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Study The Spin Down Luminosity And Flux Density For Pulsar Stars By Using Hallo Cone Model

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Abstract

There are different types of young isolated NSs: radio pulsars, compact central X-ray sources in supernova, magentas: anomalous x-ray pulsars (AXPs) and soft gamma-ray repeaters (SGRs).This paper shows that the value of magnetic field (B), characteristic age (T_{ch}), spin down luminosity (L_{sp}), equilibrium period (P_{eq}) and Flux density (S_{mjy}) was determined depending on some properties of pulsar star, such as the value of period of the pulsar (P) and the time derivative period ($P^{\bullet}$) for sample stars which were adopted. The model that which adopted is Hallo Cone Model. The results showed that the Normal pulsar stars have a big magnetic field, equilibrium period and Spin down than the Millisecond pulsar stars.But Millisecond pulsar stars have large values of Luminosity and Flux density than Normal pulsar star that mean Normal pulsar star is lose its energy in long time that mean its younger than Millisecond Pulsar star.

Keywords: Evolution stars- Neutron stars - Magnetic fields, Halo Cone model.

دراسة تباطؤ اللمعانية وكثافة الفيض للنجوم النابضة باستخدام نموذج الاسطوانة الضوئية

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الخلاصة:

هنالك انواع مختلفة من النجوم النوترونية المعزولة مثل النجوم الراديوية النابضة ونجوم مركزية من نجوم الاشعة السينية في مركز السوبر نوفا ونجوم الاشعة السينية الراديوية النابضة ونجوم اشعة كاما النابضة . في هذا البحث قيمة المجال مغناطبسي والعمر المميز وتباطؤء اللمعانية ومدة التوازن بالاضاقة الى كثافة الفيض تم تعيينها بالاعتماد على بعض الخواص لنجوم النابضات مثل الفترة للنجم النابض ومشتقة الفترة لعينة من النجوم تم اعتمادها .النموذج الذي تم الاعتماد عليه بالدراسة هو نموذج الاسطوانة الضوئبة .بينت النتائج ان النجوم الاعتيادية الفترة تملك مجالا مغناطسي اكبر وفترة توازن وكذلك اكثر تباطؤ من النجوم الملي ثانية النابضة لكن نجوم الملي ثانية لها لمعانية اكثر وكثافة فيض اكبر اي ان النجوم الاعتيادية الفترة تفقد طاقتها بزمن اطول اي انها نجوم حديثة التكوين.

Introduction:

After the discovery of the neutron by Chadwick in 1932, two astronomers, Baade & Zwicky, proposed that during Supernova explosions small, extremely dense objects could be created in the center of the exploding star. They suggested that the enormous pressure occurring in the center of the explosion would be sufficient to enable an "inverse beta-decay" during which electrons and protons are combined to neutrons and neutrinos [1].

Neutrinos could leave the star to carry away a substantial amount of energy, leaving behind a very dense object consisting mostly of neutrons. They called these objects accordingly "neutron stars".

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Based on quantum mechanical arguments they computed that neutron stars should have a diameter of about 20 km while containing 1.4 times the mass of the sun. Given this extremely small size expected for these objects, astronomers therefore considered it to be impossible to ever detect neutron stars and hence to verify the predictions by Baade &Zwicky. The situation changed dramatically in 1967. Meanwhile a new window had been opened up for astronomers, the radio window. The astronomers were puzzled by this discovery and wanted to establish its nature before they made it public. Indeed, one possibility that was seriously considered was that of a signal sent by extra-terrestrial intelligence [2]. Soon, however, the team discovered more such periodic signals, and it seemed highly unlikely that one would suddenly receive signals from many different civilizations at once. Moreover, a period variation due to a Doppler effect caused by the moving planet of a possibly transmitting civilization was not discovered. A natural origin of the signal was hence concluded [2,3].

1. Neutron stars:

Neutron stars are the densest massive objects in the universe. They are ideal astrophysical laboratories to test theories of dense matter physics and provide connections among nuclear physics, particle physics and astrophysics. Recent observations, including studies of binary pulsars, thermal emission from both isolated and accreting neutron stars, and glitches from pulsars provide information about neutron star masses, radii, temperatures, ages and internal compositions [3].

The internal structure of a normal neutron star is depicted in Figure-1. The star can be viewed as having 5 regions [4, 5]:

●The atmosphere shapes the thermal optical, ultraviolet and x-ray spectrum.

● the envelope, whose composition determines its relative effectiveness as an insulating layer, has densities ranging below (1 g.cm^{-3}).

● in the density range up to about (10^{14}) g.cm^{-3}, the crust is chiefly populated with nuclei and electrons. Above the neutron drip density (4.10^{11} g.cm^{-3}) a sea of (likely super fluid) neutrons accompanies the nuclei and becomes more abundant at higher densities. A popular model for glitches involves weak coupling between normal and super fluid matter within the crust.

●the outer core consists of nucleons, electrons and muons. Protons in the outer core may be super conducting.

●depending upon the stellar mass and the relative stiffness of matter, an inner core with exotic matter may exist.

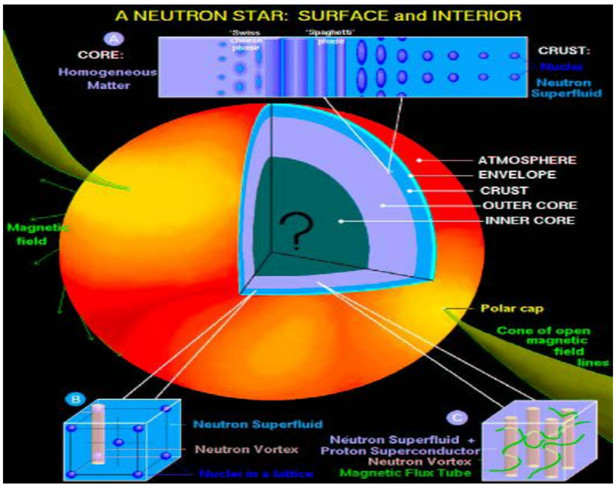

Figure 1- Internal structure of a neutron star [6]

2-1. Pulsars:

Every armchair astronomer is familiar with the concept of violently rotating neutron stars, better known as pulsars. They are, after all, popular celestial objects with unique characteristics. For instance, pulsars are highly magnetized and accompanied by beams of radiation emanating from their magnetic poles. Pulsars have regular periods that cause them to pulse in precise intervals. This pulsing is, in fact, so regular that certain types even rival atomic clocks in terms of their time keeping precision [7].

Pulsars are highly magnetized, rotating neutron stars which emit a narrow radio beam along the magnetic dipole axis. As the magnetic axis is inclined to the rotation axis, the pulsar acts like a cosmic light-house emitting a radio pulse that can be detected once per rotation period when the beam is directed toward Earth. For some very fast rotating pulsars, the so-called millisecond pulsars, the stability of the pulse period is similar to that achieved by the best terrestrial atomic clocks. Pulsars emit electromagnetic radiation and, in particular, magnetic dipole radiation as they essentially represent rotating magnets. These spinning neutron stars behave in similar way to light houses as showed in Figure-2; this figure shows that the angle between rotation axis and magnetic axis (λ) varies between (0-90˚) [8].

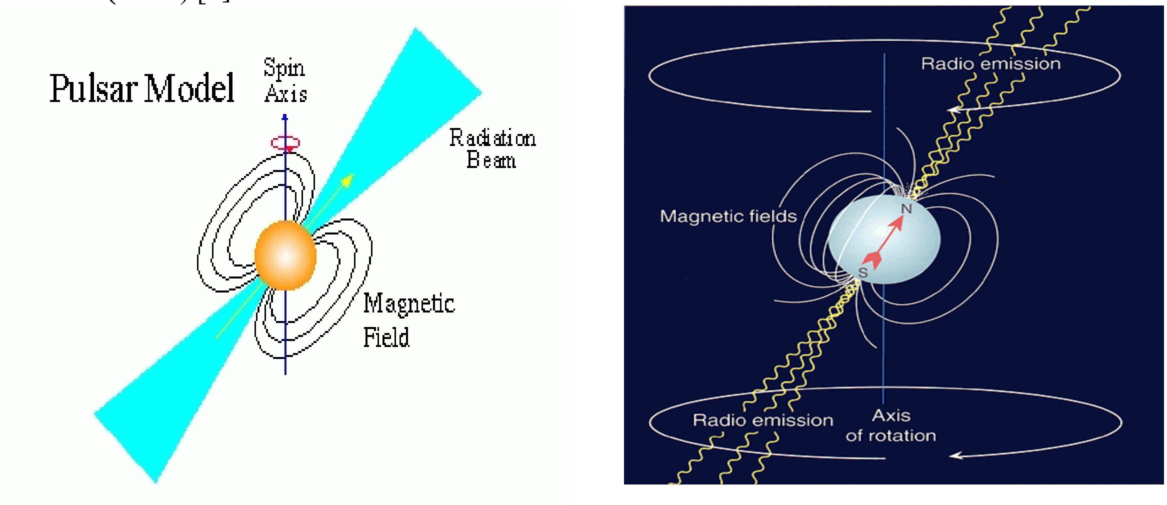

Figure 2- Halo Cone Model for Pulsar star [8].

The birth and evolution of pulsars are of considerable interest. The spatial distribution of pulsars at birth maybe used to associate them with their progenitors. Their initial spin periods may also be related to those of the progenitors' cores, which are not well predicted by theory due to differential rotation [9]. The birth properties of neutron stars are also intimately related to the physics of core-collapse supernovae in which most are thought Pulsar stars divided into two types depending on the periods of rotation, normal emission Pulsar and Millisecond pulsars (MSPs) and the different between them which are [10,11]:

●Millisecond pulsar differ in evolutionary history from that of normal pulsar also differs in their radio emission properties and MSPs spectra are signification different from normal pulsar.
●MSPs are also slightly less luminosity and less efficient radio emitters than normal pulsars.
●About 80% of all MSPs found in our galactic plane are member of binary systems.
●MSPs are rotate much faster than the normal pulsar as the observation shows the results of the period time that many approach to less than 1ms.
●The surface magnetic field of MSPs is less than the normal pulsars.
●The characteristic age of MSPs is longer than the normal pulsars because MSPs is old stars.

2-2. Millisecond Pulsars and X-ray Binaries:

The standard evolutionary picture for millisecond pulsars is that they are born in supernovae with periods of 10s of milliseconds, then evolve along a line of approximately constant magnetic field strength (i.e. n = 3) on the $P\_\dot{P}$ Diagram Figure-3, slowing down until eventually radio emission ceases once they pass into the pulsar death valley. Here, those `dead' pulsars which happen to be in binary systems can undergo accretion from their binary companion [6].This accretion can heat areas of the NS surface (`hot spots') which emit strongly in X-rays - the system is now an X-ray binary system. As well as heating the star the accretion can spin up the star to periods of a few milliseconds [12].

The pulsar is now reborn as a millisecond pulsar and once again is seen to emit as a radio pulsar. In what follows we do not consider the NSs which are millisecond pulsars or those seen in X-ray binaries as this standard evolutionary picture sees these two populations as originating from `normal' radio pulsars. Their birthrates should thus be accounted for in the pulsar birthrate. However we note that if some NSs in X-ray binaries did not originate from the normal radio pulsars the problem outlined below may be emphasized even further [13].

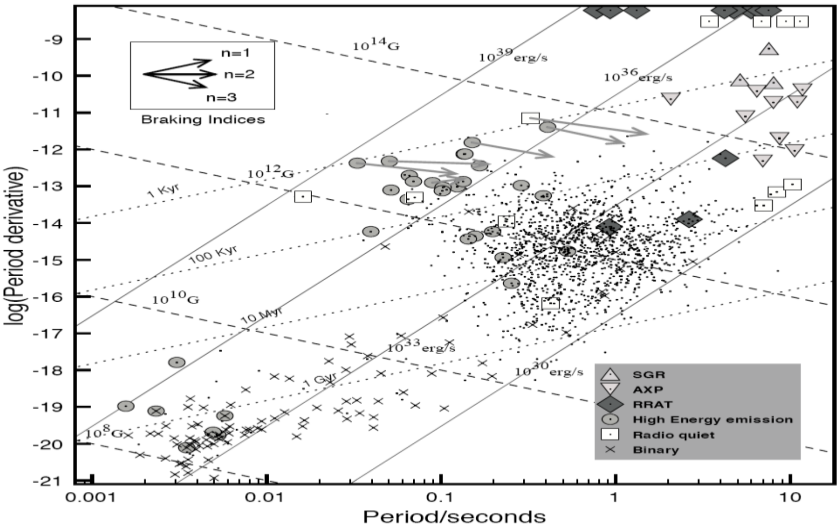

Figure 3- $P_P^{\bullet}$diagram showing the various NS populations [13].

3. Basic Consideration and Equations:

The main goal of studying the pulsars stars is to maintain the behavior of those unique stars for showing their strong magnetic field and other factors, by some samples of the Normal and Milliseconds pulsars from the “ATNF Pulsar Database” catalogue, [14,15].

3-1. The Magnetic field and Spin down Luminosity with Pulsar’s period derivative*:*

Relation can estimate the Magnetic field of Pulsar as [16,17]

$$B\ (T) = 6.8x10^{15}\sqrt{P\,P^{\bullet}} \quad (1)$$

Where:

P: Pulsar’s period, $P^{\bullet}$:Pulsar’s period derivative.

The Spin down Luminosity of Pulsar can be calculate by the relation [17]

$$L_{sp} = \frac{-4\pi^2 I P^{\bullet}}{P^3} \quad (2)$$

Where: I is the moment of inertia =10^{45} g. cm

Flux density for the pulsars giving by the relation[18]

$$S_{mjy} = L_{sp}/d^2 \quad (3)$$

Where: d is the galactic bulge =2.5 kpc

3-2. The Characteristic age, Spin down and Equilibrium Period of Pulsar Stars:

Relation can estimate the Characteristic age of Pulsar as [17]

$$T_{ch} = P/2P^{\bullet} \quad (4)$$

The counting Spinning times of Pulsars around its axis is given by [17]

$$\textit{Spin down} = P \times P^{\bullet} \quad (5)$$

Relation can estimate the Equilibrium period of Pulsar and accretion rate as [19]

$$P_{eq} = (1.9)\ B^{6/7} M^{-5/7} (M^{\bullet}/M^{\bullet}_{Edd})^{-3/7} R^{18/7} \quad (6)$$

Where:

B: is the Magnetic field

M: is the mass of Neutron star = 1.4 $M_{\odot}$

$M^{\bullet}$: is accretion rate of pulsar star = ***LR/GM***

L: Luminosity of pulsar star

R: Radius of Neutron star = 10^6cm

G: gravitation constant = 6.670× 10^{-8}

$M^{\bullet}_{Edd}$: The critical eddingtor = 1.5 × $10^{-8} M_{\odot}$

4. Calculations and Results:

By using the relations that adopted, the magnetic field strength (*B*) of the normal pulsars surface is greater than the magnetic field strength of the millisecond pulsars as shown in Table-1 and 3this return to the proportional relationship between magnetic field and the pulsar period (*P)* and the time derivative period ($P^{\bullet}$)according to measuring equation (1) and Figure-1 showed that at the smallest amount of (*P*) goes to the maximum value s of magnetic field of normal pulsar, that’s mean that the stars in those period are young and have a strong magnetic field, contrariwise of that the milliseconds pulsar has a large value of magnetic field at relatively high pulsar period (P)as shown in Figure-7. The results showed that the normal pulsars has magnetic field bigger by (10^2 Tesla) than the millisecond pulsars, this occurs because the different values of time derivative ($P^{\bullet}$), this mean that the ($PP^{\bullet}$) multiplication is identify the value of magnetic field strength of pulsars surface.

The spin down Luminosity and Characteristic age values calculated by using equations (2&4) respectively, and illustrated in Table-2 and 4.Normal pulsar stars have maximum value of Characteristic age at minimum value of spin down luminosity as shown in Figure-6, that's means that the youngest star required long time to lose its energy, and milliseconds pulsar has a large value of spin down luminosity at minimum value of characteristic age as shown in Figure-12.

The spin down value calculated by using equations (5), and illustrated in Table-2 and 4. Normal pulsar stars have maximum value of spin down at minimum value of Characteristic age as shown in Figure-5, and milliseconds pulsar has a low value of spin down at maximum value of characteristic age as shown in Figure-11.

The equilibrium period estimated by equation (6) and illustrated in Table-2 and 4, normal pulsar star has equilibrium period larger than millisecond pulsar star.

Finally, flux density is illustrated in Table-2 and 4 by using equation (5) in milijansky (mjy) unit which is proportional with luminosity.

Table 1- Represents the values of magnetic field with the period and period derivative for Adopted sample of normal pulsar star.

#	Name	P (s)	log(p)	$P^{\bullet}(s.s^{-1})$	$B\times 10^{9}(T)$	log(B)
2513	B2310+42	0.349	-1.0527	1.12×10^{-16}	0.0425	17.5653
2311	J1949+2306	1.319	0.2769	0.12×10^{-15}	0.0856	18.2646
1973	J1855+0422	1.678	0.5176	1.36×10^{-15}	0.3248	19.5989
1179	J1709-4342	1.735	0.5510	8×10^{-16}	0.2533	19.3502
2528	J2333+6145	0.756	-0.2797	1.17×10^{-15}	0.2022	19.1250
2527	B2327-20	1.643	0.4965	4.63×10^{-15}	0.5931	20.2009
2523	B2323+63	1.436	0.3619	2.82×10^{-15}	0.4327	19.8856
2522	J2325-0530	0.868	-0.1416	1.02×10^{-15}	0.2023	19.1254
2521	B2321-61	2.347	0.8531	2.58×10^{-15}	0.5291	20.0868
2529	B2334+61	0.495	-0.7032	1.93×10^{-15}	2.1018	21.4661
2519	B2319+60	2.256	0.8136	7.03×10^{-15}	0.8564	20.5682
2517	B2315+21	1.444	0.3674	1.04×10^{-15}	0.2635	19.3896
2524	B2324+60	0.233	-1.4567	3.52×10^{-16}	0.0616	17.9359

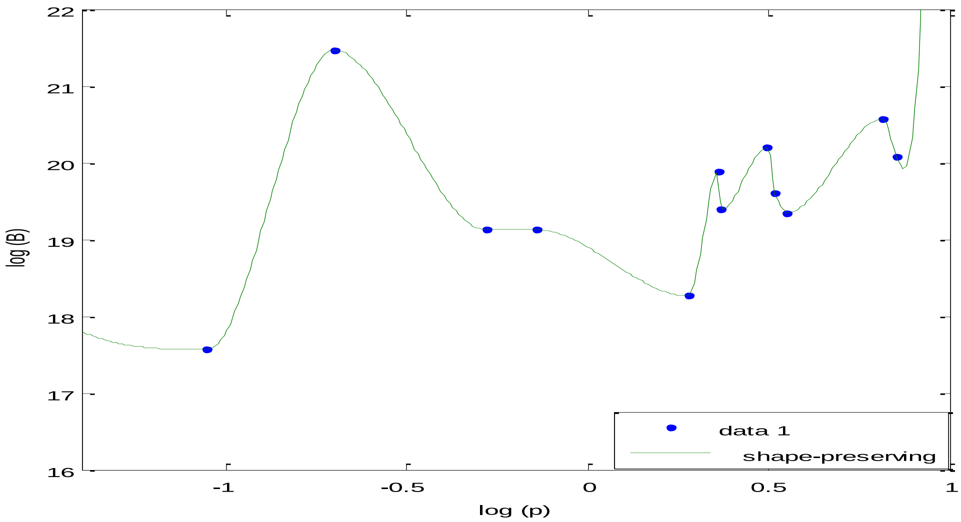

Figure 1- Represents the relationship between the Pulsar period and the magnetic field for normal.

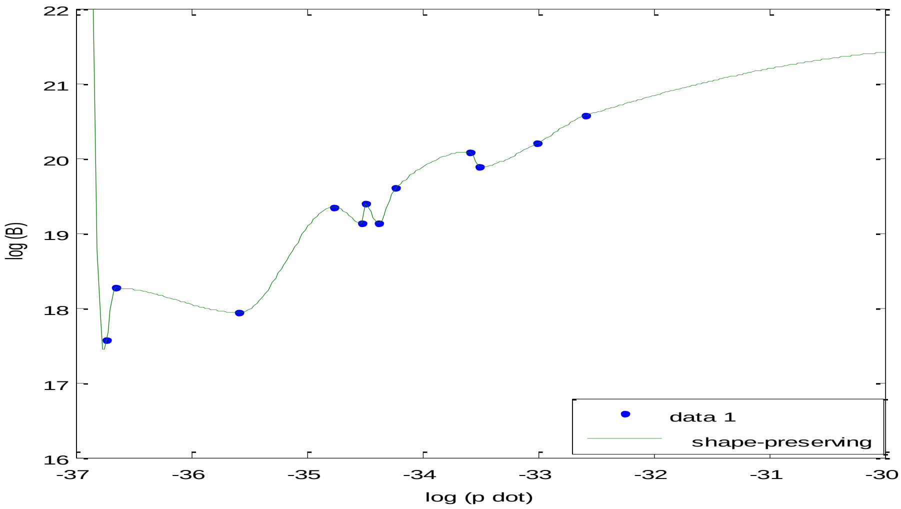

Figure 2- Represents the relationship between the Pulsar period drevitive and the magnetic field for normal.

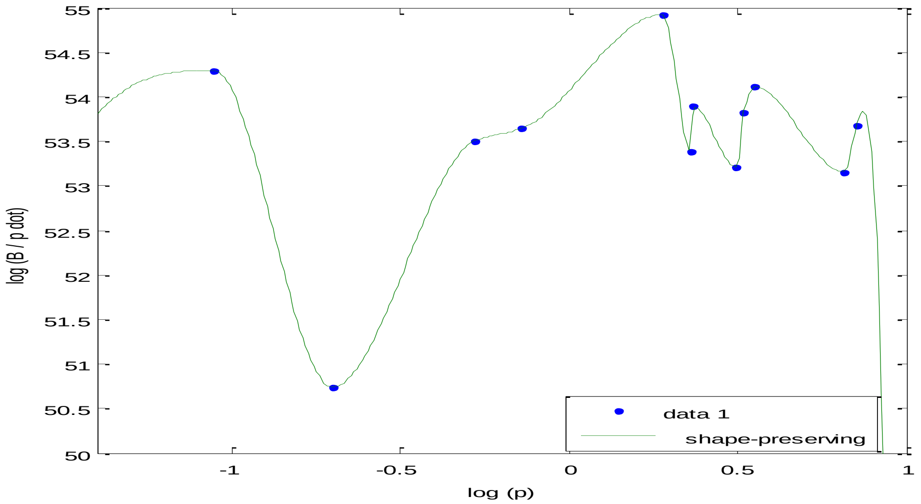

Figure 3- Represents the relationship between the Pulsar period e and the $^{B}/_{P}$. (drop potential) for normal.

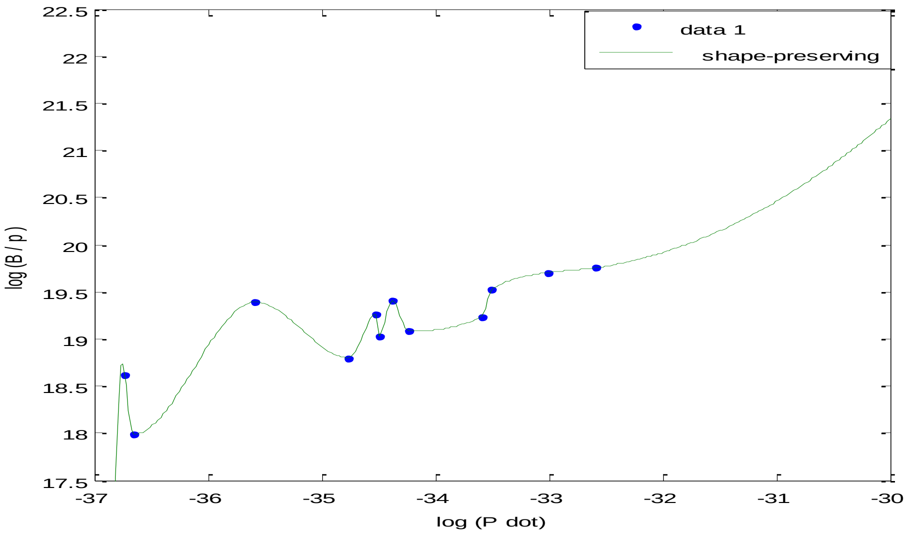

Figure 4- Represents the relationship between the Pulsar periode drevitive and the $^{B}/_{P}$(drop potential) for normal.

Table 2- Represents the values of characteristic age, Luminosity ,Equilibrium period, Spin down, Flux density and drop potential for Adopted sample of normal pulsar star.

#	*Name*	$T_{ch}\times 10^8$ (year)	L_{sp} (erg/sec)	$p_{eq}\times 10^6$	Spin down $(P\times P^{\bullet})\times 10^{-13}(sec)$	S_{mjy}	Drop potential $B/P^{\bullet}\times 10^{23}$
2513	B2310+42	0.4946	1.0402×10^{32}	0.1251	0.0004	1.6643×10^{25}	3.7959
2311	J1949+2306	1.7447	2.0645×10^{30}	1.2220	0.0016	3.3032×10^{23}	7.1292
1973	J1855+0422	0.1958	1.1364×10^{31}	1.8463	0.0228	1.8182×10^{24}	2.3886
1179	J1709-4342	0.3442	6.0472×10^{30}	1.9551	0.0139	9.6755×10^{23}	3.1667
2528	J2333+6145	0.1026	1.0690×10^{32}	0.4707	0.0088	1.7104×10^{25}	1.7285
2527	B2327-20	0.0563	4.1212×10^{31}	1.7808	0.0761	6.5939×10^{24}	1.2810
2523	B2323+63	0.0808	3.7596×10^{31}	1.4137	0.0405	6.0154×10^{24}	1.5345
2522	J2325-0530	0.1351	6.1574×10^{31}	0.5964	0.0089	9.8518×10^{24}	1.9837
2521	B2321-61	0.1444	7.8784×10^{30}	3.2819	0.0606	1.2605×10^{24}	2.0510
2529	B2334+61	0.0004	6.2821×10^{34}	0.2277	0.9554	1.0051×10^{28}	0.1089
2519	B2319+60	0.0509	2.4171×10^{31}	3.0668	0.1586	3.8674×10^{24}	1.2182
2517	B2315+21	0.2204	1.3636×10^{31}	1.4272	0.0150	2.1818×10^{24}	2.5338
2524	B2324+60	0.1051	1.0986×10^{33}	0.0626	0.0008	1.7578×10^{26}	1.7495

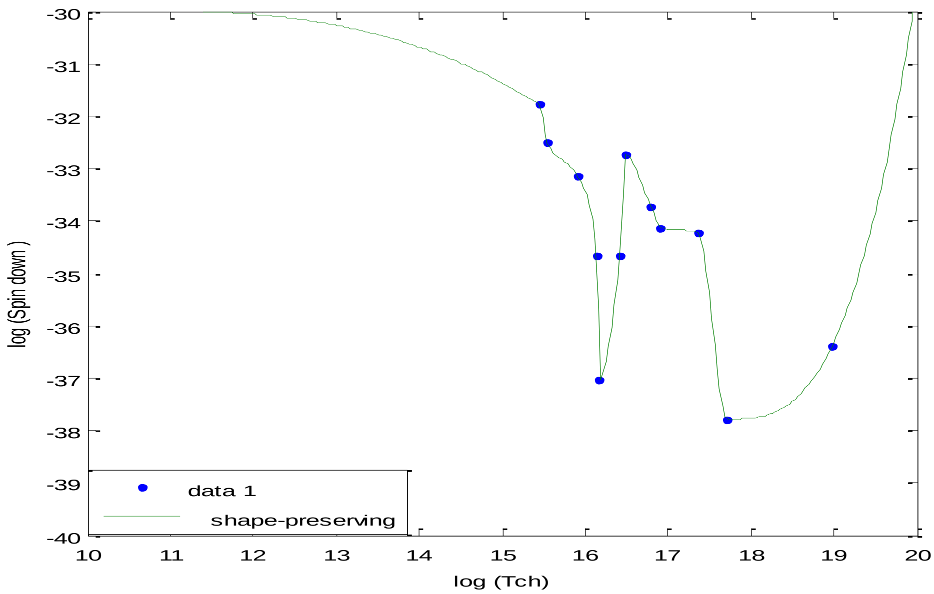

Figure 5- Represents the relationship between thecharacteristic age and the Spin down for normal.

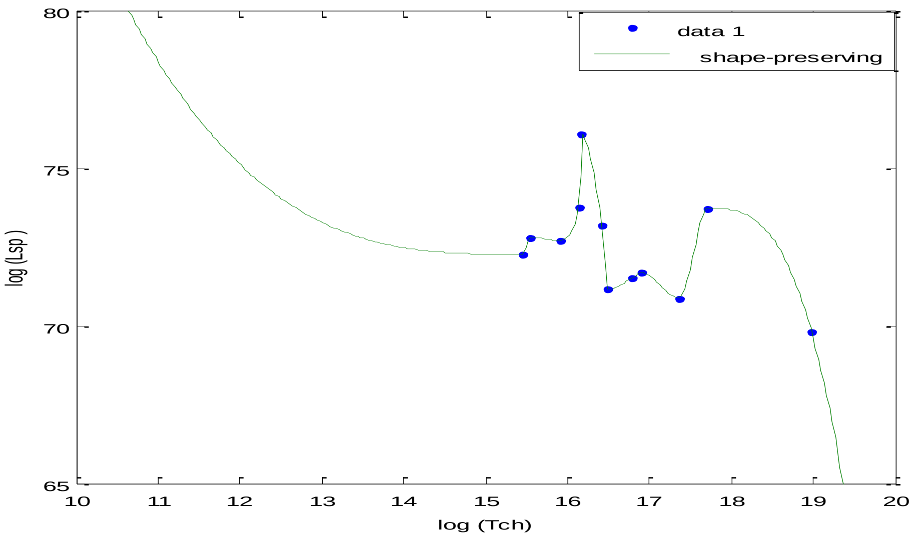

Figure 6- Represents the relationship between thecharacteristic age and Luminosity for normal.

Table 3-Represents the values of magnetic field with the period and period derivative for Adopted sample of Millisecond pulsars star.

#	Name	P (s)	log(p)	$P^{\bullet}(s.s^{-1})$	$B\times 10^{7}(T)$	log(B)
2510	J2307+2225	0.5358	-0.6240	8.7×10^{-18}	1.4681	16.5021
2391	J2033+1734	0.0059	-5.1328	1.11×10^{-20}	0.0055	10.9156
2506	J2302+4442	0.0051	-5.2785	13.3×10^{-21}	0.0056	10.9332
2491	J2235+1506	0.0597	-2.8184	1.57×10^{-19}	0.0658	13.3975
2485	J2229+2643	0.0029	-5.8430	1.46×10^{-21}	0.0014	9.5463
2496	J2241-5236	0.0021	-6.1658	6.64×10^{-21}	0.0025	10.1422
2530	J2339-0533	0.0028	-5.8781	1.41×10^{-21}	0.0043	10.6626
2516	J2317+1439	0.0034	-5.6840	2.42×10^{-21}	0.0020	9.8784
2432	J2124-3358	0.0049	-5.3185	6.17×10^{-18}	0.1182	13.9830
2475	J2215+5135	0.0026	-5.9522	3.34×10^{-20}	0.0063	11.0567
2473	J2214+3000	0.0031	-5.7764	1.40×10^{-20}	0.0045	10.7099
2455	J2145-0750	0.0160	-4.1352	2.97×10^{-20}	0.0148	11.9065
2400	J2043+1711	0.0023	-6.0748	5.24×10^{-21}	0.0024	10.0693
2520	J2322+2057	0.0048	-5.3391	9.70×10^{-21}	0.0046	10.7450

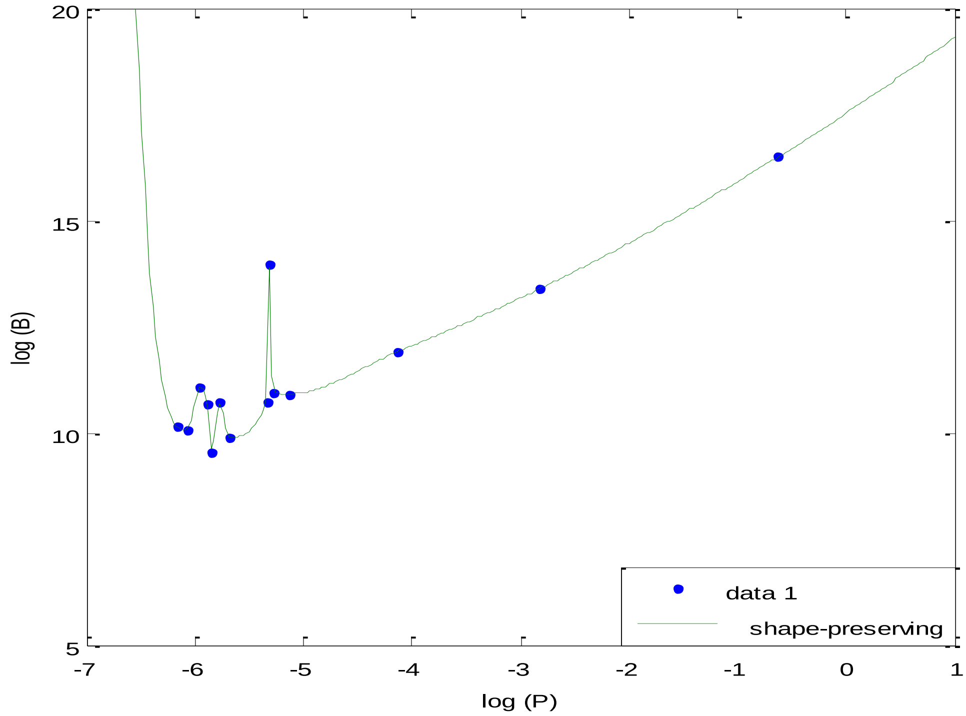

Figure 7- Represents the relationship between the Pulsar period and the magnetic field forMillisecond .

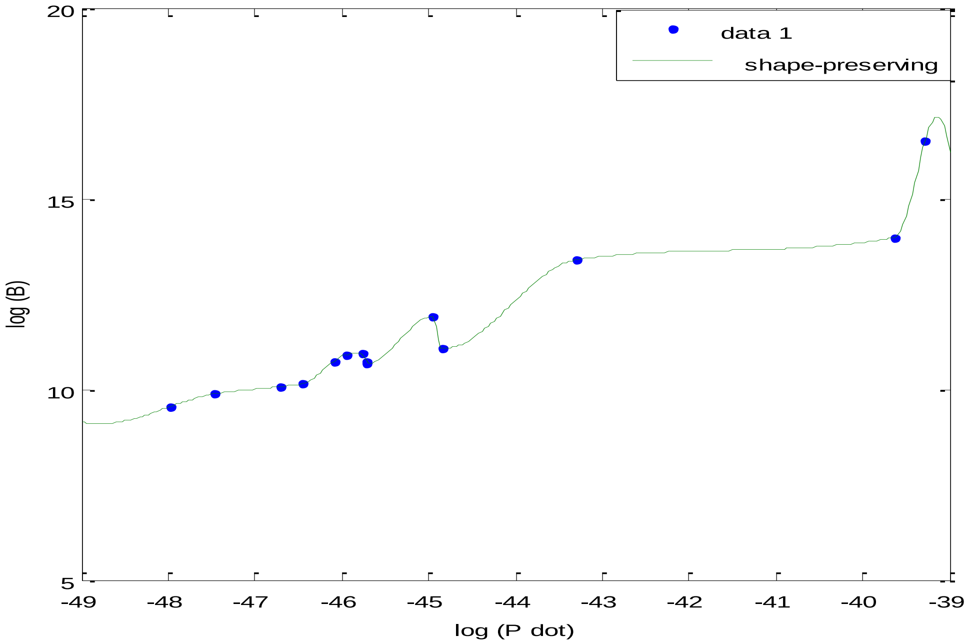

Figure 8- Represents the relationship between the Pulsar period derivitavie and the magnetic field forMillisecond .

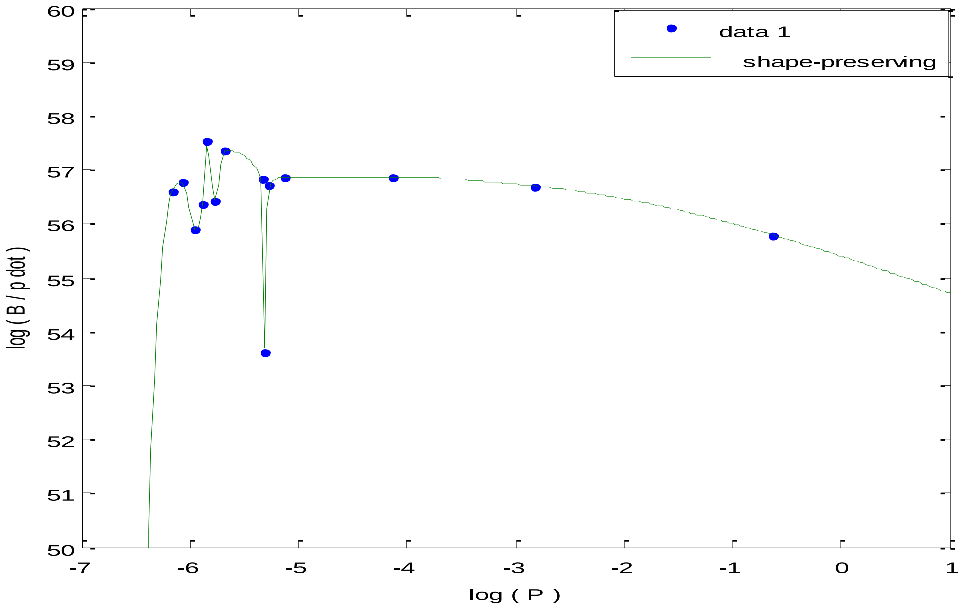

Figure 9- Represents the relationship between the Pulsar period and the $^{B}/_{P}$•(drop potential) forMillisecond .

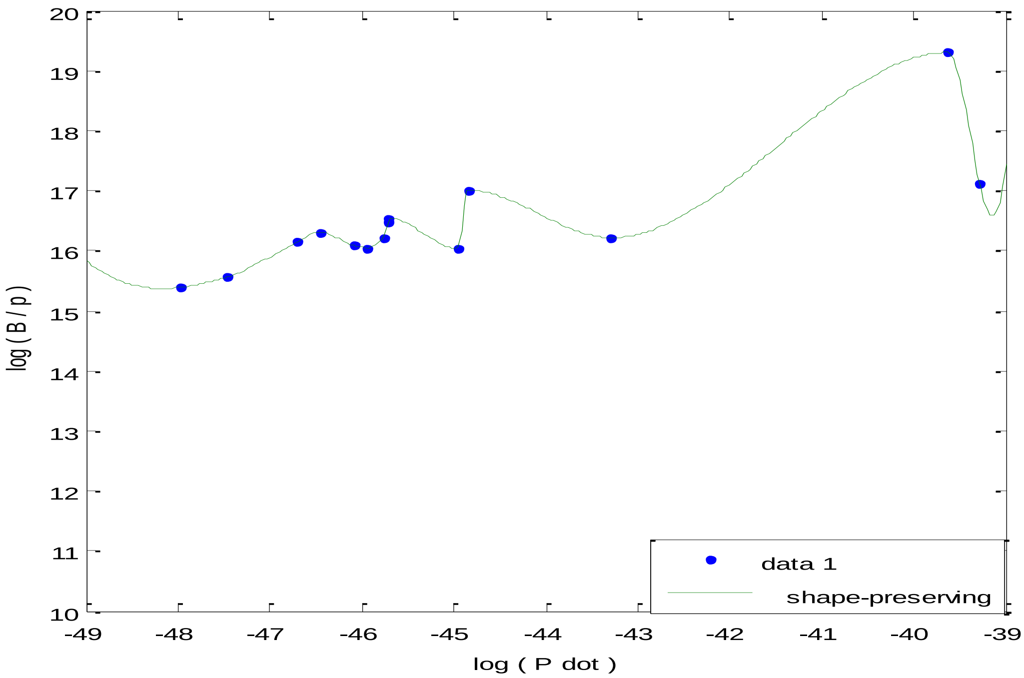

Figure 10- Represents the relationship between the Pulsar periodderivitive and the $B/_P$(drop potential) forMillisecond .

Table 4- Represents the values of characteristic age, Luminosity, Equilibrium period, Spin down, Flux density and drop potential for Adopted sample of Millisecond pulsar star.

#	Name	$T_{ch} \times 10^{10}$ $(year)$	L_{sp} (erg/sec)	$p_{eq} \times 10^5$	Spin down $(P\times P^{\bullet})(sec)$	S_{mjy}	Drop potential $B/P^{\bullet} \times 10^{24}$
2510	J2307+2225	0.0978	2.2329×10^{30}	2.6085	0.4661×10^{-17}	3.5726×10^{23}	1.6875
2391	J2033+1734	0.8437	0.0021×10^{36}	0.0012	0.0065×10^{-20}	0.0034×10^{29}	4.9576
2506	J2302+4442	0.6087	0.0040×10^{36}	0.0009	0.0068×10^{-20}	0.0064×10^{29}	4.2108
2491	J2235+1506	0.6036	2.9130×10^{30}	0.1626	0.9373×10^{-20}	4.6608×10^{23}	4.1932
2485	J2229+2643	3.1529	0.0024×10^{36}	0.0003	0.0004×10^{-20}	0.0038×10^{29}	9.5837
2496	J2241-5236	0.5020	0.0283×10^{36}	0.0002	0.0014×10^{-20}	0.0453×10^{29}	3.8241
2530	J2339-0533	0.3152	0.0254×10^{36}	0.0003	0.0039×10^{-20}	0.0406×10^{29}	3.0302
2516	J2317+1439	2.2301	0.0024×10^{36}	0.0004	0.0008×10^{-20}	0.0038×10^{29}	8.0601
2432	J2124-3358	0.0013	2.0704×10^{36}	0.0008	0.0030×10^{-17}	3.3126×10^{29}	0.1916
2475	J2215+5135	0.1236	0.0750×10^{36}	0.0003	0.0087×10^{-20}	0.1200×10^{29}	1.8972
2473	J2214+3000	0.3515	0.0186×10^{36}	0.0004	0.0043×10^{-20}	0.0298×10^{29}	3.1998
2455	J2145-0750	0.8551	0.0003×10^{36}	0.0062	0.0475×10^{-20}	0.0005×10^{29}	4.9910
2400	J2043+1711	0.6967	0.0170×10^{36}	0.0002	0.0012×10^{-20}	0.0272×10^{29}	4.5051
2520	J2322+2057	0.7855	0.0035×10^{36}	0.0008	0.0047×10^{-20}	0.0056×10^{29}	4.7835

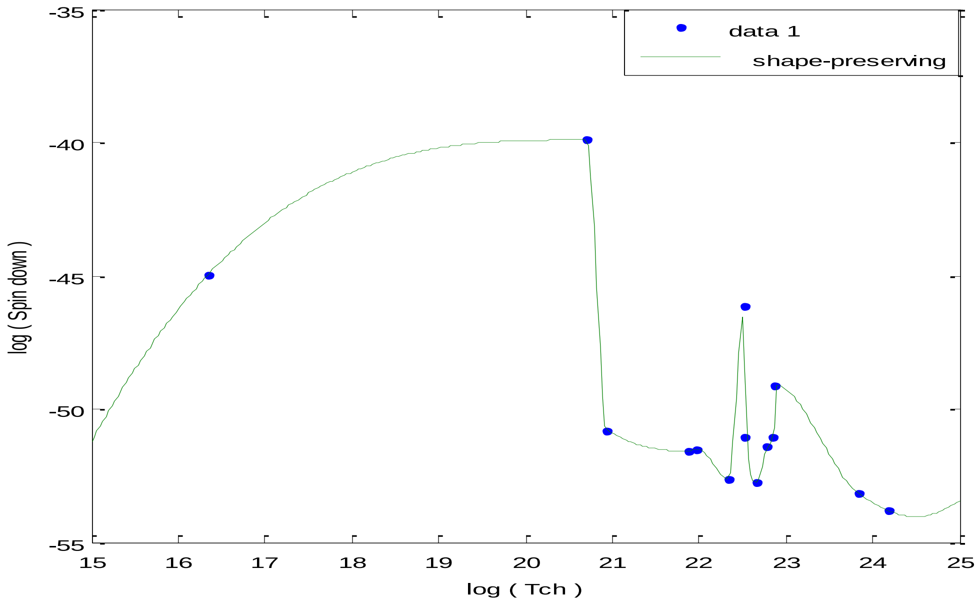

Figure 11- Represents the relationship between thecharacteristic age and Spin down for Millisecond.

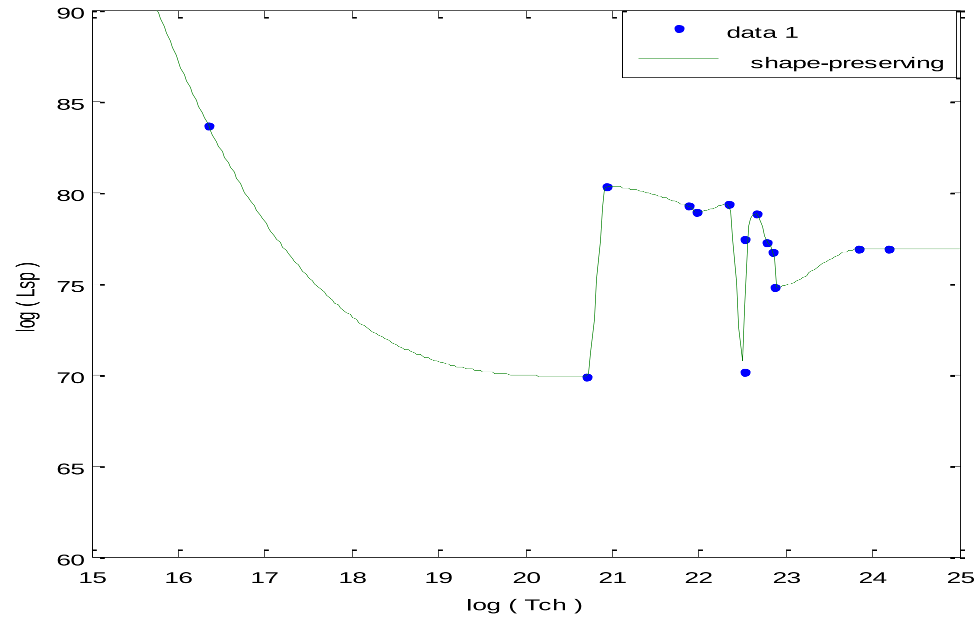

Figure 12- Represents the relationship between thecharacteristic age and Luminosity for Millisecond.

Conclusions:

1- Normal pulsars have magnetic field bigger by (10^2 Tesla) then the Millisecond pulsars.

2- Normal and Millisecond pulsar stars have maximum value of Characteristic age at minimum value of spin down luminositythat's means that the youngest star required long time to lose its energy.

3- Normal pulsar star has equilibrium period larger than Millisecond pulsar star.

4- Normal pulsar star maximum value of potential drop (7.1×10^{23}), while Millisecond pulsar star has maximum value (9.5×10^{24}).And Normal pulsar star maximum value of Flux density (9.8×10^{24}) while Millisecond pulsar star has maximum value (3.3×10^{29}), that's mean Normal pulsar star is younger than Millisecond pulsar star.

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