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

Number 5280

Konkoly Observatory
Budapest
22 May 2002

HU ISSN 0374 – 0676

V357 Her: ANOTHER W UMa-TYPE ECLIPSING BINARY MISCLASSIFIED AS HADS

BRANICKI, A.[1]; PIGULSKI, A.[2]

[1] University in Białystok, Institute of Experimental Physics, Lipowa 41, 15-424 Białystok, Poland, e-mail: branicki@alpha.uwb.edu.pl

[2] Wrocław University Observatory, Kopernika 11, 51-622 Wrocław, Poland, e-mail: pigulski@astro.uni.wroc.pl

The variable V357 Her (preliminary designation S 4350 Her) was discovered photographically by Götz and Wenzel (1956). These authors derived five times of maximum light and a period of 0.139725 d. Considering the period and the shape of the light curve, the star was classified as an RR Lyrae-type variable, reclassified later as a high-amplitude δ Scuti (HADS) star.

Not only for V357 Her, but also for some other stars classified as HADS, either there are no observations since the time of discovery or the observations are very scarce. With CCD cameras, accuracy of 0.01 mag is easily achieved, so the true nature of these stars can be verified even with a small telescope. This prompted us to carry out CCD observations of some poorly studied stars classified as HADS. The two stars we observed a few years ago, UW CVn (Kopacki and Pigulski 1995) and V879 Aql (Kopacki and Pigulski 1998) appeared to be W UMa-type eclipsing binaries. Continuing this program, one of us (A.B.) observed V357 Her during six nights in 2001. The new photometry shows clearly that V357 Her is a W UMa-type eclipsing binary as well. This was already suggested by Schmidt et al. (1995), but because their conclusions relied on only 15 V and R-filter data points covering mainly the vicinity of the maximum light, the star was still present in the newest catalogue of δ Scuti stars (Rodríguez et al. 2000).

It should be noted that a program of observing neglected HADS is now conducted also by another group of observers (Van Cauteren and Lampens 2001 and references therein) and resulted in some reclassifications too.

The new photometric observations of V357 Her have been carried out during six nights between May 21 and August 2, 2001, in the observatory of the Institute of Experimental Physics of the University in Białystok. The telescope was 30-cm Meade LX 200 Schmidt-Cassegrain equipped with a Pictor 416 XTE CCD camera of 768 × 512 pixels covering a 7.′7 × 5.′1 field-of-view. No filter was used and the exposure time was 60 seconds for all frames. A total of 377 frames have been taken. They were calibrated in a standard way and then the magnitudes of stars were derived by means of the Daophot package of Stetson (1991).

In order to know the colours of nearby stars, the field of V357 Her was also observed on one night, August 11, 2001, in the Białków Observatory of the Wrocław University. The same equipment and filters as described by Kopacki and Pigulski (1998) were used.

In total, five V-filter and five I_C-filter frames with 100-s exposure time were taken. The resulting colour-magnitude diagram helped us to choose the comparison stars. Moreover, since Białków filters match the Johnson V and Cousins I_C passbands quite well, using the colour difference between a red and a blue star from the field, we found the effective wavelength of the Białystok observations to be 670 nm. This value was used later in the fits.

Prior to the analysis, some datapoints with largest errors have been rejected and the remaining 322 differential magnitudes of V357 Her with respect to two nearby comparison stars of similar colour index have been formed. These differential magnitudes are plotted in the phase diagram in Fig. 1. The magnitudes are available through the IBVS web site as a 5280-t2.txt file.

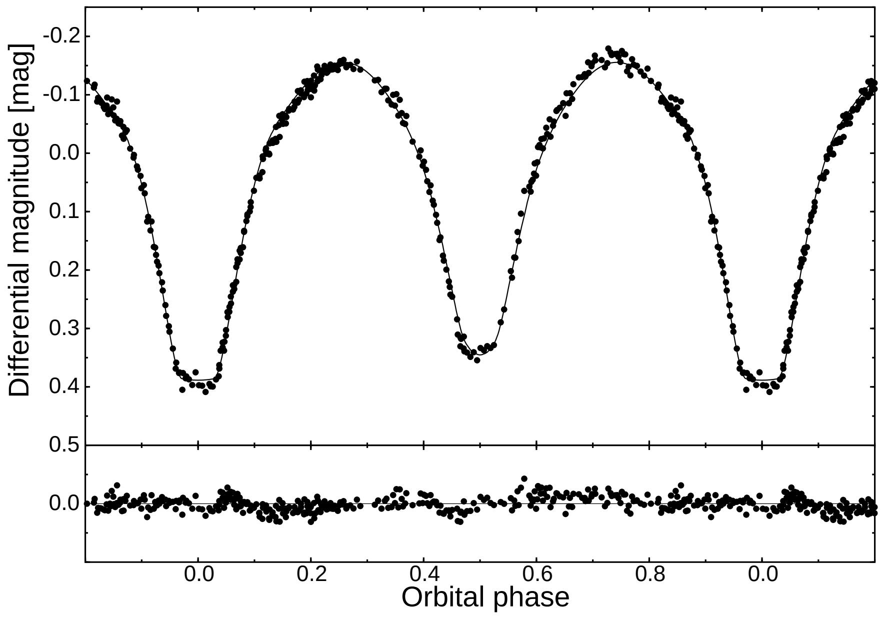

Figure 1. Differential Białystok CCD observations of V357 Her (dots), phased with the period of 0.28204111 d. The solid line is the synthetic light curve corresponding to the best solution given in Table 3. Below, the residuals from the fit are plotted in scale.

Table 1. Times of the primary minimum of V357 Her

Time of minimum HJD 2 400 000.+	Epoch E	$O-C$ [d]	Source of data
48 535.6087 ± .0013	0	0.0000	Schmidt et al. (1995)
52 051.5332 ± .0002	12466	0.0000	this paper
52 055.4823 ± .0004	12480	+0.0005	this paper
52 061.4050 ± .0005	12501	+0.0004	this paper
52 066.4812 ± .0004	12519	−0.0002	this paper
52 076.3518 ± .0005	12554	−0.0010	this paper
52 124.5818 ± .0003	12725	0.0000	this paper

The preliminary value of the orbital period has been obtained by means of the Fourier periodogram. Using Wilson-Devinney (WD) code (Wilson and Devinney 1971; Wilson 1991) we next derived the preliminary synthetic light curve, which was fitted to the observations of each of the six nights separately. The times of minimum derived from these fits are given in Table 1.

In addition, we recalculated the time of minimum light for Schmidt et al. (1995) data, using the same procedure. Since these observations were made in two filters, V and R, the corresponding entry in Table 1 is the mean of the minimum in V and R.

A linear regression of all times of minimum light given in Table 1 with weights inversely proportional to the r.m.s. errors, yielded the following ephemeris (the number in parentheses denotes the r.m.s. error of the last digits):

$$\mathrm{T_{min}\ I} = \mathrm{HJD}\,2448535.6087(15) + 0.28204111(12) \times E, \quad (1)$$

where E is the number of cycles elapsed from the initial epoch. The $O-C$ values listed in Table 1 were calculated with this ephemeris.

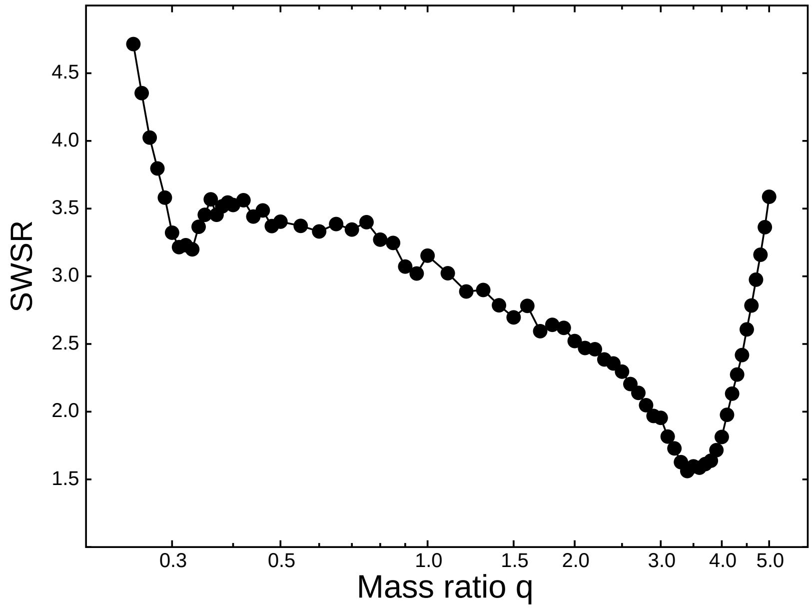

Figure 2. The smallest values of the sum of weighted squares of the residuals (SWSR) plotted as a function of the assumed mass ratio q.

Having refined the value of the orbital period, we tried to derive the parameters of the system. In order to do this, we used the WD differential correction program. Each data point was assigned a weight proportional to the reciprocal of square of the Daophot error. Since for V357 Her the mass ratio, $q = M_2/M_1$, is not known, it was derived first from the WD fits in a most common way, that is, from a series of the best fits with assumed value of q. Fig. 2 shows the results of the fits, where we used the sum of weighted squares of the residuals (SWSR) as the indicator of the quality of the fit. In these calculations we assumed the overcontact geometry and the mean surface temperature of star 1 (star 1 is, by definition, eclipsed near phase 0.0), T_1 = 4800 K. Moreover, bolometric albedos, $A_1 = A_2 = 0.5$ (Ruciński 1973) and gravity darkening coefficients, $g_1 = g_2 = 0.32$ (Lucy 1967) were adopted. Limb darkening coefficients, $x_1^{\rm bolo} = x_2^{\rm bolo} = 0.54$ and $x_1 = x_2 = 0.66$ for $\lambda_{\rm eff}$ = 670 nm were taken from the tables presented by Van Hamme (1993). The calculations were performed for q in the range between 0.25 and 5.0 (Fig. 2). Only five parameters were iterated: phase of the primary conjunction, ϕ_0, inclination, i, average temperature of star 2, T_2, surface potential, $\Omega_1 = \Omega_2$, and relative monochromatic luminosity of star 1, L_1. Since for some q there were problems with convergence, 200 iterations were performed for each q and then the solution with lowest SWSR was adopted as the best. The lowest values of SWSR achieved during 200 iterations are plotted in Fig. 2. It is clearly seen that the smallest SWSR, that is, the best solution, is obtained for $q \approx 3.5$.

Table 3. Parameters of the best-fit synthetic light curve of V357 Her

Parameter	Value
Inclination, i	$83\overset{\circ}{.}1 \pm 0\overset{\circ}{.}3$
Effective temperature of star 1, T_1	4800 K (assumed)
Effective temperature of star 2, T_2	4577 ± 5 K
Surface potential, Ω_1 ($= \Omega_2$)	7.295 ± 0.005
Mass ratio, q	3.572 ± 0.006
Relative luminosity of star 1 at $\lambda_{\rm eff} = 670$ nm, $L_1/(L_1 + L_2)$	0.2880 ± 0.0012
Overfill factor, $f = (\Omega_{\rm in} - \Omega_1)/(\Omega_{\rm in} - \Omega_{\rm out})$	0.11 ± 0.02

In order to get the final solution we started iterations with the solution for $q = 3.5$ setting q as an additional free parameter. In addition, we increased the number of the grid elements on the components' surfaces and used model atmospheres in computing monochromatic fluxes. The final solution is given in Table 3. Please note, that the WD code underestimates the errors (see e.g., Maceroni and Rucinski 1997), so the errors in Table 3 should be at least doubled in order to be realistic. The synthetic light curve is overplotted in Figure 1. One can see that the residuals are not perfectly flat and some systematic differences do remain. We have checked the differential magnitudes between other bright stars in the field of V357 Her and found that the changes at this level can be attributed to some instrumental effects. The standard deviation of the residuals equals 0.013 mag.

In V357 Her the hotter component is smaller and it is occulted in the primary (deeper) minimum. The temperature difference is large ($\sim$ 220 K) indicating a poor thermal contact.

Using the positions of 11 stars from the Hubble *Guide Star Catalogue*, we derived the equatorial coordinates of V357 Her with an accuracy to within $0\overset{''}{.}2$: $\alpha_{2000.0} = 18^{\rm h}44^{\rm m}31\overset{\rm s}{.}86$, $\delta_{2000.0} = +12°55'31\overset{''}{.}1$.

Acknowledgements. A.B. thanks Prof. B. Paczyński for donating the CCD camera used to obtain the observations presented in this paper.

References:

Götz, W., Wenzel, W., 1956, *Veröff. Sternwarte Sonneberg*, Band **2**, Heft 5.
Kopacki, G., Pigulski, A., 1995, *Acta Astron.*, **45**, 753.
Kopacki, G., Pigulski, A., 1998, *Acta Astron.*, **48**, 747.
Lucy, L.B., 1967, *Zeitschrift für Astroph.*, **65**, 89.
Maceroni, C., Rucinski, S.M., 1997, *PASP*, **109**, 782
Rodríguez, E., López-González, M.J., López de Coca, P., 2000, *ASP Conf. Ser.* **210**, 499.
Ruciński, S.M., 1973, *Acta Astron.*, **23**, 79.
Schmidt, E.G., Chab, J.R., Reiswig, D.E., 1995, *AJ*, **109**, 1239.
Stetson, P.B., 1987, *PASP*, **99**, 191.
Van Cauteren, P., Lampens, P., 2001, *Comm. in Asteroseismology*, **140**, 66.
Van Hamme, W., 1993, *AJ*, **106**, 2096.
Wilson, R.E., 1990, *ApJ*, **356**, 613.
Wilson, R.E., Devinney, E.J., 1971, *ApJ*, **166**, 605.