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THE ORBITAL EPHEMERIS OF THE PARTIAL ECLIPSING X-ray BINARY X1822-371

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ABSTRACT

X1822-371 is a low mass X-ray binary with an accretion disk corona exhibiting partial eclipses and pulsations in the X-ray band. We update its orbital ephemeris by combining new RXTE observations and historical records, with a total time span of 34 years. There were 11 RXTE observations in 2011 but the eclipsing profile can be seen in only 4 of them. The eclipsing center times were obtained by fitting the profile with the same model as previous studies. Combined with the eclipsing center times reported by Iaria et al. (2011), the O-C analysis was processed. A quadratic model was applied to fit the O-C results and produced a mean orbital period derivative of $\dot{P}_{\rm orb} = 1.339(25) \times 10^{-10}$s/s, which is slightly smaller than previous records. In addition to the orbital modulation from the orbital profile, we also present our preliminary results for measuring the orbital parameters using the orbital Doppler effect from the pulsation of the neutron star in X1822-371. The updated orbital parameters from eclipsing profiles will be further compared with the ones from pulsar timing.

Key words: X1822-371, X-ray, binary

1. INTRODUCTION

X1822−371 is a low mass X-ray binary exhibiting periodic partial eclipses with a period of 5.57 hours in its X-ray light curves. The detection of a 0.59s X-ray pulsation (Jonker & van der Klis, 2001) indicates that the accretor of this system is a neutron star. By using the O-C method to trace the time delays of the specified fiducial point in the X-ray eclipsing profile, its orbital ephemeris has been updated continuously (see Iaria et al., 2011, and the reference therein) since the discovery of its orbital period (Mason et al., 1980; White et al., 1981) in early 1980s. The latest orbital ephemeris prior to this work was reported by Iaria et al. (2011) using X-ray eclipsing times recorded from 1977 to 2008. In this paper, we further updated the orbital ephemeris with the additional eclipsing times detected by light curves from RXTE 2011 observations. We also used the orbital Doppler shift technique to obtain the spin and orbital parameters form 1998 to 2011.

2. OBSERVATIONS AND DATA ANALYSIS

The data used in this study were collected by the Proportional Counter Array (PCA) on board RXTE. The PCA, composed of five X-ray Proportional Counter Units (PCUs), has a large collection area of 6500 cm^2 to detect energy of 2-60 keV X-ray photons with an unprecedented time resolution of 1s. All data in this work have been corrected to the barycenter of the solar system (BARYTIME).

The data used in the O-C method were collected by PCA in 2011. We adopted the 2-9 keV light curves made by the standard techniques to measure the eclipsing times. Among the 11 observations processed in 2011, the eclipsing profile can be only seen in 4. In order to be consistent with previous works, the time when the X-ray flux reaches it minimum in the eclipsing profile was selected as the eclipsing time, that is, the fiducial point for the O-C method. The eclipsing times were obtained by fitting the eclipsing profile with a model consisting of a Gaussian plus a straight line, as suggested by Burderi et al. (2010). These 4 new eclipsing times were then added to historical records listed in Iaria et al. (2011). There are a total of 34 eclipsing times over a time span of 34 years. The O-C method, compared with the linear ephemeris reported by Hellier & Smale (1994) in previous studies, was then applied and the results are shown as Fig 1. The time delays from the O-C method were further fitted with a quadratic model and we obtained orbital period derivatives of

$$\dot{P}_{\rm orb} = 1.339(25) \times 10^{-10}{\rm s/s}$$

with χ^2/d.o.f. = 82.40/31. The quadratic orbital ephemeris can be written as

$$T_{\rm ecl} = 45614.80938(13){\rm MJD}_\odot + 0.232108916(15) \times N$$
$$+1.544(29) \times 10^{-11} \times N^2$$

Table 1
THE RESULTS OF EACH SEGMENTS UN-WEIGHT FITTING

	1998	2001	2002	2003	2011
$P_{\rm spin}$(s)	0.59309(1)	0.59285(1)	0.59275(2)	0.59269(2)	0.591999(9)
$P_{\rm orb}$(s)	19726.884(8)	20055.54900(3)	20053.7130(1)	20054.96500(5)	20055.50700(4)
asin(i)(lt-s)	0.9973962(2)	1.0483284(2)	0.9642420(2)	1.1177667(3)	0.9729470(2)
$T_{\pi/2}$	51018.309(3)	52086.241(1)	52435.800(9)	52724.774(7)	55718.994 (7)

The data used for the orbital Doppler shift method were collected by PCA. The RXTE performed 5 observations from 1998 to 2011. The event arrival times were chosen only for events within the energy range 9.4-22.7 keV, as the signal-to-noise ratio was highest in this energy band (Jonker & van der Klis, 2001). To resolve the orbital Doppler shift due to orbital motion, we first divided the events into ~1500s intervals (Jonker & van der Klis, 2001). Then we used the Z-test to determine pulse frequency in each divided segment. The pulse frequencies for each observation were fitted with an unweighted fit to a circular orbital Doppler model as

$$v(t) = v_0 + 2\pi f_{\rm orb} v_0 \frac{a\sin(i)}{c} \sin[2\pi f_{\rm orb}(t - T_{\pi/2})]$$

where v_0, $f_{\rm orb}$, $\frac{a\sin(i)}{c}$, and $T_{\pi/2}$ are pulsar frequency, orbital frequency, orbit radius and time when the neutron star is located at its superior conjunction. All the orbital and spin parameters of the 5 observations are listed in Table 1. We note that the spin period of the neutron star has a significant drift. All the spin periods in Table 1 were fitted with a linear model and yielded a spin period derivative of $2.597(29) \times 10^{-12}$s/s, which is slightly larger than the value proposed by Jain, Paul, & Dutta (2010).

Although the orbital period can be obtained from the orbital Doppler effect, it can be alternatively measured by $T_{\pi/2}$, as this is the time when the neutron star is located at its superior conjunction. We adopted the O-C method for the $T_{\pi/2}$ values detected in the 5 observations and obtained an orbital period of 0.232089(14) day and orbital period derivative of $6.2(2.5) \times 10^{-11}$s/s. Interestingly, there are significant time shifts of $T_{\pi/2}$ in comparison to the eclipsing time (see Fig 1), which indicates that the extended X-ray emission region or the region for occulting X-rays are probably asymmetric.

3. SUMMARY

Combining historical data and 4 additional eclipsing times detected by RXTE in 2011, we have updated the orbital ephemeris of X1822-371. From Fig 1., we can find different time delays by different methods. From the orbital Doppler shift method we obtained spin period and spin period derivatives and also a significant time shift of $T_{\pi/2}$ relative to the eclipsing time. We plan to more precisely determine the spin and orbital parameters by the pulse arrival time delay technique, then compare the results with the one we obtained from eclipsing times.

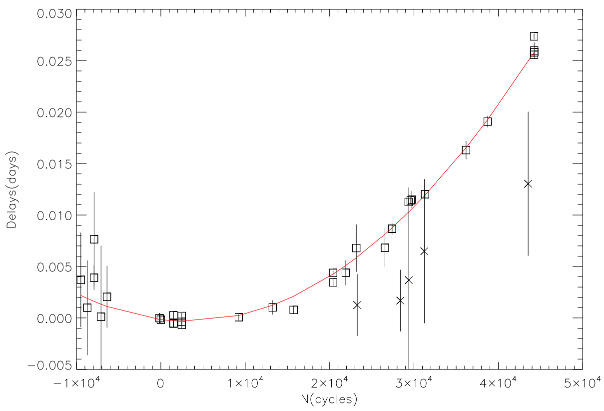

Figure 1. Orbital evolution measured from eclipsing time and orbital Doppler shift technique Squares are from eclipse times and crosses are from the $T_{\pi/2}$ values of orbital Doppler shift technique. The red line is the best fit result from a quadratic model for eclipsing time.

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