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Detection of Giant Pulses in PSR J1752+2359

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Abstract We report the detection of Giant Pulses (GPs) in the pulsar PSR J1752+2359. The energy of the strongest GP exceeds the energy of the average pulse by a factor of 200, in which it stands out from all known pulsars with GPs. PSR J1752+2359 as well as the previously detected PSR B0031–07 and PSR B1112+50, belongs to the first group of pulsars found to have GPs without a high magnetic field at the light cylinder.

Key words: stars: neutron — pulsars: general — pulsars: individual PSR J1752+2359

1 INTRODUCTION

Giant pulses (GPs) are short duration burst-like increases of an intensity of individual pulses from pulsars. The peak intensities and energies of GPs greatly exceed the peak intensity and energy of the average pulse (AP). The energy distribution of GPs has a power-law. The GPs are much narrower than the AP and their phases are of stable placement within the AP.

This rare phenomenon was first detected in the Crab pulsar (Staelin & Sutton 1970) and the millisecond pulsar PSR B1937+21 (Wolszczan et al. 1984), both with very strong magnetic fields on the light cylinder of $B_{\rm LC} = 10^4 - 10^5$ G. This gave rise to the suggestion that GPs occur in pulsars with very strong magnetic fields on the light cylinder and a search of GPs was oriented on those pulsars. As a result GPs were detected in five other pulsars with very strong magnetic fields on the light cylinder: PSR B0218+42 (Joshi et al. 2004), PSR B0540–69 (Johnston & Romani 2003), PSR B1821–24 (Romani & Johnston 2001), PSR J1823–3021 (Knight et al. 2005), PSR B1957+20 (Joshi et al. 2004).

Here we report the detection of GPs in the pulsar PSR J1752+2359. Correlating this with our previously published data on PSR B1112+50 (Ershov & Kuzmin 2003) and PSR B0031–07 (Kuzmin et al. 2004; Kuzmin & Ershov 2004), we have revealed that GPs exist in pulsars with relatively low magnetic fields at the light cylinder.

2 OBSERVATIONS

Observations were performed with the Large Phase Array (BSA) Radio Telescope at Pushchino Radio Astronomy Observatory of Lebedev Physical Institute at the frequency of 111 MHz. This is the transit telescope with the effective area of about 15 000 square meters. One linear polarization was received. We used a 128-channel receiver with the channel bandwidth 20 kHz. The sampling interval was 2.56 ms and the receiver time constant was 3 ms. The duration of each observation session was about 3 min (420 pulsar periods). A total of 120 observations containing 50 400 pulsar periods were carried out in the mode of recording single pulses. During the off-line data reduction the signal records were cleaned of radio interferences and the inter-channel dispersion delays were removed. Verification that GPs belong to PSR J1752+2359 was checked by timing and inter-channels dispersion delay.

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3 RESULTS

Figure 1 shows an example of one observation session of GPs. A group of three bright pulses standing out of the noise background and underlying weak pulses were observed inside 420 pulsar periods. The 187 pulses (1 pulse for 270 observed periods) with $S/N \geq 5$ were selected and analyzed. The observed peak flux density exceeded the peak flux density of the AP by more than a factor of 40.

Figure 2 shows the strongest observed GP together with the AP averaged over 50 400 pulsar periods. The peak flux density of the strongest GP is 105 Jy that exceeds the peak flux density of the AP by factor of 260. The energy of the strongest observed GP is 920 Jy ms, that exceeds the energy of the AP by factor of 200. This is the most pronounced energy increase factor among the known pulsars with GPs.

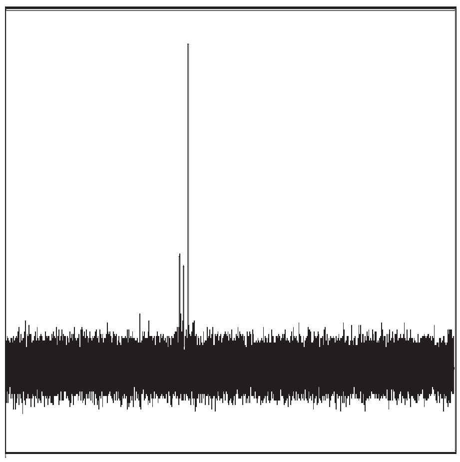

Fig. 1 One observation session of GPs. Three large pulses stand out of the noise background and weak pulses are observed inside 420 pulsar periods.

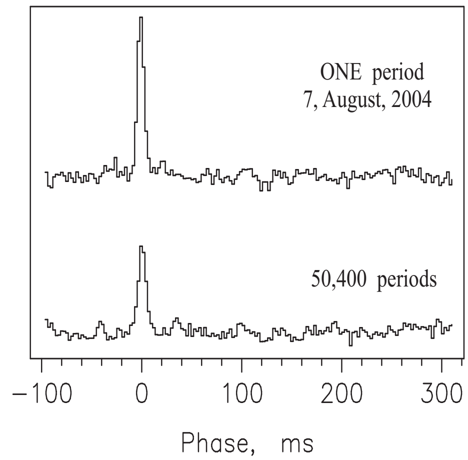

Fig. 2 **(Top)** The strongest observed pulse. **(Bottom)** The average pulse profile containing 50 400 pulsar periods. The intensity of the profiles is shown in arbitrary units.

A pulse whose energy exceeded an energy of the average pulse (AP) by more than a factor of 100 is encountered approximately once in 3000 observed periods.

Along with a large intensity, the distinguishing characteristic of the previously known pulsars with GPs is for their two-mode pulse intensity distribution. At low intensities, the pulse strength distribution is Gaussian one, but above the certain threshold the pulse strength distribution is roughly power-law distributed.

In Figure 3 we show the measured cumulative distribution of the ratio of the observed GPs energy to the AP energy for all pulses that we have selected and analyzed. The distribution shows a power-law dependence with index $\alpha = -3.0 \pm 0.4$ (the solid line). The dotted line represents the possible version of the Gaussian distribution.

The intrinsic fine structure of GPs is masked by dispersion pulse broadening of 4.4 ms and receiver time constant of 3 ms. Therefore we performed additional observations with higher temporal resolution. We used a 128-channel receiver with a channel bandwidth of 1.25 kHz, sampling interval of 0.81 ms, and time constant of 1 ms. In this mode, we performed 14 observation sessions containing 6800 pulsar periods.

Figure 4 (top) shows the high resolution GP (solid line) together with the AP (dotted line). The observed peak flux density of this GP exceeds the peak flux density of the AP by factor of 320. The plot of the AP is presented on a 250 times larger scale, and flux densities of the observed GP and AP are shown separately, on the left and right sides of the "y"-axis.The observed width of the GPs is 1 ms, which is narrower than the AP by a factor of about 10.

Figure 4 (bottom) shows the phases of the GPs. Giant pulses cluster in a narrow phase window near the middle of the AP. The clustering is closer for stronger GPs.The brightness temperature of the strongest GP is $T_{\rm B} \geq 2 \times 10^{28}$ K.

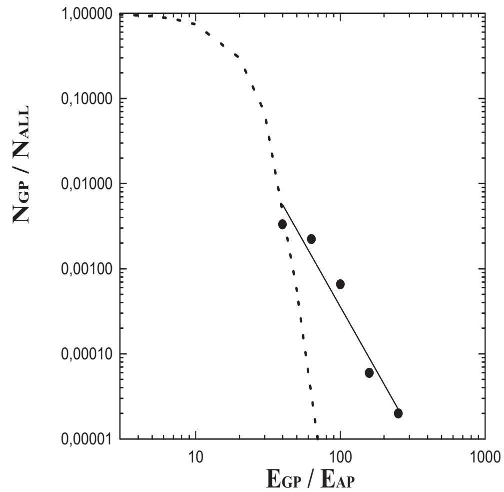

Fig. 3 The cumulative distribution of the observed GP energy $E^{\rm GP}$ as related to the AP energy $E^{\rm AP}$. The solid line is the observed power-law distribution $N^{\rm GP}/N^{\rm All} \propto (E^{\rm GP}/E^{\rm AP})^{\alpha}$ with index $\alpha = -3.0 \pm 0.4$. The dotted line represents the possible version of the Gaussian distribution $N/N^{\rm All} = \exp(-a(E/E^{\rm AP})^2)$.

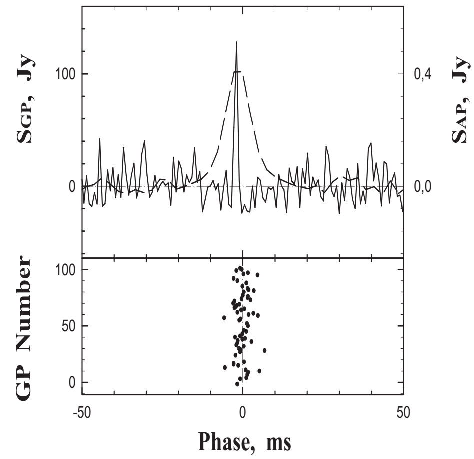

Fig. 4 **(Top)** The observed high resolution GP (bold line) and the AP (dotted line). The observed peak flux density of this GP exceeds the peak flux density of the AP by a factor of 320. The plot of the AP is presented on a 250 times larger scale and flux densities of the observed GP and AP are shown separately on the left and right sides of the "y"-axis. **(Bottom)** The phases of the GPs.

4 DISCUSSION

The GPs that we detected in PSR J1752+2359 exhibit all characteristic features of the classical GPs in PSR B0531+21 and PSR B1937+21. The peak intensities of the GPs exceed the peak intensity of the AP by more than a factor of 50. The histograms of the flux density have a power-law distribution. The GPs are much narrower than the AP and their phases are stable inside the integrated profile.

The most important aspect of this report is the fact, that PSR J1752+2359 (as well as PSR B0031–07 and PSR B1112+50) represents pulsar with relatively low magnetic field $B_{\rm LC}$ at the light cylinder. This is in contrast with the canonical suggestion that GPs occur in pulsar with strong magnetic field at the light cylinder (e.g. Romani & Johnston 2001). The detection and first searches of GPs were performed in pulsars with extremely high magnetic field at the light cylinder of $B_{\rm LC} = 10^4 - 10^5$ G. Then it was suggested, that GPs originate near the light cylinder (Istomin 2004). However, detection of GPs in the pulsars PSR B1112+50 (Ershov & Kuzmin 2003), PSR B0031–07 (Kuzmin et al. 2004; Kuzmin & Ershov 2004) and presently reported GPs in PSR J1752+2359 have revealed that GPs exist also in pulsars with ordinary magnetic field at the light cylinder of $B_{\rm LC} = 1 - 100$ G. These GPs may be associated with the inner gap emission region (Gil & Melikidze 2004; Petrova 2004).

One should note that the GPs of PSR J1752+2359 with relatively low magnetic field at the light cylinder was observed at low frequencies of 111 MHz, whereas GPs of pulsars with strong magnetic field at the light cylinder were observed mainly at high frequencies. It is of much interest to observe GPs of PSR J1752+2359 at high frequencies, where one can realize the better temporal resolution.

5 CONCLUSIONS

The Giant Pulses (GPs) from pulsar PSR J1752+2359 have been detected. The energy of the GPs exceeds the energy of the average profile by a factor of up to 200, which stands this pulsar out among the known pulsars with GPs. Cumulative distribution is fit by a power-law with index $\alpha = -3.0 \pm 0.4$. PSR J1752+2359 as well as the previously detected PSR B0031–07 and PSR B1112+50 are the first pulsars with GPs that do not have a high magnetic field at the light cylinder.

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