Investigation of RRAT J0139+33 at the Frequency of 111 MHz

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Abstract. Individual pulses of RRAT J0139+3310 were searched for at 111 MHz. Based on the data obtained, the energy distribution of pulses as a function of their signal-to-noise ratio (S/N) was constructed, and an estimate was made of the number of observed pulses and their energy in S/N units over a period of 5.5 years. The hypothesis that J0139+3310 is a pulsar with giant pulses has been tested.

Keywords: radio continuum: transients

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1 Introduction

In 2006, Rotating Radio Transients (RRATs) were discovered (McLaughlin et al. 2006). These objects differ from canonical pulsars in their sporadic radiation. Researching these types of objects is difficult because they require a large amount of observation time, as the time intervals between pulses of the transients can reach several hours. The nature of RRATs is currently unclear.

2 Observations, Processing, and Results

Since August 2014, the radio telescope BSA LPI (Big Scanning Antenna of Lebedev Physical Institute), located in Pushchino, Russia, has been carrying out continuous, 24-hour monitoring observations. These observations can be used to search for pulsars and transients (Tyul'bashev et al. 2016). BSA is a meridian-type radio telescope with a filled aperture. The receiving elements are 16384 half-wave dipoles, and the size of the BSA is 187x384 m in the East-West and North-South directions, respectively. The effective area of the radio telescope is approximately $45,000 \pm 4,000$ m^2 in the zenith direction. The central frequency is 110.3 MHz with a receiving bandwidth of 2.5 MHz. Data are recorded on a 32-channel digital receiver with a 78 kHz channel width and readout time $\tau = 12.5$ ms.

As part of this work, individual impulses of J0139+33 were found. A total of 1,013 pulses (S/N ≥ 7) were found in 1,669 observation sessions. The ratio of the peak flux densities of the strongest pulses to the weakest pulses detected is 25.7 (the strongest recorded pulse has S/N = 154).

We constructed distributions of the peak flux density in terms of S/N for all RRAT J0139+33 pulses detected within ± 1.5 minutes of the maximum in the radiation pattern, and obtain a bimodal power-law dependence, with indices of 0.4 and 1.8 (Fig. 1, left). The total number of observed pulses varies from year to year, and we show the number of observed impulses for every two months in the center panel of Fig. 1. The average energy of the pulses (in terms of S/N) in each two-month interval is shown in the right panel of Fig. 1.

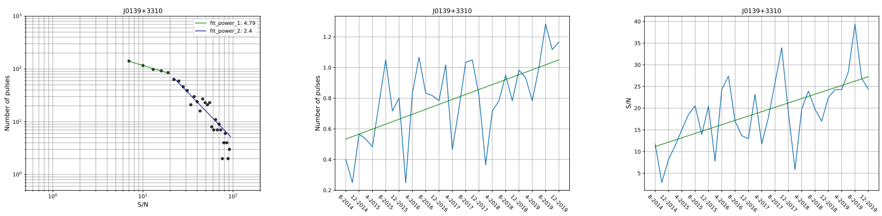

Fig. 1. *Left*: distribution of peak flux density values in S/N units at logarithmic scale for J0139+3310. The vertical axis shows the number of pulses detected and the horizontal axis shows the S/N ratio of these pulses. The histogram was constructed with a step of 3 on the abscissa, where the first cell contains pulses that have S/N in the range from 7 to 10. The upper corner of the images show the standard deviation for each relationship obtained. *Center*: the average number of observed pulses each day in the interval of 2 months. *Right*: the average energy in S/N units of observed pulses of the transients.

3 Discussion of Results and Conclusion

There are a number of theories that try to explain the observed irregular radiation of RRAT pulses, which can be divided into roughly two types. The first type of theory suggests that there should be no additional emission between the observed strong pulses (e.g. Zhang et al. 2007; Turolla et al. 2005), while the second type suggests that RRATs are ordinary pulsars with occasional strong, irregular pulses observed (e.g. Weltevrede et al. 2006).

The constructed energy distribution of pulses for J0139+33 shows a bimodal structure. This bimodality is characteristic of pulsars with giant pulses (Smirnova 2012; Kazantsev & Potapov 2017). Regular radiation from the RRAT was not detected at a flux density level of 2 mJy. Therefore, J0139+33 is most likely a pulsar with giant pulses. Fig. 1 (central and right) shows a clear trend, showing an approximately doubling of the number of observed pulses and their energy at an interval of 5.5 years. Similar trends have been observed, for example, in the paper (e.g. Bhattacharyya et al. 2018). The coincidence of increasing trends in the number of observed impulses and their energy over time indicates that the average energy in the impulses does not change over time.

There are RRATs known which have been shown to have no giant pulses (e.g. Losovsky & Dumsky 2014), and their irregularity can be explained by other models (Zhang & Gil 2005; Lomiashvili et al. 2007). This paper showed that the pulses from RRAT J0139+3310 appear to be giant pulses. Final conclusions on the nature of J0139+3310 can be made if regular weak radiation is detected from this transient.

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