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Discovery of Giant Pulses from the Pulsar B1237+25 (J1239+2453)

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Abstract. To search for Giant Pulses (GPs) from pulsars, we have carried out during 2011–2013 a survey of about 20 second-period radio pulsars of the Northern Hemisphere. The observations were carried out at a frequency of 111-MHz using the Large Phased Array (LPA LPI) scanning radio telescope in Pushchino. We have detected regular generation of strong individuals pulses from the pulsar PSR B1237+25 (J1239+2453). The peak flux density of the pulses was up to 70 times as strong as an average profile. The flux density of these pulses has a bimodal power-law distribution function, which is typical of GPs when usual pulses are log-normally distributed. The strongest detected GP had a flux density of about 900 Jy.

Keywords: pulsars, giant pulses, PSR B1237+25, PSR J1239+2453.

Introduction

Giant Pulses of radio pulsars represent a rare phenomenon, up to date only 14 radio pulsars are known to generate GPs (Table 1). As we can see, pulsars with GPs may be divided into two subclasses: pulsars with strong magnetic fields on the light cylinder, estimated B_{LC} up to 10^6 G, and pulsars with $B_{\mathrm{LC}} < 10^2$ G. Two pulsars of the 1st subclass (B0531+21 in the Crab nebula and fast spinning isolated millisecond pulsar B1937+21) have the most typical, so-called classical GPs. Pulsars of the 1st subclass demonstrate narrow features in the microstructure (to several nanoseconds), high peak flux densities (up to several MJy at 600 and 1400 MHz), and a power-law distribution in the peak flux density, their GPs are detected in a wide range of radio frequencies (e.g., 40–8300 MHz for B0531+21 and 111–5500 MHz for B1937+21). The 2nd subclass consists of pulsars with GPs generally recorded only at low radio frequencies (40–111 MHz). A typical width of such GPs is comparable to the width of a regular individual pulse, and the flux density is tens or hundreds times as strong as that of an average profile. Note that usually regular individual pulses exceed the average pulse by a factor of about 10.

Table 1: List of radio pulsars referred to as pulsars emitting GPs.

PSR	Period (s)	DM (pc/cm^{-3})	Frequency (MHz)	$B_{\rm LC}$ (gauss)	First reference
J0034−0721 (B0031−07)	0.9429	11.380	40	7.02	(Kuzmin et al., 2004)
J0218+4232	0.0023	61.252	610	31.21×10^5	(Joshi et al., 2004)
J0534+2200 (B0531+21)	0.0331	56.791	40–8300	9.8×10^5	(Staelin & Reifenstein, 1968)
J0529−6652*	1.0249	103.20	610	39.7	(Crawford et al., 2013)
J0540−6919*	0.0505	56.791	1390	3.62×10^5	(Johnston & Romani, 2003)
J0659+1414	0.3849	13.977	111	766	(Kuzmin & Ershov, 2006)
J0953+0755 (B0950+08)	0.2530	2.958	111	141	(Singal, 2001, Smirnova, 2012)
J1115+5030 (B1112+50)	1.6564	9.195	111	4.24	(Ershov & Kuzmin, 2003)
J1239+2453 (B1237+25)	1.3824	9.242	111	4.14	(Kazantsev & Potapov, 2015)**
J1752+2359	0.4091	36.000	111	71.1	(Ershov & Kuzmin, 2006)
J1824−2452A	0.0030	120.5	1510	7.41×10^5	(Johnston & Romani, 2001)
J1823−3021A	0.0054	86.834	685	2.52×10^5	(Knight et al., 2005)
J1939+2134 (B1937+25)	0.0016	71.0398	111–5500	1.02×10^6	(Wolszczan et al., 1984)
J1959+2048	0.0016	29.1168	610	3.76×10^5	(Joshi et al., 2004)

Notes to Table 1.
*pulsars in LMC
**this work; dispersion measure DM is given with the last significant digit from the referred source, all periods are given with four decimal digits, $B_{\rm LC}$ was estimated from the ATNF pulsar catalog

Observations and Processing

Physics of GPs is still unclear and, as we can see from Table 1, combination of their parameters does not demonstrate any regularity and there are no clear criteria to search for candidates. Thus, the search of objects for our observations was very simple: to observe a set of strong nearby pulsars paying special attention to objects with a considerable variation in the emission of individual pulses. Taking into account the relatively low frequency of observation, we had to limit our choice by a set of second-period pulsars with a relatively small dispersion measure DM.

Observations were performed at the Pushchino Radio Astronomy Observatory with the Large Phased Array (LPA) radio telescope in one linear polarization of the 1st diagram. During the observations the effective area was about 20,000 m^2 (in the zenith direction). The main frequency of the observations was 111 MHz, bandwidth 2.3 MHz (460×5 kHz digital receiver with post-detector DM removal). We have processed the results of 89 observational sessions containing 13,617 periods of the pulsar. We have analyzed every pulse with a peak flux density of $> 4\sigma_{\rm noise}$ and located at the phase of the average pulse.

We have calculated a histogram of pulses' intensity in units of the average pulse and a distribution of strong individual pulses *vs* peak flux density.

Results

PSR B1237+25 (J1239+2453) is an active radio pulsar with a multicomponent average pulse profile (up to 5 components were detected) and switching modes (two main modes). We have observed strong pulses in all modes of the pulsar and at the phase of all three main components that can be observed at 111 MHz. A significant part of individual pulses from PSR B1237+25 exceed the average pulse of the pulsar 10 times and more. Two of the strong GPs are shown in Figures 1–4. A histogram of the pulse distribution *vs* intensity of the average profile is shown in Figure 5. It is worth noting that the histogram of pulse intensity differs from the histogram obtained at 2695 MHz by Hesse and Wielebinski (1974). The distribution of the peak flux density (in signal to noise ratio units) in the Log-Log scale is shown in Figure 6 (with the first two and one last point omitted when fitting of the powers). As we can see, the distribution of the strong pulses is a bimodal power-law one with exponents -1.26 ± 0.05 and -3.36 ± 0.34, which is quite typical of GPs and obviously differs from that of regular individual pulses, which should be log-normal. The most powerful GP was detected on August 12, 2012, with a flux density of 900 ± 130 Jy.

Conclusion

We can conclude with confidence that strong individual pulses of PSR B1237+25 observed by us at 111 MHz satisfy the main criteria of GPs, namely: peak flux density of several pulses are more than 30 times stronger than the average pulse of the pulsar; strong pulses have a bimodal power-law distribution typical of GPs; all pulses were detected at the phase of the average profile. The pulsar B1237+25 belongs to a subclass of pulsars (see Table 1) with a low magnetic field on the light cylinder (J0034−0721, J0659+1414, J0953+0755, J1115+5030, and J1752+2359) and has properties of GPs typical of this subclass. Note that the histogram of pulse intensities obtained at 111 MHz in the present work considerably differs by its shape from the histogram obtained by Hesse and Wielebinsky (1974) at 2695 MHz; this may indicate a significant difference between the mechanisms of generation of regular pulses of the pulsar at these frequencies.

Acknowledgements

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References

1. Crawford F., Altemose D., Li H., and Lorimer D.R., ApJ **762**, 97 (2013).
2. Ershov A.A. and Kuzmin A.D., Astron. Lett. **29**, 91 (2003).
3. Ershov A.A. and Kuzmin A.D., Chin. J. Astron. and Astrophys. **6**, Suppl. 2, 30 (2006).
4. Hesse K.H. and Wielebinski R., A&A **31**, 409 (1974).
5. Johnston S. and Romani R.W., ApJL **557**, L93 (2001).
6. Johnston S. and Romani R.W., ApJL **590**, L95 (2003).
7. Joshi B.C., Kramer M., Lyne A.G., McLaughlin M.A., and Stairs I.H., IAUS **218**, 319 (2004).
8. Knight H.S., Bailes M., Manchester R.N., and Ord S.M., ApJ **625**, 951 (2005).
9. Kuzmin A.D., Ershov A.A., and Losovsky B.Ya., Astron. Lett. **30**, 247 (2004).
10. Kuzmin A.D. and Ershov A.A., Astron. Lett. **32**, 583 (2006).
11. Singal A.K., Astrophys. and Space Sci. **278**, 61 (2001).
12. Smirnova T.V., Astron. Rep. **54**, 430 (2012).
13. Staelin D.H. and Reifenstein E.C., IAU Astron. Telegram Circ. No. 2110, 6 November 1968.
14. Wolszczan A., Cordes J., and Stinebring D., Proc. NRAO Workshop, Green Bank, Eds. S.P. Reynolds and D.R. Stinebring. (Green Bank: National Radio Astronomy Observatory, 1984), p. 63.

Открытие гигантских импульсов пульсара B1237+25 (J1239+2453)

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Резюме. С целью поиска гигантских импульсов (ГИ) пульсаров в течение 2011–2013 гг. нами был проведен обзор 20 секундных радиопульсаров северного неба. Наблюдения проводились на Большой Сканирующей Антенне (БСА ФИАН) в Пущино на частоте 111 МГц. Нами была обнаружена ранее не отмечавшаяся регулярная генерация мощных индивидуальных импульсов от пульсара PSR B1237+25 (J1239+2453). Пиковая плотность потока таких импульсов превышает пиковую плотность потока среднего импульса в десятки (до 70) раз. Распределение импульсов по плотности потока бимодально и имеет степенной вид, что характерно для ГИ, в то время как обычные импульсы пульсаров имеют логнормальное распределение. Наиболее сильный из зарегистрированных нами импульсов имел плотность потока около 900 Ян.

Ключевые слова: пульсары, гигантские импульсы, PSR B1237+25, PSR J1239+2453

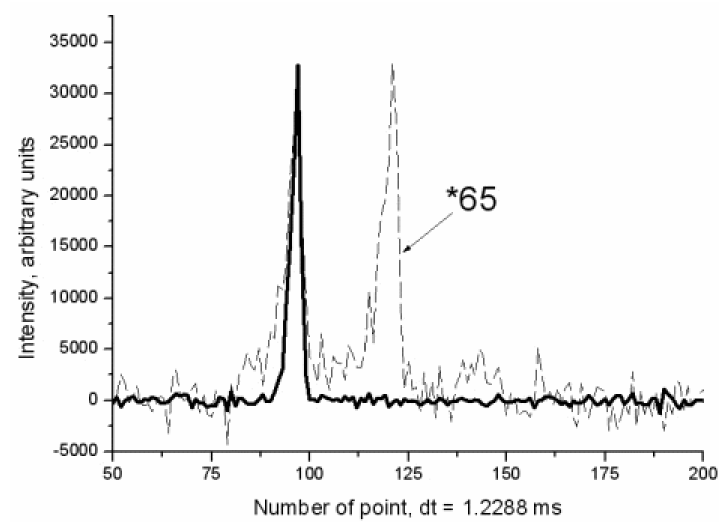

Figure 1: The strongest pulse of PSR B1237+25 observed in the session of May 14, 2012. The averaged pulse is multiplied by 65.

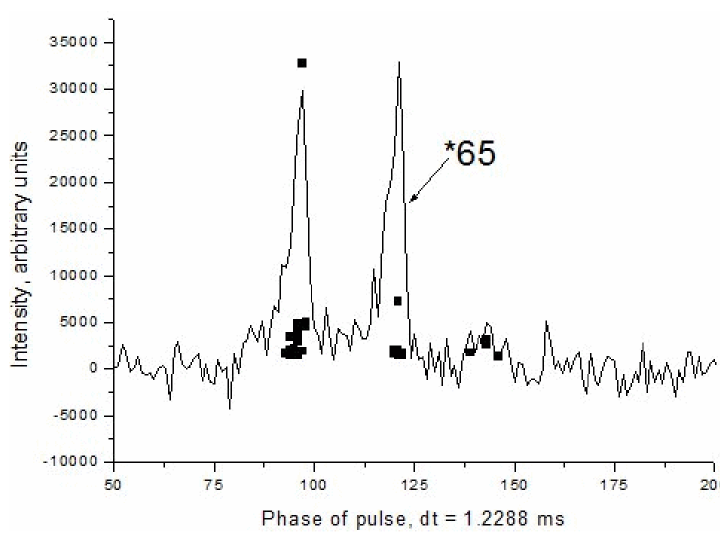

Figure 2: Strong pulses of PSR B1237+25, session of May 14, 2012. Distribution over the phase of the average profile.

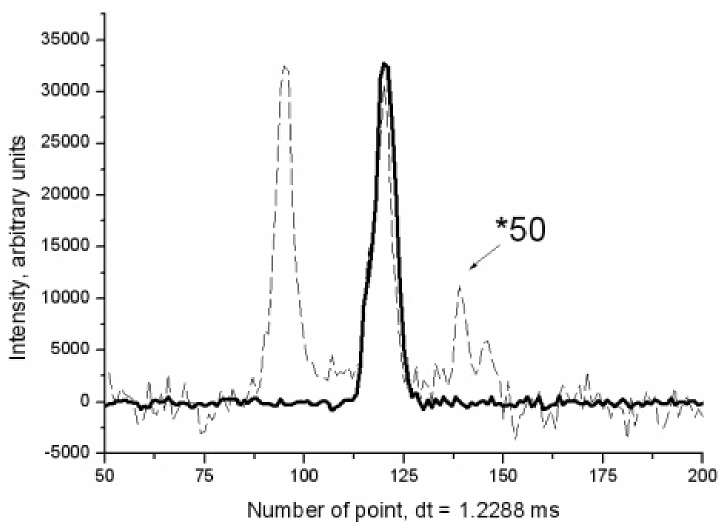

Figure 3: The strongest pulse of PSR B1237+25 observed in the session of May 04, 2012. The averaged pulse is multiplied by 50.

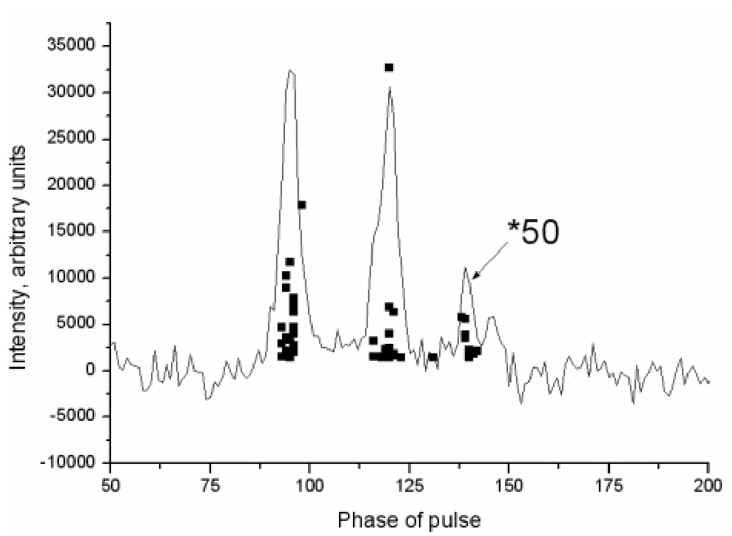

Figure 4: Strong pulses of PSR B1237+25, session of May 04, 2012. Distribution over the phase of the average profile.

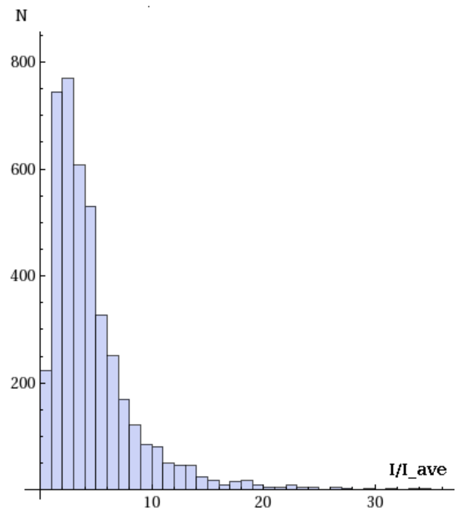

Figure 5: Histogram of the intensity of individual pulses in units of the average (per session) pulse.

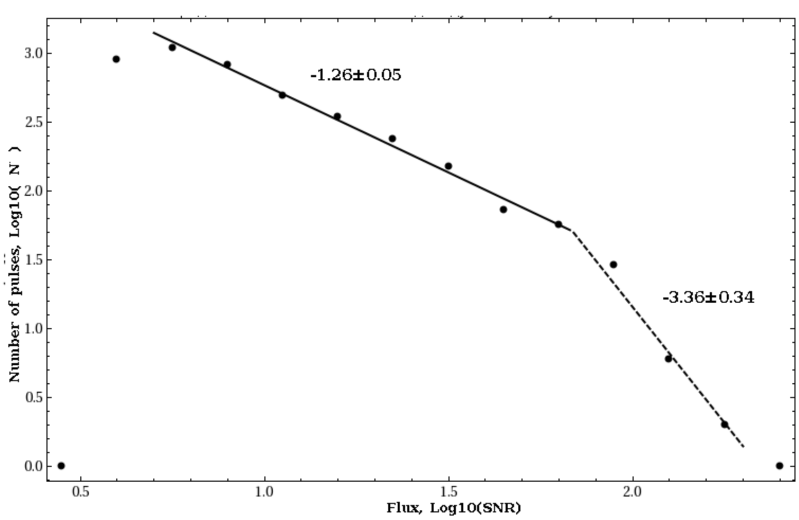

Figure 6: Distribution of the peak flux density (in SNR - signal to noise ratio units) in the Log-Log scale; $\sigma_{\mathrm{noise}} \approx 2.7$ Jy.