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THE NEW ECLIPSING POST COMMON-ENVELOPE BINARY SDSS J074548.63+263123.4

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ABSTRACT

The common-envelope process is a complicated phase in binary evolution. A lot of effort has been dedicated to study the common-envelope stage, but many questions related to this process are yet to be answered. If one member of the binary survives the common-envelope phase, the binary will emerge as a white dwarf accompanied by a low-mass main sequence star in close orbit, often referred as a post common-envelope binary (PCEB). SDSS J0745+2631 is among the list of newly found PCEBs from the Sloan Digital Sky Survey (SDSS). This star is proposed to be a strong eclipsing system candidate due to the ellipsoidal modulation in its light curve. In this work, we aim to confirm the eclipsing nature of SDSS J0745+2631 and to determine the stellar and orbital parameters using the software Binary Maker 3.0 (BM3.0). We detected the primary eclipse in the light curve of SDSS J0745+2631 in our follow-up observation from January 2014 using the ULTRASPEC instrument at the Thai National Observatory. The data obtained on 7th and 8th January 2014 in g filter show an evident drop in brightness during the eclipse of the white dwarf, but this eclipse is less prominent in the data taken on the next night using a clear filter. According to our preliminary model, we find that SDSS J0745+2631 hosts a rather hot white dwarf with an effective temperature of 11500K. The companion star is a red dwarf star with a temperature of 3800K and radius of 0.3100 $R_{\odot}$. The red dwarf star almost fills its Roche lobe, causing a large ellipsoidal modulation. The mass ratio of the binary given by the Binary Maker 3.0 (BM3.0) model is M2/M1 = 0.33.

Key words: binaries: eclipsing-star: white dwarf: close-binaries

1. INTRODUCTION

Many close binaries are believed to have encountered an unstable phase of mass transfer leading to a common-envelope (CE) phase, as proposed by Paczynski (1976). In this evolution process, the secondary companion will fall into the envelope of the primary star and slowly expel the primary's envelope due to unstable mass transfer. Binaries which are going through this process are usually known as post common-envelope binaries (PCEBs).

Recently, there have been several publications regarding new PCEBs, including one by Parsons et al. (2013). In this paper, 49 eclipsing white dwarf plus main-sequence binaries were investigated. They analysed the light curves from the Catalina Sky Survey (CSS) and the Sloan Digital Sky Survey (SDSS). The authors identified 29 eclipsing systems, 12 of which were previously unknown. One system (SDSS J0745+2631), however, is suspected but was not confirmed as an eclipsing binary. Parson et al. (2013) reported the orbital period of SDSS J0745+2631 to be 0.219 days with r-mag = 17.46. There was some evidence for a primary eclipse, but it is not clearly shown in the light curves.

Observations of this system were performed on 7th and 8th January 2014 using the Thai National Telescope (TNT) with ULTRASPEC in g filter. We present the finding chart in Figure 1 with the reference star and 4 check stars. The coordinates of the reference and check stars are provided in Table 1. The aim of this study is to do follow up observations of SDSS J0745+2631 and to check whether this system is an eclipsing binary system or not. We will also model this system using BM3.0 to determine the parameters and the geometry of the system.

2. OBSERVATIONS AND DATA REDUCTION

The observations were done at the Thai National Observatory (TNO) using the TNT 2.4-m and ULTRA-

Table 1
STAR, COORDINATES, AND MAGNITUDES.

Star	R.A.	Dec.	g'_{mag}
No.1 (Target)	07:45:48.63	+26:31:23.4	18.792
No.2 (reference)	07:46:01.45	+26:33:06.7	15.765
No.3 (check)	07:45:58.17	+26:32:31.6	16.706
No.4 (check)	07:46:03.27	+26:31:58.1	14.967
No.5 (check)	07:45:41.66	+26:27:11.9	15.454
No.6 (check)	07:45:48.79	+26:26:15.1	15.253

The target, reference, and check stars are shown in one of the g filter frames of our observations.

SPEC instrument (Dhillon et al., 2014). The data were taken on 7th and 8th January 2014 in g filter with exposure times of ∼9 s. We analysed the light curve using the differential photometry method by comparing the flux/brightness of the target star with the reference and the check stars. Some information for these stars (see Table 1) was obtained through the Aladin Sky Atlas. The target, reference, and check stars are shown in one of the g filter frames of our observations (Figure 1.). We performed standard data reduction methods with IRAF to obtain a clean science image as follow:

$$REDUCED = \frac{(Raw\ image) - (Master\ Bias)}{Master\ Flat} \quad (1)$$

where *Master Flat = (Flat-Master Bias)*

3. RESULTS

We analysed the FIT data from ULTRASPEC by finding the relative flux between the target star and reference star. The results were confirmed using several check stars and the averaged light curve is presented in Figure 2. This light curve clearly shows the primary eclipse of SDSS J0745+2631 at an orbital phase of around 1, but unfortunately we cannot detect the secondary eclipse.

Figure 3 gives a check of the light curves from our observations and Parson et al. (2013). We can see that the light curve on the left gives better evidence of the eclipse compared to the result of Parson et al. (2013).

From modelling with BM3.0 we obtain the theoretical light curve and radial velocity curves simultaneously. The fit of the theoretical to the observed light curves is shown in Figure 4 and the residual in Figure 5. When comparing the light curve from the observation and the theoretical light curve from BM3.0, the residual flux is 0.05. BM3.0 also produce the Roche geometry (surface outline) of the system. This result is illustrated in Figure 6, and the system configurations at different phases (0.25, 0.50, 0.75, and 1.0) are shown in Figure 7. By comparing the theoretical to the observed light curves, we are able to obtain the parameters of the binary system (see Table 2.).

4. DISCUSSION

SDSS J0745+2631 is one of the new white dwarf plus main sequence binaries investigated by Parson et al. (2013). The authors found this system to have very large ellipsoidal modulation, implying that the system

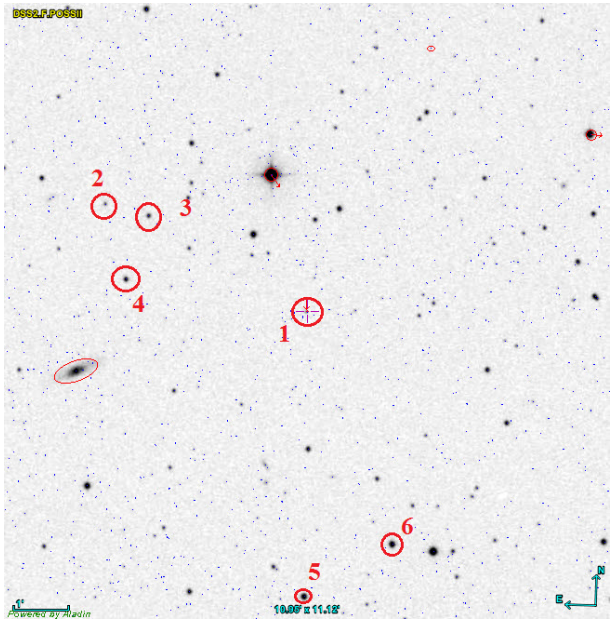

Figure 1. One of the g filter Aladin Sky Atlas images of SDSS J0745+2631. The number 1 refers to the target star, 2 to the reference star, and 3-6 to check stars.

Table 2
BM3 PARAMETERS OF SDSS J0745+2631.

Parameter	Value
Mass ratio input	0.33
Temperature 1 (K)	11500
Temperature 2 (K)	3800
Gravity coefficient 1	2.320
Gravity coefficient 2	1
r1(back)	0.01030
r1(side)	0.01030
r1(pole)	0.01030
r1(point)	0.01030
r2(back)	0.31000
r2(side)	0.27803
r2(pole)	0.26707
r2(point)	0.36647
Inclination	90
Luminosity 1	0.2124
Luminosity 2	0.7876
Wavelength	4825.00
Reflection 1	0.500
Reflection 2	1.000
*Spot co-latitude1(°)	120
*Spot longitude1(°)	130
*Spot radius1(°)	36
*Spot factor1	0.1
*Spot co-latitude2(°)	90
*Spot longitude2(°)	83
*Spot radius2(°)	10
*Spot factor2	1.3

The output parameters of SDSS J0745+2631 from modelling BM3.0.
* Spot of companion star.

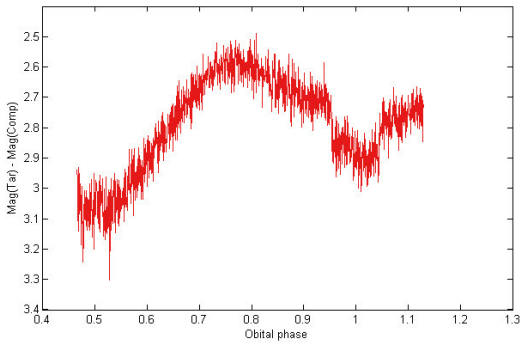

Figure 2. The light curve of SDSS J0745+2631 from TNT+ULTRASPEC in g filter observed on 7th January 2014.

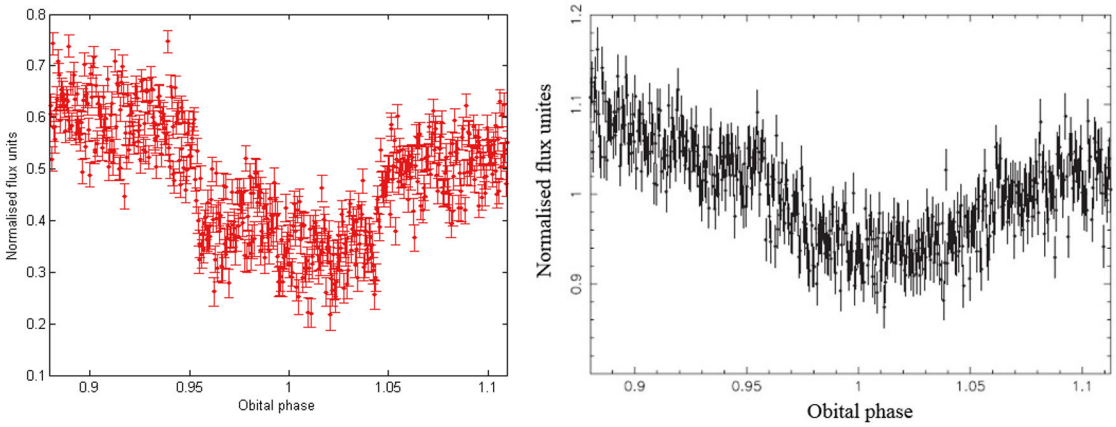

Figure 3. The light curve of SDSS J0745+2631 around orbital phase 1. It can be clearly seen that our observations (left side) can detect the primary eclipse but Parson et al. (2013) observations (right side) have a very small evidence for the primary eclipe.

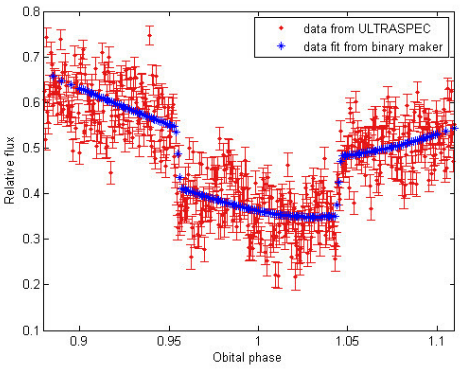

Figure 4. The light curve of SDSS J0745+2631 (red dot points) overaid with the theoretical light curve (blue line).

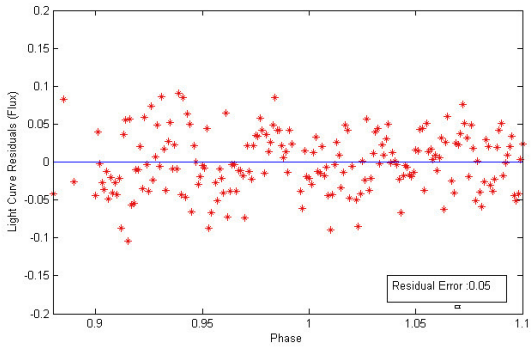

Figure 5. The light curve residual of the SDSS J0745+2631 model.

is both very close to Roche lobe overflow and at high inclination. The spectral type of the main-sequence star is fit by an M2 type star. They also have some possible evidence of the white dwarf eclipse, but the depth of the eclipse is very shallow. They argue that the reason for primary eclipse is that light in the red wavelength region was absorbed by H_2O in the atmosphere. They were not able to confirm this system as an eclipsing binary.

5. SUMMARY

SDSS J0745+2631 was investigated for the first time by Parson et al. (2013). There was some evidence for a primary eclipse, but it was not clearly shown in their light curve. Therefore SDSS J0745+2631 was not confirmed as an eclipsing binary system. We observed

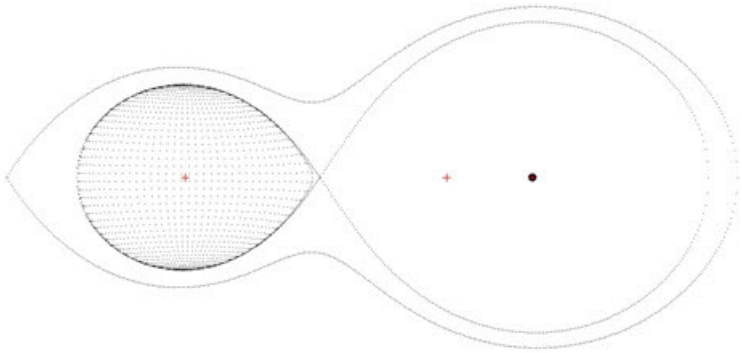

Figure 6. The surface outline of SDSS J0745+2631.

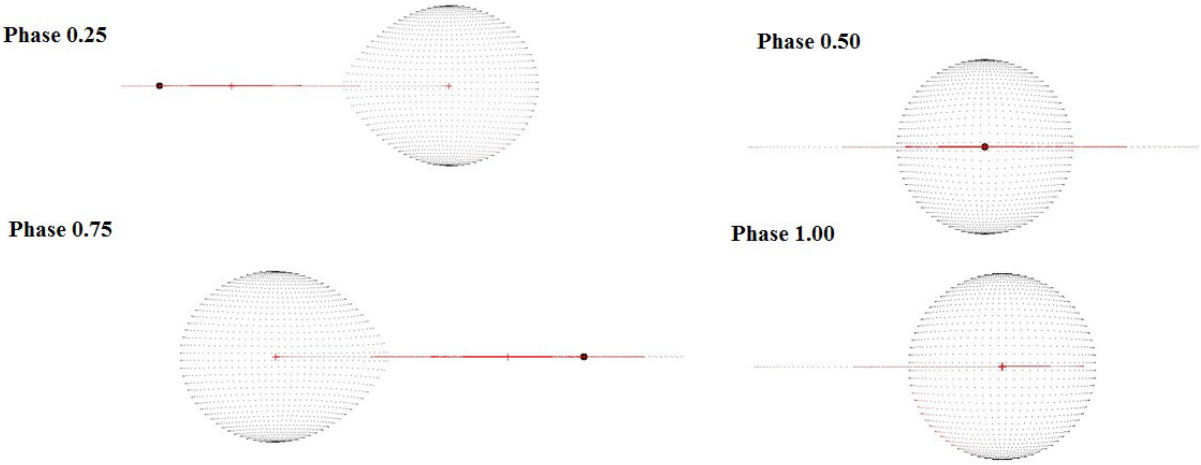

Figure 7. 3D model of SDSS J0745+2631 at different phases (0.25, 0.50, 0.75 and 1.0).

SDSS J0745+2631 with TNT+ULTRASPEC in g filter. For the surface modelling, we use the software BM3.0 where we input known parameters to get the geometry of the star. We measured a temperature and radius of the white dwarf of 11500K and 0.0103 $R_{\odot}$, respectively. The main sequence star has a temperature and radius of 3800K and 0.3100 $R_{\odot}$. The mass ratio is 0.33. From BM3.0 we know that the companion star almost fills its Roche lobe (Figure 6.). We also identified the primary eclipse and confirm that SDSS J0745+2631 is a WDMS eclipsing binary.

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