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

Number 6035

Konkoly Observatory
Budapest
7 September 2012

HU ISSN 0374 – 0676

UBVR$_C$I$_C$ PHOTOMETRIC STUDY OF THE NEAR CONTACT ECLIPSING BINARY Mis V1287

SAMEC, RONALD G.[1]; DIGNAN, JAMES G.[1]; SMITH, PAUL M.[1]; REHN, TRAVIS[1]; OLIVER, BRUCE M.[1]; FAULKNER, DANNY R.[2]; VAN HAMME, WALTER[3]

[1] Astronomy program, Department of Physics, Bob Jones University, Greenville, SC 29614, USA

[2] University of South Carolina, Lancaster, USA

[3] Florida International University, Miami, FL 33199, USA

Mis V1287 (Lacerta) [GSC 3992 2510, 2MASS J22455869+5628318, $\alpha(2000) = 22^{\rm h}45^{\rm m}58\overset{\rm s}{.}68$, $\delta(2000) = +56°28'31''\!.87$] was recently discovered by Seiichi Yoshida of the MISAO Project (Nakajima, et al. 2006), and identified as an EB type variable with a period of 0.7655d. The magnitude range is 12.25 - 12.78 (V). The discovery ephemeris is:

$$\text{HJD T}_{\rm min}\text{I} = 2453294.9863 + 0.7655\text{d} \times \text{E} \tag{1}$$

Monochromatic but phased photometric data is available at http://www.aerith.net/misao/data/misv.cgi?1287. Parabola fits were performed on all eclipse data, and 4 new times of minimum light were determined. These were used in our period study.

Our U, B, V, $R_{\rm C}$, $I_{\rm C}$ light curves were taken with the Lowell 31 inch reflector in Flagstaff with a CRYOTIGER cooled (−100°C) NASACAM and a 2K×2K chip and standard $UBVR_{\rm C}I_{\rm C}$ filters. They were taken on 22-24 September, 2009. We undertook the observing run under the auspices of the National Undergraduate Observatory (NURO) and were granted observing time by the Lowell TAC. We used the Lowell program LOIS to take our observations.

Our modeled light curves included 39 U, 298 B, 294 V, 296 $R_{\rm C}$ and 285 $I_{\rm C}$ individual CCD observations. Our U light curve is incomplete, but it was included in the analysis. These were taken by Samec and Faulkner as well as several students: Adam Jaso, Travis Rehn, Bruce Oliver. The photometric precision was ±0.005 in U and ±0.0065 in B, ±0.0045 in V, and ±0.006 in $R_{\rm C}$ and ±0.0075 in $I_{\rm C}$. Figure 1 shows sample observations of B, V and $B-V$ color curves on the night of September 22, 2009. The complete observations are given in Tables 1-5 (available electronically), in delta magnitudes, variable minus comparison star.

The variable star Mis V1287 was observed along with a comparison star (GSC 3992 2679) [$\alpha(2000) = 22^{\rm h}46^{\rm m}18\overset{\rm s}{.}069$, $\delta(2000) = +56°30'57''\!.77$], B−V = 0.501, and a check star (GSC 3992 2099) [$\alpha(2000) = 22^{\rm h}45^{\rm m}59\overset{\rm s}{.}812$, $\delta(2000) = +56°29'\!.45''\!.09$], B−V = 0.568. The field including these stars is given in Figure 2 as a convenience for future observers.

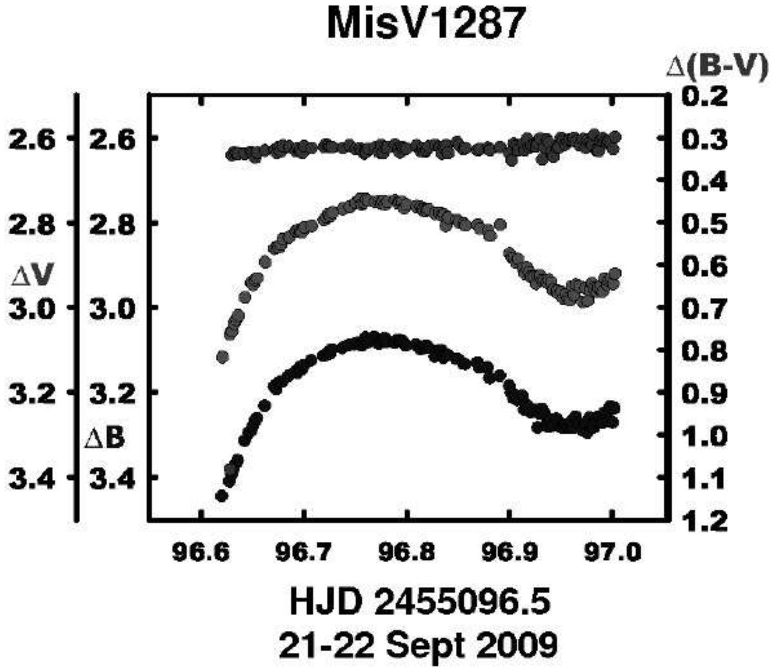

Figure 1. B, V and $B-V$ color curves of Mis V1287 on 2009 September 22.

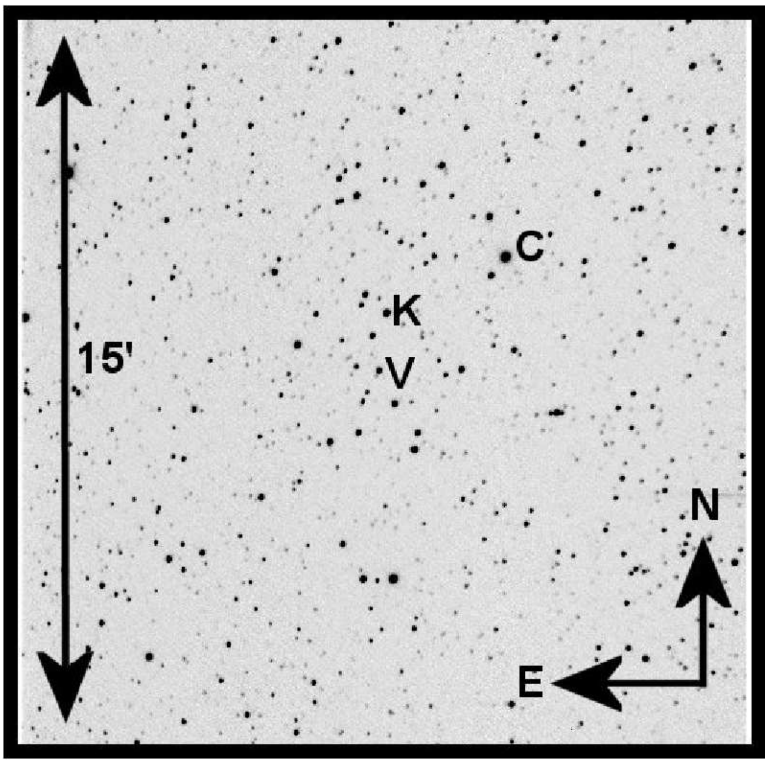

Figure 2. Finding Chart, Mis V1287 Variable (V), Comparison (C) and Check (K).

Three times of minimum light were determined from our present observations. The minima were calculated using parabola fits in each band and averaged by Samec and Dignan. With their standard errors in parentheses, they include: Min I = HJD 2455098.8780 (±0.0004) and Min II = HJD 2455097.7316 (±0.0002), 2455096.964 (±0.001). Other timings were calculated from fits to the CCD data of Nakajima (Nakajima, et al. 2006): Min I = HJD 2453299.9623, 2453293.0726, Min II = HJD 2453294.9832, 2453294.2179. The following ephemeris was calculated from all the available timings:

$$T_{min}I = \mathrm{HJD}\,2455098.8786 \pm 0.0007 + (0.7654970 \pm 0.0000004)\mathrm{d} \times \mathrm{E} \qquad (2)$$

The well-iterated ephemeris from our Wilson-Devinney program used to phase our data was:

$$T_{min}I = \mathrm{HJD}\,2455098.8785 \pm 0.0002 + (0.7644 \pm 0.0001)\mathrm{d} \times \mathrm{E} \qquad (3)$$

The linear O−C residuals, calculated from Eq. 2, are given in Table 6. The resulting O−C diagram is given in Figure 3.

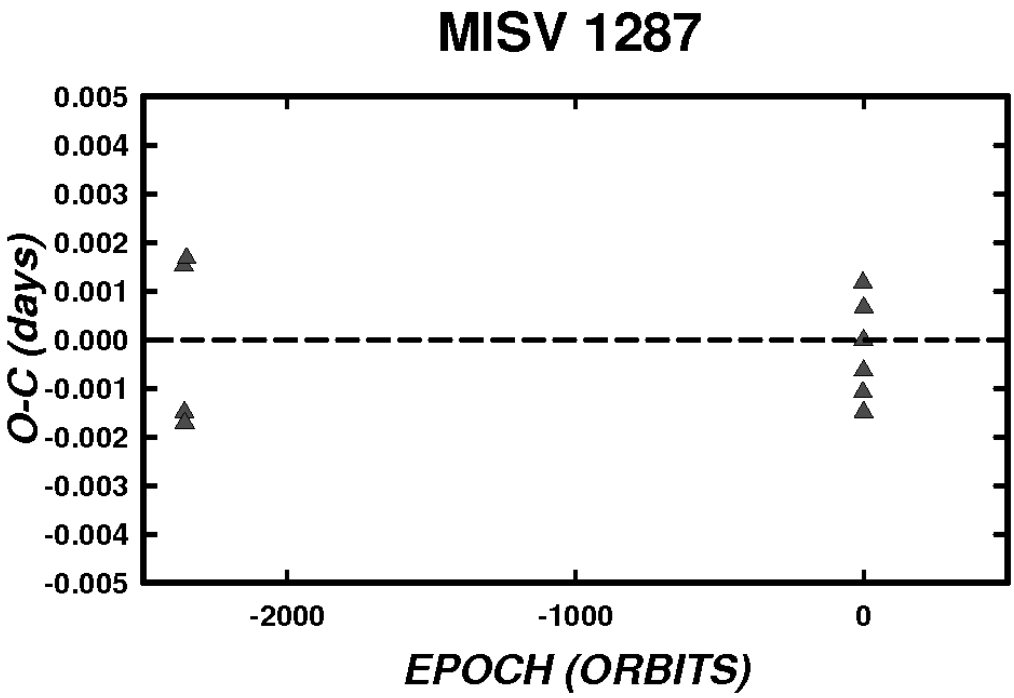

Figure 3. O−C residuals from period study calculated from Equation 2.

It is noted that the period is shorter in Eq. 3 with respect to Eq. 2. This may mean that the period is decreasing as we would expect in the scenario developed later in this paper. But further timings are needed to establish this trend.

Table 6. O−C linear residuals, Eq. [2]

No.	Epochs	Cycles	Weight	O−C
1	2453293.0726	−2359.0	0.5	0.0015
2	2453294.2179	−2357.5	0.5	−0.0015
3	2453294.9832	−2356.5	0.5	−0.0017
4	2453299.9623	−2350.0	0.5	0.0017
5	2455096.9638	−2.5	0.5	−0.0011
6	2455097.7316	−1.5	1.0	0.0012
7	2455098.8780	0.0	1.0	−0.0006

The BVR_CI_C phased light curves, phase versus delta magnitudes, in the sense of V−C, are given as Figures 4 and 5. The $UBVR_CI_C$ curves are of an EB type. The light curves show effects of night to night variability which is seen in the high scatter in the secondary minima. Light curve characteristics at quadratures are given in Table 7. The $UBVR_CI_C$ curves are typical of a semi-detached binary with a primary amplitude of 0.56 to 0.43 mags in U to I_C, respectively, and a secondary of only 0.19 to 0.25 mags in U to I_C, respectively. The difference in maxima light curves is about 2% in each filter. Thus, magnetic activity is strong in the system with dark spots and/or hot spots present. The difference of eclipse depths are 0.4 to 0.2 mags, U to I_C, respectively, indicate EB light curves and that the components are not in contact.

Table 7. Light curve characteristics of Mis V1287

Filter	Phase	Mag MaxI	Phase	Mag MaxII
U	0.25	3.426±0.020	0.75	3.442±0.020
B		3.078±0.006		3.098±0.004
V		2.751±0.002		2.773±0.005
R_C		2.554±0.006		2.576±0.003
I_C		2.317±0.007		2.333±0.006
Filter	Phase	Mag MinII	Phase	Mag MinI
U	0.50	3.629±0.020	0.00	4.000±0.020
B		3.289±0.016		3.571±0.010
V		2.975±0.021		3.249±0.005
R_C		2.806±0.021		3.019±0.008
I_C		2.588±0.006		2.764±0.008
Filter	MinI−MaxII	MinII−MaxII	MinII−MinI	
U	0.558±0.040	0.187±0.040	0.371±0.040	
B	0.473±0.015	0.190±0.010	0.283±0.026	
V	0.478±0.026	0.204±0.026	0.274±0.026	
R_C	0.443±0.014	0.230±0.010	0.213±0.029	
I_C	0.431±0.015	0.254±0.013	0.177±0.014	
Filter	MaxII−MaxI			
U	0.0162±0.040			
B	0.0205±0.010			
V	0.0220±0.007			
R_C	0.0213±0.010			
I_C	0.0169±0.013			

Dips in the color curves at phase 0.0 and rises at 0.5 indicate the system is semidetached with the primary filling its Roche-lobe(s) and the sceondary underfilling (as we view the cooler back parts of the Roche-lobe(s)).

The U, B, V, R_C, I_C light curves were hand modeled with Binary Maker 3.0 (Bradstreet et Steelman 2002). Averaged values of parameters were then entered into the Wilson-Devinney program; Wilson, 1990, 1994; Van Hamme and Wilson, 1998). From these we ran a full $UBVR_CI_C$ simultaneous solution. A mass ratio search covering regions from 0.25 to 1.9 was performed which indicated the value minimizes near ∼0.7, however there is a fairly broad area of low residual values from 0.5 to about 1.3, so the minimized q value is somewhat in doubt (see Figure 6). The full synthetic light curve solution is given in Tables 8 and 9. The temperature of the primary component (6250±500K, F8±6V spectral type, Cox 2000) which we used to model our light curves, was taken from recent 2MASS B−V, J−H color indices. The light curve solutions are shown in Figure 7 and 8. where the solution is overlying the normalized flux light curves. The Roche lobe surfaces arising from the calculation are displayed by quadratures in Figures 9-12.

Table 8. Synthetic curve parameters for Mis V1287

Parameters	Values
l_U, l_B, l_V, l_R, l_I (nm)	360, 440, 550, 640, 790
$xbol_{1,2}$, $ybol_{1,2}$	0.644, 0.643, 0.231, 0.160
$x_{1I,2I}$, $y_{1I,2I}$	0.572, 0.647, 0.267, 0.183
$x_{1R,2R}$, $y_{1R,2R}$	0.655, 0.735, 0.278, 0.165
$x_{1V,2V}$, $y_{1V,2V}$	0.728, 0.797, 0.269, 0.108
$x_{1B,2B}$, $y_{1B,2B}$	0.817, 0.853, 0.215, −0.018
$x_{1U,2U}$, $y_{1U,2U}$ 0.859, 0.855, 0.208, −0.209	
$g_1 = g_2$	0.32
$A_1 = A_2$	0.5
Inclination (°)	69.18±0.03
T_1, T_2 (K)	6250±500, 4982±1
Ω_1, Ω_2	3.267, 3.273±0.001
$q(m_2/m_1)$	0.7133±0.0005
Fill-outs: F_1, F_2	100%, 99.8%
$L1/(L1+L2)_I$	0.752±0.001
$L1/(L1+L2)_R$	0.7845±0.0005
$L1/(L1+L2)_V$	0.8112±0.0005
$L1/(L1+L2)_B$	0.8521±0.0006
$L1/(L1+L2)_U$	0.9092±0.0004
JD_0 (days)	2 455 098.8785±0.0001
Period (days)	0.7644±0.0001
r_1, r_2(pole)	0.384±0.002, 0.327±0.003
r_1, r_2(point)	0.534±0.002, 0.443±0.023
r_1, r_2(side)	0.406±0.002, 0.342±0.003
r_1, r_2(back)	0.435±0.003, 0.374±0.005

$\sum(W \times Res^2) = 2.713610$

All errors are formal, here the error in T2 is in relation to T1. We expect errors to T_1 to be on the order of ∼500K.

Table 9. Spot Parameters

STAR 1 (Cool Spot)	
Colatitude (°)	88.3±0.2
Longitude (°)	87.5±0.6
Spot radius (°)	15.6±0.01
Spot T-factor	0.673±0.009
STAR 1 (Cool Spot)	
Colatitude (°)	29.7±0.6
Longitude (°)	255.1±0.5
Spot radius (°)	15.44±0.06
Spot T-factor	0.50±0.05
STAR 2 (Hot Spot)	
Colatitude (°)	107.8±0.6
Longitude (°)	8.3±1.0
Spot radius (°)	16.2±0.2
Spot T-factor	1.286±0.007

Our model shows Mis V1287 is a semidetached, near contact binary with a mass ratio of ∼0.7. The system parameters from our model include a temperature difference of ∼1250 K, Roche lobe fill-outs of 100% and 99.8% (ratio of actual to the critical potential) for the primary and secondary components, respectively calculated by potentials. This means that the binary is very near contact. Three spots were needed to model the light curve asymmetries. Two are due to solar type activity and one is probably a stream spot since it modeled near colatitude 90°. (The presence of other spots would change the light center of the modeled hot spot.) Our photometry reveals that the secondary component is early main sequence K-type. Since it is of solar type, we expect this system will eventually become a W UMa contact binary. Thus, this is a coming-into-contact W UMa system, a rare V1010 Oph binary. The process of coalescence is believed to be magnetic braking due to stellar winds leaving the system via stiff dipole magnetic field lines. It is noted that this precess may undergo some oscillations in and out of contact until permanent contact is achieved (Csizmadia and Klagyivik 2004).

Finally, spectral identification and radial velocities are needed to confirm the mass ratios and absolute parameters of the system and to confirm the spectral type of the components.

We wish to thank Lowell Observatory for their allocation of observing time, and the American Astronomical Society and the Arizona Space Grant for travel support for this observing run.

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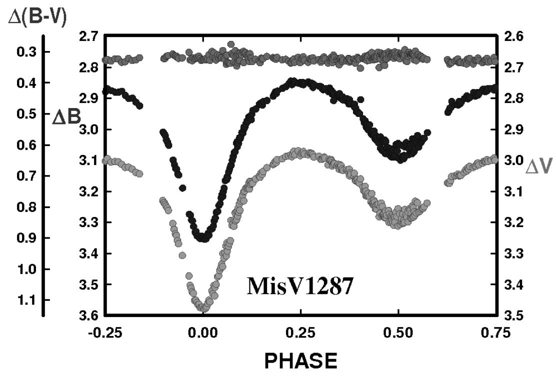

Figure 4. *B*, *V* delta magnitude and color magnitudes vs. phase plots in the sense of V−C.

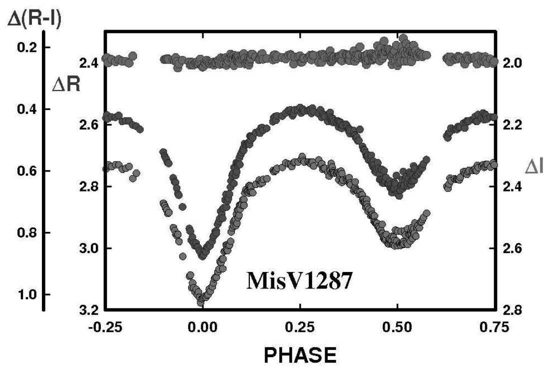

Figure 5. *R*, *I* delta magnitude and color magnitudes vs. phase plots in the sense of V−C.

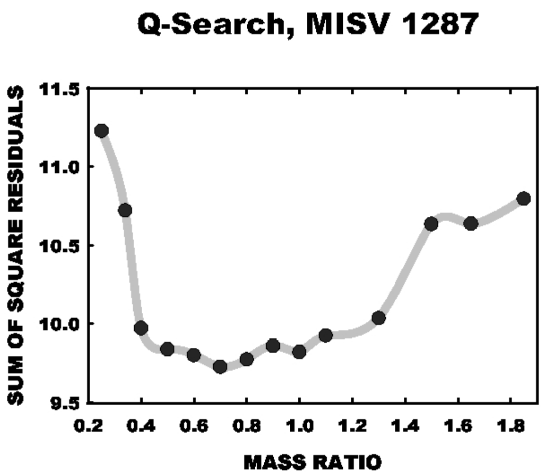

Figure 6. Mass ratio (q) search to determine the lowest residual value.

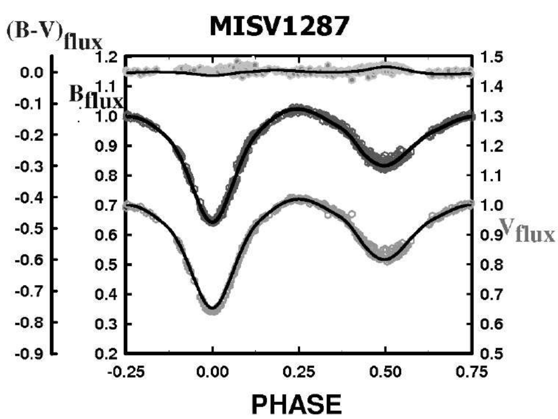

Figure 7. B,V normalized flux curves and the synthetic light curve solutions.

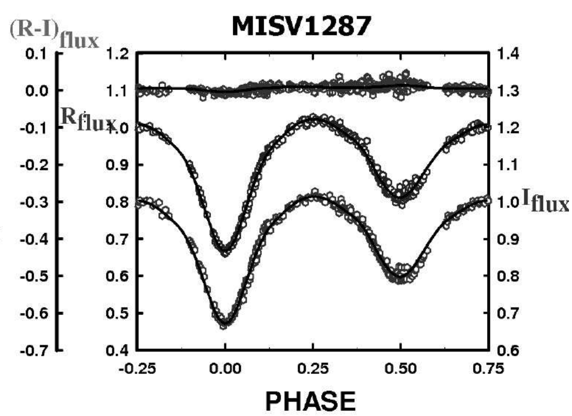

Figure 8. R,I normalized flux curves and the synthetic light curve solutions.

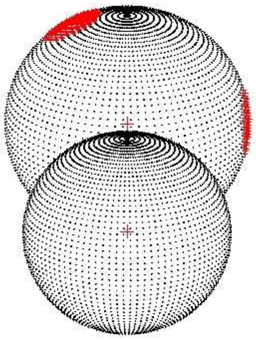

Figure 9. Roche lobe surfaces from our BVRI solution, phase 0.00 (the primary eclipse).

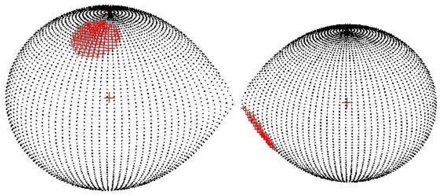

Figure 10. Roche lobe surfaces from our BVRI solution, phase 0.24.

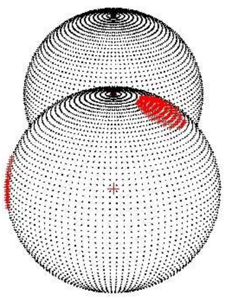

Figure 11. Roche lobe surfaces from our BVRI solution, phase 0.50 (the secondary eclipse).

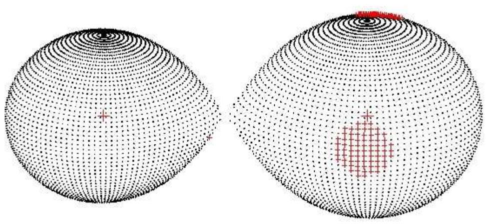

Figure 12. Roche lobe surfaces from our BVRI solution, phase 0.75.

ERRATUM FOR IBVS 6035

n the article appeared originally, author Smith, Paul M. was erroneously given as Samec, Paul M.

The Author

*This version of the paper contains corrections, and differs from the one appeared on-line originally. Date of last modification: Wed Sep 19 09:22:55 CEST 2012