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On the period of AB Andromedae (Errata: 5 172)

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COMMUNICATION FROM THE OBSERVATORY AT LEIDEN.

On the period of AB Andromedae, by *P. Th. Oosterhoff*.

Since the observations of this variable star of the W Urs. maj. type made in 1928 and published in *B. A. N.* 166 gave rather satisfactory results regarding the epochs of minimum, the observation of variable stars of this type has been continued. In *B. A. N.* 166 only six minima are given and therefore the mean error of an epoch of minimum is not reliable, the material being much too small. It will be of interest to see whether the new observations will confirm the accuracy obtained. Much will depend on the comparison stars, since differences of colour may cause some trouble, but in the case of AB And. they seem to be very favourable.

During the year 1929 I observed 12 more minima of AB And., viz: six primary and six secondary minima. As before, the observations have been made with the special aim to get accurate epochs of minimum.

The 34-cm. photographic refractor of this observatory was used, the plates are Eastman 40, 16×16 cm., the time of one exposure being 5 minutes, the time between two exposures half a minute. Only one plate (epoch 3651.5) was taken with an exposure-time of 4 minutes. All observations of one minimum were made on the same plate, with the exception of one minimum (epoch 3284.5), when two plates were taken, since the observations were made during moonlight. Again the images of one plate are placed in two rows, in such a way that the turning point is

chosen as close to the minimum as possible. The same comparison stars have been used as before (*B. A. N.* 166).

The plates are measured in the Schilt microphotometer; the reduction of these measurements to differences of magnitude is made graphically, comparing each exposure of the variable with the simultaneous exposures of the comparison stars. Also another method of reduction has been applied, but since it practically made no difference in the results, I preferred to keep to the graphical method.

One plate of the primary minimum has been rejected because the fog of the plate varied very irregularly within short distances on the plate.

The diagram shows the remaining eleven minima obtained in this way. Abscissae are phases, computed by the formula:

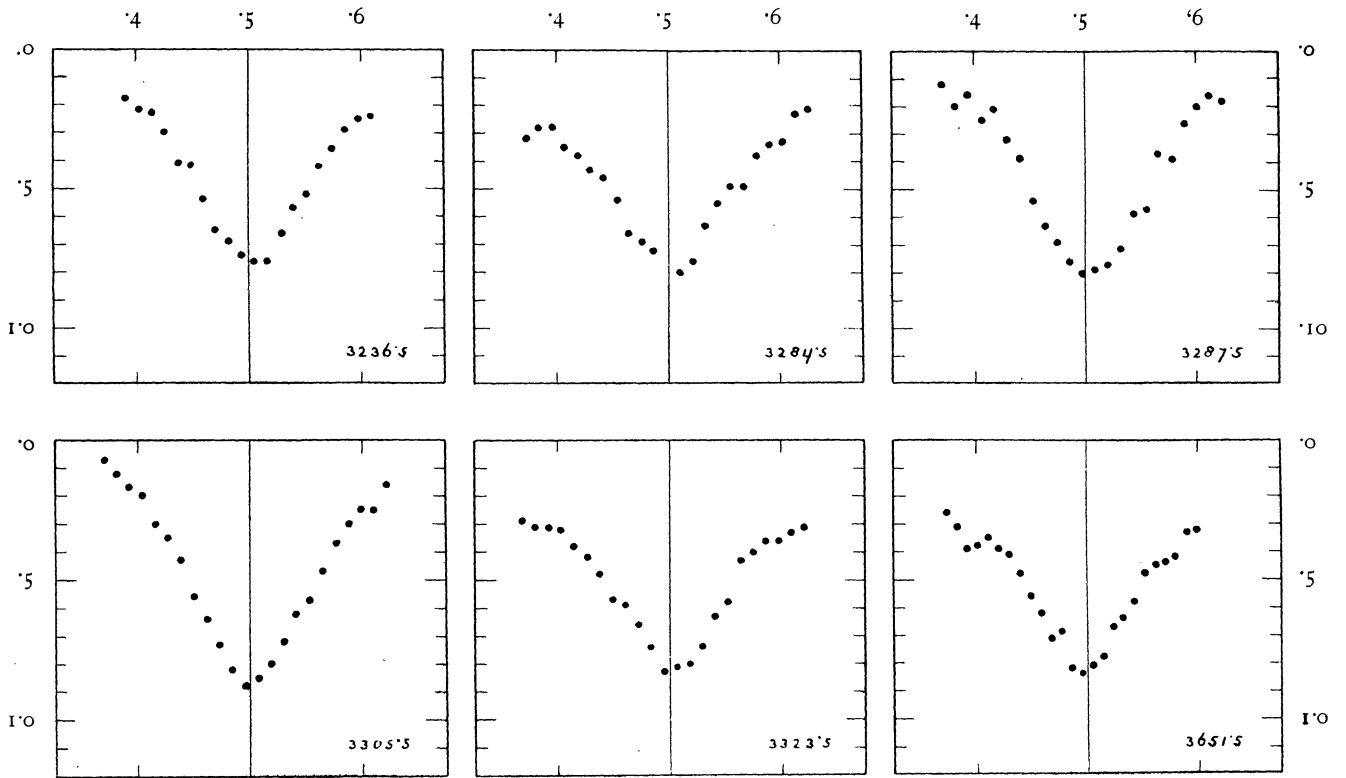
$$\text{phase} = 3^{\circ}0130837 \text{ (J.D. H. M. T. Gr. - 2425497.48034)} \\ + 2221.$$

2221 is the number of periods in the interval between the epoch given by GUTHNICK and PRAGER and the mean epoch of the earlier Leiden observations. Ordinates give Δm relatively to comparison star *a*. As may be seen from the graphs, the form of the minimum varies rather strongly, but since both descending and ascending branch are affected practically in the same manner, owing to the method of observation the epoch of minimum will not be materially influenced.

TABLE I.

J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star <i>a</i>	J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star <i>a</i>	J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star <i>a</i>
epoch 3236.5		m			m			m
5834.47415	.3906	+ .18	5834.50081	.4709	+ .65	5834.52748	.5512	+ .52
.47796	.4020	.22	.50462	.4824	.69	.53129	.5627	.42
.48177	.4135	.23	.50843	.4938	.74	.53509	.5742	.36
.48558	.4250	.30	.51224	.5053	.76	.53890	.5857	.29
.48939	.4365	.41	.51605	.5168	.76	.54271	.5971	.25
.49320	.4480	.42	.51986	.5283	.66	.54652	.6086	.24
.49700	.4594	.54	.52367	.5398	.57			

Secondary minima.



Primary minima.

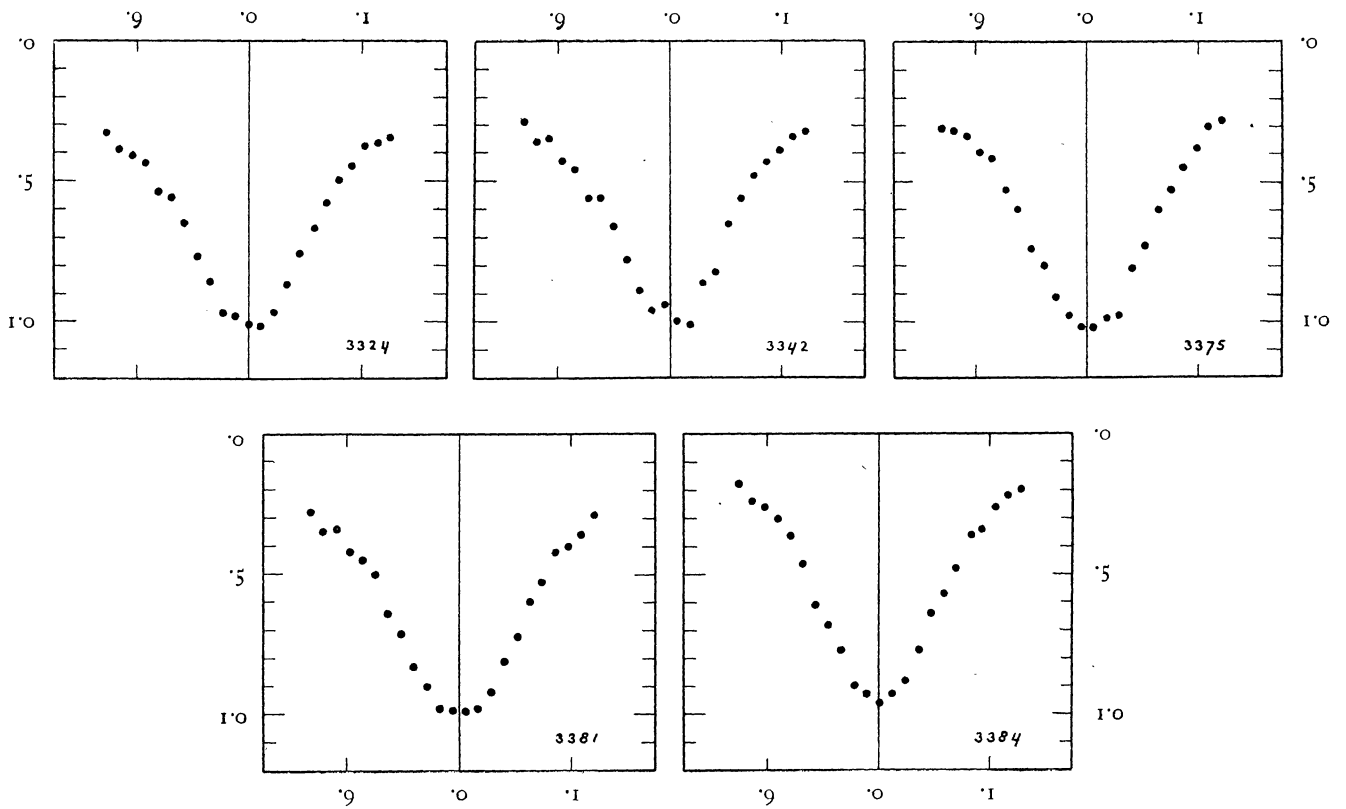


TABLE I (continued).

J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star <i>a</i>	J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star <i>a</i>	J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star <i>a</i>
epoch 3284.5		m	epoch 3287.5		m	epoch 3305.5		m
5850.39866	.3724	+ .32	5851.39389	.3711	+ .12	5857.36732	.3696	+ .07
.40247	.3839	.28	.39770	.3826	.20	.37113	.3811	.12
.40628	.3954	.28	.40151	.3941	.16	.37494	.3926	.17
.41009	.4069	.35	.40532	.4056	.26	.37875	.4040	.20
.41390	.4184	.38	.40913	.4171	.21	.38256	.4155	.30
.41771	.4298	.43	.41294	.4285	.32	.38637	.4270	.35
.42152	.4413	.46	.41675	.4400	.39	.39018	.4385	.43
.42533	.4528	.54	.42056	.4515	.54	.39399	.4500	.56
.42914	.4643	.66	.42437	.4630	.63	.39780	.4614	.64
.43294	.4757	.69	.42817	.4744	.69	.40161	.4729	.73
.43675	.4872	.72	.43198	.4859	.76	.40541	.4844	.82
.44056	.5002	.80	.43579	.4974	.80	.40922	.4958	.88
.44437	.5126	.76	.43960	.5089	.79	.41303	.5073	.85
.44818	.5251	.63	.44341	.5204	.77	.41684	.5188	.80
.45199	.5376	.55	.44722	.5318	.71	.42065	.5303	.72
.45580	.5501	.49	.45103	.5433	.59	.42446	.5418	.62
.45961	.5626	.49	.45484	.5548	.57	.42827	.5532	.57
.46342	.5751	.38	.45865	.5663	.37	.43208	.5647	.47
.46723	.5876	.34	.46246	.5778	.39	.43589	.5762	.37
.47103	.6001	.33	.46626	.5892	.26	.43970	.5877	.30
.47484	.6126	.23	.47007	.6007	.20	.44350	.5991	.25
.47865	.6251	.21	.47388	.6122	.16	.44731	.6106	.25
.48246			.47769	.6236	.18	.45112	.6221	.16
epoch 3323.5		m	epoch 3324		m	epoch 3342		m
5863.34071	.3679	+ .29	5863.50831	.8729	+ .33	5869.48096	.8690	+ .29
.34452	.3794	.31	.51212	.8844	.39	.48477	.8805	.36
.34833	.3909	.31	.51593	.8959	.41	.48858	.8920	.35
.35214	.4024	.32	.51974	.9073	.44	.49239	.9034	.43
.35595	.4138	.38	.52355	.9188	.54	.49620	.9149	.46
.35976	.4253	.42	.52736	.9303	.56	.50001	.9264	.56
.36357	.4368	.48	.53117	.9418	.65	.50382	.9379	.56
.36738	.4483	.57	.53498	.9533	.77	.50763	.9494	.66
.37119	.4596	.59	.53878	.9647	.86	.51143	.9608	.78
.37499	.4712	.66	.54259	.9762	.97	.51524	.9723	.89
.37880	.4827	.74	.54640	.9877	.98	.51905	.9838	.96
.38261	.4942	.83	.55021	.9992	1.01	.52286	.9953	.94
.38642	.5056	.81	.55402	.0106	1.02	.52667	.0067	1.00
.39023	.5171	.80	.55783	.0221	.97	.53048	.0182	1.01
.39404	.5286	.74	.56164	.0336	.87	.53429	.0297	.86
.39785	.5401	.63	.56545	.0451	.76	.53810	.0412	.82
.40166	.5516	.58	.56926	.0566	.67	.54191	.0527	.65
.40547	.5630	.43	.57307	.0680	.58	.54572	.0641	.56
.40928	.5745	.40	.57687	.0795	.50	.54952	.0756	.48
.41308	.5860	.36	.58068	.0910	.45	.55333	.0871	.43
.41689	.5975	.36	.58449	.1024	.38	.55714	.0985	.39
.42070	.6089	.33	.58830	.1139	.37	.56095	.1100	.34
.42451	.6204	.31	.59211	.1254	.35	.56476	.1215	.32
epoch 3375		m	epoch 3381		m	epoch 3381		m
5880.43301	.8684	+ .31	5880.46348	.9603	.80	5880.49395	.0521	.73
.43681	.8799	.32	.46729	.9717	.91	.49776	.0635	.60
.44062	.8914	.34	.47110	.9832	.98	.50157	.0750	.53
.44443	.9029	.40	.47490	.9947	1.02	.50538	.0865	.45
.44824	.9143	.42	.47871	.0061	1.02	.50919	.0980	.38
.45205	.9258	.53	.48252	.0176	.99	.51299	.1094	.30
.45586	.9373	.60	.48633	.0291	.98	.51680	.1209	.28
.45967	.9488	.74	.49014	.0406	.81			
epoch 3381		m	epoch 3381		m	epoch 3381		m
5882.42409	.8677	+ .28	5882.45456	.9595	+ .83	5882.48503	.0514	+ .72
.42789	.8792	.35	.45837	.9710	.90	.48884	.0628	.60
.43170	.8907	.34	.46218	.9825	.98	.49265	.0743	.53
.43551	.9021	.42	.46598	.9940	.99	.49646	.0858	.42
.43932	.9136	.45	.46979	.0054	.99	.50027	.0973	.40
.44313	.9251	.50	.47360	.0169	.98	.50407	.1087	.36
.44694	.9366	.64	.47741	.0284	.92	.50788	.1202	.29
.45075	.9481	.71	.48122	.0399	.81			

TABLE I (continued).

J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star α	J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star α	J. D. H. M. T. Gr. — 2420000	Phase	Δm between AB And. and comp. star α
epoch 3384		^m			^m			^m
5883·42205	·8747	+ ·18	5883·45252	·9665	+ ·77	5883·48299	·0583	+ ·57
·42585	·8861	·24	·45633	·9780	·90	·48680	·0698	·48
·42966	·8976	·26	·46014	·9894	·93	·49061	·0813	·36
·43347	·9091	·30	·46394	·0009	·96	·49442	·0927	·34
·43728	·9206	·36	·46775	·0124	·93	·49823	·1042	·26
·44109	·9320	·46	·47157	·0239	·88	·50203	·1157	·22
·44490	·9435	·61	·47536	·0353	·77	·50584	·1271	·20
·44871	·9550	·68	·47918	·0468	·64			
epoch 3651·5		^m			^m			^m
5972·20101	·3731	+ ·26	5972·22906	·4576	+ ·62	5972·25399	·5327	+ ·64
·20413	·3825	·31	·23218	·4670	·71	·25711	·5421	·58
·20724	·3919	·39	·23529	·4764	·69	·26022	·5515	·48
·21036	·4013	·38	·23841	·4858	·82	·26334	·5609	·45
·21348	·4107	·35	·24153	·4952	·84	·26646	·5703	·44
·21659	·4201	·39	·24464	·5046	·81	·26957	·5797	·42
·21971	·4295	·41	·24776	·5140	·78	·27269	·5891	·33
·22283	·4389	·48	·25087	·5233	·67	·27581	·5985	·32
·22594	·4482	·56						

In Table I the J. D., the phase calculated with the above formula and the Δm of each exposure, are given. All times have been reduced to the sun.

To find the epoch of each minimum, the method explained in *B. A. N.* 166, page 39 has been used. When possible the computation was made with five sums of squares, the interval in time between two sums of squares being always the interval between two exposures. If another number of sums of squares is used, the deviations are only small and the final results would not be altered.

The epochs derived are the following:

J. D.	Epoch
2425834·51164	3236·5
5850·44130	3284·5
5851·43786	3287·5
5857·41142	3305·5
5863·38494	3323·5
5863·55023	3324
5869·52453	3342
5880·47692	3375
5882·46775	3381
5883·46380	3384
5972·24202	3651·5

The epoch is counted from the minimum observed by GUTHNICK and PRAGER.

In the preceding note on this star six epochs of the primary minimum are given; from these epochs and the five new ones computed in this paper the period was redetermined by the method of least squares.

The elements are now:

$$J. D. 2425497 \cdot 48034 + \cdot 33188590 (E - 2221) \\ \pm \cdot 00007 \pm \cdot 00000011 \quad m. e.$$

The new value of the period is in good agreement with the old period, within its mean error, as given in *B. A. N.* 166.

The ($O-C$)'s calculated with these elements, have the following values:

Epoch	$O-C$
2221	+ ·00027
2224	- ·00011
2236	+ ·00006
2239	- ·00018
2242	- ·00018
2248	+ ·00014
3324	- ·00026
3342	+ ·00009
3375	+ ·00025
3381	- ·00024
3384	+ ·00015

According to these figures the mean error of a single epoch of minimum is $\pm \cdot 00021$ or ± 20 sec., the same as has been found formerly from six minima only. It seems therefore that the accuracy obtained is not merely accidental, but a larger number of observations may decide on this point.

The mean error of the final mean epoch is found to be $\pm \cdot 000063$ or about six seconds. For the elements I gave the value of this mean error a $\pm \cdot 00007$.

TABLE 2.

J. D. H. M. T. Gr.	Observer	Epoch	$O-C$	J. D. H. M. T. Gr.	Observer	Epoch	$O-C$
			d				d
2415775.514	Harvard. He.	-27072	-033	2425502.45869	Oo.	2236	+00006
6108.564	»	-26068.5	-030	5503.45411	»	2239	-00018
6427.698	»	-25107	-005	4504.44976	»	2242	-00018
8679.541	» Sh.	-18322	-007	5506.44140	»	2248	+00014
8682.507	»	-18313	-028	5834.51164	»	3236.5	+00117
8691.488	»	-18286	-008	5850.44130	»	3284.5	+00031
8936.753	»	-17547	-007	5851.43786	»	3287.5	+00121
8976.565	»	-17427	-021	5857.41142	»	3305.5	+00082
8977.580	»	-17424	-002	5863.38494	»	3323.5	+00040
2424760.360	Guthnick—Prager	o	-002	5863.55023	»	3324	-00026
5155.63713	Jordan (Oo.)	1191	-00073	5869.52453	»	3342	+00009
5174.72271	»	1248.5	+00141	5880.47692	»	3375	+00025
5497.48061	Oo.	2221	+00027	5882.46775	»	3381	-00024
5498.47589	»	2224	-00011	5883.46380	»	3384	+00015
5498.80792	Jordan (Oo.)	2225	+00004	5972.24202	»	3651.5	-00110

If later observations confirm this accuracy the question arises whether variables of this kind might not be used as time keepers for independent control of the earth's rotation, in the same way as the moon's motion, the transits of Mercury and some other phenomena in the solar system.

With a view to the possibility that the periods of these stars may be variable in many cases, it would be necessary to use a large number of variable stars.

Deriving the new elements, the secondary minima have not been used; calculating the ($O-C$)'s for these minima with the same elements we find:

Epoch	$O-C$
	d
3236.5	+00117
3284.5	+00031
3287.5	+00121
3305.5	+00082
3323.5	+00040
3651.5	-00110

Since there is a difference in depth between the primary and secondary minimum of about $m.2$ (from my own observations I found $m.17$) it is to be expected that the secondary minima will not give the same accuracy as the primary. The mean error derived from the above figures is $\pm d.00086$, but this value depends mainly on the one negative value among the ($O-C$)'s. This minimum (epoch 3651.5) falls in time far outside the other observations and the minimum has been observed early in the twilight. Therefore it seems to me rather probable that the lightcurve will not be symmetrical; the corresponding eccentricity, if showing its maximal effect, would be of the order of $.01$. It will be of much interest to get a larger number of observations to decide this point.

In *B. A. N.* 146, page 163 E. HERTZSPRUNG published

three old minima of this star, which he found on Harvard AC plates. The counting of epochs suggested in that note for these old observations is now seen to be erroneous by one whole period (see Table 2).

By the courtesy of Prof. SHAPLEY we got 42 intermediate estimates on Harvard plates. The variable was found to be faint on 6 plates, the J. D. of which is given in Table 2. Calculating the ($O-C$)'s with the elements derived in this paper, we find them all to be negative. It is not well possible to represent the old Harvard observations and the minima observed at Leiden by a uniform period and therefore we may suspect the period to be variable. No solution with a quadratic term has been made, since the old minima are very uncertain, mainly owing to the long time of exposure. It will be better to wait until more accurate data will be available later.

The new elements are in good agreement with the epoch given by GUTHNICK and PRAGER, the mean error of which I estimated to be $\pm d.002$. The ($O-C$) is $-d.002$.

A large number of photographic observations of this star has been made by JORDAN (*Publ. of the Allegheny Obs.* Vol. VII, pag. 136), but no single or mean epochs of minimum derived from this material are given. Therefore I treated these observations in the manner indicated by E. HERTZSPRUNG in *B. A. N.* 147, page 179. Mean epochs of minimum have been derived for the primary and the secondary minimum separately, using the observations of the year 1927 only. The first epoch will not be very accurate, since the number of observations near the primary minimum made during the year 1927 is very small. A third mean epoch has been derived from JORDAN's observations of the primary minimum made in 1928.

The results, with ($O-C$) calculated from the new elements, are given below: