Profile Changes in PSR B1828-11

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Pulsar B1828-11 is a young, apparently precessing pulsar with a period of 405ms, a magnetic field strength of 5.0 x 10^{12} G and a characteristic age of 0.11Myr (Stairs et al. 2000). Link and Epstein (2001) suggest an hourglass beam shape with a precession period of approximately 500 days to explain shape changes in pulse profiles. This theory, however, fails to explain the 1000 day Fourier component seen in the timing residuals as well as intra-day shape variations. We examined profile shape changes using high resolution data obtained from the Parkes telescope (512 channels of 0.5MHz centered at 1340 MHz) for different epochs over 1000 days in order to determine whether the fundamental precession period is 1000 or 500 days. Since single pulses were too weak to see, groups of 32 or 48 pulses were added together with similar results.

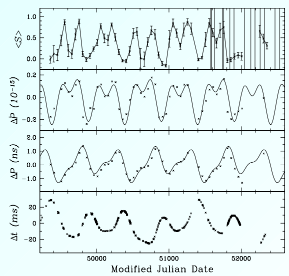

Fig.1: Variations in residuals of arrival time Δt, period ΔP, period derivative $\Delta\dot{P}$ and shape parameter <S>. Data was gathered from Jodrell Bank. Vertical lines indicate epochs where data was gathered from Parkes.

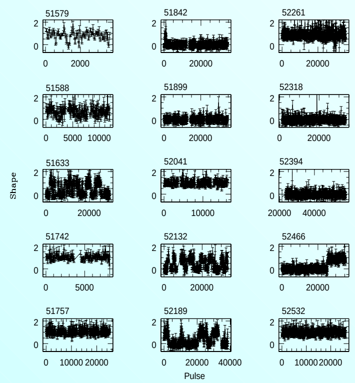

Fig.2: Shape variations for groups of 32 pulses showing the obvious mode-changing between wide and narrow profiles on both inter-day and intra-day timescales.

References:
1. Akgün, Taner et al. MNRAS submitted, astroph/0506606.
2. Dhillon, V.S. and Privett G.J. Period: A time series analysis package (1997).
3. Link, Bennet and Epstein, Richard I. ApJ. 556, 392-398 (2001).
4. Roberts, D.H. et al. Astron. J. 93, 965-989 (1987).
5. Stairs, I.H. et al. Nature. 406, 484-486 (2000).
6. Press et al. Numerical Recipes. Cambridge (1992).

Intra-day shape changes were also examined, using a Lomb-Scargle algorithm (Press et al. 1992) and compared to Clean (Roberts et al. 1987) run with the Period program (Dhillon and Privett 1997) to determine days with significant periodicities of mode-changing. Shape values are defined as S>0.7 for a narrow profile and S<0.3 for a wide profile (Stairs et al. 2000). The most significant intra-day periods were determined to be 5300 ± 200 pulses for MJD's 51633 and 52132 and 10300 ± 700 pulses for MJD 52189 (Fig.3).

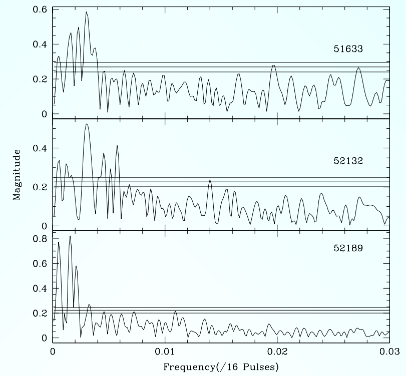

Fig.3: Lomb-Scargle periodograms for days with significant intra-day mode-changing using groups of 32 pulses. Significance levels correspond to 99.9%, 99% and 90%.

Profile widths were determined by measuring the width at 30% height for the dominant mode for each epoch. For days with intra-day mode-changing, widths of both the narrow and wide profiles were calculated.

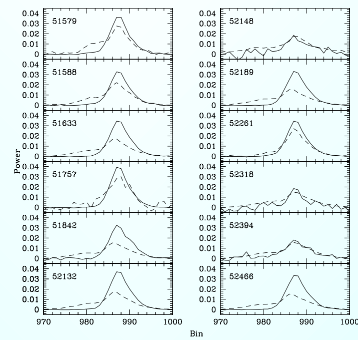

Fig.4: Cumulative narrow (solid line) and wide (dashed line) profiles for epochs where both types of profiles were seen using groups of 48 pulses. The overall normalization is arbitrary, but similar for each epoch. The relative heights may therefore be correct, assuming little refractive scintillation.

Established widths were plotted for a 500 day precession cycle using MJD 51742 as the mid-point. The first 250 days were plotted by advancing 125 days up then 125 days down the precession cycle with even spacing between days. The following 250 days were plotted in the same manner using negative values for the days. Similarly, complete cumulative profiles for each epoch were plotted after applying an arbitrary scaling factor and setting vertical offsets as determined by the precession phase (Fig.6). In both cases, and in agreement with the Link and Epstein model (2001), a 500 day precession cycle (compared to 1000 days) gives best results for a coherent beam shape.

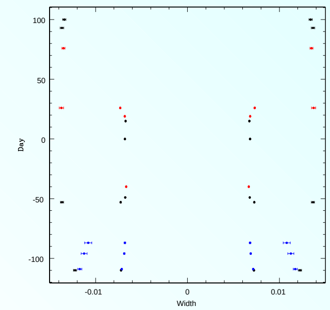

Fig.5: Widths of wide and narrow profiles for a 500 day precession period using groups of 48 pulses (Black = 1st 500 days, red = 2nd 500 days, blue = previous 500 days). Some days contain both wide and narrow widths. Widths are doubled for graphical purposes.

The cumulative profile of MJD 52189 does appear to be wider than others associated with the same precession phase (Fig.6). However, the observed mode-changing on that day may account for this. It is noted that most mode-changing epochs are associated with similar precession phases. Recent theory attempts to explain mode-changing with a model that suggests the core emitting region is surrounded by rotating conal regions of which detectability of varies throughout the precession cycle (Akgün et al.). Our preferred beam shape implies that the conal emitting regions probably do not need to circulate but could be fixed relative to the central core.

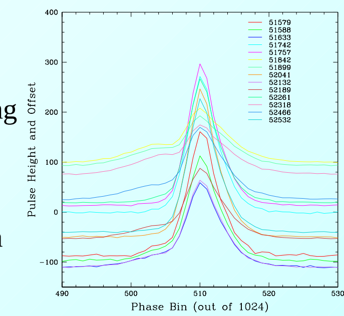

Fig.6: Cumulative profiles for a 500 day precession period.