THE LIGHT VARIATION AND THE PERIOD OF RU CAMELOPARDALIS FROM NOVEMBER 1967 TO AUGUST 1968

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RIASSUNTO. — Si presentano le curve di luce fotoelettriche *B* e *V* di RU Cam ottenute durante il periodo novembre 1967-luglio 1968. Al progressivo aumento dell'ampiezza delle curve di luce ottenute nel 1966-67 è seguita una lenta diminuzione cui è succeduta poi una fase peculiare di variazione luminosa; il valor medio dello splendore è poi diminuito leggermente. Alla lenta oscillazione del periodo riscontrata negli anni precedenti è seguita una variazione più brusca nell'intervallo 1966-68 durante il quale la rappresentazione degli istanti di minimo e di massimo richiede un termine parabolico. Sono stati fatti alcuni tentativi per ricercare un fenomeno di battimento nelle curve di luce, ma con esito incerto.

SUMMARY. — Two colours photoelectric light curves of RU Cam concerning the interval November 1967-August 1968 are presented. The mean brightness of the variable, constant during the 1966-1967 season, becomes gradually fainter of about $0^m.05$ in ten months. The amplitude of the light variation decreases slowly until March and is then followed by some peculiarities. The epochs of the minimum and maximum light indicate a strong variation of the period during the last three years and can be represented with a parabolic formula. Some trials to detect a beat phenomenum in the light curves appeared inconclusive.

The observations reported in this note have been performed to check the photometric behaviour of the W Vir type variable RU Cam whose remarkable decrease of the light variation from an amplitude of $1^m.6$ during 1962 to a nearly constant level in the summer of 1964 (HUTH 1967) has represented till now a unique event observed in the evolution of a pulsating star. In the fall of 1966 the oscillations started again with an amplitude growing progressively (BROGLIA 1967; CESTER 1967) so the expectation according to Detre (DETRE 1966) that RU Cam should have recovered in few months the old light amplitude seemed likely.

The measures here reported, altogheter 1874, are distributed along the interval J.D. 2439798-40096. They have been obtained with the 40" reflector of the Merate Observatory, with the same Lallemand photomultiplier and

(*) Ricevuta il 25 Ottobre 1969.

Schott BG 12(1) + GG 13(2) and OG 4(1) filters used in the previous study (BROGLIA 1967). Also the integrating amplifier, with the integrating time set at 25 sec. and the semiautomatic device for setting alternatively the variable and the comparison star were the same previously used. Each night RU Cam was compared with the star *BD* + 70°448; check stars were *BD* + 70°447 and *BD* + + 70°450. The values of the difference in magnitude between the variable and the comparison star were corrected for the differential atmospheric extinction using mean extinction coefficients. The average deviation of a Δm between *BD* + 70°448 and the check stars was $0^m.011$ in both colours. With the values $V = 9^m.09$ and $B\text{-}V = + 1^m.10$ assumed for the comparison star according to LENOUVEL (1957), we computed for each night the mean *B* and *V* magnitudes of RU Cam and the corresponding mean errors reported in the Tables I and II with the date and the number *n* of the individual measures.

THE LIGHT CURVES

The normal points, altogether 65 and 84 in the *B* and *V* light respectively, and the colour index curve, are plotted in Fig. 1. We see that the mean brightness of RU Cam is not constant like the 1967-68 season but decreases slightly and in

TABLE I

N.	J.D. 2439000.+	B	e.m.	n
1	804.455	$9^m.789$	$\pm 0^m.007$	8
2	816.452	.649	.003	8
3	819.501	.749	.002	9
4	824.507	.778	.003	11
5	826.418	.760	.004	15
6	828.274	.727	.003	8
7	830.500	.663	.002	7
8	831.456	.635	.004	6
9	832.409	.615	.002	7
10	833.407	.598	.002	9
11	834.435	.595	.003	7
12	836.434	.623	.002	7
13	840.463	.737	.004	12
14	842.381	.773	.002	10
15	852.441	.662	.003	12
16	855.386	.605	.004	10
17	859.421	.617	.001	10
18	861.365	.665	.004	12
19	862.329	.687	.002	10
20	864.305	.750	.001	10

TABLE I - (Cont.).

N.	J.D. 2439000.+	B	e.m.	n
21	868.416	$9^m.815$	$\pm 0^m.006$	14
22	869.445	.794	.002	12
23	875.338	.716	.004	15
24	876.358	.693	.002	15
25	877.364	.671	.002	14
26	879.378	.645	.002	14
27	880.378	.641	.002	12
28	881.361	.650	.001	12
29	885.439	.731	.002	20
30	886.434	.755	.002	17
31	915.311	.754	.005	13
32	916.373	.738	.003	14
33	920.323	.712	.004	14
34	921.449	.726	.002	10
35	924.310	.715	.004	12
36	925.310	.714	.002	11
37	932.296	.753	.001	15
38	933.297	.761	.003	13
39	934.321	.766	.005	18
40	938.332	.778	.002	10
41	939.314	.778	.005	12
42	941.335	.763	.001	16
43	942.357	.760	.003	17
44	943.311	.751	.003	12
45	945.344	.729	.004	20
46	947.357	.750	.004	14
47	950.383	.736	.004	17
48	968.443	.752	.003	10
49	969.392	.738	.003	14
50	970.455	.717	.007	16
51	972.410	.702	.003	13
52	973.464	.685	.018	3
53	983.416	.763	.003	12
54	990.362	.703	.002	12
55	1003.422	.670	.007	14
56	1011.390	.665	.008	11
57	1015.397	.669	.010	14
58	1029.400	.779	.001	15
59	1030.397	.780	.005	12
60	1032.403	.778	.004	18
61	1033.461	.761	.004	14
62	1056.389	.733	.004	12
63	1060.432	.723	.004	14
64	1089.357	.741	.003	12
65	1092.430	.709	.015	4

TABLE II

N.	J.D 2439000.+	V	e.m.	n
1	798.371	$8^m.587$	$\pm 0^m.005$	6
2	804.455	.601	.008	8
3	816.452	.440	.014	9
4	819.501	.541	.002	9
5	824.486	.581	.002	11
6	826.404	.578	.005	14
7	828.275	.547	.005	8
8	830.498	.504	.001	7
9	831.444	.483	.003	10
10	832.409	.466	.002	7
11	833.391	.450	.002	7
12	834.436	.442	.002	6
13	836.434	.459	.003	7
14	840.454	.545	.003	13
15	842.372	.570	.001	8
16	852.426	.503	.003	9
17	855.379	.450	.004	11
18	859.407	.447	.002	11
19	861.365	.476	.004	12
20	862.329	.494	.001	10
21	864.305	.540	.001	12
22	868.416	.586	.004	15
23	869.433	.576	.001	12
24	871.363	.564	.002	13
25	875.329	.543	.002	12
26	876.348	.508	.004	16
27	877.356	.497	.001	12
28	879.381	.472	.002	12
29	880.364	.457	.002	16
30	881.362	.474	.002	12
31	885.412	.526	.003	20
32	886.415	.544	.002	15
33	915.295	.570	.003	12
34	916.354	.555	.002	11
35	920.305	.532	.004	12
36	921.432	.526	.002	13
37	923.441	.496	.008	7
38	924.291	.513	.002	14
39	925.301	.515	.002	10
40	928.319	.516	.012	5
41	932.282	.555	.001	12
42	933.285	.559	.003	12
43	934.305	.564	.002	14
44	938.321	.588	.001	10
45	939.303	.588	.001	12

TABLE II - (Cont.).

N.	J.D. 2439000.+	V	e.m.	n
46	941.332	$8^m.576$	$\pm 0^m.001$	13
47	942.336	.567	.003	16
48	943.310	.556	.002	9
49	945.330	.533	.004	14
50	947.380	.535	.002	16
51	950.415	.543	.002	12
52	965.327	.602	.007	25
53	968.426	.554	.002	10
54	969.378	.543	.003	11
55	970.441	.532	.003	11
56	972.402	.504	.004	15
57	973.453	.519	.003	15
58	977.396	.523	.004	17
59	978.363	.503	.006	5
60	983.395	.586	.002	15
61	987.383	.554	.005	23
62	990.354	.505	.003	10
63	993.373	.488	.004	24
64	1000.385	.507	.005	18
65	1001.381	.499	.003	22
66	1003.399	.508	.004	20
67	1011.378	.491	.003	10
68	1015.372	.522	.006	15
69	1017.365	.489	.029	4
70	1026.404	.558	.003	18
71	1029.381	.579	.001	10
72	1030.378	.587	.003	11
73	1032.381	.574	.005	14
74	1033.440	.573	.003	14
75	1037.377	.495	.006	16
76	1056.373	.552	.002	15
77	1060.414	.532	.007	12
78	1062.435	.543	.003	26
79	1066.431	.587	.004	18
80	1087.361	.582	.003	20
81	1088.343	.565	.002	15
82	1089.344	.560	.004	13
83	1092.413	.560	.002	12
84	1096.397	.544	.011	25

ten months becomes about $0^m.05$ fainter. Also the amplitude of the light variation decreases progressively until about J.D. 2439950. After this date the oscillation grows a little and some peculiarities in the light curves, only partially shown by

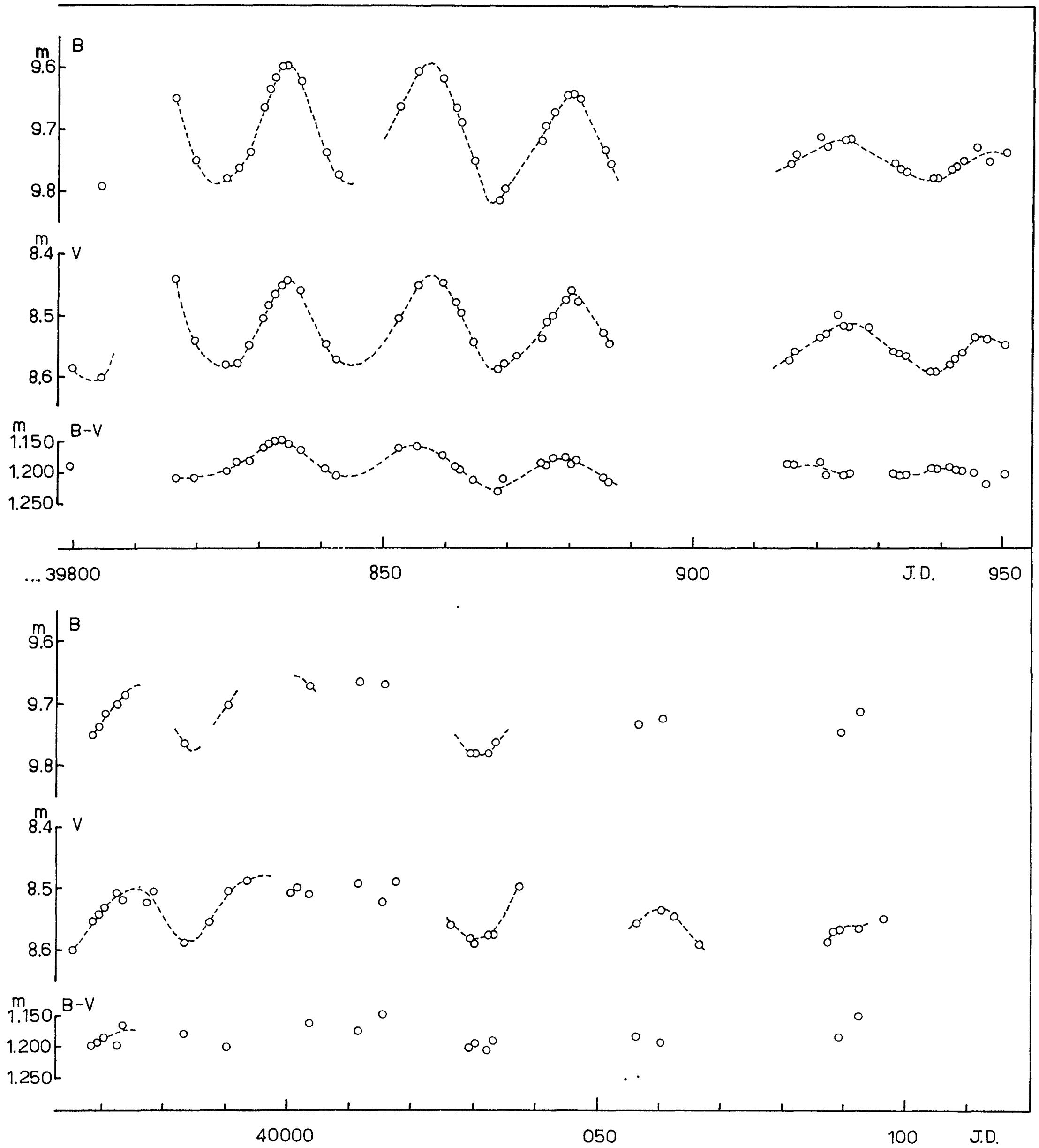

Fig. 1 - The light and colour curves of RU Cam from 1967, November to 1968, August.

the present measurements, occurre. Like for the observations we obtained during the years 1966-67 we see that each cycle of light variation has its own individuality and considering that the mean error of the normals is on average $0^m.004$ it seems useless to derive mean light curves. A feature of the light oscillations during the last few years is a marked symmetry around the maximum and a similar smoothness of the minimum and maximum while previously the minimum was much sharper than the maximum. Moreover we see that after the first three cycles the *B-V* variation practically vanishes and is slightly correlated with the variation in the *B* and *V* magnitudes. It appears also that the first three oscillations in *B* and *V* light are in phase while the *B-V* maxima occur 1.5 day before.

We have tried to represent the light curves of the two seasons 1966-67 and 1967-68 (these curves have been obtained with the same photometric equipment) by a truncated Fourier serie:

$$m_{V,B} = A_0 + \sum_{n=1}^{5} \left(A_n \cos \frac{2\,\pi\, nt}{P} + B_n \operatorname{sen} \frac{2\,\pi\, nt}{P}\right)$$

where P is the average period determined in the next section and t the Julian date of the observation. Comparing the coefficients A_n, B_n, obtained by least squares with a 1620 IBM computer, with their mean errors and bearing in mind that the average mean error of a normal is $\pm$ 0^m.004 in B and $\pm$ 0^m.003 in V, only the terms A_1, B_1 seemed significant. However this is a very crude representation, considering that the mean deviation of an observed normal with respect to the computed curves is never inferior to 0^m.02 for the two seasons and the two colours.

Afterwards by means of a filtering procedure we tried to detect if a modulation was present in the light curves. In this algorithm, as in the power spectra and in the periodogram analysis, an equally spaced sequence of points is requested. The large gap that occurs between the '66-67 and the '67-68 groups and the non uniform distribution of the normals in each group obliged us to consider only the *V* normals of the first group. After the conversion of the original data to an equally spaced series by connecting the observed magnitudes with a free hand traced curve and then interpolating, an analysis with some different amplitude filters was performed with the IBM 7044 computer of the Trieste University. After a computation with a filter whose amplitude is like the 22 day period of the basic oscillation, the envelope of the minima and maxima of the computed light curve indicated a modulation period whose ratio to the fundamental one was found to be about 28. Unfortunately the interval covering the observations which have been utilised covers about only one fourth of the supposed beat period. At last some trials were made with different values of P_b, centered around the above mentioned value, to represent by least squares all the *B* and *V* observations using the formula:

$$m_{V,B} = m_0 + a \cos \varphi + b \operatorname{sen} \varphi + a_1 \cos \varphi_1 + b_1 \operatorname{sen} \varphi_1$$

where φ and φ_1 are the phases computed with the fundamental and the secondary periods P and P_1 tied to the beat period P_b means the relation: $1/P_b = 1/P_0 - 1/P_1$. In this essay also the residuals were much too larger than the mean error of the normals so it seemed better not to continue in further analysis.

The variation of the period

On account of the slow brightness change of RU Cam, $0^m.03$ a day at the most, for deriving the epochs of minimum and maximum light we have represented by least squares the ascending and descendant branches of the light curves and

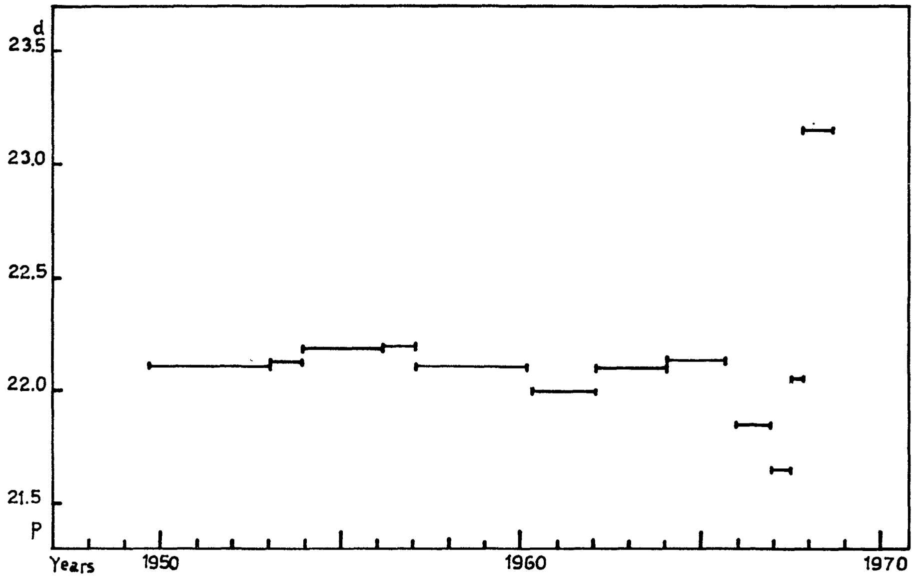

Fig. 2 - The mean period of RU Cam during the last few years.

obtained by bisection such instants, listed in the Table III for the two observing seasons. The average deviation of an epoch computed from the *B* and *V* values is $0^d.3$. As we have seen in the foregoing paragraph the light variation is quite sinusoidal so the epochs of minimum and maximum light have been combined together. The following ephemerides have been derived separately for the two groups:

$$\text{1966-67} \qquad \text{Min} = J.D.\ 2439537.65 + 21.65\ E_1$$
$$\pm .38 \quad \pm .12 \text{ e. m.}$$

$$\text{1967-68} \qquad \text{Min} = J.D.\ 2439822.37 + 23.16\ E_2$$
$$\pm .56 \quad \pm .14 \text{ e. m.}$$

The corresponding residuals $(0\text{-}C)_1$ and $(0\text{-}C)_2$ are listed in the third column of Table III. The period is changed from one season to the other of a quantity clearly superior to the mean errors. The numbers of cycles comprised between the last epoch of the first group and the first one of the second can be evaluated for certain and the mean period for the interval J.D. 39678-39823 results $P = 22^d.15$. In Fig. 2 are plotted the values of the periods after 1952 derived from photoe-

TABLE III

(Observed epochs of minimum and maximum light).

J.D. 2439..	E_1	$(O-C)_1$	E_3	$(O-C)_3$	J.D. 2439..	E_2	$(O-C)_2$	E_3	$(O-C)_3$
538.6	0	$+1^d.0$	0	$-0^d.1$	823.3	0	$+0^d.9$	13.0	$-0^d.3$
571.0	+1.5	+ .9	1.5	−0 .7	834.5	+0.5	+ .6	13.5	−0 .1
579.8	2.0	−1 .1	2.0	+1 .2	844.8	1.0	− .7	14.0	+1 .0
591.0	3.5	− .8	2.5	+0 .6	857.5	1.5	+ .4	14.5	−0 .3
601.5	3.0	−1 .1	3.0	+0 .9	867.9	2.0	− .8	15.0	+0 .7
635.1	4.5	0	4.5	−0 .4	880.4	2.5	+ .1	15.5	−0 .3
646.5	5.0	+ .6	5.0	−1 .0	924.5	4.5	−2.1	17.5	+1 .8
657.0	5.5	+ .3	5.5	−0 .6	938.3	5.0	+0 .1	18.0	−0 .4
667.9	6.0	+ .4	6.0	−0 .6	974.6	6.5	+1 .7	19.5	−1 .6
678.3	+6.5	− .1	6.5	−0 .1	984.5	7.0	0	20.0	+0 .2

lectric observations (HUTH 1967) (BROGLIA 1969). It is evident that a strong variation has occurred more recently in connection with the peculiar photometric behaviour.

We have tried to represent the epochs after 1966 adopting the same fundamental and beat periods examined in the analysis of the light curves, but again the epochs considered are too few and the interval covered too short and therefore the trials were inconclusive. It is more simple for representing such instants to adopt an ephemeride with a parabolic term. It results:

$$\text{Min} = J.D.\ 2439538.51 + 21.10\,E + 0.060\,E^2$$
$$\pm .51 \quad \pm .13 \quad \pm .\ 7$$

and the corresponding residuals are listed in the last column of Table III.

CONCLUDING REMARKS

The phase of the small quasi-periodic sinusoidal light variation which characterised the behaviour of RU Cam during the foregoing years continued till May 1968. During these months a weak evidence of some form of resonant phenomena can be seen. Afterwards a random variation seems to prevail; a recovering of the regular variation according to Detre (BROGLIA and GUERRERO 1969) then followed. It is to be remarked that a fundamental parameter of the pulsation, i.e. the period, after the decreasing occurred during 1966-67, has quickly grown beyond the value it had before the peculiar light variation occurred. Therefore not only the amplitude of the oscillation, but also the period is a sensitive function of some parameters characterizing the star structure.

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