A Model of Eclipsing Binary System V525 Sgr From CCD Photometry

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Abstract. New BVRI CCD photometry of eclipsing binary system V525 Sgr is presented. It is found that the light curves of V525 Sgr show a typical Eb-type light variation with an O’Connell effect. Photometric solutions and model of V525 Sgr were derived by qualitative fitting method using a Wilson-Devinney program. It showed that the mass ratio, q, of V525 Sgr is 0.55 and it is one of the near-contact binary in which the primary fills its Roche lobe. As the result of light curve fitting. We propose that the O’Connell effect may be attributed to the gas impacts of mass transferring in the system which is represented as a hot spot on the secondary star.

1. Introduction
V525 Sgr was discovered as an eclipsing variable star in 1934 by O’Connell (1935) and was recognized having a difference in its maxima also by O’Connell (1949). Later this difference in magnitude of its maxima is known as O’Connell effect. Cileé & Lindsay (1953) classified this system as EB-type and Payne-Gaposchkin (1949) gave A2 as its spectral type. Since the previous observations, there is no detailed study about this system.

2. Observation
The observations of V525 Sgr in the B, V, R, and I bands were carried out on seven nights from July to September 2013 with the 0.2 m (f/10) Schmidt Cassegrain telescope installed at Gunma Astronomical Observatory-Institut Teknologi Bandung Remote Telescope System (GAO-ITB RTS) house in Bosscha Observatory, Lembang, Indonesia. The telescope is equipped with a CCD camera SBIG ST9-XE. The field of view of the photometric system is 17.26 arcmin × 17.26 arcmin. The differential photometry method has been applied for the observations. CD-30°16666 and CD-30°16667 were chosen as the comparison and the check star, respectively. The coordinates and magnitudes of the variable star, the comparison star, and the check star are listed in Table 1.
Table 1. Coordinates and magnitudes of V525 Sgr, the comparison, and the check stars.

| Stars      | RA (J2000.0) | Dec. (J2000.0) | V     |
|------------|--------------|----------------|-------|
| V525 Sgr  | 19\text{h} 07\text{m} 13\text{s}.530 | -30\text{°} 09\prime 37\prime\prime.70 | 8.28-8.93 |
| The comparison | 19\text{h} 07\text{m} 19\text{s}.489 | -30\text{°} 11\prime 12\prime\prime.89 | 9.87 |
| The check  | 19\text{h} 07\text{m} 19\text{s}.915 | -30\text{°} 13\prime 34\prime\prime.75 | 9.86 |

A standard reduction using calibration images (bias, darks, and flat) has been performed for every night of observations. The instrumental magnitudes were measured by applying aperture photometry method. IRAF\(^1\) has been performed for processing the observed images either for photometry reduction using \texttt{APPHOT} task or for standard reduction using \texttt{CCDRED} task. The CCD light curves in \(B\), \(V\), \(R\), and \(I\) bands with respect to the linear ephemeris given by Kreiner (2004):

\[
HJD = 2452500.648 + 0.7051217 \times E
\]

are shown in Fig. 1.

3. Photometric Solutions
The light curves displayed in Fig. 1 are asymmetric in \(B\), \(V\), \(R\), and \(I\) bands and show typical EB-type variations. This asymmetric in light curves of eclipsing binaries is known as O'Connell effect. The photometric solutions and model of V525 Sgr were obtained by qualitative fitting method using a Wilson-Devinney program (W-D program, Wilson & Devinney 1971). Relative flux in each light curve in Fig. 1 is a normalization of the magnitude difference between V525 Sgr and the comparison star. The absolute parameters of V525 Sgr are not available due to the lack of spectroscopic observations for this object.

The light curves of V525 Sgr have shown a pattern of O'Connell effect where the maximum I (after the primary minimum) is brighter than the maximum II (after the secondary minimum) and also the differences between the two maxima is bigger in \(B\) band than other bands which is redder. These features are in agree with previous observations by O'Connell (1949) and Ciléé & Lindsay (1953). The consistent of appearance of this O'Connell effect may be caused by a hot spot due to the impact of mass transferring of gas stream in the system from the primary to secondary star. In order to obtain the photometric parameters, the temperature of primary star was adopted about 9250 K which corresponds to its spectral type. The other adopted parameters are the limb darkening coefficients for \(B\), \(V\), \(R\), and \(I\) bands as given in van Hamme (1993), the gravity darkening coefficients as given in Lucy (1967), and the period of the system as given in Kreiner (2004). We also assumed that this system has a circular orbit and there is no reflection effect and no differential rotation. The adjustable parameters were the orbital inclination \(i\), the mean temperature of secondary star \(T_2\), the mass ratio \(q\), and the spot parameters. The spot parameters are consist of coordinate (co-latitude and longitude), radius, and temperature factor of the hot spot. The light curves are fitted with a hot spot located on secondary star which in agreement with the mass transferring that may occurred in this system. Its photometric solutions are listed in Table 2.

The calculation for determining the configuration have been carried out for each value of \(q\). The final configuration of the system is a semi-detached system or near-contact system where the primary filling its Roche lobe and the secondary is very close to its Roche lobe. The model of its configuration is shown in Fig. 2.

\(^1\) Image Reduction and Analysis Facility (IRAF) is distributed by the National Optical Astronomy Observatory (NOAO), which is operated by the Association of Universities for Research in Astronomy, Inc.
Table 2. Photometric solutions for V525 Sgr.

| Parameters | Photometric Elements |
|------------|----------------------|
|            |                      |
| $g_1$      | 1.000                |
| $g_2$      | 0.320                |
| $X_{1B}$   | 0.543                |
| $X_{2B}$   | 0.860                |
| $X_{1V}$   | 0.458                |
| $X_{2V}$   | 0.668                |
| $X_{1R}$   | 0.380                |
| $X_{2R}$   | 0.516                |
| $X_{1I}$   | 0.304                |
| $X_{2I}$   | 0.413                |
| $T_1$      | 9250 K               |
| $T_2$      | 6200 K               |
| $P$        | 0.7051217 d          |
| $q (M_2/M_1)$ | 0.550          |
| $\Omega_{in}$ | 3.959         |
| $\Omega_{out}$ | 3.540       |
| $i$        | 74°                  |
| $L_1/(L_1+L_2)$ (B) | 0.901          |
| $L_1/(L_1+L_2)$ (V) | 0.877          |
| $L_1/(L_1+L_2)$ (R) | 0.862          |
| $L_1/(L_1+L_2)$ (I) | 0.828          |
| $r_1$ (pole) | 0.417          |
| $r_1$ (side) | 0.444          |
| $r_1$ (back) | 0.478          |
| $r_2$ (pole) | 0.301          |
| $r_2$ (side) | 0.314          |
| $r_2$ (back) | 0.343          |
| Co-latitude_{spot} | 90°           |
| Longitude_{spot} | 73°.7          |
| Radius_{spot} | 19°            |
| Temperature factor_{spot} | 1.75        |

4. Discussion and Summary
O’Connell (1949) found that the light curves of V525 Sgr were asymmetric from the photographic observations where the maximum after the primary minimum is brighter than the maximum after the secondary minimum. The asymmetries of the $B$, $V$, $R$, and $I$ bands are all less than 0.1 mag as shown in Fig. 1. The O’Connell effect in eclipsing binary systems has been the most challenging topic in binary star studies. There are some theories that have been suggested to explain the nature of O’Connell effect such as the starspots theory, the gas stream impacts theory, the circumstellar matter theory or the asymmetric circumfluence due to coriolis forces theory (Wilsey & Beaky, 2009). But there is no theory that has been successfully applied to an excessively number of eclipsing binary systems. The starspots theory could not explain the consistent of appearance in the maxima of V525 Sgr, but the gas stream impacts theory may
explain this phenomenon. The last two theories that have been mentioned do not have the attention as much as the first two theories. Therefore, the hot spot due to the gas stream impact is included in the analysis.

The photometric solution using W-D program indicates that V525 Sgr is a semi-detached or near-contact eclipsing binary system with a mass ratio of $q = 0.55$. Due to the lack of spectroscopic observations, the absolute parameters of this system have not derived. The orbital inclination, $i$, is obtained $74^\circ$. Further CCD photometric and spectroscopic observations are needed to gain information about the absolute parameters and to confirm if the nature of the O’Connell effect in this system is due to the gas stream impacts theory.

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Figure 1. The light curve of V525 Sgr in the $B$, $V$, $R$, and $I$ bands. The plus symbols and solid lines represent the observational and theoretical light curves, respectively.
Figure 2. The final configuration of V525 Sgr in phase 0.17 and its Roche lobe model. The red spot in the final configuration represents the location of the hot spot on the surface of secondary star.