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Double-telescope timing of the binary pulsar PSR J1811-1736

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Abstract. We present a timing solution for the binary pulsar PSR J1811-1736, obtained combining data taken with the Lovell telescope at Jodrell Bank and with the 100m telescope at Effelsberg. Our solution agrees with a previous one presented by Lyne et al. (2000), but greatly improves the precision of the measured spin parameters, Keplerian orbital parameters and the relativistic periastron advance. Such firmer constraints, in particular on the total mass of the system and on the minimum mass of the so far unseen companion (Mignani 2000), provide strong support for the double neutron star nature of this system.

Key words. Pulsars: General, 1811-1736 – Millisecond Pulsars: formation, evolution

1. Introduction

PSR J1811-1736, discovered in 1997 in the Parkes Multibeam Pulsar Survey (Lyne et al. 2000), is a 104ms pulsar in a 18.8d, highly eccentric binary orbit (see Fig. 1). The timing observations made by Lyne et al. (2000) showed a periastron advance of 0.09±0.02 deg/yr. This leads to a constraint for the total mass of the system of 2.6±0.9 $M_\odot$), leaving open the nature of the companion star.

Here we present a solution obtained from data taken with the Lovell telescope at Jodrell Bank, UK, and the 100m telescope at Effelsberg, Germany. The joint fit leads to a large increase in the precision of all measured parameters presented by Lyne et al. (2000). Moreover the solution also improves over a single telescope fit, allowing us to obtain much improved values for observed and derived parameters. Our findings support the initial suggestion that PSR J1811-1736 is a double neutron star system.

2. The two telescopes' data joint fit

Before performing the joint fit of the two datasets, single telescopes fits have been carried out, but none of them could meet the same precision in determining parameters as in the joint fit. The JBO dataset contains pulses' Time of Arrivals (ToAs) covering a long time span (from early 1998 to early 2004), but the ToAs are affected by very large uncertainties (~2ms) and they don't cover uniformly the time span between the earliest and the latest observa-

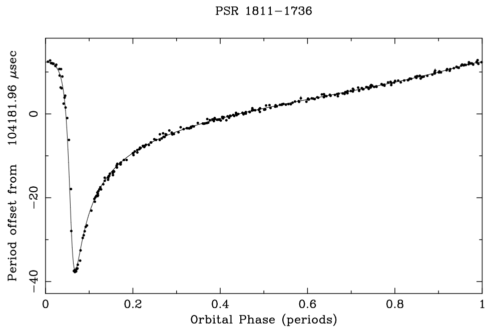

Fig. 1. Observed period's variations with orbital phase.

tions. Large error bars imply that each systematic deviation with amplitude less than the error bars cannot be accurately determined. The Effelsberg dataset contains more precise ToAs, but they cover a shorter time span compared to JBO's data. Here the gaps in observations are not as large as in the JBO's data set. The overall precision in the solutions obtained in the two single telescope's fits are anyway comparable.

Figure 2 shows post-fit residuals, once the two dataset from JBO and Effelsberg are combined. It is evident that the time span is now much more uniformly covered. The obtained solution, shown in table 1, improve results due to:

1 A larger number of ToAs: the solution is more constrained;
2 No significant gaps among observations: coherence of the solution is easily mantained;
3 The low precision data from JB constrain principal parameters, while the high precision Effelsberg ToAs help to get a better determination of post-Keplerian parameters.

3. The M_P-M_C diagram

Figure 3 shows the constraints on the masses of the system, in a pulsar mass/companion mass diagram (the M_P-M_C diagram). The region under the concave curve is excluded because of the constraint on the inclination of the system relative to the line of sight ($\sin i \leq 1$).

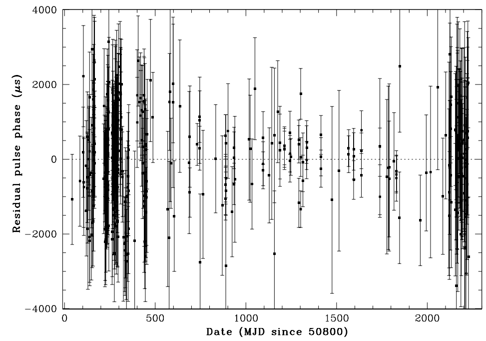

Fig. 2. Post fit timing residuals for Jodrell Bank's and Effelsberg's joint data.

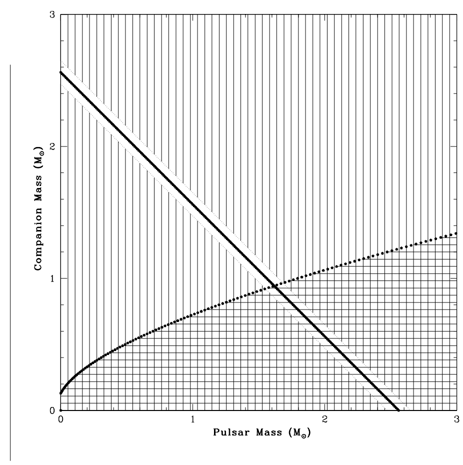

Fig. 3. M_P-M_C diagram showing masses constraints derived from the obtained solution.

The diagonal lines enclose all points for which the system's total mass is 2.56 ± 0.09 $M_\odot$, as determined from relativistic periastron advance. The intersection of the two curves gives a minimum companion mass of 0.94 ± 0.02 $M_\odot$.

4. The nature of the companion

The obtained characteristic age and magnetic field of PSR J1811-1736 is typical for a re-

Table 1. Timing and derived parameters

Timing parameters	
$RAJ\ (hh:mm:ss)$	18 : 11 : 55.031(5)
$DECJ\ (dd:mm:ss)$	−17 : 36 : 37.0(7)
$P\ (s)$	0.1041819547972(7)
$\dot{P}\ (10^{-19})$	9.16(16)
$P_{EPOCH}\ (MJD)$	51857.263128
$DATA\ SPAN\ (MJD)$	50842 − 53027
$DM\ (pc/cm^{-3})$	477.000000
$N\ of\ ToAs$	385
$a\ sin\ i\ (s)$	34.7827(8)
e	0.828014(14)
$T_{ASC}\ (MJD)$	50875.02449(4)
$P_B\ (d)$	18.7791691(8)
$\omega\ (deg)$	127.6575(16)
$\dot{\omega}\ (deg/yr)$	0.0089(4)
$rms\ timing\ residuals\ (ms)$	1.009
Derived parameters	
$Mass\ Function\ (M_\odot)$	0.128122(9)
$Total\ Mass\ (M_\odot)$	2.56(9)
$Magnetic\ Field\ (10^9 G)$	9.88(9)
$Age\ (Gy)$	1.80(3)
$Minimum\ companion\ mass\ (M_\odot)$	0.94(2)

cycled pulsar and is hence consistent with the idea that the observed pulsar is the first born neutron star. However, the long pulse period suggests that the recycling process was suddenly interrupted by the supernova explosion of the companion star, leaving behind an only mildly recycled pulsar in a wide orbit around a young neutron star. The large observed eccentricity is a signature of this catastrophic event. Our much improved mass measurements therefore confirm this scenario which was already suggested by Lyne et al. (2000).

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