The flare activity of PSR B0643+80 (J0653+8051)

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We present the investigation of PSR J0653+8051 at a frequency of 111 MHz using the Large Phase Array (Pushchino, Russia). This pulsar shows three components in the 102-4850 MHz range. We detected a few dozen very strong pulses exceeding the amplitude of the mean profile for more than 110 times. Usually this pulsar demonstrates a very weak signal on the level 3 sigma in the mean profile. The detailed analysis showed that all strong pulses with signal to noise ratio of 5-20 sigma arrived on the longitude of the central component only. This effect is uncommon because we detected such giant components on only two days out of about four hundred days of observations.

B0643+80 (J0653+8051)
p = 1,214 c
p' = 3,8 10^{-15} c/c
T = 5 10^{6} лет
B = 2 10^{12} Гс
DM = 32,5 пк/см^3

Observations

The observations of the pulsar B0643 +80 were carried out with the Large Phased Array at the Lebedev Physical Institute at 111 MHz, using a digital pulsar receiver [3]. The width of the operational frequency band is 2.5MHz. It is separated using the FFT into 512 spectral channels with the bandwidths of single channel equal to 4.88 kHz. The time resolution was 2.45 ms or 5.12 ms. The 360 observing sessions were made during the period from April 2012 to April 2014. Every observing session contains about 900 pulsar periods.

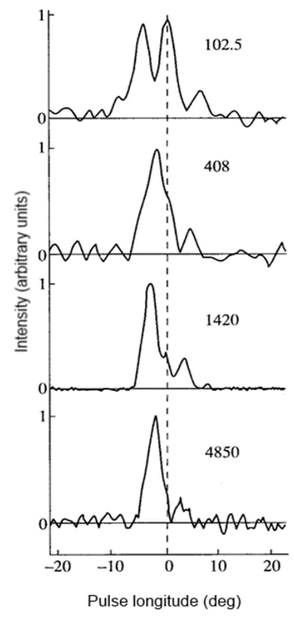

Figure 1· Mean profiles of the pulsar B0643+80 at four frequencies· The dashed line marks the phase of the component C2· [2]

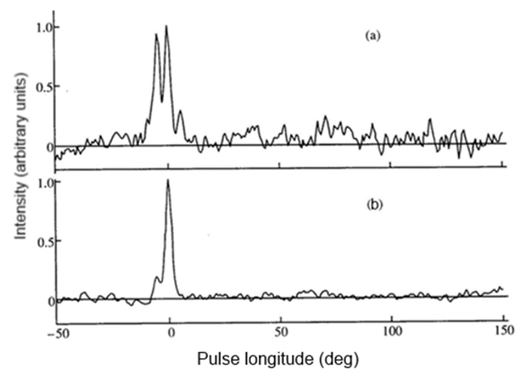

Figure 2· The mean profiles of the pulsar B0643+80 at 102,5 MHz on (a) February 2nd, 1995 and (b) March 3rd, 1996· [2]

Results and discussion

The pulsar B0643 +80 (J0653 +8051) was discovered by Arzoumanian et al. in 1994 [1]. This object has P=1.214 s, P'= 3.8 10^{-15}, the mean age 5x10^6 years, B = 2·10^{12} G and DM = 32.5 cm^{-3}pc. The pulsar has a three-component pulse profile. This profile form keeps shifting from high to low frequencies and the pulse profile has broadening with decreasing frequency. In addition, the central component (C2) shows a steeper spectrum than the other components (fig.1). The burst activity of this pulsar was detected in 1996 for the first time. B0643+80 displayed a burst in the central component (C2) with a flux increase a factor of nine above its mean value (fig.2). This event has been detected only in one session from 23 days of observations [2].

In present observations (series of 2012-2014) we also registered two cases of central component burst activity on August 1st, 2013 and May 24th, 2012. Figure 3 illustrates the signal to noise ratio for all three pulse components versus epoch with indications of the days of observations. Intensity fluctuations are presented in all three components of the pulse. The pulsar weakly emits in ordinary state (62 % of the observational time) and in this case pulses have a signal to noise ratio (SNR) in the range 3 – 5 sigma (Fig. 4b). During about 26% of the observation time, the pulsar was practically invisible (SNR < 3) (Fig. 4a). And in about 12% of events, the pulsar demonstrated an increasing of emission activity (SNR ≥ 5) (Fig. 4c), including "burst" days, when the SNR increased up to 28 times more than the average amplitude of the central component in the integrated profile (Fig. 5). The outburst on August 1st, 2013 continued for about 300 periods or 6 min (Fig. 6). Another outburst on May 24th, 2012 was weaker (Fig.7) because it was not fully registered. We observed only the end of the burst, which amounted to about 100 periods (Fig.8). This flare activity corresponds to 0.13% of the total observing time (360 days, 3.2 10^5 periods). During the period of maximum activity (two "burst" days) we detected 35 individual pulses with 10 < SNR ≥ 5 and 22 individual pulses with SNR ≥ 10. It means that the intensity of the highest pulse can be 170 times higher than its mean value. All of these strong pulses were at the phase of the central component.

At the moment there are several effects that can explain the changes in the amplitude of the integral pulse shapes:

- **Mode switching**. The effect is concerned with changes in all characteristics of the pulsar (pulse shape, polarization, emission intensity, etc.) and it is barely responsible for the burst activity of pulsar B0643+80, as this object has very rare activity events (0.13% of the total observation time).
- **Giant pulses.** This phenomenon also does not explain the "burst" effect of B 0643+80, because the pulse widths are much larger than the ones for the giant pulses. In the first case, we have a pulse width of approximately 10 ms, whereas giant pulses have nanosecond widths.
- **Radio transients**. In many ways, this is similar to the behavior of RRAT [4], taking into account that they are more distant in comparison with the object under study, and weaker pulses are invisible. The duration of RRAT pulses is in the 2 – 30 ms range and the pulse rate is in the range of 0.01 – 0.4%. The extreme pulses of B0643+80 are in agreement with these values. One more object has similar bright radio bursts. It is the pulsar B0656+14 [5]. But this pulsar has a wider emission window (~ 40°), while the B0643+80 has ~5° only.
- **«Core emission».** This may be one of the possible explanations of the central component bursts [6].
- It is likely this is a quite new effect - a giant component or pulse component burst.

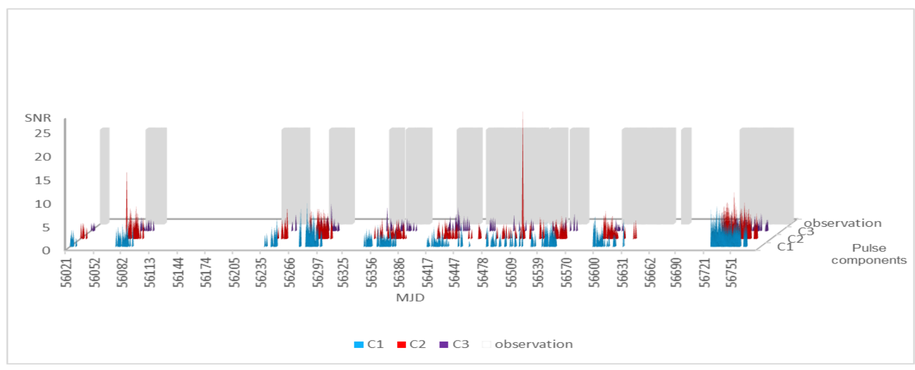

Figure 3· The fluctuations of the component intensity for B0643+80 at 111MHz· Signal to noise ratio of pulse components versus epoch· The grey blocks indicate the days of observations·

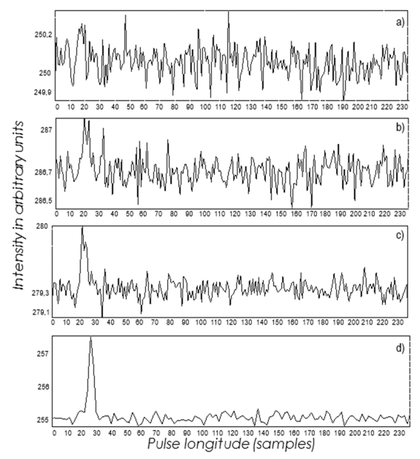

Figure 4· The examples of integrated pulse profiles of pulsar B0643+80 at the frequency 111MHz: (a) March 22nd, 2013, (b) December 31st, 2012 (c) December 12th, 2012, (d) January 8th, 2013· Sampling interval is equal to 5,12 ms·

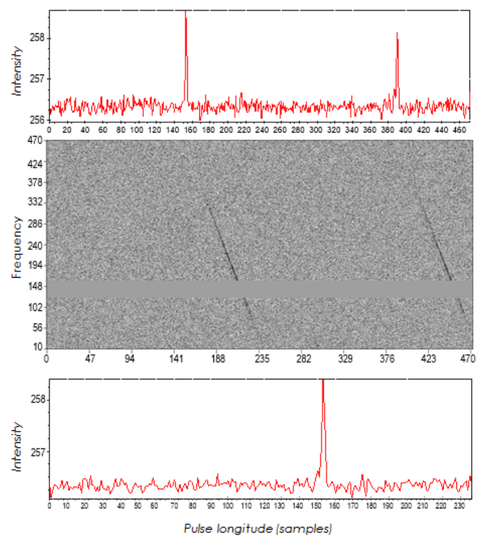

Figure 5· The observations of the pulsar B0643 +80 at 111 MHz on August 1st, 2013: (a) – the integrated pulse profile obtained by summing of the 408 groups (double periods), (b) - the dynamic spectrum, (c) - the integrated pulse profile obtained by summing of the 816 pulses (folding of the pulse profile with one period)· Sampling interval is equal to 5,12 ms·

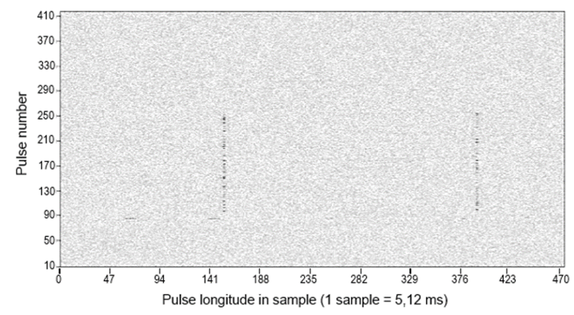

Figure 6· The intensity variations of pulses during the session on August 1st, 2013· The observation of B0643+80 has been carried out at 111 MHz using double period· The duration of the outburst is about 300 periods or ~ 6 min·

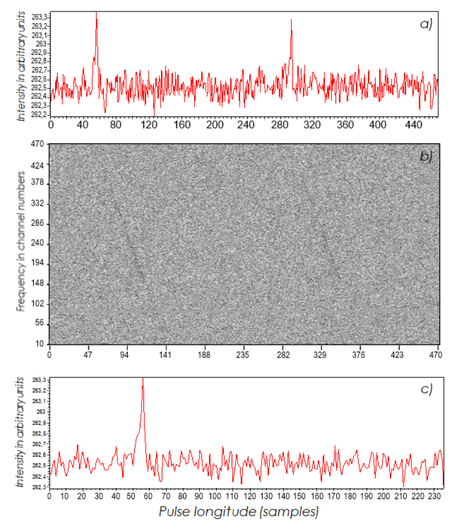

Figure 7· The observations of the pulsar B0643 +80 at 111 MHz on May 24th, 2012: (a) – the integrated pulse profile obtained by summing of the 496 groups (double periods), (b) - the dynamic spectrum, (c) - the integrated pulse profile obtained by the summing of the 992 pulses (folding of the pulse profile with one period)· Sampling interval is equal to 5,12 ms·

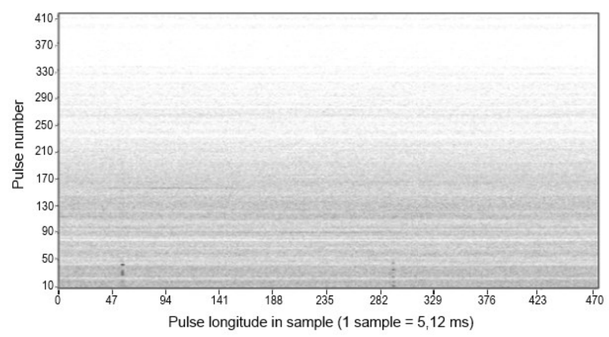

Figure 8· The intensity variations of pulses during the session on May 24th, 2012· The observation of B0643+80 has been carried out at 111 MHz using double period· Duration of the end part of outburst (in the bottom of plot) is about 100 periods·

Conclusions

⇒ We confirmed the presence of the bursts in second component of three components profile [2].

⇒ We detected that the intensity of this component can be a factor 170 higher than its mean value. The duration of the bursts is about 300 periods (~6 min) and such event is extremely seldom (about 0.13% of the total observing time).

References

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