On scattering of Giant Pulses from the Crab Pulsar: a Scattering Function

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ABSTRACT

Simultaneous dual-frequency observations of giant pulses from the Crab pulsar were performed at the frequencies of 61 and 111 MHz. It is shown that scattering of giant pulses from the Crab pulsar occurs at thick, and not at thin screen.

1. Introduction

The Crab pulsar was discovered through detection of its giant pulses (Staelin & Reifenstein (1968)). Observations of giant pulses from the Crab pulsar provide a good possibility for investigation of interstellar medium. Observed profile of giant pulse is the convolution of intrinsic pulse profile, function of scattering in interstellar medium and functions related with instrumental broadening of the profile (dispersion broadening and time integration). Scattering in interstellar medium (10 to 15 ms at the frequency of 111 MHz) leaves only millisecond time scale for investigations at low frequencies, and in this case intrinsic profile of giant pulse from the Crab pulsar may be considered as a delta-function. Therefore, at minimization of instrumental broadening an observed giant pulse profile will be function of scattering. To determine function of scattering (scattering on a thin or a thick screen, in particular) simultaneous dual-frequency observations of giant pulses from the Crab pulsar were performed.

2. Observations and Data Reduction

The observations were performed since April 1 to April 7 2007 (five observing sessions) with BSA radio telescope (at 111 MHz) and DKR-1000 radio telescope (at 61 MHz) of Pushchino Radio Astronomy Observatory. One linear polarization was received. I used Pulsar Machine with Fast Fourier Transform (512 channels in 2.5 MHz band and a central frequency of 110.83 MHz) and 128-channel receiver with a channel bandwidth of 20 kHz and a center frequency of 61.39 MHz. The sampling intervals were 1.024 and 8.192 ms; durations of one observing session were 3.4 min and 16.6 min; dispersion broadenings in one channel band for a dispersion measure of $DM = 56.759 \text{ pc cm}^{-3}$ were 1.69 ms and 40.7 ms for 111 and 61 MHz frequencies, respectively. Dispersion measure is as referred in Jodrell Bank Crab Pulsar Monthly Ephemeris 1.

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Upon observations at low frequencies with linear polarized antennae effect of rotation of radio emission polarization plane (Faraday effect) should be considered. The rotation measure of the Crab pulsar is $RM = -42.3 \text{ rad/m}^2$ and this causes periodic modulation of a signal with periods of 563 and 95.6 kHz at the frequencies of 111 and 61 MHz respectively. Therefore, at building of giant pulse profiles not all frequency channels were used, but 461 channels at 111 MHz and 125 channels at 61 MHz, only; this corresponds to 4 and 26 full periods of Faraday modulation. Thus, though observations were performed on linearly polarized antennae, resulting profiles of giant pulses are equivalent to those, obtained at total power mode.

Fig. 1 presents profiles of 14 giant pulses at 111 MHz. Signal to noise ratios of all these pulses are 20 or higher. The strongest pulse had a signal-to-noise ratio about of 150. Exponential tail, resulting scattering of emission in interstellar medium is distinctly seen in all profiles.

3. Results

Difference between scattering on thin and thick screens is demonstrated by two effects: duration of front edge (zero for a thin screen) and additional delay of pulse maximum at lower frequencies in case of a thick screen.

Fig. 2 presents fine structure of front edge for 14 giant pulses, full profiles of which are presented at the fig.1. Mean duration of front edge of these 14 pulses is approximately 6 ms. Instrumental broadening at this frequency is distinctly less, and it equals to 2.0 ms (two points on a figure). Thus, duration of front edge of scattering function (rise time) is not zero one.

Fig. 3 presents profiles of 15 giant pulses at the frequency of 61 MHz. The scattering tails are also clearly visible.

Preliminary results of processing of the observations of giant pulses result as follows: scatter broadening values $\tau_{sc}$ are 12 and 200 ms; durations of front edges are 6 and 50 ms at 111 and 61 MHz frequencies, respectively. Additional delay of giant pulse profile maximum at 61 MHz from 111 MHz is 70 ms (additional delay of low frequency giant pulses was revealed by Kuzmin et al. (2007) as well, but it was interpreted in other way). According to the theoretical approach, developed by Williamson (1972) for multiple scattering, it means that scattering of giant pulses from the Crab pulsar occurs at thick, and not at thin screen.

4. Conclusion

Simultaneous dual-frequency observations of giant pulses from the Crab pulsar were performed. It is shown that scattering of giant pulses from the Crab pulsar occurs at thick, and not at thin screen.
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REFERENCES

Kuzmin, A. D et al. 2007, private communication

Staelin, D. H., & Reifenstein, E. C. 1968, Science, 162, 1481

Williamson, I. P. 1972, MNRAS, 157, 55
Giant Pulses from the Crab Pulsar at 111 MHz

Fig. 1.— The profiles of 14 giant pulses from the Crab pulsar at the frequency of 111 MHz.
The Rise Times of Giant Pulses

Fig. 2.— The rise times of 14 giant pulses from the Crab pulsar at the frequency of 111 MHz.
Giant Pulses from the Crab Pulsar at 61 MHz

Fig. 3.— The profiles of 15 giant pulses from the Crab pulsar at the frequency of 61 MHz.