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Study the Mechanism's Glitches with Age for Neutron Stars

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Abstract

Glitches are sudden increases in the rotational frequency (ν) of a neutron star. Glitches usually occur as fractional increase in the frequency of the order of $\Delta\nu/\nu$ $=10^{-11}$- 10^{-5}.In this work we study the glitch in normal and magnetar pulsar stars, glitches are small or absent in the millisecond pulsar star because it is old star whereas the weak glitch activity of young pulsars by the fact that their internal temperatures are still too high for the crust to store a large stress .The results showed that NART (pulsed emission only at infrared) normal pulsar has more glitches than AXP (Anomalous X-ray Pulsar) and HE (Spin-powered pulsar with pulsed emission from radio to infrared or higher frequencies) stars, as the same time HE stars have more glitches than AXP, in a good agreement with the previous studies. From the results can be conclude that study of neutron star glitches is a very important study in the evolution of neutron star as it helps in probing the neutron star interior.

Keywords: Neutron stars; glitches; pulsars

دراسة ميكانيكية عدم الانتظام الظاهري للنبضات مع عمر النجوم النيوترونية

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الخلاصة

عدم الانتظام الظاهري للفترة هو زيادة مفاجئة في التردد الدوارني (ν) للنج م النيوتروني. وتحدث نتيجة زيادة جزئية في التردد وبمقدار $\Delta\nu/\nu = 10^{-11} - 10^{-5}$ في هذا البحث تمت دراسة ظاهرة التغير المفاجيء لنجوم النابضة من نوع الاعتيادية والمغناطيسية. تكون هذه الظاهرة قليلة او لاتظهر في نجوم الملي ثانية النابضة لانها نجوم قديمة التكوين جدا . ضعف نشاط النجوم الشابة النابضة يعزي نوعا ما ان درجة الحرارة الداخلية تبقى عالية جداا للقشرة النجمية لتخزن جهد عالي. بينت النتائج ان النجوم الاعتيادية نوع NART (نبض الانبعاثات فقط في الأشعة تحت الحمراء) تمتلك عدم انتظام للنبضة اكثر AXP(نابض ذات انبعاث في الاشعه السينيه) و HE (نبض ذات تردد عالي وانبعاث من الاشعاع الراديوي الى اشعاع التحت الحمراء) وHE تمتلك عدم انتظام للنبضة اكثر من AXP وهذا العمل يتفق مع نتائج الدراسات السابقة، من خلال النتائج يمكن الاستنتاج ان دراسة ظاهرة عدم الانتظام الظاهري للفترة مهم جدا لدراسة التركيب الداخلي للنجم النيوتروني.

Introduction

Glitches are sudden increases in the rotational frequency (ν) of a neutron star as shown in Figure- 1. After a glitch, the rotational frequency sometimes follows an exponential recovery or relaxation back toward the pre-glitch frequency Glitch was first observed in PSR B0833-45 (Vela) by Radhakrishnan

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& Manchester. Glitches usually occur as fractional increase in angular velocity of the order of $\Delta\Omega/\Omega\ =\ 10^{-5}$ - 10^{-11} and a corresponding relative increment in spin-down rate of the order of $\Delta\Omega^{\bullet}/\Omega\ = 10^{-4}\ -\ 10^{0}$. After the occurrence of a glitch, the spin down rate once again reach an equilibrium value in a process called 'glitch recovery', this process can take day, months or even years. The post-glitch spin-down rate value could be the same as the pre-glitch value, or as the case with those occurring in Crab pulsar could be of higher value .However, a value near the original pre-glitch spin-down rate value is obtained more often. Moreover, the process leading to a glitch is believed to be from the interior of the neutron star, rather than from the magnetosphere which causes the spin-down .This is because the structure of pulses observed during glitch events remains unchanged .Processes leading to these glitch events are still difficult to find, in spite of the many mechanisms proposed for it. It will be interesting also to note that the study of neutron star glitches is a very important study in the evolution of neutron star as it helps examine the neutron star interior [1, 2].

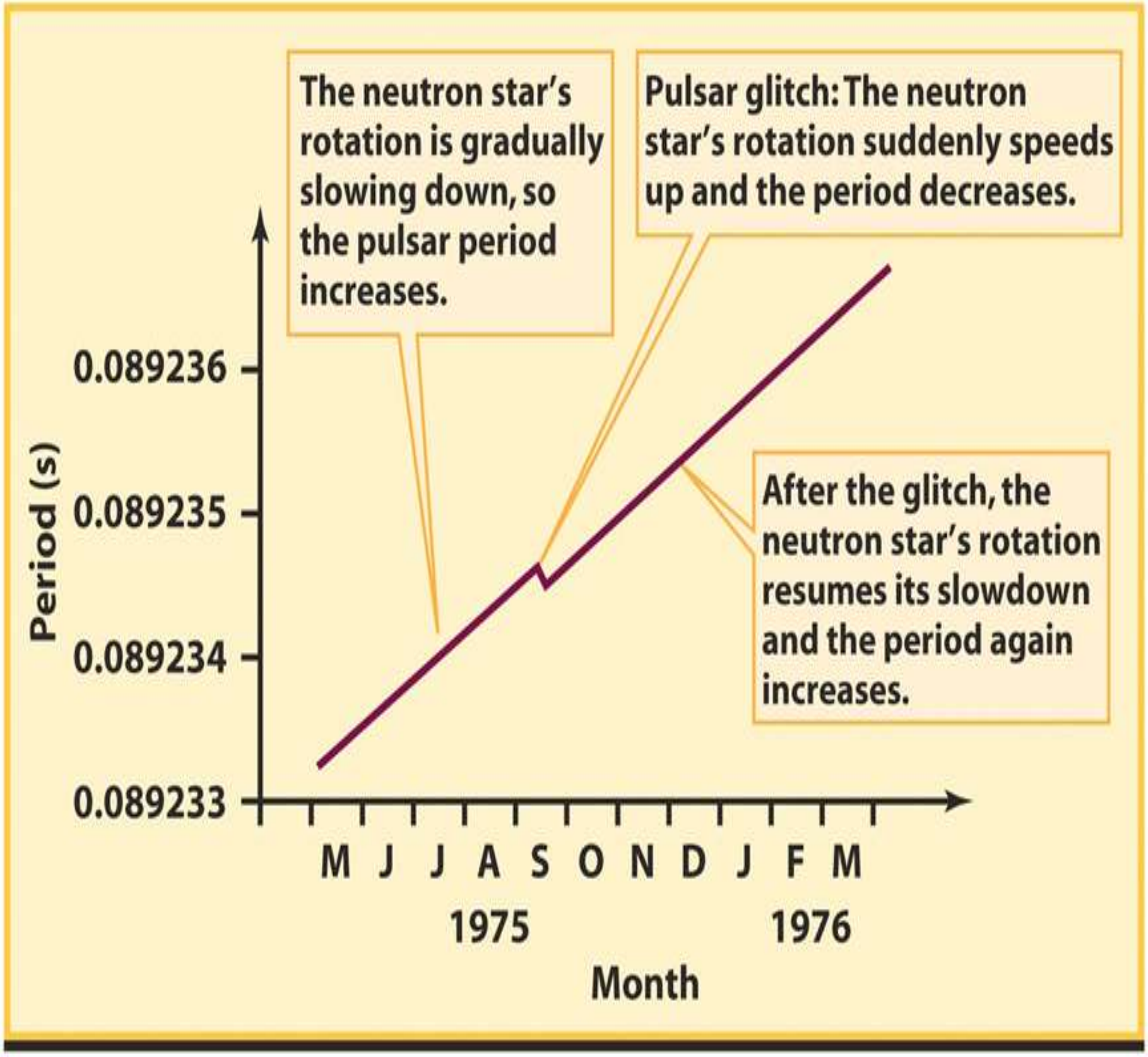


Figure 1- Anatomy of a typical glitch [1].

Glitch Phenomenology

Glitches are thought to be the result of a rapid transfer of angular momentum between this inner superfluid and the outer crust, to which the neutron star magnetosphere is attached and whose radiation we observe. The glitch is observed to be a sudden positive step in frequency, in this case followed by a negative change of the slope. The size of the frequency step is probably the main way to characterize a glitch. It is normally expressed as the fractional quantity$\Delta\nu/\nu$, where $\Delta\nu$the difference between the frequency after and before the glitch.Most glitches is are followed by an increase in the spin-down rate$|\nu^{\bullet}|$, higher frequency and spin-down Rate, confirming the possible occurrence of a glitch. There are two main models describing the origin of glitches. The first regards glitches as star quakes produced by rearrangements of an oblate crust, which would be evolving towards a most spherical Shape as the star slows down, glitches produced by rearrangements of the crust have not been ruled out completely, and they could still be the cause of many of the glitches observed. The second model considers the inner neutron star super fluid as a reservoir of angular momentum, which is transferred to the crust during rapid events, producing what is observed as a glitch [3]. The spin frequency (ν) of a pulsar is measured by recording the time of arrival (TOA) at the telescope of each pulse and fitting a spin-down model obtained by Taylor expanding around a reference timet_0:

$$\nu(t) = \nu_0 + \dot{\nu}_0(t - t_0) + \frac{1}{2}\ddot{\nu}_0(t - t_0)^2 + \cdots \quad (1)$$

After subtracting known systematic effects, such as the Earth's orbital motion and the proper motion of the pulsar, this equation is generally a good fit to the data and higher order terms are not usually included. Slow deviations from this equation are referred to as `timing noise', while sudden, impulsive, changes in the spin frequency and frequency derivative are glitches [4].

Neutron stars

Neutron stars are relativistic compact objects formed by the collapsing cores of massive stars at the end of their evolution as shown in Figure -2. The energy released by the collapsing core start a shock that ejects the outer layers of the progenitor star in a so called supernova explosion. The masses of neutron stars are in the range M ~ 1 - 3$M_{\odot}$.The radii of neutron stars are in the range R ~ 9 - 15 km [5].This material is crushed together so tightly that gravity overcomes the repulsive force between negatively charged electrons and positively charged protons. The resulting structure of the star is complex, with a solid crystalline crust about one kilometer thick encasing a core of superfluid neutrons and superconducting protons. Above the crust exists both an ocean and atmosphere of much less dense material, Walter Baade and Fritz Zwicky from Caltech first predicted the existence of neutron stars in 1934, but they were not discovered until over 30 years later [6].

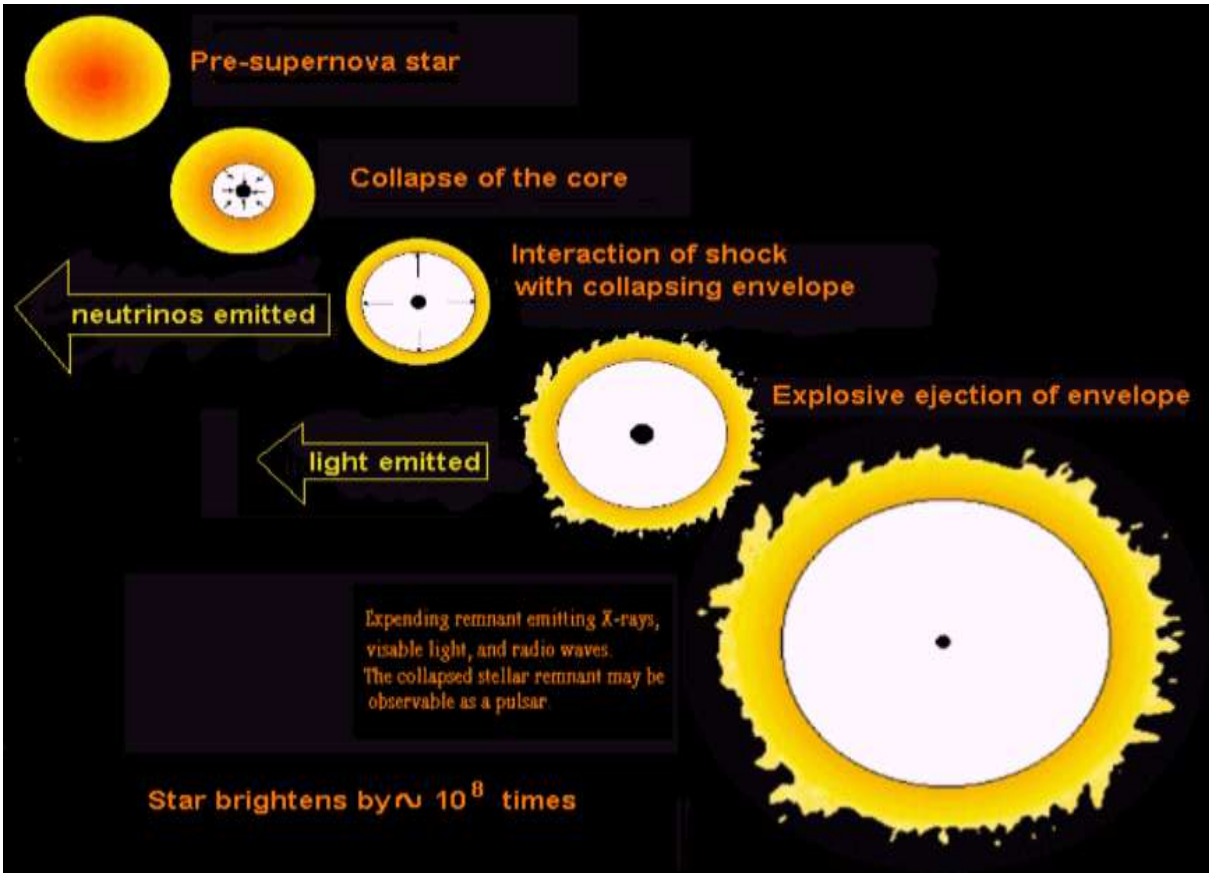


Figure 2- sequence of events Neutron Stars- Supernovae [6].

Neutron Star Spin-down and Characteristic Age

The age of a pulsar with period P and period derivative$P^{\bullet}$, is given by [7]

$$\mathbf{t} = \frac{\mathbf{P}}{(\mathbf{n-1})\mathbf{P}^{\bullet}}\left(\mathbf{1} - \left(\frac{\mathbf{P_0}}{\mathbf{P}}\right)^{\mathbf{n-1}}\right) \qquad \mathbf{(2)}$$

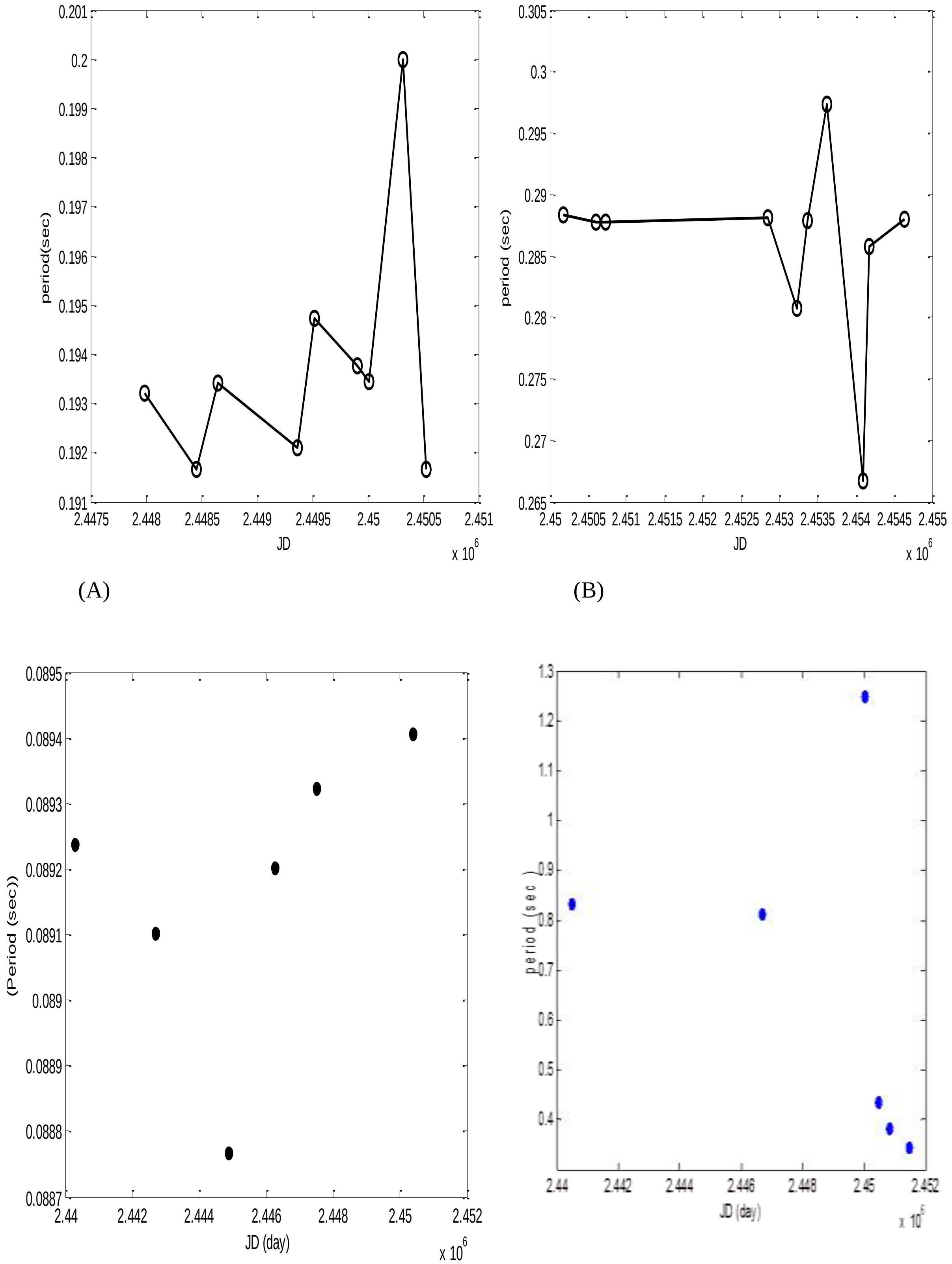
WhereP_0: is the rotation period at birth.
n: is the braking index.
P_0 can only be determined in a couple of special cases and it is generally assumed that $P_0 \ll$ P. It is further assumed that magnetic dipole braking is the dominant braking force, for which n =3. Applying these assumptions to (2) gives the characteristic age [8]

$$\mathbf{T_{ch}} = \mathbf{P/2P^{\bullet}} \qquad \mathbf{(3)}$$

Suggest that most pulsars are $10^6 - 10^7$ years old [8].

Results and Discussion:

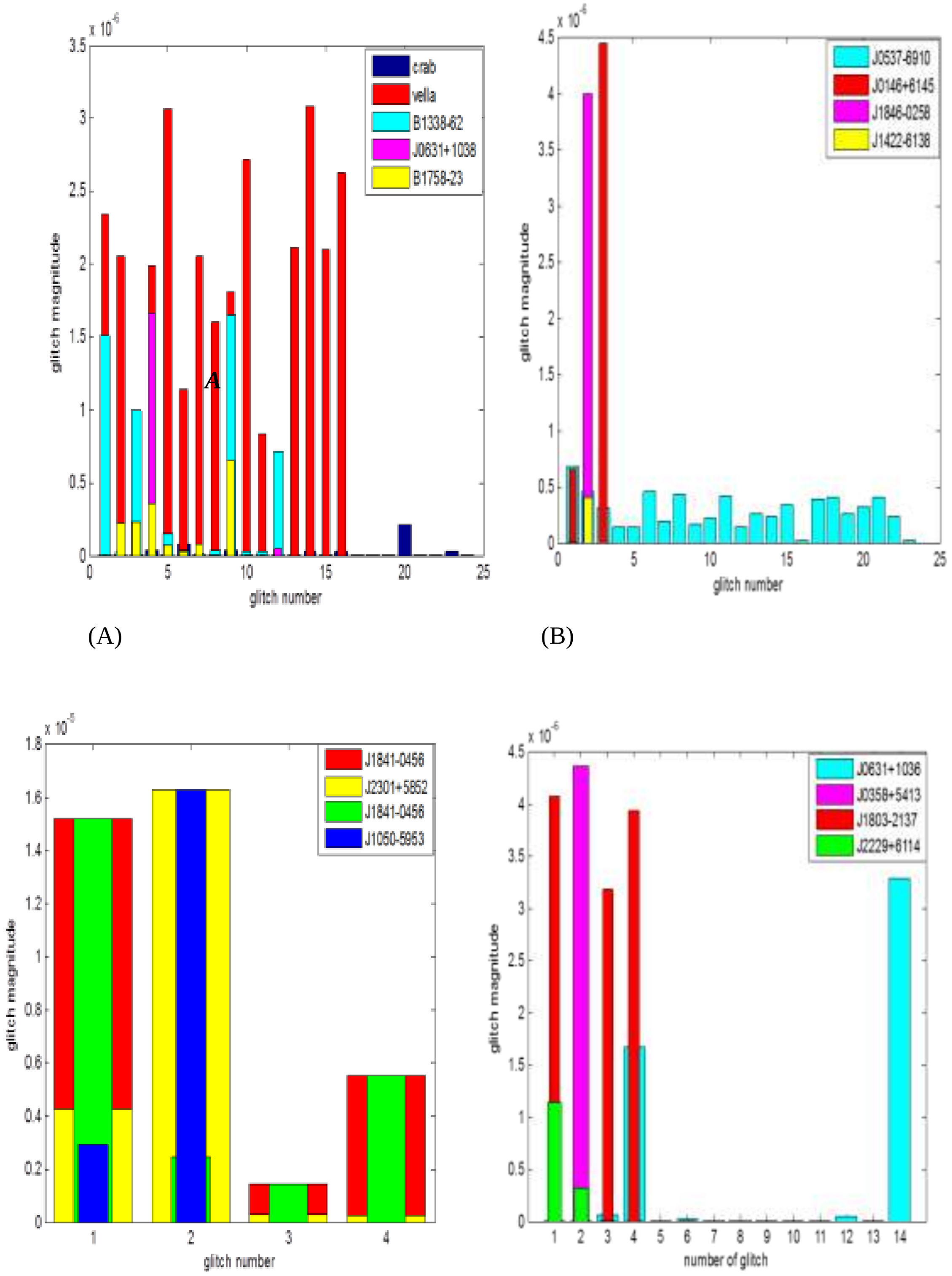
In this section the calculations for glitches in the rotational behavior of pulsars will be done by using the Jodrell Bank pulsar timing data base and take the data from ATNF pulsar data base , The glitch data base and a sample of some pulsars observed used to estimate the glitch magnitude ($\Delta\nu/\nu$) as a function of number of glitch, and the result showed that NART normal pulsar has more glitch than AXP and HE and HE have more glitch than AXP as shown in Figure-(3, 4). and also estimated the Characteristic age ($\mathrm{T_{ch}}$) as a function of number of glitch, The observed glitching rate is clearly correlated with $\mathrm{T_{ch}}$, It has been noted that glitch activity reduces as pulsars age as shown in Figure-7, Normal pulsar have more glitch than Magnetar (young stars)as shown in Figures- (4 , 6), because it have large magnitude$\Delta\nu/\nu$, Small glitches are more difficult to identify, The smallest glitch ever detected is the one in the millisecond pulsar PSR B1821−24 as comparison with previous studies (Innocent Okwudili Eya.Moreover,2011), the process leading to a glitch is believed to be from the interior of the neutron star, rather than from the magnetosphere which causes the spin-down. This is because the structure of pulses observed during. Processes leading to these glitch events are still elusive, in spite of the numerous mechanisms proposed for it will be interesting also to note that the study of neutron star glitches is a very important study in the evolution of neutron star as it helps in probing the neutron star interior.



(A) (B)

(C) (D)

Figure 3- The relationship between the period and Julian day for (A) B1338 -62, (B) J0631+1036, (C) vela and (D) crab normal pulsar.



(A) (B)

(C) **(D)**

Figure 4- The histogram between glitch magnitude and glitch number for: (A) mix, (B) NRAD, (C) AXP and (D) HE normal pulsar.

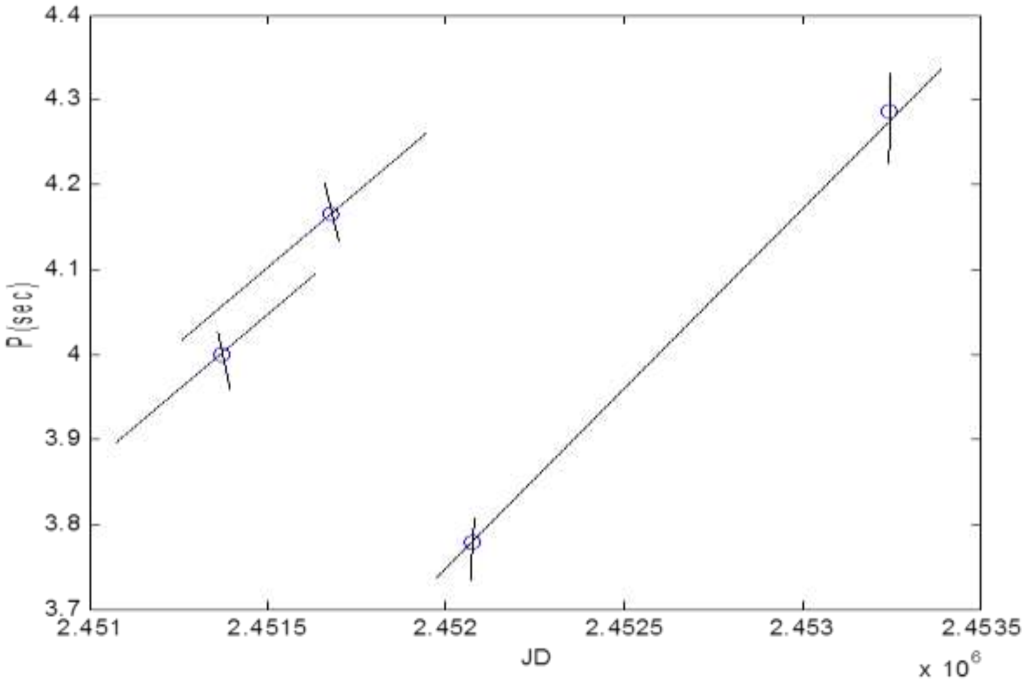


Figure 5- The relationship between the period and Julian day for magnetarJ1814-1744pulsar.

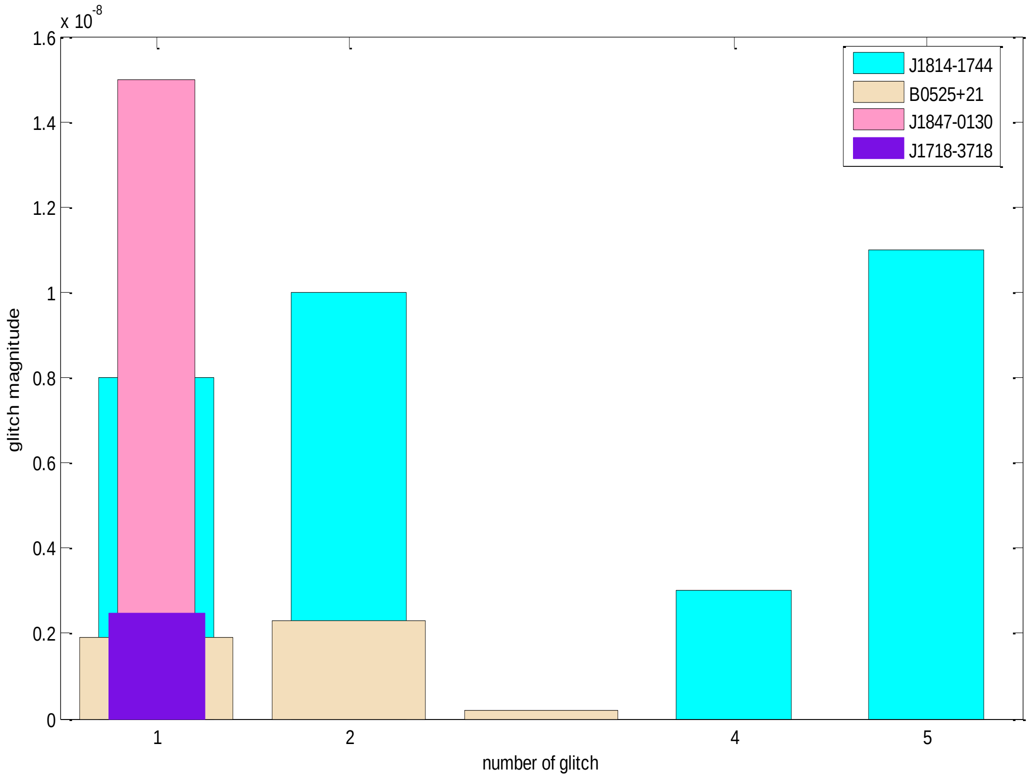
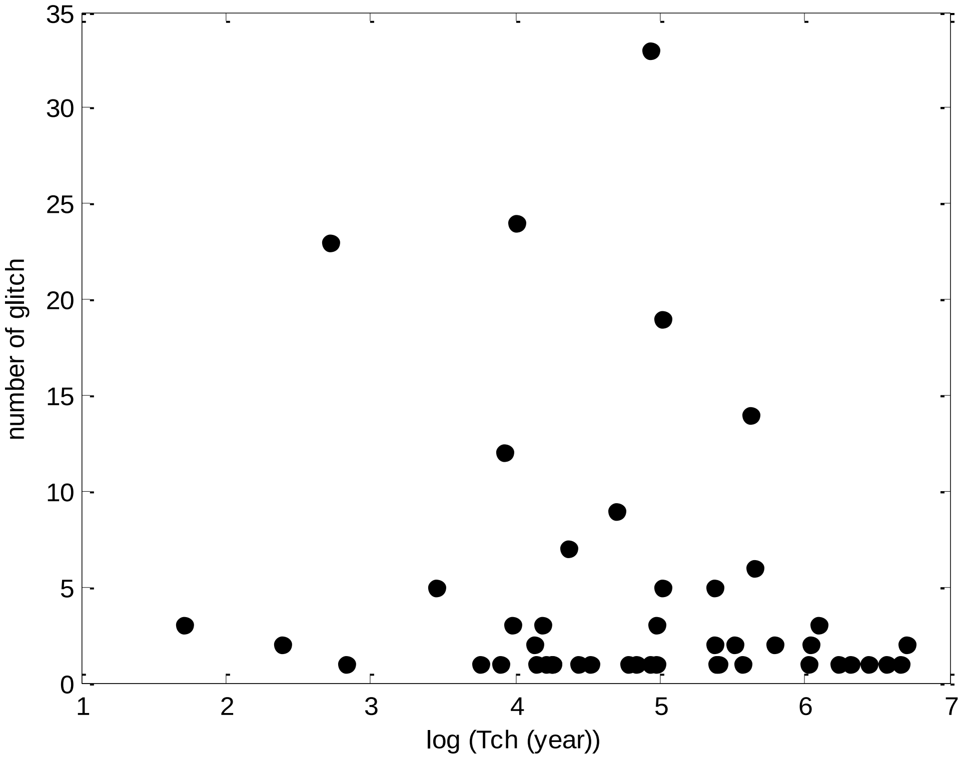
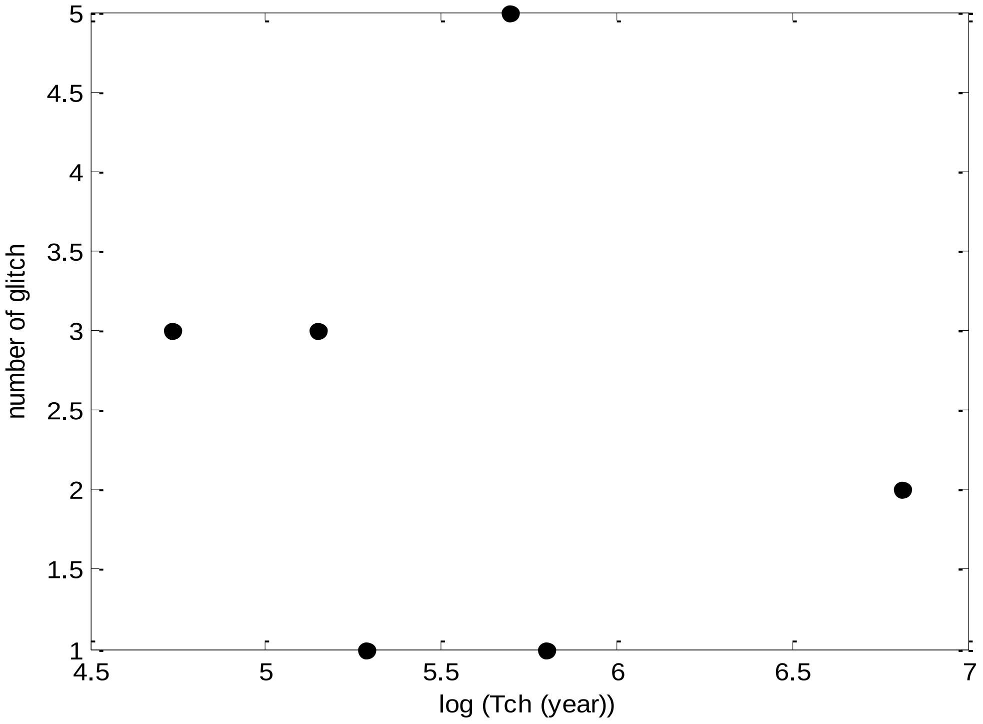


Figure 6- The relationship between glitch magnitude and glitch number for magnetar pulsar.



(A)



(B)

Figure 7- The relation between the number of glitch in a pulsar with pulsar characteristic age for: A-normal pulsar and B-Magnetar pulsar.

Conclusions

1. NART normal pulsar has more glitch than AXP and HE, HE have more glitch than AXP.
2. Normal pulsar has more glitch than Magnetar, because it has large magnitude$\Delta\nu/\nu$.
3. The tidal interaction (tidal force and tidal torque) between the crust and the core of neutron star plays a great role for the decrement of the glitches at old ages of the pulsars
4. glitch activity reduces as pulsars age.
5. In spite of the numerous mechanisms proposed for it, it will be interesting also to note that the study of neutron star glitches is a very important study in the evolution of neutron star as it helps in probing the neutron star interior.

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