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AP VELORUM, A CLASSICAL CEPHEID WITH SECONDARY PERIOD

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Hertzsprung's observations of the Cepheid AP Vel, published in 1936, can be satisfactorily explained by a fundamental period of $3^d.12781$ and a beat period of $7^d.4088$. The light variation is very similar to that of the Cepheids TU Cas and U TrA.

In a letter to me Professor Hertzsprung emphasized the importance of new observations of the variable star AP Velorum. Its variability was discovered by HERTZSPRUNG (1936a) on Franklin-Adams plates. He classified the star as a Cepheid. Later HERTZSPRUNG (1936b) published photographic magnitudes for this variable and derived a period of $3^d.13$. He remarked, however, that the star shows marked deviations from a regular light-variation.

The variability of AP Vel was independently discovered by O'LEARY (1937). Hertzsprung's conclusions were fully confirmed by O'Leary and later by GAPOSCHKIN (1952).

TABLE 1

Max. J.D. − 2 400 000	Author	E	O − C
25 714.30	Hertzsprung	0	− 0.22
25 971.36	Hertzsprung	82	+ 0.36
26 002.44	Hertzsprung	92	+ 0.16
26 011.32	Hertzsprung	95	− 0.34
26 030.44	Hertzsprung	101	+ 0.01
26 030.52	Hertzsprung	101	+ 0.09
26 121.21	Hertzsprung	130	+ 0.08
26 277.54	Hertzsprung	180	+ 0.02
26 299.47	Hertzsprung	187	+ 0.05
26 305.40	Hertzsprung	189	− 0.28
26 305.48	Hertzsprung	189	− 0.20
26 305.57	Hertzsprung	189	− 0.11
26 396.34	Hertzsprung	218	− 0.04
26 515.21	Hertzsprung	256	− 0.03
27 513.26	Hertzsprung	575	+ 0.25
27 516.22	Hertzsprung	576	+ 0.08
27 713.58	Hertzsprung	639	+ 0.39
28 254.08	O'Leary	812	− 0.22
34 522.37	Walraven, Muller and Oosterhoff	2 816	− 0.06

As similar deviations from a regular light variation for the Cepheids TU Cas and U TrA are now well understood by the work of OOSTERHOFF (1957) and JANSEN (1962), I have rediscussed Hertzsprung's observations and it soon became clear that the complicated variation in brightness of AP Vel can also be satisfactorily explained by the interference of a primary and a secondary period.

For the determination of the primary period the epochs of extreme maximum brightness were selected from Hertzsprung's measures and combined with two epochs published by O'LEARY (1937) and by WALRAVEN, MULLER and OOSTERHOFF (1958). A least-squares solution yields the following elements for maximum:

$$\text{Max.} = \text{J.D. } 2425714.52 + 3^d.12781\, E.$$
$$\pm \qquad 8 \quad \text{(m.e.)}$$

Data about this solution are given in table 1. Phases φ have then been computed with the formula:

$$\varphi = 0.319712\,(\text{J.D.}{-}2420000).$$

These phases are given in the second column of table 2. In the first column of this table Hertzsprung's measures are given. Plotting these measures against the phase φ the light curve is obtained which is shown in figure 1. This diagram closely resembles those published for TU Cas and U TrA. For these two Cepheids the ratio between secondary and primary periods was found to be 0.71 and therefore it was tried whether this value would also fit the observations of AP Vel. After a few trials it was found that a value of 0.703 gives a very nice representation of the observations.

TABLE 2

Δm $(0^m.01)$	Phase φ	Phase ψ	Δm $(0^m.01)$	Phase φ	Phase ψ	Δm $(0^m.01)$	Phase φ	Phase ψ
59	0.339	0.61	72	0.605	0.58	18	0.117	0.37
44	0.310	0.02	75	0.549	0.98	30	0.131	0.38
86	0.608	0.15	31	0.197	0.26	30	0.160	0.39
-66	0.932	0.28	90	0.508	0.39	69	0.436	0.51
27	0.892	0.69	4	0.835	0.53	66	0.317	0.51
70	0.530	0.96	35	0.126	0.65	20	0.129	0.76
52	0.371	0.58	52	0.445	0.78	93	0.517	0.45
39	0.333	0.98	76	0.784	0.93	-10	0.105	0.12
6	0.927	0.66	92	0.530	0.35	81	0.419	0.26
62	0.559	0.92	-12	0.870	0.49	21	0.767	0.40
-14	0.876	0.06	45	0.185	0.63	-37	0.985	0.34
49	0.243	0.48	-10	0.161	0.04	82	0.452	0.22
90	0.504	0.39	86	0.466	0.17	20	0.086	0.49
16	0.820	0.52	42	0.107	0.44	60	0.728	0.76
47	0.208	0.22	71	0.423	0.57	98	0.682	0.17
74	0.429	0.16	52	0.382	0.98	78	0.629	0.57
55	0.746	0.29	22	0.982	0.65	5	0.963	0.71
39	0.161	0.58	33	0.119	0.40	88	0.588	0.39
58	0.496	0.72	70	0.443	0.54	40	0.142	0.47
-26	0.114	0.98	46	0.760	0.67	-2	0.070	0.86
-12	0.143	0.99	4	0.081	0.81	76	0.734	0.14
71	0.439	0.11	-41	0.023	0.20	73	0.490	0.15
28	0.797	0.27	77	0.359	0.35	23	0.810	0.29
22	0.096	0.39	65	0.681	0.48	84	0.521	0.12
19	0.097	0.35	85	0.635	0.88	25	0.910	0.82
74	0.423	0.49	90	0.584	0.28	46	0.195	0.36
49	0.768	0.63	39	0.413	0.90	74	0.511	0.49
-20	0.053	0.17	86	0.737	0.04	74	0.436	0.31
13	0.979	0.56	14	0.015	0.58	36	0.750	0.44
77	0.614	0.83	19	0.072	0.53	36	0.076	0.58
42	0.287	0.12	-2	0.850	0.55	52	0.395	0.71
59	0.327	0.13	40	0.182	0.69	68	0.712	0.84
91	0.573	0.24	60	0.502	0.83	52	0.352	0.11
98	0.627	0.26	-16	0.121	0.09	100	0.672	0.25
-41	0.892	0.37	67	0.440	0.22	-22	0.990	0.38
60	0.258	0.53	28	0.776	0.36	71	0.301	0.58
59	0.531	0.64	60	0.738	0.77	-28	0.080	0.09
66	0.599	0.67	92	0.681	0.17	60	0.400	0.23
52	0.852	0.78	-29	0.005	0.30	58	0.769	0.39
16	0.226	0.94	-44	0.017	0.27	-26	0.026	0.49
53	0.320	0.66	37	0.302	0.81	10	0.064	0.51
64	0.629	0.79	73	0.600	0.93	75	0.374	0.64
70	0.698	0.82	-26	0.910	0.06	1	0.992	0.90
-10	0.948	0.93	-37	0.936	0.08	20	0.329	0.04
-18	0.977	0.94	-45	0.967	0.09	56	0.782	0.03
-24	0.005	0.95	40	0.246	0.21	-1	0.018	0.98
-31	0.030	0.96	39	0.200	0.61	-33	0.125	0.13
43	0.293	0.07	56	0.234	0.62	20	0.208	0.99
35	0.880	0.74	55	0.507	0.74	64	0.498	0.11
30	0.924	0.76	56	0.538	0.75	80	0.536	0.13
77	0.520	0.01	58	0.687	0.50	50	0.142	0.81
20	0.823	0.14	12	0.993	0.63	64	0.466	0.94
-17	0.866	0.16	16	0.025	0.65	68	0.726	0.05
42	0.178	0.29	66	0.618	0.89	70	0.755	0.06
-11	0.838	0.57	37	0.890	0.86	67	0.779	0.07

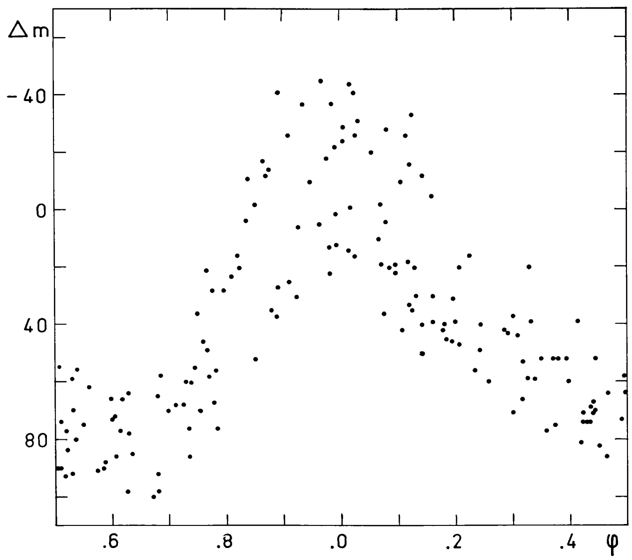

Figure 1. Brightness Δm (in $0^m.01$) plotted against phase φ of the primary period.

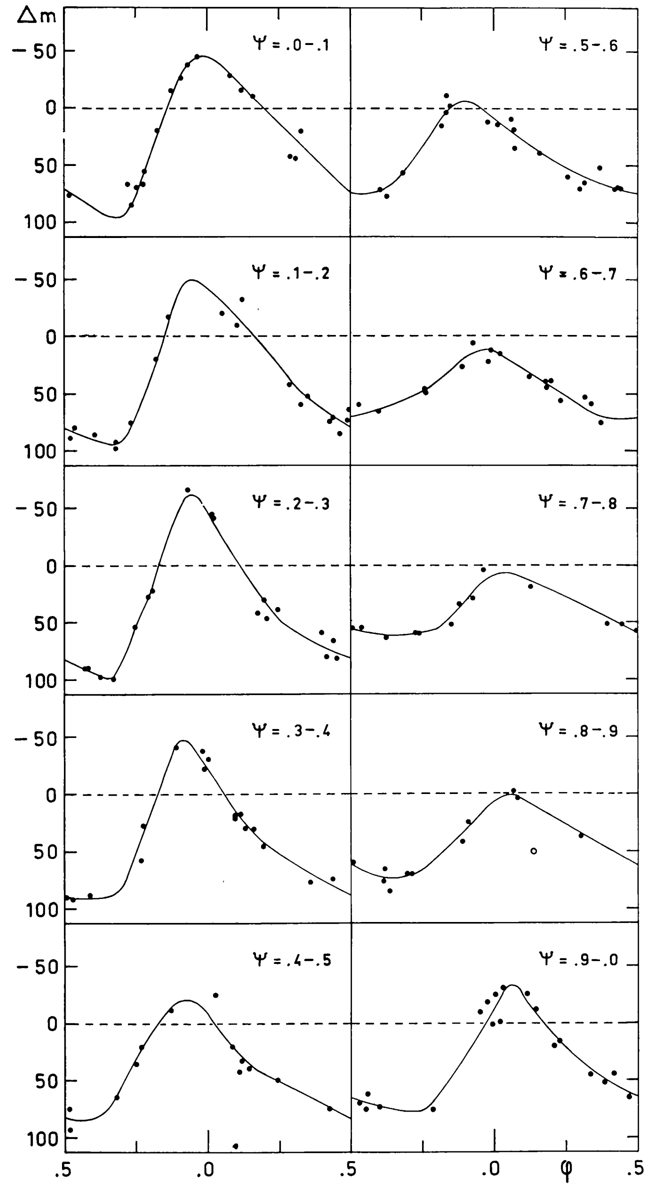

Figure 2. Brightness Δm (in $0^m.01$) plotted against phase φ of the primary period for different values of the secondary phase ψ.

This value of the ratio P_1/P_0 leads to a secondary period of $2^d.19932$, and to a beat period of $7^d.40883$. The mean error of this beat period is estimated to be about $\pm 0^d.0006$.

Phases ψ, fractions of the beat period, have been computed with the formula:

$$\psi = 0.134974\,(\text{J.D.}–2420000).$$

They are given in the third column of table 2. Figure 2 shows the final results, the light curve as a function of the phase ψ. Only one observation at $\varphi = 0.142$ and $\psi = 0.81$ does not seem to fit. It is based on a single negative. Visual inspection of this negative seems to indicate that the variable is considerably brighter than indicated by Hertzsprung's measure. Nevertheless figure 2 seems to prove convincingly that the proposed solution is the correct one.

The periods for the three Cepheids which are now known to show beat phenomena are:

	TU Cas	U TrA	AP Vel
P_0	$2^d.139295$	$2^d.568438$	$3^d.12781$
P_b	5.23026	6.3041	7.4088
P_1	1.5183	1.8249	2.1993
P_1/P_0	0.7097	0.7105	0.703

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