1977, *Astron. Astrophys. Suppl.* **27**, 285-293.

TWO-COLOUR PHOTOMETRY AND ELEMENTS OF VV UMa

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Received March 29, 1976

Photoelectric observations made from 1965 to 1973 enable us to obtain fourteen epochs of minimum light. The period of the binary system appears to be variable. The light curves are analysed using the two similar ellipsoids model and the Roche model. The brighter component is a main sequence A0–2 star and the secondary a G5–6 subgiant filling its Roche lobe.

Key words: eclipsing binary – photometric solutions

1. INTRODUCTION

VV UMa is an eclipsing binary with a primary main sequence A0–2 star and a period of 0.7 days only. As pointed out by Struve (1951) this single spectrum spectroscopic system is remarkable since the period is short for a binary of class A0 and the brighter component is notably smaller and lighter than is usual for systems of longer period and with the same spectral type.

The light curves reported in this note were obtained at the Merate Observatory during a period starting from February 1965, as at that time no photoelectric observations of the system were known to have been made. After some months a three passband photoelectric light curve appeared, derived by Wilson (1965), who also computed a photometric solution. Wilson assumed a possible extended atmosphere around the smaller component of the system in order to explain some difficulties experienced in solving the light curves. It thus seemed appropriate to continue our measurements to prove the Wilson hypothesis and to check the period, which appears to be variable.

A brief summary of the previous photometric and spectroscopic work on VV UMa is given by Wilson (1965). During the following years two new solutions were computed, based on Wilson's photometry: one by Horak (1966) and the other by Pustylnick (1969). Moreover some visual epochs of minimum were derived by Braune *et al.* (1970), Šilhán and Oburka (1971) and Diethelm *et al.* (1973).

2. LIGHT CURVES AND PERIOD

The observations were made through standard B, V filters using a Lallemand photomultiplier at the 102 cm Zeiss reflector at the Merate Observatory. The photocurrent at the beginning was fed into a high impedance Speedomax and later into a Gardiner type integrator. The variable star was compared to $c = \mathrm{BD} + 56°1396$, which was also used by Wilson. Three stars in the surrounding field allowed us to check that the comparison star is constant. The Δm's between c and the check stars have a mean error less than $0^{\mathrm{m}}01$ when the colour difference does not exceed $0^{\mathrm{m}}5$ and are a little greater when $\Delta(B-V)$ exceeds $1^{\mathrm{m}}0$. Since the $\Delta(B-V)$ between VV UMa and the comparison is at the most $0^{\mathrm{m}}23$, we can expect a smaller mean error for the VV UMa measurements. The $\Delta m = m_c - m_{\mathrm{var}}$ were corrected for differential atmospheric extinction using mean extinction coefficients. The corrections vary between $0^{\mathrm{m}}007$ and $0^{\mathrm{m}}003$ for the B measurements and between $0^{\mathrm{m}}002$ and $0^{\mathrm{m}}001$ for the V ones. By using some standard stars of Praesepe as comparisons we obtained in the UBV system:

$$\mathrm{BD}\ +56°1396:\ V = 10^{\mathrm{m}}154 \quad B - V = +0^{\mathrm{m}}46$$

For the same star Wilson (1968) obtained: $V = 10^{\mathrm{m}}14$, $B - V = +0^{\mathrm{m}}47$. During twenty-one nights, from 1st February 1965 to 30th April 1973 a total of 776 B and 943 V measurements of VV UMa were obtained. Most of them were made within a short interval of time in order to reduce a possible seasonal change of the light curves; some others were obtained in the V filter only, to derive the times of minimum. The plotting of all measurements, reduced to the same cycle, proved the system was stable during the observing interval. The individual magnitudes of the variable are listed in tables 1 and 2 along with the corresponding heliocentric Julian day.

By fitting a parabola by least squares to the central part of the eclipses, fourteen epochs of minimum were calculated. No significant difference was found between the values obtained from the B and V light curves. The average times of minimum are listed in table 3 along with the corresponding mean errors calculated from separate B and V determinations. To see whether or not the period was varying we have also collected in this table all times of minimum reported in the literature. We make use of all of them in a least squares solution with convenient weights. We obtained:

$$\text{Min I} = \text{Hel. JD } 2428925.1242 + 0.687377219\, n$$
$$\pm \quad 72 \qquad\qquad 496 \text{ m.e.}$$

The corresponding residuals are plotted in figure 1 against the cycle number n. It would appear that the period is variable and that minor fluctuations take place over a wider variation. The observations we now dispose of are however insufficient for a more detailed study of the period variation.

To calculate the phases for single observations a linear ephemerides derived only from our minima was shown to be insufficient owing to period variability. We made use therefore of the following light elements with a parabolic term, which gave mean residuals of $\pm 0^{d}.0002$ for the epochs of minimum, comparable to the observational errors reported in table 3:

$$\text{Min I} = \text{Hel. JD } 2438792.4254 + 0.68737859\, n - 148\ 10^{-11}\, n^2$$
$$\pm \quad 1 \qquad\qquad 23 \qquad 6 \quad \text{m.e.}$$

Normal light and colour curves are given in figure 2. We obtain for VV UMa:

	Max	Min I	Min II
V	$10^{m}.13$	$10^{m}.91$	$10^{m}.26$
$B-V$	$+0.255$	$+0.34$	$+0.23$

3. PHOTOMETRIC SOLUTIONS

As reported in the studies that were referred to in the introduction, based on Wilson's photometry, difficulties have been experienced in solving the light curves of VV UMa. We therefore made an attempt to see if the difficulties disappeared when new solutions, based on our observations, were calculated by two different methods.

a) The solutions were carried out in accordance with the Russell model using a computer programme for differential corrections, and following the Irwin method (Irwin 1947), adapted to a Univac 1106 system. The computations start with a Fourier analysis of the outside eclipse measurements, whose phase limits, specified as input data, are calculated with the aid of preliminary elements. The Fourier expansion includes sine and cosine terms up to the fourth. The non consistent terms, i.e. smaller or equal to the corresponding mean errors, are dropped and the computation is repeated. The values obtained for the Fourier coefficients of VV UMa are listed in table 4 along with the corresponding mean errors. The proximity effects appear to be slight judging by Fourier coefficients; however there are small complications in the light curves, expressed by A_3, B_1, B_2 terms, as noted by Wilson (1965). The standard deviation of a single measure with respect to the Fourier representation was $0^{m}.005$ in both colours. Conventional rectifications in accordance with Russell and Merrill (1952) were made (phase and light).

The rectified normals, together with an initial solution (for VV UMa we assumed the parameters derived by Wilson (1965) are the input data for the differential correction programme. Accurate values for the transit and occultation alfa-functions are calculated following the method given by Jurkevich (1970). The programme calculates the differential correction coefficients for a specified number of parameters, then minimizes the variance of the observations by a least squares method and derives the mean errors for the elements. After the starting elements have been corrected, the computation is repeated, with sets of new rectified normals, until the corrections calculated for the parameters become negligible.

At first a five parameters optimisation of the observations of VV UMa during the minima was tried, but it failed to converge, so we allowed the programme to include a third light in the solution. The adjustment therefore was carried out for the parameters i_r, r_g, r_s, L_g, L_s, x_g, simultaneously for both the minima, disregarding x_s since the secondary minimum is shallow. Moreover, as the iterations for the B light curve led to an x_g greater than one, the computations were repeated with values for x_g, x_s assumed according to the theory (Grygar *et al.* 1972).

The rectification constants are listed in table 4 and the derived parameters are given in table 5 (first and second lines); σ is the mean standard deviation, in light units, derived for a ten measurements normal. The primary minimum appears to be a transit; no consistent solutions could be found assuming the primary eclipse to be an occultation. The σ of the solutions derived with x_g as a free parameter and those calculated with assumed x_g are alike. They are however (when reduced to a single measure value) twice the mean standard deviation derived from the Fourier analysis, which can be assumed to be an indication of the accuracy of the photometric observations. The third light and the inclination moreover vary remarkably if different values for x_g are assumed, so these parameters appear to be strongly correlated. In addition no spectroscopic evidence is known of circumstellar matter around the less massive component which can account for additional lights of about 17% and 24% respectively of the B and V lights of the two components. We can also suppose that the third light could come from a close companion or from a suitably aligned foreground star, but in our opinion the correlation found between L_3, i, x_g, makes the solutions seem doubtful.

Finally further solutions were calculated using the Irwin method, allowing only the elements i_r, r_g, r_s to be adjusted, while L_g was kept fixed and no third light was included. A set of values for L_g was tested, assuming $L_s+L_g=1$, and for each solution the corresponding σ evaluated. The iterations converge, while they do not when L_g is also allowed to vary, as reported above. The best solutions are listed in table 5 (third and fourth lines). The same results are obtained if the computations are repeated with fixed values for i, allowing L_g, r_g, r_s to vary. However if we compare these results with the solutions obtained including a third light, given in table 5, we note that the representation of the light curves is worse.

b) The dissimilar shapes of the two components can be accounted for by the Wilson and Devinney (1971) model, where the components are represented as Roche figures of equilibrium and a more reliable description of the light distribution over the components and of their mutual irradiation is adopted. In order to save computing time, after a reduction of the measurements to the phase interval 0°–180°, normal points were formed of twenty measurements each, and weights inversely proportional to the light level were assigned. At first the observed light curves were fitted with theoretical curves calculated using the light curve programme of Wilson and Devinney (1971), varying only few parameters at once, by a grid research process, to see what set or sets of parameters improve the representation of the observations significantly and what parameters can be discarded. For the cooler component the fitting of the out-eclipse measurements gives albedoes A_2 approximately 0.3 and 0.4 respectively for B and V measurements, whilst for the hotter star $A_1=1$ can be assumed (subscript 1 refers to the hotter and larger star, indicated by subscript g in the Russell notation). The darkening coefficient x_2 has no influence on the solutions, on the contrary x_1 has some effect, but we gave to x_1 and x_2 the same values assumed in the Irwin solutions referred to above. In the same way for the gravity darkening exponents we put $g_1=g_2=1$ as theoretically expected for stars with radiative envelope. The third light then appeared to be inconsistent. According to the spectral type of the primary and the depths of the minima freed from radiative interactions, we assumed for the polar effective temperature of the components the values $T_1=9750°$ K, $T_2=5600°$ K. After a reasonable fit for the entire light curves had been obtained, least squares solutions using the Wilson and Devinney differential correction programme were calculated (using the programme in mode 0).

From the spectroscopic mass-function $f(M)=0.015$ ⊙ and the spectral type A0V estimated by Struve (1950), or A2V given by Hill *et al.* (1975) and the inclination reported in table 5, a mass-ratio in the range 0.19–0.23 can be evaluated. The parameters estimated from the best fitting light curves were the input data for the differential corrections programme. We allowed the programme only to adjust the parameters: q, Ω_1, Ω_2, i, L_1, L_2, separately for each light curve. It appeared that q increases beyond 0.23 and that the cooler component tends to overcome its Roche limit; thus the solutions were repeated with $q=0.23$ and with Ω_2 set to the critical value for filling the Roche lobe, employing the Wilson and Devinney mode 2 approach. The elements so derived are listed in table 6 (first and second line); σ is the standard deviation, in light units, for a twenty points normal and N is the number of normals considered in the solutions.

During the search by trial and error of the preliminary solutions by comparing synthetic to the observed light curves, a further minimum for the sum of the squares of the residuals was obtained, which was about $q=0.4$. In these solutions L_3 also appeared to be negligible. Then by means of the differential correction programme improved sets of elements were derived again. These are listed in the last two lines of table 6. The adjusted parameters are identified by their respective probable errors, whilst the errors of the radii were computed from those in Ω_1 and Ω_2.

4. DISCUSSION

In his study of VV UMa Wilson (1965) supposed the existence of an atmosphere around the cooler component because in the nomographic solution the χ curve and the depth line did not intersect for any value of the limb darkening coefficient and because of the different depths p_0 of the eclipse in B and V. However an intersection could almost be obtained for $x=0.0$, but without a satisfactory representation of the observations in the upper part of the minimum. The shoulder discrepancy can be accounted for by assuming an atmosphere around the cooler component. The solutions however give a value for r_s greater in blue than in ultraviolet as though the opacity of the atmosphere decreases instead of increasing towards shorter wavelengths. The alternative hypothesis, that a third light is present in the system, was disregarded by Wilson who has come to the conclusion that the Russell model is inadequate to represent VV UMa.

Pustylnick (1969) also assumed an atmosphere around the cooler component and calculated some models for the atmosphere. On the basis of Wilson's photometry he derived some solutions, which however he considered to be quite unsatisfactory and provisional. The values for r_s increase from longer to shorter wavelengths, but the thickness of the atmosphere decreases when its temperature rises, a trend opposite to that which his model would lead us to expect.

A solution has been obtained by Horak (1966), assuming the primary to be a sphere and the companion an ellipsoid. The Wilson light curves were represented satisfactorily with the sphere-ellipsoid model, without resorting to a third light or to an extended atmosphere. Three different rectification methods were tried. The elements i, R, b, c, were the same in all three cases, but the lights of the two stars L_1 and L_2 and the lengths a of the semi-major axis of the secondary component vary with the different rectifications; the semiaxis a moreover decreases when the wavelength increases.

All the σ derived in the solutions listed in the tables 5 and 6 (after converting them into values for a single measure) appear to be at least twice as much the observational error $\sigma=0^{m}.005$ deduced from the Fourier analysis. Serious difficulties appear moreover when deriving the solutions in accordance with the Russell model, in particular the iterations do not converge if the parameters L_g, r_g, r_s, i, are adjusted simultaneously, but they converge if L_g or i are kept fixed. If we also correct for L_s a conspicuous third light appears which is unreliable, even if the presence of a very close foreground star cannot be ruled out. This may be because a spectroscopic evidence of such a conspicuous light is lacking or because the observed light curves are stable from a season to the other and do not show humps or notable asymmetries, apart from the Fourier small sinus-perturbations, or because no third light is required in the solutions calculated by means of the Wilson and Devinney model. In our opinion the above difficulties mean that the two similar ellipsoid model is inadequate to represent VV UMa. The solutions computed using the Wilson and Devinney programmes indeed show definitely that the secondary component is rather dissimilar to the primary star.

The representation by means of the Roche figures gives rise however to further difficulty. Starting from the spectroscopic mass function we obtain the result $q=0.23$ and the cooler component fills its Roche lobe, but the solutions even tend to overfill the Roche limit. The alternative solutions give $q=0.40$ and improve the σ of the B light curve by 80% but the σ of the V measures only by 10%. Due to limitations in the computing time we were however unable to compute solutions for values of q covering a larger range and to test if at $q=0.40$ it is a local minimum or a true minimum for σ. It is disappointing that the "best" photometric mass-ratio is very different from the spectroscopic value. Since the mass-ratio $q=0.40$ gives an unlikely mass 0.47 $\odot$ for the primary, which according to two independent spectral classifications is a main-sequence A0–2 star, we believe the solutions corresponding to $q=0.23$ are more reliable. From the parameters thus derived and the spectral type of the primary, a value G5–6 can be inferred for the cooler component. The ratios J''_g/J''_s of the average surface brightnesses freed from radiative interactions by means of the relative luminous efficiencies, deduced from the reflection coefficients (table 4), also give the same value. From the solutions, moreover, the secondary component appears to be nearly three magnitudes fainter than the primary; with spectral type G5–6 it is clearly above the main sequence. From the spectroscopic orbit recomputed by Lucy and Sweeney (1971) and the elements listed in table 6 for $q=0.23$ in solar units we obtain the results:

$$m_1=1.93 \qquad R_1=1.58 \qquad m_2=0.44 \qquad R_2=1.23$$

In conclusion the short-period system VV UMa appears to be a semi-detached system with a secondary subgiant entirely filling its Roche lobe.

ACKNOWLEDGEMENTS

This work was supported in part by Consiglio Nazionale delle Ricerche. We are indebted to Dr. R.E. Wilson for the loan of the programmes for the computation of the elements in accordance with the Wilson and Devinney method.

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Table 1 *B* observations of VV UMa

HEL. J.D. 24....	B	HEL. J.D. 24....	B	HEL. J.D. 24....	B	HEL. J.D. 24....	B	HEL. J.D. 24....	B
38793.3123	10.399	38793.4976	10.447	38794.4916	11.254	38796.3896	10.384	38797.4310	10.382
.3266	10.385	.4981	10.446	.4938	11.210	.3926	10.386	.4350	10.371
.3361	10.408	.5001	10.445	.4953	11.199	.3956	10.392	.4383	10.395
.3434	10.389	.5032	10.440	.4981	11.146	.3989	10.389	.4437	10.394
.3688	10.404	.5051	10.447	.4996	11.116	.4067	10.369	.4491	10.398
.3722	10.409	.5088	10.437	.5029	11.074	.4102	10.388	.4529	10.386
.3757	10.403	.5139	10.441	.5044	11.051	.4139	10.388	.4566	10.390
.3791	10.407	38794.3538	10.388	.5085	10.973	.4202	10.378	.4628	10.389
.3858	10.419	.3580	10.379	.5105	10.933	.4247	10.380	.4722	10.393
.3899	10.423	.3630	10.381	.5136	10.870	.4269	10.395	.4802	10.405
.3929	10.423	.3651	10.394	.5148	10.857	.4317	10.408	.4862	10.404
.3998	10.427	.3687	10.372	.5169	10.806	.4396	10.401	.4896	10.408
.4038	10.429	.3721	10.382	.5202	10.754	.4414	10.396	.4925	10.417
.4069	10.448	.3743	10.393	.5214	10.739	.4454	10.399	.4959	10.414
.4128	10.450	.3798	10.412	.5245	10.700	.4473	10.391	.4991	10.411
.4150	10.450	.3837	10.413	.5259	10.681	.4510	10.399	.5039	10.413
.4184	10.437	.3854	10.404	.5282	10.673	.4552	10.417	.5079	10.424
.4204	10.454	.3891	10.422	.5316	10.626	.4576	10.407	.5126	10.413
.4239	10.469	.3935	10.410	.5329	10.620	.4645	10.411	.5168	10.422
.4259	10.464	.3992	10.410	.5357	10.567	.4686	10.426	.5225	10.435
.4299	10.477	.4054	10.407	.5398	10.522	.4724	10.420	.5280	10.456
.4316	10.482	.4096	10.418	.5467	10.495	.4756	10.422	.5328	10.453
.4359	10.464	.4134	10.426	.5481	10.485	.4786	10.421	.5374	10.455
.4375	10.472	.4237	10.473	.5506	10.464	.4804	10.438	.5409	10.455
.4411	10.472	.4294	10.482	.5517	10.461	.4872	10.459	.5460	10.456
.4434	10.480	.4328	10.502	.5550	10.459	.4906	10.484	.5513	10.465
.4471	10.482	.4367	10.546	.5562	10.446	.4920	10.502	.5558	10.463
.4493	10.486	.4401	10.583	.5597	10.426	.4949	10.508	.5573	10.478
.4528	10.488	.4439	10.635	.5627	10.422	.4978	10.534	.5627	10.478
.4548	10.482	.4456	10.645	.5648	10.421	.4997	10.552	.5702	10.470
.4585	10.481	.4494	10.684	.5696	10.415	.5029	10.588	.5770	10.501
.4603	10.485	.4528	10.739	.5713	10.426	.5042	10.598	.5821	10.497
.4637	10.482	.4543	10.762	.5750	10.415	.5081	10.630	.5858	10.488
.4657	10.492	.4575	10.789	.5805	10.414	38797.3897	10.377	.5890	10.492
.4689	10.478	.4588	10.804	.5821	10.419	.3939	10.372	.5921	10.480
.4729	10.473	.4623	10.900	.5849	10.408	.3971	10.390	.5934	10.483
.4766	10.469	.4650	10.934	.5860	10.411	.4046	10.377	.5963	10.482
.4796	10.474	.4695	11.061	38796.3514	10.384	.4076	10.394	.5997	10.462
[illegible]	10.465	.4732	11.104	.3602	10.373	.4112	10.383	38800.3887	10.430
[illegible]	10.464	.4746	11.132	.3691	10.370	.4151	10.390	.3922	10.430
[illegible]	10.468	.4800	11.188	.3745	10.373	.4166	10.368	.3957	10.425
[illegible]	10.465	.4813	11.210	.3800	10.377	.4200	10.382	.4003	10.421
.4925	10.468	.4862	11.252	.3829	10.384	.4223	10.369	.4019	10.420
.4941	10.462	.4878	11.234	.3865	10.390	.4273	10.398	.4058	10.409
38800.4128	10.411	38819.3223	10.419	38819.4752	10.391	38819.5901	10.477	38845.4233	10.451
.4151	10.415	.3281	10.428	.4776	10.397	38827.3024	10.373	.4295	10.423
.4185	10.415	.3308	10.421	.4812	10.405	.3202	10.370	.4310	10.426
.4204	10.410	.3344	10.411	.4832	10.404	.3365	10.384	.4346	10.424
.4241	10.406	.3367	10.407	.4867	10.406	.3515	10.397	.4369	10.424
.4313	10.400	.3412	10.402	.4887	10.404	38845.3220	10.795	.4440	10.426
.4333	10.402	.3466	10.402	.4930	10.406	.3253	10.835	.4465	10.423
.4365	10.408	.3486	10.400	.4955	10.408	.3272	10.871	.4500	10.425
.4384	10.399	.3548	10.396	.4992	10.412	.3308	10.933	.4517	10.425
.4417	10.393	.3572	10.396	.5012	10.420	.3331	10.974	.4599	10.419
.4441	10.393	.3612	10.397	.5042	10.425	.3346	11.002	.4624	10.431
.4474	10.404	.3633	10.391	.5057	10.424	.3390	11.084	.4658	10.410
.4536	10.403	.3702	10.391	.5077	10.424	.3417	11.129	.4674	10.411
.4543	10.399	.3723	10.387	.5108	10.416	.3433	11.161	.4758	10.411
.4564	10.392	.3757	10.379	.5147	10.418	.3467	11.202	.4774	10.397
.4600	10.393	.3775	10.377	.5162	10.426	.3482	11.216	.4810	10.397
.4617	10.406	.3827	10.390	.5197	10.429	.3500	11.233	.4832	10.388
.4659	10.385	.3901	10.381	.5219	10.425	.3519	11.245	.4894	10.400
.4680	10.392	.3922	10.386	.5251	10.428	.3554	11.251	.4922	10.394
.4740	10.377	.3987	10.380	.5269	10.438	.3567	11.243	.4958	10.391
.4758	10.376	.4012	10.376	.5289	10.439	.3591	11.222	.4975	10.387
.4799	10.384	.4048	10.378	.5322	10.453	.3608	11.203	.5013	10.393
.4815	10.379	.4068	10.380	.5336	10.452	.3649	11.148	.5038	10.393
.4852	10.389	.4076	10.384	.5358	10.448	.3670	11.113	.5099	10.388
.4867	10.391	.4117	10.394	.5394	10.453	.3687	11.077	.5106	10.393
.4906	10.379	.4139	10.380	.5410	10.455	.3698	11.066	.5133	10.389
.4928	10.375	.4176	10.388	.5432	10.465	.3736	11.000	.5167	10.398
.4955	10.382	.4196	10.394	.5476	10.466	.3750	10.958	.5188	10.392
.5008	10.379	.4233	10.386	.5490	10.467	.3777	10.910	.5238	10.393
38819.2797	10.601	.4251	10.382	.5510	10.473	.3814	10.857	.5264	10.401
.2843	10.548	.4301	10.386	.5548	10.472	.3840	10.806	.5301	10.403
.2877	10.524	.4324	10.387	.5567	10.474	.3861	10.777	38847.3007	10.409
.2898	10.507	.4360	10.397	.5604	10.464	.3904	10.716	.3046	10.408
.2933	10.484	.4379	10.409	.5628	10.475	.3920	10.695	.3084	10.413
.2954	10.469	.4420	10.392	.5663	10.482	.3945	10.658	.3099	10.410
.2987	10.449	.4440	10.400	.5679	10.485	.3979	10.622	.3132	10.421
.3008	10.435	.4447	10.408	.5712	10.480	.3995	10.600	.3150	10.408
.3040	10.436	.4482	10.397	.5733	10.488	.4021	10.578	.3182	10.401
.3062	10.429	.4503	10.393	.5765	10.491	.4053	10.549	.3201	10.417
.3097	10.422	.4543	10.393	.5779	10.479	.4069	10.533	.3273	10.423
.3119	10.421	.4617	10.394	.5815	10.473	.4092	10.511	.3294	10.413
.3149	10.422	.4635	10.387	.5828	10.473	.4130	10.487	.3322	10.439
.3171	10.424	.4679	10.390	.5835	10.473	.4170	10.465	.3365	10.424
.3202	10.413	.4702	10.390	.5871	10.465	.4208	10.464	.3407	10.430

HEL. J.D. 24....	B	HEL. J.D. 24....	B	HEL. J.D. 24....	B	HEL. J.D. 24....	B	HEL. J.D. 24....	B
38847.3430	10.438	38847.4470	10.789	38880.4288	11.002	39126.5088	11.001	39181.4623	10.994
.3470	10.477	.4512	10.736	.4331	10.933	.5125	10.966	.4662	11.061
.3500	10.470	.4535	10.707	.4353	10.895	.5158	10.914	.4682	11.106
.3532	10.470	.4548	10.695	.4390	10.836	.5186	10.860	.4722	11.170
.3564	10.490	.4585	10.659	.4403	10.812	.5229	10.810	.4741	11.192
.3610	10.512	.4598	10.633	.4444	10.752	.5259	10.759	.4758	11.217
.3643	10.553	.4621	10.606	.4460	10.728	.5288	10.713	.4790	11.241
.3671	10.566	.4671	10.553	.4491	10.693	.5309	10.678	.4806	11.249
.3690	10.579	.4687	10.536	.4514	10.665	.5341	10.634	.4819	11.244
.3730	10.634	.4730	10.518	.4548	10.622	.5362	10.611	.4847	11.226
.3752	10.669	.4744	10.488	.4592	10.573	.5396	10.574	.4865	11.222
.3785	10.703	.4771	10.480	.4650	10.513	.5416	10.562	.4876	11.213
.3804	10.716	.4831	10.448	.4717	10.487	.5447	10.537	.4911	11.162
.3832	10.768	.4850	10.454	.4766	10.439	.5466	10.521	.4924	11.148
.3844	10.788	.4889	10.439	.4820	10.426	.5497	10.493	.4942	11.117
.3855	10.810	.4925	10.439	38881.4244	10.488	.5516	10.481	.4956	11.085
.3893	10.863	.4957	10.434	.4287	10.505	.5548	10.464	.4990	11.025
.3914	10.900	.4980	10.439	.4338	10.499	.5567	10.454	.5009	10.996
.3949	10.966	.5060	10.427	.4376	10.489	.5600	10.439	.5022	10.981
.3964	11.004	.5073	10.421	.4408	10.493	.5620	10.431	.5063	10.897
.3983	11.044	.5123	10.423	.4446	10.491	.5648	10.426	.5080	10.876
.3996	11.063	38880.3632	10.601	.4483	10.497	.5669	10.423	.5095	10.842
.4032	11.113	.3680	10.648	.4515	10.502	.5700	10.419	.5124	10.792
.4048	11.141	.3716	10.695	.4554	10.489	.5722	10.418	.5144	10.765
.4068	11.175	.3758	10.758	.4587	10.492	.5752	10.410	.5176	10.722
.4081	11.187	.3794	10.815	38888.3400	10.465	.5804	10.409	.5195	10.690
.4115	11.231	.3833	10.886	.3472	10.466	.5835	10.410	.5229	10.650
.4127	11.241	.3857	10.930	.3536	10.466	.5885	10.404	.5255	10.613
.4146	11.236	.3891	11.006	.3587	10.453	.5912	10.399	39201.3580	10.503
.4160	11.253	.3913	11.009	.3642	10.441	.5932	10.404	.3617	10.533
.4189	11.246	.3949	11.076	.3695	10.437	.5966	10.396	.3653	10.560
.4203	11.233	.3970	11.129	.3766	10.432	39181.4261	10.508	.3664	10.569
.4223	11.221	.4002	11.155	.3868	10.425	.4323	10.560	.3700	10.607
.4235	11.202	.4020	11.185	.3991	10.412	.4362	10.607	.3714	10.618
.4271	11.147	.4051	11.213	.4101	10.399	.4377	10.619	.3757	10.660
.4285	11.119	.4074	11.250	39126.4450	10.593	.4412	10.655	.3772	10.677
.4307	11.078	.4107	11.264	.4498	10.640	.4431	10.681	.3815	10.741
.4322	11.061	.4120	11.249	.4535	10.685	.4456	10.719	.3850	10.790
.4357	10.997	.4154	11.217	.4584	10.756	.4476	10.743	.3896	10.837
.4371	10.974	.4168	11.202	.4620	10.829	.4505	10.791	.3937	10.940
.4391	10.937	.4205	11.160	.4655	10.871	.4524	10.816	.3992	11.087
.4404	10.914	.4218	11.131	.4689	10.944	.4553	10.865	.4035	11.135
.4440	10.858	.4232	11.104	.4726	10.998	.4570	10.893	.4044	11.152
.4455	10.826	.4269	11.045	.4765	11.082	.4602	10.952	.4070	11.196
39201.4079	11.201	39201.4553	10.669	39233.3587	10.480	39500.4137	11.159	39876.4115	11.230
.4088	11.213	.4566	10.658	.3634	10.476	.4166	11.201	.4125	11.236
.4118	11.233	.4602	10.607	.3663	10.470	.4188	11.231	.4156	11.254
.4129	11.240	.4614	10.603	.3868	10.480	.4199	11.236	.4185	11.241
.4156	11.249	.4675	10.534	.3896	10.489	.4245	11.239	.4208	11.252
.4165	11.257	.4717	10.493	.3925	10.488	.4294	11.207	.4215	11.241
.4189	11.256	.4732	10.493	.3953	10.473	.4335	11.147	.4239	11.218
.4214	11.229	.4811	10.455	.3985	10.471	.4362	11.105	.4257	11.175
.4224	11.209	.4827	10.445	.4026	10.469	.4392	11.059	.4265	11.175
.4252	11.168	.4872	10.435	.4054	10.472	.4414	11.039	.4291	11.152
.4262	11.145	.4918	10.433	.4080	10.463	.4450	10.950	.4299	11.160
.4271	11.136	.4963	10.412	.4091	10.462	.4470	10.926	.4325	11.106
.4299	11.077	.4974	10.420	.4124	10.457	.4508	10.884	.4334	11.085
.4311	11.050	39233.3301	10.428	.4136	10.459	.4521	10.856	.4362	11.023
.4332	11.022	.3335	10.435	.4199	10.443	39876.3895	10.832	.4371	11.015
.4362	10.963	.3408	10.465	.4232	10.442	.3924	10.891	.4399	10.959
.4375	10.939	.3420	10.462	.4252	10.442	.3948	10.916	.4408	10.942
.4389	10.924	.3451	10.456	39500.3966	10.862	.3980	10.985	.4433	10.903
.4427	10.862	.3462	10.454	.4006	10.961	.4010	11.042	.4451	10.874
.4442	10.853	.3492	10.458	.4017	10.973	.4042	11.122	.4475	10.842
.4482	10.754	.3503	10.455	.4067	11.027	.4051	11.130	.4486	10.829
.4493	10.743	.3540	10.470	.4086	11.066	.4080	11.155	.4542	10.741
.4508	10.722	.3556	10.465	.4119	11.127	.4088	11.177	.4548	10.723
.4539	10.692								

Table 2 *V* observations of VV UMa

HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V
38793.3126	10.140	38793.4987	10.207	38794.4870	10.907	38796.3675	10.117	38797.4173	10.118
.3273	10.147	.5008	10.198	.4909	10.908	.3720	10.133	.4207	10.131
.3361	10.150	.5039	10.197	.4932	10.892	.3751	10.129	.4218	10.123
.3440	10.145	.5060	10.194	.4946	10.877	.3806	10.135	.4282	10.145
.3684	10.154	.5095	10.191	.4987	10.821	.3872	10.132	.4317	10.132
.3716	10.153	.5133	10.177	.5002	10.797	.3901	10.128	.4356	10.124
.3753	10.147	38794.3545	10.133	.5037	10.751	.3932	10.137	.4390	10.142
.3787	10.155	.3587	10.136	.5050	10.732	.3963	10.131	.4427	10.123
.3851	10.160	.3623	10.137	.5091	10.659	.3997	10.136	.4459	10.155
.3894	10.164	.3644	10.144	.5110	10.624	.4060	10.132	.4499	10.144
.3924	10.171	.3681	10.127	.5142	10.572	.4092	10.138	.4537	10.138
.3992	10.169	.3714	10.126	.5154	10.563	.4133	10.132	.4574	10.140
.4030	10.180	.3736	10.136	.5174	10.521	.4195	10.142	.4611	10.141
.4064	10.194	.3806	10.164	.5208	10.468	.4240	10.138	.4647	10.151
.4123	10.203	.3844	10.160	.5220	10.460	.4261	10.133	.4710	10.143
.4143	10.196	.3862	10.150	.5252	10.423	.4309	10.147	.4746	10.158
.4178	10.193	.3898	10.167	.5264	10.409	.4390	10.157	.4787	10.144
.4198	10.203	.3929	10.168	.5290	10.391	.4407	10.157	.4818	10.162
.4232	10.224	.3963	10.152	.5322	10.359	.4442	10.153	.4838	10.147
.4253	10.225	.4005	10.173	.5335	10.348	.4449	10.155	.4868	10.152
.4304	10.241	.4061	10.167	.5363	10.316	.4467	10.144	.4900	10.155
.4330	10.242	.4106	10.154	.5391	10.280	.4504	10.144	.4932	10.154
.4366	10.234	.4141	10.179	.5403	10.264	.4543	10.143	.4965	10.162
.4382	10.237	.4217	10.201	.5460	10.235	.4568	10.152	.4998	10.155
.4419	10.245	.4252	10.229	.5474	10.232	.4679	10.163	.5032	10.155
.4442	10.252	.4301	10.233	.5500	10.207	.4717	10.173	.5072	10.169
.4478	10.253	.4335	10.250	.5511	10.209	.4749	10.169	.5133	10.158
.4501	10.263	.4373	10.285	.5557	10.197	.4782	10.168	.5178	10.170
.4536	10.271	.4408	10.326	.5603	10.181	.4797	10.170	.5216	10.177
.4555	10.252	.4446	10.387	.5641	10.170	.4879	10.220	.5249	10.180
.4591	10.256	.4462	10.394	.5655	10.167	.4910	10.239	.5286	10.186
.4609	10.251	.4500	10.439	.5689	10.164	.4925	10.249	.5321	10.192
.4644	10.253	.4534	10.473	.5705	10.166	.4954	10.264	.5368	10.203
.4664	10.262	.4548	10.489	.5744	10.158	.4984	10.284	.5403	10.206
.4697	10.251	.4580	10.530	.5784	10.167	.5003	10.302	.5442	10.213
.4737	10.246	.4593	10.550	.5790	10.166	.5034	10.325	.5487	10.208
.4773	10.241	.4628	10.613	.5797	10.163	.5049	10.337	.5523	10.226
.4802	10.241	.4657	10.651	.5814	10.164	.5087	10.375	.5559	10.219
.4831	10.234	.4701	10.749	.5844	10.157	38797.3946	10.141	.5600	10.243
.4847	10.226	.4739	10.789	.5855	10.152	.3976	10.134	.5641	10.246
.4878	10.227	.4753	10.796	38796.3502	10.126	.4051	10.128	.5676	10.233
.4901	10.219	.4793	10.853	.3539	10.136	.4083	10.135	.5713	10.255
.4932	10.220	.4807	10.863	.3601	10.135	.4118	10.140	.5759	10.261
.4948	10.212	.4855	10.908	.3638	10.138	.4159	10.131	.5793	10.269
38797.5827	10.253	38800.3931	10.178	38819.3124	10.172	38819.4623	10.138	38819.5809	10.254
.5865	10.259	.3964	10.173	.3157	10.175	.4642	10.138	.5822	10.247
.5896	10.259	.4009	10.163	.3177	10.179	.4674	10.145	.5865	10.255
.5928	10.243	.4026	10.157	.3209	10.170	.4695	10.136	.5907	10.246
.5939	10.239	.4065	10.156	.3229	10.172	.4757	10.139	38827.2959	10.127
.5968	10.237	.4122	10.157	.3275	10.173	.4782	10.147	.3035	10.136
.6035	10.232	.4143	10.156	.3301	10.162	.4819	10.151	.3121	10.122
38799.2748	10.608	.4178	10.155	.3335	10.156	.4839	10.153	.3212	10.124
.2796	10.697	.4197	10.150	.3359	10.149	.4874	10.152	.3297	10.123
.2823	10.741	.4234	10.148	.3407	10.153	.4894	10.155	.3374	10.135
.2855	10.780	.4307	10.145	.3473	10.146	.4939	10.155	.3445	10.149
.2897	10.873	.4327	10.145	.3493	10.153	.4962	10.159	.3520	10.133
.2934	10.913	.4357	10.147	.3541	10.151	.4997	10.158	.3600	10.158
.2983	10.913	.4378	10.146	.3566	10.135	.5018	10.164	38845.3213	10.503
.3029	10.901	.4411	10.148	.3605	10.140	.5049	10.165	.3258	10.554
.3065	10.857	.4433	10.144	.3626	10.143	.5063	10.170	.3278	10.583
.3093	10.847	.4468	10.141	.3710	10.138	.5083	10.172	.3314	10.653
.3100	10.844	.4551	10.141	.3730	10.137	.5115	10.163	.3338	10.683
.3129	10.787	.4571	10.144	.3763	10.137	.5154	10.167	.3352	10.710
.3153	10.734	.4606	10.137	.3782	10.142	.5169	10.173	.3398	10.785
.3159	10.717	.4624	10.143	.3824	10.144	.5203	10.174	.3424	10.821
.3191	10.694	.4667	10.128	.3846	10.158	.5226	10.187	.3440	10.843
.3214	10.662	.4685	10.138	.3865	10.152	.5258	10.190	.3475	10.882
.3221	10.652	.4746	10.128	.3908	10.139	.5276	10.199	.3488	10.885
.3269	10.563	.4765	10.128	.3930	10.135	.5296	10.192	.3507	10.904
.3296	10.535	.4806	10.128	.3980	10.135	.5328	10.210	.3525	10.905
.3303	10.533	.4824	10.130	.4004	10.125	.5343	10.207	.3560	10.909
.3330	10.481	.4861	10.126	.4042	10.128	.5364	10.204	.3574	10.902
.3354	10.452	.4874	10.128	.4060	10.136	.5402	10.208	.3598	10.879
.3378	10.407	.4913	10.129	.4110	10.137	.5417	10.219	.3613	10.869
.3442	10.360	.4935	10.120	.4132	10.127	.5438	10.220	.3656	10.812
.3479	10.326	.4989	10.118	.4168	10.128	.5469	10.220	.3677	10.776
.3518	10.274	.5001	10.120	.4189	10.127	.5483	10.221	.3692	10.759
.3590	10.245	38819.2803	10.357	.4226	10.134	.5504	10.229	.3706	10.744
.3637	10.213	.2836	10.301	.4245	10.128	.5538	10.235	.3743	10.683
.3702	10.195	.2883	10.282	.4309	10.133	.5558	10.242	.3757	10.661
.3763	10.185	.2904	10.259	.4330	10.136	.5597	10.239	.3783	10.597
.3828	10.168	.2938	10.228	.4366	10.141	.5621	10.240	.3820	10.554
.3923	10.153	.2960	10.227	.4386	10.148	.5655	10.252	.3846	10.513
.3977	10.167	.2994	10.213	.4427	10.142	.5672	10.252	.3867	10.489
.4031	10.154	.3016	10.193	.4455	10.151	.5707	10.248	.3911	10.422
.4082	10.149	.3047	10.182	.4489	10.138	.5726	10.249	.3926	10.406
.4158	10.145	.3069	10.182	.4510	10.136	.5760	10.255	.3951	10.378
38800.3881	10.179	.3103	10.177	.4550	10.137	.5772	10.254	.3986	10.343

HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V
38845.4001	10.328	38847.3175	10.156	38847.4316	10.752	38854.3652	10.163	38880.4025	1 .863
.4026	10.307	.3194	10.146	.4352	10.696	.3703	10.167	.4058	1..891
.4050	10.281	.3266	10.159	.4364	10.674	.3764	10.181	.4081	10.899
.4076	10.277	.3287	10.164	.4385	10.634	.3832	10.177	.4112	10.902
.4099	10.258	.3317	10.173	.4398	10.620	.3810	10.160	.4127	10.897
.4136	10.236	.3359	10.172	.4433	10.559	.3962	10.154	.4159	10.883
.4163	10.221	.3400	10.162	.4448	10.543	.3993	10.152	.4174	10.873
.4199	10.200	.3425	10.174	.4463	10.514	.4016	10.155	.4211	10.822
.4226	10.189	.3465	10.193	.4505	10.451	.4035	10.166	.4224	10.805
.4288	10.174	.3494	10.184	.4528	10.425	.4075	10.163	.4240	10.776
.4304	10.167	.3538	10.217	.4541	10.408	.4097	10.150	.4275	10.722
.4340	10.170	.3569	10.237	.4578	10.371	.4124	10.162	.4295	10.689
.4361	10.161	.3603	10.251	.4592	10.365	.4148	10.143	.4338	10.624
.4434	10.165	.3635	10.283	.4615	10.339	.4170	10.152	.4360	10.599
.4458	10.162	.3664	10.312	.4654	10.301	.4191	10.145	.4396	10.545
.4493	10.164	.3685	10.319	.4662	10.299	.4214	10.158	.4416	10.517
.4509	10.161	.3725	10.371	.4680	10.279	.4233	10.151	.4452	10.451
.4592	10.152	.3745	10.398	.4723	10.250	.4253	10.142	.4466	10.449
.4618	10.160	.3779	10.424	.4737	10.235	.4282	10.156	.4498	10.411
.4653	10.152	.3799	10.447	.4764	10.215	.4301	10.135	.4520	10.384
.4667	10.149	.3828	10.476	.4839	10.201	.4326	10.157	.4554	10.348
.4751	10.144	.3840	10.506	.4857	10.196	.4347	10.136	.4599	10.311
.4767	10.148	.3850	10.516	.4904	10.180	.4369	10.144	.4644	10.268
.4803	10.147	.3886	10.575	.4932	10.176	.4398	10.131	.4710	10.237
.4826	10.138	.3909	10.592	.4963	10.172	.4423	10.137	.4760	10.192
.4899	10.141	.3943	10.649	.4986	10.178	.4452	10.134	.4814	10.185
.4929	10.143	.3956	10.677	.5054	10.164	.4506	10.140	38881.4252	10.255
.4966	10.133	.3977	10.719	.5066	10.169	.4530	10.141	.4292	10.254
.4982	10.133	.3990	10.736	.5115	10.146	.4541	10.136	.4331	10.259
.5020	10.135	.4026	10.788	38854.2975	10.845	.4560	10.126	.4370	10.254
.5045	10.136	.4043	10.802	.3011	10.824	.4570	10.139	.4400	10.259
.5094	10.139	.4062	10.844	.3043	10.781	38880.3611	10.318	.4439	10.262
.5126	10.138	.4075	10.850	.3074	10.721	.3641	10.335	.4476	10.268
.5163	10.132	.4110	10.887	.3106	10.644	.3673	10.365	.4509	10.258
.5181	10.125	.4121	10.887	.3201	10.545	.3723	10.434	.4547	10.253
.5243	10.127	.4140	10.895	.3237	10.479	.3765	10.483	.4580	10.248
.5270	10.132	.4153	10.898	.3275	10.437	.3800	10.534	38888.3340	10.241
.5307	10.131	.4184	10.899	.3338	10.362	.3840	10.597	.3401	10.232
38847.3012	10.156	.4196	10.896	.3370	10.339	.3863	10.634	.3472	10.217
.3041	10.156	.4216	10.886	.3402	10.319	.3897	10.701	.3541	10.219
.3078	10.159	.4230	10.874	.3433	10.283	.3920	10.715	.3594	10.217
.3094	10.153	.4265	10.830	.3518	10.228	.3955	10.772	.3648	10.191
.3125	10.159	.4278	10.814	.3563	10.206	.3975	10.805	.3701	10.184
.3146	10.160	.4300	10.776	.3603	10.189	.4009	10.843	.3767	10.168
38888.3868	10.167	39181.4274	10.265	39181.5250	10.351	39201.4595	10.367	39500.4079	10.740
.3992	10.166	.4280	10.272	39201.3586	10.257	.4607	10.363	.4114	10.800
.4103	10.157	.4287	10.279	.3622	10.280	.4681	10.281	.4132	10.836
39126.4457	10.337	.4294	10.285	.3658	10.300	.4725	10.245	.4158	10.852
.4509	10.408	.4328	10.310	.3670	10.323	.4740	10.242	.4182	10.889
.4541	10.419	.4356	10.339	.3706	10.345	.4804	10.209	.4194	10.903
.4595	10.481	.4372	10.350	.3721	10.376	.4820	10.198	.4222	10.900
.4650	10.572	.4407	10.386	.3763	10.405	.4879	10.180	.4256	10.916
.4683	10.631	.4426	10.410	.3777	10.414	.4926	10.167	.4276	10.910
.4721	10.685	.4451	10.442	.3835	10.506	.4969	10.161	.4314	10.854
.4758	10.749	.4470	10.462	.3878	10.540	.4980	10.168	.4324	10.846
.4798	10.834	.4499	10.504	.3923	10.627	39233.3306	10.179	.4356	10.809
.5093	10.702	.4517	10.527	.3966	10.735	.3344	10.191	.4367	10.785
.5131	10.662	.4548	10.573	.4013	10.777	.3413	10.215	.4397	10.749
.5164	10.604	.4564	10.604	.4040	10.813	.3425	10.213	.4419	10.718
.5191	10.565	.4596	10.655	.4049	10.823	.3457	10.214	.4445	10.662
.5223	10.507	.4617	10.684	.4075	10.871	.3467	10.209	.4465	10.639
.5252	10.464	.4656	10.742	.4083	10.878	.3497	10.222	.4495	10.604
.5282	10.445	.4677	10.781	.4093	10.883	.3508	10.220	.4502	10.593
.5302	10.416	.4716	10.830	.4124	10.898	.3547	10.231	.4515	10.569
.5334	10.386	.4734	10.861	.4133	10.909	.3562	10.229	39876.3890	10.547
.5356	10.355	.4752	10.883	.4161	10.904	.3592	10.245	.3927	10.601
.5390	10.323	.4783	10.905	.4171	10.918	.3604	10.239	.3952	10.633
.5409	10.306	.4799	10.904	.4181	10.934	.3639	10.227	.3971	10.685
.5441	10.286	.4813	10.911	.4208	10.897	.3669	10.228	.3995	10.743
.5459	10.268	.4842	10.896	.4220	10.886	.3872	10.251	.4013	10.745
.5491	10.248	.4859	10.888	.4229	10.867	.3901	10.256	.4046	10.795
.5511	10.236	.4871	10.884	.4257	10.830	.3931	10.246	.4055	10.815
.5541	10.216	.4906	10.843	.4266	10.820	.3958	10.234	.4083	10.837
.5561	10.206	.4918	10.839	.4276	10.807	.3990	10.237	.4092	10.852
.5592	10.190	.4936	10.804	.4305	10.757	.4031	10.232	.4119	10.897
.5614	10.183	.4950	10.782	.4317	10.760	.4059	10.229	.4128	10.886
.5642	10.179	.4984	10.729	.4327	10.722	.4085	10.216	.4160	10.907
.5663	10.173	.5003	10.704	.4356	10.683	.4096	10.213	.4181	10.918
.5694	10.166	.5016	10.686	.4369	10.659	.4129	10.213	.4204	10.924
.5716	10.167	.5050	10.630	.4383	10.642	.4141	10.215	.4211	10.920
.5745	10.163	.5057	10.611	.4421	10.586	.4193	10.202	.4236	10.883
.5798	10.158	.5074	10.597	.4434	10.586	.4226	10.199	.4253	10.882
.5830	10.162	.5089	10.573	.4477	10.495	.4246	10.196	.4261	10.858
.5879	10.157	.5118	10.530	.4488	10.475	.4276	10.193	.4287	10.838
.5907	10.155	.5137	10.508	.4502	10.459	39500.3972	10.576	.4294	10.825
.5926	10.151	.5170	10.459	.4533	10.430	.4012	10.646	.4321	10.794
.5973	10.151	.5190	10.427	.4545	10.410	.4025	10.688	.4330	10.784
39181.4266	10.258	.5223	10.396	.4559	10.394	.4061	10.719	.4358	10.718

Table 2 (continued)

HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V	HEL. J.D. 24....	V
39876.4367	10.711	41802.3916	10.460	41802.4045	10.656	41802.4175	10.840	41802.4284	10.928
.4395	10.670	.3926	10.481	.4054	10.663	.4185	10.850	.4293	10.920
.4404	10.642	.3934	10.476	.4066	10.674	.4195	10.867	.4304	10.913
.4430	10.607	.3945	10.487	.4077	10.699	.4209	10.873	.4308	10.908
.4446	10.585	.3959	10.519	.4091	10.718	.4213	10.896	.4321	10.915
.4472	10.548	.3969	10.537	.4102	10.747	.4218	10.894	.4331	10.907
.4481	10.557	.3977	10.537	.4112	10.744	.4230	10.901	.4347	10.875
.4490	10.532	.3987	10.554	.4124	10.764	.4234	10.893	.4353	10.874
.4551	10.448	.3996	10.572	.4132	10.773	.4242	10.899	.4417	10.764
41802.3876	10.413	.4008	10.585	.4150	10.806	.4254	10.912	.4482	10.667
.3884	10.419	.4020	10.602	.4154	10.809	.4267	10.922	.4533	10.599
.3897	10.425	.4030	10.623	.4159	10.817	.4281	10.919	.4582	10.535
.3908	10.433	.4042	10.644	.4169	10.843				

Table 3 Times of minima of VV UMa

Observer		w	n	Helioc. J.D.		O–C
S,O	ph	1	– 4809	2425619.491		$-0^d.036$
" "	"	1	4220	26024.350		– .042
" "	"	1	3370	26608.632		– .031
" "	"	1	– 420	28636.417		– .009
" "	"	1	0	28925.135		+ .011
" "	"	1	+ 392	29194.553		– .023
" "	"	1	472	29249.578		+ .012
R	"	1	9151	35215.379		+ .066
"	"	1	9154	35217.446		+ .071
S,O (')	"	1	11172	36604.489	±.027	– .014
" " (")	"	1	11185	36613.427	.022	– .011
" "	"	1	11220	36637.481		– .016
" "	"	1	11249	36657.420		– .011
W	pe	10	12255	37348.9309		– .0011
"	"	10	12339	37406.6696		– .0021
B,C	"	2	14356.5	38793.4574	.0002	+ .0021
" "	"	10	14358	38794.4873	.0002	+ .0010
" "	"	1	14362.5	38797.5784	.0004	– .0011
" "	"	5	14365	38799.2991		+ .0011
" "	"	10	14432	38845.3537	.0001	+ .0015
" "	"	10	14435	38847.4159	.0001	+ .0016
" "	"	10	14483	38880.4097	.0001	+ .0012
" "	"	3	14841	39126.4914	.0001	+ .0019
" "	"	10	14921	39181.4815	.0001	+ .0017
" "	"	10	14950	39201.4151	.0001	+ .0015
" "	"	1	14996.5	39233.3798	.0002	+ .0031
B,H,E (')	v	1	15014	39245.407	.002	+ .001
B,C	pe	10	15385	39500.4234	.0001	+ .0007
" "	"	10	15932	39876.4180	.0001	– .0001
O	v	1	17159	40719.817		– .013
" (')	"	1	17205	40751.441	.003	– .008
M	"	1	18682	41766.683		– .022
"	"	1	18685	41768.745		– .023
B,C	pe	5	+18734	41802.4278		–0.0212

S,O = W. Strohmeier, H. Ott; R = R. Rudolf; W = R.E. Wilson
B,C = P. Broglia, P. Conconi; B,H,E = W. Braune, J. Hubscher, W. Eckert; O = O. Oburka; M = T. Mallama.
(') normal epoch deduced from three minima.
(") normal epoch deduced from two minima.

Table 4 Fourier coefficients, rectification constants and rectified minima

Filter	A_0	A_1	A_2	A_3	B_1	B_2	C_0	z	l_0^{pr}	l_0^{sec}
B	.9584 ± 9	–.0097 30	–.0276 15	–.0035 20	–.0016 7	–.0014 8	.0093	.047	.498	.947
V	.9610 ± 7	–.0059 10	–.0259 11		–.0018 6	–.0009 6	.0049	.045	.523	.934

Table 5 Solutions for VV UMa calculated according to the Russell model. *N* is the number of normals used in the solutions

Filter	i_r	r_g	r_s	L_g	L_s	x_g	x_s	σ	N
B	84°.1 ± 9	.367 5	.281 5	.797 20	.054 3	.65	.80	.0032	54
V	84.7 ± 6	.368 2	.286 2	.742 13	.065 1	.50	.70	.0027	65
B	81.3 ± 6	.369 3	.269 4	.944	.056	.65	.80	.0043	54
V	81.3 ± 5	.371 3	.267 3	.928	.072	.50	.70	.0047	65

Table 6 Solutions for VV UMa calculated according to the model of Wilson and Devinney

Filter	q	1	2	i	A_2	L_1	L_2	r_{1pt}	r_{1pl}	r_{1bk}	r_{1sd}	r_{2pt}	r_{2pl}	r_{2bk}	r_{2sd}		N
B	.23	3.066 ± 4	2.306	84°.6 1	.47	.962 4	.038 4	.370 1	.351 1	.366 1	.361 1	.353	.242	.285	.252	.0047	39
V	.23	3.049 ± 4	2.306	83.3 1	.47 4	.939 1	.061 1	.373 1	.353 1	.369 1	.363 1	.353	.242	.285	.252	.0032	48
B	.404 ± 1	3.273 9	2.869 5	82.3 1	.44 3	.976 2	.024 2	.373 1	.346 1	.366 1	.357 1	.290 1	.252 1	.278 1	.260 1	.0026	39
V	.402 ± 3	3.245 11	2.889 11	82.3 2	.33 2	.951 2	.049 2	.377 2	.349 1	.369 2	.360 1	.282 3	.248 2	.271 2	.255 2	.0029	48

pt = point pl = pole bk = back sd = side

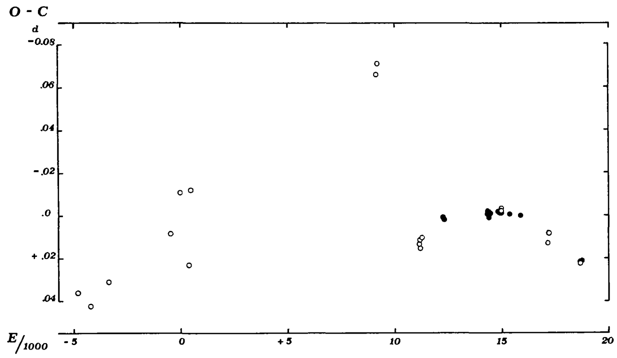

Figure 1 $O-C$ diagram obtained by means of a linear ephemerides from all the times of minimum.

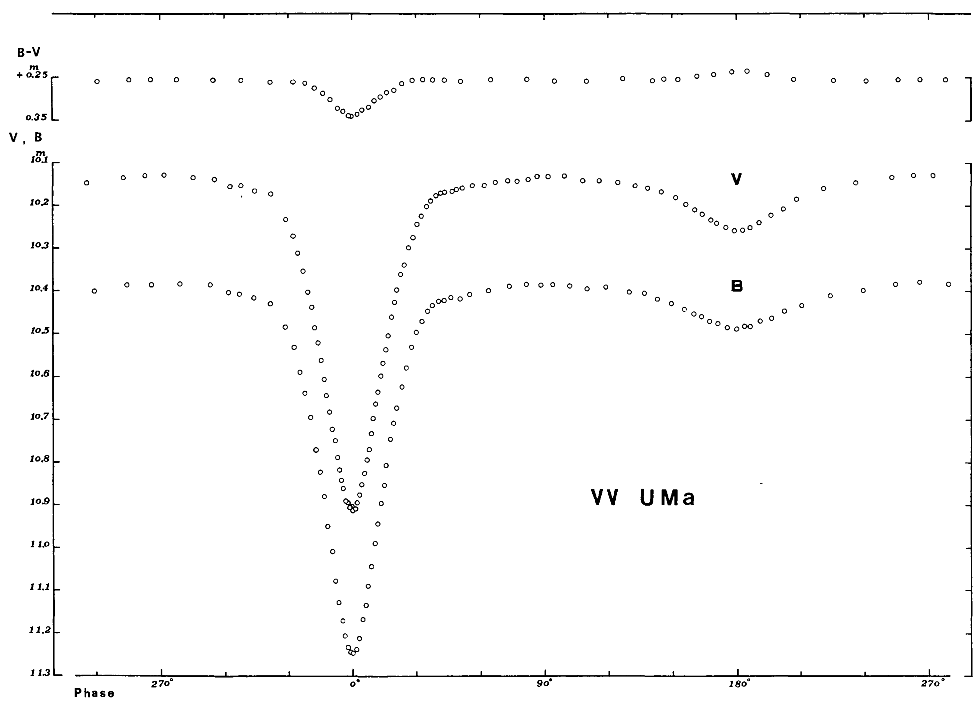

Figure 2 Light and colour curves of VV UMa. The normal points are the mean of ten single observations.