THE CONNECTION OF SPECTRA WITH OTHER PULSAR PARAMETERS

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Abstract

An analysis has been made of the connection of characteristic frequencies and spectral indices with the following parameters of pulsars: P, $\dot{P}$, T, L_{400}, B, and χ. It is shown that a number of pulsar spectra apparently demonstrate the presence of two emission regions at a short distance between levels in the magnetosphere of pulsars, where the effects of the low-frequency turnover (LFT) and the high frequency cutoff (HFC) take place.

Introduction

At present there are more than 60 pulsars whose energy has been measured over the frequency range from 100 MHz to 1.7 GHz. In the last few years a large sample of pulsars has been observed for the first time at 2.7, 4.6 and 10.7 GHz (Kuz'min *et al.* 1986, Izvekova *et al.* 1990). Using the collection of pulse energy values of Malofeev and Malov (1980) and the new measurements, mean spectra were computed. About 60% of pulsar spectra have two sections with a simple power-law frequency dependence $E = E_0\nu^{-\alpha}$ and two characteristic points: a low-frequency turnover (LFT) at frequency ν_{max}, and a high-frequency cutoff (HFC) at frequency ν_c. An example of this type of spectrum is given in figure 1. About 20% of pulsar spectra have no HFC, and a few pulsars demonstrate more complex spectral forms (for example PSR 1822−09 and 2020+28).

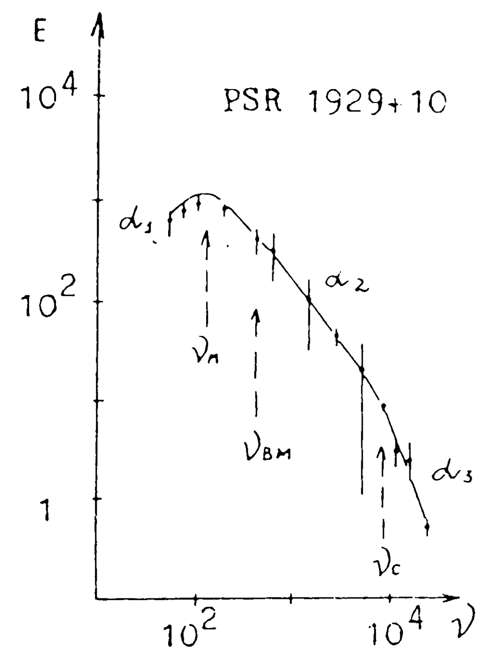

Figure 1

Analysis

We have made a brief analysis of two groups of pulsars. The first group consists of 31 pulsars which have an HFC. The second group consists of 11 pulsars with no HFC, but for which measurements of the pulse energy up to 10.7 GHz exist. We have analyzed the correlation of ν_{max}, ν_c and spectral indices α_2, α_3 with the pulsar parameters P (period), $\dot{P}$ (period derivative), T (age), and L_{400} (luminosity at 400 MHz) (Manchester and Taylor 1981). Values of $\nu_{max}, \alpha_2, \alpha_3$ are given in table 1 and the ν_c values can be found in table 1 of the previous paper (Malov and Malofeev 1992).

Spectral indices α_2 and α_3

All attempts to obtain a relationship with parameters P, $\dot{P}$, T, L_{400} and impact parameter χ (Malov and Malofeev 1992) have been unsuccessful for both groups of pulsars, but there is mutual correlation (figure 2).

The frequency ν_{max}

The relationship between ν_{max} and P (Malofeev and Malov 1980) is confirmed for the first group of pulsars (figure 3) but not for the second group (figure 4). We obtained a new correlation between ν_{max} and both the age T (not shown) and the radio luminosity at 400 MHz (figure 5). For the second group the ν_{max} values are shown by circles. These correlations must be checked because both parameters T and L_{400} retain an implicit dependence on P. The correlation coefficients are 0.4 for both parameters. No correlation was found between ν_{max} and $\dot{P}$.

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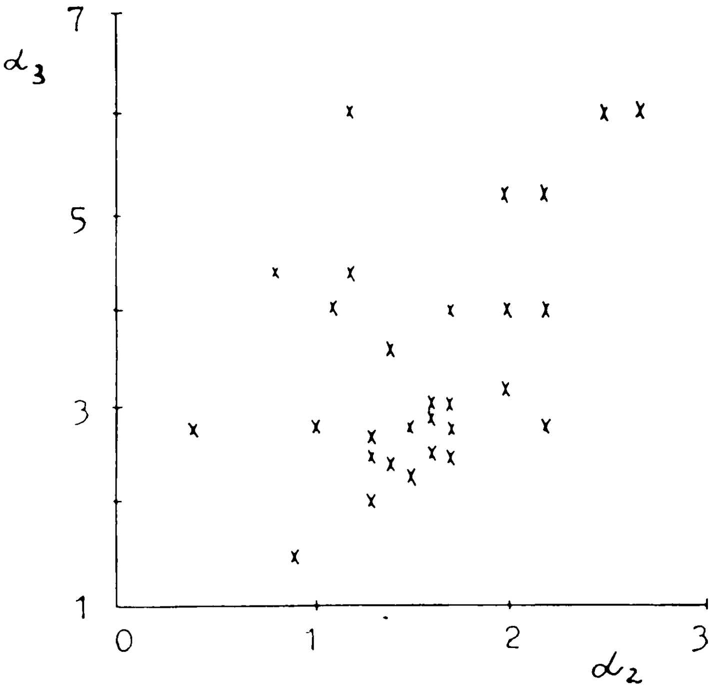

Figure 2

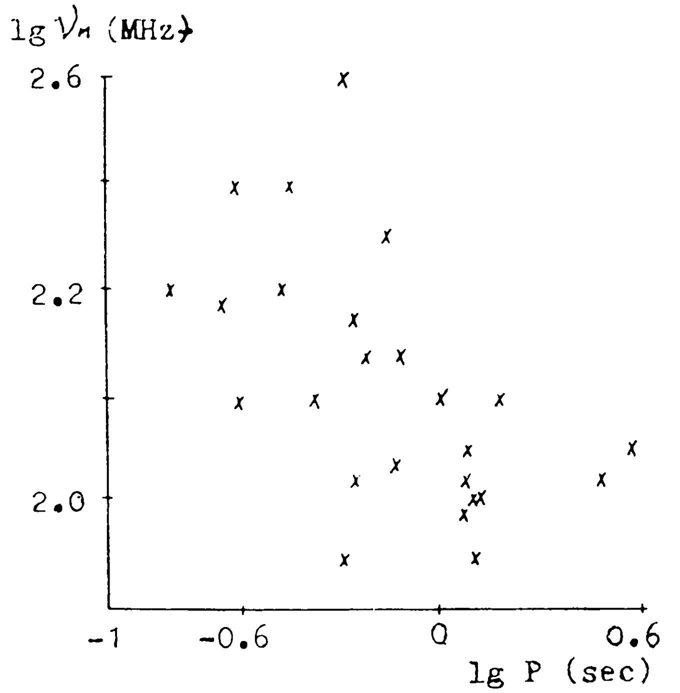

Figure 3

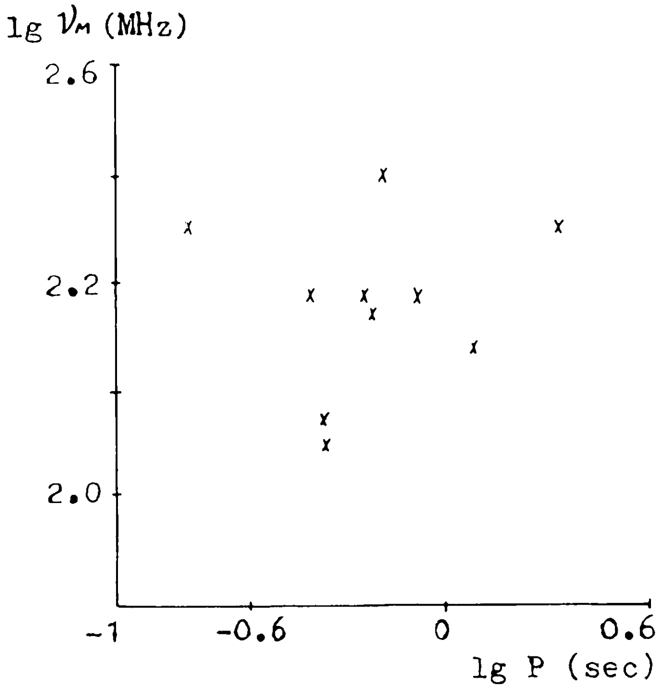

Figure 4

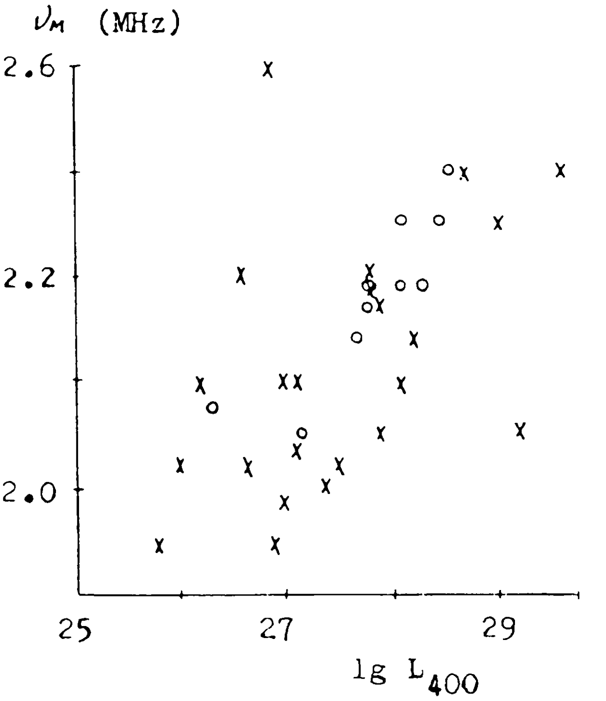

Figure 5

The frequency ν_c

The relationship between ν_c and P (Malofeev and Malov 1980) is confirmed. Figure 6 demonstrates this dependence for 31 pulsars.

We obtain significant a correlation between ν_c and the impact parameter χ (Malov and Malofeev 1992), but we do not find a correlation between the value ν_c and either $\dot{P}$, T, or L_{400}.

Comparison of the two groups of pulsars

The distributions and mean values of 12 parameters have been obtained for the two groups. For 7 parameters P, $\dot{P}$, T, L_{400}, B_0, ν_{max}, and Q (Beskin, Gurevich, and Istomin 1988b) the respective mean values are similar, but there is a difference in the values of $\overline{\alpha}_2$ (1.6 ± 0.1 for 31 pulsars and 2.1 for 11

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Table 1

PSR	ν_{max} (MHz)	α_2	α_3	ν_{BM} (GHz)	$\log B$ ν_{BM}	$\log B$ ν_c
0031−07	70	1.7	3	0.4	6.8	7.6
0320+39	70	1	3*			
0329+54	200	2	4	0.4	7.1	7.5
0355+54	160	0.9	1.5	0.4	7.8	
0525+21	80	1.4	3.6	0.4	7.7	9.1
0540+23	250	1.1	4	0.4	7.6	8.9
0628−28	80	1.6	2.9	0.4	7.4	7.9
0809+74	50	1.6	2.5	0.3	7.9	7.5
0823+26	50	1.3	2	0.2	8.1	9.9
0834+06	65	2.2	5			
0950+08	100	2.2	2.8	0.4	11	11
1133+16	60	1.5	2.3	0.2	8.1	8.7
1426−66		1.3	2.5	0.3	8.2	8.4
1508+55	75	2.2	4			
1612+07	-	1.7	4			
1857−26	120	1.7	2.5	0.3	7.8	8.1
1859+03		2.4	6*	0.4	7.7	8.4
1919+21	65	2.7	6*			
1929+10	150	1.4	2.4	0.4	7	7.6
1933+16	150	2	5.2	0.6	7.1	6.9
1944+17	95*	1.2	6	0.3	8.5	8.4
1952+29		1.3	2.5	0.4	4.4	5.2
2016+28	140	1.7	2.7	0.4	7.4	7.5
2021+51	400	1.6	3	1.7	8.1	8.6
2045−16		0.4	2.8	0.1	7	8.3
2111+46	95*	1.5	2.8			
2154+40	95*	1.3	2.7	0.2	8	8.3
2224+65		0.8	4.4			
2310+42	160*	1.7	4			
2324+60		2	3.2	0.6	9.8	10
2327−20		1.2	4.4	0.3	8.5	9.3
Second Group.						
0740−28	200*	1.8		0.4	9.9	
0818−13	120	2.4		0.4	9	
0919+06	80	1.8		0.4	7.5	
1604−00	90	1.6		0.4	9.9	
1642−03	150*	2.7		0.4	6.8	
1749−28	150*	2.9		0.4	7.1	
1818−04	140*	2.5		0.4	10.2	
1845−01	250*	1.9		1	9.4	
1911−04	150*	2.5		0.4	9.1	
2044+15		1.6		0.4	8.7	
2319+60	200*	1.7		0.6	8	

*Estimates

pulsars), and $\overline{\chi}$ (0.69 ± 0.04 and 0.8 ± 0.07). The first group consists of half S_d and D-type pulsars (Rankin 1990) and half T, S_t, or M type. The other group contains 72% S_t, or T type pulsars. We calculated the values of the magnetic field corresponding to the two frequencies ν_c and ν_{BM} (table 1) in the pulsar magnetosphere for the case of a dipole field. Here the frequency ν_{BM} lies before the maximum of the spectrum at the beginning of a steep section. We used the published profile widths W_{10} and the known formula

$$r = \sin^2\theta(Pc/2\pi), \qquad (1)$$

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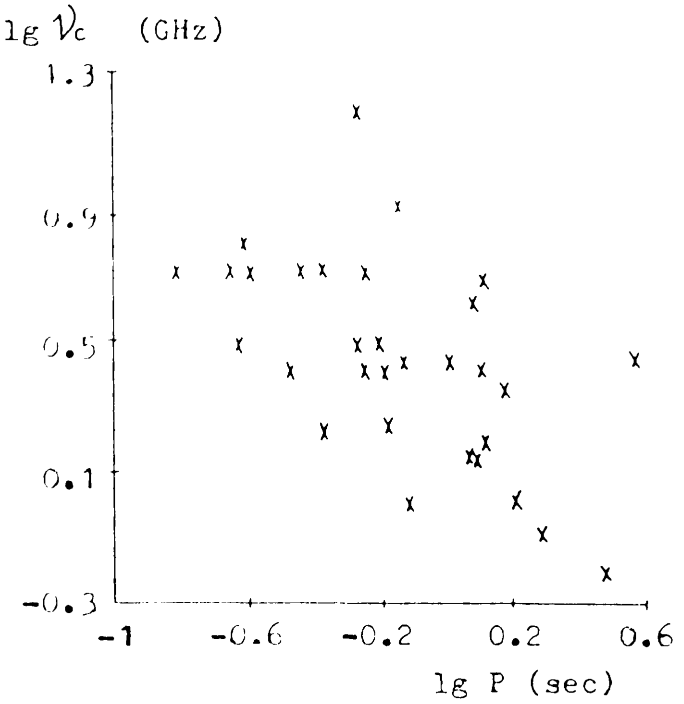

Figure 6

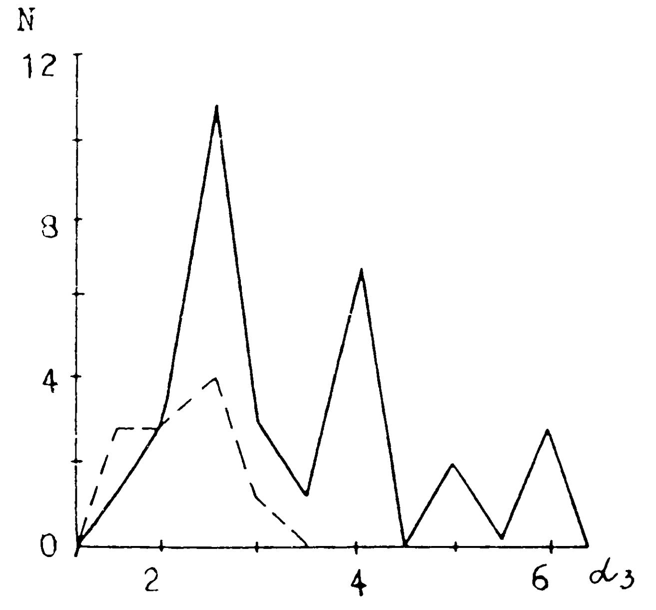

Figure 7

where θ is the opening angle between the magnetic axis and the field line tangent,

$$\theta = (W_{10} \sin \beta)/3 \sin(\arccos \chi). \qquad (2)$$

We take into account not only the angle between the rotation and magnetic axes, β (Malov 1986, Rankin 1990), but also the impact parameter χ (Malov and Malofeev 1992). The value of the magnetic field is

$$B = B_0(r/r_*)^{-3} \qquad (3)$$

where $r_* = 10^6$ cm is the radius of neutron star. The mean emission radius at ν_{BM} is $34 \pm 8\ r_*$ for the first group and $21 \pm 5\ r_*$ for the second group. It is interesting, that this value is equal to $21 \pm 3\ r_*$ at ν_c for the first group. We have the same situation for the mean magnetic field: $\overline{B} = 7.8 \pm 0.3$ and 8.7 ± 0.3 at ν_{BM}, respectively, and $\overline{B} = 8.4 \pm 0.3$ at ν_c.

Conclusion

We can conclude that the emission radius and value of the magnetic field for the second group of pulsars at ν_{BM} coincide with the same values of the first group at ν_c. In the second group we observe pulsars which have a HFC in their spectrum, but it is very difficult to detect because the HFCs are located very close to the maxima of the spectra. In this group are pulsars with broad maxima and large spectral indices, $\alpha_2 \geq 2.5$ (PSR 0818−13, 1642−03, 1911−04). It is clear why we do not see the correlation between ν_{max} and P (figure 4). The distribution of spectral indices of this group (the dotted line in figure 7) shows a good correlation with the first maximum in the distribution of α_3. This conclusion is confirmed by a number of pulsars, which have a short section with spectral index α_2 and small values of α_3 in their spectra [PSR 0320+32, 0450−18, 2045−16, 1133+16 (figure 8)].

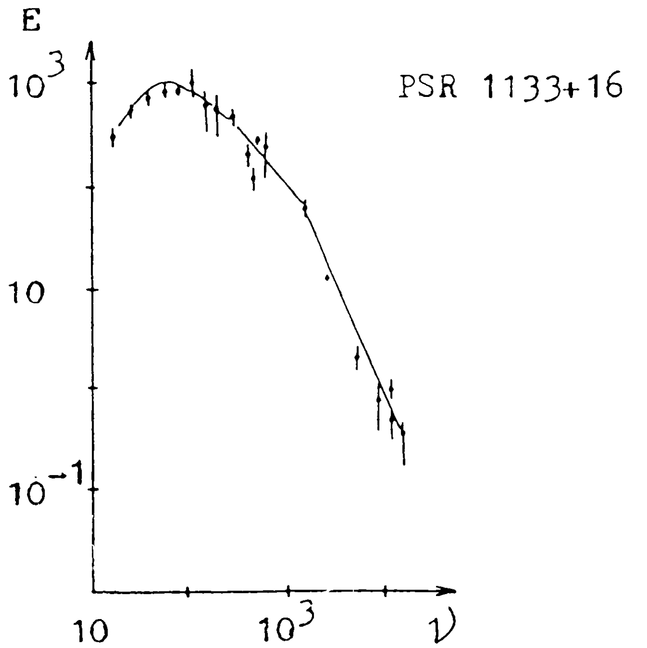

Figure 8

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