OBSERVATION OF THE LINEAR POLARIZATION OF PULSAR INTEGRATED PULSES AND SUB-PULSES AT METER WAVELENGTHS

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Abstract

A brief review of polarization observations at 103, 60, and 40 MHz is given. Our peculiar measurement technique allows us to obtain average polarization profiles as well as statistical distributions of the polarization parameters of individual pulses and subpulses. Some examples are given in this paper.

Measurement technique

Since the early 1980's meter-wavelength polarization measurements of pulsars have been carried out using the large BSA (103 MHz) and DKR-1000 (60, 40 MHz) telescopes. Since the telescopes are linearly polarized antennas, a special technique is used, based on the Faraday rotation of the linear polarization plane in the magnetized interstellar plasma. Faraday rotation produces a frequency-dependent *quasi*-sinusoidal intensity modulation at the output of a multichannel radiometer. For observations at 103 MHz we usually used a radiometer with 64 × 20-kHz contiguous channels. At 60 and 40 MHz a radiometer with 32 × 5-kHz channels with a total bandwidth 160 kHz was used.

Every sample in pulse longitude has its own phase and amplitude within the overall sinusoidal spectrum. These spectra were fitted to the equation

$$a_k^i = a^i \sin(2\pi/\Delta F f_k + \psi^i) + b^i ,$$

where i is the longitude of the sample, f the frequency of the k^{th}-channel, a^i, ψ^i, and b^i the parameters which define the polarization characteristics—that is, $P_{\text{lin}} = a^i/b^i[\%]$, and the position angle $PA = \psi^i$. The period of the Faraday modulation $-\Delta F = 17.48 f_c^3/RM$ (RM is the rotation measure for a given pulsar) was calculated for the central frequency of the radiometer and fixed for all samples along the pulse. As the time resolution was typically several milliseconds, we obtained well defined profiles in total intensity, fractional linear polarization and position angle for average profiles and for individual pulses (subpulses).

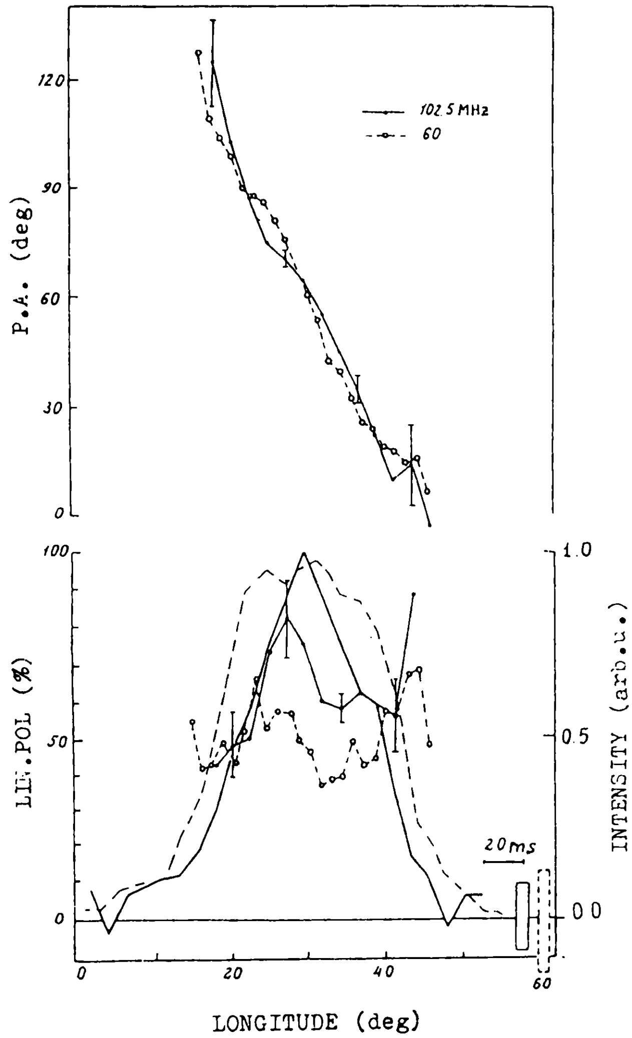

Figure 1 Average polarization profiles for PSR 0628−28 at 102.5 (solid lines) and 60 MHz (dashed lines); the rms baseline noise and the sample intervals are shown by the resolution boxes.

Average profile polarization

The average profile for a given pulsar is the result of averaging hundreds of individual pulses synchronously with the pulsar period. The polarization characteristics of the average profile were measured for 18 pulsars at 103 MHz and for 9 pulsars at 60 and/or 40 MHz. These results were published recently by Suleymanova (1989).

The profiles for PSR 0628−28 in figure 1 illustrate the fact that measurements made at different frequencies, using different antennas and radiome-

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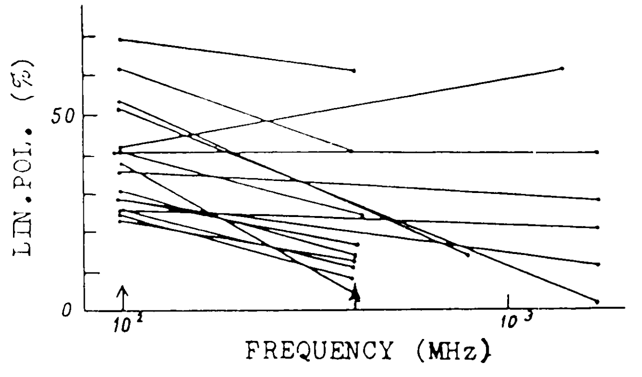

Figure 2 Frequency dependence of the linear polarization of the average profile for 18 pulsars between 100 MHz and 400 MHz (schematically). Observations at higher frequencies were used when data at 400 MHz were unavailable.

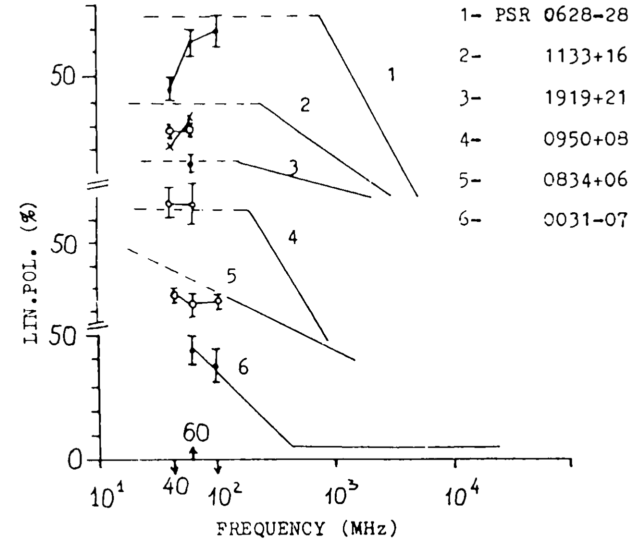

Figure 3 Linear polarization data for the strongest pulsars at 103, 60 and 40 MHz. Percentage behavior at higher frequencies is shown schematically. Dashed lines show the behavior predicted by Manchester *et al.* (1973). For PSR 1133+16 simultaneous observations are indicated by an "x".

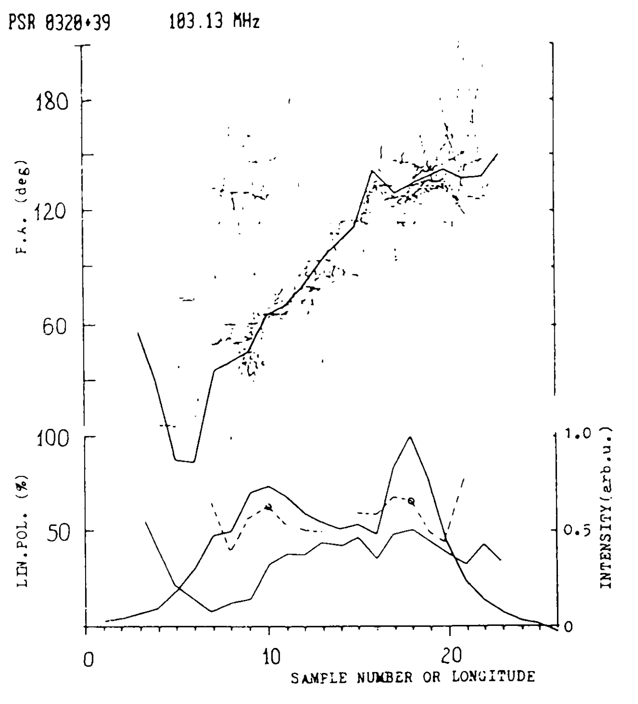

Figure 4 Average polarization profiles of PSR 0320+39 at 103 MHz. Statistical distributions of the position angle for individual pulses and the mean linear polarization profile for subpulses in the first and second components (dashed lines) are shown. The sample interval is 5.184 ms.

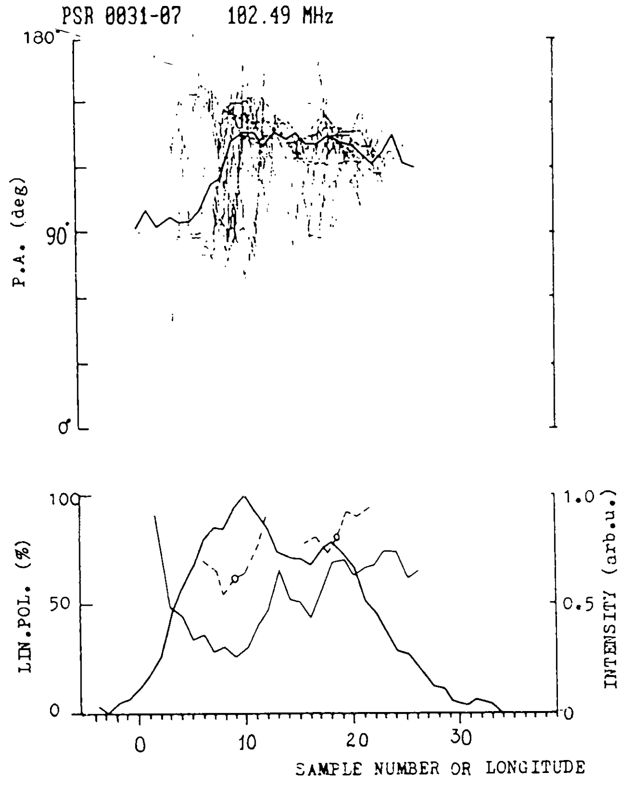

Figure 5 PSR 0031−07 (see figure 4). The sample interval is 5.184 ms.

ters, yield very similar results. This similarity supports the validity of our measurement technique.

It is of great interest to know how the fractional linear polarization P_{lin} of profiles behaves at low frequencies. Observational results are as follows:

1. The linear polarization at 103 MHz is generally higher than at 400 MHz (see figure 2).

2. Below 103 MHz (see figure 3) P_{lin} can increase (as for PSR 0031−07) or be constant as was predicted earlier (Manchester, Taylor, and Huguenin 1973) for pulsars 0950+08 and 1919+21.

3. Additionally, two pulsars, PSR 0628−28 and PSR 1133+16, show polarization "turn-off" at low frequencies. Such a "turn-off" is confirmed by observations of PSR 1133+16 simultaneously at 60 and 40 MHz.

This results in a decrease of P_{lin} in the second, more intensive component of the pulsar below 100 MHz. The statistical distribution of the *PA* for individual pulsars shows that *quasi*-orthogonally polarized radiation spans both compo-

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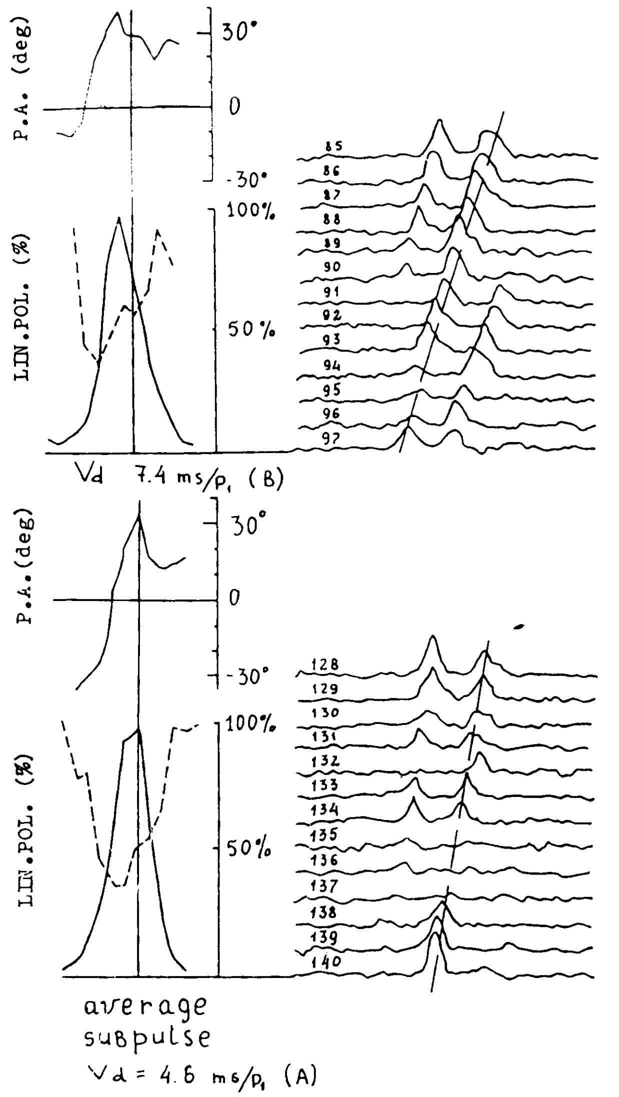

Figure 6 Two sets of consecutive pulses of PSR 0031−07 at 103 MHz, drifting with different rates B and A. When averaged along a drift band they form very similar average subpulse polarization profiles.

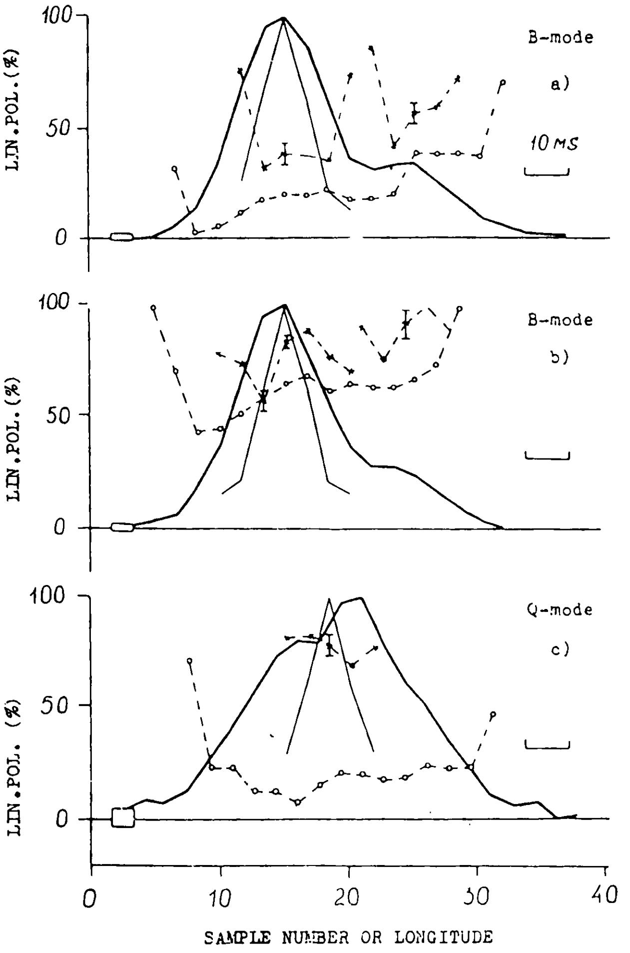

Figure 7 Three 200-pulse averages of PSR 0943+10 together with P_{lin} profiles (–o–). Subpulse polarization profiles were measured and then averaged after combination subpulse maxima (–*–).

nents of PSR 1133+16, while at higher frequencies it occurs only in component one.

Drifting subpulse polarization

Pulsars 0031−07 and 0320+39 are known to exhibit very regular subpulse drift behavior. While the subpulses of PSR 0320+39 drift "abnormally" from the leading to the trailing edge of the average profile, the subpulses of PSR 0031−07 drift in the opposite ("normal") direction. PSR 0031−07 is also known to switch between three harmonically related drift rates A, B and C (Huguenin, Taylor, and Troland 1970). So, we had the possibility of investigating the subpulse polarization behavior as a function of drift rate and direction.

The results are as follows:

1. For both pulsars, independent of the drift direction, a deep minimum of P_{lin} is evident for the first component of the double-shaped average intensity profile. Depolarization is caused by the increasing numbers of *PA* jumps in this longitude region (see figures 4 and 5).

2. For PSR 0031−07 the polarization profiles of the subpulses, averaged along a drift band for drift rates A and B, look very similar (figure 6) and resemble the 403-MHz profiles of Manchester, Taylor, and Huguenin (1975). We can conclude that the polarization properties of subpulses are poorly correlated with their drift parameters.

Time variations in the polarization state of average pulses and subpulses

PSR 0943+10 is known to be a "mode-switcher" (Suleymanova and Izvekova 1984). It has two distinct average profiles: the more intense double-shaped B-mode and the weaker single (or double-

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unresolved?) Q-mode profile. Routine day-to-day observations have shown significant changes in the polarization state for both modes. Variations of the fractional linear polarization of the average profile and subpulses can correlate (as in figure 7a and b) or not (see figure 7c). In the latter case (c), the generally highly polarized subpulses result in depolarization of the average profile due to strong pulse-to-pulse position-angle variations. For case (b) these variations are moderate. This leads us to the conclusion that pulse-to-pulse variations can change drastically with a time scale of days or hours. The character of the statistical distribution of PA (not shown here) confirms this idea.

Another important conclusion from our point of view is that the subpulse polarization can either be sensitive to orthogonally polarized radiation (see (figure 7a and b) or not (figure 7c). The two orthogonally polarized radiation intensities compete inside the subpulse. In case (c) only one polarization mode is present; therefore the polarization of the subpulse is high. Increasing the influence of orthogonally polarized radiation inside the subpulse causes depolarization of the leading part of the subpulse [case (b)] and then depolarization of the whole subpulse. The character of the competition with the observed depolarization, varying from day to day, has yet to be investigated.

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