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On the mode switching timescales of pulsar PSR B0329+54

Hong-Guang Wang[1], **Jian-Ling Chen**[2], **Zhi-Gang Wen**[3] and **Fei-Peng Pi**[1]

[1]Center for Astrophysics, Guangzhou University, High Education Mega Center, Guangzhou 510006, Guangdong, China
email: hgwang@gzhu.edu.cn

[2]Department of Physics & Electronic Engineering, Yuncheng University Yuncheng 044000, Shanxi, China

[3] Xingjiang Astronomical Observatory, Urumqi 830011, Xingjiang, China

Abstract. Chen *et al.* (2011) found that the durations (timescales) of the normal and abnormal modes of PSR B0329+54 follow a gamma distribution, and constrained the parameters of the distribution function. In this paper, we perform a further analysis on the relationship between the timescales of the two modes. The ratio between the durations of a normal mode and the succeeding abnormal mode is calculated for 54 such pairs. It is found that the cumulative distribution function (CDF) of the ratio is consistent with the CDF obtained by assuming random mode switching, suggesting that the two modes work independently.

Keywords. Pulsars, emission mechanism, mode switching

1. Introduction

The mode switching phenomenon has been observed in a few tens of pulsars. The pulse profile, polarization and the radio spectra of profile components change when the mode switches. It is known that the duration of mode can range from tens of rotating periods to tens of days (Lyne *et al.* 2010). However, the statistical property of the mode durations has been unknown for a long time because of limited observations. Thanks to the two 8-day continuous observations to PSR B0329+54 in March 2004 with the 25m radio telescope at Xingjiang Astronomical Observatory (XAO), and the daily monitoring data with 15m telescope at Jodrell Bank Observatory (JBO), Chen *et al.* (2011), for the first time, identified the statistical distribution of mode duration for this pulsar. It was found that both the timescales of the normal and abnormal modes follow gamma distributions, i.e. the probability distribution function (PDF) $\propto t^{\mathrm{k}-1}\mathrm{e}^{-t/\tau}$, where the shape parameter k is $0.75^{+0.22}_{-0.17}$ for the normal mode and $0.84^{+0.28}_{-0.22}$ for the abnormal mode, and the typical timescales τ are 154^{+41}_{-36} and $31.5^{+8.0}_{-5.5}$ minutes for the normal and abnormal modes, respectively. Since the shape parameters are similar, the major difference between their distribution is the typical timescale, of which the normal mode is much longer than the abnormal mode. One may ask a further question: is there any correlation between the durations of succeeding normal and abnormal modes, e.g. a tendency that a longer abnormal mode follows a longer normal mode, or are durations just random? In this paper, we present further results regarding this question.

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2. Results

Using the data of mode duration used in Chen *et al.* (2011), we calculate the ratio between the durations of a normal mode ($t_{\rm n}$) and the succeeding abnormal mode ($t_{\rm a}$), $\eta = t_{\rm n}/t_{\rm a}$. A total of 54 pairs and ratios were identified. No clear tendency of correlation is found in a brief view of the ratios. The cumulative distribution function (CDF) of the data is plotted in Fig. 1 and compared with the random-switching CDF obtained by assuming that the two modes are independent gamma distributions with the best fitted parameters $(k_{\rm n}, k_{\rm a}, \tau_{\rm n}, \tau_{\rm a}) = (0.75, 0.84, 154, 31.5)$, depicted by the smooth curve.

In order to test if the distribution of real ratios is consistent with the random-switching ratio distribution, we perform Kolmogorov-Smirnov (KS) test. While considering the uncertainty in the parameters $(k_{\rm n}, k_{\rm a}, \tau_{\rm n}, \tau_{\rm a})$, we set up 54k grid points spanning the 95% confidence interval of the four parameters, and each grid point yields a random-switching ratio distribution. We then calculate the probability in KS test for each pair of the real data and a grid point. Fig. 2 presents the CDF of the probability value of KS test. The results show that the probability is larger than 5% (the highest up to 95%) for nearly 53% of the grid points, which means the distribution of real ratio data is consistent with random-switching distribution in these cases at 5% significance level. This fraction increase to 70% at 1% significance level. The small fraction of inconsistency may result from the uncertainty in the measured timescales (note that the smallest integration time to obtain a pulse profile is 1 minute, see Chen *et al.* 2011).

3. Discussion

The above results show that there is no correlation between the timescales of normal and abnormal modes. The duration of an abnormal mode is independent to the duration of the preceding normal mode.

We also investigated another problem: is it possible to constrain the intrinsic distribution of mode timescales by using non-continuous observations? One may concern this when there is no long and continuous observations but a number of historical data of

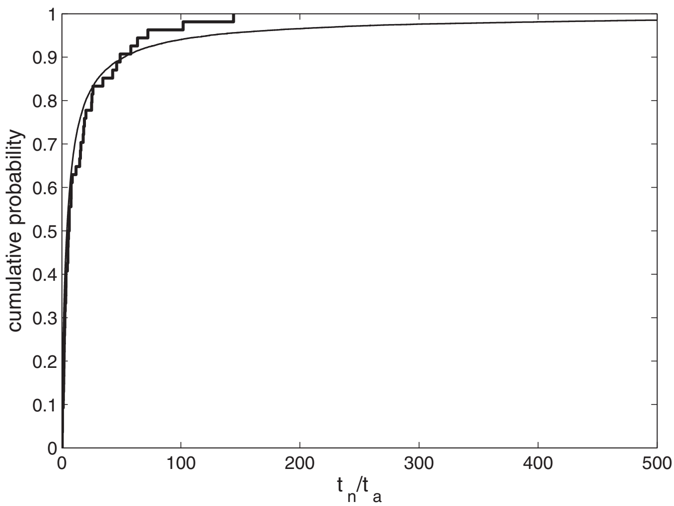

Figure 1. *Stepwise curve:* Cumulative distribution function (CDF) of the ratio $t_{\rm n}/t_{\rm a}$, where $t_{\rm n}$ and $t_{\rm a}$ are the durations of a normal mode and the succeeding abnormal mode, respectively. *Smooth curve:* the CDF assuming that the two modes are independent gamma distributions with the best fitted parameters $(k_{\rm n}, k_{\rm a}, \tau_{\rm n}, \tau_{\rm a}) = (0.75, 0.84, 154, 31.5)$

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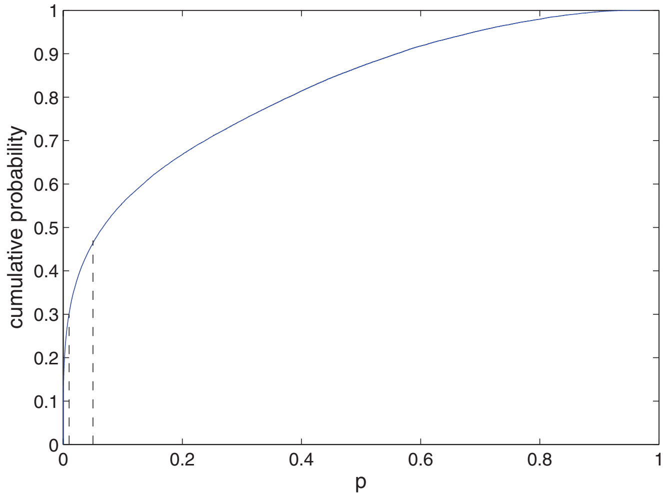

Figure 2. Cumulative distribution function of the probability p in KS test for 54k grid points. The two dashed lines represent for $p = 1\%$ and $p = 5\%$.

separated observations. Based on the 90 separated observations with XAO 25m telescope, mostly 2-hour long, we use Monte Carlo method to simulate the mode timescales in the given observational time windows, and then compare with the observed timescales to constrain the parameters of gamma distributions. However, the constrained region in parameter space is much wider than that determined with continuous observations. Therefore, it is important that the observational time intervals should be much larger than the typical timescale of modes.

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