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Polarimetric Observations of PSR J0437−4715

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1. Introduction

To date there have been few polarimetric observations of millisecond pulsars, mainly due to the instrumental challenge of simultaneous high time resolution and large bandwidth. Such observations provide our most direct clues to the structure of the magnetic fields around pulsars, and are especially important in the case of millisecond pulsars, where radio emission necessarily originates very close to the neutron star surface.

We have observed the bright millisecond pulsar J0437−4715 at the Parkes Radiotelescope with the Caltech Fast Pulsar Timing Machine, at several radio frequencies and in full polarimetric mode. Our analyses show significant deviations from the standard dipole field geometry.

2. Observations

We observed PSR J0437−4715 (Johnston et al. 1993) with the 64-m radiotelescope at Parkes, Australia, in two sessions in December 1994 and June/July 1995. We used receivers at 436, 661, 1050 and 1448 MHz and recorded the data with the Caltech Fast Pulsar Timing Machine (Navarro 1994). The observations at 436, 661 and 1448 MHz were done with linear feeds, while those at 1050 MHz where in circular polarization. The observing bandwidth was 32 MHz for radio frequencies below 1 GHz and 128 MHz above 1 GHz.

In each case the radio signals were downconverted to baseband in one or more steps and digitized at a rate of 256 MHz with 2-bit resolution. The digital streams were then run through a high speed correlator, producing 128 lags for each of the two auto-correlations and the two cross-correlations. The lag data were subsequently folded at the pulsar period into 1024 phase bins of 5.6 μs each, then converted to the frequency domain by means of Fourier transforms. Stokes parameters were formed for each of the 128 synthesized filterbank channels and were then weighed and dedispersed to a single central frequency using the pulsar parameters of Bell et al. (1995).

Each observation consists of several 90 s scans with interspersed feed rotations and pulsed calibrator scans. Figure 1 shows the Stokes parameters I, V, L and F at all four radio frequencies.

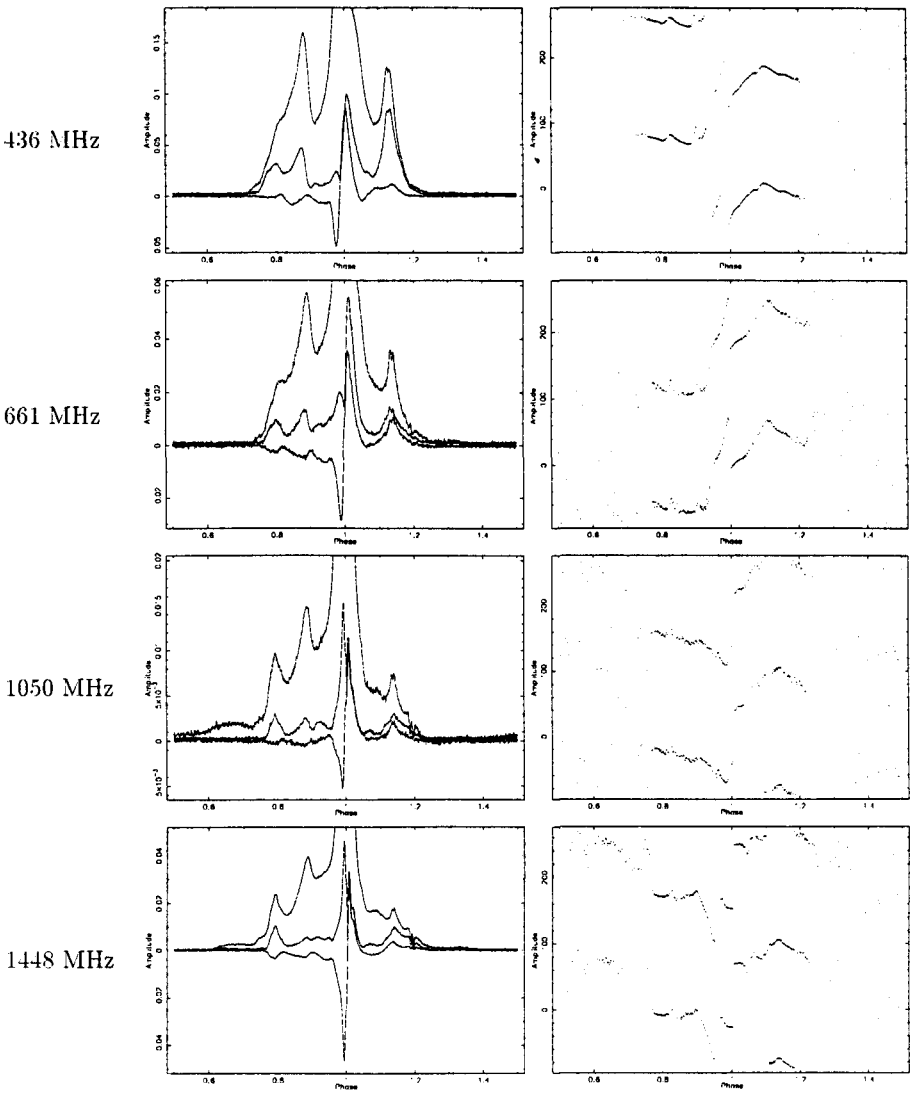

Figure 1. Polarimetric observations of PSR J0437−4715 at four different radio frequencies. The plots on the left show the profiles in Stokes I, L and V with arbritary absolute scales. Stokes I is the upper curve in each plot and is clipped to show the low level emission. In all cases Stokes V is the lowest curve of the three. The plots on the right show the position angle of the linear polarization. The position angle is shown twice in the range $(-90, 270)$ deg to assist the eye.

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3. Discussion

The position angle profile at 436 MHz suggests a rapid swing near the main pulse of more than 180 deg, something which is not possible in the Radhakrishnan & Cooke (1969) rotating vector model if geometrical effects alone are involved. Indeed, the 1448 MHz profile shows the existence of an unresolved 90 deg mode change which must be removed before a geometrical interpretation is possible.

Once the 90 deg mode change is removed from all four position angle profiles it becomes clear that there is no obvious overall position angle swing, unless it is of exactly 180 deg. This observation is contrary to what is stated in the literature (Manchester & Johnston 1995, Gil & Krawczyk 1996) and implies that the line of sight passes directly over a magnetic pole.

Nevertheless, regardless of the overall position angle swing, it is difficult to explain the local features or deviations from a smooth curve. The simplest explanation requires a complicated magnetic field, with strong local deviations from a dipole configuration. Such a contorted field has never been observed before even in millisecond pulsars such as B1937+21 (Thorsett & Stinebring 1990), and requires independent confirmation to be credible. An alternative explanation for the apparent features is that there are frequent 90 deg mode changes and that the integrated profiles in figure 1 are distorted and do not therefore have a geometrical explanation. Such an argument is implausible given the constancy of the integrated position angle profiles, but its refutation or confirmation requires single pulse polarimetry such as in Stinebring et al. (1984). Work to that effect is in progress (see Anderson et al. 1996).

PSR J0437−4715 is an unusual pulsar in that its intensity profile presents many components. Likewise, its position angle profile presents many features that are not be easily explained away with a pure dipole magnetic field model.

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