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Circumbinary planet study around NSVS 14256825

Circumbinary planet study around NSVS 14256825

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Abstract. The period variability of (O-C) diagram of an eclipsing binary, NSVS 14256825, which is composed of a hot subdwarf type OB star (sdOB) and a main-sequence low-mass type M star (dM) in close orbit with period P= 0.110374 days, previously showed sinusoidal signal cause by the light travel time effects. This signal can be caused by the presence of third bodies. We re-examined (O-C) diagram of the system. We combined eclipse timings from published data and the data taken from ULTRASPEC at 2.4 m at Thai National Telescope on November 2018. From the fitting model, the parameters of the third body in NSVS 14256825 system are obtained.

1. Introduction

NSVS 14256825 is a binary system consisted of a hot subdwarf type OB star and a main-sequence low-mass type M with orbital period 0.110374230 days, that probably have a planet around them. It was discovered by the Northern Sky Variability Survey [1]. From previous studies, its geometrical and physical parameters were obtained i = 82.5 deg, $M_1 = 0.419\ M_\odot$, $R_1 = 0.188\ R_\odot$, $M_2 = 0.109\ M_\odot$, $R_2 = 0.162\ R_\odot$ and $a = 0.80$ AU [2]. Almeida *et al* [3] showed that the system has periodic (O-C) variation which might be caused by the Light Travel Time (LTT) effect from the presence of circumbinary bodies. From that study, the system might be composed of two circumbinary planets. Their orbital periods would be P_3 = 3.5 years and P_4 = 6.9 years with semi-major axes $a_3 \sin i_3$ = 1.9 AU, $a_4 \sin i_4$ = 2.9 AU and masses M_3 = 2.9 M_{Jup} and M_4 = 8.1 M_{Jup}. On the other hand, Nasiroglu *et al* [4] indicated that periodic of O-C variability can be explained by the presence of a brown dwarf-mass third-body with the minimal mass of 14.75 M_{Jup} in an elliptical orbit (e = 0.175) with orbital period of ∼10 years.

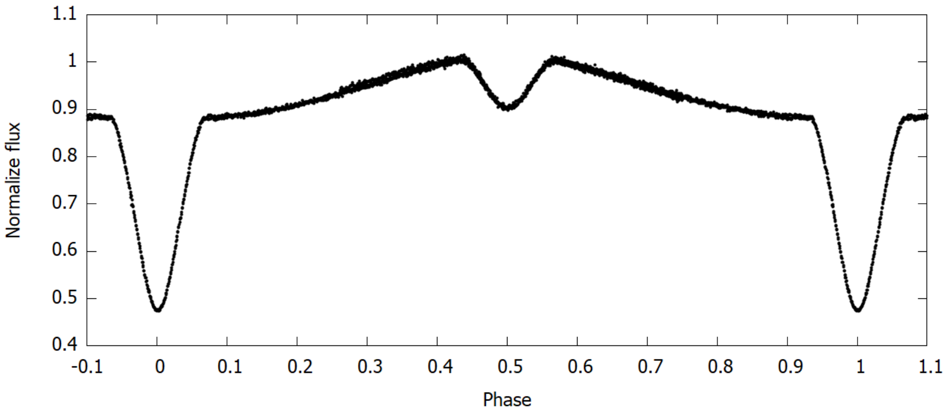

Figure 1. Phase diagram of NSVS 14256815 obtain with ULTRASPEC on the TNT.

In this paper, we present two new primary eclipse times of NSVS 14256825 obtained on 2nd and 5th November 2018. We combine our primary eclipse timings and published data to find physical parameters of its third body.

2. Observation and data reduction

The observation data was taken from ULTRASPEC CCDs (1k x 1k EMCCDs) attached to the 2.4 m Thai National Telescope (TNT) at the Thai National observatory; TNO (lat. $= 90°43'$ N, long. $= 98°28'$ E, alt $= 2{,}457$ m) [5]. Three nights data was obtained in g'-band on 2nd, 3rd and 5th November 2018. The calibration was carried out using the IRAF routine and the photometry was carried out using Python and Sextractor [6]. The phase diagram is shown in figure 1.

3. Analysis and results

From the obtained data, two primary times of minimum from 2nd and 5th November 2018 observations were fitted with PHysics Of Eclipse BinariES (PHOEBE)[7] by using parameters in model 2 of Almeida *et al* [2]. Two primary times of minimum were obtain as $T_{0,2\ \mathrm{Nov}\ 2018}(\mathrm{BJD}) = 2458425.047851 \pm 0.000010$ and $T_{0,5\ \mathrm{Nov}\ 2018}(\mathrm{BJD}) = 2458428.027951 \pm 0.000016$, respectively. To determine the third body in NSVS 14256825, we combine our primary times of minimum with the primary eclipse time from previous study [3-4][8-11]. In order to fit cyclic variation in O-C curve, we use the EMCEE Python package which employs the Markov Chain Monte Carlo (MCMC) technique to examined the orbital period change and parameters of the third body in the system [12].

In order to fit the light-time effect caused by a third body, we use following equation to fit the data,

$$O - C = T_0 + P \times E + K\left[(1-e^2)\frac{\sin(\nu+\omega)}{1+e\cos\nu} + e\sin\omega\right] \quad (1)$$

where T_0 is reference time of minimum, P is orbital period, E is Epoch, K is light travel-time effect amplitude, ν is true anomaly[12], e and ω are eccentricity and Longitude of the periastron passage of the third body's orbit, respectively. In this work, 100,000 MCMC steps with 100 walkers are performed figure 2 and figure 3 fits. The medians of posterior probability from MCMC are used to be the bast fitted parameters. From the MCMC fitting, we obtained the new linear ephemeris as,

$$T_{eph} = \mathrm{BJD}2455793.839930(0) + E0.110374103(2). \quad (2)$$

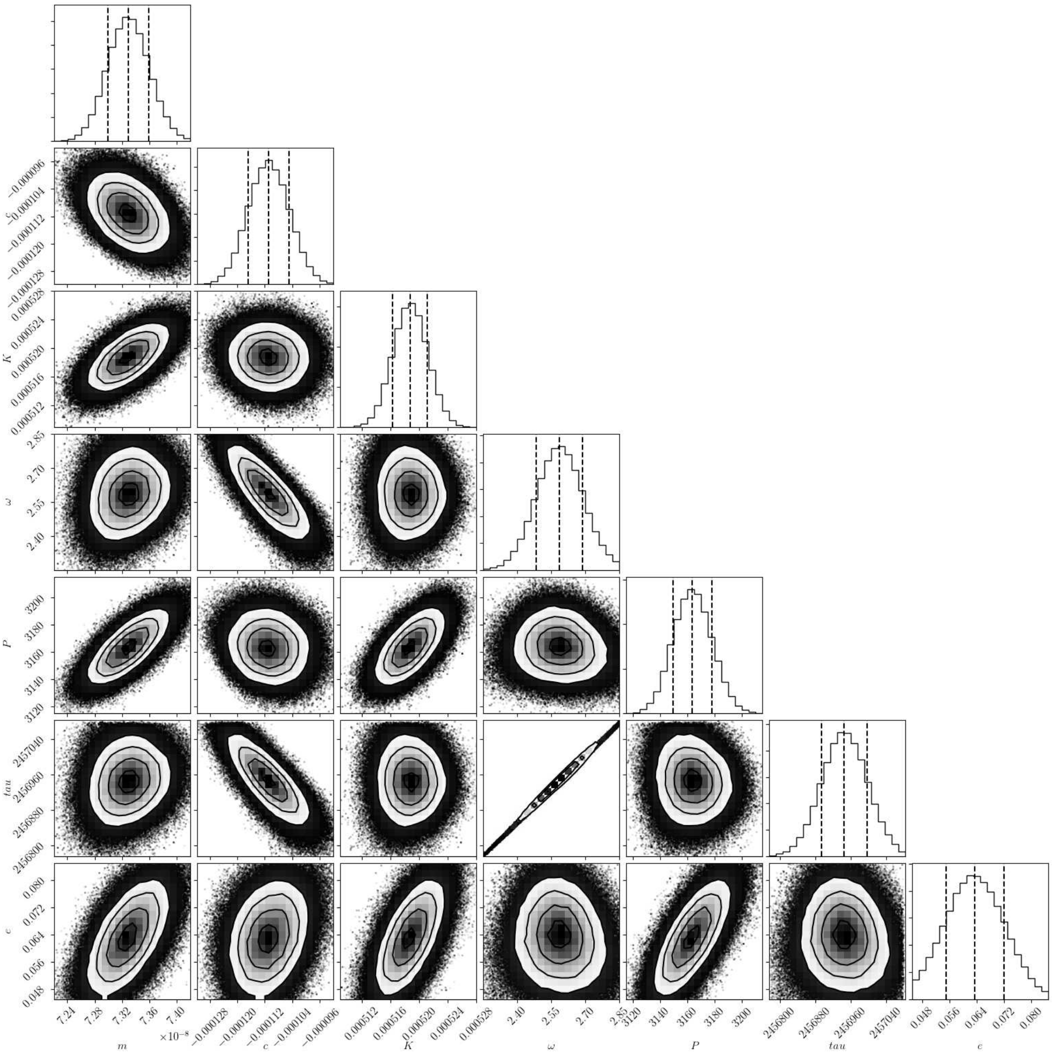

Figure 2. Posterior probability distribution of third body parameters from the MCMC fitting of NSVS 14256825 O-C curve with equation (1). The best fitted parameters (median of posterior probability) are shown in table 1.

Table 1. System parameters of NSVS 14256825.

Parameter	Unit	Value
Third body parameters		
Light travel-time effect amplitude (K)	s	44.8±0.2
Orbital period (P_3)	day	3160±10
Eccentricity (e)	-	0.063±0.008
Longitude of the periastron passage (ω)	deg	148±6
Periastron passage (τ)	BJD	2456940±50
Minimum Mass ($M_3 \sin i_3$)	M_{Jup}	16±1

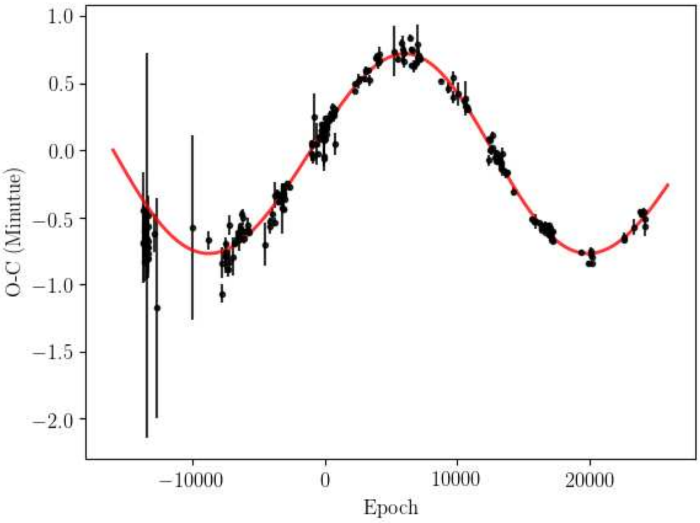

Figure 3. O-C curve of NSVS 14256825 with the best fitting parameters from MCMC (solid line)(see table 1 for detail).

when T_{eph} is time of minimum. The fitting parameters of the third bodies are shown in table 1. The minimum mass of the third body was calculated by mass-function equation and the stellar masses obtained from [2] ($M_1 = 0.419 \pm 0.070 M_{\odot}$ and $M_2 = 0.109 \pm 0.023 M_{\odot}$). As the result, the minimal mass of third bodies is 16 ±1 M_J.

Spiegel *et al* [13] studied on various deuterium-burning masses for a range of models and found that mass brown dwarf is $\sim 13.0 \pm 0.8 M_J$. From zero-metallicty model, with 10 and 90 percent of deuterium burning, masses of brown dwarf are $\sim 11.0 M_J$ and $\sim 16.3 M_J$, respectively.

4. Conclusion

We present the parameters of third body in NSVS14256825 as show in table 1. The O-C variation of the system can be explained by the presence of circumbinary body with minimum mass 16±1 M_J with orbital period 8.66 ± 0.04 years. From obtain minimum mass of third body, the third-body might be a brown dwarf.

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