Part 10
Radio Pulsar Timing

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Long-term Radio Timing Observations of PSR B1509–58

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Abstract. We present an updated phase-coherent timing solution for the young, energetic pulsar B1509–58 from twenty years of data. Using a partially phase-coherent timing analysis, we show that the second frequency derivative is changing in time, implying a third frequency derivative of $\dddot{\nu} = (-9 \pm 1) \times 10^{-32}$ s^{-4}. This value is consistent with the simple power law model of pulsar rotation.

1. Introduction

Radio pulsars are powered by rotational kinetic energy and experience losses due to the emission of electromagnetic energy while spinning down. The spin-down of radio pulsars is described by (Manchester & Taylor 1977):

$$\dot{\nu} \propto -\nu^n, \tag{1}$$

where ν is the spin frequency, $\dot{\nu}$ is the frequency derivative and n, the braking index, equals 3 for a spinning magnetic dipole in a vacuum. Taking the derivative of Equation (1), we find that $n = \nu\ddot{\nu}/\dot{\nu}^2$. Taking further derivatives of Equation (1), and defining the second braking index as $m_0 = n(2n-1)$ (Kaspi et al. 1994), we find an expression $m = \nu^2\,\dddot{\nu}/\dot{\nu}^3$. Measuring a value of m that agrees with the predicted value m_0 is an excellent check on the validity of the power law spin-down model of radio pulsars given in Equation (1). Kaspi et al. (1994) reported values of $n = 2.837 \pm 0.001$ and $m = 14.5 \pm 3.6$ for PSR B1509–58.

2. Results and Discussion

Performing a phase-coherent timing analysis on twenty years of radio timing data for PSR B1509–58 obtained from the Molongolo Observatory Synthesis Telescope and from the Parkes 64-m telescope, we found the second frequency derivative to be $\ddot{\nu} = (1.962 \pm 0.001) \times 10^{-21}$ s^{-3}, implying a braking index of $n = 2.814 \pm 0.001$. Significant low-frequency timing noise in the data prohibited a phase-coherent analysis to determine an accurate value of the third frequency derivative. This prompted a partially phase-coherent timing analysis by breaking

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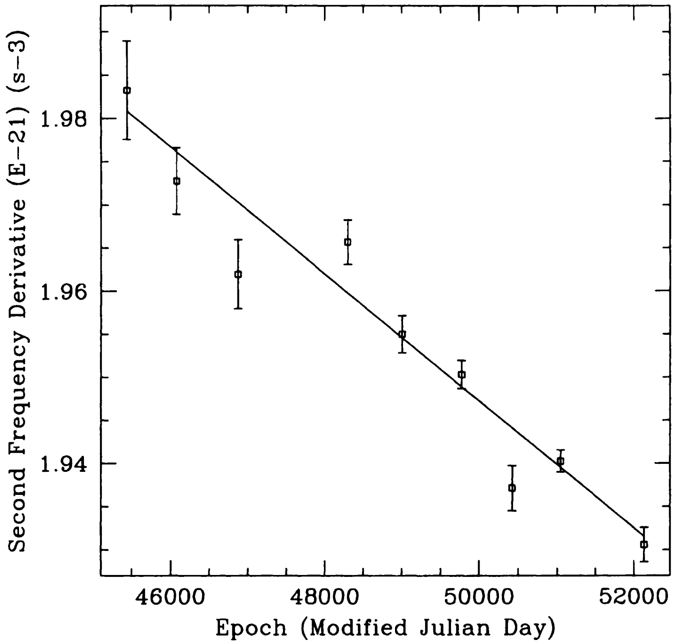

Figure 1. Phase-coherent subsets plotted versus epoch. The slope of the line is the third derivative and has a value of $(-9 \pm 1) \times 10^{-32}$ s^{-4}.

up the data into subsets of $\sim$ 2 yr (such that phase residuals were "white" in each interval following a fit of ν, $\dot{\nu}$ and $\ddot{\nu}$) and plotting the values of $\ddot{\nu}$ against time, the results of which are shown in Figure 1. This method is less sensitive to timing noise which dominates on long time scales. We found a value $\dddot{\nu} = (-9 \pm 1) \times 10^{-32}$ s^{-4} by a weighted least-squares fit to the data. This value for $\dddot{\nu}$ is in agreement with that predicted from the spin-down law of $\dddot{\nu} = -9.37 \times 10^{-32}$ s^{-4}. This measured value for $\dddot{\nu}$ implies a second braking index of $m = 12.7 \pm 1.4$, also in agreement with the predicted value of $m = 13.3$, though less than the value $m = 15$ expected for an ideal spinning dipole. Our measurement of $\dddot{\nu}$ implies that the spin-down law correctly predicts the behaviour of PSR B1509–58, reinforcing the use of the power law given in Equation (1) to describe the rotation of pulsars.

References

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