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Orthogonal Polarization Modes and Emission Regions of PSR B1133+16

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Abstract. Results from an analysis of polarization data, at three different frequencies, for PSR B1133+16, show a clear systematic phase shift between the mode separated profiles for the two orthogonal modes. It is found that the shift has opposite signs for the two components of the profile. Further, the shift shows a tendency to increase at lower frequencies. The implications of these results for the origin of orthogonal modes and the location of pulsar emission regions are discussed.

In the average polarization properties of many pulsars, the position angle (PA) of the linearly polarized radiation shows a smooth, systematic "S-shaped" variation across the pulse profile, which is interpreted as a signature of the underlying dipolar magnetic field. However, there are several pulsars where the PA curve shows distortions in the form of discontinuous jumps (often $\approx 90°$) at one or more pulse longitudes, due to the presence of orthogonal polarization modes (e.g. Backer & Rankin 1980). It is not clear whether orthogonal polarization states are intrinsic to the pulsar emission mechanism or are an artifact of propagation through the magnetospheric plasma.

Data for PSR B1133+16 taken at three different frequencies – 1410 MHz, 610 MHz and 430 MHz – have been analysed to obtain mode separated total intensity profiles. These data were obtained from the Effelsberg, Jodrell Bank and Arecibo radio telescopes.

The results (Figure 1a) show that the secondary mode is relatively weak for the trailing component of the two component profile and becomes weaker at lower frequencies. There is almost complete absence of the secondary mode in the bridge region between the two components, especially at the lower frequencies. Most importantly, there is a clear phase shift between the primary and secondary mode profiles. It is easily visible for the leading component (at all the three frequencies) but is harder to discern for the trailing component (especially for the 610 and 430 MHz data), due to the weak signal in the secondary mode. Furthermore, the shift is *opposite* for the two components for the profile, i.e. it is roughly symmetric about the centre of the profile. As a result, the overall

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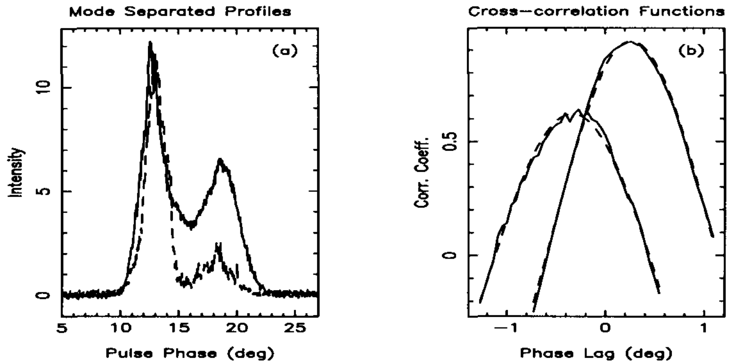

Figure 1. **(a)** Mode separated total intensity profiles for PSR B1133 at 1410 MHz: The solid curve is the primary mode and the dashed curve is the secondary mode. **(b)** Cross-correlations of primary and secondary mode profiles for leading component (curves peaking at positive lags) and for trailing component (curves peaking at negative lags). The dashed curves are the best fit gaussian models

width of the secondary mode profile is less than that of the primary. A cross-correlation analysis (see Figure 1b) esitmates the shifts to be $0.27°$ for the leading component at 1410 MHz ; $-0.34°$ for the trailing component at 1410 MHz ; $0.38°$ for the leading component at 610 MHz. There is no discernible increase in the shift from 610 MHz to 430 MHz. For the 610 MHz and 430 MHz data, the secondary mode is too weak in the trailing component to give any reliable estimates for the shifts there.

Our results can be understood if the emission regions of the orthogonal modes are laterally separated on the polar cap of the pulsar. This is consistent with recent scintillation observations of this pulsar (Gupta, Bhat,& Rao 1999), which suggest that the emission regions for the secondary mode are significantly offset in location from those for the primary mode. Such a separation can be produced due to a difference in emission altitudes of the two modes, while following the same field line. This supports a propagation effect origin for orthogonal modes. Our results support models (e.g. Barnard & Arons 1986) where the magnetospheric plasma produces a frequency dependent separation of the orthogonally polarized X-mode and O-mode waves.

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