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The optical & IR lightcurve of PSR B1957+20

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Abstract. We present a new analysis of the light curve of the secondary star in the PSR B1957+20 system. Combining previous data and new data points at minimum from the *Hubble Space Telescope*, we have 100% coverage in the R-band. We also have a number of new K_s band data points, which we use to constrain the IR magnitude of the system. We model this with the Eclipsing Light Curve code. From the modeling we obtain colour information about the secondary at minimum in BVRI & K. For our best fit model we are able to constrain the system inclination to 66.6 ± 2.1^o for pulsar masses ranging from 1.35 – 1.9 $M_\odot$. The pulsar mass is unconstrained. We also find that the secondary is *not* filling its Roche lobe, which has important consequences for evolutionary models of this system. The temperature of the un-irradiated side of the companion is in agreement with previous estimates.

Keywords. X-rays: binaries, pulsars: individual (PSR B1957+20).

1. Introduction

The binary millisecond pulsar *PSR B1957+20* (Fruchter *et al.* 1988) is the original and one of the best studied members of its class. It consists of a 1.6 ms radio pulsar, which is eclipsed for approximately 10% (in the radio) of its 9.17 hr orbit, by a companion of mass no less than 0.022$M_\odot$. The eclipsing region is considerably larger than the Roche lobe of the companion star, suggesting a wind of material from the secondary, due to ablation by the impinging pulsar radiation (Fruchter *et al.* (1988)).

2. Modeling

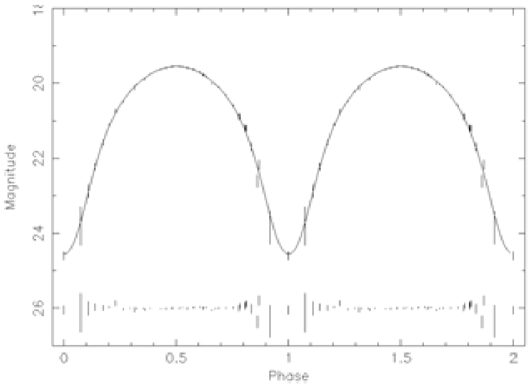
The data, consisting of optical photometry from the *WHT* and the *HST* and infra-red data from the *Magellan* telescope, were modeled with the ELC code (Orosz & Hauschildt 2000).

2.1 Inclination

We modeled the system for a number of prospective pulsar masses ranging from 1.35 – 1.9 $M_\odot$. For a given pulsar mass the inclination was constrained to within $\sim 2°$, i.e. for a pulsar of mass 1.40 $M_\odot$, $i = 67.4° \pm 1.2°$ (see Fig. 1). Overall for the above range of pulsar masses we find the inclination of the system to be $i = 66.6° \pm 2.1°$, at the 2σ level.

2.2 Roche lobe filling factor

At no point in our attempts to model this system were we able to obtain an acceptable fit for a secondary filling its Roche lobe. For our models using the NEXTGEN model



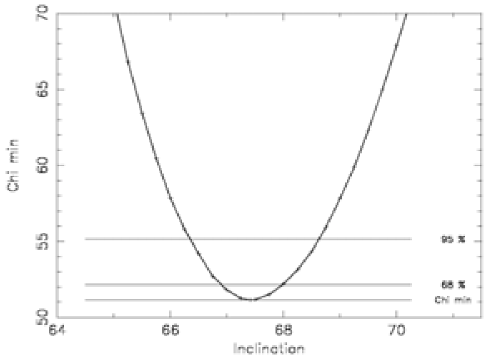


Figure 1. Left: The best fit to the combined R-band data with residuals. The residuals are to scale. Two orbital phases are displayed for added clarity. Right: The best fit inclination is $i = (67.4 \pm 1.2)^\circ$ with a $\chi^2_\nu = 1.16$. The pulsar mass is 1.40 $M_\odot$.

atmospheres the Roche lobe filling factor, f, was approximately constant, $0.80 \leqslant f \leqslant 0.84$ (2σ level), Hence the secondary is tightly constrained as *not* currently filling its Roche lobe. This appears to rule out Roche lobe overflow as the primary means of mass loss in this system.

2.3 Temperature of the Secondary @ max/min

We obtained a value of $T = 2980 \pm 150$ K (2σ), for the effective temperature of the un-illuminated side of the companion star for pulsar masses in the range $1.35 - 1.90$ $M_\odot$. For individual pulsar masses the 2σ error was only $\pm$ 70 K. The corresponding temperature at maximum is $T = 8500 \pm 200$ K (2σ).

2.4 Modeling the Temperature Gradient

The temperature gradient across the surface of the low mass secondary was simulated using a modified version of the code described in Beer *et al.* (2002). It was found that the heated material extended beyond the directly irradiated region but that not all of the unilluminated portion of the star was heated. Consequently a large temperature gradient between the illuminated and unilluminated sides was found to exist.

We now plan to obtain phase resolved spectroscopy of the companion in an effort to measure the mass of the Neutron star. As the error on the inclination is so low, this will ensure that any mass determination will be limited primarily by the accuracy of the radial velocity measurements.

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