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Leotta-Janin, C.

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ON THE BEAT PERIOD IN THE LIGHT-VARIATION OF THE CLASSICAL CEPHEID BK CENTAURI

CHRISTIANE LEOTTA-JANIN

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The classical Cepheid BK Centauri has a fundamental period of 3.17 days. From photo-electric observations made by Dr. C. J. van Houten at the Leiden Southern Station and from visual estimates on Franklin-Adams plates a beat period of 7.57 days was derived.

The variable BK Centauri was discovered by OOSTERHOFF (1928) on Franklin-Adams plates. Later (1936) he derived a more accurate period from estimates on Harvard plates. This period, 3.173 97 days, is still given in the second edition of the *General Catalogue of Variable Stars*. Oosterhoff noticed that the scatter of the observations is much larger near maximum than near the minimum of the light-curve. Therefore the variable resembles AP Velorum which has a similar period and was proved by OOSTERHOFF (1964) to have a secondary period. At the request of Prof. Oosterhoff some photo-electric observations were made by Dr. C. J. van Houten at the Leiden Southern Station in 1965. He used the WALRAVENS' (1960) five-colour photometer. The star HD 309 120 was used as comparison star. The writer has reduced these observations. The resulting magnitudes and colours, corrected for differential extinction, are given in table 1. The phases φ and ψ will be explained below. Although these observations confirm the varying height of the maximum, their number is too small to allow a reliable determination of the beat period.

Therefore visual estimates were made of the variable on all available Franklin-Adams plates. Since the discovery of the star by Oosterhoff the number of plates of this field has nearly been doubled. They now cover the interval from 1924 to 1950. All available epochs of maximum have been collected in table 2. The first ten are from Harvard plates, the last five are photo-electric and the others are from Franklin-Adams plates. We used these epochs to derive an improved value for the fundamental period. With the aid of the method of least squares the following elements were derived for the time of maximum brightness:

$$\text{Max.} = 2\,426\,112.885 + 3.173\,887\,E$$
$$\pm 41 \quad \pm \quad 21 \quad \text{(m.e.)}.$$

The phases φ used in this article have been computed with the formula

$$\text{phase } \varphi = 0.315\,070\,82\ (\text{J. D. Hel.} - 2\,420\,000).$$

In the upper part of figure 1 the photo-electric observations have been plotted against phase φ. In the lower part of this figure the same has been done with the estimates on Franklin-Adams plates. Both plots confirm that the dispersion of the observations is larger near maximum than near minimum of the light-curve.

In order to find the beat period the highest maxima from table 2 have been collected in table 3. In the second column are given the number of fundamental periods elapsed since the first epoch. It is to be expected that the deviations from the elements given above are smaller for the high maxima than for all the maxima of table 2. The mean deviation for a single epoch was found to be $\pm$ 0.08 days for the high maxima and $\pm$ 0.25 days for the maxima collected in table 2.

In the third column of table 3 are given the intervals in days between successive epochs. These intervals are multiples of the fundamental period, but they should also be multiples of the beat period. The shortest interval, which occurs twice, is 37.97 days. The other intervals are very much larger. Without any preliminary knowledge of the beat period, it would hardly be possible to derive its value from these data. However, for the three Cepheids with known beat phenomena, TU Cas, U TrA and AP Vel, the ratio between beat period and fundamental period has a value very close to 2.41. If this same ratio holds for BK Cen the beat period should be about 7.6 days. Making this assumption we conclude that the interval of 37.97 days corresponds with five beat periods. We then find the number of beat periods elapsed since the first epoch as given in the fourth column of table 3. A least-squares solution yields the elements

$$\text{Max.} = 2\,423\,986.55 + 7.574\,15\,E$$
$$\pm 15 \quad \pm \quad 14 \quad \text{(m.e.)}.$$

The residuals from these elements are given in the last column of table 3. The mean deviation of a single epoch is ± 0.32 days or ± 0.042 beat periods. The phase ψ,

TABLE 1

Photo-electric observations

J. D. Hel. −2 430 000	φ	ψ	ΔV	$B-V$	$L-B$	$U-B$
8813.48	.58	.91	0.699	0.473	0.371	0.562
8814.49	.90	.04	0.346	0.281	0.225	0.573
8814.59	.93	.05	0.309	0.279	0.261	0.633
8815.48	.21	.17	0.338	0.329	0.231	0.574
8815.55	.23	.18	0.358	0.330	0.234	0.546
8818.48	.15	.57	0.392	0.338	0.280	0.621
8818.57	.18	.58	0.404	0.381	0.294	0.597
8821.48	.10	.96	0.386	0.346	0.248	0.623
8823.54	.75	.24	0.689	0.478	0.388	0.598
8823.61	.77	.24	0.686	0.461	0.319	0.623
8824.29	.98	.33	−0.017	0.148	0.123	0.637
8829.27	.55	.99	0.665	0.447	0.434	0.631
8830.41	.91	.14	0.349	0.337	0.249	0.594
8832.28	.50	.39	0.700	0.541	0.483	0.685
8832.52	.58	.42	0.788	0.552	0.527	0.646
8840.27	.02	.44	0.071	0.182	0.167	0.641
8841.58	.43	.62	0.782	0.496	0.434	0.643
8843.27	.96	.84	0.283	0.288	0.234	0.579
8849.37	.89	.65	0.113	0.163	0.160	0.633
8855.38	.78	.44	0.529	0.244	0.268	0.556
8856.27	.06	.56	0.265	0.311	0.231	0.617
8857.38	.41	.70	0.724	0.467	0.463	0.630
8861.36	.66	.23	0.783	0.526	0.353	0.592
8861.48	.70	.24	0.785	0.501	0.423	0.559
8862.26	.95	.35	−0.153	0.221	0.085	0.702
8870.39	.51	.42	0.783	0.570	0.443	0.512
8870.45	.53	.43	0.720	0.550	0.454	0.599
8871.25	.78	.53	0.356	0.289	0.214	0.537
8873.35	.44	.81	0.569	0.464	0.390	0.606
8873.38	.45	.82	0.654	0.417	0.406	0.593
8874.26	.73	.93	0.599	0.391	0.338	0.550
8875.28	.05	.07	0.129	0.182	0.226	0.658
8876.38	.40	.21	0.608	0.498	0.341	0.588
8876.43	.41	.22	0.614	0.453	0.439	0.600
8877.38	.71	.34	0.825	0.483	0.401	0.611
8877.43	.73	.35	0.731	0.474	0.395	0.579
8883.32	.58	.13	0.721	0.503	0.486	0.617
8883.38	.60	.14	0.700	0.498	0.441	0.638
8886.40	.55	.53	0.760	0.541	0.450	0.686
8904.21	.16	.89	0.317	0.312	0.250	0.551
8907.22	.11	.28	0.274	0.327	0.206	0.577
8908.20	.42	.41	0.731	0.512	0.413	0.646
8920.19	.20	.00	0.326	0.272	0.245	0.654
8930.21	.36	.32	0.681	0.501	0.377	0.587
8931.20	.67	.45	0.674	0.361	0.419	0.678
8946.12	.37	.42	0.683	0.529	0.429	0.673
8947.21	.71	.56	0.547	0.398	0.316	0.552
8948.29	.05	.71	0.325	0.280	0.185	0.635
8950.24	.67	.96	0.741	0.495	0.450	0.656

TABLE 2

Least-squares solution of the fundamental period from epochs of maximum

J. D. Hel. −2 400 000	E	$O-C$
16 594.58	−2999	+0^{d}18
17 241.75	−2795	−0.12
18 041.64	−2543	−0.05
18 339.77	−2449	−0.27
18 368.67	−2440	+0.07
19 542.61	−2070	−0.33
20 602.64	−1736	−0.38
21 447.48	−1470	+0.21
21 745.54	−1376	−0.08
23 221.51	− 911	+0.04
23 916.42	− 692	−0.14
23 977.25	− 673	+0.39
23 986.23	− 670	−0.15
23 999.21	− 666	+0.13
24 259.33	− 584	0.00
24 262.28	− 583	−0.23
24 288.32	− 575	+0.42
24 297.30	− 572	−0.12
24 586.52	− 481	+0.27
25 357.36	− 238	−0.14
25 360.46	− 237	−0.21
25 386.32	− 229	+0.26
25 415.35	− 220	+0.72
26 113.21	0	+0.32
26 122.39	+ 3	−0.02
26 471.37	+ 113	−0.16
28 014.20	+ 599	+0.16
28 191.54	+ 655	−0.24
28 658.27	+ 802	−0.07
28 699.29	+ 815	−0.31
28 750.25	+ 831	−0.14
29 020.33	+ 916	+0.16
38 824.29	+4005	−0.01
38 840.27	+4010	+0.10
38 849.37	+4013	−0.32
38 862.26	+4017	−0.13
38 875.28	+4021	+0.20

in terms of the beat period, has been computed with the formula

$$\text{phase } \psi = 0.132\,028\ (\text{J. D. Hel.} - 2\,420\,000).$$

TABLE 3

Least-squares solution of the beat period

J. D. Hel. −2 400 000	Number of fund. periods	Δ	E	$O-C$
23 986.23	0.00		0	$-0^{d}.32$
		$273^{d}.10$		
24 259.33	86.05		36	+0.1
		37.97		
24 297.30	98.01		41	+0.21
		1060.06		
25 357.36	432.00		181	−0.11
		1114.01		
26 471.37	783.00		328	+0.50
		2278.88		
28 750.25	1501.00		629	−0.44
		10074.04		
38 824.29	4675.04		1959	−0.02
		37.97		
38 862.26	4687.00		1964	+0.08

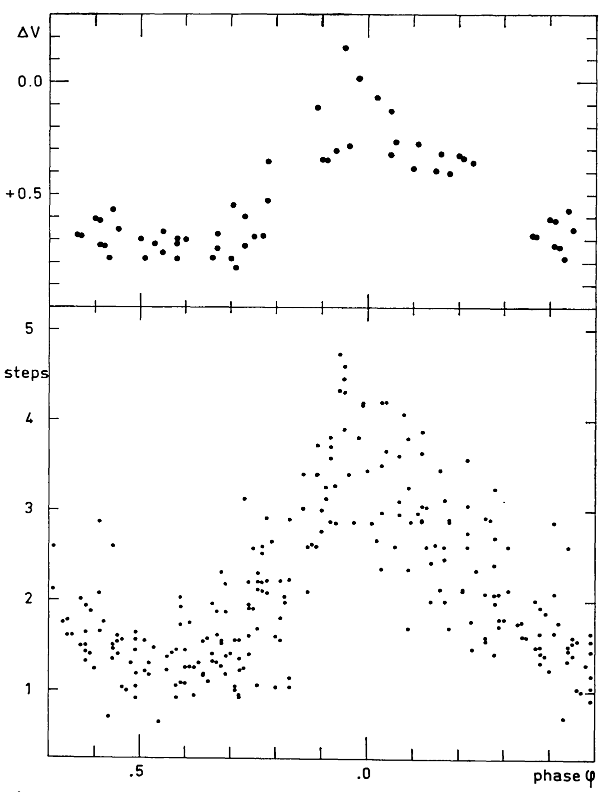

Figure 1. Individual observations. Upper part: photo-electric, lower part: estimates.

In figure 2 we have plotted light-curves for different intervals in the phase ψ. In the left-hand part of the figure the photo-electric observations are represented. Due to the small number of observations the intervals in the phase ψ are rather large. Nevertheless it is clear that the light-curve has a large range for ψ equal to .3 and .4, whereas the amplitude is small for ψ values near .8 and .9. In the right-hand part of the figure similar plots are given for the visual estimates on Franklin-Adams plates. Although the accuracy of these estimates is very much smaller than that of the

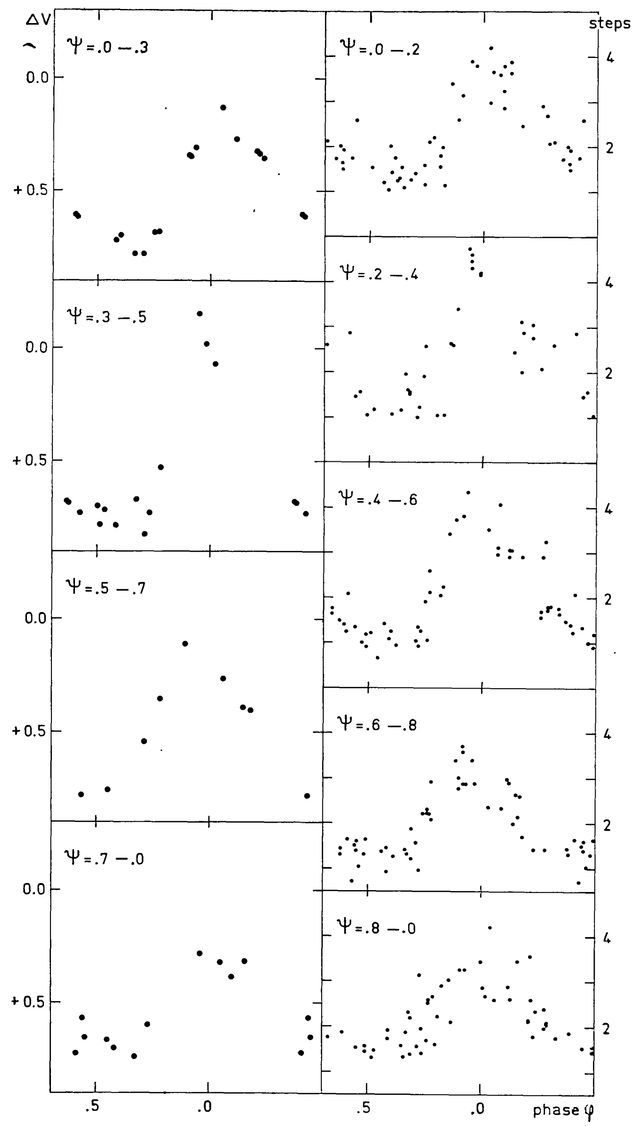

Figure 2. Light-curves for different intervals in the phase of the beat period. Left: photo-electric, right: estimates.

photo-electric measures, we find the same systematic variation in the amplitude of the light-curve as a function of the phase ψ. We conclude that the beat phenomena of BK Cen resemble very closely those observed by OOSTERHOFF (1957) for TU Cas, by JANSEN (1962) for U TrA and by OOSTERHOFF (1964) for AP Vel. The primary, secondary and beat periods for these four classical Cepheids are given in the following table:

	TU Cas	U TrA	AP Vel	BK Cen
P_0	$2^d.139295$	$2^d.568438$	$3^d.12781$	$3^d.17389$
P_1	1.5183	1.8249	2.1993	2.2366
P_b	5.23026	6.3041	7.4088	7.57415
P_1/P_0	0.7097	0.7105	0.703	0.705

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