# Light curve analysis of the new eclipsing binary LD355

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**Abstract.** The V light curve of eclipsing binary LD355 was analyzed by using the latest version of Wilson Program in order to derive photometric elements of this system. Since no spectroscopic mass ratio is available, the q-search method was applied to yield the preliminary range of mass ratio in order to search for the final solution. The solution was performed by assuming detached (mode 2) and semi-detached (mode 5) configurations, since no classification of the system based on the shape of light curve is possible . The solution in mode 5 leads to an acceptable model. The present solution reveals that LD355 has a photometric mass ratio $q = 0.178$ and is a semi-detached binary with the secondary component filling the Roche lobe.

**Key words:** binaries – eclipsing

## 1. Introduction

The new eclipsing binary LD355 ( GSC 3560.1804, $\alpha_{2000} = 19^h35^m23^s.12$, $\delta_{2000} = +48°03'0.''75$, $m_v = 13.8 - 14.6$) has been discovered to be variable by Dahlmark (2000) and is classified as an eclipsing binary with an uncertain period of P=$25^d.81$. Later on a team of AAVSO members( Guilbault et al. 2001) used CCD, visual and photographic observations to more precisely determine the nature and brightness history of this system. They used Minima of all sources and derived the following new linear ephemeris :

$$MinI = 2451874.6174 + 1^d.1051023 \times E \qquad (1)$$

Henden (2000) accomplished all sky photometry of the field of LD355 in standard Johnson-Cousins BV$(RI)_c$ bandpasses. He measured the magnitude and colors of LD355 at maximum light and at primary and secondary minimum. As CCD data in V-color bandpass as well as all sky photometry of this system proved to be highly precise and reliable, we utilized the same data for analysis.

## 2. Light curve analysis

The CCD data we obtained through correspondence with P.R. Guilbault were analyzed to derive the photometric elements of the system. Based on ephemeris (1), light curve in V filter is shown in Fig.1.

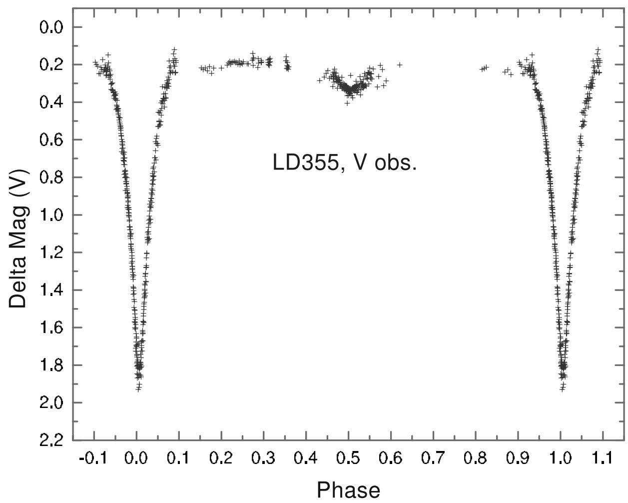


**Fig. 1.** The individual V observations of LD355

The analysis of the light curve is quite difficult for the following reason: (a) Unknown spectroscopic mass-ratio; (b) inadequate observational data between phase interval 0.1-0.45 and 0.6-0.85 to determine any possible spot on the stars.

Photometric solution of the LD355 was obtained by employing the latest version of the Wilson program (2002).

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This version possesses an option to work with either observed times or phases, additional solution parameters (the zero point of the orbital ephemeris $HJD_0$, orbital period at initial epoch $P$, and first time derivative of the orbital period $dP/dt$, among other parameters), the Marquardt algorithm (Marquardt 1963) in differential corrections solutions and conversion of the entire program to double precision. In the differential corrections program (DC) the adjusted parameters were divided into multiple subsets (Wilson and Biermann 1976), whose members were not strongly correlated. The DC program output provided a table of correlation coefficients and each subset consisted of the largest number of adjusted parameters which were uncorrelated. The adjustments from the subset with the smallest predicted $\sum(\mathrm{res})^2$, the sum of the weighted squares of the residual, were applied to the parameters of next run of the program. The run continued until adjustments became smaller than corresponding mean errors.

We first obtained normal points in order to get the preliminary solution, but afterwards, all CCD data in V-color bandpass(612 points) were used to obtain the final solution. Since no spectroscopic mass-ratio was known, a search for solution was made for mass-ratio q ranging from 0.1 to 3.3. The lowest values of the sum of the weighted squared residuals, $\sum(\mathrm{res})^2$, occurred around q=0.2 in mode 5 (semidetached mode) and q=2.8 in mode 2 (detached mode). Figure 2 shows the fit parameters $\sum(\mathrm{res})^2$ as a function of mass-ratio q in modes 2 and 5. We finally adopted the solution in mode 5 (with $q = 0.178 \pm 0.003$) by taking into account the better fit of the solution.

The spectral type information of the system being unavailable, we made use of the color index $(B-V)_{max} = 0.310$ given in Henden and the tables of Popper (1980), Flower (1996) and those of Zombeck (1990) to determine the temperature of the primary component (star eclipsed at Min.I). As a result, the temperature of the primary component proved to be $T_1 = 7200\ ^\circ$K and The corresponding spectral class was the type $F0$, which is a generally accepted spectral type for the primary component of Algol stars. The gravity-darkening coefficients were adopted to be $g_1 = g_2 = 0.32$ (Lucy 1967), and bolometric albedo to be $A_1 = A_2 = 0.50$ (Rucinski 1969) in accordance with the assumed stellar convective envelope. Stellar rotation was assumed to be synchronized for both components. We used bolometric linear, logarithmic and square root limb-darkening law in Wilson Program and the best result was obtained for bolometric logarithmic limb darkening law of Klinglesmith and Sobieski(1970) of the form:

$$I = I_0(1 - x + x\cos\theta - y\cos\theta\ln(\cos\theta)) \tag{2}$$

and both x and y parameters of the two components were fixed to their theoretical values, interpolated from Vhlimb program of Van Hamme(1993). The grid resolution values were taken as 20, 20, 15, 15 for N1, N2, N1L and N2L, respectively and we used the simple reflection model (Wilson, 1990), with a single reflection (MREF=1, NREF=1).We also assumed that the stars had no spots and nor third light, $l_3 = 0.0$. The adjustable parameters were: the inclination i, the mean surface temperature of secondary component $T_2$, the non-dimensional surface potential of primary component $\Omega_1$, the monochromatic luminosity of the primary component $L_1$,the orbital period p, the zero point of the orbital ephemeris $HJD_0$, the time derivative of orbital period $dp/dt$ and the mass ratio $q = m_2/m_1$. These parameters were varied until the solution converged. That is, the convergent solution was obtained with the adjustable parameters by iterating, until the corrections on the parameters became smaller than corresponding mean errors. The results of final solutions are given in Table 1. The theoretical light curve calculated with the final elements given in Table 1 are shown in Fig. 3. The configuration of the LD355 calculated with the Roche model is shown in Fig. 4. Accordingly, the system LD355 is a semi-detached binary.

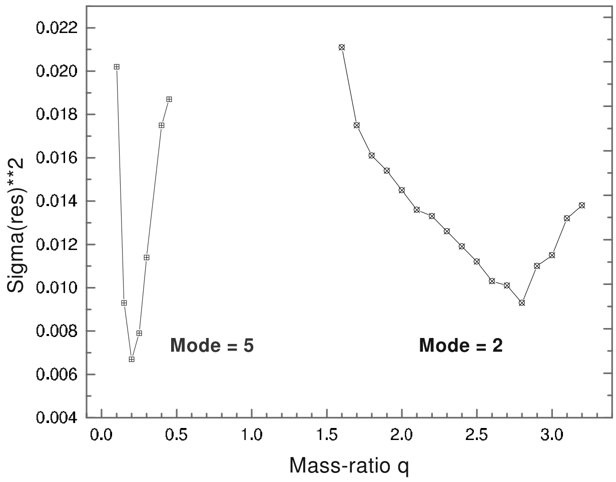


**Fig. 2.** The behavior $\sum(\mathrm{res})^2$ as a function of mass-ratio q

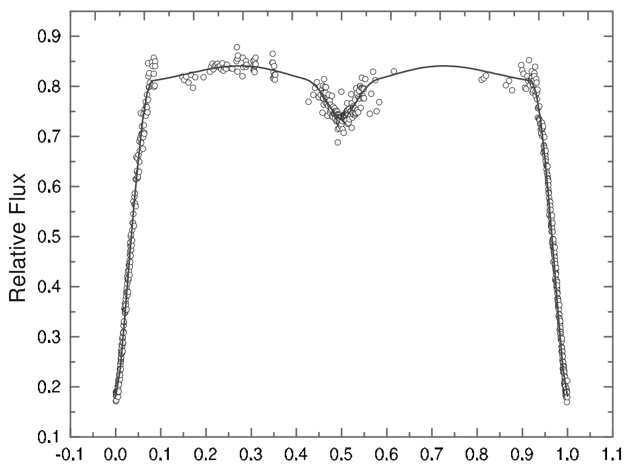


**Fig. 3.** V light curve (open circles) and the synthetic light curve (solid lines) based on the photometric solution of LD355.

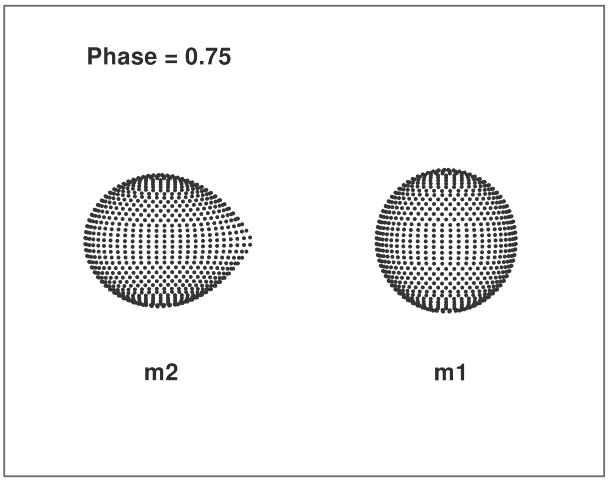


**Fig. 4.** A three-dimensional model of LD355 for phase 0.75

**Table 1.** Photometric solutions of LD355

| Parameter | Value |
|---|---|
| $i\ (degree)$ | $86.934 \pm 0.161$ |
| $q = m_2/m_1$ | $0.178 \pm 0.003$ |
| $\Omega_1$ | $4.3092 \pm 0.0215$ |
| $A_1 (= A_2)$ | $0.500^*$ |
| $g_1 (= g_2)$ | $0.320^*$ |
| $l_3$ | 0.00 |
| $T_1(K)$ | $7200^*$ |
| $T_2(K)$ | $4628 \pm 21$ |
| $x_1$ | $0.776^*$ |
| $x_2$ | $0.831^*$ |
| $y_1$ | $0.303^*$ |
| $y_2$ | $-0.127^*$ |
| $L_{1V}/(L_1 + L_2)$ | $0.8874 \pm 0.0041$ |
| $L_{2V}/(L_1 + L_2)$ | $0.1125 \pm 0.0041$ |
| $r_1(pole)$ | $0.2417 \pm 0.0013$ |
| $r_1(point)$ | $0.2449 \pm 0.0014$ |
| $r_1(side)$ | $0.2438 \pm 0.0013$ |
| $r_1(back)$ | $0.2446 \pm 0.0013$ |
| $r_2(pole)$ | $0.2251 \pm 0.0012$ |
| $r_2(point)$ | $0.3309 \pm 0.0133$ |
| $r_2(side)$ | $0.2341 \pm 0.0013$ |
| $r_2(back)$ | $0.2663 \pm 0.0013$ |
| $period$ | $1^d.1050862 \pm 0.0000107$ |
| $HJD_0$ | $2451874.61749 \pm 0.00018$ |
| $\sum(\text{res})^2$ | 0.0064 |

$^*$assumed

## 3. Conclusion

In our photometric analysis, LD355 is found to be a semi-detached binary system. The secondary component is in contact with its Roche lobe and the primary is inside of its Roche lobe. The photometric mass-ratio is estimated about $q = 0.173 \pm 0.003$ and radial velocity curves are necessary for more reliable estimation of mass-ratio. The temperature of primary was adopted to be $T_1 = 7200\ ^\circ$K, corresponding to a spectral type of F0V, while the surface temperature difference between the two components is computed to be about $\Delta$T=2572 °K and the temperature of secondary is derived as $T_2 = 4628 \pm 21\ ^\circ$K, corresponding to a spectral type of K2.

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