1975, *Astron. Astrophys. Suppl.* **22**, 243-261.

BEAT PHENOMENA IN THE DWARF CEPHEID AE UMa

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Received February 3, 1975

AE UMa is an ultrashort pulsating variable. 1900 photoelectric B and V observations were carried out at the Merate Observatory during 1974. They enable us to determine nineteen new epochs of maximum and nineteen epochs of minimum light and to indicate a strong modulation in the light curves. The main period has been improved: $P_0 = 0\overset{d}{.}086016883$. The residuals computed by means of P_0 and the variation in the brightness of the maxima and of the minima can be accounted for by a beat phenomenon whose period is found to be: $P_b = 0\overset{d}{.}293616$. The secondary period follows: $P_1 = 0\overset{d}{.}066527$ and the ratio $P_1/P_0 = 0.7734$. This ratio and the amplitudes of the oscillations relating to P_0 and to P_1 are compared with those of other double mode AI Vel variables.

Key words: dwarf cepheids – AI Vel stars – beat phenomena

1. INTRODUCTION

The ultrashort-period cepheids, or AI Vel stars, or dwarf cepheids studied up to the present are a small group of stars, some of which show remarkable beat phenomena in the light curves. Photometric observations of some variables of this type were started at the Merate Observatory during 1952 and are being continued to check possible secular changes of the pulsation period. Beat phenomena were also shown to be present in the variables RV Ari (Broglia and Pestarino 1955, Broglia 1958) and BP Peg (Broglia 1959).

During the past year, Tsesevich (1973) presented evidence that the variable AE UMa has a very short period ($P = 124$ min.) with no secular variations, and moreover that its light curve shows large amplitude variations. After this announcement, light variations of this pulsating star were followed during seven nights on February and March 1974. A beat phenomenon appeared at once, and a provisional value for the beat period was evaluated (Broglia and Conconi 1974).

During the first half of 1974 Szeidl (1974), from more than one thousand photoelectric measures obtained at Konkoly Observatory, also determined the beat period and the amplitude of the beat modulation at maximum light. The literature of the variable has also been reviewed by Szeidl (1974).

2. THE PHOTOMETRIC OBSERVATIONS

B,V measurements, in a system close to UBV, were obtained with the single channel photoelectric photometer at the 102 cm Zeiss reflector of Merate Observatory. The output from a charge-integrator system was recorded on a Speedomax chart recorder. The short integration time, twenty seconds, and the rapid switch from variable to comparison star by means of an automatic device, allowed us to reduce the influence of variable atmospheric transmission and to monitor accurately the rapid brightness variations near the maximum. Observations, once digitized on a measuring machine, were corrected for atmospheric extinction and plotted using a Calcomp plotter. Only the corrections for the colour difference between comparison and variable star were significant. The colour of the variable can change two tenths of a magnitude during a cycle, and varies also from one cycle to another through the beat phenomenon. The reduction programme therefore computes a preliminary colour curve for the variable, then corrects for the colour extinction. The corrections were at most $0^m.007$ for the B measurements and $0^m.002$ for V, but were mostly negligeable.

The star c = BD + 46°1882 was used as a comparison; it was also used by Szeidl. Check stars were a = BD + 46°1884 and b, an eleven magnitude star, south-west of the variable ($\Delta\alpha = 0.63$ min.; $\Delta\delta = 2'.5$). These stars give no sign of any variability. The mean of the magnitude differences between comparison and check stars, and the mean errors for a single Δm were:

	B	V
$m_c - m_a =$	$-0^m.386$ ($\pm 0^m.006$)	$-0^m.099$ ($\pm 0^m.004$)
$m_c - m_b =$	-1.423 (.009)	-1.197 (.006)

The reliability of our differential photometry of AE UMa can be seen from the above mean errors. A transfer to the international system was achieved by comparing c with the star no. 1 ($V = 8^m.47$, $B-V = +0^m.13$) from the field 920–35 (Sanders 1966). We obtained for the comparison star c:

$$V = 10^m.19 \qquad B - V = +0^m.30$$

The individual observations of AE UMa are listed as a function of heliocentric Julian Date in tables 1 and 2, and they are plotted in figures 1 and 2.

3. FUNDAMENTAL AND BEAT PULSATIONS

The light curves have the typical asymmetrical shape of the dwarf cepheids; moreover the large variation in the amplitude of the light curves suggests that AE UMa is a multiperiodic variable. The beat phenomenon is much more evident near maximum light than near minimum. The amplitudes of the colour curves appear to be roughly proportional to the amplitudes of the light curves, and vary in phase.

To study the characteristics of the beat modulation, we have fitted the observations near the top and bottom of the light curves with third order polynomials. A least squares calculation gave us the instants and the magnitudes at maximum and at minimum. The standard error of a single magnitude with respect to the polynomial fitting gave the result $\pm 0^m.005$ for both the colours, comparable to the errors quoted above for the stars c, b, a. The values for the maximum are listed in table 3, together with those reported in the literature; the epochs and the magnitudes obtained for the minimum are given in table 4. All the epochs are the mean of the B and V results. Moreover, whilst the difference between the B and V instants of maximum is never greater than $0^d.0004$ and the differences are randomly distributed, we note a systematic difference, the value of which is on the average $+0^d.0009$, in the sense minimum V minus minimum B. To derive the fundamental period P_0 we considered all the epochs of maximum light. The entire set of observations gave the result:

$$\text{Max.} = \text{Hel.JD } 2442062.5823 + 0.086016883\, n$$

The cycle number n and the residuals $(O–C)_1$ between observed times of maximum and the times computed from the above expression are given in table 3; the corresponding values for the minimum, with reference to the normal epoch: Min. = Hel.JD 2442062.5526, are listed in table 4. The value for P_0 confirms and slightly improves the one determined by Tsesevich (1973). The study of the beat phenomenon relies on photoelectric observations only. The main period P_0 was held constant, and the observations were represented by a sine function: $A \sin(f_b - f_0) + C$. Starting from the provisional value for the beat period (Broglia and Conconi 1974), P_b was varied to minimize the sums of the squares of the residuals. Least squares solutions were obtained for the amplitude A of the sine curve and for the constants f_0 and C. The Szeidl $(O–C)_1$ and our residuals were considered together. The magnitudes at maximum light for both colours were handled in a similar way. However due to a possible small difference between Szeidl's instrumental colour system and ours, the two sets of measurements were treated separately. The same computation was then performed for the magnitudes and the instants of minimum light. All the values calculated for P_b agree; the more accurate determination, however, is that obtained from the residuals $(O\text{–}C)_1$. It gave:

$$P_b = 0.293616 \pm 0.000022 \text{ m.e.}$$

in accordance with the value $P_b = 0.29364$ given by Szeidl (1974). With this value, sine curves were again fitted to the observations, and beat phases were computed by means of the formula:

$$f_b = (\text{Hel.JD} - 2442062.5825)\, P_b^{-1}$$

The observations, plotted against beat phases, are shown in figure 3 and figure 4 together with the computed curves. The corresponding residuals, $(O\text{–}C)_2$ for the epochs, and $(O\text{–}C)_B$ and $(O\text{–}C)_V$ for the magnitudes are given in tables 3, 4. The means of the residuals are comparable to the estimated precision of the observations (epochs and magnitudes) noted above. We consider therefore that the observed and computed points agree well, even though a few measurements deviate a little: in our opinion these latter do not justify a possible third period.

4. CONCLUSIONS

Our results call for the following comments, and for a comparison with the AI Vel stars which show beat phenomena.

a) The main period P_o seems to be constant over the more than one hundred and fifty thousand cycles interval monitored by the observations. In this connection, AE UMa falls in with the dwarf cepheids, which have stable periods unlike the cluster variable (Balazs-Detre and Detre 1966). We believe that the marked residuals $(O\text{–}C)_1$ of some former epochs are incorrect, and are due to relative poor precision, and perhaps to an unfavourable distribution of the old visual and photographic measurements.

b) The skew shape of the light curve, its amplitude and the Ludendorf coefficient for the basic pulsation: (epoch max.-epoch min.)/$P_o = 0.35$ are like those found for the AI Vel stars with moderate beat distortion.

c) The main pulsation is characterized by the following parameters, calculated by least squares:

	B		V		$B\text{–}V$
Max.	$11^{\text{m}}.131 \pm 0^{\text{m}}.002$	m.e.	$10^{\text{m}}.985 \pm 0^{\text{m}}.001$	m.e.	$+0^{\text{m}}.146$
Min.	11.774	.002	11.489	.003	+ .285
total amplitude	0.64		0.50		0.14

The colour indices are comprised in the range common to these variables (Bessell 1969).

d) According to the interpretation that the beat phenomenon results from interference of two pulsations, the period P_1 of the first overtone pulsation follows from the relation: $1/P_1 = 1/P_o + 1/P_b$. It gives the result: $P_1 = 0^{\text{d}}.066527$. In table 5 the periods are given for the AI Vel stars with two excited overtones. The ratio P_1/P_o for the five variables with P_o between $0^{\text{d}}.08$ and $0^{\text{d}}.15$ are very close, which for the remaining stars, however, is also close to the mean value for the group $P_1/P_o = 0.773$.

e) The oscillations of the instants of maximum and minimum light are in phase (figure 3). Their amplitudes gave the same result: $0^{\text{d}}.0027 \pm .0001$ m.e. and $0^{\text{d}}.0022 \pm .0004$ m.e. respectively. Amplitudes of the same order were evaluated for RV Ari, $0^{\text{d}}.0048$ (Broglia 1958) and for BP Peg, $0^{\text{d}}.003$ (Broglia 1959), whilst for V 703 Sco, which shows a stronger modulation of the light curves, $A = 0^{\text{d}}.007$ (Ponson 1963).

We note, moreover, that there is a phase lag of about $P_b/4$ with respect to the sine curve representing the magnitudes at maximum light (figure 4). It appears also (figure 3 and 4) that starting from the phase f_b when the variable is brightest and the $O\text{–}C$ is near zero, since P_1 is below P_o, the light maximum resulting from interference of the two pulsations comes earlier and the corresponding $O\text{–}C$ is more negative.

The larger dispersion of $(O\text{–}C)_1$ around the sine curve for the minima is due to the poor precision of the instants computation. The mean deviation, however is only one minute, the same as the precision estimated above.

f) The way that the secondary pulsation modulates the brightness of the maximum and minimum light is shown in figure 4. The following total amplitudes of the modulation were calculated by least squares:

	B	V	B–V
Max.	$0^{m}.240$	$0^{m}.182$	$0^{m}.06$
Min.	.044	.032	.01

The magnitude distortion due to the interfering pulsations appears to be much stronger near maximum than at minimum light. From figure 4, it appears also that the two modulations differ in phase $P_b/2$: when the maximum is brightest, the minimum is faintest. An analogous phase-relation holds for SX Phe (Stock and Tapia 1971) and also for AI Vel (Walraven 1955).

g) In the last five columns of table 5, the total amplitudes 2A (for the V and B measurements) of the light oscillations with periods P_o and P_1 respectively, have been listed for all the double mode AI Vel stars. It appears that the modulation can be very different. For AI Vel and V 703 Sco, the two pulsations have about the same amplitude: accordingly the light curves undergo conspicuous variations, and humps also appear. For RV Ari, VZ Cnc, AE UMa and SX Phe the modulation is moderate, it touches mainly the light curves near the maximum and no hump appears. The P_1 pulsation of BP Peg is still smaller; for CY Aqr, the star of the group with the shortest period, the beat phenomenon is very small and moreover little humps can be seen near the minimum. The conclusion follows that whilst the ratios of the observed periods, first overtone to the main pulsation, of all the double mode AI Vel variables are practically the same, the ratios of the pulsational energies of the two excited modes can be very different.

We acknowledge the financial support of the Italian Consiglio Nazionale delle Ricerche.

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Table 1 *B* observations of AE 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
42065.5363	11.601	42065.6038	11.252	42065.6691	11.433	42068.3567	11.294	42068.4346	11.243
.5389	11.639	.6056	11.286	.6711	11.290	.3612	11.382	.4368	11.275
.5406	11.639	.6070	11.307	.6723	11.195	.3627	11.433	.4388	11.320
.5425	11.662	.6089	11.344	.6731	11.140	.3651	11.476	.4411	11.343
.5433	11.665	.6105	11.372	.6747	11.053	.3658	11.478	.4418	11.347
.5456	11.676	.6122	11.414	.6763	10.991	.3676	11.518	.4436	11.381
.5459	11.690	.6129	11.423	.6769	10.998	.3687	11.526	.4443	11.390
.5506	11.697	.6146	11.455	.6787	10.979	.3708	11.560	.4464	11.420
.5517	11.713	.6154	11.471	.6794	10.999	.3716	11.568	.4473	11.441
.5536	11.712	.6173	11.506	.6820	11.052	.3741	11.603	.4502	11.482
.5543	11.720	.6190	11.524	.6827	11.073	.3756	11.631	.4509	11.488
.5568	11.732	.6197	11.538	.6833	11.103	.3784	11.647	.4528	11.512
.5605	11.734	.6218	11.566	.6852	11.148	.3796	11.656	.4545	11.529
.5620	11.741	.6234	11.581	.6867	11.181	.3822	11.675	.4570	11.553
.5639	11.742	.6250	11.600	.6885	11.230	.3831	11.698	.4581	11.570
.5655	11.749	.6260	11.613	.6892	11.246	.3851	11.717	.4589	11.581
.5673	11.763	.6279	11.628	.6898	11.270	.3912	11.757	.4612	11.617
.5679	11.746	.6286	11.639	.6916	11.315	.3945	11.762	.4620	11.618
.5697	11.749	.6304	11.665	.6933	11.346	.3952	11.778	.4642	11.639
.5711	11.731	.6320	11.690	42068.3225	11.779	.3974	11.781	.4658	11.647
.5732	11.712	.6339	11.687	.3242	11.776	.3982	11.777	.4678	11.665
.5739	11.714	.6346	11.695	.3261	11.767	.4029	11.770	.4693	11.683
.5743	11.712	.6365	11.708	.3275	11.749	.4060	11.742	.4712	11.694
.5760	11.685	.6372	11.719	.3221	11.772	.4068	11.740	.4721	11.698
.5766	11.694	.6388	11.724	.3238	11.753	.4089	11.721	.4740	11.704
.5786	11.639	.6402	11.733	.3256	11.726	.4097	11.717	.4784	11.726
.5802	11.627	.6420	11.758	.3272	11.710	.4119	11.682	.4803	11.733
.5819	11.576	.6437	11.762	.3292	11.681	.4127	11.673	.4822	11.749
.5826	11.545	.6446	11.765	.3329	11.539	.4147	11.638	.4828	11.753
.5846	11.502	.6469	11.794	.3344	11.474	.4165	11.606	.4851	11.741
.5852	11.457	.6476	11.781	.3365	11.307	.4186	11.528	.4861	11.750
.5869	11.404	.6492	11.792	.3373	11.258	.4196	11.486	.4881	11.756
.5886	11.320	.6507	11.798	.3390	11.152	.4205	11.457	.4899	11.757
.5906	11.235	.6523	11.785	.3396	11.094	.4231	11.353	.4921	11.756
.5913	11.214	.6540	11.792	.3422	11.022	.4238	11.336	.4928	11.763
.5919	11.198	.6558	11.771	.3448	11.032	.4244	11.309	.4949	11.733
.5941	11.178	.6574	11.735	.3454	11.040	.4263	11.263	.4959	11.731
.5948	11.157	.6588	11.724	.3471	11.074	.4270	11.249	.4979	11.721
.5955	11.170	.6613	11.726	.3478	11.087	.4274	11.231	.4997	11.707
.5971	11.171	.6619	11.694	.3497	11.133	.4293	11.223	.5030	11.650
.5978	11.186	.6635	11.682	.3513	11.168	.4302	11.210	.5037	11.640
.5995	11.198	.6652	11.613	.3533	11.222	.4309	11.220	.5057	11.593
.6014	11.214	.6669	11.550	.3541	11.252	.4317	11.219	.5067	11.568
.6032	11.242	.6675	11.523	.3560	11.290	.4338	11.246	.5074	11.548

Table 1 *(continued)*

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
42068.5093	11.486	42068.5590	11.685	42068.6143	11.249	42068.6665	11.746	42069.3359	11.729
.5099	11.459	.5607	11.692	.6149	11.261	.6682	11.719	.3366	11.736
.5114	11.400	.5614	11.710	.6164	11.311	.6689	11.706	.3389	11.743
.5121	11.367	.5632	11.729	.6171	11.324	.6703	11.686	.3406	11.740
.5141	11.297	.5640	11.738	.6180	11.348	.6718	11.650	.3440	11.765
.5147	11.278	.5656	11.747	.6198	11.385	.6725	11.638	.3448	11.761
.5156	11.247	.5677	11.762	.6207	11.398	.6731	11.608	.3467	11.758
.5174	11.202	.5684	11.761	.6213	11.415	.6748	11.559	.3483	11.762
.5180	11.202	.5702	11.764	.6230	11.438	.6754	11.542	.3511	11.755
.5187	11.197	.5712	11.766	.6247	11.471	.6760	11.520	.3518	11.761
.5194	11.189	.5738	11.774	.6264	11.503	.6779	11.441	.3569	11.728
.5211	11.189	.5748	11.779	.6270	11.501	.6787	11.396	.3605	11.674
.5217	11.195	.5765	11.784	.6287	11.538	.6794	11.367	.3616	11.672
.5225	11.200	.5772	11.775	.6294	11.536	.6821	11.225	.3636	11.632
.5244	11.213	.5792	11.773	.6300	11.551	.6828	11.201	.3643	11.621
.5250	11.236	.5799	11.773	.6318	11.586	.6835	11.178	.3655	11.595
.5264	11.257	.5820	11.763	.6324	11.581	.6852	11.145	.3661	11.567
.5271	11.265	.5828	11.754	.6333	11.599	.6859	11.136	.3680	11.520
.5288	11.294	.5834	11.745	.6350	11.614	.6865	11.122	.3687	11.496
.5295	11.305	.5851	11.729	.6357	11.624	.6881	11.139	.3694	11.455
.5311	11.328	.5866	11.702	.6372	11.646	.6885	11.144	.3713	11.406
.5318	11.337	.5872	11.686	.6388	11.668	.6894	11.142	.3722	11.373
.5325	11.354	.5889	11.651	.6396	11.675	.6910	11.177	.3742	11.317
.5342	11.377	.5896	11.626	.6403	11.685	.6925	11.205	.3748	11.304
.5348	11.388	.5903	11.600	.6419	11.690	.6931	11.212	.3769	11.260
.5354	11.398	.5922	11.528	.6426	11.698	.6952	11.257	.3838	11.255
.5370	11.430	.5930	11.488	.6443	11.711	.6960	11.266	.3871	11.293
.5384	11.456	.5938	11.449	.6451	11.714	.6966	11.271	.3900	11.331
.5392	11.469	.5955	11.335	.6472	11.734	.6986	11.307	.3942	11.389
.5407	11.500	.5965	11.260	.6487	11.747	.6994	11.328	.3977	11.459
.5415	11.502	.5983	11.133	.6506	11.761	.7001	11.329	.4010	11.473
.5421	11.499	.5998	11.054	.6515	11.757	.7017	11.365	.4050	11.553
.5439	11.531	.6005	11.031	.6521	11.756	.7034	11.404	.4093	11.614
.5444	11.537	.6011	11.023	.6538	11.782	.7053	11.435	.4133	11.637
.5467	11.564	.6028	11.018	.6546	11.767	.7060	11.440	.4176	11.687
.5474	11.578	.6036	11.019	.6552	11.769	.7077	11.463	.4206	11.704
.5491	11.593	.6042	11.017	.6573	11.780	.7092	11.490	.4232	11.727
.5505	11.628	.6062	11.054	.6588	11.768	42069.3192	11.609	.4260	11.740
.5523	11.637	.6068	11.066	.6604	11.779	.3221	11.613	.4328	11.775
.5531	11.642	.6075	11.079	.6612	11.774	.3255	11.651	.4358	11.773
.5537	11.645	.6093	11.133	.6618	11.769	.3288	11.674	.4385	11.777
.5554	11.661	.6099	11.146	.6634	11.761	.3296	11.688	.4409	11.754
.5561	11.678	.6118	11.185	.6642	11.751	.3319	11.707	.4441	11.743
.5583	11.686	.6136	11.232	.6658	11.743	.3335	11.713	.4473	11.710

Table 1 *(continued)*

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
42069.4491	11.693	42069.5233	11.783	42069.5941	11.745	42069.6634	11.589	42086.5352	11.697
.4511	11.627	.5240	11.795	.5956	11.742	42086.4208	11.320	.5391	11.751
.4519	11.581	.5258	11.771	.5971	11.741	.4245	11.382	.5440	11.788
.4539	11.500	.5279	11.741	.5987	11.757	.4280	11.424	.5494	11.797
.4558	11.401	.5297	11.699	.6003	11.762	.4310	11.510	.5541	11.798
.4566	11.366	.5315	11.679	.6022	11.754	.4344	11.536	.5582	11.765
.4585	11.226	.5333	11.636	.6039	11.754	.4379	11.564	.5621	11.735
.4591	11.193	.5350	11.579	.6059	11.746	.4474	11.700	.5643	11.647
.4599	11.151	.5369	11.509	.6077	11.745	.4529	11.719	.5649	11.628
.4623	11.083	.5385	11.435	.6094	11.745	.4595	11.780	.5667	11.580
.4654	11.038	.5400	11.336	.6112	11.721	.4647	11.800	.5681	11.511
.4660	11.031	.5416	11.230	.6127	11.716	.4695	11.787	.5688	11.515
.4667	11.052	.5433	11.144	.6144	11.700	.4754	11.755	.5706	11.398
.4687	11.091	.5439	11.121	.6163	11.702	.4803	11.672	.5714	11.348
.4698	11.117	.5457	11.074	.6179	11.657	.4830	11.612	.5736	11.192
.4717	11.169	.5464	11.067	.6185	11.657	.4838	11.576	.5743	11.163
.4728	11.194	.5479	11.086	.6201	11.640	.4857	11.496	.5758	11.115
.4751	11.267	.5486	11.094	.6218	11.595	.4870	11.419	.5779	11.082
.4758	11.287	.5505	11.115	.6237	11.553	.4891	11.264	.5788	11.088
.4774	11.313	.5529	11.169	.6254	11.481	.4900	11.230	.5805	11.099
.4797	11.371	.5547	11.199	.6272	11.444	.4921	11.109	.5814	11.109
.4805	11.382	.5563	11.243	.6287	11.384	.4947	11.055	.5836	11.141
.4813	11.403	.5571	11.265	.6302	11.340	.4977	11.057	.5851	11.166
.4832	11.442	.5592	11.306	.6319	11.294	.4985	11.050	.5877	11.233
.4840	11.466	.5607	11.336	.6337	11.265	.5008	11.090	.5897	11.287
.4868	11.500	.5626	11.377	.6344	11.261	.5037	11.218	.5939	11.376
.4891	11.540	.5634	11.396	.6361	11.259	.5057	11.238	.5970	11.424
.4899	11.549	.5651	11.433	.6367	11.247	.5065	11.262	.6004	11.503
.4921	11.583	.5673	11.464	.6383	11.257	.5085	11.306	.6057	11.564
.4934	11.599	.5679	11.472	.6391	11.264	.5103	11.356	42087.3803	11.529
.4959	11.635	.5699	11.518	.6407	11.284	.5122	11.403	.3818	11.558
.4969	11.638	.5717	11.540	.6414	11.283	.5144	11.456	.3835	11.577
.4993	11.670	.5735	11.555	.6430	11.308	.5152	11.446	.3845	11.577
.5014	11.689	.5754	11.585	.6447	11.322	.5170	11.492	.3862	11.594
.5055	11.707	.5769	11.591	.6464	11.359	.5182	11.516	.3868	11.601
.5065	11.720	.5786	11.625	.6480	11.360	.5201	11.538	.3886	11.608
.5084	11.745	.5805	11.634	.6498	11.396	.5216	11.558	.3900	11.632
.5106	11.745	.5823	11.639	.6516	11.425	.5235	11.576	.3923	11.659
.5126	11.767	.5840	11.660	.6532	11.456	.5255	11.602	.3929	11.677
.5145	11.779	.5865	11.692	.6546	11.467	.5275	11.619	.3950	11.689
.5159	11.785	.5883	11.699	.6567	11.503	.5294	11.641	.3968	11.711
.5178	11.783	.5900	11.704	.6584	11.513	.5303	11.660	.3981	11.728
.5199	11.784	.5906	11.712	.6602	11.544	.5320	11.688	.3998	11.732
.5217	11.779	.5923	11.733	.6619	11.558	.5334	11.689	.4029	11.762

Table 1 *(continued)*

HEL. J.D. 24....	B
42087.4063	11.793
.4101	11.798
.4140	11.786
.4167	11.774
.4183	11.768
.4199	11.754
.4214	11.726
.4231	11.708
.4238	11.694
.4251	11.659
.4269	11.606
.4276	11.566
.4282	11.537
.4298	11.478
.4308	11.406
.4314	11.370
.4329	11.259
.4347	11.132
.4354	11.106
.4374	11.058
.4381	11.042
.4388	11.044
.4401	11.051
.4418	11.069
.4425	11.080
.4432	11.099
.4448	11.134
.4456	11.149
.4475	11.188
.4496	11.240
.4503	11.263
.4511	11.274
.4528	11.317
.4535	11.326
.4556	11.379
.4562	11.400
.4576	11.415
.4589	11.452
.4603	11.465
.4611	11.470
.4655	11.547
.4669	11.562
.4685	11.595
.4692	11.594
42087.4731	11.644
.4738	11.657
.4752	11.662
.4768	11.673
.4779	11.682
.4797	11.686
.4804	11.700
.4818	11.719
.4859	11.752
.4907	11.755
.4927	11.762
.4960	11.764
.4993	11.756
.5025	11.742
.5033	11.731
.5041	11.729
.5060	11.705
.5067	11.696
.5082	11.664
.5101	11.632
.5108	11.616
.5114	11.598
.5133	11.557
.5140	11.538
.5147	11.512
.5170	11.431
.5173	11.419
.5180	11.400
.5195	11.348
.5212	11.290
.5220	11.266
.5228	11.256
.5246	11.237
.5252	11.226
.5259	11.221
.5274	11.229
.5281	11.230
.5289	11.241
.5310	11.261
.5318	11.267
.5335	11.291
.5351	11.310
.5358	11.319
.5374	11.350
42087.5382	11.345
.5388	11.352
.5408	11.384
.5415	11.395
.5422	11.408
.5444	11.442
.5463	11.474
.5488	11.509
.5495	11.513
.5510	11.539
.5528	11.573
.5538	11.569
.5554	11.581
.5572	11.614
.5581	11.616
.5602	11.646
.5621	11.654
.5627	11.662
.5645	11.665
.5663	11.682
.5709	11.712
.5724	11.717
.5742	11.732
.5748	11.740
.5768	11.734
.5819	11.753
.5826	11.755
.5841	11.757
.5860	11.754
.5866	11.753
.5883	11.742
.5902	11.734
.5909	11.734
.5927	11.726
.5944	11.721
.5951	11.707
.5966	11.695
.5982	11.675
.5990	11.656
.5998	11.638
.6016	11.600
.6025	11.581
.6039	11.523
.6063	11.442
42087.6070	11.435
.6077	11.362
.6096	11.270
.6105	11.242
.6136	11.173
.6144	11.156
.6161	11.161
.6170	11.155
.6186	11.180
.6209	11.205
.6216	11.212
.6224	11.223
.6243	11.278
.6251	11.275
.6266	11.309
.6284	11.340
.6291	11.365
.6310	11.392
.6318	11.420
.6333	11.437
42103.3153	11.760
.3201	11.763
.3234	11.765
.3275	11.760
.3301	11.738
.3334	11.696
.3348	11.664
.3365	11.651
.3380	11.605
.3395	11.557
.3402	11.551
.3419	11.512
.3427	11.472
.3447	11.315
.3462	11.252
.3479	11.204
.3486	11.209
.3502	11.184
.3509	11.183
.3525	11.185
.3539	11.187
.3556	11.211
.3567	11.228
.3585	11.243
42103.3602	11.271
.3626	11.315
.3664	11.363
.3747	11.508
.3803	11.511
42122.3330	11.772
.3364	11.775
.3391	11.772
.3417	11.762
.3450	11.740
.3469	11.704
.3488	11.668
.3495	11.650
.3501	11.635
.3519	11.558
.3527	11.528
.3541	11.453
.3559	11.344
.3565	11.300
.3571	11.251
.3594	11.093
.3610	11.032
.3638	11.040
.3668	11.061
.3684	11.095
.3702	11.126
.3719	11.178
.3735	11.226
.3753	11.263
.3769	11.309
.3784	11.334
.3800	11.368
.3820	11.435
.3839	11.455
.3855	11.488
.3872	11.506
.3898	11.560
.3918	11.584
.3935	11.601
.3959	11.621
.3976	11.636
.3989	11.646
.4005	11.675
.4022	11.690

Table 1 *(continued)*

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
42122.4039	11.698	42122.4342	11.622	42122.4554	11.265	42122.4821	11.629	42122.5176	11.710
.4056	11.714	.4349	11.608	.4579	11.291	.4836	11.644	.5197	11.697
.4071	11.729	.4364	11.553	.4599	11.314	.4853	11.658	.5212	11.652
.4035	11.734	.4380	11.510	.4613	11.342	.4857	11.659	.5219	11.644
.4101	11.757	.4386	11.480	.4640	11.385	.4874	11.678	.5226	11.640
.4117	11.753	.4403	11.426	.4658	11.415	.4922	11.703	.5244	11.591
.4133	11.754	.4410	11.400	.4675	11.442	.4952	11.728	.5251	11.570
.4149	11.760	.4428	11.306	.4691	11.469	.4983	11.731	.5257	11.545
.4186	11.767	.4442	11.257	.4708	11.493	.5020	11.746	.5274	11.517
.4202	11.770	.4458	11.209	.4714	11.500	.5054	11.745	.5286	11.477
.4221	11.764	.4463	11.197	.4731	11.533	.5085	11.741	.5307	11.394
.4256	11.748	.4480	11.185	.4737	11.536	.5107	11.747	.5314	11.369
.4230	11.731	.4487	11.193	.4754	11.557	.5135	11.727	.5320	11.345
.4288	11.724	.4503	11.203	.4760	11.569	.5154	11.725	.5336	11.310
.4311	11.679	.4510	11.211	.4805	11.624	.5160	11.720	.5345	11.280
.4324	11.663	.4524	11.218						

Table 2 *V* observations of AE 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
42065.5366	11.359	42065.6053	11.104	42065.6694	11.191	42068.3720	11.324	42068.4469	11.226
.5395	11.381	.6061	11.115	.6715	11.082	.3745	11.362	.4476	11.225
.5409	11.378	.6085	11.149	.6726	11.015	.3760	11.374	.4505	11.267
.5429	11.397	.6101	11.167	.6734	10.972	.3789	11.385	.4512	11.269
.5436	11.404	.6118	11.193	.6751	10.923	.3799	11.406	.4533	11.295
.5453	11.407	.6126	11.199	.6766	10.894	.3826	11.414	.4550	11.310
.5462	11.424	.6143	11.231	.6772	10.897	.3835	11.429	.4574	11.326
.5488	11.431	.6150	11.242	.6791	10.904	.3855	11.439	.4584	11.329
.5511	11.431	.6169	11.271	.6798	10.902	.3915	11.485	.4592	11.347
.5533	11.437	.6187	11.274	.6817	10.938	.3948	11.480	.4616	11.364
.5539	11.436	.6193	11.291	.6823	10.940	.3955	11.472	.4623	11.370
.5562	11.454	.6211	11.315	.6830	10.964	.3978	11.488	.4645	11.375
.5590	11.468	.6229	11.330	.6847	10.994	.3991	11.483	.4661	11.395
.5617	11.476	.6247	11.344	.6863	11.024	.4032	11.500	.4690	11.408
.5636	11.475	.6254	11.363	.6881	11.051	.4057	11.487	.4697	11.418
.5651	11.468	.6275	11.382	.6889	11.051	.4064	11.483	.4716	11.420
.5670	11.459	.6283	11.377	.6895	11.079	.4086	11.478	.4725	11.438
.5676	11.472	.6300	11.401	.6913	11.112	.4093	11.460	.4743	11.440
.5693	11.474	.6317	11.415	.6938	11.142	.4112	11.438	.4788	11.449
.5708	11.464	.6335	11.420	42068.3295	11.405	.4124	11.425	.4806	11.466
.5727	11.457	.6343	11.417	.3311	11.347	.4143	11.390	.4825	11.464
.5736	11.442	.6362	11.433	.3334	11.275	.4162	11.360	.4833	11.465
.5755	11.442	.6369	11.434	.3346	11.236	.4182	11.316	.4856	11.465
.5763	11.436	.6385	11.445	.3369	11.104	.4193	11.283	.4865	11.473
.5782	11.404	.6399	11.447	.3376	11.069	.4200	11.263	.4885	11.482
.5799	11.384	.6417	11.458	.3393	10.992	.4228	11.171	.4903	11.481
.5816	11.336	.6434	11.468	.3400	10.944	.4235	11.155	.4924	11.477
.5823	11.322	.6443	11.463	.3425	10.910	.4241	11.129	.4933	11.480
.5843	11.279	.6462	11.482	.3451	10.916	.4260	11.094	.4953	11.466
.5849	11.266	.6473	11.472	.3457	10.931	.4266	11.077	.4963	11.462
.5866	11.210	.6489	11.468	.3475	10.961	.4278	11.056	.4983	11.445
.5882	11.158	.6503	11.482	.3481	10.966	.4298	11.054	.5001	11.433
.5903	11.076	.6520	11.486	.3499	11.009	.4305	11.046	.5034	11.398
.5909	11.060	.6527	11.469	.3517	11.022	.4313	11.061	.5040	11.382
.5916	11.055	.6554	11.475	.3536	11.060	.4320	11.052	.5059	11.347
.5936	11.019	.6561	11.457	.3544	11.076	.4342	11.072	.5063	11.341
.5945	11.012	.6578	11.453	.3563	11.099	.4349	11.075	.5070	11.322
.5952	10.997	.6592	11.445	.3573	11.122	.4373	11.099	.5089	11.277
.5968	11.017	.6616	11.431	.3616	11.199	.4388	11.126	.5096	11.251
.5974	11.015	.6622	11.443	.3630	11.225	.4396	11.136	.5111	11.211
.5992	11.042	.6641	11.398	.3654	11.245	.4413	11.143	.5117	11.189
.6008	11.047	.6655	11.348	.3661	11.262	.4421	11.159	.5137	11.131
.6027	11.060	.6672	11.297	.3683	11.288	.4440	11.179	.5144	11.105
.6035	11.081	.6678	11.271	.3713	11.314	.4446	11.190	.5151	11.088

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
42068.5171	11.057	42068.5706	11.481	42068.6233	11.220	42068.6757	11.290	42069.3451	11.471
.5177	11.042	.5717	11.484	.6250	11.238	.6764	11.276	.3471	11.462
.5184	11.034	.5743	11.489	.6267	11.261	.6784	11.207	.3486	11.472
.5191	11.028	.5752	11.490	.6273	11.273	.6791	11.168	.3507	11.471
.5207	11.026	.5768	11.489	.6291	11.306	.6797	11.150	.3514	11.465
.5214	11.032	.5776	11.494	.6297	11.302	.6818	11.064	.3552	11.455
.5222	11.033	.5796	11.495	.6303	11.311	.6825	11.034	.3555	11.453
.5240	11.043	.5802	11.483	.6321	11.328	.6831	11.032	.3576	11.452
.5246	11.048	.5824	11.478	.6328	11.346	.6848	11.003	.3601	11.425
.5268	11.075	.5831	11.475	.6336	11.345	.6855	10.995	.3611	11.415
.5276	11.088	.5837	11.474	.6354	11.362	.6862	10.987	.3632	11.388
.5292	11.097	.5855	11.451	.6360	11.370	.6878	10.987	.3640	11.373
.5298	11.107	.5869	11.438	.6375	11.379	.6889	10.997	.3652	11.349
.5314	11.138	.5876	11.426	.6393	11.395	.6897	11.007	.3658	11.328
.5321	11.151	.5893	11.398	.6399	11.399	.6914	11.031	.3676	11.303
.5329	11.153	.5900	11.368	.6406	11.407	.6928	11.034	.3684	11.287
.5345	11.175	.5906	11.348	.6422	11.411	.6937	11.052	.3691	11.258
.5351	11.192	.5927	11.277	.6429	11.419	.6956	11.075	.3709	11.224
.5357	11.192	.5933	11.258	.6447	11.433	.6963	11.086	.3718	11.193
.5373	11.218	.5941	11.220	.6454	11.433	.6969	11.100	.3738	11.142
.5388	11.236	.5960	11.115	.6475	11.441	.6991	11.127	.3744	11.124
.5395	11.245	.5968	11.066	.6491	11.464	.6997	11.133	.3764	11.108
.5411	11.265	.5986	10.974	.6511	11.465	.7004	11.148	.3773	11.071
.5418	11.274	.6002	10.924	.6518	11.469	.7020	11.172	.3795	11.053
.5425	11.280	.6008	10.912	.6524	11.477	.7037	11.186	.3803	11.054
.5447	11.312	.6014	10.904	.6543	11.477	.7057	11.216	.3825	11.070
.5452	11.331	.6033	10.899	.6549	11.482	.7064	11.224	.3833	11.068
.5470	11.332	.6039	10.901	.6555	11.477	.7080	11.241	.3857	11.103
.5477	11.340	.6046	10.905	.6577	11.487	.7096	11.255	.3878	11.123
.5494	11.345	.6065	10.932	.6592	11.483	42069.3188	11.343	.3895	11.146
.5509	11.360	.6072	10.947	.6608	11.491	.3203	11.362	.3937	11.185
.5527	11.374	.6078	10.954	.6615	11.486	.3221	11.366	.3971	11.228
.5540	11.384	.6096	10.991	.6622	11.481	.3228	11.366	.4006	11.257
.5558	11.397	.6102	11.003	.6639	11.488	.3250	11.399	.4044	11.295
.5566	11.411	.6121	11.027	.6645	11.481	.3267	11.406	.4090	11.349
.5586	11.415	.6140	11.066	.6661	11.473	.3291	11.422	.4130	11.377
.5593	11.418	.6146	11.082	.6668	11.467	.3300	11.428	.4170	11.408
.5610	11.436	.6152	11.092	.6686	11.442	.3323	11.442	.4203	11.427
.5617	11.436	.6167	11.128	.6692	11.438	.3340	11.438	.4235	11.433
.5636	11.453	.6176	11.140	.6706	11.423	.3362	11.447	.4265	11.459
.5643	11.462	.6184	11.159	.6722	11.386	.3370	11.441	.4331	11.490
.5659	11.461	.6204	11.186	.6728	11.367	.3393	11.447	.4362	11.492
.5681	11.475	.6210	11.189	.6734	11.357	.3409	11.456	.4396	11.493
.5688	11.466	.6217	11.187	.6751	11.314	.3443	11.470	.4427	11.482

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
42069.4454	11.453	42069.5141	11.477	42069.5855	11.401	42069.6543	11.253	42086.5259	11.352
.4484	11.413	.5155	11.490	.5879	11.412	.6564	11.267	.5289	11.386
.4507	11.395	.5173	11.486	.5896	11.430	.6581	11.280	.5314	11.420
.4516	11.364	.5196	11.492	.5903	11.427	.6598	11.290	.5350	11.435
.4535	11.300	.5213	11.493	.5919	11.450	.6615	11.320	.5395	11.463
.4555	11.211	.5230	11.495	.5937	11.460	.6631	11.337	.5449	11.500
.4561	11.196	.5237	11.492	.5953	11.464	42086.4203	11.130	.5499	11.505
.4569	11.159	.5253	11.486	.5968	11.470	.4240	11.183	.5536	11.517
.4588	11.051	.5272	11.464	.5984	11.471	.4277	11.246	.5577	11.508
.4595	11.023	.5293	11.455	.6000	11.476	.4299	11.287	.5617	11.476
.4602	10.986	.5312	11.421	.6019	11.469	.4324	11.293	.5643	11.398
.4618	10.954	.5329	11.389	.6036	11.476	.4358	11.309	.5671	11.336
.4626	10.931	.5346	11.357	.6052	11.481	.4423	11.392	.5685	11.280
.4635	10.934	.5364	11.290	.6073	11.468	.4506	11.464	.5692	11.256
.4657	10.914	.5382	11.240	.6089	11.474	.4557	11.476	.5710	11.171
.4663	10.921	.5397	11.163	.6109	11.450	.4628	11.504	.5718	11.129
.4670	10.931	.5412	11.094	.6124	11.446	.4681	11.522	.5740	11.014
.4690	10.974	.5429	11.021	.6140	11.445	.4725	11.497	.5747	10.991
.4702	10.992	.5436	10.986	.6159	11.425	.4780	11.471	.5762	10.960
.4724	11.032	.5454	10.953	.6176	11.403	.4816	11.429	.5784	10.951
.4732	11.044	.5460	10.944	.6182	11.400	.4835	11.347	.5791	10.949
.4755	11.103	.5476	10.951	.6198	11.386	.4852	11.305	.5810	10.962
.4762	11.116	.5483	10.953	.6215	11.354	.4866	11.232	.5829	10.984
.4777	11.126	.5501	10.981	.6231	11.337	.4882	11.188	.5868	11.041
.4801	11.175	.5525	11.019	.6250	11.286	.4895	11.070	.5900	11.118
.4809	11.192	.5544	11.045	.6268	11.245	.4918	10.966	.5945	11.191
.4816	11.193	.5559	11.086	.6284	11.202	.4945	10.923	.5975	11.242
.4835	11.227	.5568	11.079	.6299	11.151	.4959	10.916	.6008	11.267
.4844	11.242	.5589	11.117	.6316	11.121	.4982	10.931	.6046	11.295
.4868	11.268	.5603	11.134	.6333	11.097	.4988	10.935	42087.3807	11.289
.4875	11.274	.5622	11.162	.6341	11.090	.5012	10.961	.3823	11.314
.4895	11.306	.5631	11.186	.6357	11.092	.5032	11.018	.3839	11.332
.4903	11.309	.5648	11.212	.6364	11.076	.5053	11.064	.3848	11.339
.4930	11.347	.5667	11.238	.6379	11.094	.5061	11.076	.3865	11.338
.4943	11.352	.5676	11.239	.6388	11.089	.5082	11.108	.3871	11.352
.4963	11.368	.5696	11.267	.6404	11.101	.5100	11.153	.3889	11.376
.4976	11.383	.5714	11.281	.6411	11.118	.5118	11.173	.3903	11.382
.4997	11.405	.5732	11.311	.6426	11.119	.5148	11.223	.3926	11.397
.5018	11.409	.5750	11.337	.6443	11.134	.5155	11.226	.3932	11.401
.5058	11.427	.5765	11.328	.6461	11.151	.5177	11.275	.3953	11.426
.5062	11.439	.5783	11.348	.6476	11.175	.5185	11.289	.3971	11.435
.5080	11.447	.5801	11.361	.6494	11.196	.5204	11.324	.3984	11.447
.5099	11.472	.5818	11.373	.6511	11.216	.5220	11.349	.4002	11.463
.5122	11.478	.5836	11.401	.6528	11.237	.5239	11.336	.4008	11.456

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
42087.4026	11.468	42087.4689	11.340	42087.5284	11.067	42087.5954	11.441	42103.3476	11.059
.4039	11.485	.4696	11.349	.5303	11.092	.5969	11.426	.3482	11.045
.4077	11.508	.4734	11.377	.5307	11.097	.5987	11.397	.3499	11.027
.4120	11.501	.4741	11.386	.5314	11.086	.5994	11.384	.3506	11.029
.4134	11.510	.4755	11.403	.5332	11.097	.6001	11.380	.3523	11.028
.4153	11.504	.4772	11.408	.5346	11.110	.6021	11.337	.3536	11.039
.4161	11.503	.4776	11.400	.5354	11.117	.6028	11.325	.3553	11.048
.4179	11.501	.4793	11.424	.5378	11.152	.6043	11.284	.3560	11.065
.4186	11.472	.4801	11.434	.5385	11.153	.6067	11.231	.3582	11.082
.4203	11.482	.4815	11.433	.5391	11.161	.6074	11.183	.3589	11.090
.4217	11.457	.4833	11.455	.5412	11.194	.6081	11.170	.3607	11.109
.4235	11.434	.4878	11.468	.5419	11.200	.6101	11.086	.3619	11.121
.4241	11.424	.4894	11.478	.5427	11.218	.6108	11.067	.3650	11.165
.4254	11.392	.4913	11.478	.5447	11.244	.6140	11.004	.3698	11.242
.4272	11.346	.4920	11.485	.5460	11.253	.6147	11.004	.3739	11.267
.4279	11.321	.4928	11.495	.5484	11.268	.6166	11.010	.3763	11.293
.4285	11.302	.4947	11.499	.5492	11.279	.6175	11.021	.3850	11.368
.4305	11.223	.4960	11.484	.5507	11.308	.6189	11.014	.3874	11.399
.4311	11.178	.4981	11.482	.5524	11.329	.6205	11.030	42122.3334	11.492
.4317	11.154	.4998	11.493	.5534	11.336	.6213	11.033	.3368	11.500
.4333	11.066	.5022	11.475	.5550	11.350	.6220	11.045	.3395	11.497
.4344	11.013	.5029	11.465	.5568	11.354	.6240	11.076	.3421	11.494
.4351	10.966	.5037	11.467	.5577	11.362	.6248	11.080	.3454	11.472
.4378	10.908	.5056	11.452	.5599	11.371	.6262	11.103	.3473	11.452
.4385	10.906	.5064	11.445	.5617	11.401	.6281	11.149	.3491	11.402
.4397	10.922	.5078	11.421	.5624	11.399	.6288	11.158	.3498	11.396
.4415	10.938	.5097	11.393	.5641	11.404	.6306	11.199	.3505	11.377
.4422	10.940	.5105	11.386	.5660	11.409	.6313	11.204	.3523	11.316
.4428	10.950	.5111	11.370	.5706	11.429	.6330	11.216	.3530	11.291
.4445	10.982	.5129	11.364	.5720	11.434	42103.3153	11.479	.3546	11.215
.4452	10.996	.5137	11.319	.5739	11.450	.3198	11.484	.3562	11.135
.4471	11.025	.5144	11.301	.5745	11.453	.3228	11.475	.3568	11.090
.4488	11.056	.5161	11.257	.5763	11.472	.3272	11.482	.3575	11.052
.4500	11.078	.5167	11.241	.5774	11.458	.3298	11.465	.3597	10.935
.4507	11.091	.5177	11.211	.5823	11.479	.3331	11.434	.3613	10.908
.4523	11.118	.5191	11.179	.5829	11.479	.3345	11.412	.3639	10.905
.4532	11.135	.5208	11.113	.5844	11.473	.3362	11.393	.3646	10.913
.4549	11.183	.5215	11.106	.5863	11.482	.3377	11.372	.3664	10.924
.4559	11.189	.5224	11.087	.5870	11.482	.3393	11.313	.3679	10.943
.4573	11.206	.5242	11.064	.5886	11.474	.3399	11.309	.3688	10.964
.4599	11.247	.5249	11.060	.5905	11.476	.3416	11.264	.3705	10.994
.4607	11.262	.5255	11.053	.5912	11.475	.3424	11.227	.3722	11.027
.4652	11.306	.5271	11.051	.5931	11.464	.3444	11.142	.3738	11.064
.4672	11.324	.5277	11.059	.5947	11.445	.3459	11.095	.3756	11.100

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
42122.3773	11.134	42122.4242	11.475	42122.4513	11.056	42122.4833	11.379	42122.5135	11.461
.3787	11.148	.4283	11.447	.4528	11.069	.4849	11.385	.5142	11.454
.3803	11.174	.4291	11.437	.4548	11.080	.4860	11.396	.5157	11.449
.3824	11.218	.4315	11.414	.4566	11.100	.4876	11.405	.5173	11.430
.3843	11.236	.4327	11.392	.4584	11.117	.4921	11.431	.5194	11.415
.3859	11.261	.4344	11.361	.4602	11.138	.4928	11.432	.5210	11.411
.3875	11.273	.4352	11.348	.4616	11.155	.4945	11.444	.5216	11.394
.3902	11.315	.4367	11.327	.4635	11.177	.4965	11.449	.5223	11.375
.3922	11.333	.4382	11.268	.4654	11.209	.4984	11.453	.5240	11.373
.3929	11.346	.4389	11.253	.4672	11.216	.4990	11.453	.5247	11.347
.3956	11.367	.4406	11.208	.4688	11.241	.5007	11.463	.5254	11.339
.3973	11.380	.4413	11.189	.4704	11.266	.5041	11.470	.5272	11.315
.3986	11.384	.4431	11.109	.4711	11.273	.5049	11.461	.5289	11.256
.4010	11.399	.4445	11.082	.4727	11.287	.5065	11.460	.5304	11.209
.4045	11.433	.4461	11.035	.4734	11.303	.5080	11.458	.5310	11.175
.4075	11.444	.4467	11.036	.4751	11.305	.5096	11.456	.5317	11.150
.4106	11.460	.4484	11.032	.4757	11.309	.5103	11.461	.5333	11.117
.4138	11.477	.4490	11.042	.4801	11.354	.5117	11.465	.5341	11.096
.4191	11.472	.4506	11.045	.4818	11.369				

Table 3 Epochs and magnitudes at the maximum light

Observer	Hel.J.D.	n	$(O-C)_1$	$(O-C)_2$	B	$(O-C)_B$	V	$(O-C)_V$
T	28632.398	-156134	-^{d}.025					
F	31875.122	118436	+.035					
F	33379.256	100949	-.008					
F	35601.188	75118	+.022					
T	35604.337	75081	-.012					
F	35607.173	75048	-.014					
F	35981.202	70700	+.013					
T	38106.402	45993	-.006					
T	41059.368	11663	+.001					
T	41773.223	-3364	+.001					
S	42062.5835	0	+.0012	+^{d}.0007	11^m.26	+^{m}.02	11^m.09	+^{m}.02
B,C	65.5956	+35	+.0027	-.0002	11.165	+.007	.006	+.002
B,C	.6781	36	-.0008	-.0001	10.984	-.027	10.890	-.003
B,C	68.3438	67	-.0016	+.0002	11.029	+.005	.903	.000
B,C	.4303	68	-.0011	-.0002	.217	+.004	11.049	+.002
B,C	.5203	69	+.0028	-.0001	.187	+.002	.024	-.001
B,C	.6029	70	-.0006	-.0005	.016	+.001	10.899	+.002
B,C	.6871	71	-.0024	-.0001	.130	+.003	.987	+.006
B,C	69.3808	79	+.0032	+.0006	.214	-.001	11.050	-.006
B,C	.4651	80	+.0014	+.0005	.036	-.001	10.917	+.004
B,C	.5473	81	-.0024	+.0001	.071	-.005	.942	-.001
B,C	.6363	82	+.0006	-.0002	.253	+.003	11.085	+.010
B,C	86.4965	278	+.0015	+.0006	.046	+.012	10.913	+.002
B,C	.5787	279	-.0023	+.0002	.081	+.002	.944	-.002
B,C	87.4390	289	-.0022	.0000	.039	+.001	.904	-.010
B,C	.5263	290	-.0009	-.0006	.222	-.009	11.049	-.011
B,C	.6155	291	+.0023	-.0006	.154	-.007	.004	-.002
S	95.5293	383	+.0025	-.0003	.18	-.02	11.04	-.01
S	.6118	384	-.0010	-.0010	.00	-.01	10.88	-.01
B,C	103.3513	474	-.0030	-.0012	.182	+.011	11.024	+.009
S	106.4520	510	+.0011	-.0003	.03	-.02	10.92	.00
S	119.5258	662	+.0003	+.0010	.18	-.03	11.02	-.02
S	121.5017	685	-.0022	+.0001	.01	-.02	10.89	.00
B,C	122.3628	695	-.0012	+.0003	.028	+.010	.901	+.002
B,C	.4484	696	-.0016	-.0004	.187	-.011	11.032	-.004
S	128.2968	764	-.0024	-.0002	.12	.00	11.00	+.03
S	.3872	765	+.0020	-.0002	.25	+.01	11.10	+.02
S	.4727	766	+.0015	.0000	.07	+.01	10.96	+.03
S	.5550	767	-.0022	+.0001	.06	+.02	.93	+.03
S	133.4622	824	+.0020	+.0004	.07	+.01	.92	-.01
S	.5440	825	-.0022	+.0001	.03	.00	.88	-.01
S	134.4055	835	-.0009	+.0008	.02	+.01	.89	+.01
S	147.3935	986	-.0014	+.0004	.15	.00	.98	-.01
S	148.4295	998	+.0024	+.0004	.09	+.01	.92	-.02
S	.5096	999	-.0036	-.0014	.03	+.01	.88	.00
S	159.4365	1126	-.0008	+.0009	11.16	.00	.97	-.03
S	161.4145	+1149	-.0012	+.0004	10.99	-.01	10.86	-.01

Table 4 Epochs and magnitudes at the minimum light

Hel.J.D.	n	$(O-C)_1$	$(O-C)_2$	B	$(O-C)_B$	V	$(O-C)_V$
42065.5652	35	$+.^d0020$	$+.^d0008$	$11.^m751$	$-.^m007$	$11.^m472$	$-.^m005$
.6502	36	+.0010	-.0005	.791	-.001	.478	-.024
68.3995	68	-.0023	-.0001	.777	+.005	.495	+.008
.4896	69	+.0018	+.0012	.757	+.002	.479	+.004
.5764	70	+.0026	+.0008	.780	-.009	.492	-.008
.6592	71	-.0006	+.0009	.777	-.010	.489	-.009
69.3480	79	+.0001	+.0004	.761	+.009	.469	-.004
.4360	80	+.0020	-.0001	.774	-.006	.493	-.001
.5203	81	+.0003	+.0011	.790	-.003	.496	-.007
.6021	82	-.0039	-.0022	.758	-.002	.478	-.001
86.4655	278	+.0002	-.0019	.797	+.017	.521	+.027
.5509	279	-.0004	+.0004	.810	+.017	.525	+.022
87.4116	289	+.0001	+.0001	.796	.000	.510	+.005
.4950	290	-.0025	-.0004	.767	.000	.491	+.007
.5845	291	+.0010	-.0002	.755	-.002	.482	+.005
122.4185	696	-.0019	+.0003	.770	-.005	.481	-.009
.5059	697	-.0005	-.0008	.751	-.002	.464	-.010

Table 5 AI Vel stars with two excites modes

Ref*	Star	P_o	P_b	P_1	P_1/P_o	$2A_V$ (unit=$0.^m01$)		$2A_B$		A_o/A_1
1	SX Phe	$0.^d05496437$	$0.^d192834$	$0.^d042773$	0.7782	55	21			2.6
2	CY Aqr	.0610383	.17766	.04543	.7443	72	12			6.0
	AE UMa	.08601688	.293616	.066527	.7734	50	21	64	28	2.3
3	RV Ari	.09313	.31634	.07195	.7726	49.5	31	63.5	40	1.6
4	BP Peg	.10954	.3698	.0845	.771	43	9	57	14	4.4
5	AI Vel	.111574	.379188	.086208	.7727	39	51			.76
6	V 703 Sco	.14996	.497295	.115216	.7683	40	50			.80
7	VZ Cnc	.17836376	.716292	.142800	.8006	50	29	70	38	1.8
8	VX Hya	.223389	.761475	.17272	.7732					

*References: 1. Stock, Tapia (1971); 2. Elst (1972); Fitch (1973); 3. Broglia (1958); 4. Broglia (1959); 5. Walraven (1955); 6. Ponsen (1963); 7. Spinrad (1960); 8. Fitch (1966).

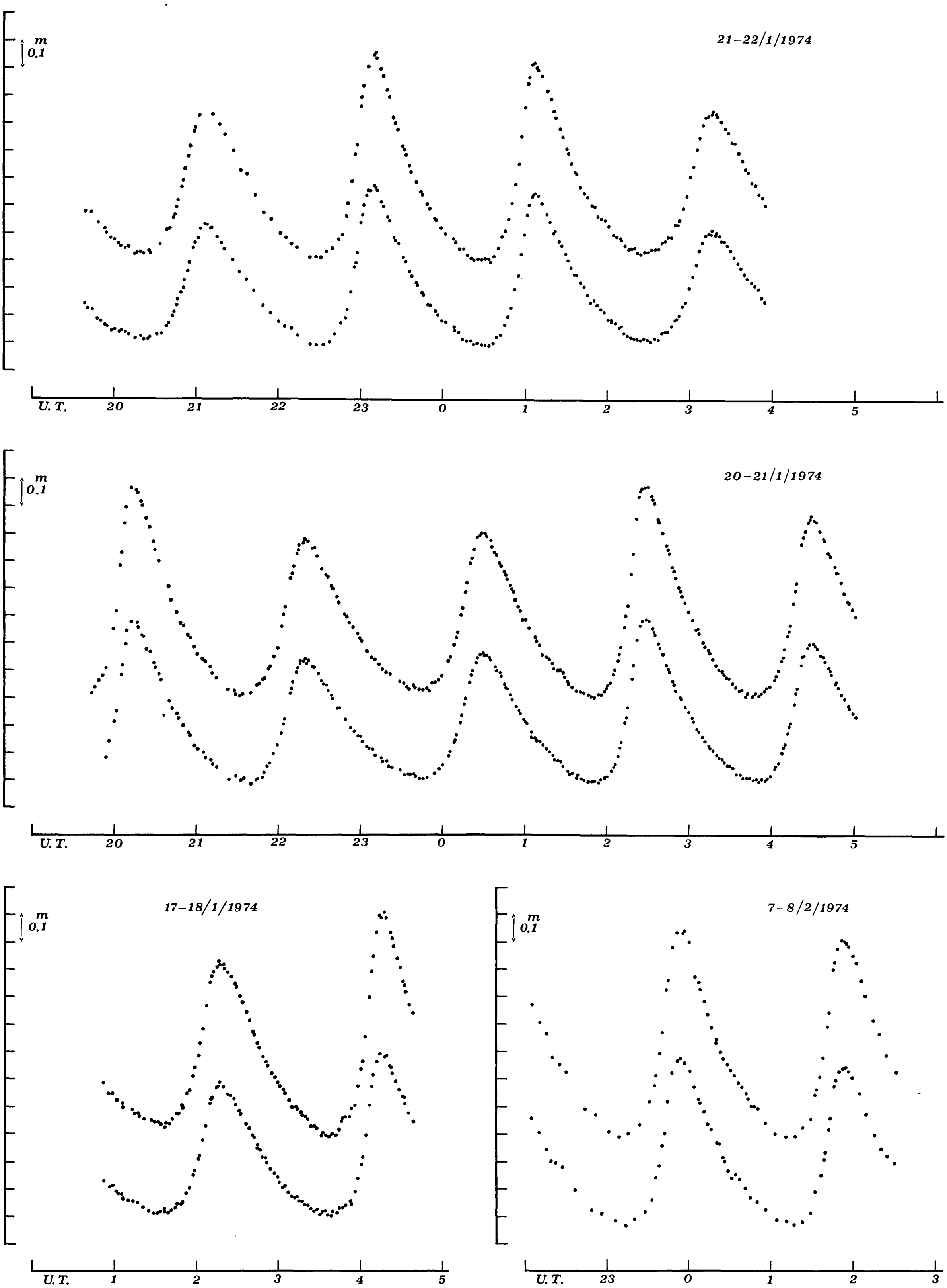

Figure 1 *B* and *V* light curves of AE UMa. The two curves are shifted by the same arbitrary quantity along the vertical axis.

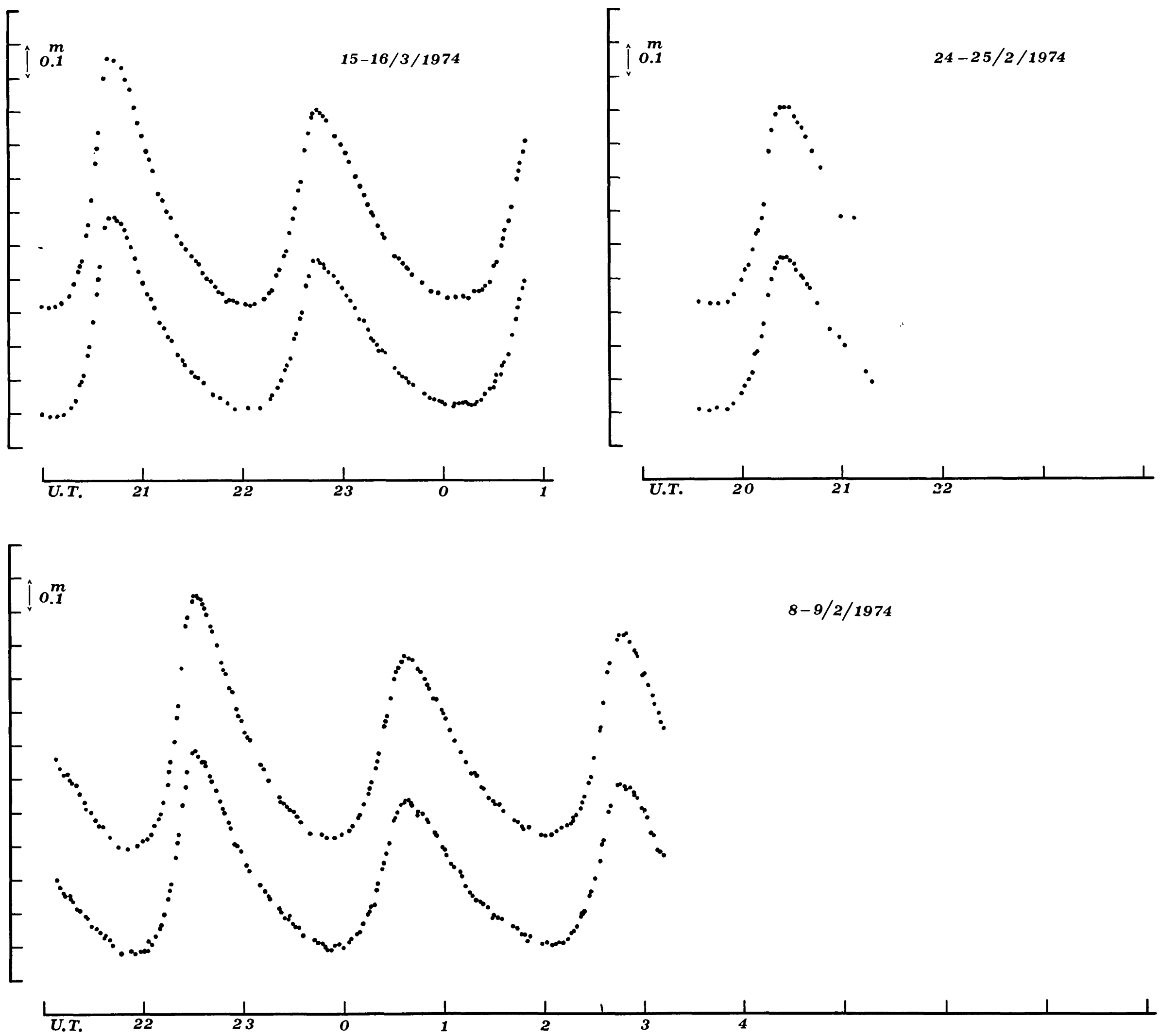

Figure 2 *B* and *V* light curves of AE UMa. The two curves are shifted by the same arbitrary quantity along the vertical axis.

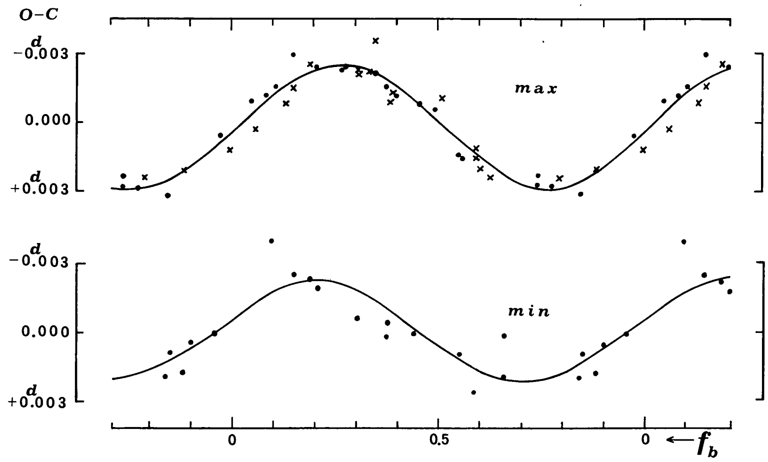

Figure 3 The $(O-C)_1$, computed by means of the fundamental period P_0 for all the photoelectric measures, plotted against beat phases. The crosses represent the Szeidl observations, the dots ours. The sinusoids have been calculated by least squares.

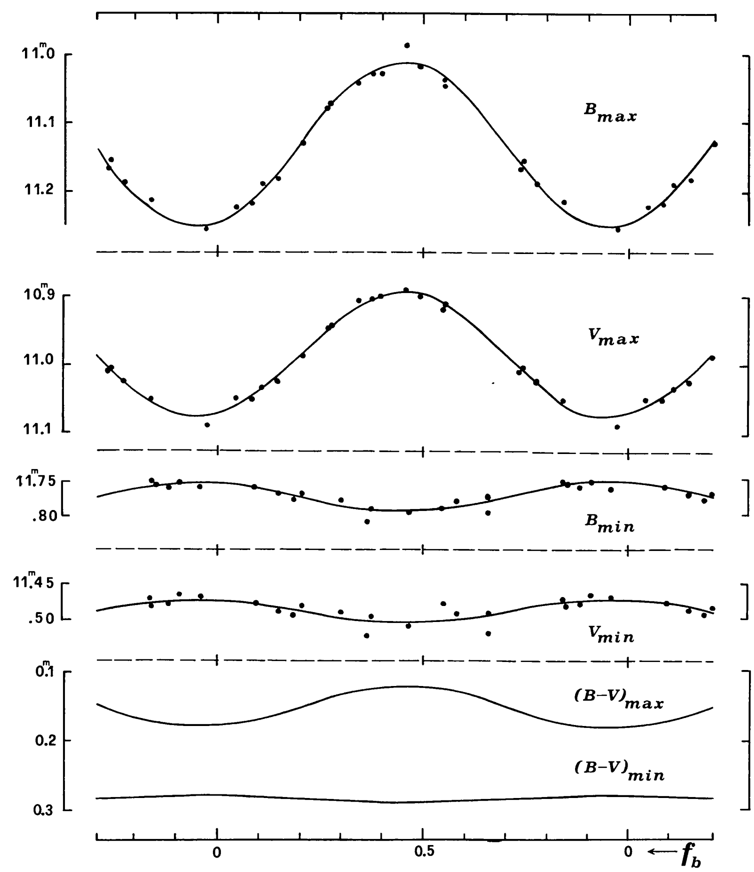

Figure 4 The B, V magnitudes and the colours of AE UMa, at maximum and minimum light, plotted against beat period phases. A $P_b/2$ phase difference appears between the minimum and maximum curves. The curves have been calculated by least squares.