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A Decade of Low Frequency Pulsar Polarimetry at PRAO: a Review of the Main Results

Svetlana A. Suleymanova, V.D. Pugachev

Pushchino Radio Astronomy Observatory of P.N.Lebedev Physics Institute, 142292, Pushchino, Russia

Abstract. The main results of the linear polarization measurements of pulsars done at the lowest radio frequencies 40, 60 and 103 MHz are summarized in this paper. We have analyzed 35 integrated polarization profiles and 20 statistical distribution displays and compared them with published high frequency results.

1. Introduction

Expansion of the polarization measurements toward the lower frequencies can help to better understanding the mechanism of pulsar radiation. The rich information on pulsar emission polarization is available for analysis at the frequencies above 400 MHz. Much less is known about even what is factually done at lower frequencies, near and below 100 MHz. The measurements were carried out at the most sensitive to meter wavelengths telescopes - BSA and DKR-1000 using special technique. The ultimate goal of this digest of low frequency measurements at PRAO is to draw reader's attention to our results which are unfortunately poorly known to pulsar people.

2. Observational results

2.1. Integrated pulse linear polarization

We shall begin with the examples of integrated polarization profiles for the pulsar B0329+54 which are given on Figure 1. Pulsars in the Table 1 are presented by observational frequencies, Faraday's intensity modulation bandwidth, integrated pulse linear polarization and estimated depolarization index above critical frequency (for marked (∗) depolarization indexes there are no counterparts in papers (Manchester R.N. 1973; Morris et al. 1981)).The technique of measurements and polarization profiles are published in (Suleymanova 1992). The comparison of our data with polarization catalogs at higher frequencies show that statistically averaged linear polarization of pulsar's radiation keeps continuous increasing down to 40 MHz . For individual pulsars a half of a number we studied show similar continuous spectral behaviour of linear polarization, i.e. have single depolarization index over whole frequency range; less number of pulsars (30%) show a change in depolarization index near some critical frequency. In these cases the dependence of Plin of integrated pulses can be described in terms of two power-laws for frequency ranges above and below Fcrit. For two pulsars

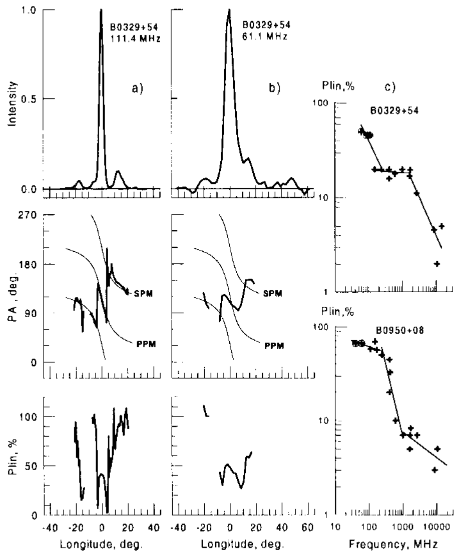

Figure 1. Integrated profiles of PSR B0329+54. a) - first measurement at a new frequency 111.4 MHz after upgrading of BSA array in 1999. b) - polarization integrated profiles at a lowest frequency 61.1 MHz ever published for given pulsar. Sampling intervals 1.0 and 4.1 mc, total bandwidth 32X20 kHz and 32X5 kHz, TC 1 and 5 mc correspondingly. Superposed three curves correspond to primary and secondary polarization modes in the rotating vector model with $\alpha = 51^0$ and $\beta = -4^0$ (Gil & Lyne 1995) c) - frequency dependence of the integrated degree of linear polarization for B0329+54 and B0950+08 which need three power-law fit.

depolarization index is not estimated because of large scatter of data at high frequencies. A new result we want to present is that in the case of B0329+54 at 103 MHz we were forced to introduce a third power-law fit below 240 MHz when we have found a substantial increase of Plin in a factor of two(Plin $= 46 \pm 3\%$ at 103 MHz) as compared with polarization of about 20% in 150-1720 MHz range (Suleymanova & Pugachev 1998). Another pulsar with the three power law fit of the spectral behaviour of Plin is PSR B0950+08 (Fig.1c).

One of the most intriguing property of pulsar emission is that the adjacent components in the integrated pulses frequently show distinct polarization properties combined with different energy spectra (individualism of the components). The bright examples supporting this conclusion are double profiles of two pulsars B1822-09 and B2224+65 . They include one component with ordinary (negative) depolarization index and another highly polarized component having no changes of Plin on frequency. For each pulsar completely linearly polarized component disappear at low frequencies. This circumstance should be taken into account in studies the relationships between depolarization indexes, critical frequency and some general characteristics of pulsars: rotation period, period derivative and the parameters of the star, derived from former two ones. The question arises, is polarization properties in adjacent components of the pulse profile determined by some particular local conditions in magnetosphere above emitting region?. On the other hand, if this difference in polarization is

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connected with different altitudes of emitting regions, then how this idea coordinates with radius-frequency mapping model?

Table 1. Polarization characteristics

PSR B	F_{obs}, MHz	Faraday BW, MHz	P_{lin}, %	α	F_{crit}, MHz
0031-07	103	1.84	37±7	-0.6*	-
	61	0.37	44±6		
0138+59	103	0.40	25±5	-0.3*	400
0320+39	103	0.28	38±2	?	?
0329+54	111	0.38	46±3	-0.8	< 240
	103	0.31	46±3	-0.8	> 1500
	87	0.18	46±6		
	61	0.06	50±6		
0450+55	103	2.56	55±4	?	?
0628-28	103	0.40	69±7	-1.2	1000
	61	0.09	64±6		
	40	0.025	44±4		
0823+26	61	0.70	24±4	-0.3	400
0834+06	103	0.77	25±3	-1.0	200
	60	0.16	25±5		
	41	0.045	27±5		
0919+06	103	0.42	41±4	-0.1*	-
	61	0.12	38±3		
0943+10	103	1.20	40±5	-0.2*	-
	60	0.28	33±5		
	41	0.075	40±5		
0950+08	61	1:84	67±9	-1.5	>240
	39	0.48	67±6	-0.3	>1000
1133+16	60	0.82	28±2	-0.6	400
	40	0.27	27±2		
1541+09	103	1.06	35±3	-0.5*	-
1642-03	103	1.20	30±8	-0.5	-
1749-28	103	0.19	24±4	-0.8	-
1822-09	103	0.26	53±6	-0.0(1)*	-
				-0.5(2)*	-
1919+21	59	0.21	14±3	-0.6	300
2016+28	103	0.55	23±3	-0.5	-
2020+28	103	0.27	61±3	-0.3	-
2154+40	103	0.48	40±6	-0.2*	-
2217+47	103	0.52	28±3	-0.3	-
2224+65	103	0.76	56±3	-1.1(1)	-
				-0.0(2)	-

2.2. Single pulse linear polarization

Single pulse properties known from observations at high frequencies which are observed at low frequencies as well. a) The asymmetry in orthogonal polarization modes (OPR) distribution on longitude is frequent. Note that individual and integrated pulse polarization properties as well as the polarization and the strength of micropulses (Cordes & Hankins 1977) are strongly dependent on pulse longitude. The nature of such strong asymmetry in axi-symmetrical hollow cone of pulsar beam is still unclear.

b) The lower linear polarization is observed for longitudes at which OPR is clearly visible. The correlation is clearly observed in the majority of the pulsars we have studied at low frequencies.

c) Two orthogonal polarization modes intensity ratio depends on total intensity. The preference for polarization mode transitions to occur on boundaries of strong subpulses suggests that low-intensity regions have different polariza-

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tion states than high-intensity regions. If the intensity is below some threshold value transition preferably occur between two subpulses. The feature is again present at micropulse level (Cordes & Hankins 1977).

Single pulse polarization properties found at low frequencies a) Enhancement of the Secondary Polarization Mode (SPM) in the pulsar emission at low frequencies. Pulsars are proposed to be depolarized primarily through increased modality at high frequencies. Hence, one can expect higher linear polarization of integrated pulses to be caused by decreased modality at a frequencies below 100 MHz. Our measurements show that orthogonal polarization modes is wide spread feature in pulsar emission even at lowest frequencies.All pulsars studied (except B0628-28) show OPR at least in one component of the integrated profile. The similarities of the polarization distributions allow to identify the primary (PPM) and secondary (SPM) polarization modes at widely separated frequencies and to study the evolution on frequency of their energy ratio. We have found that of the six pulsars for which we had comparable displays at higher frequencies, three (B0329+54, B1133+16 and B2020+28) evidently show the increased fraction of the secondary polarization mode in the emission at low frequencies. We propose at least two different mechanisms producing orthogonal modes having different efficiency at different frequencies (Malov et al 1997).

b) Temporal variations in intensity ratio of two orthogonal modes. PSR B0943+10 is a mode switcher. An integrated pulse polarization in both modes show significant day-to-day variations , depending on the ratio of intensities in two orthogonal polarization modes. Note that PSR B0943+10 (in contrary to B0329+54) show significant changes in intensity of two polarization modes both in time and during a mode switch. What is the parameters in pulsar magnetosphere that determine the different OPR stability factor for different pulsars?

c) Subpulse polarization properties are poorly correlated with drift parameters. A relationship between subpulse drifting phenomenon and OPR was investigated. For pulsars B0031-07 and B0320+39 independently on the drift direction and rate, a deep minimum in Plin profile is evident for the first component of double shaped integrated profile. Depolarization is caused by gradual enhancement of SPM toward the earlier longitudes in both pulsars.

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