Binary Pulsar B1259-63 Spectrum Evolution and Classification of Pulsar Spectra

M. Dembska, J. Kijak, W. Lewandowski

Kepler Institute of Astronomy, University of Zielona Góra, Lubuska 2, 65-265 Zielona Góra, Poland

Abstract. Recently published results (Kijak et al. 2011a) indicated the evidence for a new aspect in radio pulsars spectra. We studied the radio spectrum of PSR B1259-63 in an unique binary with Be star LS 2883 and showed that this pulsar undergoes a spectrum evolution due to orbital motion. We proposed a qualitative model which explains this evolution. We considered two mechanisms that might influence the observed radio emission: free-free absorption and cyclotron resonance. According to published results (Kijak et al. 2011b), there were found objects with a new type of pulsar radio spectra, called gigahertz-peaked spectra (GPS) pulsars. Most of them were found to exist in very interesting environments. Therefore, it is suggested that the turnover phenomenon is associated with the environment than being related intrinsically to the radio emission mechanism. Having noticed the apparent resemblance between the B1259-63 spectrum and the GPS, we suggested that the same mechanisms should be responsible for both cases. Thus, we believe that this binary system can hold the clue to the understanding of gigahertz-peaked spectra of isolated pulsars. Using the same database we constructed spectra for chosen observing days and obtained different 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.

1. The Gigahertz-peaked Spectra Pulsars

Generally, the observed radio spectra of most pulsars can be modelled as a power law with negative spectral indices of about -1.8 (Maron et al. 2000). If a pulsar can be observed at frequencies low enough (i.e., 100-600 MHz), it may also show a low-frequency turnover in its spectrum (Siebel 1973; Malofeev et al. 1994). On the other hand, Lorimer et al. (1995) mentioned three pulsars which have positive spectral indices in the frequency range 300-1600 MHz. Later, Maron et al. (2000) re-examined spectra of these pulsars taking into account the data obtained at higher frequencies (above 1.6 GHz). In paper Kijak et al. (2007), the authors presented the first direct evidence for turnover in pulsar radio spectra at high frequencies. Based on their observations of these pulsars, Kijak et al. (2011b) provided a definite evidence for a new type of pulsar radio spectra. These spectra show the maximum flux above 1 GHz, while at higher frequencies the spectra look like a typical pulsar spectrum. At lower frequencies (below 1 GHz), the observed flux decreases, showing a positive spectral index (see. Fig. 1). A frequency at which such a spectrum shows the maximum flux was called the peak frequency. They called these objects the gigahertz-peaked spectra (GPS) pulsars. Kijak et al. (2011b) also indicated that the GPS pulsars are relatively young objects,
and they usually adjoin such interesting environments as HII regions or compact pulsar wind nebulae. Additionally, some of them seem to be coincident with the known but sometimes unidentified X-ray sources from third EGRET Catalogue or HESS observations. We can assume that the GPS appearance owes to the environmental conditions around the neutron stars rather than to the radio emission mechanism.

2. PSR B1259-63 Spectrum Evolution

PSR B1259-63 was also inscribed by Lorimer et al. (1995) in the list of pulsars with positive spectral indices. Therefore, seems a natural candidate to be classified as the GPS pulsar.

PSR B1259-63 has a short period of 48 ms and a characteristic age of 330 kyr. Its average dispersion measure (DM) is about 147 pc cm$^{-3}$ and the corresponding distance is about 2.75 kpc. The companion star LS 2883 is a 10-mag massive Be star with a mass of about 10M$_\odot$ and a radius of 6R$_\odot$. Be stars are generally believed to have a hot tenuous polar wind and a cooler high-density equatorial disc. We studied the radio
spectrum of B1259-63 and showed that the shape of the spectrum depends on the orbital phase [Kijak et al. 2011a]. We analysed the available measurements of the pulsed flux obtained during three periastron passages (1997, 2000 and 2004) which allowed us to study shapes of the pulsar spectrum in details (see Fig. 2). Our analysis showed that this pulsar undergoes a spectrum evolution due to orbital motion. We suggested that this effect is caused by the interaction of the radio waves with the Be star environment. In addition, we have shown that the peak frequency also depends on the orbital phase and therefore it varies with the changes of the pulsar environment. We argued that such behaviour can be explained by the radio-wave absorption in the magnetic field associated with the disc. We proposed a qualitative model which explains this evolution. We argued that the observed variation of the spectra is caused by a combination of two effects: the free-free absorption in the stellar wind and the cyclotron resonance in the magnetic field. This field is associated with the disc and is infused by the relativistic particles of the pulsar wind.

3. B1259-63 Spectrum: Detailed Study and Classification of Pulsar Spectra

Using the same database (Johnston et al. 1999, Connors et al. 2002; Johnston et al. 2005), we constructed spectra for chosen observing days. As previously (Kijak et al. 2011a)

![Figure 3](image)

Figure 3. The fits to the B1259-63 spectra for chosen days. Each panel shows different type of spectra.

we analysed the shapes of the B1259-63 spectrum at various orbital phase ranges and obtained results are consistent with those for intervals. The flux 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.

4. Conclusions

Having noticed the apparent resemblance between the B1259-63 spectrum and the GPS, we suggested that the same mechanisms should be responsible for both cases (Kijak et al. 2011a). The only difference could be an invariable shape of the GPS, in contrast to the B1259-63 spectrum, which undergoes evolution due to orbital motion. We can concluded that the GPS feature should be caused by some external factors rather than by the emission mechanism. Thus, the case of B1259-63 can be treated as a key factor to explain the GPS phenomenon observed for the solitary pulsars with interesting environments.

Close to the periastron point the spectra of B1259-63 resemble those of the GPS pulsars. The spectrum for the orbital epochs further from the periastron point are more consistent with typical pulsar spectra (i.e. power-law and broken). Moreover, detailed study of PSR B1259-63 spectra revealed the appearance of all types of spectral shapes, including a flat spectrum (see Fig. 3).

We believe that the case of 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.

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References

Connors, T. W., Johnston, S., Manchester, R. N., & McConnell, D. 2002, MNRAS, 336, 1201
Johnston, S., Ball, L., Wang, N., & Manchester, R. N. 2005, MNRAS, 358, 1069
Johnston, S., Manchester, R. N., McConnell, D., & Campbell-Wilson, D. 1999, MNRAS, 302, 277
Kijak, J., Dembska, M., Lewandowski, W., Melikidze, G., & Sendyk, M. 2011a, MNRAS, 418, L114
Kijak, J., Gupta, Y., & Krzeszowski, K. 2007, A&A, 462, 699
Kijak, J., Lewandowski, W., Maron, O., Gupta, Y., & Jessner, A. 2011b, A&A, 531, A16
Lorimer, D. R., Yates, J. A., Lyne, A. G., & Gould, D. M. 1995, MNRAS, 273, 411
Malofeev, V. M., Gil, J. A., Jessner, A., Malov, I. F., Seiradakis, J. H., Sieber, W., & Wielebinski, R. 1994, A&A, 285, 201
Maron, O., Kijak, J., Kramer, M., & Wielebinski, R. 2000, A&AS, 147, 195
Sieber, W. 1973, A&A, 28, 237