Evolution of the PSR B1259–63 spectrum: detailed study

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Accepted...Received...; in original form...

Abstract
In the previous paper by Kijak et al. it was demonstrates that the spectrum of PSR B1259–63 undergoes evolution while it orbits the companion Be star and was suggested that this binary system can help to understand the origin of gigahertz-peaked spectra of pulsars. In the present paper we study in detail the spectra of PSR B1259–63 corresponding to various orbital phases based on all available observational data and model the influence of free-free absorption in the hot stellar wind on the evolution of observed spectra. Our model explains qualitatively the observed alterations of the spectral shapes depending on the orbital phases. Therefore, the case of PSR B1259–63 can also contribute to our understanding of the origin of untypical spectra (e.g. flat or broken spectra). Thus, our results support the hypothesis that the external factors have a significant impact on the observed radio emission of a pulsar.

Key words: pulsars: general, individual (B1259–63) - radiation mechanism: non-thermal - stars: winds, outflows - ISM: general

1 Introduction

The gigahertz-peaked spectra (GPS) pulsars were introduced by Kijak et al. (2011) providing a definite evidence for a new type of pulsar radio spectra that show the maximum flux density above 1 GHz. At higher frequencies these spectra look like a typical pulsar spectrum, while at frequencies below 1 GHz the observed flux density decreases showing a positive spectral index. A frequency at which such a spectrum shows the maximum flux density was called the peak frequency νp. Kijak et al. (2011) also indicated that the GPS pulsars are relatively young objects and they usually adjoin some active environments like HII regions or compact pulsar wind nebulae (PWN).

On the other hand the shapes of pulsar spectra are providing important information for understanding of the pulsar radio emission mechanism. Typical radio spectrum of a pulsar can be described using either a simple power law with a negative spectral index of −1.8 or two power laws with spectral indices of −0.9 and −2.2 and a break frequency on average of 1.5 GHz (Maron et al. 2000). Worth mentioning that in the spectra of several pulsars a low frequency turnover were observed (Siebel 1973; Malofeev et al. 1994). Lorimer et al. (1995) also reported about some pulsars having positive spectral index or flat spectrum in the frequency range between 400 MHz and 1600 MHz. Thus, Kijak & Maron (2004) selected candidates for GPS pulsars from those which showed a decreasing flux density at frequencies below 1 GHz. Using multifrequency flux measurements Kijak et al. (2007) presented the first direct evidence of a high frequency turnover. All the pulsars with such a feature in the spectra have been proved to be relatively young and having a high value of dispersion measure (DM around 150 pc cm−3 and above).

The PSR B1259–63 (J1302–6350) spectrum evolution can be treated as a key factor to define physical mechanisms which potentially are responsible for GPS phenomenon. This pulsar was mentioned to have a positive spectral index by Lorimer et al. (1993), which was the primary reason (along with radio spectrum evolution, age and value of dispersion measure) to consider it as a good candidate for GPS pulsar. PSR B1259–63 is a member of the unique binary system along with a massive (10M⊙) main-sequence Be star LS2883 with a radius of 6R⊙ (Mo and Ro are the solar mass and radius respectively). Negueruela et al. (2011) estimates the mass of LS 2883 to be about 30M⊙, however, their result is subject to large uncertainties. PSR B1259–63 is a middle-aged pulsar (330 kyr) with a short period of 48 ms. Its average DM is about 147 pc cm−3. The orbital period of this eccentric (e = 0.87) binary system is 3.4 yr and a projected semi-major axis a sin i is about 1300 light seconds (2.6 AU). Johnston et al. (1994) and Melatos et al. (1993)
suggested the existence of a disk around LS 2883. Both the star and its disk possibly produce strong magnetic field. It was shown that the disk is highly tilted with respect to the orbital plane by an angle 25’ and PSR B1259–63 is eclipsed for about 36 days as it goes behind the disk (Johnston et al. 2003). The PSR B1259–63/LS 2883 emits unpulsed non-thermal emission over a wide range of frequencies ranging from radio to γ-rays, and the fluxes vary with orbital phase. Kijak et al. (2011, Paper I, hereafter) studied the radio spectrum of PSR B1259–63 using the available measurements of the pulsed flux obtained during three periastron passages (1997, 2000 and 2004). They also presented spectral evolution of the pulsar radio emission due to its orbital motion and dependence of the peak frequency on the orbital phase. Kijak et al. (2011, Paper I) proposed two effects possibly responsible for the observed variation in spectra: the free-free absorption in the stellar wind and the cyclotron resonance in the magnetic field. This field is associated with the disk and is infused by the relativistic particles of the pulsar wind. The apparent resemblance between the PSR B1259–63 spectrum and the GPS suggests that the same mechanisms should be responsible for both cases (Paper I). Thus, there appears a conclusion that the GPS feature should be caused by some external factors rather than by the emission mechanism.

In the present paper we study in details the spectra of PSR B1259–63 using the flux measurements obtained during three periastron passages (Johnston et al. 1999; Connors et al. 2002; Johnston et al. 2005). We have constructed radio spectra for different observing days and analysed their shapes taking into account the influence of interstellar scintillations. We have also modeled the stellar wind in the vicinity of the PSR B1259–63/LS 2883 binary system. Using this model we have investigated the impact of free-free absorption on the shapes of PSR B1259–63 spectra and created the computer simulation of PSR B1259–63 spectrum evolution. We have presented as well implications of PSR B1259–63 case on classification of radio pulsar spectra in general.

2 PSR B1259–63 RADIO SPECTRUM: DETAILED ANALYSIS

As it was mentioned above, the typical pulsar spectrum can be usually described in terms of a simple-power law in the form

\[ S(\nu) = c \cdot \nu^x, \]  

(1)

which is a good approximation except a frequency range below some critical (so called cut-off) frequency. We presume that a cut-off of a spectrum is related to the radio emission mechanism and is caused by a loss of coherence (Melikidze et al. 2000; Gil et al. 2004).

However, there are also known more complicated spectra, e.g. turnover or broken-type. In the case of the broken-type spectrum it is necessary to fit the data to two power laws, which can be written as

\[ S(\nu) = \begin{cases} \ c_1 \cdot \nu^x : & \nu \leq \nu_b \\ c_2 \cdot \nu^y : & \nu > \nu_b \end{cases} \]  

(2)

Here \( \nu_b \) denotes the break frequency. The broken-type spectrum is usually defined as a spectrum fitted by two negative spectral indices and becoming steeper at higher frequencies. Spectrum with turnover, either at low or high frequency, can be modeled in a way proposed by Kuzmin & Losovsky (2001)

\[ S(\nu) = 10^{ax^2 + bx + c}, \quad x \equiv \log_{10} \nu, \]  

(3)

where \( \nu_p = 10^{\frac{c}{b}} \) denotes the peak frequency.

Table 1. The chosen fits to PSR B1259–63 spectra for each observing day. “−” and “+” denote days before and after periastron passage respectively, year is the epoch of observation.

| Day | Year | Best fit | Comments |
|-----|------|----------|----------|
| -60 | 1997 | turnover |          |
| -48 | 1997 | unclear  | no trend |
| -46 | 2000 | broken   |          |
| -40 | 1997 | turnover |          |
| -24 | 1997 | turnover |          |
| -21 | 2004 | turnover |          |
| -18 | 2000 | turnover |          |
| +16 | 1997 | turnover |          |
| +20 | 1997 | turnover |          |
| +21 | 2004 | broken/tur |          |
| +24 | 2000 | turnover |          |
| +27 | 1997 | turnover |          |
| +28 | 2004 | power-law|          |
| +29 | 2000 | power-law|          |
| +30 | 1997 | unclear  | no trend |
| +33 | 2004 | power-law/broken | small break |
| +34 | 2000 | broken/tur |          |
| +36 | 1997 | turnover |          |
| +38 | 2004 | broken/unclear | difficult to classify |
| +40 | 2000 | unclear  | no trend |
| +42 | 1997 | flat     |          |
| +47 | 1997 | broken/tur |          |
| +55 | 2000 | unclear  | no trend |
| +63 | 2000 | broken   |          |
| +64 | 2004 | turnover |          |
| +70 | 2000 | power-law/broken | small break |
| +83 | 2000 | broken   |          |
| +94 | 2004 | broken   |          |
| +113| 2000 | unclear  | significant error bars |
| +150| 2004 | broken   |          |
| +186| 2004 | power-law|          |
Figure 1. The fits to the PSR B1259–63 spectra for the each of the considered orbital phase intervals, prior to (left panel) and after (right panel) the periastron passage. See also, Section Discussion on the possible effects of scintillation.

we have chosen those fits which most accurately reflect the shapes of the spectra and used them to re-examine the spectrum evolution presented in Paper I.

To clarify the spectrum evolution, we have also examined the PSR B1259–63 spectra compiled for each observing day using the same database. We analyse only the spectra containing flux measurements at four frequencies (again with additional spectrum for −18d) to get the reliable results. The methods chosen by us were a combination of those used by Maron et al. (2000) for radio spectra of about 280 pulsars and in Paper I for PSR B1259–63 spectrum evolution.

2.1 Data analysis

To analyse the spectra in details, we have attempted to fit one/two power law function(s) and function 3 to the data with their errors. We have performed the fitting using an implementation of the nonlinear Marquard-Levenberg least-squares fitting algorithm. To choose the best fit we have analysed the results in a complex way. At first, we have rejected the evidently inaccurate approximations and non-physical results, e.g. break at frequency below the lowest or above the highest frequencies. We cannot simply compare the values of χ² to denote the best fit because there are available at most four data points. Otherwise, most of spectra would be classified as broken-type spectra. Let us note that based on an existing classification of spectra of pulsar radio emission we can distinguish three basic types of the spectra.

As mentioned above, we expect the broken-type spectra to have two negative spectral indices. This in turn leads us to classify the spectra showing positive spectral indices below

Table 2. Best fits and parameters fitted to spectra presented on Figolie for more details see Eq. 1, 2 and 3. “−” and “+” denote days before and after periastron passage respectively, year is the epoch of observation.

| Day | Year | Best fit | Parameters |
|-----|------|----------|------------|
| +33 | 2004 | power-law | d = 6.3, α = −0.88 |
| +83 | 2000 | broken | d₁ = 5.6, α₁ = −0.18, d₂ = 69.7, α₂ = −2.3, νₚ = 3.3 GHz |
| +20 | 1997 | turnover | a = −4.7, b = 5.2, c = −0.79, νₚ = 3.6 GHz |
| +42 | 1997 | flat | c = 3.9, α = −0.14 |
some peak frequency as the turnover spectra. We also specify power-law spectra with a very small value (close to zero) of spectral index as the flat spectra. Some of the spectra show two different trends (for more details see Tab. 1). Any of other existing cases are denoted as unclear. We present the results of the best fit for each spectrum in Table 1.

2.2 Results

Detailed study of PSR B1259−63 spectra constructed for few orbital epochs was presented in Paper I. The authors also analysed published data of the pulsar radio fluxes measured during three periastron passages in: 1997, 2001 and 2004. But in Paper I while calculating the average flux densities were used only those data sets that contained the flux measurements at least for four frequencies in a given observing day. We have extended the database by including all measurements published so far. Fig. 1 shows the spectra for various orbital phase ranges which can be used as a reference spectra while analysing the spectrum for a given observing day. It seems clear that the shape of the PSR B1259−63 spectrum depends on the orbital phase. Therefore, we acknowledge that the spectrum of PSR B1259−63 undergoes evolution. In Paper I it was suggested that the free-free absorption in the stellar wind can be responsible for this effect. Moreover, our analysis confirms that the shape of spectra are not fully symmetric with respect to the periastron point (see Paper I). One can note that the flux density values on the left panel are generally smaller that those on the right panel of Fig 1. This effect can be explained by the fact that the waves emitted before the periastron passage travel longer distance through the stellar wind (see Fig. 4 in Paper I).

Thus, they are affected by the free-free absorption stronger than the waves emitted after the eclipse. We can also confirm that the peak (or in some cases break) frequency depends on the orbital phase.

Comparing the results of fitting presented in Tab. 1 one can note that the shape of spectrum obtained in each day of observation is generally consistent with the spectrum obtained by averaging over the corresponding orbital phase interval. One can also note the GPS feature more or less dominates during the orbital phases before the eclipse. It is important to mention that first sign of more or less typical spectrum (i.e. broken or power-law) appears as early as 20 days after the periastron passage. The flux density at the given frequency apparently changes with orbital phases. When the pulsar is close to periastron, the flux generally decreases at all observed frequencies and the most drastic decrease is observed at the lowest frequency. Moreover, one can notice all types of radio pulsar spectra, including a flat spectrum (see Fig. 2). Close to the periastron point the spectra of PSR B1259−63 resemble those of the GPS pulsars. The spectra for the orbital epochs further from the periastron point are more consistent with typical pulsar spectra (i.e. power-law and broken).

3 PSR B1259−63 RADIO SPECTRUM EVOLUTION: SIMULATION

We have simulated a pulsar spectrum evolution by using our model of the binary system PSR B1259−63/LS 2883. The model has been used to examine the influence of a hot stellar wind on a pulsar flux density. The variation of PSR B1259−63 spectrum shape is believed to be caused by two physical processes: the free-free absorption and the cyclotron resonance (Paper I). In our computations only the first mechanism is considered, we have neglected the presence of the stellar equatorial disk.

3.1 The model

We have calculated pulsar flux absorption using the radiative transfer equation, where the optical depth is given by the following formula (Sieber 1973):

\[ \tau_\nu = 3.014 \cdot 10^{-2} \left( \frac{T_e}{K} \right)^{-\frac{3}{2}} \left( \frac{\nu}{GHz} \right)^{-2} \left( \frac{EM}{pc \cdot cm^{-2}} \right) \ln \left( 4.955 \cdot 10^{-2} \frac{\nu}{GHz} \right) + 1.5 \ln \left( \frac{T_e}{K} \right). \]

(4)

Here \( T_e \) denotes the electron temperature and an emission measure \( EM \) is defined as (Rohlf & Wilson 2004):

\[ \frac{EM}{pc \cdot cm^{-3}} = \int_0^{\infty} \left( \frac{N_e}{cm^{-3}} \right)^2 \left( \frac{s}{pc} \right) d\omega. \]

(5)

where \( N_e \) denotes the electron density.

Optical depth depends on thickness of an absorbing medium as well as on its properties, and therefore it is changing during the pulsar’s orbital motion. The simulated pulsar orbit has a semi-major axis of \( a = 4.41 \) AU and the eccentricity of \( e = 0.87 \). The inclination of the orbit is set to \( i = 36^\circ \) and the orbital period of \( P = 1237 \) days is assumed. For our initial approach we have positioned the orbit in such a way, that the projection of the apse line is pointing towards the observer and the periastron is the furthest away point of the orbit (\( \omega = 90^\circ \)).

In the model we assume that the stellar wind has a spherical symmetry, the electron density decreases as \( 1/r^2 \), the wind speed and the electron temperature are constant. We use the density at 1 AU as the reference value. In such a model one can of course expect a symmetry of results with regard to the periastron passage. However, the absorption should increase as the pulsar gets closer to periastron, since the fraction of the pulsar’s line-of-sight that lies inside the stellar wind increases. Another factor that increases the absorption is the electron density which also increases while the pulsar’s line-of-sight approaches the Be star.

3.2 Results

In order to estimate the electron density that is needed to explain the observed spectral shapes we start with assumption that the pulsar is located at a fixed position (corresponding to 30 days after the periastron passage) and model absorption using various values of the electron density at our reference distance, i.e. at 1 AU.

The top left panel (a) in Fig. 3 shows our results, where different line types correspond to different values of \( N_e \). As expected with increasing the value of \( N_e \) the amount of absorption at all observed frequencies also increases. Because the absorption is more significant at lower frequencies the peak frequency shifts towards higher observed frequencies and the total flux steadily decreases. As one can see on the
plot (panel (a) in Fig. 3) to explain the observed behaviour of spectra we need the stellar wind to have the electron density of the order of a few million particles per cm$^3$ (at the distance of 1 AU from the star).

We have not mentioned yet another important factor affecting a resulting spectrum of a pulsar – the shape of its intrinsic spectrum. In our simulations we assume that the intrinsic spectrum can be described by a single power-law function. Since there is no way we can observe the intrinsic spectrum, we try to model it using various spectral indices. The top right panel (b) in Fig. 3 shows the apparent change of the out-coming spectrum for two intrinsic spectral indices, namely $\xi = -0.8$, which is the spectral index obtained from averaging of all the available data, and $\xi = -1.3$, which is the average spectral index based on measurements performed only on 5 GHz and 8 GHz frequencies. We believe that the latter ($\xi = -1.3$) is more realistic, since higher observing frequencies are supposed to be less affected by absorption, almost regardless of the pulsar’s orbital phase. As one can see, using the steeper intrinsic spectrum yields the sharper shape of the observed spectrum and slightly shifts the peak frequency towards lower observing frequencies.

For the next step of our modeling we have used the intrinsic spectrum with the spectral index of $\xi = -1.3$ and have calculated the shape of the spectrum for various orbital phases. Like the real observations we denote them by number of days pre or post the periastron passage.

The bottom left panel (c) in Fig. 3 shows the simulated radio fluxes at the four observing frequencies, i.e. the frequencies which are used to perform the real observations. As one can see the simulated flux densities corresponding to the orbital phase 20 days after the periastron passage (open circles) can be clearly identified as a GPS type, although we admit that it is not as symmetric as the real spectrum from that phase (see the bottom left plot of Fig. 2). The spectra from day 30 after the periastron passage (open

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Figure 2. The fits to the PSR B1259–63 spectra for chosen days (“-” and “+” denote days before and after periastron passage respectively). Each panel shows different type of spectra.
Figure 3. Spectra resulted from modelling the influence of the free-free absorption for the PSR B1259−63 radio emission. The orbit inclination \( i \) is equal 36° and the electron temperature \( T_e \) is equal 10^4 K. (a) Pulsar spectra for the different values of the star wind electron density. The values of the spectral index, the star wind electron temperature and the day after periastron passage are fixed. The optical depth increases with electron density. The same results would be obtained for a decreasing electron temperature at a fixed electron density value. (b) Flux density spectra for two different values of the spectral indices at the fixed values of the star wind electron temperature and density. (c) Flux density values for chosen frequencies (1.4, 2.6, 4.8 and 8.4 GHz) for the chosen days after periastron passage and for fixed values of the spectral index, the star wind electron temperature and density. (d) Pulsar spectra for the chosen days after the periastron passage and for the fixed values of the spectral index, the star wind electron temperature and density.

We believe that this simple model shows some promise as it is able to simulate some basic properties of the observed spectra, although it clearly requires further investigation. Obviously, in its current stage it is not able to recreate the observed asymmetry between the spectra collected prior to and after the periastron passage. To model the asymmetry we need to introduce the real geometry of the system (namely the real value of the ascending node angle \( \omega \)). Also, starting from about 40 days after the periastron passage our simulated spectra (within the chosen frequency range) tend to show almost no absorption, which is not true, as the observed spectra show some absorption (see Fig. 1). This may have to do with the geometry of the wind as in our simulation we assume it to have spherical symmetry, while the real stellar wind from a Be star is bi-modal, constituting from the slow equatorial and fast polar winds. Hence the wind distribution is far from isotropic. Finally, our simple model does not include possible cyclotron resonance effects that may happen when the pulsar comes near the stellar disk.

4 DISCUSSION

4.1 Influence of interstellar scintillations on PSR B1259−63 spectrum

Pulsars are generally known to be stable radio sources although the pulsar signal is affected in a number of ways...
by the interstellar medium (Lorimer & Kramer 2003). Thus, the measured flux density varies due to diffractive and refractive scintillation effects. Scintillation studies are extremely successful in determining some properties of the interstellar medium and positioning of the dominant scattering screen. PSR B1259–63 is an object with a relatively high dispersion measure therefore the scintillation is in the strong regime. Thus we definitely have to take into consideration both refractive (RISS) and diffractive (DISS) scintillations while analysing the spectra.

To estimate the characteristic timescales $\Delta t_{\text{RISS}}$ and $\Delta t_{\text{DISS}}$ of scintillation we have used observations by McClure-Griffiths et al. (1998). They observed PSR B1259–63 at 4.8 GHz and 8.4 GHz during 46 sessions between August 1993 and February 1997, however, excluded from their analysis the data taken during the periastron passage. The observations were typically between 30 and 100 minutes long.

Based on their results we have estimated the values of $\Delta t_{\text{DISS}}$ to be ranging from 40s at 1.4 GHz to 360s at 8.4 GHz which suggests that the diffractive scintillations should not affect the average flux measurements as the observing sessions we use are usually 4 hours long. In contrary the refractive scintillations may play a significant role, as the estimated refractive timescales $\Delta t_{\text{RISS}}$ vary from 12 hours at 8.4 GHz to more than 20 days at 1.4 GHz. At lower frequencies, however, the modulation index is relatively small which means that the uncertainty of flux measurement is also relatively small. On the other hand, observations at higher frequencies may be affected strongly by the refractive scintillations, as the modulation index is higher and the typical duration of an observing session (4 hours) is still shorter than $\Delta t_{\text{RISS}} > 12$ hours. We can definitely point out at least a couple of high frequency observations that are affected by refractive scintillations. Definitely, this is the case for the orbital phase range from $+113$ to $+186$ days (see Tab. 1), which includes the data obtained during only three sessions. Thus, the spectrum obtained for this orbital phase range (see the dashed line in the right panel of Fig. 1) may differ essentially from the real and/or simulated (see the spectrum represented by solid line in the bottom right panel (d) of Fig. 3) spectra.

It should be mentioned, that despite the above example, it is always profitable to average data obtained during few neighbouring orbital phases to get more reliable estimate of the spectrum. However, let us note, that the clear signature of the spectral evolution is recognisable even by classification of spectra obtained during each session (see column 3 in Table 1), as the spectra close to periastron seem to be classified mostly as “turnover”, while the spectra far from periastron preferably are classified as “broken” or “power-law”.

### 4.2 Implications of PSR B1259–63 case on classification of radio pulsar spectra

Maron et al. (2000) concluded that the single power law spectrum is the most typical for a sample of about 280 pulsars in a wide frequency range, as only 10% of this sample require two power law spectra. Amount of both low and high frequency turnover spectra are also relatively small (Sieber 1972; Maron et al. 2000; Kijak et al. 2011, Paper I). These results indicate the possible existence of the “true” shape of spectrum for each pulsar, while other types of spectra should be rare exceptions of an unknown but definitely external origin.

It is clear that the existing classification of radio pulsar spectra is strictly morphological and any direct connection between external or internal factors and the shape of spectrum cannot be made. Paper I suggested that the GPS feature should be caused by some external factors rather than by the emission mechanism. One can note that shapes of spectra for each day, presented in Tab. 4 confirm the strong environmental influence on the observed pulsar radio emission. This fact leads us to suggestion that occurrence of different types of pulsar radio spectra owes to the environmental conditions around the neutron stars. However, assuming that the appearance of various non-standard spectra shapes in the general population of pulsars can be caused by peculiar environmental conditions, it seems impossible to isolate some kind of factor that influences the pulsar radio emission and to analyse it separately. Despite that, we still can distinguish between the typical broken and the turnover spectra.

### 4.3 Conclusions from the simulation of the spectrum evolution

As it was stated in Paper I, the case of PSR B1259–63 can play a crucial role in understanding the main factors that affects the observed spectra. Since the observed shape of PSR B1259–63 spectrum depends on the orbital phase, it is important to investigate how and why the changing environment causes the spectrum evolution. As an initial approach to study this problem we have constructed a simplified model of the system which includes the thermal absorption in a spherically symmetrical stellar wind (see Section 5). Using this model we are able to recreate the basic properties of the PSR B1259–63 spectrum evolution, although the model is far from perfect and does not explain some peculiarities of the spectrum variations. However, we have estimated that the electron density has to be of the order of a few million particles per cubic cm (at the reference distance of 1 AU) in order to get any significant absorption. To sustain such densities one needs a stellar mass loss of the order of $10^{-9} M_{\odot}$/year assuming the wind speed of 1000 km/s and equal number of protons and electrons escaping the star. This mass-loss rate seems to be reasonable.

It is obvious that the model requires further modifications to simulate all the characteristics of the observed spectrum evolution. We realise that using this model to ascertain the real physical parameters of the PSR B1259–63/LS 2883 system may prove futile, as there is a large number of free parameters in the model that we have no way to constrain. Nevertheless we believe that this model, even in its current simplified state shows that the thermal free-free absorption occurring in the stellar wind is a viable explanation for the pulsar spectra shapes and their evolution.

The next step should be incorporation of the second wind component into the model. The equatorial wind could influence especially the spectrum observed during the orbital phases before and after the eclipse (approximately $\pm 20$ days). At the moment it is difficult to estimate the param-
etters, i.e. density, temperature and velocity, of this component.

It is also important to estimate the electron density by independent (from absorption) method, using estimations of the dispersion measure variability that corresponds to various orbital phases ([Johnston et al. 2007]). In our model we have estimated the optical thickness of the environment that guarantees the observed absorption. The depth, however, depends on both the temperature and the density of electrons, and the independent estimation of the electron density allows to separate influences of these parameters. Preliminary estimations show that the densities that we obtain from our model are consistent with the observed DM variations. In order to calculate accurately variations of DM caused by the hot stellar wind we need to use the dispersion law in the hot plasma.

It is clear that more radio observations of PSR B1259–63 corresponding to various orbital phases are necessary. Particularly, it is very important to measure the flux density near the apastron passage to obtain the intrinsic spectrum of the pulsar. Moreover, additional observations at as many as possible orbital phases will help us to take into account the influence of interstellar scintillations, as its impact on the shape of observed spectra can be critical (see section 4.1).

5 SUMMARY

We can finalize that detailed analysis of the PSR B1259–63 spectra for observing days reveals that the shape of the spectrum depends on the orbital phase. Moreover, the observed evolution is widely consistent with changes of spectra averaged over orbital phase intervals. Furthermore, the fits presented in Table 1 show significant differences between spectra before and after eclipse. The results leads us to conclusion that the PSR B1259–63 spectrum varies with the changes of the pulsar environment what can be explained by combination of two effects: free–free absorption and cyclotron resonance ([Kijak et al. 2011], Paper I). The same time the detailed analysis of the PSR B1259–63 spectra for observing days revealed appearance of all types of spectra. Comparing to current classification of pulsar spectra, there occurs a suggestion that the appearance of various spectra shapes, different from a simple power law which is typical for radio pulsars, is possibly caused by environmental conditions around neutron stars.

We believe that the case of PSR B1259–63 can be treated as a key factor to our understanding of not only the GPS phenomenon (observed for the solitary pulsars with interesting environments) but also other types of untypical spectra as well (e.g. flat or broken spectra). This in turn would suggest, that the appearance of various non-standard spectra shapes in the general population of pulsars can be caused by peculiar environmental conditions.

The results of our simulations also support the hypothesis that the external factors can have a significant impact on the observed radio emission of a pulsar. The obtained spectrum evolution is consistent with the observational data and it shows that the free-free absorption can be a cause of observed variety of spectral types.

ACKNOWLEDGMENTS

This paper was supported by the grants DEC-2012/05/B/ST9/03924 and DEC-2013/09/B/ST9/02177 of the Polish National Science Centre. MD was a scholar within Sub-measure 8.2.2 Regional Innovation Strategies, Measure 8.2 Transfer of knowledge. Priority VIII Regional human resources for the economy Human Capital Operational Programme co-financed by European Social Fund and state budget.

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