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# Problem of the Estimate of Distances to Pulsars*

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*Abstract*

We analyse the distributions of regions of star formation and supernova remnants. From this analysis our knowledge of the distribution of pulsars and of the electron concentration in the vicinity of the Sun is improved.

It is known that the distance to pulsars is determined by the dispersion measure (DM), a function of the number of electrons in the line of sight. The value of DM can be determined with high accuracy. However, because of large uncertainties in the distribution of electron concentration $n_e$ in the Galaxy, distances to pulsars are not well known. Still, the results of statistical investigations of pulsars are, for example, more certain than those of unidentified X-ray sources. In the latter case there is not a parameter similar in accuracy to DM, and the break in the spectrum in the long-wave region is determined both by the quantity of hydrogen atoms in the line of sight and by the source temperature. Can we for certain identify the number of hydrogen atoms in the line of sight to some definite distance? No, we cannot; although the average distribution of neutral hydrogen in the Galaxy is known, it is very difficult to estimate the number of hydrogen atoms. There are large inhomogeneities in the distribution, though to a lesser extent than dust. There are also uncertainties connected with the Galaxy's rotation curve. It is obvious that model conceptions about the distribution of hydrogen in the Galaxy and, in particular, electron concentration and dust are very rough. From observations of starlight extinction we see changes in the distribution of dust in directions differing only by one angular degree. Along the line of sight there are abrupt changes of absorption and interstellar polarisation of light.

Up to date 422 pulsars are known, most of which are located at a distance within 3 kpc of the Sun. Their distribution is caused, first, by a considerable increase in the space density of pulsars with decrease of luminosity and, second, by the decrease of sensitivity of the search with DM growth and the decrease of pulse period $P$. Therefore, in the determination of distances for most pulsars, one must proceed from

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the data on objects located in the vicinity of the Sun, the number of electrons in the line of sight being dependent on them. However, the average data for the whole Galaxy may turn out to be different for the local region in the vicinity of the Sun. Giant regions of ionised matter are rather far from each other, and therefore averaging is more accurate only at large scales comparable with the galactic radius. Proceeding from this we have determined (Guseinov *et al.* 1981; Guseinov and Yusifov 1984) distances based on the set values of $n_e$ taking different distances from the Sun and in the chosen intervals of galactic longitude $l$.

At present the relationship between pulsars and massive stars is not doubted. Massive stars are concentrated in the galactic regions where star formation occurs. These regions generally have small $z$-coordinates. It is true that, in some places, centres of star formation regions move away from the symmetry plane to a distance of $z = 100$–$120$ pc. On the other hand, it is known that pulsars move away from the galactic plane during their life to distances of up to 300–400 pc. Among young pulsars, those born at large $z$ are discovered more easily. Therefore, on average, known pulsars must be distributed symmetrically relative to the galactic plane.

We have considered the $z$ distribution of pulsars in various directions and distances from the Sun and found regions where pulsars have different $z$-coordinates from the mean value of most pulsars. It is obvious that unknown regions of ionised matter must lead to an overestimation of distances to pulsars, and thus of their $z$-coordinates. For pulsars in whose lines of sight the actual values of $n_e$ are lower than the average one, underestimated values of $z$ will be obtained. Therefore, we chose values of $n_e$ so that pulsars in all directions and at all distances would fill a volume of approximately the same height and would not be found beyond the limits of the Galaxy with an assumed radius of 15 kpc.

In the work by Guseinov *et al.* (1981) this principle was satisfied by taking into account H II and star formation regions. It turned out that estimates of distances in this work agree better with distances obtained from H I than with the data in the catalogue by Manchester and Taylor (1981). Note that on the basis of the distribution of model $n_e$ (Manchester and Taylor 1981) there is a symmetry in relation to the galactic centre, but that this symmetry is strongly distorted in the vicinity of the Sun, as shown by consideration of H II regions and distances to pulsars obtained from H I. In the work by Guseinov and Yusifov (1984) the distances were obtained by taking into account known distances to pulsars obtained from H I. We do not consider here the works by Harding and Harding (1982), Gailly *et al.* (1978), Lyne *et al.* (1985) and Vivekanand and Narayan (1982) on the distribution of $n_e$ and distances to pulsars as they are well known.

Investigating pulsars with proper motions (Lyne *et al.* 1982; Downs and Reichley 1983; Amnuel *et al.* 1986) showed that they were born in most cases in regions of concentrations of OB associations. Note that the observed ring-shaped distribution of pulsars points to their connection with arms and regions of star formation which have ages larger by an order of magnitude than individual OB associations. Therefore young pulsars—those with small values of the characteristic time $\tau$—in most cases must be located in the vicinity of OB associations.

In three regions of the Galaxy, deviations of the centre of gravity of OB stars from the symmetry plane to more than 70 pc are known (Voroshilov *et al.* 1982). In these regions pulsars with $\tau < 2\times10^6$ yr are located in the same semi-planes of the Galaxy where OB stars are concentrated (Guseinov and Yusifov 1987). Finally, in the work by Allakhverdiyev and Guseinov (1987) it was shown that the delay time of a Type I supernova outburst, i.e. the time separating the outburst from the end of the evolution of the main component of a close binary, in most cases is $\sim 10^8$ yr. Therefore, even if Type I supernova outbursts, similar to Type II, lead to the formation of pulsars,

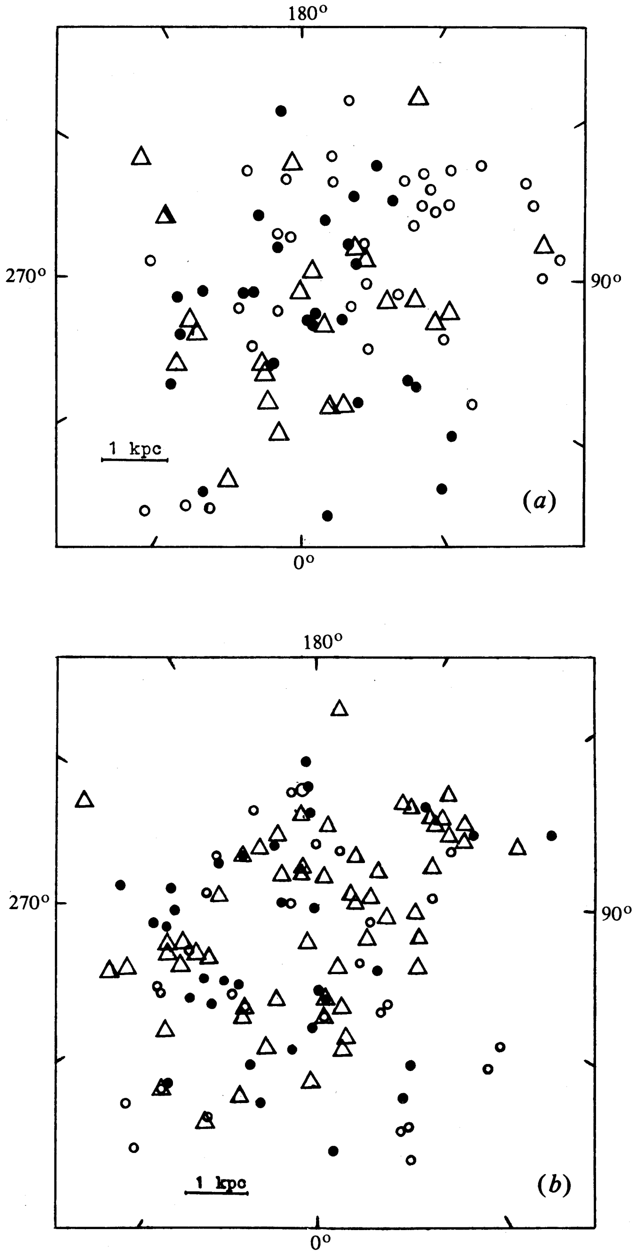


**Fig. 1.** Distribution of objects within 4 kpc of the Sun for (*a*) $b > 0°$ and (*b*) $b \leqslant 0°$. OB associations are given by triangles, pulsars with $\tau \leqslant 2\times10^6$ yr by solid circles, and SNRs by open circles.

then in this case pulsars must also be connected with regions of star formation. So, the location of young pulsars in the regions of star formation must be the second principle in adopting the distribution of $n_e$ in the Galaxy and in estimating distances to pulsars.

In Fig. 1, maps of the location of OB associations (shown by triangles) are given in the vicinity of the Sun, according to the data of Humphreys (1978). Also shown are pulsars with $\tau < 2\times10^6$ yr (solid circles), distances to which were determined by setting $n_e$ in the form given in Fig. 2. Here distances to all pulsars are determined by a method similar to that by Guseinov *et al.* (1981) and Guseinov and Yusifov (1984), with the additional requirement of the second principle mentioned above. Supernova remnants (SNRs) with distances taken from the work by Allakhverdiyev *et al.* (1986) are designated by the open circles in Fig. 1.

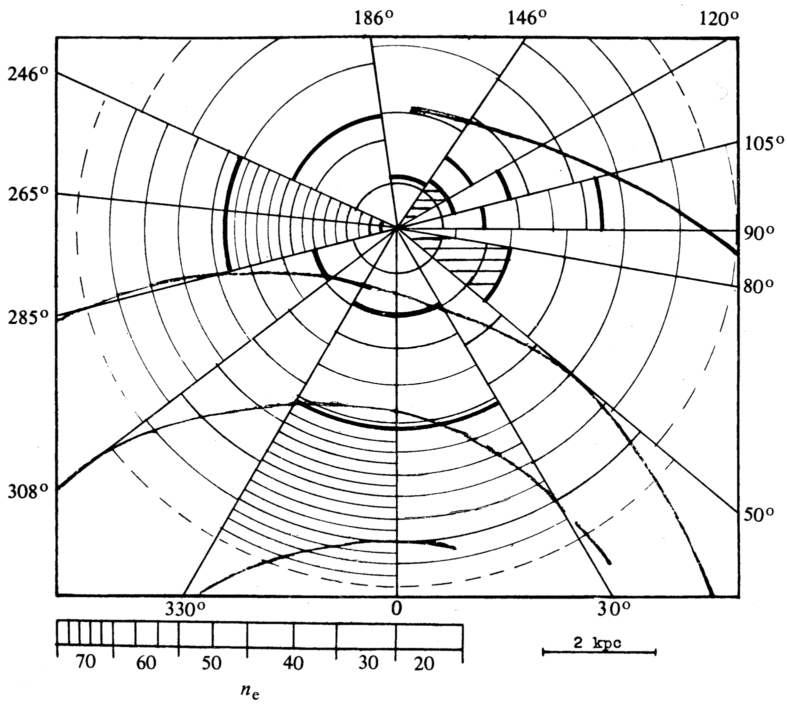


**Fig. 2.** Distribution of electron density $n_e$ in units of $0 \cdot 001$ cm$^{-3}$. In the double-hatched regions at $b \leqslant 0°$, $n_e$ is taken to be $0 \cdot 02$ cm$^{-3}$. The spiral lines represent the spiral arms of the Galaxy.

For PSR 0833−45 and PSR 1509−58 distances are known in connection with the SNRs G263·9−2·0 and G320·4−1·2. Their distances are, respectively, $\sim 2 \cdot 2$ and $\sim 1 \cdot 5$ times less than the values obtained according to the suggested model $n_e$. The individual distance value of $0 \cdot 16$ kpc has also been taken for a third pulsar PSR 1642−03. By our model $n_e$ the distance of $1 \cdot 1$ kpc for this pulsar is obtained. This is quite unacceptable because in this case the estimated values of the component of the velocity directed to the galactic plane turn out to be too large (Amnuel *et al.* 1986). The accepted distance, close to the actual one for this pulsar, was given earlier by Lyne *et al.* (1982).

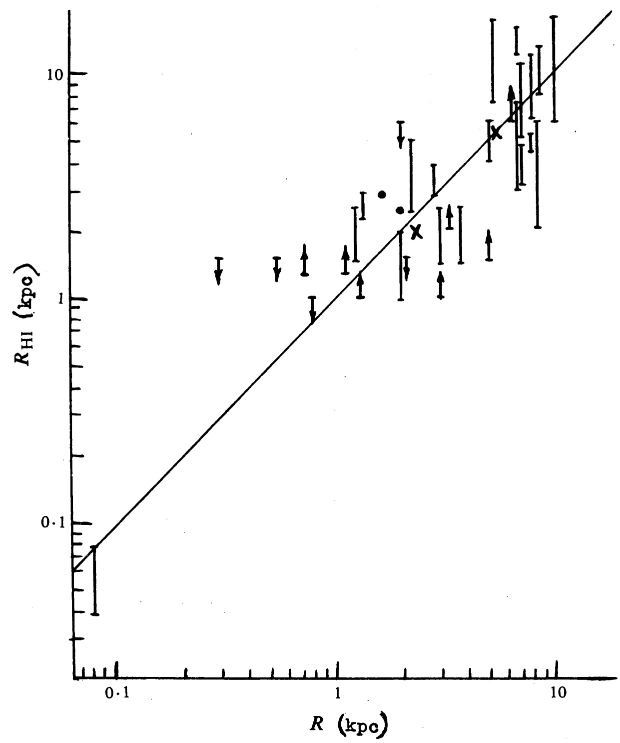


**Fig. 3.** Comparison of model distances to pulsars with those obtained by H I lines. The crosses are for PSR 0531+21 and PSR 1937+21.

In Fig. 3 the degree of conformity between our new distance values and those obtained by the H I line (Manchester and Taylor 1981) is shown. The three pulsars with individually set distances are not shown. For PSR 0531+21 the model gives the reasonable distance of ~2·3 kpc, as well as the same distance for the millisecond PSR 1937+21, the distance to which was also obtained by H I (Heiles *et al.* 1983). Both pulsars are shown in Fig. 3 by crosses. It is obvious that the number of pulsars with independently measured distances must grow further as no model can take into account all the changes in $n_e$ values.

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