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Testing the relationship between nulling, drifting and mode-changing

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Abstract. Recent observations, suggesting that subpulse drifting, pulse nulling and profile mode-changes are related phenomena, are reviewed and it is argued that these are associated with global changes in the magnetosphere. Long simultaneous multi-frequency observations are useful to test this premise as is illustrated by the preliminary results from a recent study of PSR B0031−07, B0809+74 and B2319+60. Such observations for a larger sample of pulsars will be useful to constrain recent models, invoking global changes in the pulsar magnetosphere, proposed to explain observations demonstrating association of spin-down changes with profile mode-changes.

Keywords. radiation mechanisms: general, pulsars: general, pulsars : B0031−07, pulsars : B0809+74, pulsars : B2319+60

1. Introduction

A rich diversity is seen in the radio emission in the individual pulses from pulsars. Apart from pulse-to-pulse intensity variations, many pulsars show changes in pulse phase, pulse shapes, pulse widths, number of components in a pulse (subpulses), separation between components and the ratio of intensity in components. In some pulsars, these variations are correlated across several successive individual pulses. Such correlated behaviour is broadly classified in three phenomena. A systematic advancement of subpulse phases with progressively increasing pulse number is called subpulse drifting. PSRs B0809+74 and B0031−07 are two pulsars, which show prominent subpulse drifting, and with different drift modes in the latter pulsar (Lyne & Ashworth 1983; Vivekanand & Joshi 1997). About 100 pulsars, such as B0031−07 and B2319+16, show abrupt cessation of emission for several periods, called pulse nulling (Wright & Fowler 1981; Vivekanand & Joshi 1997). The average profiles of some pulsars, such as B0329+54, switch between two or more stable forms and this is called profile mode-changes (Lyne 1971). While subpulse drifting is believed to be associated with spark discharges in pulsar polar gaps (Ruderman & Sutherland 1975), the mechanism for pulse nulling and mode-changes are not well understood. Although it has been suggested that nulls and profile mode-changes may be geometric in origin, relationship between these phenomena with subpulse drifting, particularly over a wide range of frequencies, in recent studies suggest a more dynamic origin. This aspect is discussed in this paper.

2. Relationship between subpulse drifting, nulling and mode-changes

A change in drift rate during the null and a correlation between the subpulse phase before and after the null was reported in PSR B0809+74 by Lyne and Ashworth (1983). A similar correlation for short nulls (duration 1 to 4 pulses) is seen in PSR B0031−07 (Joshi and Vivekanand 2000). It has not been possible to conduct such studies on other

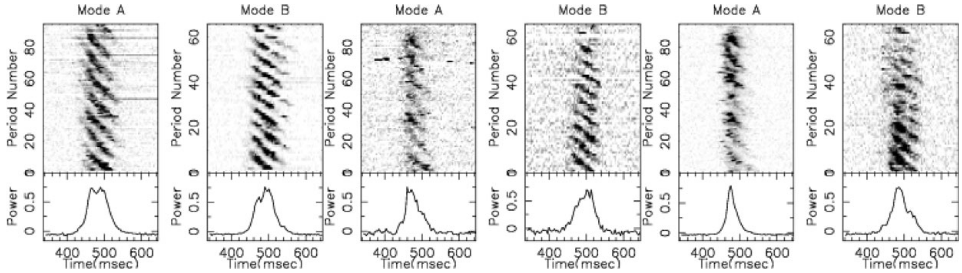

Figure 1. Subpulse drift mode A and B (top left and right plots respectively at 325, 610 and 1460 MHz - left to right plots) and associated profiles (bottom panels) for PSR B0031-07, observed simultaneously.

pulsars due to lack of pulsars with systematic drift. Nevertheless, these observations do suggest a link between the two phenomena.

Vivekanand & Joshi (1997) claimed that the average pulse profiles for PSR B0031−07, formed with pulses corresponding to different drift rates, differ significantly from each other. Although this conclusion was based on single polarisation data from Ooty Radio Telescope, both profile mode-changes and sub-pulse drift are observed as a systematic correlation across a number of pulses and it is plausible that these two are related to each other. A pulse null can also be considered an extreme form of profile mode-change (Wang *et al.* 2007).

As changes in subpulse drift are believed to be related to magnetospheric changes, relationship of profile mode-changes and nulls with subpulse drift implies that all the three phenomena are results of global magnetospheric changes and are expected to be correlated across a wide range of frequencies. This can be tested by long simultaneous multi-frequency observations of pulsars, exhibiting such phenomena.

3. Simultaneous multi-frequency observations of nulling-drifting pulsars

A handful of pulsars show all the three phenomena. The most prominent and relatively strong pulsars of these are PSR B0809+74, B0031−07, B2319+60 and B2111+46. A study of these pulsars (Gajjar *et al.* in preparation; Joshi *et al.* in preparation) is currently in progress and implies such a correlation across a wide range of frequencies.

Figure 1 shows the subpulse drift and average profiles for PSR B0031−07 at 325, 610 and 1480 MHz for the dominant different drift modes A and B of this pulsar (with drift rates −4.05 and −7.78 ms/period at 325 MHz respectively). The drift rates estimated for individual drift bands in PSR B0031−07 for 325, 610 and 1480 MHz are correlated at a high significance across the frequencies (Joshi *et al.*, in preparation). Moreover, the drift rate of the subpulse change at the same time across the frequencies studied.

The bottom panels of Figure 1 show that the profiles, obtained after averaging all periods belonging to a given drift mode, are different for the two modes. The most striking difference between the average profiles for Mode A and B is seen at 610 MHz (middle two plots). While the peak of Mode A profile is at the leading edge, Mode B profile exhibits a peak at the trailing edge. The averaged pulse for the drift mode A arrives earlier than that for mode B at all three frequencies confirming the results of Vivekanand & Joshi (1997). Similar behaviour was seen for PSR B2319+60.

Figure 2 shows the on-pulse intensity as a function of pulse number for PSRs B0031−07 and B2319+60 respectively. The abrupt drop in the intensity, visible in these plots,

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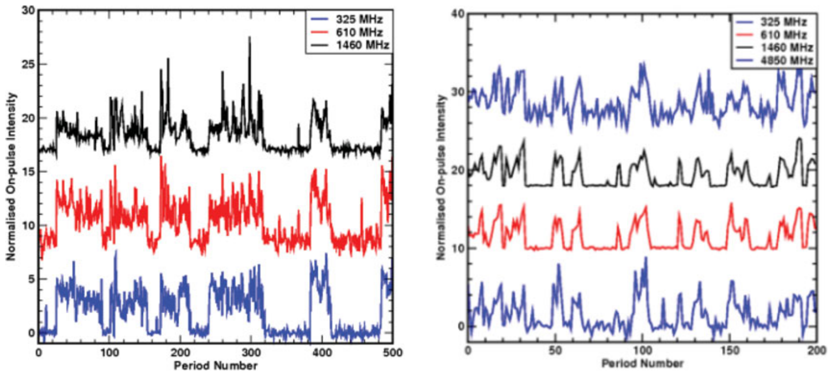

Figure 2. Intensity in the on-pulse window for PSR B0031-07 and B2319+60 for pulses observed simultaneously at 325, 610, 1460 and 4850 MHz.

indicates the nulls, which also appear to be correlated across the frequencies. A more detailed analysis of these data indicates a high degree of correlation between nulling fraction (NF) and null and burst length histograms from 325 MHz to 4.8 GHz (Gajjar *et al.* in preparation)

4. Discussions

Simultaneous multi-frequency study of a small sample of pulsars, which show pulse nulling, subpulse drifting and profile mode changes, suggests that these phenomena are broadband and related to each other. This correlation is consistent with the recent detailed studies of single pulse emission from other pulsars such as B1822-09, B0943+10 (See van Leeuwen *et al.*, this volume). If such a relationship does indeed exist for all the pulsars, then the changes in spin-down rate associated with extended off and on-emission duration of intermittent pulsars such as PSR B1931+24 (Kramer *et al.* 2006) and with the profile mode-changes reported by Lyne *et al.* (2010) link the three phenomena to changes in particle outflow density in the pulsar wind. While it is not clear what causes these changes, models invoking global changes in pulsar magnetosphere have recently been proposed (Timokhin 2010). Thus, it appears that subpulse drifting, nulling and profile mode-changes are all manifestations of global changes in magnetosphere. Future long simultaneous observations of these phenomena at widely separated frequencies will be very useful for constraining such models.

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