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DISCOVERY AND PHOTOMETRIC ORBITAL SOLUTION OF A NEW DOUBLE-LINED AND HIGHLY ECCENTRIC B5V ECLIPSING BINARY

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ANS (Asiago Novae and Symbiotic stars) Collaboration is monitoring in $UBVR_{\rm C}I_{\rm C}$ bands the photometric evolution of the 80 symbiotic stars for which Henden and Munari (2000, 2001, 2006) provided calibration photometric sequences. While observing the symbiotic star AX Per, it was noted that the star *b* of the photometric sequence by Henden and Munari (2006), located at RA=$01^{\rm h}36^{\rm m}42\overset{\rm s}{.}4$ and DEC=$+54^\circ15'21\overset{''}{.}0$ (J2000.0) and coincident with GSC 3671.0099 (= 3UC 289-030898 in the UCAC3 catalog), was indeed variable. Henden and Munari sequences, while accurately placed on the Landolt (1992) equatorial photometric standards, have been built from only three separate epoch observations. Unknown eclipsing binaries could easily pass undetected when only few observations are available, and Henden and Munari warned against the risk.

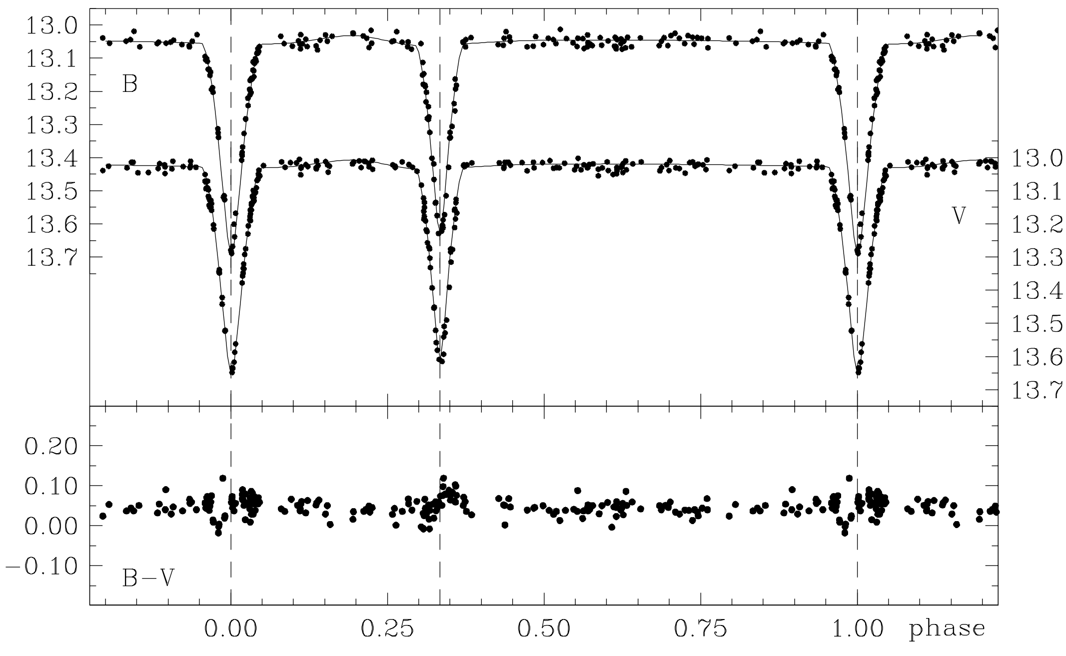

Figure 1. The photometric observations from Table 1 are plotted together with the light-curves corresponding to the photometric orbital solution from Table 2.

Table 2. Photometric orbital solution for the eccentric eclipsing binary GSC 3671.0099.

T_0(HJD)	2454158.301	±	0.275	$T_2(K)$	14480	±	60
P(d)	4.30885	±	0.00001	Ω_1	9.07	±	0.08
Phase shift	0.911	±	0.064	Ω_2	8.34	±	0.10
e	0.284	±	0.002	$R_1(R_\odot)$	3.08	±	0.03
ω(deg)	201.67	±	0.95	$R_2(R_\odot)$	3.41	±	0.05

After the serendipitous discovery of its variability (to which contributed the ANS Collaboration members G. Cherini, G.L. Righetti, S. Tomaselli, S. Moretti, A. Vagnozzi and S. Bacci), we started an intensive monitoring of GSC 3671.0099. During 135 different nights, we obtained 201 observations in B and 212 in V band with a 30cm telescope located in Cembra (Trento, Italy) and equipped with a SBIG ST-9 CCD camera, 512×512 array, 20 μm pixels ≡ 1''.72/pix, with a field of view of 13'×13'. The B filter was from Omega and the V filter from Custom Scientific. The data are given in Table 1 (available in electronic form through the IBVS website as `5936-t1.txt`). A Deeming-Fourier analysis promptly revealed the variability to be periodic with a period P=4.30885 days. Figure 1 plots the data in phase with the ephemeris for the primary minima $t_{minI} = 2454158.30072 + 4.30885 \times$ E. The light-curve shows GSC 3671.0099 to be a highly eccentric eclipsing binary, with secondary eclipse occurring photometric phase 0.33. The mean brightness values away from eclipses are $V = 13.046$ and $B - V = +0.047$, and the depth of the primary eclipse is $\Delta m = 0.65$. The star does not change color during both eclipses, or away from them.

To classify the variable, a low resolution, wide wavelength range spectrum of GSC 3671.0099 was obtained with the AFOSC imager+spectrograph mounted on the Asiago 1.82m telescope. The spectrum is presented in Figure 2. Comparison with the MK spectral atlas by Yamashita et al. (1977) shows the spectrum to be that of a normal B5V star. The intrinsic color of a B5V star is $(B - V)_\circ = -0.16$ (Fitzgerald, 1970), and therefore the reddening affecting GSC 3671.0099 is $E_{B-V} = +0.21$. This is close to $E_{B-V} = +0.27$ generally accepted for the nearby symbiotic star AX Per (Skopal et al., 2001; Mikołajewska & Kenyon, 1992).

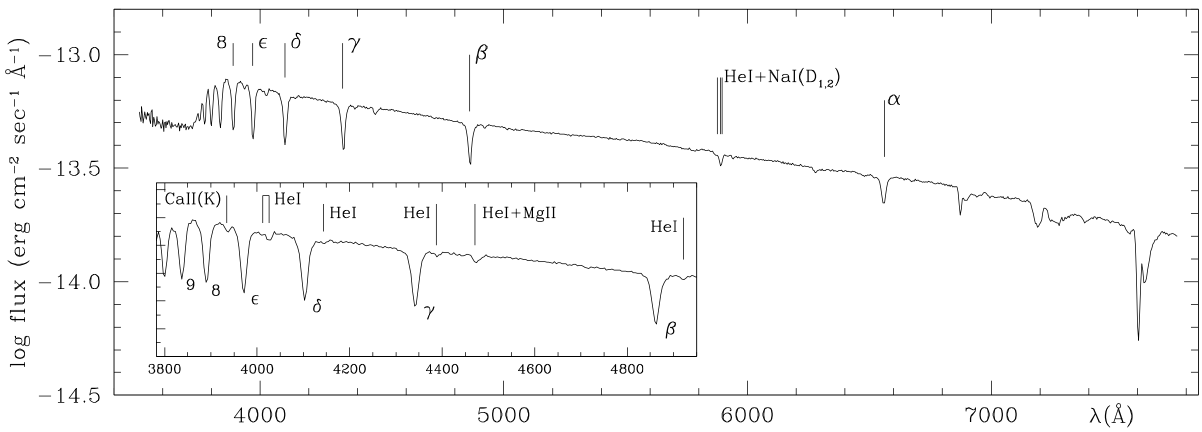

Figure 2. Low-resolution spectrum of the discovered new eclipsing star GSC 3671.0099. The insert highlights the wavelength range adopted by Yamashita et al. (1977) for spectral classification.

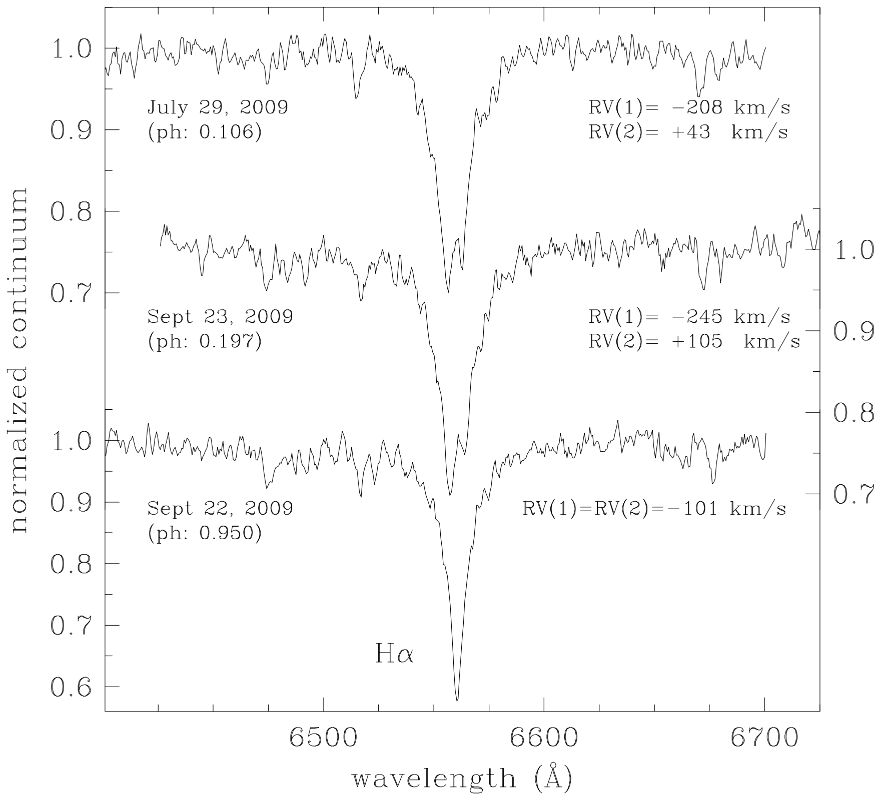

Figure 3. Observed H_α profiles and heliocentric radial velocities for GSC 3671.0099.

The presence of equally deep primary and secondary eclipses led to expect a double-lined nature for the newly discovered eclipsing binary. To verify this, three medium resolution spectra were obtained with the B&C spectrograph mounted on 1.22m Asiago telescope, and equipped with an ANDOR iDus 440A CCD camera, housing a EEV 42-10BU back-illuminated chip, 2048×512 pixels of 13.5 μm size. A 1200 ln/mm grating provided a dispersion of 0.61 Å/pix and a covered wavelength range of 5640-6860 Å. On these spectra, only Hα turned out to be strong enough to allow a meaningful profile to be recorded. The Hα profiles for the three spectra are presented in Figure 3, were heliocentric radial velocities and orbital phases are also provided. Figure 3 gives three strong indications: the system is double-lined as expected, the velocity separation of the two components support a mass ratio very close to 1.0, the luminosities of the two components are similar. However, given the low signal-to-noise ratio of the three spectra we avoid to use them to improve the orbital solution.

The WD98k93d code (Wilson and Devinney, 1971) was used to obtain only a photometric solution of the new eclipsing binary. From the B5V spectral classification and the calibrations of Straižys and Kuriliene (1981), we adopted as starting values for the primary a temperature $T_{\rm eff}$=15400 K and a mass M=4.79 $M_\odot$. The linear limb darkening coefficients were taken from Van Hamme (1993). The best fit to the light-curves was found for a mass ratio $q = 0.7$ and individual masses of M_1=5.62 $M_\odot$ and M_2=3.93 $M_\odot$. These nicely bracket the M=4.79 $M_\odot$ corresponding to B5V the spectral classification and are in visual good agreement with the radial velocity curves showed in Figure. 4. The semi-major axis is $a = a_1 + a_2$=23.62 $R_\odot$. The orbital inclination is not a critical parameter for deeply eclipsing binary stars. We obtained a set of different solutions for different values of the inclination and we found that $i = 87.5$ was the one best fitting the observed data. Finally, we assumed a periastron-syncronized rotation, with gravity brightening and albedo values equal to 1. The photometric orbital solution is given in Tab. 2. The radii of the stars are similar and close to the R=3.16 $R_\odot$ radius listed by Straižys and Kuriliene (1981) as typical for B5V stars. They are far smaller than their Roche lobe radii, and both component stars are not deformed by binary interaction. The light-curves corresponding to the orbital solution are overplotted to the *B* and *V* data in Figure 1 and show an excellent match.

The radial velocity curves corresponding to the photometric orbital solution of Table 2 are presented in Figure 4, where the measured radial velocities from Figure 3 are overplotted. The spectrum for Sept 22, 2009, secured at photometric orbital phase 0.950, corresponds to passage at stellar conjunction, and thus fixed to −101 km/sec the barycentric velocity of GSC 3671.0099. The model radial velocity curves were scaled to this value. The radial velocities at the other two observing dates well match the computed radial velocity curves. Given the limited resolution and S/N of the spectroscopic observations, and the fact that we were able to measure just one line (Hα), we do not attach more significance to this match than that of a welcome support to the photometric orbital solution. More accurate and far more numerous radial velocities, well distributed in orbital phase, are necessary to justify a combined photometric/orbital solution for this binary. The acquisition of the necessary spectroscopic observations are encouraged.

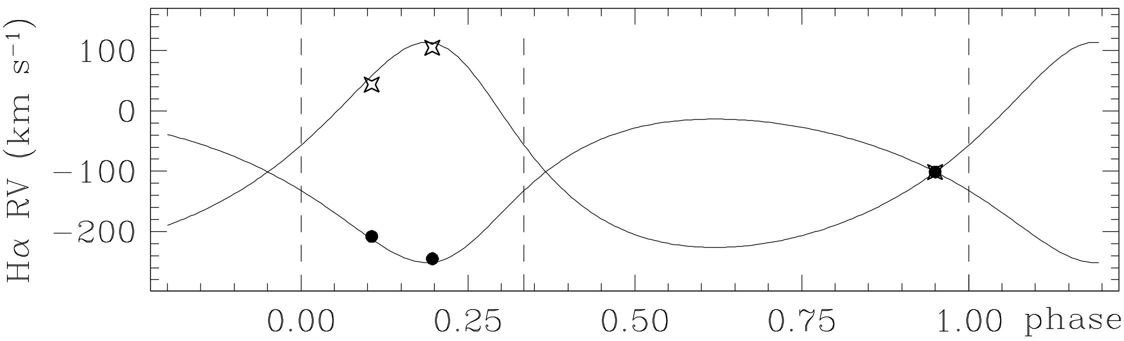

Figure 4. Radial velocity curves predicted from the orbital solution compared to observations of GSC 3671.0099 from Figure 3 (filled circles: primary component, stars: secondary component). The dashed lines marked the phases of eclipses from Figure 1.

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