

Preliminary Result of Photometric Study of V899 Her

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Abstract. We present new CCD photometric observation of V899 Herculis system which obtained in May-June 2010 at Bosscha Observatory ITB, Lembang Indonesia, using the 20.3 cm(f/10.0) Schmidt-Cassegrain GAO-ITB RTS telescope equipped with ST8 CCD camera. We secure 1 time of primary minimum. We employed Cubic Fit method (Breinhorst et al. 1973) to make minimum timing and define the primary minima. Discussion on the nature of V899 Her based on new O-C diagram analysis will be presented.

1. Introduction

The light variation of V899 Herculis (HIP 81191, HD 149684) system was first discovered by Hipparchos satellite (ESA 1997) with photometric amplitude of 0.137. The first linear ephemeris of the system was obtained by Hipparchos satellite gives the mean orbital period equal to 0.421173 with epoch HJD 2448500.1360. The first ground-based photometric observation carried out by Özdemiir et al. (2001) and they obtained a new ephemeris for V899 Her with $P=0.421172204$ days.

Lu et al. (2001) carried out the first spectroscopic observation of V899 Her system and they reported that the system is actually composed of three or even four components which V899 Her system is the faintest (component B). Their spectroscopic solution gives the value of mass ratio, $q=0.5662$ dan fungsi massa $(M_1 + M_2) \sin^3 i = 2.33 \pm 0.08 M_\odot$ which indicates the orbital inclination of the system is close to 90° . They also found that the component slowly changes its radial velocity, but these variations are not reflected in the systemic velocity of the close pair, hence probably the component itself is a wide spectroscopic binary. Özdemiir et al. (2002) then confirmed the presence of the third body in V899 Her system that contributes a large amount of light, approximately 68% of the total light of the system. Then Qian et al. (2006) added a sinusoidal term into the ephemeris of V899 Her due to the existence of sinusoidal variations in the O-C curve which suggests a cyclic oscillation with a period of 3.7 years and amplitude of 0.0117 day.

2. Observation and Data Reduction

The CCD photometric observations were carried out on May 28th 2010, June 1st 2010, and February 16th 2011 at Bosscha Observatory, Lembang, Indonesia, with the SBIG ST-7 and ST-8 CCD Camera attached to the 8-inch f/10 Celestron 8 reflecting telescope,

GAO-ITB RTS. TYC 2584 1724 1 and TYC 2584 1631 1 was picked as the comparison star and check star, respectively. Both stars are within one degree from V899 Her, so that they are in the same CCD field (see left panle of Fig. 1). The observations successfully cover only one primary minimum. The February 16th 2011 observation was made in order to complete the light curve of V899 Her, but unfortunately cannot cover any minimum time. The observations were relatively hard to be done due to the bad weather in Lembang during March until June 2010.

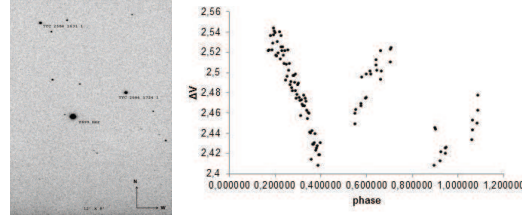


Figure 1. Left: Image of V899 Her, comparison star, and check star in V filter which obtained on February 16th 2011, with 60 seconds exposure time. Right: The light curve of V899 Her.

We used IRAF to do all the data reduction and obtained the instrumental magnitude from the photometric data. A total of 115 individual photometric readings in V were combined to produce folded light curve. The phase computed using the newest ephemeris for V899 Her system derived by Qian et al. (2006). The light curve is shown in the right panel of Fig. 1. Here, we employed the Cubic fit (Breinhorst et al. 1973) instead of the well-known Kwee and van Woerden (Kwee & van Woerden 1956) method, due to the asymmetric minima we got from our observation. From the Cubic fit method, we got the observed time of minimum light of our data is on HJD 2455349.227681 (see left panel of Fig. 2).

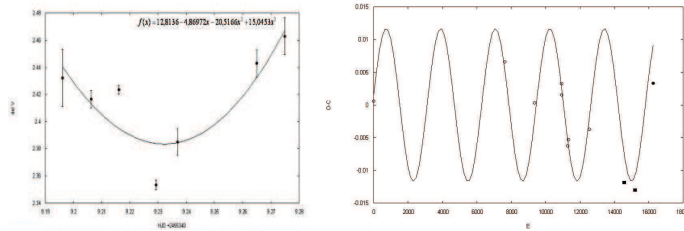


Figure 2. Left: The Cubic fit (Breinhorst et al. 1973) method for determining time of minimum light. Right: The O-C diagram plotted with the new quadratic ephemeris. The solid line represents the sinusoidal trend derived by Qian et al. (2006).

3. Discussion and Conclusions

Lu et al. (2001) concluded from their spectroscopic observation and analysis using broadening function, that V899 Her contact pair is the faintest component in the system. They showed that the third body companion is brighter and gives a large amount of light to the system (68% of the total light). According to their spectra, V899 Her (bright

Table 1. Photoelectric and CCD time of minimum light of V899 Herculis.

HJD +2400000	Min.	E	O-C	Metode	Referensi
48500.1360	I	0	0.0006	mean epoch	Hipparcos (ESA, 1997)
51708.4150	II	7617.5	0.0066	pe	Ozdemir et al. (2001)
52438.5093	I	9351	0.0003	pe	Drodz and Ogloza (2005)
53098.4878	I	10918	0.0033	pe	Porowski (2005)
53099.7496	I	10921	0.0016	CCD	Dvorak (2005)
53255.3646	II	11290.5	-0.0063	pe	Dvorak (2005)
53266.3160	II	11316.5	-0.0053	pe	Dvorak (2005)
53781.4102	II	12539.5	-0.0037	CCD	Qian et al. (2006)
54632.8000	I	14561	-0.0119	CCD	Dvorak (2009)
54899.8215	I	15195	-0.0130	CCD	Dvorak (2009)
55349.2276	I	16262	0.0033	CCD	Present author

companion) is classified into F5V with a slowly changes radial velocity. They suspected V899 Her is an independent wide spectroscopic binary. From the O-C diagram, Qian et al. (2006) found the cyclic period of the O-C curve is 3.7 years which corresponds with the period of the third body around the eclipsing pair. Their results showed the V899 Her has the lowest value of mass of $2.84 M_{\odot}$ which larger than the mass of F5V star. They suggested that the third component may be a non-eclipsing binary where the primary is F5 main sequence star and the secondary is unseen spectroscopically.

The analysis of data set was performed in the following way. As the first step, we try to find a second order term (parabola) from the O-C diagram which is proving that the orbital period of this system is changing with time. If the system changes with time, the observed time of minimum T_m will fit the following formulae (with $a = P_0$)

$$T_m = T_0 + aE + \frac{1}{2}bPE^2 \quad (1)$$

Thus the expected time of minimum and the O-C will be

$$T_m = T_0 + P_0E + \frac{1}{2}\frac{dP}{dE}E^2 \quad (2)$$

$$O - C = \frac{1}{2}\frac{dP}{dE}E^2 \quad (3)$$

Using least square fitting, we attempted to find the parabolic term which yields to the following equation

$$HJD_{Min.} = 2448500.137391 + 0.421172^dE - 5.91653 \times 10^{-11}E^2 \quad (4)$$

Hence the least square parabolic fit yields the orbital period of V899 Her at $T_0 = 2448500.137391$ is $P_0 = 0.421172$ days, which consistent with the period derived by Özdemir et al. (2001). The rate of period change of the eclipsing system is -2.95826×10^{-11} days per cycle, or -7.02389×10^{-11} days per day, or -2.215×10^{-3} seconds per year, or 0.2215 seconds in a century. This suggests that the orbital period of V899 Her system is decreasing over time. After removing the parabolic term from the O-C diagram, we fitted the points with the sinusoidal trend given by Qian et al. (2006), shows in the right panel of Fig. 4.

This result is synchronous with the Qian et al. (2006)s sinusoidal term which suggests a third body with $P_3 = 3.7$ years and $A = 0.0117$ days. It is very convincing,

since a third body will leave its signature on the orbital period changes of the close pair which show a strictly periodic variation. The parabolic component of the period change of V899 Her corresponds to a secular period decreases of 0.2215 seconds per century. The rate of transfer mass can be computed using the well known equation

$$\frac{\Delta_2 P}{P} = 3 \left[\left(\frac{M}{M_c} \right) \left(\frac{M}{M_h} \right)^{\frac{1}{2}} \left(\frac{R_h}{A} \right)^{\frac{1}{2}} \right] \quad (5)$$

It must be noted that the equation can measure only the mass transferred to and assimilated by the hotter star, not necessarily all the mass lost by the cooler star. The secular period decreases within V899 Her system implies a mass transfer of $2.8848 \times 10^{-8} M_{\odot}$ per year to the hotter star, assuming that the mass and angular momentum of the system are conserved and the masses of the eclipsing components given by Özdemiř et al. (2001) are $M_1(T_1 = 5700K, R_1 = 1.57R_{\odot}) = 2.1M_{\odot}$ and $M_2(T_2 = 5677K, R_2 = 1.22R_{\odot}) = 1.19M_{\odot}$, and the semi major axis, $a = 3.511R_{\odot}$.

One new CCD time of minimum of V899 Herculis was added along with the other two times of minima obtained by AAVSO observer, S. W. Dvorak in 2008. A total of 11 timings are available, including our own. In this work, we improved the ephemeris for V899 Herculis system with a quadratic term and the light time term (sinusoidal) derived by Qian et al. (2006).

$$\begin{aligned} HJD_{Min.} = & 2448500.137391 + 0.421172^d E - 5.91653 \times 10^{-11} E^2 \\ & + 0.0117 \sin(0.1134^\circ \times E + 7.4^\circ) \end{aligned} \quad (6)$$

We also found the parabolic term of the period change V899 Her which implies a secular period decreases of 0.2215 seconds per century and a mass transfer of $2.8848 \times 10^{-8} M_{\odot}$ per year to the cooler star, assuming the conservation of energy.

It is hard to be sure, even if at the present time we have a convincing reasonable explanation of the V899 Her O-C diagram behavior, due to the lack of observational data. Even though the evidence suggests that the period changes shown in the O-C diagram is caused by the presence of a brighter third body and mass transfer in the eclipsing system, the future eclipse timings will therefore be crucial, mostly for improving our understanding of the system.

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