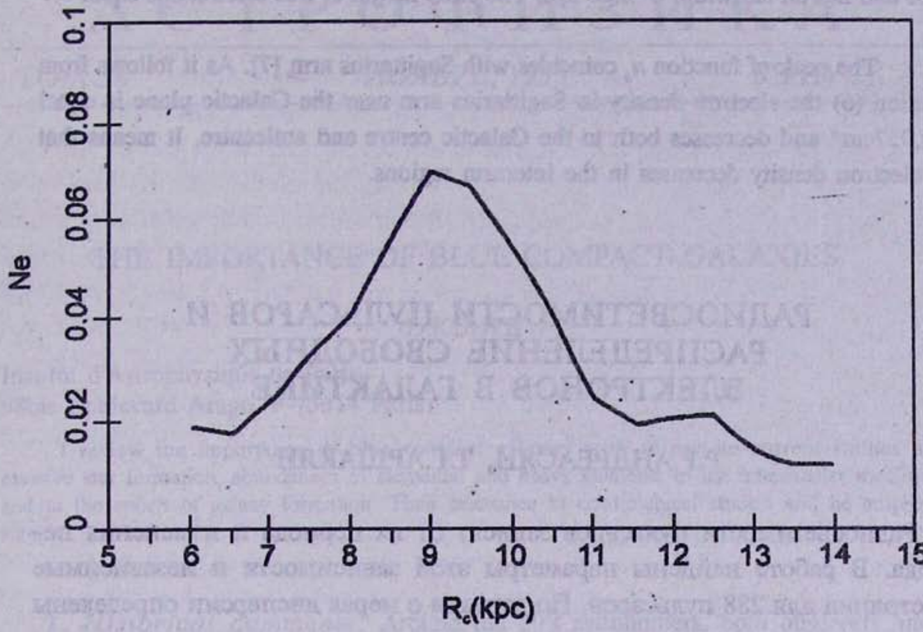

Fig. 2. The mean electron density versus Galactocentric distances. The PSRs with R_t<1kpc were excepted because the neighbouring dense HII regions can essentially increase the mean electron density in the given direction.

Since distribution of the free electrons coincides with the space distribution of HII regions surrounding O-B stars, associations and young star clusters and they are sources of free electrons, then one may suggest that obtained distances R_t are well defined. For this purpose we plot the mean electron density versus Galactocentric radius (Fig.2). It is seen that there is a dependence between the values n_e and r_c. This relation could be aproximated by the function in the range of 6 kpc to 12 kpc (β =2)

$$n_e(r_c, z) = n_1 + n_0 e^{-z/h_e[(r_c - r_0)/\sigma]^\beta}, \qquad (6)$$

where the terms $e^{-z/h}$ and $e^{[(r_c-r_0)/\sigma]^\beta}$ describe the variation of electron density by z and by Galactocentric radius respectively.

Varying the values n_1 and r gives most probable values for n_0, h, and σ :

n_0 =0.052cm^{-3}, r_0 =9 kpc, σ=2.88 kpc,

n_1 =0.005cm^{-3}, h =0.7 kpc.

We obtained a symmetric function, which reaches to its maximum at the distance

9 kpc and has an halfwidth σ=2.88 kpc. The scale height of free electrons is equal 0.7 kpc.

The peak of function n_e coincides with Sagittarius arm [7]. As it follows from equation (6) the electron density in Sagittarius arm near the Galactic plane is equal to $0.057 cm^{-3}$ and decreases both to the Galactic centre and anticentre. It means that the electron density decreases in the interarm regions.

РАДИОСВЕТИМОСТИ ПУЛЬСАРОВ И РАСПРЕДЕЛЕНИЕ СВОБОДНЫХ ЭЛЕКТРОНОВ В ГАЛАКТИКЕ

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Радиосветимости пульсаров зависят от их периода и изменения периода. В работе найдены параметры этой зависимости и независимые расстояния для 288 пульсаров. По данным о мерах дисперсии определены средние плотности в направлениях пульсаров и крупномасштабное распределение электронной концентрации в Галактике. На расстоянии 9 кпк от центра (в рукаве Стрельца) наблюдается максимум распределения. В межрукавных областях электронная концентрация убывает экспоненциально.

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