Observations of the Gamma-Ray Pulsar J1836+5925 at 111 MHz

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Abstract. We describe radio observations of the gamma-ray pulsar J1836+5925. Observations were carried out on the Pushchino Radio Astronomical Observatory at the frequency of 111 MHz using the Large Phased Array of the Lebedev Physical Institute. This telescope is one of the most sensitive instruments in the meter wavelengths in the world.

Keywords: pulsars: general; gamma-rays: stars; X-rays: stars

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1 Introduction

The bright gamma-ray source J1836+5925 (also known as GRO J1837+59, 2EG J1835+5919, 3EG J1835+5918, and GEV J18351+5921) has been the object of considerable interest since its discovery in the mission of Energetic Gamma Ray Experiment Telescope (EGRET) aboard the NASA Compton Gamma-Ray Observatory (CGRO) (Lin et al. (1994) and later by Nolan et al. (1994)).

This source was not identified many years with any plausible counterpart at other wavelengths (Halpern et al. (2002, 2007)). In 2014 X-ray radiation was detected by Pavlov (2014) and Arumugasamy et al. (2014).

In the ATNF catalog (Manchester et al. 2005) J1836+5925 is listed as an isolated neutron star with the period of 173 msec (Abdo et al. 2009).

It was proposed in Malov & Timirkeeva (2018) to search for radio emission from some gamma-ray pulsars using 2 criteria such as rates of rotational energy losses $\frac{dE}{dt} > 3 \times 10^{34}$ erg/sec and magnetic fields near the light cylinder $B_{lc} > 1000$ G. Pulsar J1836+5925 has slightly lower values of $\frac{dE}{dt}$ $(1.1 \times 10^{34}$ erg/sec) and $B_{lc} = 930$ G) (Manchester et al. 2005), but it was observed as well.

Characteristics of J1836+5925 are typical for features of gamma-ray pulsars like Geminga, and candidates in radio-quiet pulsars like J0007+7302 (Lin et al. 2010), J2021+4026 (Lin et al. 2013), J1813-1246 (Marelli et al. 2014).

We planned in our work to search for radio emission from the pulsar J1836+5925 at 111 MHz, estimate the dispersion measure (DM) and the flux density at this frequency.

2 Observations

Numerous attempts to detect radio emission at other frequencies were made (see estimates in Table 1). Our observations do not suggest a strong radio emission from J1836+5925.

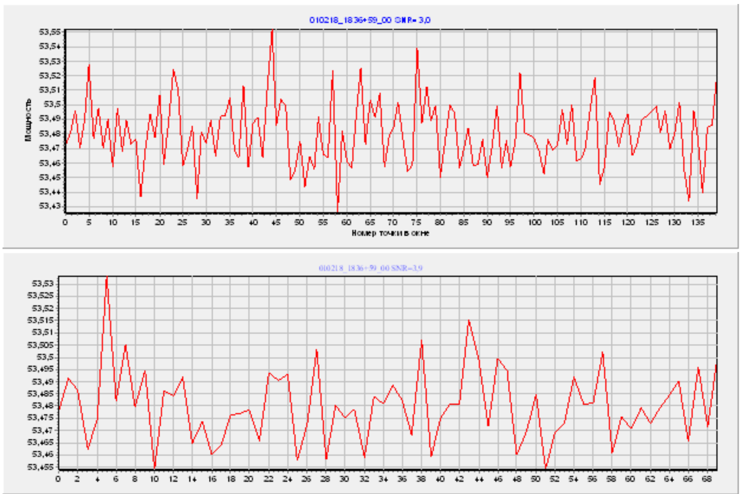

Fig. 1. Pulsar profile at 111 MHz for DM = 22 cm^{-3} pc obtained by summing about 1000 selected groups of pulses for the time interval equaled to double pulsar periods (top panel). Sum of two periods for the same observations (bottom panel).

Observations were carried out on the Pushchino Radio Astronomical Observatory (PRAO) using the Large Phased Array of the Lebedev Physical Institute (LPA LPI). This telescope is one of the most sensitive instruments in the meter wavelengths in the world with effective area $\approx 30000 m^2$. In order to make a more sensitive search for radio pulsations, we carried out the observations during 3 years on 170 days at the frequency of 111 MHz. To verify the presence of weak signals and enhance the reliability of results we selected observing sessions equal to double periods. During the observing sessions 1089 pulses have been accumulated. After summation of all pulses we get the weak pulsed signal with the signal-to-noise ratio (SNR) of 4-5 for the certain values of DM.

We present the results of our observations for the integrated pulses at 111 MHz in Fig. 2.

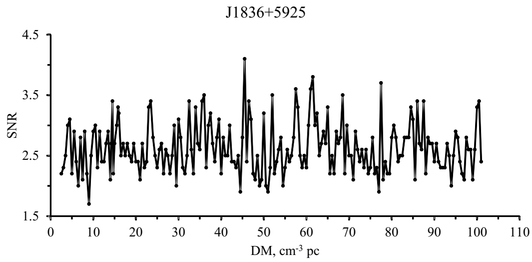

Fig. 2. Dependence of DM on SNR

The value of DM is still unknown. We iterated different values of DM (from 2 to 100 cm^{-3} pc) and estimated SNR. In the case of the true estimation of DM we obtain the maximal value of SNR (Fig. 2).

For the distance range 500$\pm$ 300 pc (Halpern et al. 2002) and the mean value of the n$_e$ = 0.03 cm $^{-3}$ the DM predicted is 8-24 cm $^{-3}$ pc. For the distance range 250-800 pc (Halpern et al. 2007) DM predicted by the NE2001 electron density model (Cordes & Lazio 2002) is 2-9 cm^{-3} pc (Abdo et al. 2010). According the new model for the distribution of free electrons in the Galaxy (Yao et al. 2017), the distance is equal to 300 pc (Manchester et al. 2005) and expected DM $\sim$ 6 cm^{-3} pc.

3 Results

According to Shishov et al. (2016), the limiting sensitivity of the LPA for the time constant τ_0 of 0.1 sec changes from 0.1 to 0.14 Jy. If we accept $S_0 = 0.12$ Jy for the 5σ-signal, then using our observation parameters, we obtain the upper limit of the flux density equal to S_{max} = 82 mJy (see eq. 1)

$$S_{max} = \frac{5 \times S_0 \times \sqrt{\dfrac{\tau_0}{\tau_{obs}}}}{\sqrt{N_{total}}} = \frac{5 \times 0.12\, Jy \times \sqrt{\dfrac{100\, msec}{2.458\, msec}}}{\sqrt{2178}} = 82\, mJy \qquad (1)$$

The observational data listed in Table 1 made it possible to plot the radio spectrum of the pulsar (Fig. 3).

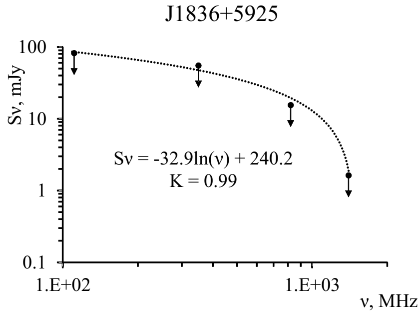

Fig. 3. Radio spectrum

Table 1. Radio parameters for J1836+5925

Frequencies, MHz	Flux density mJy	Ref.
111	< 82	this issue
350	< 55	Abdo et al. (2010)
820	< 14	Abdo et al. (2010)
820	< 17	Halpern et al. (2007)
1400	< 3	Abdo et al. (2010)
1400	< 0.25	Halpern et al. (2002)

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