Birth rates of different types of neutron star and possible evolutions of these objects

Oktay H. Guseinov\textsuperscript{1,2}, Aşkı̈n Ankay\textsuperscript{1}†, Sevinç O. Tagieva\textsuperscript{3}‡

\textsuperscript{1}TÜBİTAK Feza Gürsey Institute
81220 Çengelköy, İstanbul, Turkey
\textsuperscript{2}Akdeniz University, Physics Department, Antalya, Turkey
\textsuperscript{3}Academy of Science, Physics Institute, Baku 370143, Azerbaijan Republic

Abstract
We estimate the spatial densities of different types of neutron star near the Sun. It is shown that the distances of dim isolated thermal neutron stars must be on average about 300-400 pc. The combined birth rate of these sources together with radio pulsars and dim radio quiet neutron stars can be a little more than the supernova rate as some of the dim isolated thermal neutron stars can be formed from dim radio quiet neutron stars and radio pulsars. Some of these sources must have relations with anomalous X-ray pulsars and soft gamma repeaters. In order to understand the locations of different types of neutron star on the P-\overset{\text{\text{\text{\text{P}}}}}{} diagram it is also necessary to take into

\textsuperscript{*}e-mail:huseyin@gursey.gov.tr
\textsuperscript{†}e-mail:askin@gursey.gov.tr
\textsuperscript{‡}email:physic@lan.ab.az
account the differences in the masses and the structures of neutron stars.

Key words: Neutron star; evolution, pulsar

1 Introduction

Existence of single neutron stars with different physical properties is very well known. But the amount of data about different types of neutron star except radio pulsars is small. Actually, the change in the beaming factor together with the value of and the change in the angle between the magnetic field and the rotation axes are not well known. It is also not clear how the relation between the characteristic time ($\tau$) and the real age changes in time. Therefore, the birth rate, initial periods and values of the real magnetic field are not known well. So, it is difficult to understand what the evolutionary tracks of pulsars on the P-$\dot{P}$ diagram must be and where these tracks end. As there are not many available observational data for the other types of neutron star and since they show some exotic phenomena such as $\gamma$-ray bursts, it is difficult to understand their nature. Below, we analyse birth rates of different types of neutron star, their locations on the P-$\dot{P}$ diagram and possible evolutions of these objects.

2 Analysis of the data about the birth rates of DITNSs and supernova rate around the Sun

According to Yakovlev et al. (2002) and Kaminker et al. (2002) neutron stars cool down to $T=4.6\times10^5$ K (or $kT=40$ eV) in $t\lesssim10^6$ yr. According to Haberl (2003, and references therein), there are 7 X-ray dim isolated thermal neutron stars (DITNSs) located within 120 pc around the Sun and only one DITNS, namely RX J1836.2+5925, is located at a distance of 400 pc. All of these 8 radio-quiet objects have $T>4.6\times10^5$ K. On the other hand, there are only 5 radio pulsars with characteristic times smaller than $10^7$ yr in the cylindrical volume around the Sun with a radius of 400 pc and height $2|z|=400$ pc, where $|z|$ is the distance from the Galactic plane. Among these
5 pulsars, Vela has $\tau \sim 10^4$ yr and the other 4 pulsars have $3 \times 10^6 < \tau < 5 \times 10^6$ yr. The real ages of 1-2 of these 4 radio pulsars may be smaller than $10^6$ yr. We have included Geminga pulsar (B0633+1748) in Table 1 to compare it with different types of neutron star, since this pulsar has properties in between the properties of DITNSs and of young radio pulsars.

In order to make a reliable estimation of the number density of the sources in each considered volume, it is necessary to consider how these objects move in the Galaxy. Practically, for pulsars with such ages the space velocity must not decrease in the gravitational field of the Galaxy. In order to demonstrate this in a simple and reliable way, we can use the observational data about the scale height and the average peculiar velocity of old stars near the Sun.

The average values of $|z|$ and $|V_z|$ for population II stars which belong to the old disk, the intermediate and the halo are, respectively, 400 pc and 16 km/s, 700 pc and 25 km/s, and 2000 pc and 75 km/s (Allen 1991). Ages of these stars are close to $10^{10}$ years. They are in dynamical equilibrium and their ages are large enough to make many oscillations in the gravitational field of the Galaxy.

Let us consider, in the first approximation, their oscillations in a homogeneous field in the direction perpendicular to the Galactic plane. In this case

$$V_z = A \sqrt{z} \text{ cm/sec} \quad (1)$$

and the period of oscillation is

$$T = \frac{8V_z}{A^2} \text{ sec} \quad (2)$$

where $A$ is a constant which is related to the gravitational field intensity near the Sun. If we use the average values of $|z|$ and $|V_z|$ for different subgroups of population II stars as written above, then we find values of $A$ very close to each other showing the reliability of the approximation. Therefore, we can adopt a value of $A=5.2 \times 10^{-5} \text{ cm}^{1/2} \text{s}^{-1}$, which is the average value for the 3 subclasses of population II objects, for all objects located up to about 2000 pc away from the Galactic plane and we can also use this value for pulsars. If we put the average value of $|V_z|=170-200 \text{ km/s}$ for pulsars in eqn. (1), then we find $T=(1.2-1.7) \times 10^9$ yr. As we see the age values of young radio pulsars are very small compared to the average period of pulsar oscillation. So, we can adopt that pulsars with ages $10^6-10^7$ yr move practically with constant velocity which they gain at birth.
Since the progenitors of neutron stars have scale height of about 60 pc, most of the neutron stars are born close to the Galactic plane. Therefore, they can go 200 pc away from the plane in about $10^6$ yr. As the Sun is located very close to the Galactic plane, considering the value of $z$ of the Sun in the analysis does not change the results and so can be neglected.

There are 23 supernova remnants (SNRs) within about 3.2 kpc around the Sun with surface brightness $>$ $10^{-21}$ Wm$^{-2}$Hz$^{-1}$sr$^{-1}$ and the ages of these SNRs are not greater than $(3-4) \times 10^4$ yr (Green 2001; AnKay et al. 2003). So, the number of neutron stars which were born in the last $10^6$ yr within the region of 400 pc around the Sun must be about 11. Only 2 or 3 of these 11 neutron stars can go more than 200 pc away from the Galactic plane. Therefore, the considered region may contain about 8-9 neutron stars. But the birth rate of radio pulsars is up to 3-4 times smaller than the supernova explosion rate in our galaxy (AnKay et al. 2003). So, we can expect only 3 radio pulsars with an age up to $10^6$ yr located in this region and this is in accordance with the data mentioned above.

According to Haberl (2003) (see also the references therein), surface temperatures of DITNSs are 40-95 eV and their ages must not be more than $10^6$ yr (Kaminker et al. 2002; Yakovlev et al. 2002) as they are in the cooling stage. Guseinov et al. (2003a) include most of these sources (for which there exist considerably more information) in the list of isolated radio quiet neutron stars which were observed in X-ray band. We have included in Table 1 only a few very important data taken from the tables given in Guseinov et al. (2003a) together with some new data. In some cases, the distance values of DITNSs are about 2-3 times larger than the ones given in Haberl (2003) and in some other papers (see also the references in Guseinov et al. 2003a and Haberl 2003). Is it acceptable to adopt such smaller values of distance as given by Haberl (2003) for these objects?

The statistics about the SNRs and the radio pulsars in the considered region are very poor, but the number density of DITNSs for the case of small distances (Haberl 2003) is very large so that there exists a contradiction. If the data about the distances and ages of DITNSs were reliable, then their birth rate would turn out to be about 4 times more than the supernova explosion rate.

Since the measured space velocities of all types of neutron star are very large compared to the space velocities of O and B-type stars, there is no doubt about the origin of neutron star formation which is due to the collapse
of the progenitor star together with supernova explosion. For example, RX J0720.4-3125 at a distance of 200 pc (which may actually be $\sim$300 pc) has a tangential velocity of about 100 km/s calculated from the proper motion $\mu=97\pm12$ mas/yr (Motch et al. 2003). PSR J0538+2817 has proper motion $\mu=67$ mas/yr and has a transverse velocity in the interval 255-645 km/s at a distance of 1.2 kpc (Kramer et al. 2003). Therefore, the birth rate of neutron stars can not exceed the rate of supernova explosion. How can we explain the contradiction between the neutron star birth rate and the supernova explosion rate? Note that Haberl (2003) does not assume all the DITNSs to be only cooling neutron stars but also discusses other possibilities, for example the accretion from interstellar gas. But as a rule, today the cooling origin of the X-ray radiation is considered and this is reliable (Haberl 2003). In order to solve the problem about the difference in the birth rates it is necessary to adopt either larger distance values or longer lifetimes for DITNSs.

3 The distances of DITNSs

Since the theory of cooling of neutron stars has been well developed and all the DITNSs have $T>4.6\times10^5$ K, we can say that these neutron stars have ages less than $10^6$ yr (Pavlov et al. 2002a,b; Kaplan et al. 2003a,b; Pavlov & Zavlin 2003; Yakovlev et al. 2003). As the ages of these objects are small, their number density must be small. Therefore, it is better to adopt larger values of distance for these neutron stars.

Before beginning to discuss how to adopt distance values, it is necessary to analyse the data of DITNSs. These data vary a lot from one observation to another. The most recent data about DITNSs are given in Haberl (2003) and Guseinov et al. (2003a).

For all DITNSs there exist data about their temperatures and it is known that they have approximately blackbody radiation (Pavlov et al. 2002b; Haberl 2003). In this work, we have used the temperature values given in Pavlov et al. (2002b) and Haberl (2003) which are more in accordance with the other data that they are more reliable.

The cooling curves of neutron stars, which are obtained from the fit of the data of different pulsars on the surface temperature versus age diagram, are given in various articles (see for example Yakovlev et al. 2002). Since the
general form of the cooling curves given by different authors is approximately the same in all the works, we will use the data given in Yakovlev et al. (2002).

DITNS RX J1605.3+3249 (Motch et al. 1999) is located in a region of sky (l=53°, b=48°) where it is easier to determine the temperature with small uncertainty. There are 2 different distance estimations for this source, 0.1 kpc (Haberl 2003) and 0.3 kpc (Kaplan et al. 2003b). We may adopt reliable distance values for any source which has a spectrum close to the blackbody using luminosity values. The temperatures of DITNS RX J1605.3+3249 and of radio pulsars J1057-5226 and J0659+1414 which have similar soft X-ray spectrums are 0.092, 0.070 and ≤0.092 keV, respectively (Yakovlev et al. 2003). Therefore, the luminosity of RX J1605.3+3249 must not be smaller than the luminosity of these radio pulsars (Becker & Aschenbach 2002; Guseinov et al. 2003b), i.e. it must not be less than about 10^{33} erg/s.

The luminosity of RX J1605.3+3249 at 0.1 kpc is 1.1×10^{31} erg/s (Haberl 2003), so that, its luminosity at 0.3 kpc must be about 10^{32} erg/s. On the other hand, Geminga pulsar (B0633+17), which has temperature of about 0.045 keV, has L_x=1.05×10^{31} erg/s in 0.1-2.4 keV band (Becker & Trumper 1997). This also suggests to adopt a larger L_x value for RX J1605.3+3249. So, we can adopt a distance value of 0.3 kpc (Kaplan et al. 2003b) or even a larger value which is more reliable.

Following the same path, we can adopt distance values for other DITNSs; the distances of J0420.0-5022, J0720.4-3125, J0806.4-4123, J1308.8+2127, and J214303.7+065419 must be about 3-4 times larger than the distance values given in Haberl (2003). All the new distance values and other reliable data are represented in Table 1.

4 Where must DITNSs be located on the P-\dot{P} diagram?

There are 6 single radio pulsars (J1952+3252, J0659+1414, J0117+5914, J1057-5226, J0358+5413 and J0538+2817) with characteristic times in the range 10^{5}-6×10^{5} yr from which X-ray radiation has been observed (Becker & Aschenbach 2002; Possenti et al. 2002). These pulsars are located up to 2 kpc from the Sun. The luminosities of these radio pulsars are in the range 10^{31}-5×10^{33} erg/s (Guseinov et al. 2003b). There are also 3 radio pul-
sars (J0826+2637, J0953+0755 and J1932+1059) with characteristic times $3 \times 10^6 < \tau < 2 \times 10^7$ yr (it is necessary to remember that value of $\tau$ may considerably exceed the real age value). The distances of these 3 radio pulsars are less than 400 pc and their luminosities are $< 10^{30}$ erg/s (Possenti et al. 2002).

As seen from Table 2, the X-ray luminosities of all the 8 DITNSs and Geminga are in the interval $10^{30}$-1.7$x10^{32}$ erg/s. Among these sources, Geminga has the lowest luminosity ($T_{\text{eff}}$ value of Geminga is also very small, see Table 1) and the $\tau$ value of Geminga is $3.5 \times 10^5$ yr. Taking these data into consideration, the ages of DITNSs can be adopted as $10^5$-$10^6$ yr in accordance with the age values calculated from the cooling models. Moreover, these sources are nearby objects and there is not any pulsar wind nebula around them nor any SNR to which they are connected; this also shows that the ages of these objects must be greater than $10^5$ yr. On the other hand, pulsar wind nebula is present around the neutron stars with the rate of rotational energy loss $\dot{E} > 5 \times 10^{35}$ erg/s and with $L_x(2-10 \text{ keV}) > 5 \times 10^{32}$ erg/s (Guseinov et al. 2003b). Naturally, it may be possible to observe pulsars with smaller values of $\dot{E}$ and $L_x (2-10 \text{ keV})$ which are located closer to the Sun. Taking these facts into account, we can assume that $\dot{E}$ values of DITNSs must be less than about $3 \times 10^{35}$ erg/s (constant $\dot{E}=3 \times 10^{35}$ erg/s line is shown on the P-$\dot{P}$ diagram, see Figure 1).

It is well known that the difference between $\tau$ and the real age can be significant for very young pulsars (Lyne & Graham-Smith 1998). On the other hand, for single-born old pulsars $\tau$ must be approximately equal to the real age if the evolution takes place under the condition $B=\text{constant}$. But none of the DITNSs is connected to a SNR, so that, DITNSs must be located in the belt between $\tau=3 \times 10^4$ yr and $\tau=10^6$ yr lines on the P-$\dot{P}$ diagram if the condition $B=\text{constant}$ is satisfied.

For 5 of the 9 DITNSs (including Geminga) represented in Table 1, the spin periods (P) have been measured. Four of these objects have spin periods greater than 8 s and Geminga pulsar has $P=0.237$ s. As known, the period values of anomalous X-ray pulsars (AXPs) and soft gamma repeaters (SGRs) are greater than 5 s (see for example Mereghetti 2001; Guseinov et al. 2003a and the references therein). The small value of $\dot{P}=5.4 \times 10^{-13}$ s/s belongs to AXP 1E2259+586 which has $P=6.98$ s. Therefore, all single neutron stars with $P>10$ s must be related to AXPs and SGRs. The $P=10$ s line is displayed in Figure 1 to show the two separate regions in which DITNSs can be located.
The DITNSs with $\tau<10^6$ yr may have values of $P>10$ s (see Table 1) and this is possible if the values of $\dot{P}$ are very large. Therefore, these objects may be the evolutionary continuations of SGRs and AXPs. Naturally, their birth rates should be in agreement with each other for this assumption to be true.

The locations of pulsars Geminga, RX J0720.4-3125 and RX J1308.8+2127 on the $P$-$\dot{P}$ diagram are shown in Figure 1. From the position of Geminga pulsar it is seen that this pulsar evolves similar to the radio pulsars with $B=10^{12}$-$10^{13}$ G. The position of pulsar RX J0720.4-3125 is not within our chosen interval of $\tau=10^4$-$10^6$ yr, but as this pulsar has a high value of $kT_{\text{eff}}$ (see Table 1) its real age (according to the cooling models) must be smaller than its $\tau$ value. So, there may be magnetic field decay or some other reason for this pulsar (i.e. $n>3$, where $n$ is the braking index). Pulsar RX J1308.8+2127 is located in the SGR/AXP region on the $P$-$\dot{P}$ diagram so that this pulsar seems to have a relation with the SGR/AXP class of neutron stars. Pulsars RX J0806.4-4123 and RX J0420.0-5022 with ages $<10^6$ yr have large values of $P$. Although their $\dot{P}$ values are not known, they must be located on the upper part of the $P$-$\dot{P}$ diagram and their positions must not be lower than the position of J0720.4-3125, if the $P$ values are correct.

5 Birth rates of different types of neutron star near the Sun

In section 2, we have mentioned that the birth rate for all the types of neutron star, in other words the supernova rate, must be about 11 in $10^6$ yr in the region up to 400 pc from the Sun. In the same region, the birth rate of radio pulsars can be about 3-4 in $10^6$ yr.

In Figure 1, we have plotted all the 9 radio pulsars with $\tau\leq4\times10^4$ yr which are connected to SNRs and located at distances up to 3.5 kpc (Guseinov et al. 2003c). There are also 2 other radio pulsars, J1048-5832 and J1837-0604, in this region with such values of $\tau$ but without any connection with SNRs (Guseinov et al. 2003b). From these data it follows that the birth rate of radio pulsars is 3.6 in $10^6$ yr in the region up to 400 pc. It is necessary to take into consideration that for such young radio pulsars the beaming factor is close to 1 and the influence of the luminosity function on the estimations is small. Note that the searches of pulsars near the Sun in the central regions of
SNR shells and the searches of pulsar wind nebulae are considerably better than the searches of pulsars under the surveys. Also note that in some cases pulsars have been found after observing point X-ray sources in the central parts of SNRs. Therefore, we can adopt that the birth rate in the region up to 400 pc from the Sun is about 3-4 radio pulsars in $10^6$ yr.

It is necessary to take into account that in the region with distance up to 3.5 kpc from the Sun, there are also 6 dim radio quiet neutron stars (DRQNSs) which are connected to SNRs (Table 1). The locations of 2 of these objects, 1E1207.4-5209 and RXJ0002+6246, are shown in Figure 1. These objects have considerably large values of $\tau$ compared to the ages of the SNRs in which they are located, so that, they have different evolutionary tracks compared to other radio pulsars which are connected to SNRs. If we assume that all DRQNSs are also radio pulsars with $10^{12} < B < 10^{14}$ G, then they must have low radio luminosities and/or the direction of their radio radiation does not pass through the line of sight. On the other hand, all of them may have large $P$ and $\tau$ values and significantly different evolutionary tracks compared to other pulsars with the same magnetic field, because there exist some other important differences between DRQNSs and most of the radio pulsars. Practically, all the radio pulsars which are connected to SNRs and which have similar ages as DRQNSs have pulsar wind nebula (Guseinov et al. 2003b). None of the DRQNSs has such property. Therefore, these DRQNSs have $\dot{E} < 3 \times 10^{35}$ erg/s. The positions of 1E1207.4-5209 and RX J0002+6246 on the P-$\dot{P}$ diagram require magnetic field decay or some additional ideas for the pulsar models (in Fig.1 the location of RX J0002+6246 has been found using the condition $\tau = \text{age of the SNR}$). Therefore, the number of SNRs which contain ordinary and other types of pulsars with similar properties for $d \leq 3.5$ kpc is 17. By this approach, we give the upper limit for pulsar birth rate in the region up to 400 pc which is $5.5 \times 10^6$ yr.

In section 3, we have adopted up to 3-4 times larger distance values for DITNSs and this gives us the possibility to estimate the birth rate of this type of neutron star as 9 in $10^6$ yr in the same region with a radius of 400 pc. These sources have $P > 0.1$ s, $\dot{E} < 3 \times 10^{35}$ erg/s and, according to the cooling theories, ages between $3 \times 10^4$-$10^6$ yr that they must be in later stages of the evolution of single neutron stars with initial magnetic field $B > 10^{12}$ G (see the locations of these sources in Figure 1). But how can we explain such a large birth rate for these sources which is comparable with the supernova rate? First, note that the statistical data are poor. Second, the actual ages
of the SNRs may be not up to $4 \times 10^4$ yr but up to $3 \times 10^4$ yr (see Table 1). On the other hand, the rate of supernova must be a little more if we take into account the SNRs which have low surface brightness during their evolution. In this case, the birth rate of DITNSs must roughly be equal to the birth rate of radio pulsars and DRQNSs together.

As seen from Figure 1, there exist 5 single radio pulsars which have been detected in X-ray band and have $10^5 < \tau < 6 \times 10^5$ yr and $5 \times 10^{11} < B < 1.1 \times 10^{12}$ G. They are located in the region up to 2 kpc from the Sun and 2 of them, J0659+1414 and J0538+2817, are most probably connected to S type SNRs (Kramer et al. 2003; Guseinov et al. 2003b and the references therein). If we also consider that 2 such pulsars may go far away from the Galactic plane that they can be missed in the surveys, the total number of the pulsars in the considered volume turns out to be 7. Therefore, the birth rate of this type of pulsar in the region with $d \leq 400$ pc is not more than 0.6 in $10^6$ yr.

From the estimations done in this section, we see that approximately 60% of the SNRs with surface brightness $> 10^{-21}$ Wm$^{-2}$Hz$^{-1}$sr$^{-1}$ are connected to normal pulsars and DRQNSs. The rate of birth for DITNSs is also approximately equal to 60% of the rate of supernova explosion. Therefore, the neutron stars with ages approximately $< 5 \times 10^5$ yr, which show themselves as radio pulsar or DRQNS in SNRs, may mainly transform to DITNSs.

The numbers of radio pulsars with effective values of magnetic field $B \geq 10^{13}$ G and $B \geq 3 \times 10^{12}$ G which have $\tau < 10^6$ yr and $d \leq 3.5$ kpc are 5 and 32, respectively (ATNF pulsar catalogue 2003; Guseinov et al. 2002). From these data, the birth rates of radio pulsars with $B \geq 10^{13}$ G and $B \geq 3 \times 10^{12}$ G located up to 400 pc from the Sun must be considerably more than 0.06 and 0.4, respectively, in $10^6$ yr, because the $\tau$ values may be several times larger than the real ages.

In the region up to 8 kpc from the Sun, there are 4 AXPs and one SGR and the ages of these objects must not be larger than $5 \times 10^4$ yr (Mereghetti 2001; Guseinov et al. 2003a). Therefore, the birth rate of AXPs and SGRs in the considered cylindrical volume with the radius of 400 pc in $10^6$ yr is not less than 0.15. This is about 60 times smaller than the supernova rate in the same volume and the time interval, but it approximately coincides with the birth rate of radio pulsars with effective value of $B \geq 10^{13}$ G. As seen from Figure 1, only 3 pulsars, J1740-3015, J1918+1444 and J1913+0446 (in the order of increasing value of $P$), are located in the volume with a radius of 3.5 kpc and with $\tau \leq 10^5$ yr.


6 Discussion and Conclusions

It is known that, different types of neutron star which have different properties are born as a result of supernova explosion: radio pulsars, DRQNSs, DITNSs, AXPs and SGRs. There exist PWN and often SNR shell around very young single radio and X-ray pulsars which have $\dot{E}>5\times10^{35}$ erg/s (Guseinov et al 2003b). There may exist only the shell around pulsars with $\dot{E}<3\times10^{35}$ erg/s, DRQNSs and AXPs the ages of which are less than $10^5$ yr. No shell nor PWN has been found around some of the very young pulsars (e.g. J1702-4310 and J1048-5832) and SGRs. Absence of the shell or PWN around DITNSs must be considered normal because they have considerably large ages.

In section 4, we have adopted $\sim3$-4 times larger distance values, compared to the values usually adopted (Haberl 2003), for most of the DITNSs and this gives the possibility to decrease their birth rate down to the sum of the birth rates of radio pulsars and DRQNSs. Birth rate of these 3 types of neutron star together is approximately equal to the rate of supernova. The combined birth rate of these 3 types of neutron star may be more than the supernova rate, because some of the DITNSs may be formed as a result of the evolution of DRQNSs and radio pulsars. Birth rate of AXPs and SGRs, which belong to the same class of objects, is about 60 times smaller than the supernova rate and it is about same as the birth rate of radio pulsars with effective values of $B\geq10^{13}$ G.

As seen from Table 1, the period values of 4 DITNSs are very large, though their ages are smaller than $10^6$ yr. From this situation, there arises a possibility of a relation between some of the DITNSs and AXPs/SGRs. Naturally, we must take into account the position of each DITNS on the P-P diagram to show the relation between some of these objects and AXPs/SGRs.

Existence of radio pulsars with $n<3$ and with real ages smaller than $\tau$ (for young pulsars) show that the condition $B=$constant is not satisfactory in all cases and this is well seen in Figure 1. Most of the pulsars with $10^5<\tau<10^7$ yr are not in the belt $B=10^{12}-10^{13}$ G where most pulsars are born in; often, there occurs magnetic field decay. But the evolutions of AXPs/SGRs and some of the DITNSs according to the field decay approach (the magnetar model) lead to bimodality in the number of neutron stars versus the magnetic field distribution. On the other hand, the time scale of the magnetic field decay must be very short. This shows that the large effective B values of these
objects and the shape of their evolutionary tracks must be related mainly to the masses of and the density distributions in the neutron stars and also to the activity of the neutron star. This is also necessary to understand the different positions of radio pulsars which are connected to SNRs and of DRQNSs on the P-\dot{P} diagram despite the fact that they have similar ages. If the evolution under the condition B=constant were true, then they would be located along \tau=constant belt, but not along the constant magnetic field belt.

We think that there is a possibility to get rid of these difficulties and to understand the large X-ray luminosities and also the bursts of AXPs/SGRs. It is necessary to assume the birth of neutron stars with masses about half of the maximum mass values found from the given equations of state and rotational moment. In principle, it must be easy to identify such smaller mass neutron stars as they are far away from hydrodynamical equilibrium. They must have an ellipsoidal shape due to rotation and possibly they do not rotate as a rigid body. In this case, the young pulsar may especially demonstrate itself when the angle between the magnetic field and the rotation axes is close to 90°. In such a case, a considerably larger effective value of magnetic field can be produced as compared to the real magnetic field.

References

Allen, C. W.: 1991, *Astrophysical Quantities*, The Athlone Press.
Ankay, A., Guseinov, O. H. and Tagieva, S. O.: 2003, submitted to *Astronomy Reports* (astro-ph/0305490).

ATNF Pulsar Catalogue: 2003, http://www.atnf.csiro.au/research/pulsar/psrcat/

Becker, W. and Trumper, J.: 1997, *A&A* 326, 682.

Becker, W. and Aschenbach, B.: 2002, Proceedings of the 270. WE-Heraeus Seminar on: *Neutron Stars, Pulsars and Supernova Remnants*, eds. W. Becker, H. Lesch and J. Trumper, MPE Report 278, p.64.

Bignami, G. F., Caraveo, P. A., De Luca, A. and Mereghetti, S.: 2003, *Nature* 423, 725.

Brazier, K. T. S., Kanbach, G., Carraminana, A., Guichard, J. and Merck, M.: 1996, *MNRAS* 281, 1033.

Brazier, K. T. S. and Johnston, S.: 1999, *MNRAS* 305, 671.
De Luca, A., Mereghetti, S., Caraveo, P. A., Mignani, R. P., Becker, W. and Bignami, G. F.: 2002, to appear in Radio Pulsars, ASP Conf. Ser., eds. M. Bailes, D. Nice, and S. Thorsett, (astro-ph/0211101).
Green, D. A.: 2001, A Catalogue of Galactic Supernova Remnants (2001 December version)', http://www.mrao.cam.ac.uk/surveys/snrs/.
Guseinov, O. H., Yerli, S. K., Özkân, S., Sezer, A. and Tagieva, S. O.: 2002, to be published by Astron. and Astrop. Transactions (astro-ph/0206050).
Guseinov, O. H., Yazgan, E., Ankay, A. and Tagieva, S. O.: 2003a, IJMPD 12, 1.
Guseinov, O. H., Ankay, A., Tagieva, S. O. and Taşkin, M. Ö.: 2003b, submitted to IJMPD (astro-ph/0308375).
Guseinov, O. H., Ankay, A., Sezer, A. and Tagieva, S. O.: 2003c, Astron. and Astrop. Transactions 22, 273.
Guseinov, O. H., Ankay, A. and Tagieva, S. O.: 2003d, to be published by Ap&SS (vol. 286).
Haberl, F., Pietsch, W. and Motch, C.: 1999, A&A 351, L53.
Haberl, F. and Zavlin, V. E.: 2002, A&A 391, 571.
Haberl, F.: 2003, COSPAR Symposium on High Energy Studies of Supernova Remnants and Neutron Stars (astro-ph/0302540).
Haberl, F., Schwoppe, A. D., Hambaryan, V., Hasinger, G. and Motch, C.: 2003, A&A 403, L19.
Hailey, C. J. and Craig, W. W.: 1995, ApJ 455, L151.
Halpern, J. P. and Wang, F. Y. -H.: 1997, ApJ 477, 905.
Hambaryan, V., Hasinger, G., Schwoppe, A. D. and Schulz, N. S.: 2002, A&A 381, 98.
Kaminker, A. D., Yakovlev, D. G. and Gaedcke, O. Y.: 2002, A&A 383, 1076.
Kaplan, D. L., van Kerkwijk, M. H. and Anderson, J.: 2002, ApJ 571, 447.
Kaplan, D. L., van Kerkwijk, M. H., Marshall, H. L., Jacoby, B. A., Kulkarni, S. R. and Frail, D. A.: 2003a, ApJ 590, 1008.
Kaplan, D. L., Kulkarni, S. R. and van Kerkwijk, M. H.: 2003b, ApJ 588, L33.
Kargaltsev, O., Pavlov, G. G., Sanwal, D. and Garmire, G. P.: 2002, ApJ 580, 1060.
Kramer, M., Lyne, A. G., Hobbs, G., Lohmer, O., Carr, P., Jordan, C. and Wolszczan, A.: 2003, (astro-ph/0306628).
Lyne, A. G. and Graham-Smith, F.: 1998, *Pulsar Astronomy*, Cambridge University Press.
McLaughlin, M. A., Cordes, J. M., Hankins, T. H. and Moffett, D. A.: 1999, *ApJ* **512**, 929.
Mereghetti, S.: 2001, *Frontier Objects in Astrophysics and Particle Physics*, Vulcano Workshop 2000, edited by F. Giovannelli and G. Mannocchi, p. 239 (astro-ph/0102017).
Motch, C., Haberl, F., Zickgraf, F. J., Hasinger, G. and Schwope, A. D.: 1999, *A&A* **351**, 177.
Motch, C., Zavlin, V. E. and Haberl, F.: 2003, (astro-ph/0305016).
Pavlov, G. G., Sanwal, D., Kiziltan, B. and Garmire, G. P.: 2001, *ApJ* **559**, L131.
Pavlov, G. G., Zavlin, V. E., Sanwal, D. and Trumper, J.: 2002a, *ApJ* **569**, L95.
Pavlov, G. G., Zavlin, V. E. and Sanwal, D.: 2002b, Proceedings of the 270. WE-Heraeus Seminar on *Neutron Stars, Pulsars, and Supernova Remnants*, MPE Report 278, edited by W. Becker, H. Lesch, and J. Trumper, p. 273 (astro-ph/0206024).
Pavlov, G. G. and Zavlin, V. E.: (2003), to be published in the Proceedings of the XXI Texas Symposium on *Relativistic Astrophysics* (astro-ph/0305435).
Petre, R., Becker, C. M. and Winkler, P. F.: 1996, *ApJ* **465**, L43.
Possenti, A., Cerutti, R., Colpi, M. and Mereghetti, S.: 2002, *A&A* **387**, 993.
Vasisht, G., Kulkarni, S. R., Anderson, S. B., Hamilton, T. T. and Kawai, N.: 1997, *ApJ* **476**, L43.
Yakovlev, D. G., Kaminker, A. D., Haensel, P. and Gnedin, O. Y.: 2002, *A&A* **389**, L24.
Yakovlev, D. G., Gnedin, O. Y., Kaminker, A. D., Levenfish, K. P. and Potekhin, A. Y.: (2003), Proceedings of the 34th COSPAR Scientific Assembly (astro-ph/0306143).
Zane, S., Haberl, F., Cropper, M., Zavlin, V. E., Lumb, D., Sembay, S. and Motch, C.: 2002, *MNRAS* **334**, 345.
Table 1 - The data of DRQNSs and DITNSs. Ages of the SNRs connected to these objects are given in the 4th column. References are shown at the end of the table. Some data adopted in this work are given without reference.

| Names                  | P    | $\tau$ | t   | d   | $kT_{\text{eff}}$ | $L_x 10^{32}$ | $L_x/E$ |
|------------------------|------|--------|-----|-----|-------------------|---------------|--------|
|                        | s s  | kyr    | kyr | kpc | keV               | erg/s         |        |
| 1E1207.4-5209          | 0.424| 340-   | 7-20| 1.8 | 0.11              | $10d_2^2$     | $\sim0.1$|
| G296.5+10.0            | [4]  | 480    | [5,15]| 2   | [1]               | (0.5-6)       |        |
| S                      | [4,5]| [6]   | 0.25| [7] |
|                        |      | 2.1    | (0.5-6)|    |                    |               |
|                        |      | [7]    | [7] |
| 1E0820-4247            | 3-4  | 2      | 0.15| 12  |                    |               |
| RXJ0822-4300           | [5,11,12]| [8] | [1] | (0.1-2.4) | (0.1-2.4) |        |
| Puppis A               |      |        | 0.44| ?   | [8,9]             |               |
| G260.4-3.4             |      |        |     | [10]|
| S                      |      |        |     |        |
| CXOJ2323+5848          | 0.32 | 3.2    |     | 0.16 | 0.048             | 0.01          | 0.00003|
| Cas A                  | [25] | [2]    |     |      |                   |               |
| G111.7-2.1             |      |        |     |      |                   |               |
| RXJ0002+6246           | 0.2418| 10-20  | 3.5 | 0.10 | 2                 | 0.0002         |
| $\gamma$-ray source   | [11] | [5,7]  | [11]| [1] | (0.5-2)           | 0.0006         |
| G117.7+0.6             |      | [11,2]|
| RXJ0007.0+7302         | 10-24| 1.4    |     | 0.15 |                   |               |
| G19.5+10.2             | [5,8-10]| [2] |     | (0.1-2.4) | (0.1-2.4) |        |
| CTA 1                  |      | [2]    |     |      |                   |               |
| RXJ2020.2+4026         | 6-10 | 1.5    |     | 9   | 0.0009            |
| $\gamma$-ray source   | [4-6]| [12]  | [12]| [12]|                   | 0.00009        |
| G78.2+2.1              |      |        |     |      |                   |
| $\gamma$ Cyg           |      |        |     |      |                   |
| CXOJ0852-4615          | 0.7-2| 1      |     | 0.40 | 2.3               |
| G266.2-1.2             | [13,14]| [13]| [13]| (0.4-6) | (0.4-6) |        |
| Geminga                | 0.237| 350    | 0.16| 0.048| 0.01             | 0.00003       |
| B0633+1748             | [21] | [9]    | [1] | (0.6-5) | (0.6-5) |        |

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Table 1 (continued)

| Names                | P  | τ  | t  | d  | kT<sub>eff</sub> | L<sub>x</sub>10<sup>32</sup> | L<sub>x</sub>/E |
|----------------------|----|----|----|----|-------------------|------------------|-------------|
| RXJ1836.2+5925       |    |    |    |    |                   |                  |             |
| RXJ1856.5-3754       |    |    |    |    |                   |                  |             |
| RXJ0720.4-3125       | 8.39 | 3000 |    | 3  | 0.085             | 1.7              | 55          |
| RXJ0420.0-5022       | 22.7 |    |    |    |                   |                  |             |
| RX J0806.4-4123      |    |    |    |    |                   |                  |             |
| RX J1308.8+2127      | 10.3 | 7-14 |    | 0.4| 0.091             | 0.82             | ~0.2-0.6    |
| RBS 1223             |    |    |    |    |                   |                  |             |
| 1RXSJ214303.7        |    |    |    |    |                   |                  |             |
| +065419              |    |    |    |    |                   |                  |             |
| RBS 1774             |    |    |    |    |                   |                  |             |
| RXJ1605.3+3249       |    |    |    |    |                   |                  |             |

[1] Yakovlev et al. 2002; [2] Guseinov et al. 2003c; [3] Haberl 2003; [4] Bignami et al. 2003; [5] De Luca et al. 2002; [6] Vasisht et al. 1997; [7] Pavlov et al. 2002a; [8] Petre et al. 1996; [9] Brazier & Johnston 1999; [10] Pavlov et al. 2002b; [11] Hailey & Craig 1995; [12] Brazier et al. 1996; [13] Kargaltsev et al. 2002; [14] Zane et al. 2002; [15] Kaplan et al. 2003a; [16] Hambaryan et al. 2002; [17] Haberl & Zavlin 2002; [18] Haberl et al. 2003; [19] Kaplan et al. 2002; [20] Kaplan et al. 2003b; [21] McLaughlin et al. 1999; [22] Haberl et al. 1999; [23] Halpern & Wang 1997; [24] Pavlov et al. 2001; [25] Guseinov et al. 2003d.
Figure Caption

Figure 1: Period versus period derivative diagram for different types of pulsar. The '+' signs denote the radio pulsars with d≤3.5 kpc which are connected to SNRs. The 'X' signs show the positions of the radio pulsars with d≤3.5 kpc and $10^5 < \tau < 2 \times 10^7$ yr which have been detected in X-rays. The locations of 3 radio pulsars which have d≤3.5 kpc and $\tau < 10^5$ yr are shown with 'circles' to make a comparison between the birth rates (see text). DITNSs are represented with 'stars' and DRQNSs are displayed with 'empty squares'. The 'filled squares' show the positions of all AXPs/SGR in the Galaxy. Names of DITNSs, DRQNSs, 2 of the AXPs, and some of the radio pulsars are written. Constant lines of $B = 10^{11-15}$ G, $\tau = 10^{3-9}$ yr, and $\dot{E} = 10^{29}, 10^{32}, 10^{35}, 3 \times 10^{35}$ and $10^{38}$ erg/s are shown. P=10 s line is also included (see text).
