A Trustworthy and Simple Method to Determine Pulsar Distances and the Electron Distribution in the Galaxy

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Abstract

We present the model for determination of pulsar distances or average electron distribution using a method similar to the widely used dependence of $A_V$ on distances in different directions. To have reliable pulsar distances, we have used several natural requirements and distances of pulsar-calibrators. We have constructed dispersion measure-distance relations for pulsars in 48 different directions.

KEY WORDS: PULSAR DISTANCES, ELECTRON DISTRIBUTION, GALAXY
1 Introduction

In this paper, our goal is to give dependence between the dispersion measure (DM) and distances (d) for radio pulsars (PSRs) in each different direction, similar to the dependence between $A_V$ and distance. Naturally, degree of irregularity in electron distribution in the Galaxy is very small when compared with dust distribution. Most of the times, as a rule, a mathematical model for electron distribution is used to find distances of PSRs in the Galaxy. Using such models, PSR distances can be found with much error. Moreover, some of the PSR distances do not agree with the models. For them, individual distances are given. This is natural and this will not change even if perfectly complete models are constructed and used. We determined the distances to PSRs by using natural requirements (which will be explained) and distances which are well known by independent methods. This provided us with the knowledge to construct DM-distance relation for PSRs and the Galactic electron distribution very easily and with much less error.

2 Some Necessary General Information Which We Must Take into Consideration in the Construction of d-DM Relations

1. As it is known boundary mass of the progenitors of white dwarfs (WD) and neutron stars (NS) ranges from about 5 $M_\odot$ (Lorimer et al. 1993; Strom 1994) up to 6-11 $M_\odot$ (Weidemann 1990). We consider 7-8 $M_\odot$ (Nomoto 1984; Aydın et al. 1996) as a better value for the boundary mass which corresponds to main sequence stars with spectral class B3V. Error in this mass value (in spectral class) must be greater for NS which are born in close binary systems.

2. According to Garmany & Stencel (Garmany & Stencel 1992) 75% of O stars and 58% of stars with spectral classes B2V and earlier, are born in OB associations. In addition, many young open clusters (they contain O or early type B stars and massive supergiants) are located far from OB associations. However, progenitors of PSRs may be located in regions where there are no nearby open clusters or OB associations. For example, near the Sun, within a region of radius 110 pc there are 6
stars with masses about 9 $M_\odot$ where there are no young open clusters (Zombeck 1990). Similarly we know that there are no O stars or young open clusters and also no HII regions, near the Crab PSR (Lynga 1987; Barbon & Hassan 1996). In these cases, where a PSR is located far away from young open clusters or OB associations, the progenitor may have a smaller mass of about 6 $M_\odot$ or it might be a runaway star.

3. Sizes and masses of molecular clouds (MC) change in very large intervals (Patel & Pudritz 1994). MCs are generally located in galactic arms, and their distribution is highly inhomogeneous. Therefore stars may be born in small groups (open clusters-OC) and big clusters (OB association). One big association may consist of several open clusters with ages up to (5-6) $10^7$ years. This means, the duration of star formation in one large OB association might continue for such long times (Aydın et al. 1997). As the average life times of most of the single PSRs do not exceed this value, in such a short time positions of arms, big star formation regions (SFRs, which contain several OB associations and many OCs) and OB associations do not change in the Galaxy.

4. Dependence of the number of main sequence stars on their masses has an exponential character. For different star formation regions in the Galaxy (also in Magellanic Clouds) the degree of this exponent may change from 1.5 up to 2.5 (Salpeter 1955; Blaha & Hamphreys 1989; Parker & Garmany 1993; Garmany et al. 1982). Error in the value of the degree of the exponent is higher for massive stars. Naturally, these uncertainties lead to uncertainties in number-mass distribution of PSR progenitors. We may accept that the size of the birth place of PSRs not to be limited with the size of the SFR. This is because the distribution of young PSRs and SNRs in the neighborhood of Sun (closer than 3 kpc) indicate that these objects may be born far from SFR and OB associations.

5. As well known, the distances for radio PSRs and all young objects such as HII and HI regions and molecular clouds in average cannot be determined better than 30%. Therefore the location of galactic arms and SFR, for which we have not detected enough number of massive
stars, are defined only roughly. Despite that, their directions are very well known.

6. It is well known that the luminosity of single PSRs \( L = F \nu d^2 \text{mJy kpc} \) at 400 MHz practically does not depend on spin period \( (P) \) and period derivative \( (\dot{P}) \), i.e., the positions of PSRs on the \( P-\dot{P} \) diagram. For this reason radio luminosity of single PSRs depend very weakly on the magnetic field strength of NSs \( (B=3.3 \times 10^{19}(P\dot{P})^{1/2}) \) and their rate of rotational energy loss, \( \dot{E}=4\pi^2 I\dot{P}/P^3 \) (Allakhverdiev et al. 2002; Guseinov et al. 2002a). Therefore we may accept that radio luminosity of single PSRs practically does not depend on their ages, the masses and duplicity of their progenitors (but close binaries may be an exception).

7. The average velocity of a single PSR is about 250 km/s (Allakhverdiev et al. 1997; Hansen & Phinney 1997). Therefore PSRs with ages up to \( 5 \times 10^5 \) years cannot runaway from their birth places to distances more than 200 pc (which corresponds to 160 pc if we project this velocity to the Galactic plane). But even for PSRs whose velocities are very high (a very small number of them), it is practically impossible for them to pass from one arm to another in a time shorter than \( 10^6 \) years. Sizes of huge SFRs which are located in the arms may approach to 1 kpc. The distance between the arms is about 1 kpc or more. Therefore PSRs with ages up to \( 5 \times 10^5 \) years stay at birth places.

3 Deviation of Star Formation Regions (Part of the Arms) From The Plane of Symmetry of the Galaxy

Only old population stars (stars with ages about \( 10^{10} \) years) can come to dynamical stability. The scale height and number density distributions in the Galactic center direction of old and young population stars are different. This shows that old and young populations stars are not in equilibrium with each other, because the scale height and density distributions of the two populations are different. The total mass of gas and young stars located in the Galactic arms is only about 1-3% of the mass of the whole Galaxy.
and the parameters of these arms change with a characteristic time $\sim 10^9$ years. SFRs in the arms are yet more unstable having ages about an order of magnitude less than the characteristic ages of the arms of the Galaxy. Here, the arms are neither in dynamical equilibrium with the Galaxy, nor with SFRs. Therefore not in all regions on the geometrical plane, arms must be coincident with the geometrical plane of the Galaxy. For some regions SFRs may stay higher or lower from the plane of the Galaxy. As shown by optical observations of cepheids with high luminosities (with long pulsation periods) and red supergiants, which are located at distances about 5-10 kpc from the Sun, in the direction $l=220^\circ-330^\circ$, SFRs lie about 300 pc below the plane of the Galaxy. At the same distance, in the direction $l=70^\circ-100^\circ$ it is found that SFRs lie about 400 pc above the plane of the Galaxy. The young objects closer than 3-5 kpc in the direction $l=270^\circ-320^\circ$ are located about 150 pc down the geometric plane of the Galaxy (Berdnikov 1987). Figure 1 displays l-z distribution of 108 galactic PSRs with characteristic ages $\tau<5 \times 10^5$ years and distances $>5$ kpc. As seen from the figure between $250^\circ < l < 300^\circ$ these young PSRs are below the galactic plane and between $50^\circ < l < 80^\circ$ they are above the plane. These data must be taken into account in estimating distances of PSRs and in the construction of the electron distribution model of the Galaxy.

4 Distribution Of Electrons In The Galaxy

Irregularities have been observed in the distribution of dust, molecular clouds and neutral Hydrogen (HI) in the Galaxy. It is also natural to expect irregularities in the electron distribution where the degree of irregularity is (naturally) considerably small. Considerable variations in opacity and interstellar polarization can be observed for stars with the same distance in a very small region of sky ($\sim 1^\circ$ square) close to the Galactic plane (Nickel & Klare 1980). This is due to the highly inhomogeneous distribution of dust clouds. For determination of hydrogen column density along the line of sight, there are two surveys that included large number of stars; one with 554 stars (Diplas & Savage 1994) and the other with 594 stars (Fruscione et al. 1994). Both of these surveys show that HI distribution and its degree of irregularity are quite different from the distribution (and its the degree of irregularity) of dust
and MCs (Ankay & Guseinov 1998). The dispersion measure (DM), which is related with the electron distribution, is different for PSRs with similar distances, but for different locations on the sky. These irregularities in electron distribution are due to the contribution of both HII regions and SNRs along the line of sight, and also the gravitational potential, the gas temperature and the cosmic ray distribution in the Galaxy. Even, in the central part (halo) of the Galaxy, novae and planetary nebulae have very small contribution to the electron density in large scale and to the background radio radiation. But irregularities in electron distribution is considerably smaller than the ones in other components of interstellar medium that we have mentioned above. Even though these irregularities are small, there is no simple model for Galactic electron distribution to calculate each pulsar’s distance. Moreover, constructing a complex mathematical model which requires a lot of data for different components of the interstellar medium and for PSRs (e.g. Taylor & Cordes 1993) cannot avoid large errors in the distances of individual pulsars.

Number density distribution of electrons in the Galaxy depends on the galactic longitude $l$, latitude $b$ and distance from the Sun $d$. However, in some directions the number density of electrons change considerably under small changes of $l$, $b$ and $d$. This has been taken into account for a long time when estimating the PSR distances (Guseinov et al. 1978; Taylor & Cordes 1993). Dispersion measure for PSRs is defined through $DM = \int n_e dl$; where $l$ is the distance to the PSR and $n_e$ is the electron density in the line of sight. DM naturally depend on the number of HII regions and SNRs on line of sight and their electron capacities (Lyne & Graham-Smith 1998). Of course, for PSRs with small distance from the Sun the value of DM strongly depend on the number of HII regions and SNRs on the line of sight mainly in the anticenter direction. The best example is the Vela PSR. Is this statement valid as a rule for distant PSRs (with distances more than 3-4 kpc)? If it is valid, the value of DM must strongly depend on the number of HII regions (OB associations) in the line of sight, and their electron capacities. If it is true, then contribution of electrons between the arms must be small in the value of DM. In other words, when we consider a direction between the arms we should expect small contributions to the value of DM.

As well known, the value of DM for PSRs are obtained very precisely by comparing their distances and distances for all objects (including also normal stars) which determines the location of the arms. We take this into
account and show in Figure 2 the dependence of the values of DM for PSRs with characteristic ages $\tau \leq 5 \times 10^5 \text{ yrs}$ on galactic longitude $l$. As seen from Figure 2 there are clusterings in the value of DM around some values of $l$ (in the line of sight). The clusterings are easily seen for directions $l=300^\circ$ and $l=360^\circ$. If there are empty regions (where there is no SFR) in the line of sight, then there are clusterings. Figure 3 represents the galactic distributions of PSRs with $\tau \leq 5 \times 10^5 \text{ yrs}$ and shows a similar effect. We compare these figures with the picture of galactic arms (see Figure 4) given in Georgelin and Georgelin (1976) which was constructed by utilizing the space distribution of giant HII regions. Note that the distance between the Sun and the galactic center is given as 10 kpc (correct value is 8.5 kpc) in this figure. Clustering of young PSRs may be an evidence that dominant number of PSRs are born inside or close to OB associations and SFRs. As seen from Figures 2, 3 and 4, in the directions where the distance between the SFRs are large, young PSRs and giant HII regions are practically absent or very rare, value of DM continues rapidly to increase. How can we interpret this fact? SFRs and OB associations spatially occupy only a small part of arms and their cross-section, where active PSRs are born. Of course, electron density and total number of electrons considerably increase in HII regions and SNRs. But the value of DM, as seen in Figure 2, changes smoothly in the plane of Galaxy. Therefore the value of electron density is also large for regions between the arms. Naturally the number density of electrons increase in galactic center direction rapidly. But this increase depends on and also form the ability SFR today in different directions in the Galaxy. In Figure 2, it is seen considerable difference between the DM values for PSR with approximately equal distance from the Sun ($d=5.5–6.5 \text{ kpc}$) in symmetrical longitude directions $l$ about $300^\circ$ and $l$ about $60^\circ$. As it is known these directions have been scanned carefully in search of PSRs with almost the same accuracy.

5 How we estimate the distances of PSRs

In order to investigate the arm structure and the locations of SFRs around the Sun within a distance of 4–5 kpc, usually OB associations, OCs and red supergiants are studied. For these objects the relative errors in estimating their distances can be 30% (Humphreys 1978; Efremov 1989; Aydm et
al. 1996; Ahumada & Lapasset 1995). There is no single good method to estimate the distance of all extended objects belonging to the arms (MCs, neutral Hydrogen clouds, SNRs and HII regions). In determining the distances to these objects using HI 21 cm line and Galaxy rotation models, the error exceeds 30%. It is known that it is impossible to calculate an object’s distance using HI line at 21 cm if the object’s radial velocity component of Galactic rotational velocity is small. In addition to this, in certain directions (in the vicinity of longitude l=0°) and distances the hydrogen lines gives two different distance value. However, it is the most widely used model.

It is a well known fact that no relation has been found in PSR parameters to estimate their distance. For ordinary distant stars, however, one can use the relations either between luminosity and spectral class, or luminosity and pulsation period to estimate their distance. In the early days of PSR astronomy between 1970 and 1980, since the origin of pulsars, the mass of their progenitors and their birth rates were not well known (even worse than today). Therefore, a homogeneous electron density distribution in Galaxy had been assumed. In doing this, one should also know some of the pulsar distances independent of their DM. Thus, PSRs with distances estimated using HI line in general are used as an extra distance calibrator (Manchester & Taylor 1981). However, later on PSR distances have been estimated according to the rough model of Galactic electron distribution and some natural requirements (Guseinov & Kasumov 1981; Johnston et al. 1992; Taylor & Cordes 1993; Gök et al. 1996). Nowadays, calibrators are chosen from members of globular clusters (GCs) or Magellanic clouds (MC), PSRs connected to Supernova remnants (SNRs) with well known distances and from PSRs whose distances are known from other available data (Lyne & Graham-Smith 1998). In determining the calibrators for PSRs, distance estimates calculated using the 21 cm line are not accepted as a rule.

In estimating pulsar distances, the model of Galactic electron distribution constructed by Taylor and Cordes (Taylor & Cordes 1993) has been widely used in recent years. However, in estimating the pulsar distances, the approach of Gök et al. (1996) gave smaller distances than the ones calculated using the model of Taylor and Cordes (1993) for PSRs farther than 4 kpc and also for PSRs with Galactic latitudes greater than about 10°at distances d>1 kpc. To form a new model electron distribution, Gómez et al. (2001)
have published a huge PSR list which could be used as calibrators. We have
decided to revise their distance values to use them as calibrators. In Table 1
we present 39 pulsars for which errors in distances should not be higher than
30%. Since the distances of PSRs in the same GC are the same, only one pul-
sar from each GC has been included in the table. Number of pulsars which we
used as calibrators, is considerably smaller than the one in the calibrator list
of Gómez et al. (2001). In this table, one of the most problematic calibrators
is PSR J0835-4510 (in Vela SNR). Distance of this PSR has been discussed
in detail by Guseinov et al. (2002b). This discussion shows how much infor-
mation is necessary to analyze in order to obtain trustworthy distance values.

Radio luminosity of PSRs should not depend on their birth place and
should not considerably exceed luminosities of the strongest pulsars (e.g.
Crab with a very well known distance and being the strongest pulsar in
Magellanic clouds). Luminosity of Crab is $2.6 \times 10^3$ mJy kpc$^2$, 56 mJy kpc$^2$
at 400 MHz and 1400 MHz, respectively. Luminosity of the strongest PSR
in the Large Magellanic Cloud (PSR J0529-6652) is $6 \times 10^3$ mJy kpc$^2$ at 400
MHz and $7.5 \times 10^3$ mJy kpc$^2$ at 1400 MHz. PSR J0045-7319 which is in the
Small Magellanic Cloud has the highest luminosity at 400 MHz is $9.5 \times 10^3$
mJy kpc$^2$ whereas its luminosity at 1400 MHz is $1.3 \times 10^3$ mJy kpc$^2$.
Therefore the upper limit for luminosities of PSRs might be close to the value of
$1.5 \times 10^4$ mJy kpc$^2$ and $3.5 \times 10^3$ mJy kpc$^2$ for 400 MHz and 1400 MHz,
respectively (spectral indices of radiation in radio band of PSRs have been
also taken into account). In our list of PSRs the strongest one among the
galactic PSRs is PSR J1644-4559 with luminosities of $7.6 \times 10^3$ mJy kpc$^2$
and $6.3 \times 10^3$ mJy kpc$^2$ at 400 and 1400 MHz, respectively (Guseinov et al.
2002a and references therein). These PSRs have extraordinarily flat spectra
(Taylor et al. 1996).

Since PSRs were born in the Galactic plane and surveys have scanned the
Galactic plane many times, most of the PSRs, especially the farthest ones,
have small Galactic latitudes ($|b| < 5^\circ$) [Manchester et al. 2002; Morris et
al. 2002, Lyne et al. 1998; D’Amico et al. 1998; Manchester et al. 1996].
As can be seen in our calibrator table (Table 1), there are 14 PSRs with
$|b| > 30^\circ$, 10 PSRs with $30^\circ > |b| > 7^\circ$, 6 PSRs with $7^\circ > |b| > 3^\circ$, and
only 14 PSRs with $|b| < 3^\circ$. Thus, the calibrators in Magellanic Clouds, GCs
and calibrators with known trigonometric parallax’s become insignificant for
PSRs with small $|b|$. Only 3 from our calibrator list belong to $|b| < 3^\circ$ and have distances greater than 5 kpc. Therefore, for the PSRs with large distances and low $|b|$ values there are almost no calibrators. In addition to this, for such distances it is quite difficult to judge the value of the electron density.

Considering the reasons given above in adopting distances for PSRs, the following criteria become very important:

1. In the direction of $40^\circ < l < 320^\circ$ we see the most luminous PSRs throughout the Galaxy.

2. For all Galactic longitudes ($l$), pulsars with equal characteristic times ($\tau$) must have, on the average, similar $|z|$ values except PSRs with $\tau \leq 5 \times 10^6$ years in the regions where SFRs are considerably above or below the Galactic plane.

3. PSRs with $\tau < 5 \times 10^5$ years must still be closer to their birth places, i.e. in the SFRs.

4. The PSR luminosity does not depend on $l$ and $d$, and it should not considerably exceed the luminosity of known strongest pulsars at 400 and 1400 MHz. The value of luminosities at 400 and 1400 MHz must at most be $1.5 \times 10^4$ mJy kpc$^2$ and $3 \times 10^3$ mJy kpc$^2$ respectively.

5. Electron density in the Galaxy must be correlated with the number density of HII regions and OB associations but not strongly at large distances. Electron density must increase as one approaches to the galactic center and galactic plane similar to background radiation in radio band.

6. PSR distances must be arranged in such a way that their value should correspond to a suitable distance value of PSRs in Table 1 (value of DM and the direction of the PSR have to be taken into account).
6 PSR Distances and Electron Distribution in the Galaxy

DM of PSRs (or electron column density) depend on number density of electrons and PSR distances. Therefore, if we know the PSR distances, we may have correct information about the electron distribution. And vice versa if we know electron distribution in the Galaxy then we also know the PSR distances. Therefore, there is no difference between electron or PSR distribution if our goal is to estimate the distances of PSRs. Of course if it was possible to have all information about electron distribution in the Galaxy and construct a mathematical model, it would be very good. However, it is impossible to have such information and construct a model which would be easy for practical use. At the same time, it is hard to use a model for PSRs having large $|b|$ values. There exists some PSRs even at galactic plane, whose distances do not fit the models. Hence, we have chosen a more practical and correct way. We continued the work of Guseinov et al. (2002a) and adapted distances for each PSR in such a way that satisfies our natural requirements taking into consideration the independently known distances (Table 1). We arranged pulsar distances in different directions for different longitude ($l$) and latitude ($b$) intervals. We have divided all PSRs in the Galaxy into 14 longitude intervals, and for each longitude interval we divide PSRs into different latitude ($b$) intervals. For example Figures 1a−1d represent distance ($d$) versus dispersion measure (DM) for PSRs with $-10^\circ < l < 10^\circ$ and $3^\circ < b < 3^\circ$; $-7^\circ < b < -3^\circ$ and $3^\circ < b < 7^\circ$; $-15^\circ < b < -7^\circ$ and $7^\circ < b < 16^\circ$; $-25^\circ < b < -15^\circ$ and $15^\circ < b < 25^\circ$. The total number of such figures, where electron distribution is different, is 48.

As seen from figures (from the inclination of $d$−DM dependence in each figure) the electron number density depends also on distances from the Sun in each interval of $l$ and $b$. PSRs with independent distances listed in Table 1 are also shown in figures. Our adapted distances for all 1328 PSRs, which we have used in the 48 figures in this paper are included in the list of Guseinov et al. (2002b). What must we do to estimate the distances of newly observed PSRs? We must take the figure which corresponds to the direction of the newly observed PSR. Then choose the distance that corresponds to the value of DM with taking into consideration the value of latitude. For example, Figure 1b corresponds to $-10^\circ < l < 10^\circ$ and $3^\circ < |b| < 7^\circ$. If PSR has a $|b|$ value close to $7^\circ$ we must choose the value of the distance close to maximum
among the distances which correspond to the value of DM. Of course, if \(|b|\) is close to 3°, then we must choose the lower distance value.

7 Discussion and Conclusion

To compare the distances of PSRs (new distances) that is obtained by our model and the distances obtained by the model of Taylor & Cordes (1993), in Figure 5 we have plotted out our new distances vs. Taylor & Cordes distances of PSRs. For most of these PSRs (from Table 1) almost the same independent distances are agreed on, but for some of them we have taken considerably different independent distances from that of Taylor & Cordes (1993) model gives. The names of these PSRs, as shown in Figure 5, are as follows; PSR J1302-6350, J1748-2021, J1804-0735 and J1910-59. As seen in Figure 5, the new distances and the distances given by Taylor & Cordes (1993) model differ up to more than twice. Most of these PSRs are located in south semi-sphere and were discovered during the 1400 MHz survey (with l between 300°-360°). Among the PSRs which are close to the Sun, the greatest difference in the distance given by our model and the model of Taylor & Cordes is owned by PSR J1939+2134 (see the distance value calculated from Taylor & Cordes model in the book by Lyne & Graham-Smith (1998).

To decide which model give the true distances, we need to test. In the previous section, in finding the PSR distance we have several criteria. One of these criteria is that the PSRs at the same age should be at almost the same distances from the Galactic plane. As we said before, the surveys done at 1400 MHz scanned the Galactic plane with \(|b| < 5°\). Hence, they have discovered a lot of young PSRs. It is necessary to mention that the ratio of flux at 1400 MHz to flux at 400 MHz of young PSRs is several times more than this ratio for old PSRs (Guseinov et al. 2002a). This makes the discovery of young PSRs easier. In Figure 6, latitude (b)-longitude (l) distribution of PSRs whose l is between 300°-360° and characteristic ages below 10⁶ years, is given. As seen from this figure, dominant number of these PSRs have \(|b| < 2°\). In Figures 7 and 8, the distance from the Galactic plane (z) vs. the distance from the Sun (d) for PSRs with age<10⁶ years and in the longitude interval l=300°-360° is given according to the new model and old model of
electron distribution, respectively. The cone corresponds to 2 degrees since most of the young PSRs have $|b| < 2^\circ$ as can be seen from Figure 6. It gives the limits of $z$ at each distance $d$. As seen from these figures there is not an important difference neither in $z$ nor in $d$. For only four of these PSRs Taylor & Cordes (1993) model has given very large distance values. This indicates that for small $b$ values ($|b| < 2^\circ$) there is no significant difference in electron distributions of the two models for $l$ between $300^\circ$-$360^\circ$. This is in general also true for other longitude directions.

For PSRs whose characteristic ages are between $10^6-10^7$ years, $b$-$l$ distribution with $l$ between $300^\circ$ and $360^\circ$, is shown in Figure 9. As seen from the figure dominant number of these PSRs have $|b| < 5^\circ$. In Figures 10 and 11, the distance from Galactic plane $z$ vs. the distance from the Sun $d$ is given according to the new model and old model electron distribution, respectively. PSRs with high $b$ values are nearer PSRs. As seen from Figures 10 and 11, for PSRs farther than $\sim 3$ kpc, the new distances $(d,z)$ are considerably smaller than the distances $(d,z)$ given by the old model. It is seen from Figure 10 that for all distances number density of PSRs are higher near the Galactic plane, and for PSRs farther than 6 kpc the distances from the Galactic plane is in average the same. The distance distribution according to the old model does not agree with this criterion. Thus according to the Taylor & Cordes model, as the distances of PSRs increase, average distances from Galactic plane increases. It indicates that the space velocities of farther PSRs are larger, however there is no reason for this.

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### Table 1: Distance calibrators.

| Name         | l   | b   | d   | DM  | n_e | Location       | Ref                  |
|--------------|-----|-----|-----|-----|-----|----------------|----------------------|
| 0024+724W    | 305.9 | -44.9 | 4.5 | 24.3 | 0.005 | GC NGC 104 (47 Tuc) | [1,2]               |
| 0045-7319    | 303.5 | -43.8 | 57  | 105.4 | 0.002 | SMC            | [3]                  |
| 0113-7220    | 300.6 | -44.7 | 57  | 125  | 0.002 | SMC            | [4]                  |
| 0205+6449    | 130.7 | 3.1  | 3.2 | 140.7 | 0.044 | SNR G130.7+3.1 | [5]                  |
| 0455-6951    | 281.2 | -35.2 | 50  | 94.9  | 0.002 | LMC            | [4]                  |
| 0529-6652    | 277.0 | -32.8 | 50  | 103.2 | 0.002 | LMC            | [7]                  |
| 0534+2200    | 184.6 | -5.8  | 2   | 56.79 | 0.028 | SNR G184.6-5.8 (Crab) | [6]               |
| 0535-6935    | 280.1 | -31.9 | 50  | 89.4  | 0.002 | LMC            | [4]                  |
| 0540-6919    | 279.7 | -31.5 | 50  | 146   | 0.003 | LMC            | [7]                  |
| 0826+2637    | 190.9 | 51.7  | 0.4 | 19.48 | 0.049 | Parallax       | [8]                  |
| 0835-4510    | 263.6 | -2.8  | 0.45 | 68.2  | 0.152 | SNR G263.9-3.3 (Vela) | [9,10,11] |}

[1] Harris 1996; [2] Hesser et al. 1987; [3] Feast & Walker 1987; [4] Crawford et al. 2001a; [5] Camilo et al. 2002b; [6] Trimble & Woltjer 1971; [7] Taylor et al. 1995; [8] Gwinn et al. 1986; [9] Cha et al. 1999; [10] Legge 2000; [11] Guseinov & Ankay 2002; [12] Chatterjee et al. 2001; [13] Fomalont et al. 1999; [14] Brisken et al. 2000; [15] Crawford et al. 2001b; [16] Kaspi & Helfand 2002; [17] Camilo et al. 2002a; [18] Johnston et al. 1994; [19] Roy et al. 1998; [20] Caswell et al. 1992; [21] Bailes et al. 1990; [22] Brocato et al. 1996a; [23] Sandquist et al. 1996; [24] Cudworth & Rees 1990; [25] Paltrinieri et al. 1998; [26] D’Amico et al. 2001; [27] Brocato et al. 1996b; [28] Heitsch & Richtler 1999; [29] Alcaino et al. 1987; [30] Ortolani et al. 1994; [31] Ortolani et al. 1996; [32] Thorsett et al. 2002; [33] Frail et al. 1994; [34] Allakhverdiev et al. 1997; [35] Finley & Ogelman 1994; [36] Armandroff 1988; [37] Kaspi et al. 1994; [38] arejedini & Norris 1994; [39] Rees & Cudworth 1991; [40] Buonanno et al. 1986; [41] Camilo et al. 2002c; [42] Weisberg et al. 1980; [43] Salter et al. 1979; [44] Backer & Sramek 1982; [45] Campbell et al. 1995; [46] Forst et al. 1993
Figure 1. Galactic height (z) vs. Galactic longitude (l) for 108 pulsars with age < 5 \times 10^5 years and d > 5 kpc.
Figure 2. Dispersion measure as a function of Galactic longitude ($l$) for 189 pulsars with age $< 5 \times 10^5$ years
Figure 3. Distance ($d$) as a function of Galactic longitude ($l$) for 189 pulsars with age < $5 \times 10^5$ years
Figure 4. Galactic arm structure constructed from the distribution of giant HII regions (Georgelin & Georgelin 1976).
Figure 5. Our distances vs. distances predicted by Taylor & Cordes model for 1318 pulsars.
Figure 6. Galactic longitude (l) vs. latitude (b) for pulsars within l=300°-360° and younger than $10^6$ years.
Figure 7. Our distance values vs. Galactic height (z) for pulsars within l=300°-360° and younger than 10⁶ years.
Figure 8. Distances calculated from Taylor & Cordes model vs. Galactic height (z) for pulsars within l=300°-360° and younger than 10^6 years.
Figure 9. Galactic distribution of pulsars with l=300°-360° and |b| < 15° and with $10^6 < 10^7$ years.
Figure 10. Our distance values vs. Galactic height (z) for pulsars with $l=300^\circ-360^\circ$ which have ages of $10^6-10^7$ years.
Figure 11. Distance values from Taylor & Cordes model for pulsars with $l=300^\circ-360^\circ$ which have ages of $10^6-10^7$ years.
Fig. 12a  \( 350 < l < 10, -3 < b < 3 \)

Fig. 12b  \( 350 < l < 10, -7 < b < -3, 3 < b < 7 \)

Fig. 12c  \( 350 < l < 10, -15 < b < -7, 7 < b < 16 \)

Fig. 12d  \( 350 < l < 10, -25 < b < -15, 15 < b < 25 \)
Fig. 20a  $100 < l < 170$, $-3 < b < 3$

Fig. 20b  $100 < l < 170$, $-7 < b < -3$, $3 < b < 7$

Fig. 20c  $100 < l < 170$, $-25 < b < -7$, $7 < b < 15$
Fig. 21a  170<l<255, 3<b<0

Fig. 21b  170<l<255, -3<b<-3, 3<b<7

Fig. 21c  170<l<255, -25<b<-7

Fig. 21d  170<l<255, 7<b<25
Fig. 22a  255<l<285, -3<b<3

Fig. 22b  255<l<285, -7<b<-3, 3<b<7

Fig. 22c  255<l<285, -15<b<-7, 7<b<15

Fig. 22d  255<l<285, -25<b<-15, 15<b<25
Fig. 25c: $285 \leq l < 325$, $-25 \leq b < -15$, $15 < b < 25$

Fig. 26: $325 \leq l < 335$, $-3 < b < 3$

Fig. 27: $335 \leq l < 350$, $-3 < b < 3$

Fig. 28a: $325 \leq l < 350$, $-7 < b < -3$, $3 < b < 7$

Fig. 28b: $325 \leq l < 350$, $-15 < b < -7$, $7 < b < 15$

Fig. 28c: $325 \leq l < 350$, $-26 < b < -15$, $15 < b < 25$