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Seasonal light curves of TY UMa : observations and solutions

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Summary. — Two sets of *B* and *V* observations of W UMa type binary system TY UMa have been obtained at a distance of fourteen years. Small seasonal changes can be seen in the light curves. The period also is varying. Solutions of seasonal light curves have been derived using the Wilson computer programs, and the photometric disturbances analysed.

Key words : eclipsing binary — photometric solutions.

1. **Observations.** — In a short communication (Broglia and Conconi, 1981) we have briefly reported the photoelectric *B* and *V* measurements obtained during 1967 for the W UMa type variable TY UMa (= SVS 366). During 1981 at the Merate Observatory we obtained new *B* and *V* light curves using the same telescope (102 cm reflector) and photometer used in 1967. The integration time for a single measurement was 20 s.

The star BD + 56°1573, which has a colour very similar to that of the variable, served as comparison star in both the seasons. The differential extinction corrections for the variable resulted 0.004 mag at the most. On the basis of tie-in to *UBV* standards on five nights we obtained for BD + 56°1573 :

$$V = 10.243 \pm 3 \qquad B\text{-}V = +0.700 \pm 3 \text{ m.e.}$$

The comparison star was checked against the stars named b and a in the finding chart given by Beliawsky (1933). No evidence of variability appeared between the two seasons. The average standard deviation of a single differential magnitude between comparison and check stars is to the order of ± 0.014 and ± 0.011 mag respectively for *B* and *V* filters.

The observations of TY UMa, about 2500 altogether, are listed in tables I and II.

2. **Period.** — By means of a least squares fitting of a parabola to the observations around the bottom of the minima, eleven epochs have been computed. The mean incertitude of an epoch estimated from the comparison of *B* and *V* fittings is ± $0^d.0002$. The times of minimum are given in table III, where the timings given in the literature are also given with the corresponding sources. A linear ephemeris is sufficient to represent our epochs and the mean residual resulted ± $0^d.0006$. However considering all the epochs reported in table III, which span over an interval of almost 50000 orbital revolutions, it appeared that adding a parabolic term the residuals were reduced by half. We obtained the ephemeris :

$$\text{Min I} = \text{helioc. JD } 2439532.4965 + \underset{68}{0.354538609}\, n + \underset{4 \text{ m.e.}}{6.4 \times 10^{-11}}\, n^{\underset{3}{2}} \quad (1)$$

The corresponding *O-C* are given in table III with the weight assigned to each epoch. In spite of poor precision of some visual or photographic timings, as some large residuals prove, we can be certain that the period is changing slowly.

Considering the photoelectric instants only, we can see a systematic trend for the residuals. Indeed during 1967 the occultation, in this season the shallower minimum, occurs on average $0^d.0005$ later and the transit is in advance by the same amount in relation to the time calculated according to the ephemeris (1) ; the reverse occurs during 1981, where the occultation became deeper than the transit. This fact arises from a perturbation shifting along the light curve and explains the larger values of the residuals, calculated by means of the ephemeris (1), compared to the estimated internal precision ± $0^d.0002$.

3. **Seasonal light curves.** — The light curves of TY UMa obtained during 1967 and 1981 are plotted in figures 1 and 2. The brightness at the maxima, the depths of the minima and in general all the light curves differed slightly between the two seasons. The maximum following the deepest eclipse is always the brighter one ; the deepest eclipse during 1967 becomes the shallower one during 1981. The values given in table IV have been derived. The colour is redder by about $0^m.02$ during the minima. It can also be noticed that when the maximum is brighter the colour is slightly bluer. An harmonic analysis of the light

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curves confirms that the asymmetry can be represented principally by a $\sin\theta$ term, and the corresponding coefficients B_1 are given in table IV. We note that between 1967 and 1981 the value of B_1 turned from negative into positive. The observations obtained during 1981 moreover prove that the photometric disturbance varies also during an interval of a few months. Though the effect is small, there is no doubt that these two light curves are different in some parts ; we have therefore found it useful to consider separately two subsets, named 1981_1, from JD 44634 to 44642 and 1981_2, from JD 44723 to 44730. Because of the minor systematic differences visible in the 1967 measurements and of the unfavourable coverage of the light curves, we thought is advisable to consider these observations as a whole when computing the elements.

4. **Light curves analysis.** — Perturbations in light curves are a common feature of close systems and when they are substantial they hamper the calculation of reliable solutions. The disturbances in TY UMa appear moderate but cannot be allowed for completely by subtraction of $\sin\theta$ term. However by comparing the solutions calculated from seasonal light curves we can hope to obtain a more correct evaluation of the elements of the unperturbed system and their incertitude can thus be evaluated more realistically than as given by the internal errors computed for the adjusted parameters.

Moreover the plot of the residuals of measurements calculated with reference to seasonal solutions (where the elements like the inclination i, the mass ratio $q = m_2/m_1$, the surface potential Ω, which can reasonably be regarded as constant during our observing interval, are kept the same in all the solutions) can give some information about the changing morphology of photometric perturbations.

The solutions of TY UMa were based on modified light curves from which the $\sin\theta$ distortion was subtracted out before the elements were derived. The single B and V measurements of each group have been calculated by means of a PDP 11/34 minicomputer using the Wilson and Devinney programs updated by Leung and Wilson (1977) and modified in order to have a greater computing speed (Broglia, Conconi, 1981a).

Since preliminary solutions showed that the components of the system are in marginal contact, we derived the elements both in mode 0 and in mode 3, which according to the Wilson code refer respectively to semidetached and contact configurations. No spectroscopic mass-ratio is known for TY UMa, so a photometric estimate of q has been performed.

To eliminate the uncertainties due to the correlations between q and some other parameters, correlations which are however weaker in totally eclipsing systems like TY UMa than in partially eclipsing stars, sets of solutions have been obtained with values of q ranging from 0.36 to 0.50 at steps of 0.02, separately for the three seasonal light curves. Theoretical values have been assumed for the darkening coefficients x_1 and x_2 (Grygar *et al.*, 1972) ; the choice of x_1 and x_2 however can be regarded as having no effect on the solutions. Moreover when computing in mode 0 the corrections for i, Ω_1, Ω_2, for the reflection albedos A_1, A_2, and for the B and V luminosities of the components L_{1V}, L_{1B}, L_{2V}, L_{2B}, the values of the gravity darkening parameters $g_1 = g_2 = 1$ were assumed. In mode 3 the adjusted parameters were : i, T_2, A, g, L_{1V}, L_{1B}, and the filling factor F. The polar temperature T_1 of the larger and heavier component, which gives a transit deeper than the occultation in 1967 and the reverse during 1981, was fixed to 5550 K in accordance with the B-V values observed at the central phase of the occultation minimum, the same within observational error from 1967 to 1981, and with the Allen (1973) temperature scale.

The solutions calculated in mode 3 point to a marginal configuration with $q = 0.40$. The mode 0 solutions give $q = 0.42$ and display that the more massive component fills its Roche lobe and the less massive nearly fills its lobe, but the albedo A_1 overcomes the unity. The best solutions in both modes give practically the same sums of squares of residuals : because in mode 3 a smaller number of parameters has been adjusted and no difficulty appears for the albedo, the contact configuration is more acceptable. The elements derived in mode 3 are given in table V, where we have assumed : $L_1 + L_2 = 1$. We note that because i, q, Ω, have been assumed to be the same in the different seasons, in table V the averages of values of i, q, Ω, derived from solving each light curve are given with the corresponding r.m.s. errors. With these values kept fixed the other elements have been calculated separately for each season in order to show a possible connection with the time-dependent perturbation. In particular when computing in mode 3 the temperature T_2 of the smaller, lighter star is a free parameter. Looking at table IV we see that whilst during the total eclipse B-V is constant, at Min II small changes in fact appear from one season to other.

The degree of overcontact, defined as $(\Omega_{\text{inner}}-\Omega)/(\Omega_{\text{inner}}-\Omega_{\text{outer}})$, is 12 percent and as figure 4 shows, the configuration of TY UMa has a moderate overcontact, typical of the W-type subgroup.

The iterations with the differential correction program were stopped when the corrections calculated were similar or smaller than their errors. N is the number of measurements utilized and σ is the standard deviation of a single B or V observation from the computed light curves.

These values compare with the errors evaluated for the Δm between comparison and check stars and are three time larger than the mean deviation between synthetic light curves computed with the best solutions in mode 0 and in mode 3. This fact explains the difficulty in the choice of the better configuration for the system on the basis of the respective sums of the residuals ; the configurations computed in both modes look very similar indeed (Fig. 4).

5. **Discussion.** — TY UMa is a totally eclipsing system and exhibits moderate asymmetry in the light curves. The position of the disturbancy is not fixed in the system but it shifted 180° during the interval 1967-1981 and changed also within a few weeks, so the perturbation does not corotate synchronously with the stars. The mean total luminosity of the system between the eclipses, as given by the A_0 term in the Fourier representation of light curves, is constant during all the observing seasons within 0.005 mag, whilst the ratio of the luminosities of the components changes, as the solutions display.

The time-dependent asymmetry, the increasing period, both signs of a quasi-equilibrium state, and the colour $B-V$ suggesting a spectral type G5 for the components, place TY UMa in the W-subgroup of the W UMa systems. The spectral type of these binaries is later than F0-F5, the transition range from A-type to W-type behaviour, and the occultation minimum is deeper than the transit one. During 1981 this is indeed the configuration of TY UMa, but in 1967 the transit eclipse is a little deeper than the occultation, so this criterion of classification appears meaningless when the minima have the same depths and a photometric activity is present. The interchanging depths of occultation and transit minima have already been observed in several W-type systems like AC Boo, AM Leo, TZ Boo (Hoffmann, 1980) and CK Boo (Aslan *et al.*, 1981) so this feature appears to be fairly common in the W-subgroup.

TY UMa conforms to the rough correlation between the degree of overcontact and the period of the W UMa variables given by Mochnacki (1981), where the W-subgroup is characterized by small overcontact.

To know more about the morphology of the perturbation, the residuals of single observations, with the sin θ term removed, calculated with reference to the solutions given in table V, have been plotted in figure 3. Some small systematic behaviour can be seen, the same for the B and V measurements, with opposing trends between 1967 and 1981. This applies also to the chief sinusoidal component of the perturbation.

The behaviour of the residuals and their dispersion, the same at all orbital phases, shows that the perturbation is not located in a particular region of the system and suggests that all the thin common envelope is in an unstable, short-time scale, thermal equilibrium.

On the other hand the changing period implies a mass transfer between the components on a longer time-scale and a semidetached configuration. The discrepancy between the semidetached configuration supported by the variable period and the contact configuration (Fig. 4) is not so serious when taking into account the marginal contact computed.

The subtraction of the sin θ perturbation is a method commonly used to eliminate the complications when solving light curves of eclipsing binaries. However one can question about the influence of perturbations on computed elements. A test was performed using the 1967 observations, where the complications are larger, without subtraction of the sin θ term, either computing with all B and V observations together, or using separately the measurements included in the phase intervals 0.0-0.5 and 0.5-1.0. In both cases the values derived for q, i, Ω, agree with the values given in table V within the errors quoted there. The photometric parameters also agree in the first case, but the corresponding errors are about twice the formal errors given in table V. When computing separately with the 0.0-0.5 and 0.5-1.0 groups a remarkable difference resulted for the two sets of values of g, A, T_2, $L_{V,B}$. In other words the sin θ complication fundamentally affects only the photometric parameters. In particular the temperatures of the two hemispheres of the less massive star resulted 5500 K and 5600 K compared to the value $T_2 = 5545$ K pertinent to complete star (Table V). This difference confirms the quasi-equilibrium condition of the system suggested by the residuals (Fig. 3) and by the temperature T_2 changing from one season to the other.

It is known that the Roche geometry of a contact system with complete eclipses allows for quite a reliable mass-ratio being found. The agreement of the three seasonal solutions and the test on the effect over the elements of the sin θ perturbation give us confidence that the value derived for q is practically not influenced by photometric perturbations. The incertitude $\pm$ 0.02 derived for q corresponds to an increase of the sum of the squares of residuals of about 8 percent over the value of the adopted solution, so this value appears to be a realistic estimate. Within this error the value of q, derived when computing in mode 0 or in mode 3, also agree.

No difficulties appear for g and A derived from the three complete light curves : the averages of the gravity darkening exponents and of bolometric albedos are respectively 0.29 and 0.58, close to the convective observationally average values $g_{conv} = 0.31$ and $A_{conv} = 0.56$ given by Rafert and Twigg (1981) for the W-subgroup. The temperature of the less massive star is the same as the heavier component during 1967, when the transit is only a little deeper than the occultation. In the following seasons, when the depths of the minima reverse, the less massive star appears hotter by 120 K and some weeks later hotter by 300 K. It appears difficult to interpret the temporal changes of A and g, either referring to their original meaning or in terms of influence of photometric perturbations.

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TABLE I. — *B observations of TY UMa.*

HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B
532.4494	12.278	532.6597	12.715	561.6208	12.281	563.4780	12.364	564.3716	12.378
.4547	12.322	.6626	12.767	.6245	12.252	.4806	12.395	.3745	12.415
.4577	12.330	.6654	12.794	.6256	12.258	.4815	12.402	.3780	12.476
.4616	12.376	.6681	12.816	.6305	12.249	.4855	12.428	.3789	12.490
.4641	12.395	.6708	12.834	.6353	12.228	.4880	12.453	.3814	12.534
.4681	12.473	.6724	12.818	.6361	12.224	.4888	12.476	565.3759	12.150
.4711	12.506	.6751	12.809	.6409	12.211	.4915	12.507	.3792	12.147
.4727	12.546	.6772	12.814	.6421	12.213	.4923	12.516	.3821	12.162
.4755	12.580	.6798	12.799	.6489	12.214	.4951	12.562	.3825	12.180
.4771	12.616	.6825	12.777	.6497	12.212	.4959	12.580	.3854	12.169
.4797	12.663	.6852	12.720	562.3139	12.392	.4986	12.610	.3881	12.172
.4814	12.692	.6877	12.684	.3198	12.327	.4993	12.634	.3908	12.170
.4839	12.763	.6891	12.675	.3254	12.283	.5020	12.665	.3914	12.173
.4866	12.775	.6915	12.604	.3282	12.277	.5028	12.679	.3946	12.164
.4882	12.811	.6930	12.585	.3312	12.286	.5037	12.706	.3971	12.182
.4908	12.813	.6958	12.527	.3341	12.268	.5062	12.738	.4001	12.187
.4923	12.810	.6976	12.526	.3377	12.261	.5070	12.746	.4031	12.200
.4947	12.827	.7007	12.483	.3411	12.245	.5078	12.757	.4058	12.203
.4961	12.840	.7023	12.466	.3446	12.245	.5115	12.822	.4086	12.219
.4988	12.838	.7052	12.412	.3473	12.262	.5122	12.826	.4115	12.246
.5015	12.828	.7070	12.408	.3506	12.258	.5131	12.824	.4142	12.251
.5043	12.812	561.4726	12.166	.3615	12.199	.5157	12.840	.4176	12.265
.5071	12.780	.4768	12.147	.3642	12.205	.5163	12.832	.4233	12.292
.5087	12.777	.4826	12.155	.3669	12.208	.5171	12.848	.4261	12.295
.5111	12.717	.4940	12.166	.3696	12.200	.5198	12.838	.4291	12.321
.5127	12.676	.4996	12.174	.3723	12.213	.5205	12.832	.4318	12.349
.5150	12.664	.5030	12.176	.3732	12.218	.5225	12.831	.4346	12.391
.5165	12.632	.5058	12.191	.3763	12.213	.5246	12.814	.4387	12.438
.5191	12.620	.5087	12.208	.3770	12.222	.5254	12.818	.4441	12.493
.5211	12.562	.5096	12.218	.3801	12.216	.5281	12.772	.4502	12.638
.5237	12.527	.5131	12.239	.3812	12.216	.5292	12.744	.4549	12.698
.5241	12.507	.5161	12.248	.3837	12.235	.5303	12.735	.4572	12.727
.5259	12.488	.5171	12.258	.3852	12.238	.5335	12.683	.4596	12.764
.5288	12.455	.5200	12.269	.3886	12.258	.5344	12.677	.4621	12.784
.5303	12.441	.5210	12.284	.3894	12.259	.5351	12.639	566.3679	12.705
.5307	12.423	.5246	12.279	.3924	12.261	.5367	12.630	.3715	12.626
.5338	12.387	.5272	12.294	.4233	12.475	.5374	12.599	.3742	12.595
.5364	12.375	.5281	12.312	.4271	12.485	.5403	12.576	.3811	12.501
.5396	12.342	.5308	12.351	.4300	12.533	.5412	12.555	.3857	12.452
.5433	12.321	.5316	12.352	.4332	12.567	.5419	12.537	.3886	12.437
.5450	12.329	.5353	12.389	.4364	12.622	.5428	12.517	.3895	12.421
.5477	12.312	.5380	12.442	.4372	12.623	.5458	12.485	.4036	12.292
.5494	12.299	.5404	12.460	.4400	12.693	.5467	12.486	.4087	12.247
.5547	12.293	.5446	12.505	.4408	12.698	.5476	12.456	.4125	12.242
.5599	12.291	.5471	12.559	.4432	12.733	.5487	12.447	.4331	12.164
.5616	12.277	.5498	12.609	.4440	12.763	.5522	12.408	.4380	12.145
.5643	12.264	.5506	12.626	.4468	12.806	.5534	12.387	.4410	12.141
.5657	12.242	.5539	12.684	.4476	12.794	.5542	12.383	.4440	12.152
.5687	12.235	.5548	12.715	.4580	12.833	.5589	12.338	.4499	12.151
.5714	12.239	.5576	12.736	.4587	12.817	.5597	12.349	.4565	12.166
.5743	12.233	.5585	12.765	.4613	12.786	.5606	12.330	.4617	12.191
.5783	12.217	.5619	12.784	.4619	12.779	.5637	12.307	.4660	12.195
.5798	12.216	.5628	12.800	.4644	12.758	.5646	12.297	.4687	12.202
.5825	12.218	.5661	12.791	.4653	12.725	.5667	12.291	.4718	12.217
.5839	12.232	.5672	12.789	.4681	12.690	.5702	12.271	.4775	12.227
.5874	12.220	.5708	12.778	.4689	12.677	.5716	12.261	.4806	12.229
.5915	12.207	.5716	12.786	.4715	12.621	.5728	12.250	.4840	12.256
.5930	12.221	.5749	12.783	.4742	12.589	.5783	12.231	.4867	12.280
.5958	12.240	.5771	12.758	.4772	12.534	.5793	12.228	.4893	12.288
.5975	12.226	.5809	12.711	.4805	12.507	.5823	12.215	.4924	12.311
.6011	12.240	.5832	12.692	.4818	12.491	.5834	12.222	.4933	12.324
.6027	12.237	.5864	12.647	563.4432	12.209	.5926	12.191	.4960	12.338
.6054	12.249	.5874	12.624	.4463	12.217	.5935	12.184	.4977	12.359
.6070	12.242	.5884	12.616	.4514	12.252	.5960	12.182	.5006	12.409
.6125	12.281	.5893	12.600	.4552	12.261	.5969	12.183	.5020	12.426
.6172	12.297	.5931	12.536	.4575	12.265	.5978	12.189	.5043	12.465
.6220	12.308	.5939	12.502	.4598	12.280	.5984	12.186	.5050	12.468
.6257	12.321	.5970	12.478	.4622	12.294	564.3447	12.216	.5077	12.504
.6274	12.320	.5978	12.467	.4649	12.284	.3509	12.235	.5083	12.530
.6312	12.379	.6011	12.431	.4658	12.297	.3565	12.231	.5111	12.591
.6449	12.502	.6019	12.414	.4684	12.325	.3598	12.253	.5119	12.587
.6465	12.511	.6071	12.371	.4691	12.329	.3633	12.282	.5144	12.609
.6504	12.573	.6125	12.314	.4720	12.344	.3673	12.341	.5153	12.631
.6542	12.634	.6162	12.305	.4731	12.339	.3682	12.344	.5180	12.681
.6572	12.689	.6198	12.288	.4773	12.366	.3706	12.373	.5189	12.704

TABLE I *(continued)*.

HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B
566.5217	12.755	614.4329	12.374	648.4205	12.758	5634.6039	12.216	5635.5243	12.356
.5224	12.753	.4336	12.362	.4235	12.790	.6058	12.214	.5263	12.382
.5249	12.795	.4371	12.333	.4265	12.782	.6089	12.223	.5280	12.395
.5256	12.786	.4397	12.320	.4292	12.797	.6112	12.241	.5299	12.399
.5285	12.801	.4434	12.311	.4333	12.816	.6133	12.244	.5307	12.408
.5293	12.785	.4480	12.308	.4392	12.804	.6153	12.259	.5328	12.435
.5324	12.805	.4511	12.287	.4435	12.733	.6184	12.263	.5337	12.437
.5341	12.785	.4540	12.279	.4459	12.683	.6203	12.293	.5357	12.468
.5386	12.821	.4547	12.277	.4486	12.656	.6224	12.301	.5372	12.499
.5411	12.786	.4579	12.250	.4517	12.622	.6256	12.312	.5392	12.534
.5420	12.762	.4611	12.237	.4544	12.543	.6302	12.336	.5400	12.530
.5457	12.718	.4618	12.229	.4577	12.508	.6309	12.342	.5420	12.558
.5465	12.682	.4649	12.220	5634.4339	12.193	.6328	12.365	.5428	12.575
.5488	12.657	.4685	12.213	.4372	12.234	.6338	12.360	.5449	12.602
.5496	12.660	.4718	12.218	.4402	12.251	.6359	12.374	.5459	12.633
.5522	12.618	.4749	12.205	.4432	12.269	.6381	12.407	.5485	12.685
.5531	12.613	.4757	12.203	.4464	12.273	.6405	12.414	.5498	12.705
.5555	12.594	.4791	12.187	.4473	12.270	.6418	12.430	.5519	12.736
.5579	12.553	.4823	12.195	.4498	12.286	.6439	12.463	.5527	12.754
.5606	12.490	.4831	12.204	.4533	12.316	.6445	12.470	.5548	12.798
.5638	12.452	.4862	12.186	.4555	12.325	.6463	12.500	.5571	12.794
.5647	12.440	.4892	12.186	.4563	12.329	.6470	12.518	.5589	12.796
.5650	12.435	.4900	12.186	.4583	12.353	.6489	12.551	.5608	12.803
.5679	12.397	.4938	12.184	.4602	12.373	.6508	12.590	.5620	12.796
.5689	12.378	.4979	12.201	.4632	12.391	.6528	12.601	.5640	12.794
.5720	12.361	.5021	12.195	.4661	12.426	.6535	12.620	.5647	12.791
.5743	12.345	.5086	12.240	.4690	12.451	.6553	12.634	.5670	12.796
.5786	12.305	.5115	12.242	.4717	12.501	.6561	12.659	.5694	12.780
.5830	12.312	.5122	12.253	.4744	12.529	.6586	12.700	.5701	12.765
.5870	12.302	643.4034	12.192	.4781	12.598	.6618	12.749	.5721	12.741
.5878	12.297	.4050	12.194	.4820	12.659	.6625	12.771	.5729	12.733
.5904	12.271	.4074	12.203	.4844	12.695	.6646	12.783	.5736	12.716
.5910	12.260	.4087	12.202	.4851	12.704	.6658	12.804	.5756	12.678
.5962	12.251	.4112	12.225	.4884	12.770	.6677	12.815	.5774	12.639
.6004	12.236	.4129	12.224	.4925	12.798	.6684	12.818	.5793	12.623
.6032	12.226	.4163	12.252	.4945	12.791	.6704	12.807	.5797	12.624
.6075	12.211	.4179	12.262	.4953	12.805	.6711	12.810	.5827	12.601
.6099	12.219	.4212	12.271	.4984	12.830	.6735	12.807	.5870	12.547
.6140	12.216	.4252	12.296	.5009	12.827	.6766	12.824	.5902	12.494
.6149	12.232	.4266	12.311	.5036	12.797	5635.4307	12.282	.5928	12.453
614.3649	12.424	.4304	12.347	.5063	12.784	.4351	12.272	.5988	12.388
.3652	12.455	.4327	12.356	.5090	12.757	.4379	12.260	.6041	12.339
.3699	12.536	.4338	12.374	.5116	12.695	.4395	12.247	.6079	12.306
.3730	12.568	.4365	12.416	.5143	12.655	.4423	12.244	.6114	12.298
.3755	12.599	.4372	12.424	.5180	12.613	.4462	12.231	.6151	12.292
.3761	12.617	.4400	12.481	.5209	12.558	.4497	12.216	.6194	12.278
.3789	12.656	.4409	12.484	.5237	12.509	.4540	12.198	.6235	12.260
.3796	12.654	.4434	12.533	.5264	12.478	.4572	12.191	.6275	12.269
.3821	12.707	.4442	12.542	.5292	12.445	.4593	12.183	.6329	12.249
.3825	12.727	.4467	12.575	.5328	12.401	.4614	12.160	.6375	12.214
.3850	12.762	.4475	12.599	.5357	12.371	.4645	12.176	.6397	12.229
.3872	12.783	.4501	12.637	.5376	12.355	.4787	12.163	.6413	12.224
.3905	12.798	.4513	12.652	.5464	12.305	.4720	12.169	.6429	12.216
.3924	12.781	.4544	12.728	.5499	12.291	.4728	12.159	.6472	12.210
.3948	12.784	.4577	12.768	.5532	12.279	.4765	12.147	.6487	12.204
.3954	12.781	.4585	12.778	.5554	12.250	.4798	12.156	.6503	12.192
.3979	12.797	.4616	12.816	.5574	12.240	.4823	12.165	.6564	12.187
.3986	12.797	.4654	12.795	.5595	12.235	.4851	12.158	.6583	12.190
.4011	12.804	.4686	12.798	.5603	12.231	.4882	12.173	.6590	12.193
.4018	12.802	.4708	12.801	.5626	12.232	.4905	12.160	.6620	12.198
.4043	12.778	.4728	12.822	.5642	12.244	.4913	12.168	.6647	12.201
.4063	12.758	.4758	12.788	.5663	12.238	.4932	12.164	.6665	12.203
.4085	12.707	.4795	12.723	.5670	12.229	.4949	12.189	.6679	12.210
.4111	12.660	.4828	12.654	.5696	12.214	.4988	12.202	5641.4412	12.468
.4118	12.662	.4877	12.589	.5720	12.212	.5018	12.213	.4426	12.462
.4123	12.632	.4919	12.547	.5778	12.207	.5038	12.235	.4443	12.443
.4147	12.612	.4992	12.426	.5804	12.220	.5066	12.241	.4449	12.443
.4155	12.599	.5032	12.383	.5846	12.203	.5095	12.250	.4470	12.396
.4192	12.548	.5053	12.353	.5869	12.206	.5113	12.267	.4500	12.387
.4199	12.523	.5075	12.344	.5891	12.199	.5152	12.278	.4506	12.375
.4225	12.486	648.4054	12.498	.5915	12.212	.5172	12.289	.4529	12.357
.4232	12.464	.4088	12.580	.5943	12.208	.5181	12.291	.4569	12.351
.4261	12.435	.4122	12.624	.5968	12.201	.5201	12.310	.4595	12.338
.4282	12.419	.4149	12.665	.5992	12.216	.5209	12.325	.4610	12.327
.4303	12.377	.4179	12.732	.6019	12.226	.5236	12.359	.4627	12.295

TABLE I *(continued)*.

HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B	HEL. J.D. 2439000.+	B
5641.4653	12.287	5641.5853	12.795	5723.4016	12.167	5725.4041	12.429	5725.5288	12.151
.4692	12.265	.5873	12.804	.4023	12.167	.4059	12.456	.5295	12.155
.4714	12.264	.5879	12.802	.4043	12.171	.4073	12.471	.5316	12.143
.4720	12.251	.5895	12.810	.4051	12.178	.4089	12.505	.5323	12.153
.4739	12.255	.5912	12.814	.4073	12.181	.4096	12.523	.5343	12.168
.4759	12.246	.5931	12.801	.4079	12.165	.4103	12.530	.5366	12.165
.4776	12.243	.5937	12.795	.4100	12.167	.4122	12.569	.5408	12.183
.4783	12.248	.5942	12.806	.4109	12.160	.4129	12.560	.5435	12.171
.4799	12.236	.5959	12.779	.4135	12.168	.4136	12.582	.5463	12.174
.4808	12.223	.5966	12.765	.4168	12.180	.4154	12.604	.5497	12.194
.4837	12.215	.5971	12.775	.4198	12.200	.4161	12.611	5730.3462	12.308
.4855	12.222	.5987	12.747	.4206	12.198	.4178	12.650	.3474	12.313
.4860	12.208	.5993	12.733	.4228	12.200	.4185	12.687	.3498	12.328
.4876	12.220	.5998	12.726	.4235	12.207	.4204	12.709	.3515	12.325
.4882	12.210	.6014	12.722	.4260	12.213	.4212	12.744	.3539	12.321
.4918	12.215	.6035	12.685	.4285	12.226	.4232	12.752	.3551	12.342
.4938	12.190	.6048	12.665	.4304	12.237	.4239	12.765	.3574	12.354
.4944	12.182	.6068	12.630	.4331	12.260	.4254	12.794	.3583	12.360
.4978	12.199	.6075	12.603	.4353	12.264	.4273	12.811	.3612	12.364
.5002	12.195	.6093	12.593	.4431	12.277	.4285	12.837	.3619	12.381
.5020	12.192	.6099	12.588	.4451	12.289	.4307	12.830	.3644	12.403
.5025	12.187	.6104	12.575	.4571	12.403	.4313	12.843	.3668	12.429
.5043	12.185	.6120	12.557	.4625	12.485	.4324	12.840	.3688	12.465
.5057	12.203	.6126	12.539	.4662	12.552	.4350	12.843	.3697	12.476
.5079	12.194	.6132	12.534	.4697	12.594	.4357	12.842	.3717	12.488
.5084	12.204	5642.4319	12.345	.4720	12.625	.4379	12.829	.3726	12.512
.5099	12.192	.4350	12.353	.4727	12.623	.4385	12.832	.3747	12.547
.5119	12.185	.4379	12.403	.4789	12.723	.4405	12.845	.3755	12.554
.5131	12.191	.4402	12.413	.4819	12.750	.4422	12.854	.3776	12.597
.5144	12.194	.4452	12.485	.4826	12.747	.4449	12.807	.3793	12.620
.5158	12.202	.4460	12.496	.4850	12.758	.4493	12.767	.3814	12.661
.5163	12.206	.4480	12.523	.4857	12.763	.4524	12.725	.3823	12.689
.5178	12.194	.4486	12.536	.4877	12.752	.4559	12.659	.3845	12.741
.5190	12.208	.4507	12.578	.4899	12.771	.4579	12.612	.3854	12.746
.5211	12.218	.4526	12.621	.4937	12.744	.4585	12.603	.3876	12.766
.5234	12.206	.4533	12.634	.4990	12.671	.4607	12.558	.3885	12.789
.5272	12.237	.4553	12.659	.5020	12.646	.4613	12.568	.3906	12.810
.5292	12.241	.4566	12.704	.5039	12.597	.4633	12.525	.3934	12.846
.5379	12.274	.4585	12.721	.5056	12.567	.4640	12.509	.3953	12.850
.5400	12.281	.4599	12.756	.5079	12.559	.4660	12.491	.3973	12.844
.5422	12.314	.4606	12.755	.5102	12.518	.4667	12.467	.3980	12.847
.5441	12.309	.4627	12.782	.5119	12.508	.4674	12.469	.4001	12.856
.5447	12.301	.4646	12.802	.5149	12.469	.4693	12.425	.4024	12.865
.5464	12.308	.4668	12.835	.5175	12.420	.4699	12.435	.4044	12.850
.5477	12.337	.4692	12.822	.5181	12.413	.4723	12.386	.4063	12.862
.5493	12.352	.4699	12.830	.5201	12.398	.4737	12.391	.4082	12.848
.5499	12.354	.4719	12.831	.5220	12.364	.4757	12.369	.4090	12.840
.5515	12.374	.4726	12.814	.5239	12.355	.4764	12.355	.4116	12.830
.5522	12.388	.4745	12.827	.5259	12.326	.4782	12.340	.4140	12.767
.5539	12.384	.4753	12.823	.5278	12.321	.4801	12.323	.4157	12.732
.5545	12.396	.4760	12.820	.5296	12.302	.4809	12.341	.4164	12.726
.5566	12.407	.4783	12.818	5725.3619	12.206	.4829	12.311	.4185	12.680
.5589	12.433	.4800	12.824	.3632	12.217	.4836	12.319	.4202	12.649
.5595	12.447	.4807	12.829	.3652	12.222	.4883	12.273	.4221	12.615
.5611	12.472	.4827	12.818	.3675	12.227	.4898	12.264	.4230	12.581
.5626	12.499	.4847	12.808	.3684	12.219	.4939	12.236	.4251	12.572
.5642	12.510	.4874	12.769	.3707	12.224	.4946	12.240	.4262	12.555
.5659	12.529	.4967	12.600	.3714	12.231	.4966	12.232	.4279	12.523
.5664	12.547	.5005	12.556	.3737	12.229	.4975	12.238	.4306	12.470
.5670	12.561	.5042	12.507	.3746	12.230	.5026	12.200	.4323	12.441
.5687	12.584	.5072	12.471	.3771	12.241	.5032	12.211	.4343	12.420
.5694	12.589	.5100	12.426	.3786	12.250	.5053	12.189	.4351	12.409
.5699	12.619	.5135	12.385	.3807	12.256	.5070	12.196	.4374	12.383
.5715	12.626	.5171	12.359	.3814	12.261	.5090	12.186	.4410	12.355
.5720	12.651	.5202	12.341	.3836	12.268	.5098	12.183	.4448	12.346
.5736	12.687	.5232	12.340	.3843	12.276	.5132	12.176	.4478	12.332
.5741	12.676	.5264	12.321	.3870	12.281	.5139	12.162	.4506	12.308
.5747	12.693	5723.3882	12.180	.3898	12.307	.5160	12.174	.4535	12.281
.5768	12.725	.3909	12.194	.3907	12.306	.5166	12.171	.4555	12.272
.5776	12.734	.3929	12.190	.3915	12.325	.5186	12.151	.4559	12.264
.5797	12.747	.3940	12.185	.3937	12.332	.5193	12.154	.4591	12.243
.5818	12.769	.3960	12.162	.3964	12.363	.5212	12.149	.4632	12.216
.5824	12.762	.3968	12.172	.3992	12.395	.5220	12.150	.4682	12.199
.5829	12.780	.3987	12.175	.4013	12.401	.5248	12.165	.4701	12.193
.5848	12.798	.3995	12.167	.4034	12.430	.5254	12.164	.4731	12.192

TABLE II. — *V observations of TY UMa.*

HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V
532.4475	11.580	532.6177	11.598	561.5475	11.865	562.3894	11.547	563.5210	12.118
.4515	11.597	.6215	11.611	.5503	11.908	.3932	11.586	.5233	12.100
.4543	11.621	.6232	11.626	.5511	11.931	.3937	11.591	.5242	12.099
.4573	11.652	.6261	11.635	.5544	11.990	.4222	11.751	.5250	12.083
.4620	11.699	.6278	11.653	.5552	12.007	.4235	11.761	.5288	12.030
.4645	11.736	.6308	11.664	.5580	12.041	.4266	11.788	.5297	12.019
.4678	11.779	.6323	11.671	.5594	12.060	.4296	11.827	.5307	12.012
.4708	11.800	.6350	11.683	.5624	12.078	.4328	11.862	.5340	11.969
.4724	11.849	.6367	11.695	.5632	12.079	.4359	11.926	.5347	11.944
.4751	11.891	.6410	11.751	.5667	12.078	.4368	11.937	.5355	11.928
.4768	11.907	.6425	11.756	.5676	12.092	.4396	11.955	.5370	11.923
.4793	11.960	.6452	11.795	.5704	12.091	.4404	11.974	.5378	11.902
.4810	11.970	.6468	11.791	.5712	12.089	.4428	12.015	.5408	11.862
.4836	12.033	.6495	11.862	.5738	12.093	.4437	12.016	.5416	11.853
.4862	12.074	.6520	11.880	.5753	12.080	.4464	12.078	.5423	11.821
.4879	12.085	.6547	11.929	.5780	12.065	.4472	12.091	.5433	11.813
.4905	12.105	.6575	11.978	.5804	12.035	.4576	12.095	.5463	11.782
.4920	12.091	.6602	12.005	.5828	12.009	.4596	12.081	.5472	11.768
.4943	12.083	.6629	12.063	.5871	11.940	.4616	12.071	.5480	11.754
.4958	12.097	.6658	12.082	.5879	11.926	.4641	12.052	.5491	11.743
.4984	12.119	.6684	12.100	.5889	11.905	.4648	12.034	.5528	11.698
.4999	12.119	.6711	12.105	.5898	11.883	.4677	12.006	.5538	11.687
.5025	12.116	.6727	12.116	.5935	11.831	.4684	12.001	.5548	11.689
.5039	12.111	.6755	12.112	.5944	11.811	.4712	11.956	.5553	11.688
.5067	12.073	.6775	12.110	.5974	11.764	.4719	11.952	.5584	11.663
.5084	12.054	.6800	12.086	.5982	11.762	.4753	11.882	.5593	11.648
.5108	12.025	.6828	12.050	.6014	11.741	.4760	11.858	.5601	11.642
.5123	11.995	.6855	12.021	.6023	11.712	.4812	11.818	.5633	11.616
.5147	11.968	.6881	11.966	.6071	11.674	.4822	11.800	.5642	11.616
.5161	11.935	.6894	11.960	.6078	11.669	563.4456	11.534	.5663	11.604
.5188	11.910	.6918	11.905	.6116	11.630	.4498	11.541	.5710	11.578
.5202	11.884	.6934	11.898	.6125	11.620	.4538	11.568	.5721	11.560
.5234	11.843	.6962	11.841	.6158	11.621	.4566	11.574	.5778	11.544
.5255	11.787	.6980	11.813	.6194	11.597	.4594	11.580	.5788	11.543
.5284	11.769	.7011	11.790	.6204	11.596	.4602	11.585	.5817	11.523
.5300	11.727	.7027	11.754	.6240	11.593	.4644	11.599	.5828	11.530
.5334	11.712	.7056	11.726	.6250	11.577	.4653	11.605	.5930	11.490
.5361	11.675	.7073	11.708	.6301	11.556	.4683	11.622	.5938	11.488
.5385	11.658	561.4691	11.475	.6348	11.541	.4726	11.651	.5965	11.484
.5400	11.650	.4696	11.482	.6357	11.547	.4735	11.655	.5973	11.494
.5430	11.643	.4730	11.471	.6425	11.525	.4769	11.686	.5988	11.482
.5446	11.634	.4758	11.456	.6432	11.539	.4777	11.674	564.3421	11.559
.5474	11.630	.4787	11.473	.6484	11.512	.4802	11.709	.3468	11.554
.5491	11.609	.4819	11.476	.6493	11.525	.4811	11.707	.3501	11.570
.5526	11.608	.4849	11.456	562.3143	11.684	.4841	11.726	.3534	11.582
.5559	11.592	.4884	11.465	.3183	11.681	.4849	11.730	.3577	11.610
.5601	11.580	.4925	11.481	.3214	11.639	.4876	11.753	.3612	11.638
.5619	11.582	.4969	11.495	.3250	11.622	.4883	11.774	.3651	11.637
.5647	11.575	.5002	11.507	.3276	11.614	.4912	11.803	.3690	11.664
.5675	11.553	.5034	11.516	.3307	11.602	.4919	11.813	.3726	11.697
.5705	11.541	.5062	11.520	.3335	11.591	.4948	11.857	.3767	11.753
.5731	11.552	.5091	11.540	.3373	11.579	.4955	11.867	.3806	11.819
.5747	11.551	.5100	11.532	.3407	11.558	.4982	11.916	565.3763	11.474
.5779	11.535	.5136	11.547	.3452	11.570	.4990	11.933	.3787	11.489
.5807	11.528	.5166	11.563	.3500	11.543	.5014	11.941	.3817	11.473
.5835	11.543	.5176	11.567	.3545	11.515	.5024	11.970	.3849	11.485
.5863	11.535	.5204	11.582	.3612	11.519	.5033	11.979	.3876	11.473
.5879	11.523	.5214	11.595	.3638	11.524	.5059	12.020	.3905	11.487
.5918	11.519	.5252	11.614	.3665	11.519	.5067	12.048	.3942	11.514
.5934	11.530	.5276	11.616	.3691	11.537	.5074	12.037	.3976	11.503
.5962	11.544	.5284	11.630	.3718	11.519	.5111	12.088	.4006	11.524
.5978	11.554	.5312	11.648	.3728	11.524	.5119	12.097	.4035	11.537
.6015	11.545	.5321	11.664	.3759	11.528	.5126	12.097	.4063	11.538
.6030	11.539	.5357	11.689	.3766	11.532	.5152	12.109	.4104	11.546
.6065	11.549	.5384	11.743	.3796	11.524	.5160	12.122	.4146	11.556
.6110	11.579	.5394	11.745	.3808	11.527	.5167	12.130	.4172	11.556
.6127	11.593	.5426	11.775	.3846	11.528	.5193	12.127	.4201	11.569
.6161	11.586	.5461	11.854	.3855	11.537	.5201	12.117	.4228	11.592

TABLE II *(continued).*

HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V
565.4258	11.628	566.5333	12.118	614.4222	11.791	643.4517	11.975	676.3992	11.639
.4285	11.633	.5374	12.115	.4229	11.778	.4544	12.016	.4066	11.713
.4314	11.660	.5395	12.115	.4258	11.767	.4552	12.038	.4088	11.730
.4355	11.704	.5416	12.097	.4264	11.760	.4581	12.067	.4108	11.772
.4412	11.769	.5454	12.026	.4293	11.727	.4589	12.077	.4117	11.769
.4463	11.849	.5461	12.009	.4300	11.712	.4615	12.098	.4133	11.804
.4519	11.946	.5493	11.967	.4326	11.683	.4622	12.099	.4147	11.860
.4545	11.989	.5500	11.950	.4333	11.688	.4653	12.101	.4203	11.928
.4584	12.049	.5526	11.902	.4367	11.644	.4687	12.108	.4247	11.961
.4624	12.077	.5535	11.900	.4374	11.641	.4717	12.090	.4272	12.007
566.3625	12.074	.5558	11.869	.4409	11.630	.4725	12.105	.4310	12.086
.3640	12.048	.5565	11.870	.4416	11.619	.4751	12.088	.4339	12.097
.3655	12.031	.5606	11.809	.4443	11.617	.4759	12.075	.4373	12.095
.3683	12.002	.5648	11.739	.4451	11.614	.4787	12.035	.4430	12.118
.3711	11.974	.5683	11.733	.4500	11.607	.4795	12.035	.4468	12.120
.3736	11.916	.5694	11.723	.4508	11.587	.4825	11.991	.4498	12.078
.3769	11.847	.5715	11.689	.4536	11.582	.4878	11.860	.4543	12.003
.3792	11.798	.5724	11.674	.4543	11.585	.4919	11.836	.4575	11.931
.3824	11.765	.5752	11.657	.4573	11.571	.4926	11.836	.4626	11.839
.3848	11.757	.5761	11.651	.4580	11.560	.4988	11.748	.4658	11.816
.3856	11.734	.5793	11.650	.4607	11.570	.4998	11.735	.4675	11.781
.3886	11.725	.5800	11.638	.4614	11.551	.5029	11.687	.4705	11.720
.4019	11.612	.5824	11.630	.4641	11.550	.5036	11.683	681.3835	11.929
.4055	11.606	.5839	11.635	.4649	11.550	.5063	11.664	.3863	11.985
.4091	11.552	.5873	11.615	.4682	11.532	.5072	11.648	.3885	12.009
.4130	11.547	.5883	11.597	.4718	11.523	648.4050	11.821	.3943	12.099
.4332	11.481	.5906	11.580	.4726	11.530	.4078	11.873	.3998	12.085
.4376	11.487	.5913	11.581	.4754	11.510	.4084	11.903	.4045	12.079
.4405	11.490	.5953	11.563	.4761	11.515	.4118	11.933	.4080	12.081
.4436	11.483	.5961	11.569	.4791	11.508	.4146	11.973	.4116	12.068
.4476	11.488	.5996	11.551	.4798	11.510	.4175	12.018	.4149	12.038
.4502	11.484	.6004	11.543	.4826	11.505	.4201	12.063	.4184	11.984
.4529	11.496	.6058	11.524	.4834	11.525	.4232	12.091	.4207	11.945
.4560	11.490	.6065	11.519	.4863	11.496	.4263	12.085	.4230	11.887
.4592	11.505	.6097	11.522	.4870	11.495	.4288	12.104	.4255	11.835
.4628	11.510	.6104	11.514	.4903	11.500	.4315	12.097	.4304	11.755
.4656	11.505	.6136	11.516	.4942	11.507	.4344	12.096	.4334	11.734
.4683	11.530	.6145	11.529	.4968	11.508	.4373	12.097	.4385	11.674
.4714	11.525	614.3678	11.772	.4989	11.502	.4406	12.047	.4409	11.668
.4742	11.534	.3725	11.869	.5019	11.524	.4431	12.007	.4466	11.613
.4771	11.551	.3751	11.891	.5026	11.525	.4463	11.976	.4510	11.592
.4801	11.577	.3759	11.919	.5091	11.557	.4490	11.931	.4542	11.592
.4862	11.593	.3786	11.960	.5118	11.573	.4522	11.887	.4570	11.568
.4888	11.624	.3793	11.967	.5125	11.580	.4547	11.830	.4593	11.560
.4916	11.642	.3817	11.995	643.4038	11.501	.4580	11.796	.4618	11.551
.4928	11.657	.3828	12.020	.4054	11.507	673.4096	11.965	.4652	11.548
.4956	11.688	.3853	12.070	.4077	11.537	.4135	12.025	.4684	11.556
.4965	11.683	.3861	12.051	.4091	11.526	.4191	12.072	5634.4328	11.516
.4998	11.710	.3889	12.076	.4116	11.546	.4253	12.100	.4343	11.523
.5001	11.720	.3896	12.081	.4133	11.557	.4302	12.090	.4369	11.531
.5015	11.732	.3921	12.077	.4166	11.566	.4330	12.065	.4399	11.555
.5039	11.761	.3927	12.077	.4175	11.576	.4350	12.040	.4448	11.562
.5047	11.774	.3951	12.086	.4202	11.588	.4370	12.009	.4476	11.572
.5072	11.817	.3957	12.089	.4220	11.598	.4398	11.956	.4501	11.598
.5080	11.828	.3982	12.096	.4248	11.608	.4425	11.902	.4528	11.616
.5108	11.891	.3989	12.089	.4257	11.621	.4439	11.884	.4552	11.625
.5115	11.906	.4014	12.087	.4299	11.666	.4462	11.838	.4560	11.631
.5140	11.930	.4021	12.088	.4323	11.692	.4481	11.813	.4584	11.651
.5149	11.942	.4046	12.055	.4335	11.694	.4507	11.767	.4609	11.676
.5176	11.992	.4054	12.058	.4360	11.733	.4528	11.762	.4617	11.689
.5186	12.007	.4081	12.018	.4369	11.727	.4552	11.708	.4643	11.705
.5213	12.038	.4088	12.007	.4397	11.779	.4587	11.688	.4668	11.730
.5222	12.066	.4108	11.959	.4405	11.776	.4618	11.651	.4676	11.752
.5245	12.096	.4115	11.945	.4432	11.830	.4638	11.637	.4696	11.772
.5253	12.081	.4143	11.914	.4438	11.847	.4675	11.609	.4713	11.790
.5281	12.096	.4150	11.909	.4463	11.877	.4700	11.601	.4740	11.833
.5290	12.113	.4189	11.842	.4478	11.904	.4724	11.591	.4777	11.884
.5320	12.114	.4196	11.831	.4504	11.956	.4779	11.549	.4810	11.932

TABLE II *(continued).*

HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V
5634.4827	11.968	5634.6253	11.606	5635.5108	11.577	5635.6645	11.533	5641.5536	11.705
.4847	11.988	.6306	11.648	.5116	11.570	.6668	11.545	.5542	11.718
.4854	12.003	.6312	11.661	.5148	11.587	.6679	11.550	.5564	11.727
.4891	12.081	.6335	11.683	.5173	11.602	5641.4415	11.786	.5587	11.749
.4921	12.107	.6342	11.686	.5197	11.628	.4429	11.770	.5593	11.762
.4941	12.109	.6363	11.716	.5218	11.652	.4446	11.750	.5609	11.792
.4950	12.102	.6385	11.717	.5240	11.664	.4452	11.730	.5614	11.803
.4980	12.107	.6408	11.740	.5260	11.692	.4470	11.708	.5633	11.812
.5012	12.109	.6422	11.745	.5286	11.711	.4476	11.702	.5639	11.832
.5029	12.097	.6442	11.750	.5304	11.718	.4502	11.688	.5656	11.841
.5049	12.092	.6458	11.795	.5324	11.751	.4508	11.692	.5662	11.862
.5057	12.078	.6474	11.809	.5343	11.770	.4529	11.683	.5676	11.868
.5076	12.063	.6493	11.848	.5369	11.798	.4536	11.664	.5691	11.903
.5083	12.048	.6532	11.895	.5392	11.835	.4558	11.645	.5696	11.919
.5103	12.028	.6538	11.906	.5420	11.877	.4584	11.648	.5713	11.942
.5110	12.006	.6557	11.939	.5445	11.925	.4608	11.626	.5718	11.945
.5130	11.966	.6564	11.950	.5468	11.952	.4625	11.615	.5734	11.987
.5137	11.953	.6582	11.965	.5495	12.012	.4643	11.598	.5739	11.998
.5157	11.944	.6596	11.993	.5516	12.033	.4672	11.565	.5753	12.024
.5173	11.919	.6614	12.032	.5523	12.055	.4702	11.561	.5768	12.045
.5197	11.862	.6622	12.041	.5541	12.053	.4727	11.557	.5774	12.033
.5222	11.828	.6648	12.073	.5549	12.075	.4756	11.552	.5789	12.066
.5230	11.814	.6674	12.091	.5556	12.072	.4773	11.540	.5807	12.088
.5251	11.799	.6681	12.104	.5583	12.074	.4788	11.547	.5821	12.108
.5258	11.792	.6701	12.113	.5605	12.085	.4802	11.540	.5826	12.105
.5278	11.777	.6718	12.107	.5612	12.092	.4805	11.528	.5842	12.109
.5285	11.762	.6745	12.109	.5640	12.076	.4834	11.513	.5850	12.114
.5306	11.737	.6780	12.118	.5664	12.073	.4850	11.518	.5873	12.116
.5322	11.733	.6813	12.090	.5671	12.085	.4857	11.521	.5883	12.134
.5341	11.717	.6859	12.059	.5695	12.057	.4879	11.515	.5900	12.130
.5360	11.699	.6908	11.944	.5717	12.041	.4918	11.526	.5909	12.122
.5380	11.665	.6947	11.906	.5725	12.017	.4932	11.529	.5928	12.105
.5467	11.620	.6988	11.846	.5732	12.014	.4946	11.521	.5934	12.116
.5502	11.608	.7022	11.798	.5757	11.978	.4976	11.509	.5948	12.103
.5529	11.579	5635.4311	11.621	.5782	11.949	.4987	11.512	.5965	12.090
.5551	11.570	.4351	11.590	.5789	11.950	.5002	11.513	.5984	12.064
.5571	11.556	.4360	11.574	.5824	11.897	.5007	11.513	.5990	12.068
.5591	11.566	.4392	11.582	.5860	11.849	.5023	11.507	.5996	12.064
.5599	11.556	.4414	11.568	.5894	11.781	.5027	11.498	.6018	12.010
.5622	11.546	.4430	11.565	.5928	11.750	.5043	11.504	.6040	11.968
.5639	11.550	.4452	11.548	.5985	11.680	.5062	11.507	.6046	11.973
.5659	11.543	.4479	11.537	.6038	11.660	.5079	11.516	.6067	11.934
.5667	11.545	.4488	11.524	.6078	11.635	.5096	11.514	.6082	11.911
.5689	11.523	.4526	11.515	.6089	11.612	.5109	11.515	.6096	11.888
.5696	11.534	.4547	11.504	.6107	11.596	.5121	11.503	.6110	11.873
.5717	11.521	.4575	11.493	.6114	11.595	.5137	11.517	.6124	11.851
.5764	11.517	.4598	11.490	.6133	11.592	.5142	11.520	.6129	11.837
.5785	11.511	.4630	11.482	.6139	11.598	.5155	11.527	.6150	11.796
.5801	11.512	.4672	11.495	.6158	11.585	.5160	11.534	.6172	11.763
.5840	11.511	.4699	11.480	.6166	11.588	.5177	11.526	.6204	11.757
.5859	11.522	.4723	11.479	.6187	11.569	.5198	11.536	.6257	11.694
.5874	11.513	.4746	11.476	.6218	11.565	.5216	11.534	5642.4315	11.644
.5895	11.512	.4786	11.479	.6249	11.557	.5222	11.532	.4330	11.657
.5918	11.510	.4804	11.495	.6278	11.544	.5246	11.533	.4350	11.683
.5928	11.503	.4827	11.486	.6310	11.562	.5265	11.533	.4357	11.685
.5964	11.509	.4849	11.480	.6365	11.528	.5294	11.542	.4378	11.712
.5972	11.513	.4863	11.490	.6382	11.526	.5373	11.583	.4386	11.718
.5995	11.524	.4882	11.502	.6400	11.517	.5379	11.588	.4406	11.732
.6013	11.537	.4902	11.505	.6407	11.522	.5396	11.599	.4453	11.795
.6034	11.527	.4917	11.508	.6426	11.517	.5401	11.612	.4464	11.810
.6043	11.523	.4935	11.501	.6433	11.510	.5417	11.613	.4483	11.829
.6061	11.532	.4955	11.507	.6478	11.523	.5423	11.619	.4490	11.829
.6086	11.542	.4962	11.501	.6500	11.514	.5439	11.609	.4512	11.879
.6118	11.539	.5006	11.509	.6507	11.510	.5444	11.615	.4529	11.904
.6160	11.561	.5014	11.515	.6561	11.509	.5467	11.645	.4536	11.916
.6191	11.581	.5035	11.537	.6579	11.510	.5490	11.664	.4556	11.954
.6200	11.595	.5069	11.561	.6586	11.522	.5496	11.672	.4569	11.965
.6221	11.596	.5089	11.564	.6617	11.532	.5516	11.694	.4589	12.000

TABLE II *(continued)*.

HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V	HEL. J.D. 2439000.+	V
5642.4602	12.032	5723.4623	11.803	5724.3751	12.136	5725.4388	12.150	5730.3502	11.609
.4610	12.035	.4632	11.807	.3762	12.132	.4419	12.137	.3518	11.607
.4630	12.071	.4658	11.854	.3804	12.109	.4456	12.090	.3543	11.620
.4643	12.086	.4673	11.867	.3822	12.111	.4483	12.068	.3554	11.628
.4665	12.120	.4698	11.899	.3843	12.085	.4497	12.056	.3578	11.654
.4688	12.116	.4713	11.921	.3878	12.032	.4520	12.021	.3587	11.662
.4696	12.107	.4730	11.962	.3911	11.956	.4551	11.946	.3615	11.675
.4716	12.107	.4789	12.025	.3926	11.939	.4576	11.911	.3626	11.710
.4723	12.118	.4796	12.044	.3945	11.904	.4582	11.914	.3648	11.720
.4741	12.104	.4823	12.049	.3974	11.875	.4603	11.850	.3664	11.730
.4749	12.111	.4841	12.067	.4031	11.808	.4610	11.847	.3685	11.761
.4756	12.116	.4870	12.055	.4065	11.743	.4629	11.827	.3704	11.793
.4787	12.124	.4894	12.056	5725.3534	11.507	.4636	11.822	.3732	11.815
.4796	12.124	.4912	12.067	.3554	11.508	.4657	11.796	.3752	11.841
.4803	12.123	.4920	12.047	.3571	11.502	.4663	11.782	.3773	11.874
.4828	12.115	.4966	11.988	.3575	11.507	.4671	11.789	.3800	11.929
.4853	12.087	.4998	11.959	.3593	11.514	.4689	11.750	.3819	11.977
.4860	12.090	.5017	11.947	.3596	11.513	.4696	11.757	.3842	12.014
.4880	12.065	.5036	11.906	.3629	11.521	.4720	11.718	.3851	12.019
.4971	11.927	.5053	11.868	.3656	11.532	.4734	11.706	.3870	12.054
.5024	11.849	.5076	11.846	.3678	11.547	.4754	11.679	.3890	12.095
.5054	11.802	.5105	11.819	.3688	11.543	.4760	11.663	.3909	12.124
.5066	11.789	.5137	11.784	.3710	11.540	.4782	11.651	.3934	12.140
.5084	11.752	.5155	11.763	.3733	11.551	.4804	11.632	.3946	12.139
.5092	11.742	.5171	11.752	.3742	11.567	.4812	11.637	.3969	12.145
.5115	11.713	.5188	11.720	.3768	11.565	.4832	11.623	.3977	12.153
.5122	11.715	.5217	11.697	.3783	11.580	.4862	11.594	.3994	12.152
.5150	11.688	.5236	11.684	.3804	11.581	.4902	11.579	.4020	12.148
.5178	11.664	.5266	11.666	.3810	11.595	.4936	11.579	.4041	12.149
.5197	11.647	.5293	11.637	.3836	11.600	.4942	11.568	.4048	12.148
.5232	11.636	5724.3191	11.578	.3866	11.608	.4963	11.560	.4071	12.132
.5267	11.617	.3198	11.584	.3895	11.615	.4970	11.549	.4079	12.140
5723.3877	11.505	.3212	11.592	.3903	11.631	.5023	11.525	.4087	12.134
.3903	11.507	.3227	11.621	.3912	11.640	.5029	11.521	.4108	12.120
.3932	11.494	.3242	11.624	.3942	11.651	.5050	11.507	.4116	12.100
.3943	11.498	.3256	11.637	.3971	11.669	.5083	11.505	.4125	12.091
.3964	11.497	.3267	11.645	.3979	11.684	.5101	11.503	.4146	12.046
.3982	11.487	.3294	11.657	.4000	11.694	.5129	11.489	.4153	12.042
.3998	11.491	.3320	11.659	.4010	11.714	.5136	11.502	.4160	12.008
.4020	11.487	.3343	11.675	.4030	11.745	.5156	11.485	.4182	11.967
.4027	11.489	.3390	11.743	.4037	11.741	.5163	11.483	.4207	11.924
.4047	11.479	.3497	11.863	.4056	11.753	.5183	11.487	.4236	11.877
.4055	11.492	.3515	11.878	.4070	11.786	.5189	11.487	.4266	11.840
.4076	11.483	.3519	11.893	.4093	11.810	.5209	11.485	.4285	11.796
.4083	11.481	.3532	11.911	.4100	11.826	.5216	11.487	.4302	11.775
.4105	11.490	.3535	11.921	.4106	11.847	.5251	11.478	.4319	11.752
.4116	11.494	.3552	11.952	.4125	11.857	.5257	11.486	.4340	11.721
.4136	11.505	.3564	11.969	.4133	11.871	.5285	11.484	.4347	11.735
.4143	11.492	.3572	12.007	.4139	11.894	.5292	11.477	.4368	11.716
.4164	11.499	.3587	12.021	.4157	11.918	.5311	11.477	.4374	11.704
.4180	11.505	.3592	12.024	.4164	11.921	.5320	11.476	.4414	11.678
.4201	11.525	.3606	12.048	.4181	11.947	.5340	11.469	.4435	11.657
.4210	11.520	.3610	12.062	.4188	11.962	.5347	11.480	.4462	11.630
.4231	11.520	.3624	12.072	.4207	12.010	.5384	11.485	.4481	11.627
.4238	11.528	.3627	12.081	.4215	12.023	.5402	11.499	.4510	11.606
.4260	11.532	.3645	12.085	.4235	12.038	.5421	11.502	.4538	11.599
.4267	11.530	.3663	12.125	.4251	12.056	.5428	11.495	.4562	11.568
.4298	11.533	.3667	12.124	.4258	12.077	.5450	11.497	.4582	11.556
.4335	11.566	.3681	12.127	.4276	12.109	.5466	11.501	.4606	11.557
.4344	11.568	.3684	12.130	.4285	12.105	.5496	11.508	.4636	11.528
.4476	11.635	.3688	12.125	.4291	12.126	.5503	11.508	.4686	11.505
.4497	11.643	.3701	12.120	.4310	12.121	5730.3414	11.581	.4705	11.511
.4518	11.676	.3705	12.109	.4316	12.124	.3419	11.583	.4724	11.510
.4542	11.683	.3708	12.115	.4328	12.129	.3435	11.587	.4745	11.497
.4579	11.736	.3724	12.131	.4356	12.133	.3443	11.601	.4798	11.482
.4603	11.771	.3736	12.128	.4382	12.150	.3471	11.599		

TABLE III. — *Times of minima of TY UMa.*

Helioc JD 24...	n	w	O–C	Observer		Helioc JD 24...	n	w	O–C	Observer	
			d						d		
27283.443	-34549.5	1	+0.001	Z	v	39711.365	504.5	1	+0.004	G	pg
27360.375	34332.5	1	- .001	Z	"	39760.286	642.5	1	- .002	"	"
38112.393	4005.5	1	.000	P,K	"	39944.455	1162.	1	- .015	"	"
38112.391	4005.5	1	- .002	"	"	39969.469	1232.5	1	+ .003	"	"
38112.391	4005.5	1	- .002	"	"	40007.415	1339.5	1	+ .014	"	"
39532.4971	0.	10	+ .0005	B,C	pe	40021.411	1379.	1	+ .006	"	"
39532.6727	+0.5	10	- .0011	"	"	40093.385	1582.	1	+ .008	"	"
39533.572	3.	1	+ .012	G	pg	42464.341	8269.5	1	- .017	D	v
39561.5685	82.	10	- .0002	B,C	pe	42568.409	8563.	1	- .006	"	"
39562.4545	84.5	10	- .0006	"	"	44304.287	13459.	1	+ .044	"	"
39563.5179	87.5	10	- .0007	"	"	44634.4983	14390.5	10	+ .0006	B,C(1)	pe
39566.5328	96.	10	+ .0005	"	"	44634.6740	14391.	10	- .0010	"	"
39593.461	172.	1	- .016	G	pg	44635.5621	14393.5	10	+ .0008	"	"
39614.3955	231.	10	+ .0005	B,C	pe	44641.5888	14410.5	10	+ .0003	"	"
39643.4673	313.	10	+ .0002	"	"	44642.4752	14413.	10	+ .0003	"	"
39648.4306	327.	10	- .0001	"	"	44649.3890	14432.5	10	+ .0006	H	"
39648.442	327.	1	+ .011	G	pg	44649.564	14433.	2	- .002	"	"
39651.447	335.5	1	+ .003	"	"	44723.4870	14641.5	10	- .0004	B,C(1)	"
39673.4247	397.5	5	- .0009	B,C	pe	44724.3735	14644.	10	- .0002	"	"
39676.4407	406.	10	+ .0015	"	"	44725.4366	14647.	10	- .0007	"	"
39681.4023	420.	5	- .0005	"	"	44730.4005	14661.	10	- .0004	"	"
39701.401	476.5	1	- .033	G	pg						

Z = Zverev (1933, 1937); P,K = Pohl, Kizilirmak (1965); B,C = Broglia, Conconi (1981); G = Götz (1969); D = Diethelm (1975, 1980); B,C(1) = present paper; H = Hoffmann (1981).

TABLE IV. — *Extrema of light and colour and sin θ distortion coefficient B_1.*

		Min I	Max	Min II	Max	B_1	
1967	V	12.m100	11.528	12.119	11.475	V	-0.0196
	B-V	+0.706	.685	.719	.678	B	-0.0232
1981_1	V	12.114	11.496	12.107	11.513	V	+0.0068
	B-V	.708	.680	.697	.690	B	+0.0089
1981_2	V	12.137	11.487	12.062	11.506	V	+0.0112
	B-V	.706	.679	.703	.689	B	+0.0125

TABLE V. — *Photometric elements of TY UMa.*

i = 83.°3±1.0 m.e. q = 0.40±.02 Ω = 2.648±.002

T_1 = 5550°K X_V = 0.5 X_B = 0.7

Group	g	A	T_2	L_{1V}	L_{1B}	N	σ_{obs}
1967	0.47	0.75	5545	0.696	0.696	1196	0.m014
	1	4	5	1	2		
1981_1	0.29	0.73	5672	0.675	0.670	748	.014
	1	4	5	1	2		
1981_2	0.12	0.25	5849	0.641	0.629	530	.014
	2	6	8	1	2		

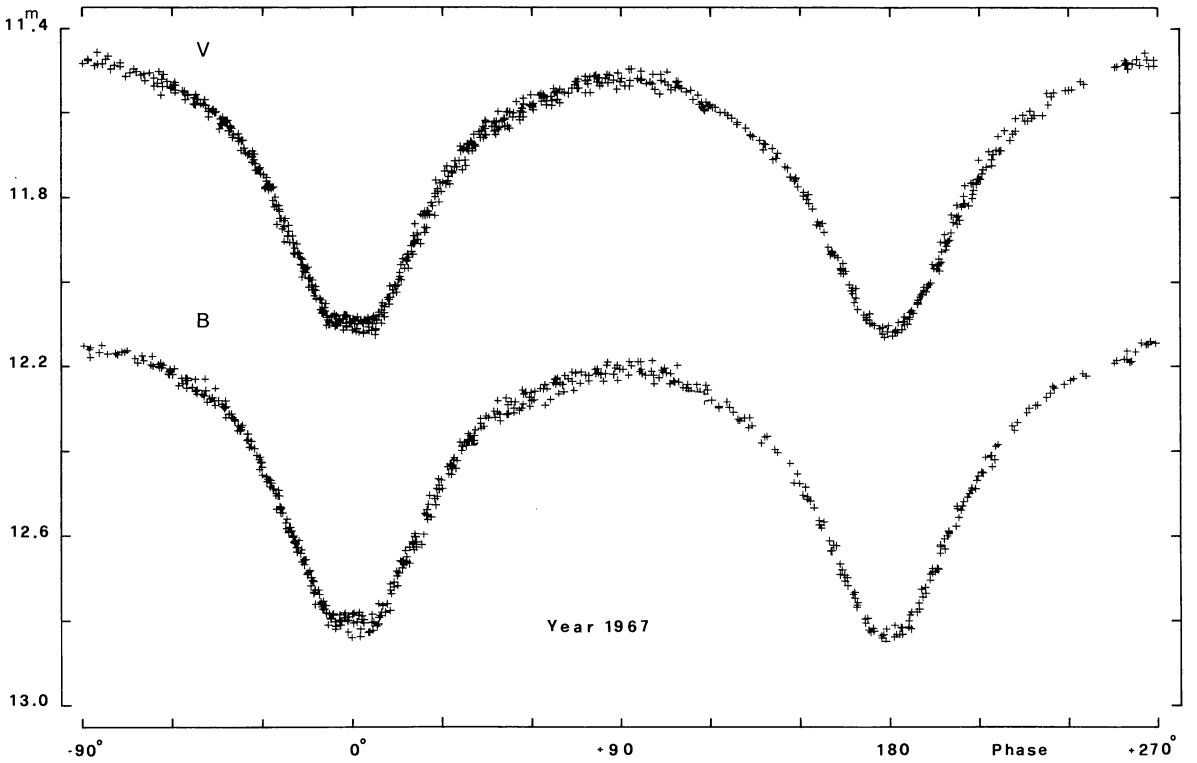

FIGURE 1. — Light curves of TY UMa during 1967.

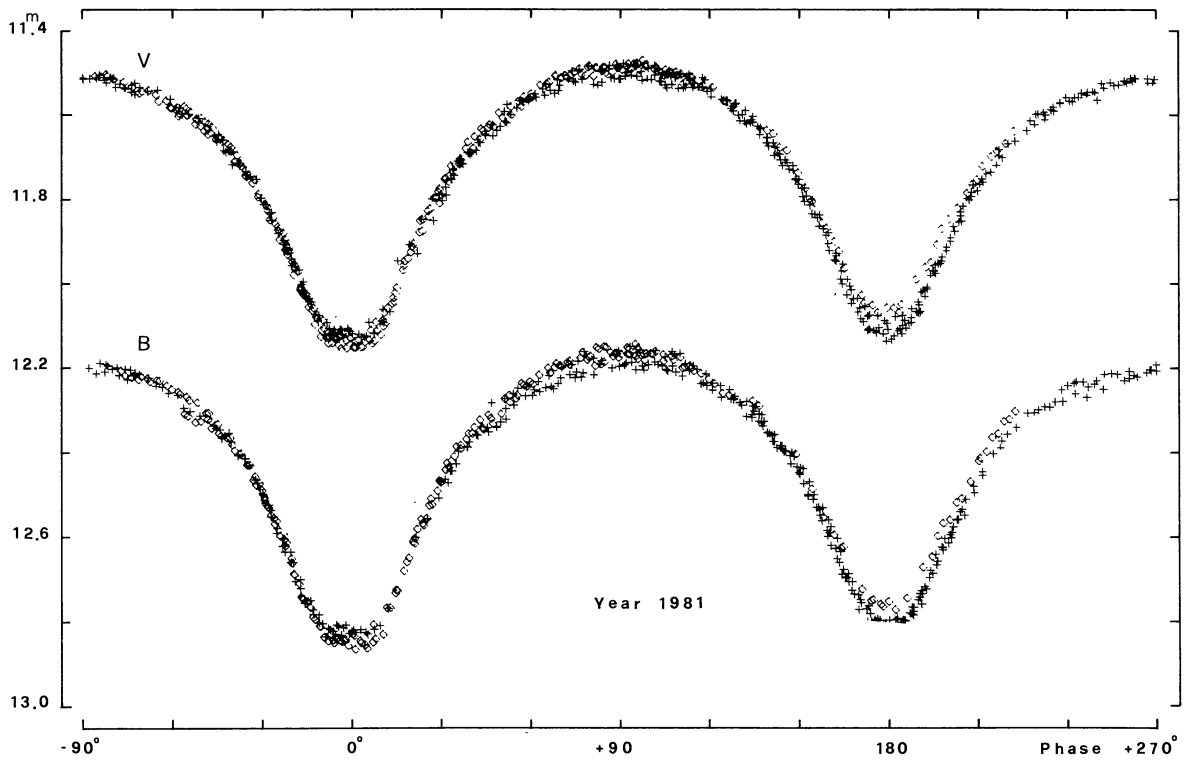

FIGURE 2. — Light curves of TY UMa during the seasons 1981_1 (crosses) and 1981_2 (squares).

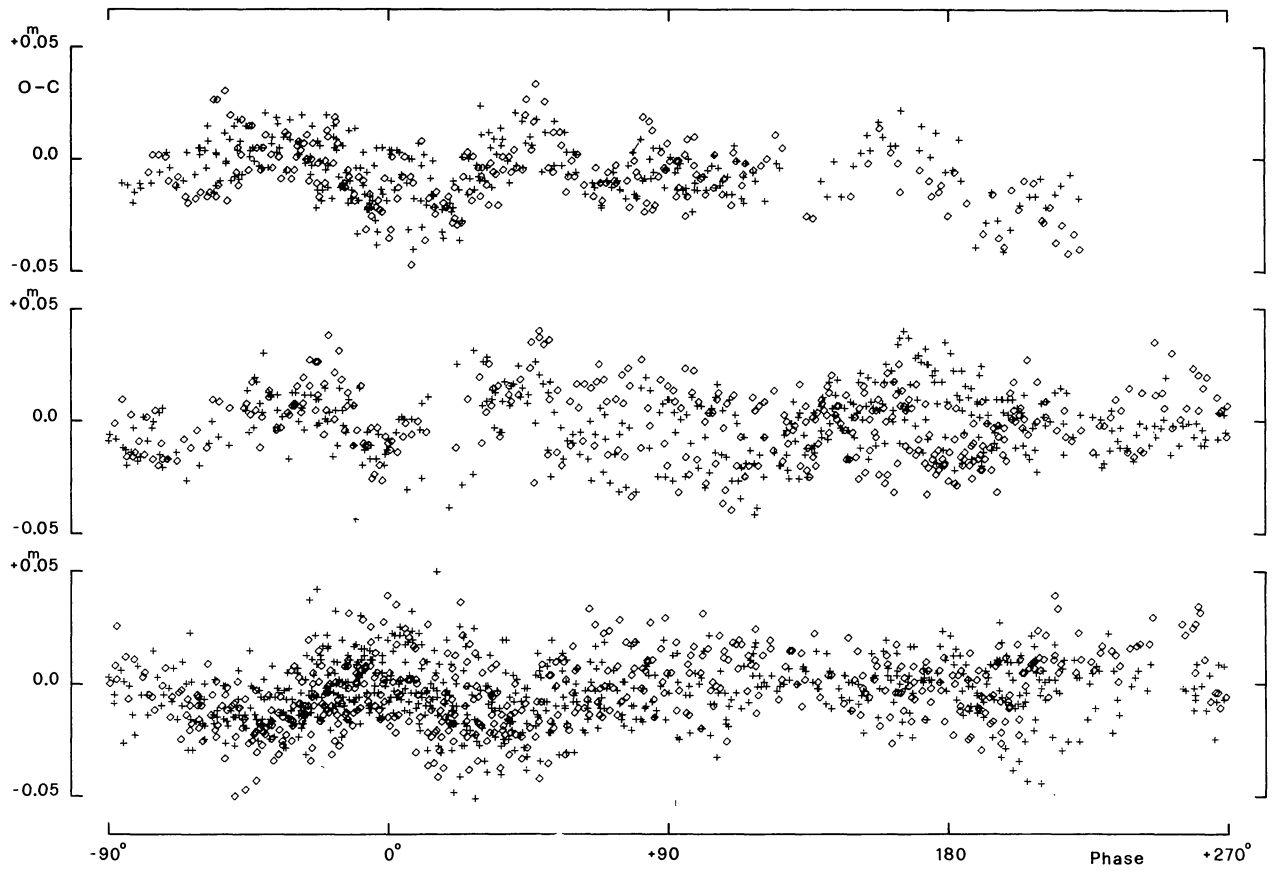

FIGURE 3. — Residuals derived by fitting synthetic light curves to single observations, after the sin θ perturbation has been removed. Squares and crosses represent respectively B and V measurements. From bottom to top : 1967, 1981_1 and 1981_2 groups.

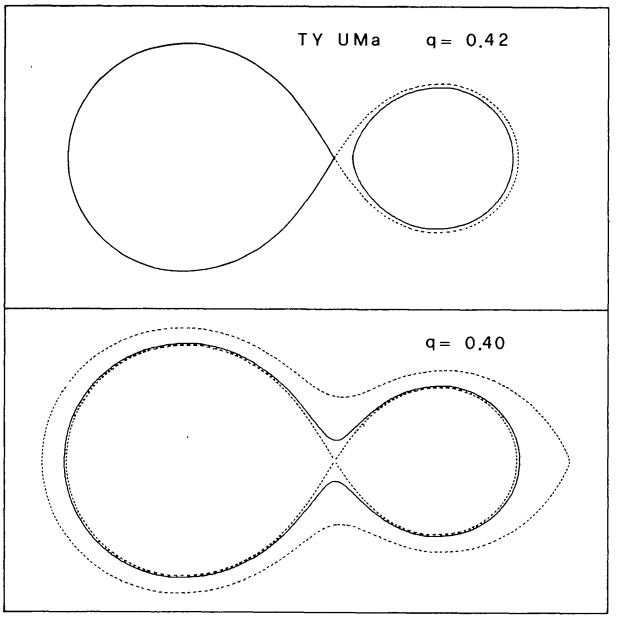

FIGURE 4. — Configuration of TY UMa in the orbital plane as derived from the best solutions computed in mode 0 ($q=0.42$) and in mode 3 ($q=0.40$).