Publications of the Korean Astronomical Society
30: 593 ∼ 594, 2015 September

pISSN: 1225-1534
eISSN: 2287-6936
http://dx.doi.org/10.5303/PKAS.2015.30.2.593

THE UPDATED ORBITAL EPHEMERIS OF DIPPING LOW MASS X-ray BINARY 4U 1624−49

Nai-Hui Liao, Yi Chou, Hung-En Hsieh, and Po-Sheng Chuang
Institute of Astronomy, National Central University, Taiwan
E-mail: anc88756@gmail.com
(Received November 30, 2014; Reviced May 31, 2015; Aaccepted June 30, 2015)

ABSTRACT

We present our analysis results for an updated orbital ephemeris for the dipping low mass X-ray binary 4U 1624−49, using the light curve collected by the All Sky Monitor (ASM) on board the Rossi X-ray Timing Explorer (RXTE) and the Monitor of All-Sky X-ray Image (MAXI). To make clear dip profiles, the light curve from the ASM and the MAXI were divided into ten 500d segments and four 400d segments for ASM and MAXI light curves, respectively, and folded with the linear ephemeris proposed by Smale et al. (2001). The phases of dip centers were determined by the method adopted from Hu et al. (2008). The phase drift was then fitted with a linear function. We obtained an updated orbital period of 0.869896(1) d and a phase zero epoch of JD 2450088.6618(57). No clear orbital period derivative is detected with a 2-sigma upper limit of $1.4 \times 10^{-6}(yr)^{-1}$ from a quadratic curve fitting of the dip phase evolution.

Key words: X-ray binary: 4U 1624−49: period

1. INTRODUCTION

4U 1624−49, a low-mass X-ray binary (LMXB) discovered by Watson et al. (1985), is composed of a neutron star and a low mass companion, and exhibits intense recurrent X-ray dips with a period of 21 hr and dip duration of 6-8 hr. The more accurate dip period of 0.869907(12) d was refined by Smale et al. (2001) using the X-ray light curve of ∼4.5 yr collected by RXTE/ASM. The X-ray dips are believed to be due to the occultation of the X-rays emitted around the compact object by the bulge on the rim of accretion disk where the gas stream from the companion impacts on it. Therefore the periodic X-ray dips reflect the orbital period of the binary system and allow us to probe the orbital period and its evolution.

2. OBSERVATIONS

2.1. ASM

The ASM, an instrument on board RXTE, is able to scan the whole sky every 90 minutes to monitor the variations of cosmic X-ray sources and to discover transient X-ray sources. The ASM is sensitive to X-ray photons in an energy band of 2-12 keV, and the light curves can be further divided into three energy bands to study the variations of hardness ratios for difference sources. The ASM began to scan the sky as soon as the RXTE was launched in late 1995, and continued until the end of the mission in early 2012. In this study, we used the X-ray light curve of 4U 1624−49 collected by ASM only from 1996 to 2010 (MJD 50134 to MJD 55371). The rest of the data were discarded to to the loss of sensitivity of the ASM.

2.2. MAXI

MAXI, an X-ray slit camera aboard the ISS, continuously monitors astronomical X-ray objects every 96 minutes over a broad energy band (0.5 to 30 keV). Although the primary scientific purpose of MAXI is to monitor the variation of active galactic nuclei, as its sensitivity is much higher than ASM, it is also suitable for recording the long-term variations of X-ray binaries. MAXI was launched in July 2009. In this study, we used the X-ray light curve of 4U 1624−49 from 2009 to 2014 (MJD 55058 to MJD 56795).

3. DATA ANALYSIS

The periodic light curves of ASM and MAXI were first tested by using the epoch folding searching method to search around the expected period (21 hr). A strong periodic signal can be detected as shown in Figure 1.

To enhance the dip profile and trace the dip phase evolution, we divided the light curve of ASM into ten segments with 500d for each segment, and divided the light curve of MAXI into four segments with 400d for each one. To test if the dip profile was significantly detected, we performed the epoch folding searching method for the whole light curve for each segment. We found no significant periodic signals for two of the ten segments of ASM. For the MAXI light curve, the orbital periodicity can be significant detected for all four segments. Therefore, there are twelve data segments for further analysis. We folded each of twelve segment light curves

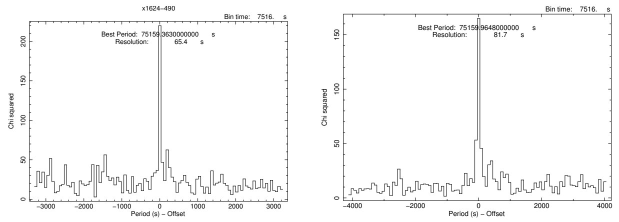

Figure 1. Epoch folding searches for the first segment from the ASM data (left) and the MAXI data (right), whose time intervals are TJD 10588 to 11086 and MJD 55100 to 55499 respectively.

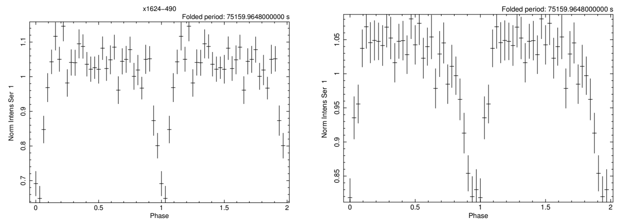

Figure 2. The folded light curve for the first window from the ASM data (left) and the MAXI data (right). The bin number is 32.

with the ephemeris proposed by Smale et al. (2001). The typical dip profiles form ASM and MAXI are shown in Figure 2.

As described by Watson et al. (1985), the dip profile has a complex and variable structure. We therefore adopted the method proposed by Hu et al. (2008), which is able to extract the dip center time, as well as the dispersion and the equivalent width for a complex dip profile to trace the dip phase variation. Figure 3 shows the phase of the dip center time evolution from these twelve light curve segments. Significant phase drift can be detected. To refine the orbital period, we fitted a linear function to update the linear ephemeris. The phase evolution is well fitted with a straight line with χ^2 of 7.85 for 10 degrees of freedom. The parameters of the linear function are shown on Table 1. The orbital ephemeris is updated to be

$$T_n = JD2450088.6618(57) + N \times 0.569898(1)$$

We further fit the phase evolution with a quadratic curve whose parameters are also shown in Table 1. The F-test to compare the linear and quadratic fittings shows that the null hypothesis probability is only 53.6%, which indicates that the quadratic term is not significant. We therefore conclude that no significant orbital period derivatives can be detected with 2σ upper limit of $\dot{P}_{orb}/P_{orb} = 1.4 \times 10^{-6}(yr)^{-1}$

4. SUMMARY

We have updated the orbital ephemeris of 4U 1624−49 using the dip center time evolution obtained by the X-ray light curve of ASM on board RXTE with a time span of more than 4000 d and the X-ray light curves of MAXI on board ISS with time span about 1700 d. Although no significant period derivatives can be detected, its upper limit is consistent with the expected value ($\dot{P}_{orb}/P_{orb} \sim 10^{-8} - 10^{-7}(yr)^{-1}$)

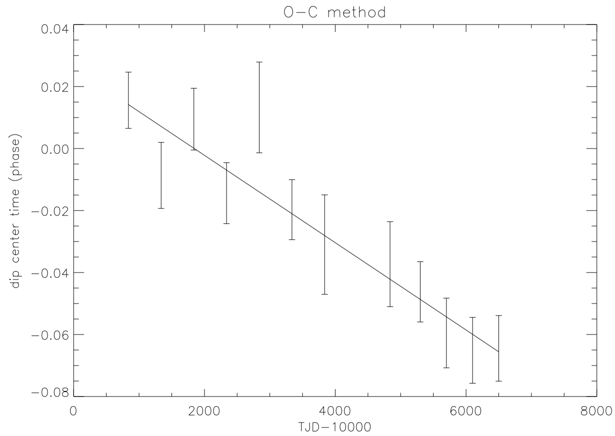

Figure 3. Linear fitting for the phase of dip center times. The first seven points are from the ASM and the others are from the MAXI.

Table 1
THE FITTING RESULTS FOR THE PHASE OF DIP CENTER TIME EVOLUTION

Parameter	Linear fitting	Quadratic fitting
Constant term	0.026(7)	0.018(12)
Linear term	$-1.4 \pm 0.2 \times 10^{-5}$	$-8.3 \pm 8.5 \times 10^{-6}$
Quadratic term	—	$-7.8 \pm 11 \times 10^{-10}$
χ^2	7.85	7.37
DOF	10	9

ACKNOWLEDGMENTS

The RXTE/ASM data of this research were obtained from High Energy Astrophysics Science Archive Research Center (HEASARC) online service provided by NASA/Goddard Space Flight Center. The ISS/MAXI data of this research were obtained from Rikagaku Kenkysho(RIKEN) online service. This research was supported by the Ministry of Science and Technology (MOST) through the grant NSC 102-2112-M-008-020-MY3.

REFERENCES

Hu, C. -P., Chou, Y., & Chung, Y. -Y., 2008, A Parameterization Study of the Properties of the X-Ray Dips in the Low-Mass X-Ray Binary X1916-053, ApJ, 680, 1405

Smale, A. P., Church, M. J., & Bałucińska-Church, M., 2001, The Ephemeris and Dipping Spectral Behavior of 4U 1624−49, ApJ, 550, 962

Watson, M. G., Willingale, R., King, A. R., Grindlay, J. E., & Halpern, J., 1985, 4U 1624−49, IAU Circ, 4051, 2