High-Resolution Observations of PSR B1828−11

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Abstract. We present high-time-resolution observations of the young precessing pulsar B1828−11, which yield clues to the true beam shape and the fundamental precession period.

1. Introduction

PSR B1828−11 is a young, 405-ms pulsar discovered in the 20-cm pulsar survey at Jodrell Bank in the late 1980s (Clifton et al. 1992). Regular observations at Jodrell Bank over nearly 15 years have revealed correlated changes in the pulsar’s average pulse profile shape and rotational parameters, with strong periodicities of roughly 1000, 500 and 250 days. It appears likely that some form of precession is setting the timescale for these changes (Stairs, Lyne, & Shemar 2000), which continue steadily.

2. Continued Evidence for Precession

We describe the pulse profile from a given observation as a linear combination of two templates, one slightly wider than the other. The resulting “shape parameter” is \( S = A_N / (A_N + A_W) \), where \( A_N \) and \( A_W \) are the fit heights of the narrow and wide standard profiles respectively, so that \( S \simeq 1 \) for narrow pulses and \( S \simeq 0 \) for wider ones. It is the average of this parameter, along with the rotational quantities, which is observed to vary with the phase of the precession (Figure 1).

In addition to the regular observations at Jodrell Bank Observatory (gaps in the data in Figure 1 correspond to maintenance or resurfacing of the 76-m telescope), we have been acquiring high-resolution data with the 64-m Parkes telescope at selected epochs throughout the current 1000-day precession cycle. These data are taken with a \( 2 \times 512 \times 0.5 \)-MHz filterbank using 0.25 ms sampling. At the same time, we acquire correlator data with which to study polarization. Unfortunately, individual pulses are too weak to be distinguished in the Parkes data. Instead, we add the time series into groups of 16 pulses, finding that this generally provides reasonable signal-to-noise. At each Parkes epoch, we
Figure 1. Residuals in arrival time $\Delta t$, period $\Delta P$ and period derivative $\Delta \dot{P}$ relative to a simple spin-down model, and the mean pulse shape parameter $S$ for over 3000 days of observations. The latter three series were calculated over time intervals of 100 days which overlapped by 50 days. The solid curves show the predictions of a fit of three harmonically-related sinusoids to $\Delta P$. The vertical lines indicate the epochs at which Parkes data were obtained.

separate these groups into “wide” and “narrow” sets using the shape parameter, and show the averaged separated profiles in Figure 2. These data show that both narrow and wide modes are present at nearly all epochs, indicating that mode-changing is occurring at each epoch, with some evidence for changes in shape of the narrow and wide profiles. There is also good evidence for changes in average flux correlated with the changes in average profile shape. Overall the data appear to be consistent with a combination of precession and mode-changing. Future work will determine whether the apparent differences in shape and intensity at epochs separated by 500 days (for instance, MJDs 51757 and 52261) truly indicate a difference in pulse properties and hence a fundamental precession period of 1000 days rather than 500 days, an important issue in attempting to model the behaviour of this object (e.g., Link & Epstein 2001, Jones & Anderson 2001, Rezania 2002, Link, these proceedings).
Figure 2. Narrow (solid) and wide (dashed) profiles at 12 different Parkes observing epochs in 2000-2, produced by determining the shape parameter $S$ for groups of 16 pulses. The peak alignments are arbitrary. The flux normalization is arbitrary, though consistent from epoch to epoch.

3. Mode-Changing at Different Precession Phases

In an attempt to study the mode-changing at each epoch more closely, we calculate averages of the shape parameter $S$ in overlapping bins of 500 pulses, using a method similar to that in Figure 1. The results are displayed in Figure 3, where at the most “active” epochs mode-switching can be seen to occur on timescales of a few thousand periods, or tens of minutes. In fact, significant periodicities can be discerned at some of these epochs, as discussed in the caption to Figure 3. We are constructing a 2-dimensional model of the pulse beam shape and mode-changing properties, which will attempt to address how these periodicities relate to the precession phase and/or the average beam shape.

4. Investigating Polarization Properties

Another crucial clue to the 2-dimensional beam shape of this pulsar lies in the polarization properties at different precession phases. While careful calibration of the Jodrell Bank polarization data is still in progress (see the contribution by Athanasiadis et al.), there is already some evidence for a steeper position angle swing when wide modes are strong. Preliminary analysis of Parkes correlator polarization data suggests similar behaviour, though instrumental effects due to
The shape parameter $S$ during each epoch of Parkes data, averaged over 500 pulses, with bins overlapped by 250 pulses. The abrupt mode changes can be distinguished, and it is also evident that the timescale for the mode changes varies dramatically with precession phase. Through Fourier analysis, significant periodicities can be distinguished at the following MJDs: 51589 (3700 pulses), 51634 (7500 and 5000 pulses), 51742 (1100 pulses), 52132 (5000 pulses) and 52189 (7500 pulses).

the linear telescope feeds need to be carefully calibrated. We will soon begin similar monitoring with the Green Bank Telescope in order to achieve better signal-to-noise for small groups of pulses, and to minimize instrumental effects in the observed polarization.

References

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