COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 5797

Konkoly Observatory
Budapest
27 September 2007

HU ISSN 0374 – 0676

PHYSICAL PARAMETERS OF THE COMPONENTS OF THE VISUAL BINARY CCDM 11289–6256

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Recently (Fabricius et al., 2002), the star HD 99898 was discovered to be a visual binary (CCDM 11289–6256) with $V_A = 9\overset{m}{.}9$, $V_B = 10\overset{m}{.}3$, and $\rho = 0\overset{''}{.}8$. Somewhat earlier, it was found to be an eclipsing system with $P = 5\overset{d}{.}048912$ (Pojmanski, 2000). Otero and Wils (2006) reported fast apsidal motion of the eclipsing binary's elliptic orbit, with the period $U_{\rm obs} = 135 \pm 10$ years.

Earlier the star, which is a member of the young association Cru OB1, was considered a single object. Its brightness variability was first noticed from outside-atmosphere ultraviolet observations by Wesselius et al. (1982), and it entered the Supplement to the NSV catalog as NSV 18773. From Strömgren and H_β photometry, Kaltcheva and Georgiev (1994) estimated the star's absolute parameters. However, the discovery of the star being a visual binary and of its eclipsing variability makes it necessary to revise the parameters determined earlier.

Figures 1 and 2 present the V-band and I-band light curves of NSV 18773, respectively from ASAS-3 (Pojmanski, 2002) and ASAS-2 (Pojmanski, 2000) data. To plot the curves, the phases of the observations near MinI and MinII were calculated with the same epoch, MinI = HJD 2452068.1717(22), which corresponds to the primary minimum epoch in the middle of the available observations, but with different periods, $P_{\rm I}$ and $P_{\rm II}$ respectively for MinI (phases between 0.75 and 0.25) and MinII (phases between 0.25 and 0.75), derived from our analysis of all the observations:

$$P_{\rm I} = 5\overset{d}{.}049164(10), \quad P_{\rm II} = 5\overset{d}{.}049833(12).$$

It appears from the figures that the V-band and I-band light curves are very similar and that the primary minimum is twice wider than the secondary one, evidencing a large orbital eccentricity. We determined the photometric elements from our analysis of these light curves applying the iterative method of differential corrections (Khaliullina and Khaliullin, 1984), they are presented in the figures using the standard notation. Table 1 contains the V- and I-band magnitudes of all the components of the system, found from the derived L_1, L_2, and L_3 and the combined outside-eclipse V and I magnitudes of the system. The physical parameters of the components computed from our photometric elements are collected in Table 2.

The following remarks to the tables are needed.

1. The contribution of the third light to the V-band and I-band light curves is the same, $L_3 \equiv L_A = 0.61$ of the visual system's combined brightness. Thus, it is the fainter B component of the visual system that is the eclipsing binary, $L_B \equiv L_1 + L_2 = 0.39$.

2. The minima being shallow, the light curves do not permit to find the components' radius ratio precisely enough without additional assumptions. Thus we used the natural assumption that the components are of equal age. The ages of the components were determined by comparison of $\log g_1$ and $\log g_2$ to the stellar evolutionary models from Claret and Gimenez (1992).

3. Since it is the A component that mainly contributes to the system's light, the spectral type estimate Sp = O9V (Jaschek, 1978) must refer to this particular component. In such a case, we are able to estimate the spectral type of the primary of the eclipsing binary as Sp_1 = B0V and of its secondary, as Sp_2 = B1V from the V-magnitude differences of all the components (equivalent to the differences of their absolute magnitudes, M_V) and the ratio of surface brightnesses, J_2/J_1.

4. No radial velocity curves were published for the system. We thus adopted $M_1 = (20 \pm 1.5)M_\odot$ and $T_1 = (31\,500 \pm 1\,500)$ K for Sp_1 = B0V, in agreement with the known empirical relations between stellar parameters. The rest of the absolute parameters in Table 2 are derived from M_1, T_1, and the photometric elements.

5. The color excess, $E_{B-V} = 0^{\mathrm{m}}.65$, and the extinction, $A_V = R \cdot E_{B-V} = 2^{\mathrm{m}}.02$ for $R = 3.1$, were calculated using the UBV magnitudes of HD 99898: V = $9^{\mathrm{m}}.35$, B–V = $0^{\mathrm{m}}.34$, U–B = $-0^{\mathrm{m}}.63$ (Nicolet, 1978) and $(\mathrm{B{-}V})_0 = -0^{\mathrm{m}}.31$ for Sp = O9V. IR photometry of HD 99898 is known from the 2MASS Point Source Catalog: J = $8^{\mathrm{m}}.421$, H = $8^{\mathrm{m}}.352$, and K = $8^{\mathrm{m}}.287$. The value $R = 3.1$ used to calculate A_V is based on the agreement of $(\mathrm{V{-}K})_0^{\mathrm{obs}}$ with the mean $(\mathrm{V{-}K})_0 = -0^{\mathrm{m}}.90$ for OV and B0V stars.

The age we derive for the system, $t = (2.8 \pm 0.5) \cdot 10^6$ years, is twice lower than that found by Kaltcheva and Georgiev (1994), whereas our distance to the system, $d = (3.3 \pm 0.3)$ kpc, is larger by a factor of 1.5. This is obviously due to multiplicity of HD 99898 not taken into account in the cited paper.

With the derived parameters of the system, we can use the known theoretical relations (Kopal, 1978) and models of stellar evolution (Claret and Gimenez, 1992) to compute the theoretically expected apsidal-motion period:

$$U_{\mathrm{th}} = 169 \pm 15 \text{ years.}$$

U_{th} somewhat exceeds $U_{\mathrm{obs}} = 135 \pm 10$ years, as found in Otero and Wils (2006). To improve the system parameters, spectroscopic observations permitting to obtain the radial velocity curves and to determine the axial-rotation angular velocities of the components are needed.

This study was supported, in part, by a grant from the Russian Foundation for Basic Research (grant No. 05-02-16289) and by a grant from the "Origin and Evolution of Stars and Galaxies" Program of the Presidium of the Russian Academy of Sciences.

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Table 1. Magnitudes and spectral types of the components of the visual binary CCDM 11289–6256 (A + B), the eclipsing binary NSV 18773 (B = Pr + Sec), and the whole system of HD 99898 (A + Pr + Sec)

	A	B = Pr + Sec	Primary	Secondary	HD 99898 A + Pr + Sec
V	$9\overset{\mathrm{m}}{.}89$	$10\overset{\mathrm{m}}{.}37$	$10\overset{\mathrm{m}}{.}80$	$11\overset{\mathrm{m}}{.}58$	$9\overset{\mathrm{m}}{.}35$
I	$9\overset{\mathrm{m}}{.}37$	$9\overset{\mathrm{m}}{.}85$	$10\overset{\mathrm{m}}{.}27$	$11\overset{\mathrm{m}}{.}09$	$8\overset{\mathrm{m}}{.}83$
Sp	O9V	–	B0V	B1V	–

Table 2. Physical parameters for the eclipsing binary NSV 18773

Parameter	Primary	Secondary
Mass $M/M_\odot$	20 ± 1.5	14 ± 1.0
Radius $R/R_\odot$	6.5 ± 0.2	5.0 ± 0.2
Effective temperature T_e, K	$31\,500 \pm 1\,500$	$27\,000 \pm 1\,000$
Luminosity $\log L/L_\odot$	4.57 ± 0.08	4.08 ± 0.06
Gravity $\log g$	4.11 ± 0.03	4.18 ± 0.03
Abs. visual magnitude M_V	$-3\overset{\mathrm{m}}{.}79 \pm 0\overset{\mathrm{m}}{.}21$	$-3\overset{\mathrm{m}}{.}00 \pm 0\overset{\mathrm{m}}{.}17$

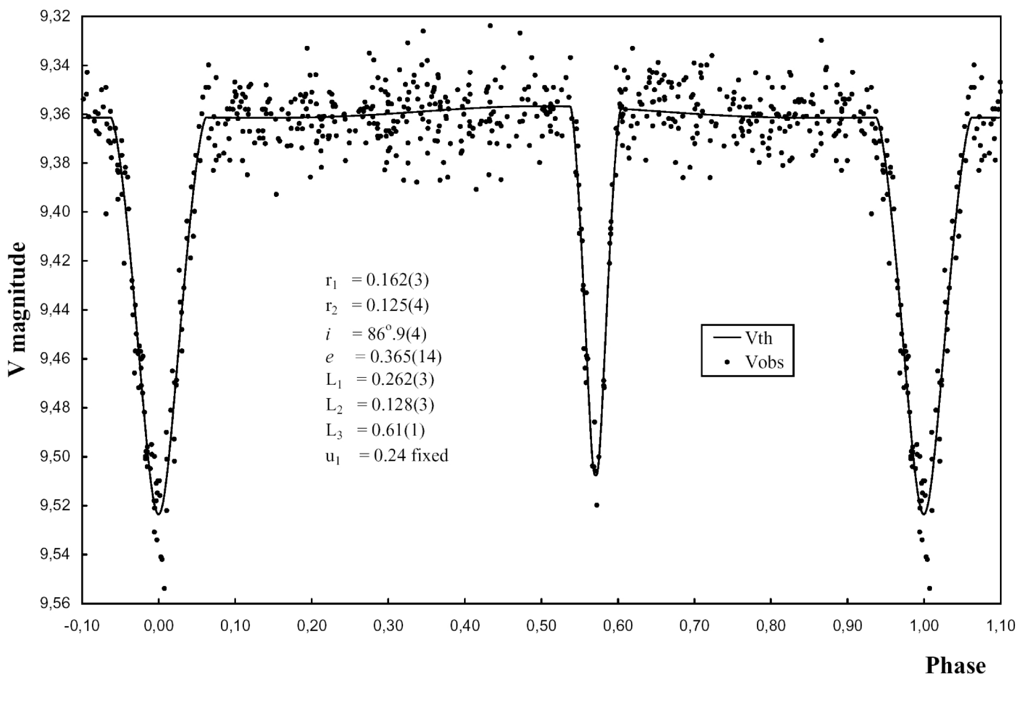

Figure 1. The ASAS-3 V-band light curve of NSV 18773. The solid curve is the theoretical light curve with the photometric elements given in the figure

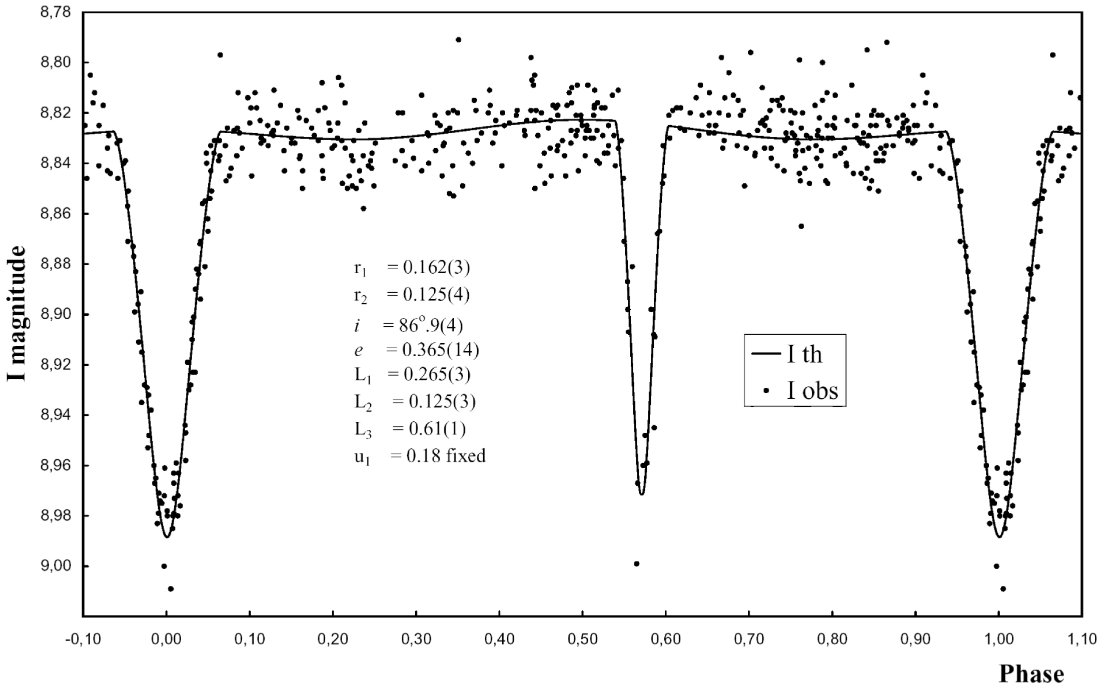

Figure 2. The ASAS-3 I-band light curve of NSV 18773. The solid curve is the theoretical light curve with the photometric elements given in the figure