Light Curve Analysis and System Parameters of Contact Binary V608 Cassiopeiae

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Abstract. A new photometric data study of eclipsing binary system is presented. The accepted solutions of analyzing the light curve revealed that V608 Cassiopeiae is a contact binary with two solar-type spectra component. The primary component of this system is the massive one. The geometric configuration indicates that each component of V608 Cas exactly fills its limited Roche lobe and mass overflows outside of the lobe, which makes it the common envelope. The new epoch, the primary and secondary minimum and the absolute physical parameters of the contact binary system were calculated. The evolution status of contact binary V608 Cas has been investigated.

1. Introduction
The evolution study of stars has resulted in us knowing the hidden truths of the universe. Researching topics associated with binary star systems provide us with a higher understanding to an origin and end of stars. The short-period orbital of eclipsing binary systems makes it an ideal target for stellar evolution studies. V608 Cassiopeiae or V608 Cas or GSC4320-1035 (α = 02h 24m 26.1s and δ = + 71° 23′ 07″) was found to be a variable star by Hübel (1976) [1]. Period variations of V608 Cas are studied by numerous authors (period shorter than 0.47 days [2]). Blättler and Diethelm (2001) rediscovered it to be an eclipsing binary of W Uma-type (EW) [3]. This system is a Beta Lyrae-type (EB) variable given by Samus et al. (2003) [2]. However, Liu et al. (2016) reported the photometric solution data of V608 Cas that it is an EW type contact binary [4]. The evolution of V608 Cas may be on the thermal relaxation oscillation (TRO) theories-controlled stage [4].

This paper presents the observations and the data reduction procedures in section 2. Section 3 an analysis of the orbital solution and period variation of V608 Cas with a time of minima. The details of photometric solutions are described in section 4. In section 5, the evolutionary status of V608 Cas is discussed and get to the conclusion.

2. Observations and data reduction
This work carried out the new photometric observations of V608 Cas on 14 to16 December 2016 using the 0.7-m reflecting telescope at Gao Mei Gu Observatory in Lijiang, China. The telescope is equipped with 2048 × 2048 pixel CCD. Johnson VR filters were used. The exposure time for V and R filters are the 60s. The data reduction and differential magnitude measurements were made with MaxIm DL5 program. The stars 2Mass J02235161 (α = 02h 23m 51.7s and δ = + 71° 19′ 34″) and 2Mass J02241045 (α = 02h 24m 10.4s and δ = + 71° 23′ 51″) were used as comparison and check stars, respectively. The VR light curves of V608 Cas plotted in figure 1.
3. Period analysis and (O-C) diagram

The data reduction was imported to a spreadsheet and the new times of minima calculated by the polynomial fitting program. The linear ephemeris of V608 Cas was then monitored many times by several researchers such as Blättler and Diethelm (2001), Hubscher and Walter (2007), Diethelm (2009, 2010, 2011, 2012, 2013), Nelson (2010, 2015), Hubscher (2011), Hubscher and Lebmann (2012), Honkova et al. (2013), Lui et al. (2016) and Pena et al. (2015) [3-16]. In this paper, the data for V608 Cas was initially phased with linear ephemeris by Liu et al. (2016) [4]:

\[
\text{Min. } I = \text{HJD}2456289.0819(\pm0.0012) + 0.685 \times 38040239(\pm0.00000022) \times E
\]

Where \(E\) stands for the epoch number. The (O-C) residuals for all the times of minimum light according to the linear and quadratic ephemeris were calculated. Using the least squares method, this work revised the new linear ephemeris of V608 Cas:

\[
\text{Min. } I = \text{HJD}2457739.00125(\pm0.00083) + 0.6853804057(\pm0.0000025) \times E
\]

According to the quadratic ephemeris, this paper presents the (O-C) diagram of the period analysis of V608 Cas in figure 2. The figure showed a parabola curve to fit the formula of a long-term increase tendency. The following quadratic ephemeris of V608 Cas was amended:

\[
\text{Min. } I = \text{HJD}2457739.00097(\pm0.00078) + 0.6853804063(\pm0.0000029) \times E + 3.44(\pm0.06) \times 10^{-6} \times E^2
\]

Equation 3 shows that the quadratic term denotes a continuous period of V608 Cas increase at a rate of \(\frac{dP}{dt} = +6.6(\pm0.7) \times 10^{-7}\) days/year.

![Figure 1](image1). The VR light curves of V608 Cas were observed on 14 to 16 December 2016.

![Figure 2](image2). The (O-C) diagram of the time of light minimum for V608 Cas.

4. Photometric solutions

The VR light curves of V608 Cas were analyzed with the PHOEBE program, which based on the Wilson Devinney (WD) code (https://sourceforge.net/projects/phoebe/). The effective temperature of primary component \((T_1)\) as 5660 K from calibration of Liu et al. (2016) [4]. The gravity darkening and the bolometric albedo coefficients were set values of \(g_1 = g_2 = 0.32\) from Lucy (1967) [17] and \(A_s = A_r = 0.5\) from Rucinski (1969) [18]. The logarithmic limb-darkening coefficients interpolate from VanHamme (1993) [19]. A q-search method was used to get an initial input parameter of the mass ratio \((q = M_2/M_1)\). The best \(q\) value for V608 Cas was investigated by \(q - \Sigma(O-C)^2\) relations.

The double contact (Mode 6) of the WD code with each component fills its Roche lobe is computed for V608 Cas. The other parameters such as the effective temperature of secondary component \((T_2)\), the orbital inclination \((i)\), the Surface potentials \((\Omega_1 = \Omega_2)\) and the relative luminosity of primary component...
\(\frac{L_1}{(L_1+L_2)}\) are adjusted. The best fit of V and R light curve between the observation and model for V608 Cas in figure 3. The light curve presents the maximum asymmetry, which so-called O’ Connell effect [20]. A cool spot model was used to treat asymmetry of the VR light curve on primary component. The following table 1, lists the obtained parameters and the geometrical structure of V608 Cas is shown in figure 4. The absolute physical parameters of V608 Cas are calculated using the empirical relations computed by Harmanec (1988) [21], which are listed in table 2.

**Table 1. Photometric solutions for V608 Cas**

| Parameters | Value | Error | Parameters | Value | Error |
|------------|-------|-------|------------|-------|-------|
| \(g_1=g_2\) | 0.32  | Fixed | \(q=M_2/M_1\) | 0.34  | ±0.0028 |
| \(A_1=A_2\) | 0.5   | Fixed | \(I \) (degree) | 81.44 | ±0.0052 |
| \(\Omega_1=\Omega_2\) | 2.553031 | ±0.219 | \(L_1/(L_1+L_2)\) | 0.7061 | ±0.026 |
| \(x_1, x_2\) | 0.64699, 0.64691 | Fixed | \(\theta \) (degree) | 40 | ±5.3 |
| \(y_1, y_2\) | 0.20208, 0.20208 | Fixed | \(\Psi \) (degree) | 280 | ±6.4 |
| \(T_1(K)\) | 5660  | Fixed | \(r_1\) (degree) | 16 | ±0.2 |
| \(T_2(K)\) | 5830  | ±64   | \(T_1/T_2\) | 0.9 | ±0.014 |
| \(\Sigma(O-C)^2\) | 0.069326 | |

**Table 2. Absolute physical parameters of V608 Cas.**

| Element | value | Element | value | Element | value | Element | value |
|---------|-------|---------|-------|---------|-------|---------|-------|
| \(M_1(M_ʘ)\) | 0.93  | \(R_1(R_ʘ)\) | 0.47  | \(T_1(K)\) | 5660  | \(m_{bol2}\) | 6.38  |
| \(M_2(M_ʘ)\) | 0.38  | \(L_1(L_ʘ)\) | 0.55  | \(T_2(K)\) | 5830  | \(Log g_1\) | 4.13  |
| \(R_1(R_ʘ)\) | 0.77  | \(L_2(L_ʘ)\) | 0.23  | \(m_{bol1}\) | 5.42  | \(Log g_2\) | 4.10  |
| Spectral Type | G2-G5 |

![Figure 3. The VR light curves for V608 Cas fitted with the spotter model.](image1.png)

![Figure 4. The geometrical structure of V608 Cas at phase 0.00, 0.25, 0.50 and 0.75.](image2.png)

5. Discussion and Conclusions

The evolutionary status of each component used the Zero Age Main Sequence (ZAMS) and the Terminal Age Main Sequence (TAMS) of the evolutionary models, that adopted by Polst et al. (1998) [22]. In figure 5 and figure 6 show the components of V608 Cas on the Mass-Luminosity (M-L) relation and Mass-Radius (M-R) relation, respectively. The components of contact binary V608 Cas on the M-L and M-R relations revealed that the primary component is a main sequence star, that used the intermediate mass stars by Malkov (2007) [23]. The secondary component is an evolved component with considerably over luminous are compared by the main sequence stars.
The primary component of V608 Cas is the massive one. The V608 Cas is a contact binary system in a stage of evolution in which each component fills exactly its critical Roche lobe. The geometric configuration indicates that mass of each component overflows outside of the lobe, that makes it a common envelope.

The effective temperature of each component denoted by spectral types G5 and G2 (solar-type spectra) for the primary and the secondary component, respectively. The best fit for the V\textsubscript{R} light curves of V608 Cas yields mass ratio q = 0.34. The observed asymmetry among the light curves of V608 Cas is explained by a cool spot on the primary component that is 90% cooler than the surrounding.

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