The meaning inferred from the spin period distribution of normal pulsars

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We make statistics about the number distribution of normal radio pulsars according to the pulsar spin period. And find the physical meaning of the traditional statistical method about this problem is very limited. According to the statistical method proposed by us, the distribution rule is exactly the exponentially decay with the spin period increasing, especially important, which can be interpreted as normal radio pulsar number decays as the radiative elements decay. It discloses that though belonging to two different extreme scales of the universe and having different inner active mechanisms, the normal radio pulsars and radiative elements accord with the same varying rule. And like the half decay period of the radiative elements we can also introduce the half decay spin period of the normal radio pulsars.

1 Introduction

Pulsars—a kind of charming compact objects in the sky, are generally known to be born in the supernova explosion. Exploring them will provide the opportunity for people to understand the fundamental physics and astrophysics (Cordes 2004). There are many questions about pulsars deserved to be studied. In this paper we would concentrate on one of the attractive problems that is how the pulsar number distributes according to the spin period. In section 2 we introduce the usual statistical method at present on the spin periods of normal pulsars; in section 3 we point out the problem existing in this present statistical method, and introduce the concept of “generation” of normal pulsars; in section 4 we introduce a new statistical method on the spin period distribution of normal pulsars; in section 5 we make a conclusion.

2 Usual Statistical Method on the Spin Periods of Normal Pulsars at Present

As is well known pulsar spin periods usually span three magnitudes or so from milliseconds to seconds. So people like to do statistics for the log values of the spin periods (Manchester, Hobbs, Teoh & Hobbs 2005; Manchester 2009), or directly under the log coordinate of the spin periods (Manchester 2009), because the log function can transform the different scales of spin periods to the same scale. In Fig. 1 we illustrate this method for the normal pulsars whose spin periods exceed 30 ms (Lyne & Smith 2006) in the ATNF pulsar catalogue (Manchester et al. 2005). It seems to accord with the following Gaussian distribution very well:

\[ y = y_0 + \frac{A}{w\sqrt{\pi/2}} e^{-2\left(\frac{x-x_c}{w}\right)^2}, \]

where \( y_0 = 11.741 \pm 3.963, A = 243.163 \pm 8.562, w = 0.678 \pm 0.020, x_c = -0.225 \pm 0.008 \) are the fit-
ting parameters. The coefficient of determination (COD) is 0.99438. The smaller the relative errors and the closer to 1 the COD, the better the fitting. Apart from $y_0$, the relative errors of the other parameters are all less than 5%. So it seems safely to say that the normal pulsars distribute Gaussianly according to the log values of spin periods.

3 Concept of “Generations” of Pulsars

But we should not forget that these normal pulsars were not born in the same period. In fact, they are born with some birthrate $1 \sim 3$ per century (Vranesevic et al. 2004; Faucher-Giguère & Kaspi 2006) which can be larger five times taking into the uncertainties to form the current of pulsars in the Galaxy. At the beginning of the current, i.e., the newborn pulsars have a distribution of the spin periods which nowadays is regarded to be about 0.1-0.5 s for up to 40% of all pulsars (Vranesevic et al. 2004; Lorimer 2006). So maybe we could guess that the distribution of spin periods of newborn normal pulsars is pulse form like Gaussian distribution with the distribution peak at 0.1-0.5 s. Certainly, the distribution pulse form of spin periods of the newborn pulsars could not approach to the 0 infinitely because there is a smallest rotation period of pulsars smaller than which the pulsar will be broken up and which can approximately be estimated as small as 1.5 ms when the centrifugal force is just equal to the gravity at the equator (Lyne & Smith 2006).

In the initial part of the current of pulsars which can be imaged as “initial generation of pulsars”, the spin period distribution should be like the spin period distribution of newborn pulsars. Due to the radiative energy taking out the rotation energy of pulsars (Gold 1968, 1969; Pacini 1968), the rotation of pulsars will turn slow gradually and this pulse-like distribution of spin periods of the initial generation will move in the right direction of spin period axis, certainly with the possibility that some pulsars could not radiate the radio pulses owing to the extinction of the polar cascade process (Chen & Ruderman 1993; Hibschman, Johann & Arons 2001) and the pulse distribution form may also change as illustrated in Fig. 2.

Let us focus on the statistical step sizes in Fig. 1. The peak in Fig. 1 is at $10^{-0.225} \approx 0.6$ s approaching to the assumed 0.1-0.5 s magnitude of the distribution peak of the spin periods of the initial generation pulsars. So we can guess there are not many generations of pulsars left to the peak in Fig. 1. In addition the statistical step size left to the peak is even so smaller that it could not contain one pulsar generation and in fact to some extent reflect on the distribution pulse form inner structure of spin periods of the initial several generations of pulsars. Whereas the statistical step sizes right to the peak in Fig. 1 are generally very large that can contain a few generations in the same statistical step. So in fact the statistics right to the peak in Fig. 1 reflects the change rule of pulsar numbers of different generations with spin periods.

4 New Statistical Method on the Spin Periods of Normal Pulsars

Now we make clear that the statistical step sizes in Fig. 1 are suitable to do different things that reflect different physical meanings: one is for the distribution of spin periods in the pulse-distribution-form of the initial generations; the other is for the distribution of pulsar numbers among different pulsar generations. The log transformation mixes the different study scales of the two different questions, consequently confuses the two questions. The result is that the physical meaning of Gaussian distribution in Fig. 1 is very limited.
5 Conclusion

The pulsars and radiative elements belong to very different scales of the universe respectively, and have very different inner active mechanisms, whereas they have such similar decay rules, i.e., their activities drop exponentially though with different variables: one with the spin period; the other with the time.

Fig. 3 does not take into count the selective effect of observation, the most important selective effect is the luminosity, because the radiative capability of pulsars declines with age. It is very difficult to count this selective effect. Besides this, we do not forget that pulsars are the high velocity objects (Vranesevic et al. 2004; Arzoumanian, Chernoff & Cordes 2002; Hobbs, Lorimer, Lyne & Kramer 2005), which would make the number of pulsars in some region of the sky have some change. So Taking into account various effects will bring very large uncertainties. In spite of all these, we still believe that the law disclosed in Fig. 3 is true, partly from the philosophical consideration that the different scales in the universe might abide by some similar law.

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