GEMINGA: NEW OBSERVATIONS AT LOW RADIO FREQUENCIES

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ABSTRACT. After nearly 10 years, we have succeeded to detect radio emission from Geminga more again. In this report we present new evidence for presence of radio emission from Geminga in the range 42-112 MHz. The observations were carried out on two sensitive transit radio telescopes We used three new digital receivers to detect the pulses and to obtain dynamic spectra.The examples of mean pulse profiles are presented. Exact value of the dispersion measure have been calculated using the simultaneous observations at three frequencies.

Keywords: pulsars, radio emission.

Introduction

Geminga was discovered in gamma-ray in 1975 (Fichtel et al., 1975). For a long time this source was remained unidentified until its detection as X-ray pulsar (Halpern & Holt, 1992) and slightly late as gamma-ray pulsar (Bertsch et al., 1992) with a period of 237 ms. All attempts to detect the radio source or pulsar have been unsuccessful till 1997, when three group from Pushchino Observatory (Astro Space Center, Lebedev Physical Institute, Russia) reported the detection of pulsed radio emission from Geminga at frequency 102.5 MHz (Malofeev & Malov 1997; Kuzmin & Losovsky 1997; Shitov & Pugachev 1998). In 1999 presence of radio emission were conformed at the same frequency 103 MHz (Vats et al., 1999). At now there is no evidence for detections of radio emission at more high frequency. But recently the weak continuum radio emission has been detected at the frequency 4.8 GHz (Pellizzoni et al., 2011).
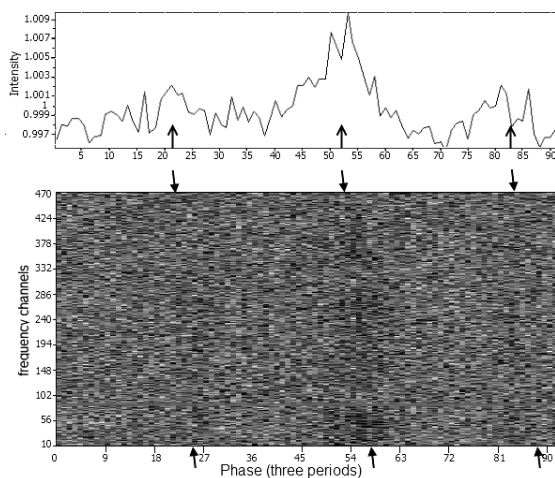

Figure 1: Example of a pulse profile (upper) and a dynamical spectrum (lower) of Geminga at 111 MHz, obtained by summing 36 selected groups (triple periods) on the 20.01.12. The horizontal axis is in samples of the triple period of the pulsar. The dispersion track is marked by arrows.

Observations and results

The observations were carried out on two sensitive transit radio telescopes in Pushchino in the range 42-112 MHz. First of them is Large Phase Array (LPA) antenna, with operating frequency 111.5±1.5 MHz and the effective area $3 \cdot 10^4 \, m^2$. Second one is DKR-1000 (East - West arm), which operates at 30-110 MHz and has the effective area $\sim 7000 \, m^2$. New series of observations was obtained using a unique set of digital, multi-channel receivers designed for pulsar observations, which came into use in 2006-09. The spectrum of the signal is calculated using an instrumental realization of a 1024-point FFT processor. The time resolution that can be obtained is 0.2048 ms. The width of the operational frequency band is 2.5 MHz, which is separated by the FFT into 512 spectral channels with widths of 4.88 kHz each. The reduction programs implement several techniques for removing interference, using several criteria for distinguishing false pulses from real signals (see, for detail, (Malofeev et al. 2012)).

We continued the observations of Geminga at low radio frequencies and hoped to detect strong signal, but did not reported most of unsuccessful observations or the seldom week pulses. Suddenly in the beginning of this year new observations in Pushchino showed the evidence for the detection of Geminga at three low frequencies during two months (January-February of 2012) in a few sets of observations. Here, we present the results for three days 19 — 21 of January integrated profiles of selected groups at all three frequencies (Fig. 1-3). To check the presence the weak pulsar signal and to raise the reliability we determine the observing window or the group as three apparent pulsar period with the sampling interval 7.5776 ms. One observation set contained 280 or 841 groups (triple periods) at frequencies 111 MHz and 42/62 MHz accordingly. The direct integration of all groups showed weak signal with signal-to-noise ratio (S/N) about 5 in some observations. But if we used the method of visible pulses selection (Malofeev et al. 2012) for reduction of data in these observations, the value of S/N ratio can reach more than 10 in these days (Fig.1,3).

In this case we summed all group, where have been the pulses with S/N > 2 at selected phase. The mean profile of 36 selected groups is presented at Fig.1 (upper). Here the integration was carried out at phase sample 52 ± 3, but possible see two other more week pulses at the phases near samples 21 and 83. All three pulses are separated by one pulse period (31.29 samples). Next method was the summing of selected groups with pulses, which show S/N > 2 in folding profile for the observing window as one pulsar period, as shown in Fig.2b. This selection showed the presence of three pulses in the observing window (Fig. 2-3). Both types of selected groups of integration
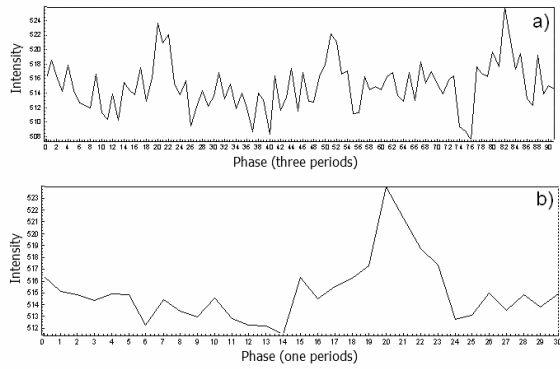
Figure 2: (a) Example of a pulse profile of Geminga at 62 MHz, obtained by summing 20 selected groups (triple periods) on the 20.01.12. (b) The mean profile for one period obtained by the folding of data. The horizontal axis is in samples of the triple period (a) and one period (b) of the pulsar.
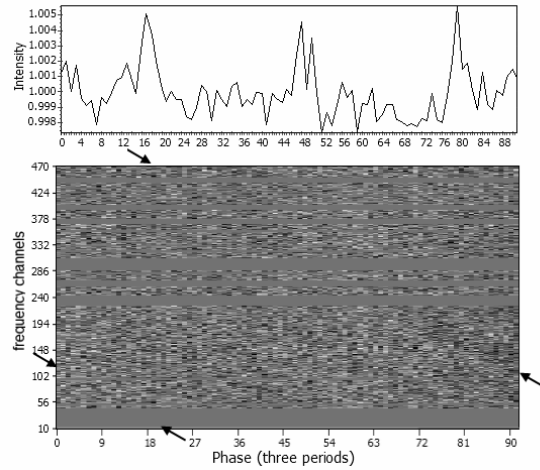

Figure 3: Example of a pulse profile (upper) and a dynamical spectrum (lower) of Geminga at 42 MHz, obtained by summing 23 selected groups (triple periods) on the 21.01.12. The dispersion tracks are marked by arrows.
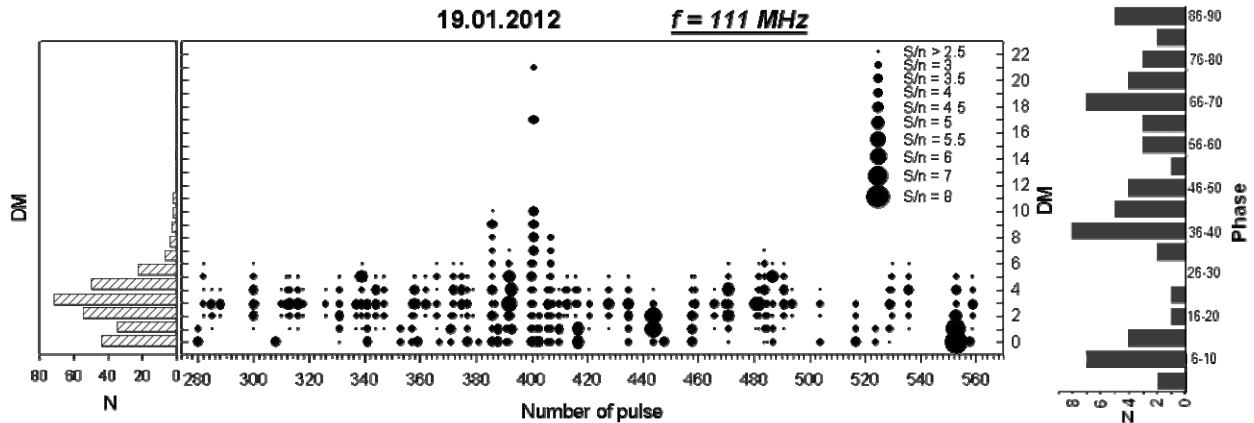

Figure 4: The central panel shows events with *S/N* > 2.5 at different DM versus number at pulse (time) (size of the circle indicates the value of the signal to noise ratio). The left panel shows the histogram of the number of events vs DM. The right panel shows histogram of the events with *S/N* > 2:5 versus of period phase for 19.01.2012 (triple period).

demonstrates the presence of periodical radio emission from Geminga at low frequencies. Next very important thing is the presence of the signal dispersion. We have been luck and first time new simultaneous observation at three frequencies on 20 of January give us possibility to measure more exactly the value of DM = 2.89 ± 0.02. The dispersion tracks are seen at dynamic spectra of Fig. 1,3 (bottom panels). Fig. 4 shows events with *S/N* > 2.5 in depend on number of pulse, DM and phase of period for 19.01.2012 at 111 MHz.

Conclusions

1. The presence of periodic radio emission has been confirmed at all three low frequencies.
2. We measured precise value of the dispersion measure (DM = 2.89 ± 0.02) using the simultaneous observations at three frequencies.
3. The long-term (a few years) intensity variation can be the cause of the absence of low frequency radio emission from Geminga during about 10 years.

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