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The Distribution of Fractional Linear Polarization and the Random Component of Polarization Position Angle

M. M. McKinnon

NRAO, Green Bank, WV, USA

D. R. Stinebring

Oberlin College, Oberlin, OH, USA

1. Introduction

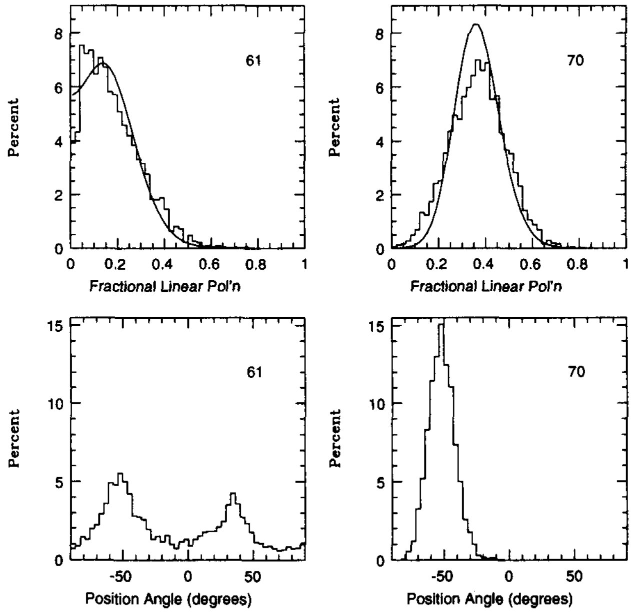
One of the most fascinating features of the polarization of pulsar radio emission is the occurrence of orthogonal modes of polarization. The origin of the modes is not clear, but, whatever their underlying nature, the modes will affect observables such as the instantaneous linear polarization. We derive an idealized distribution of fractional linear polarization assuming that the modes are superposed and compare our result with observations. We discuss how superposed modes may affect the position angle distributions.

2. The Distribution of Fractional Linear Polarization

Consider a subpulse composed of superposed modes of orthogonal polarization. We assume that each mode is completely linearly-polarized with no dispersion in position angle. If the flux densities of the individual modes are represented by the independent random variables X_1 and X_2, then the linear polarization of the subpulse is related to $X = X_1 - X_2$ and its total intensity is $Y = X_1 + X_2$. We denote the means of the mode distributions by μ_1 and μ_2 and their standard deviations by σ_1 and σ_2. The means are generally not the same because observed distributions of position angle (e.g. Stinebring et al. 1984) show that the modes generally do not occur with equal frequency. If the individual modes are normally-distributed with identical standard deviations, X and Y are also normally-distributed, independent random variables. In this ideal case, the distribution of fractional polarization, $Z = |X/Y|$, is

$$f_z(z) = \sqrt{\frac{2}{\pi\sigma^2}}\frac{1}{(z^2+1)^{3/2}}\exp\left[-\frac{\mu_x^2+\mu_y^2z^2}{2\sigma^2(z^2+1)}\right] \times\left\{\mu_y\cosh\left[\frac{\mu_x\mu_y z}{\sigma^2(z^2+1)}\right]+z\mu_x\sinh\left[\frac{\mu_x\mu_y z}{\sigma^2(z^2+1)}\right]\right\}$$

where $\mu_x = \mu_1 - \mu_2$, $\mu_y = \mu_1 + \mu_2$, and $\sigma^2 = 2\sigma_1^2$. The distribution has two free parameters, μ_x/σ and μ_y/σ. Histograms of fractional polarization and position angle measured at two different pulse phase bins of PSR B2020+28 are shown in the figure below. The data were taken from Stinebring et al. Orthogonal modes occur with nearly equal frequency at bin 61, but only one polarization mode is obvious at bin 70. The smooth curves through the histograms of fractional polarization represent the best fits of the model distribution to the data.



3. The Random Component of Polarization Position Angle

The figure and the observations of Stinebring et al. clearly show that a random, or uniform, component in distributions of position angle is only found when orthogonal modes are also present. The uniform component may arise from superposed modes. When $\mu_1 \simeq \mu_2$, a large fraction of subpulses will have very little polarization. The statistics of the polarization may then be dominated by instrumental noise. Since the position angle of noise is distributed uniformly over the interval $0 \leq \psi \leq \pi$, we would expect a uniform component to accompany superposed modes. If orthogonal modes occur more often at high radio frequency, we would also expect an *apparent* increase in the randomization of position angle (Manchester et al. 1975). The observations of Stinebring et al. did not confirm the previous claim (Manchester et al.) that pulsars depolarize by randomization of position angle. Therefore, we find no compelling reason to attribute the uniform component of position angle to the emission mechanism, and suggest that pulsars depolarize by superposed modes.

References

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