Is it possible to predict glitches?

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Abstract

Pulsar glitches are thought to be unpredictable. We analysed the sizes and the waiting times of pulsar glitches based on the Australian Telescope National Facility (ATNF) pulsar glitch catalogue and the Jodrell Bank pulsar glitch catalogue. Here we present some probable regularities of glitches occurred in PSRs B0833−45, B0740−28 and B1823−13. Most waiting times of glitches of PSR B0833−45 are around 3 years. For PSR B0740−28, the ratios between each two adjacent waiting times are similar before the glitch occurred on MJD 55020. For PSR B1823−13, the correlation coefficient between the glitch sizes and corresponding trailing waiting times is 0.915, implying that the waiting time is tend to be long after a large glitch.

Introduction

Pulsars are highly magnetized neutron stars with rotations. The stability of rotations are extremely high, especially for millisecond pulsars (MSPs) like PSR J0437−4715, whose rotational stability is comparable to atomic clock on the time-scale of decades. Nevertheless, there is a kind of rotational irregularity named the glitches. A glitch infers a sudden jump of pulsar spin-down frequency. It is thought to be caused by changes of pulsar interiors.

There are two main models of pulsar glitch that are the star quake model and the superfluid vortex model [1, 5], respectively. The superfluid vortex model describes the glitches as results of the fast transfer of the angular momentum from inner superfluid to the outer crust of a pulsar. The avalanche model in the superfluid vortex scenario can describe the cumulative distributions of glitch sizes ($\Delta\nu/\nu$) of some pulsars well with a power law function and fit the cumulative distributions of waiting times of some pulsars well with a Poisson model [4]. It is commonly believed so far that glitches are not able to be predicted. However, the fact that cumulative distributions of the glitch sizes and waiting times of some pulsars can be well described by particular models hints the possible regularities in distributions of glitch sizes and waiting times of glitches. Actually, there are indeed some general regularities between glitch sizes and waiting times of some pulsars. For example, waiting times of PSR J0537−6910 are tend to be long after large glitches. The correlation coefficient between glitch sizes and corresponding trailing waiting times is 0.931 [2].

In order to study if there is any significant regularity in distributions of glitch sizes and waiting times, we selected pulsars with at least 5 glitches reported based on the Australian Telescope National Facility (ATNF) pulsar glitch catalogue[1] and the Jodrell Bank pulsar glitch catalogue[2]. We obtained some results in PSRs B0833−45, B0740−28 and B1823−13. They are presented in the following contents. A conclusion is made in the final section.

Results

We concluded some probable regularities in PSRs B0833−45, B0740−28 and B1823−13. The regularities in three pulsars are different from each other.

PSR B0833−45

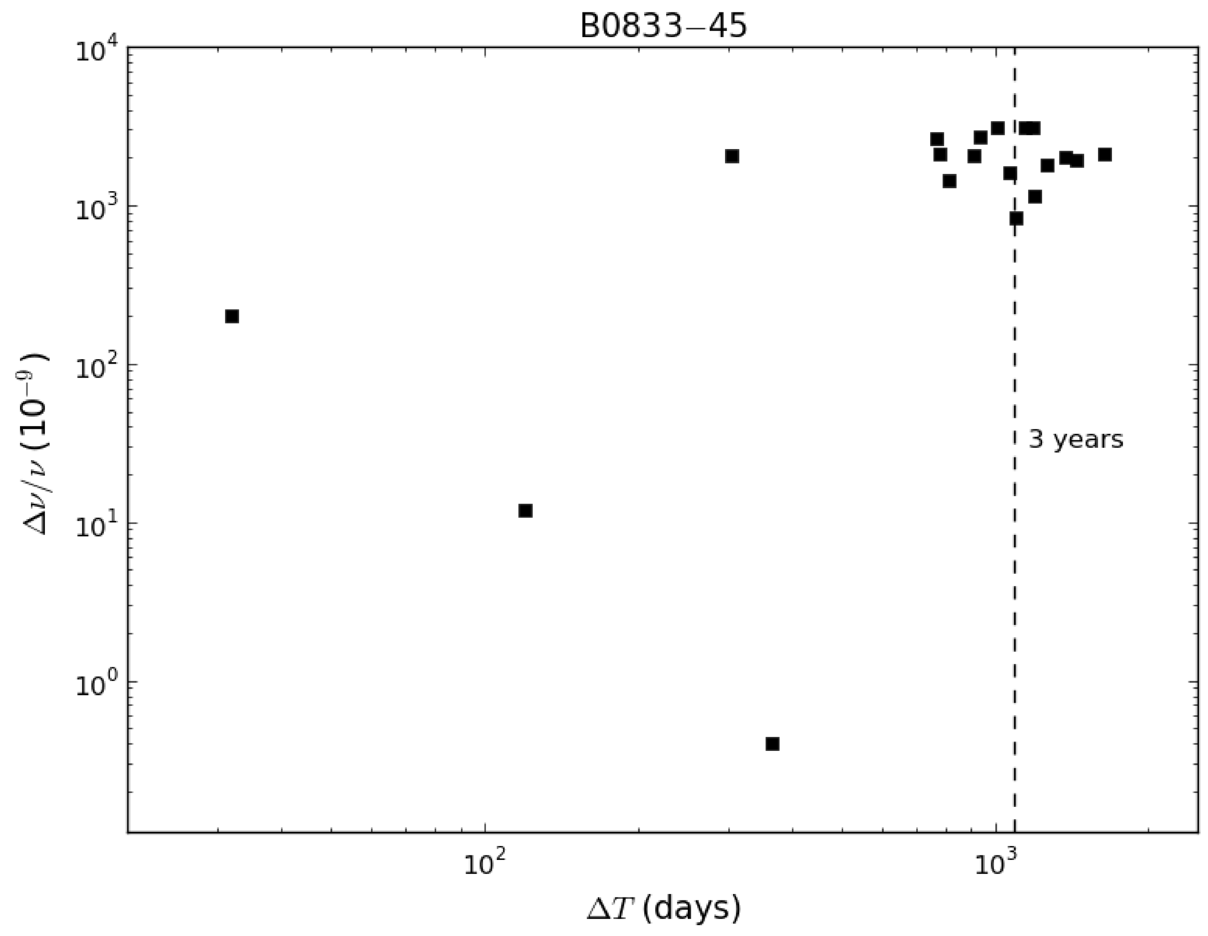

Figure 1: The photograph of the waiting time against preceding glitch size of the Vela pulsar. The vertical dashed line is at ΔT of 3 yr.

PSR B0833−45, which is also named the Vela pulsar, is a young pulsar with a characteristic age τ_c of 11.3 kyr. Generally, glitch activities are more frequent in young pulsars than old ones. For the Vela pulsar, there have been about 20 glitches reported so far. Most glitches of the Vela pulsar are large glitches with $\Delta\nu/\nu$ greater than 10^{-6}. It is proposed that large glitches occurred in the Vela pulsar about every 3 years[3]. As can be seen in Figure 1, most waiting times of glitches of the Vela pulsar distribute in the range of 1000-1400 day, that is about 2.8-3.6 yr. According to Figure 1, for most glitches, the glitch size is large if the trailing waiting time is long. This means that the waiting time after a large glitch will probably be long for the Vela pulsar, and the waiting time is likely to be around 3 yr. There are frequent glitches in the Vela pulsar, the probable regularity of glitches of this pulsar makes it possible to roughly predict the time when the next glitch will occur and the size of the glitch. Even if such regularity does not work well every time, it is still valuable for the study of glitches of the Vela pulsar.

PSR B0740−28

The characteristic age τ_c of PSR B0740−28 is 157 kyr. There are 8 glitches reported in this pulsar. Most glitches of this pulsar are small glitches with a size smaller than 4×10^{-9}, only one relatively large glitch occurred on MJD 55020 with a size of 9.2×10^{-8} [3]. By calculating the ratio between each two adjacent waiting times, we found that the large waiting time is about 4 times of its preceding small waiting time for glitches before MJD 55020, and ratios between the smaller waiting times and their preceding waiting times are less than 0.4 before MJD 55020. The ratio of about 1.1 after the glitch at MJD 55020 is different from previous ratios. Considering that the size of the glitch at MJD 55020 is really different from other glitches of this pulsar, the regularities of ratios may be affected by this glitch.

Glitchepoch (MJD)	Size 10^{-9}	Waiting time (days)	Ratio
47625	1.2	–	–
48332	1.2	707	–
51770	1	3438	4.865289373
52028	3.7	258	0.075037082
53083	1.7	1055	4.089147287
53468	1.8	385	0.36464455
55020	92	1552	4.036311411
56728	1.9	1708	1.099475196

Table 1: The epochs, sizes, waiting times of glitches of PSR B0740−28, and the ratios between each two adjacent waiting times.

PSR B1823−13

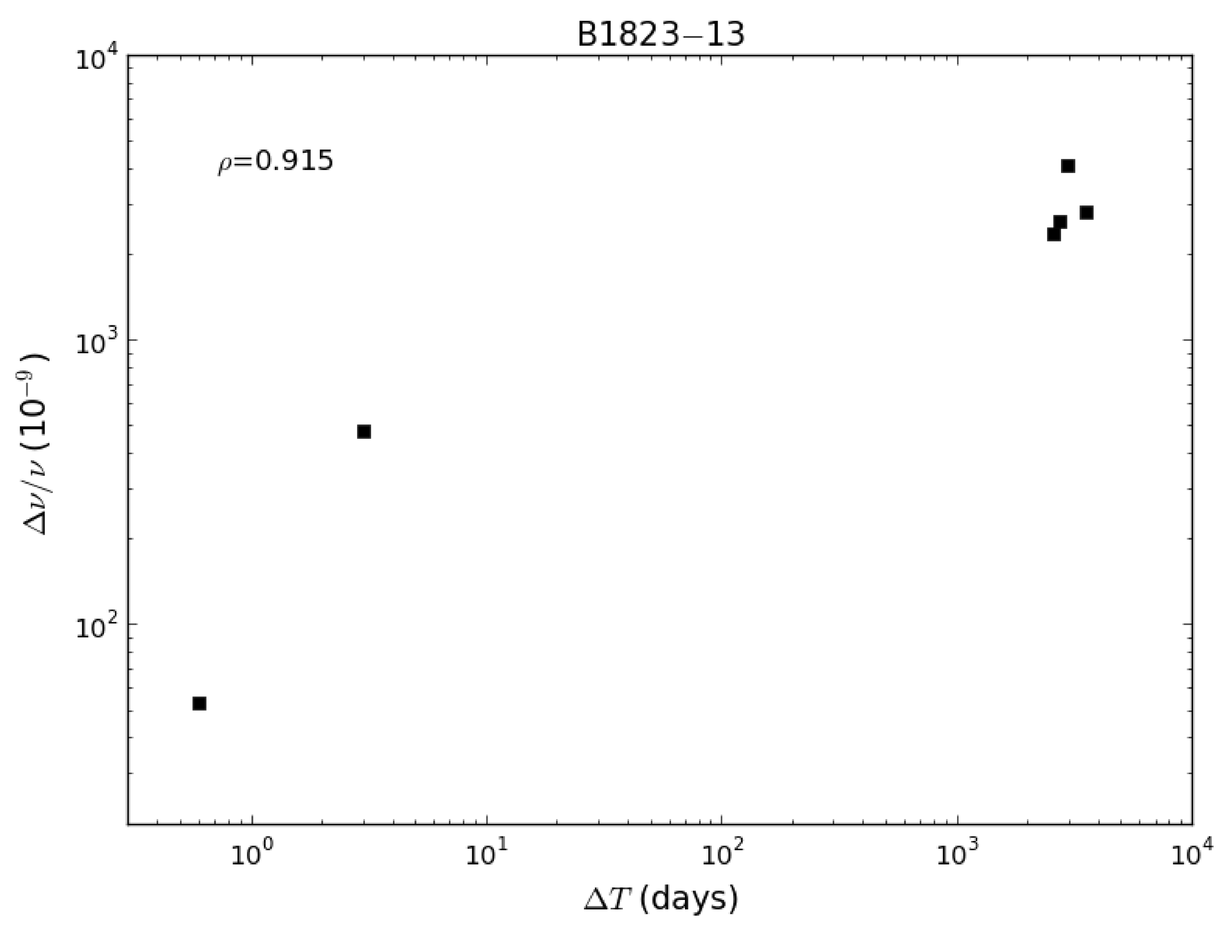

Figure 2: The photograph of the waiting time against preceding glitch size of PSR B1823−13.

PSR B1823−13 is a young pulsar whose τ_c is 21.4 kyr. There are 7 glitches reported in this pulsar. For the waiting times and corresponding preceding glitch sizes of glitches of this pulsar, the correlation between two parameters is high with a correlation coefficient $\rho = 0.915$. As is similar to the regularity of glitches of the Vela pulsar, such strong correlation implies that the waiting times of glitches occurred in PSR B1823−13 are more likely to be long after large-size glitches.

Conclusions

We obtained some probable regularities of distributions of pulsar glitches. The waiting times of glitches occurred in the Vela pulsar are mostly about 3 yr. For almost all glitches of this pulsar, the waiting times are long if the size of preceding glitches are large. For glitches before MJD 55020 of PSR B0740−28, there is a nearly stable ratio between each two adjacent waiting times. The waiting times and the preceding glitch sizes of PSR B1823−13 are highly correlated, suggesting that the waiting times are tend to be long after large-size glitches of this pulsar.

Forthcoming Research

There will be more glitches detected in the future, some new glitches may occur in pulsars without any glitch reported so far. With more glitches, more potential regularities may be found. At the same time, it is necessary and interesting to check the regularities mentioned above by predicting glitches according to them.

References

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