CAUSAL RELATIONSHIP BETWEEN DRIFTING SUBPULSE PARAMETERS AND SOME PULSAR QUANTITIES

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Abstract

Correlation analysis of subpulse spacing P_2, subpulse bands P_3, subpulse drift rate with some quantities such as pulsar period P, profile width W_e, characteristic age τ and others indicates some new casual dependencies not previously confirmed. Relations obtained in this paper possibly point out that interaction between pulsar radio emission and the interstellar environment may exert some influence on the drift appearance.

Introduction

The drifting subpulse phenomenon was observed for the first time by Drake and Craft (1968). Numerous attempts have been made to understand the nature of the drifting subpulses that would be important for further development of pulsar theories. The purpose of this paper is to carry out a statistical analysis of parameters of pulsars which show a regular subpulse drift. Drift appearance is called regular if the P_2 and P_3 periods of drift may be measured and kept constant during certain intervals of time. (P_2 is the periodic subpulse spacing; the P_3 period is the spacing between the successive bands). A similar search of P_3 period correlations was carried out for a sample of 17 pulsars discussed by Wolszczan (1980). Only 8 pulsars from this sample showed regular drift.

Analysis

Nowadays more pulsars with regular drift have been recognized. I analyzed three samples: "L", "S" and "P", put together from published data.

The "L" sample included drift parameters of 18 pulsars with regular drift. Drift parameters of this sample were chosen for the general mode of pulsar emission. The "S" sample included 19 pulsars: 18 from the "L" sample plus PSR 0611+22 whose drift is not particularly stable. However the P_3 period of this pulsar has a maximum value, and its drift rate has a minimum value as compared with the drift parameters of other pulsars, which permits us to extend correlations on other scales. The "P" sample included 37 values of drift parameters for all the modes of radio emission of the 19 pulsars of "S" sample (*cf.* table 1).

P_2 values for most pulsars are constant for different modes, so statistical analyses of P_2 periods were carried out only for the "L" and "S" samples. Correlations of P_3 periods were calculated for all three samples.

At first it was interesting to consider the earlier known strong dependencies between the P_3 periods of pulsars with their magnetic fields, [$B \propto (P\dot{P})^{1/2}$] and characteristic ages [$\tau \propto P/\dot{P}$] (Wolszczan 1980). In three samples significant correlations were not found (example of figure 1). The formal difference between my results and previous work results from using a different sample population of pulsars. Probably some pulsars belonging to Wolszczan's sample are not associated with the drifting subpulse phenomenon.

For finding the statistically significant dependencies between drift parameters and different quantities of pulsars, I calculated a correlation matrix of logarithmic values of all parameters from table 1. STATGRAFIC's software package was used for the calculations. More significant correlations were found between the P_2 periods and the profile width, W_e (figure 2).

The correlation coefficient was $R = 0.82$ with a logarithmic regression slope having a range of values $0.63 < \alpha < 0.80$ for "L" and "S" samples. The known relationship W_e–P had a poorer correlation ($R = 0.52$) for the same samples. The last relationship permits us to find the numbers of subpulses, n, inside the emission window. Assuming $n = W_e/P_2$ we get $n \propto W_e^{0.25\pm0.1}$, and the number of subpulses is not more than 4 for all pulsars with regular drift.

P_3 did not show any significant correlations with the internal parameters of any sample, but demonstrated surprise correlations with external pulsar parameters. The P_3 periods showed dependence on the distance of the galactic plane and the mean value of the magnetic field averaged along the line of sight

$$P_3 \propto Z^{-0.4\pm0.03}\ (RM/DM)^{-0.27\pm0.12},$$

$$0.52 < R < 0.66$$

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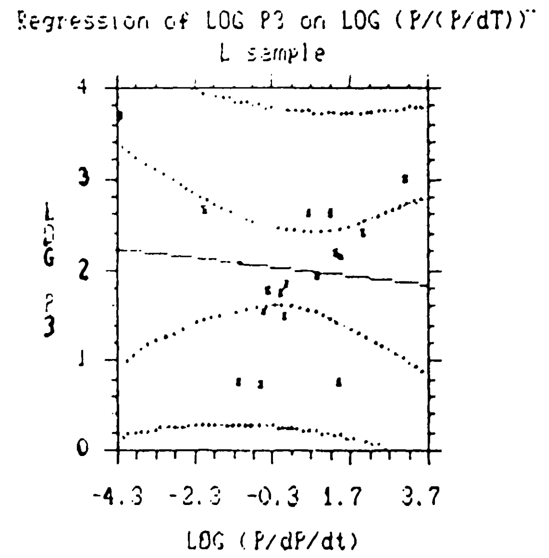

Figure 1 P_3 periods *vs.* characteristic ages of pulsars.

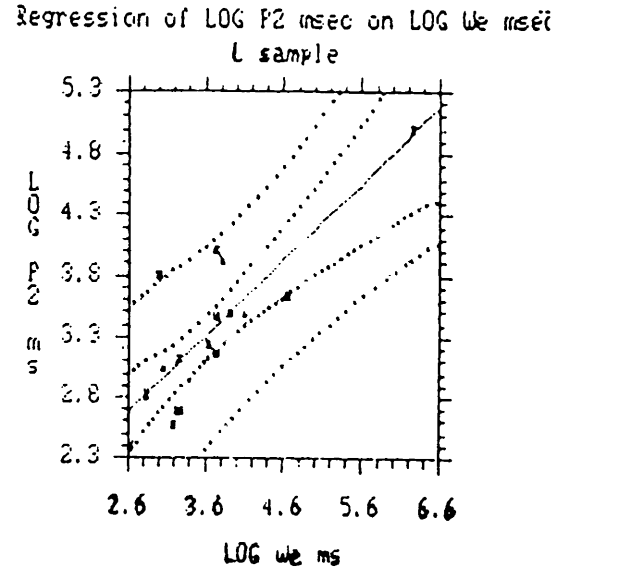

Figure 2 Correlations between the P_2 periods and profile width W_e.

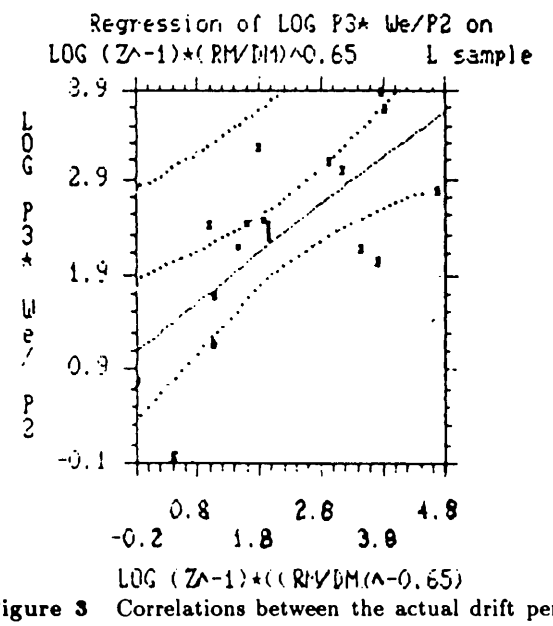

Figure 3 Correlations between the actual drift periods and external parameters of pulsars.

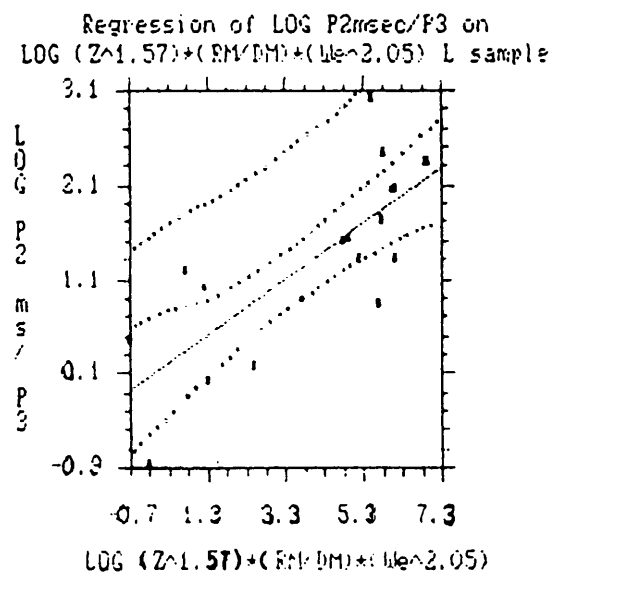

Figure 4 Correlations between drift rate and some parameters of pulsars.

It is more interesting to analyze the relationship of real drift periods $\hat{P}_3 = P_3 n$. Using $n = W_e/P_2$ we get $\hat{P}_3 = P_3 W_e/P_2$. Results of the correlation analysis for $\hat{P}_3$ values confirm the same picture for P_3 periods but with higher correlation. This was to be expected.

$$\hat{P}_3 \propto Z^{-0.5\pm0.1} (RM/DM)^{0.5\pm0.23},$$

$$0.60 < R < 0.71.$$

An example of one of the dependencies discussed is given in figure 3.

As long as the value of W_e does not too exactly reflect the real width of the emission window it was interesting to calculate the dependence between P_3/P_2 and the variable W_e, Z, and RM/DM. Note that the inverse value of P_3/P_2 is determined as a drift rate.

The final statistical analysis of the different pulsar parameters gave the next result (figure 4)

The "L" sample for

$$P_2/P_3 \propto W_e^{0.61} Z^{0.47} (RM/DM)^{0.3},$$

$$R = 0.77,$$

T value = 4.78 and probability level = 2×10^{-4}.

The "S" sample for

$$P_2/P_3 \propto W_e (Z\, RM/DM)^{0.42},$$

$$R = 0.71,$$

T value = 4.2 and probability level = 6×10^{-4}.

Table 1

N	PSR	P (sec)	P_2 (°)	P_3 (P)	W_e (ms)	$\dot{P}$ (10^{-15}) s/s	DM (pc cm^{-3})	RM (rad/m)	R (kpc)	Z (kpc)	ref
1	0031−07	0.943	21.0	7.0	42	0.41	10.89	9.8	0.39	0.37	1
2	0148−06	1.465	8.0	13.9	60	0.45	25.10	2.0	0.97	0.88	2
3	0301+19	1.388	6.2	6.4	42	1.30	15.69	8.3	0.56	0.31	1
4	0320+39	3.032	3.8	8.5	42	0.71	25.80	58.0	0.89	0.22	3
5	0809+71	1.292	14.0	11.0	45	0.17	5.76	11.7	0.17	0.09	1
6	0818−13	1.238	3.8	4.7	24	2.11	41.00	1.2	1.50	0.32	4
7	0826−34	1.849	29.0	14.0	520	1.00	47.30	59.0	0.45	0.02	5
8	0943+10	1.098	8.4	2.2	38	3.53	15.35	13.3	0.56	0.38	6
9	1112+50	1.656	3.2	6.0	27	2.49	9.16	3.2	0.32	0.28	7
10	1632+24	0.491	33.1	2.2	20	0.12	23.80	31.0	0.88	0.56	8
11	1822−09	0.769	8.0	40.0	17	52.32	19.90	65.0	0.51	0.01	9
12	1845−01	0.659	12.4	14.2	26	5.20	159.10	580.0	3.70	0.003	8
13	1918+19	0.821	14.5	5.8	50	0.90	154.40	160.0	5.00	0.23	8
14	1919+21	1.337	4.0	4.5	25	1.35	12.43	16.5	0.33	0.02	1
15	1944+17	0.441	17.0	20.0	21	0.02	16.30	28.0	0.43	0.03	1
16	2016+28	0.558	7.0	9.0	14	0.15	14.90	34.6	1.30	0.09	1
17	2303+30	1.576	3.8	2.1	17	2.90	49.90	84.0	1.90	0.86	1
18	2319+60	2.256	6.0	8.0	105	7.04	93.80	230.0	2.80	0.03	10
19	0611+22	0.335	2.0	75.0	8	59.63	96.70	67.0	3.30	0.13	11
20	1112+50		1.4								
21	1112+50		6.1								
22	1822−09		6.0	11.0							
23	0031−07			13.0							
24	0031−07			4.0							
25	0148−06			26.7							
26	0943+10			2.5							
27	0943+10			1.9							
28	0826−34			19.0							
29	1918+19			3.9							
30	1918+19			2.5							
31	2016+28			15.0							
32	2016+28			3.0							
33	2303+30			2.4							
34	2303+30			1.8							
35	2319+60			4.0							
36	2319+60			3.0							
37	0611+22			100.0							

Title of column: 1–pulsar number; 2–pulsar name; 3–basic period; 4–P_2 period; 5–P_3 period; 6–W_e, equivalent width, the full width at half intensity; 7–dP/dt, period derivative; 8–DM, dispersion measure; 9–RM, rotation measure; 10–R, distance to pulsars; 11–Z, height above the galactic plane; 12–references: 1) Manchester and Taylor 1977; 2) Biggs *et al.* 1985; 3) Izvekova *et al.* 1982; 4) Biggs *et al.* 1987; 5) Biggs *et al.* 1985a; 6) Sieber and Oster 1975; 7) Wright, Sieber and Wolszczan 1986; 8) Hankins and Wolszczan 1987; 9) Fowler *et al.* 1980; 10) Wright and Fowler 1981; 11) Ferguson and Boriakoff 1980.

The "P" sample for

$$P_2/P_3 \propto W_e^{1.2}(Z\,RM/DM)^{0.66},$$

$$R = 0.74,$$

T value = 6.52 and probability level = 2×10^{-7}.

The relations obtained in this paper are unusual and it is difficult to explain in the frames of known theoretical models. It is possible that the interaction of the pulsar radio beam with the interstellar medium exerts some influence on the drift parameters.