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The Young Binary Pulsar J1740–3052

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Abstract. The young pulsar PSR J1740–3052, discovered in the Parkes Multibeam Pulsar Survey, is in a highly eccentric 8-month orbit with a companion of at least 11 solar masses. The up-to-date timing solution for this pulsar incorporates effects likely due to the spin mass quadrupole of the companion star; we discuss the implications for the geometry of the orbit. The pulsar signal displays increased dispersive delays as the pulsar passes behind its companion, indicating an interaction with the companion wind.

1. Introduction

PSR J1740–3052 is a young binary pulsar ($P = 570\,\mathrm{ms}$, $\tau_c = 3.5 \times 10^5$ kyr) recently discovered in the Parkes Multibeam Pulsar Survey (e.g., Manchester et al. 2001). While a late-type star is coincident with the pulsar position, we have argued (Stairs et al. 2001) that the most likely companion is in fact an early-B star. Among the justifications for a B-star companion are the small measured advance of periastron (an order of magnitude too small to be due to the mass quadrupole of a late-type supergiant), and the small dispersion measure (DM) variations observed as the pulsar passes "behind" its companion just before periastron — these variations are far smaller than those expected for a late-type companion. We are acquiring near-infrared spectroscopic Gemini-South and VLT data on the late-type star to check for Doppler variations in the spectral lines and definitively settle the question of the association.

2. New Observations

The radio timing data set on this pulsar includes observations taken with the Parkes 64-m, Jodrell Bank 76-m and Green Bank (GBT) 100-m telescopes. In particular, the GBT data set consists of multi-frequency data at each epoch, allowing us to track and model the DM variations as a function of orbital phase. Using a simple model in which the pulsar signal passes through a spherically symmetric B-star stellar wind (see Kaspi, Tauris & Manchester 1996a, and references therein), the shape of the DM changes constrains the orbital inclination angle of the system to be about $64^\circ \pm 8^\circ$, implying a companion mass of 14.5 $M_\odot$ (see Figure 1).

We use the timing model for pulsar–main-sequence binaries (Wex 1998), incorporating fixed DM variations with orbital phase, predicted from the 64°-

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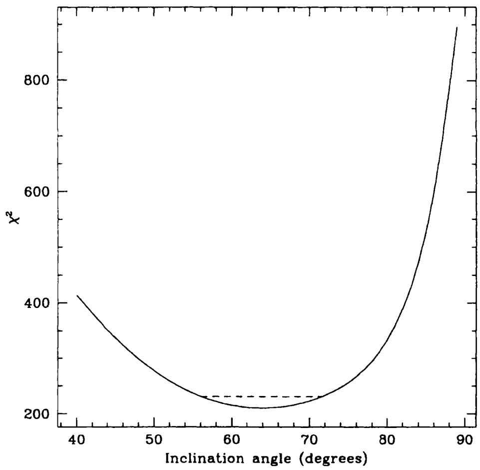

Figure 1. Values of χ^2 for fits to the observations of the expected changes in the DM if the pulsar signal passes through a spherically symmetric B-star wind with mass-loss rate 2×10^{-9} $M_\odot$/yr and terminal velocity 2000 km s^{-1}, which are typical values. The best fit, albeit with a χ^2 of 210 for 41 degrees of freedom, occurs at 64°, and the 8° range indicates an estimate of the 1-σ uncertainty.

inclination model described above. Along with the five standard Keplerian orbital parameters, two corrections representing secular evolution of the observed orbit must also be fit. These are the advance of periastron ($\dot{\omega}$, a 7-σ detection), and the apparent change of the projected semi-major axis of the orbit ($\dot{x}$, a still-rough 5-σ detection). The measured $\dot{\omega}$ is likely due to a mixture of general relativistic orbital precession and precession due to the spin quadrupole of the companion star, while $\dot{x}$ is likely entirely due to the companion spin. Together with the orbital inclination angle discussed above, these may be used to constrain the misalignment angle between the B-star spin and the orbital angular momentum (e.g., Wex 1998). We find that this angle most likely falls between about 20° and 60° — the fact that this angle is most probably non-zero is strong evidence for an asymmetric kick in the supernova explosion that created the pulsar (c.f., Kaspi et al. 1996b).

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