Neutron Stars and Pulsars: Challenges and Opportunities after 80 years
Proceedings IAU Symposium No. 291, 2012
J. van Leeuwen, ed.

doi:10.1017/S1743921312024660

Detection of Giant pulses from pulsar PSR B0950+08

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Abstract. We investigated pulse intensities of PSR B0950+08 at 112 MHz at various longitudes (phases) and detected very strong pulses exceeding the amplitude of the mean profile by more than one hundred times. The maximum peak flux density of a recorded pulse is 15240 Jy, and the energy of this pulse exceeds the mean pulse energy by a factor of 153. The analysis shows that the cumulative distribution function (CDF) of pulse intensities at the longitudes of the main pulse is described by a piece-wise power law, with a slope changing from n=-1.25±0.04 to n=-1.84±0.07 at I⩾600 Jy. The CDF for pulses at the longitudes of the precursor has a power law with n=-1.5±0.1. Detected giant pulses from this pulsar have the same signature as giant pulses of other pulsars.

Keywords. Giant pulses, PSR B0950+08, pulse intensities distribution

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1. Observations and data reduction

PSR B0950 is one of the strongest pulsars at the meter wavelengths and also nearby: its flux density is S = 2 Jy at f = 102 MHz, its distance is R = 262 pc. The observations of PSR B0950+08 were conducted on the Large Scanning Antenna of the Pushchino Radio Astronomy Observatory at 111.846 MHz during 22 days in June ÷ July 2009. Linearly polarized emission was received. For each session we recorded 765 individual pulses with a sampling of 0.4096 ms. We used 461 channels of the digital receiver with a bandwidth per channel of 5 kHz. We recorded pulses in a window of 200 ms covering the range of the pulse and out-of-pulse in all channels. For each session, we calculated the peak amplitude of the mean profile A, signal-to-noise ratio S/N and the energy in the average pulse, obtained by summing the intensities within the mean profile at the level $I \geqslant 4\sigma_N$. The shape of the session-mean pulse and S/N vary strongly from day to day, due to propagation effects in the inhomogeneous interstellar plasma which strongly modulate the intensity in both frequency and time. The characteristic temporal and frequency scales for B0950+08 at 112 MHz are $t_{dif} > 200$ s and $f_{dif} = 220$ kHz obtained by Smirnova & Shishov (2008). Therefore, diffractive scintillations do not effect the intensity variations of individual pulses within a session, only the session-to-session variation of the mean profile amplitude. The Faraday modulation period at 112 MHz corresponds to 15 MHz, which considerably exceeds the receiver bandwidth. It leads to a session-to-session change in the relative amplitude of the profile components. Accordingly, we took these effects into account in our analysis.

2. Mean profile and Giant pulses

We used the following relation to scale the pulse peak amplitudes for different days in flux-density units (Jy): $A(t)[Jy] = A(t) \cdot S \cdot k / < A >$, where S = 2 Jy at our frequency,

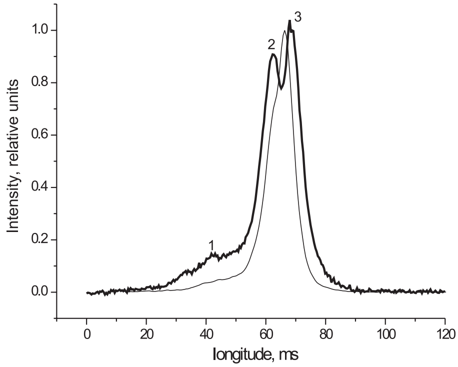

Figure 1. Mean pulse profiles at 112 MHz (thick line) and at 430 MHz (thin line)

k = 14.9 is a coefficient relating to the ratio of the peak amplitude to pulse energy averaged over the pulsar period, and <A> is the mean value of amplitudes A(t) for the entire series of observation in relative units, <A> = 30 Jy. The mean profile obtained by summing of 17 profiles (13000 pulses) with S/N > 14 is shown in Fig. 1 by thick line. The profile has three components, with a separation between components 2 and 3, $\Delta S =$ 6.2 ms. We included here also the mean profile at 430 MHz (thin line) taken from European Pulsar Network Data Archive normalized to the same amplitude. We see the weak precursor with two unresolved components in the main pulse at 430 MHz. The frequency dependence of the profile width in this range is: $W_{0.5} \propto f^{-0.35}$. Our analysis of individual pulses included the determining of positions (phases) and amplitudes for subpulses with a peak amplitude which exceeded some level in units of σ_N within each pulse. We detected very strong pulses at longitudes of all three components. In Fig 2 we show giant pulses and mean profiles multiplied by 100 for two days of observation. Amplitude of the strongest pulse by 120 times exceeds the amplitude of mean profile for this day and by 508 times exceeds the amplitude of averaged for 17 days profile. Peak flux density of this pulse is 15240 Jy and energy of it is 81240 Jy*ms which exceeds the mean pulse energy by a factor of 153. We receive rare but strong pulses at the longitude of component one (precursor), their amplitude can be 490 times more than amplitude of mean profile at this longitude. We see in this figure that when emission takes place at the precursor it is absent at the longitude of the main pulse (MP) and vice-versa. In common emission becomes much weaker in MP when strong pulses exist in precursor. If we combine the profile from weak pulses ($3\sigma_N < I < 6\sigma_N$) at longitudes of MP we see emission in the precursor which means that weak pulses in MP do not influence it.

3. Cumulative distribution function

To exclude influence of scintillation and polarization effects on intensity variations from day to day we did the following correction of pulse intensities: I(t) = $I_n(t)\sigma_N^0 \cdot A_0/(\sigma_N^n \cdot A_n)$, where σ_N^0 and A_0 are sigma noise and amplitude of the mean profile for the reference day, index n corresponds to day number n. Fig. 3 shows the cumulative distribution function (CDF) of the number of pulses with I > $5\sigma_N$ taken place at longitudes of MP from 17 days of observation in log-log scale. The common number of pulses was 3385. Two lines are the result of a least-squares fit. CDF has a power law with a changing of slope from n = -1.25 ± 0.04 to n = -1.84 ± 0.07 for I > 600 Jy. We also build CDF using the same procedure but for pulses within longitudes of component 1 (precursor). We chose 5 days with pronounced intensity in the mean profiles at these longitudes. The number of pulses here was 30 times less than for MP. Data can be fitted within a power law with n = -1.5 ± 0.1. The studied properties of the precursor: strong modulation,

https://doi.org/10.1017/S1743921312024660 Published online by Cambridge University Press

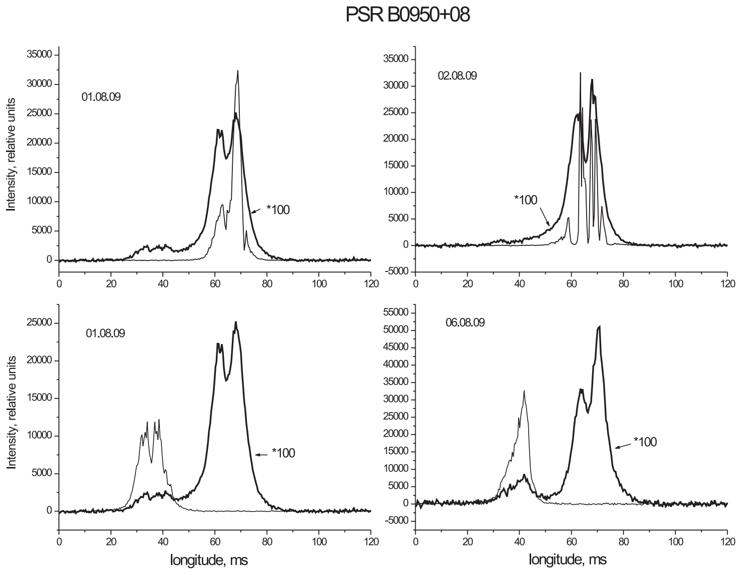

Figure 2. Giant pulses at different longitudes of mean profile. The mean profile was multiplied by 100.

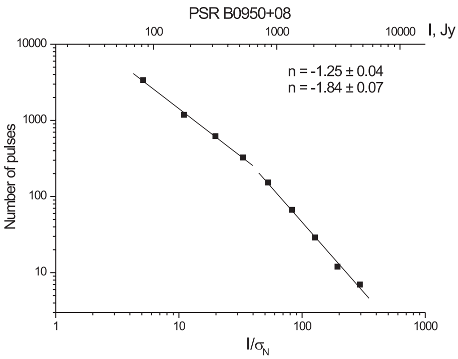

Figure 3. Cumulative distribution function for pulses with $I/\sigma_N > 5$.

absence of emission in the MP in the presence of powerful GPs in the precursor range, similarity of the precursors shape with that of the mean profile obtained for strong pulses, and increase of the emission intensity at low frequencies are well explained by the mechanism proposed by Petrova (2008), involving induced scattering of the MP emission by relativistic particles of strongly magnetized plasma in the pulsar magnetosphere.

Acknowledgements

This work was supported by the Russian Foundation for Basic Research (project code 12-02-00661) and the Basic Research Program of the Presidium of the Russian Academy of Sciences "The Origin, Structure, and Evolution of Objects in the Universe".

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