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THE PHOTOMETRIC ACTIVITY OF RU CAM DURING THE YEARS 1970-72

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RIASSUNTO. — Le curve di luce *B*, *V* della cefeide di popolazione II RU Cam, ottenute nel periodo 1970-72, mostrano cambiamenti in ampiezza simili a quelli degli anni precedenti. La variazione quasi-sinusoidale del periodo osservata durante gli anni 1966-70.5 è praticamente cessata.

La mancanza di correlazione tra la variazione delle ampiezze delle curve di luce, in cui è presente una forte componente irregolare, e quella del periodo di pulsazione, mentre la luminosità media della stella è costante, indica che la causa delle perturbazioni fotometriche è localizzata nelle regioni più esterne della stella. È verosimile che l'emissione di materia, evidenziata dalle osservazioni spettroscopiche, abbia alterato la stabilità dell'inviluppo e delle regioni sottostanti dove si origina la pulsazione.

SUMMARY. — Two colour light curves of RU Cam for the years 1970-72 are shown. Variations of the light amplitudes are evident in the course of a few cycles, whereas the mean luminosity remains constant. The quasi-sinusoidal variation of the period which occurred during the years 1966-70.5, about an year after the strong diminution of the light pulsation, is not stationary. The lack of correlation between the changes of the period and the light amplitude variations, indicates that a disturbing phenomenon is localized in the more external regions of the star. The existence of ejections of matter, supported by spectroscopic observations, have probably altered the stability of the envelope and of the underlying regions where the pulsational energy is stored.

1. - INTRODUCTION

In a previous note (BROGLIA and GUERRERO 1972), we have considered the photometric behaviour and the variation of the period of the peculiar variable RU Cam during the years in which there was the strong reduction in amplitude of its light curves. There was clearly an abrupt change on the trend of the *0-C* of the instants of minimum or maximum light, computed with reference to a linear ephemeris, just one year after the quasi cancellation of the light pulsation. Over the interval 1965-70 the *0-C* diagram looks almost like a sinusoid. This means simply that the variance of the *0-C* can be minimized by representing

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(*) Ricevuta il 22 Dicembre 1972. Testo definitivo il 12 Marzo 1973.

them with a sinusoid, but it does not follow that the oscillation is a stable physical condition and that it will continue outside the 1965-70 interval. However this behaviour gave rise to a doubt that some new state of pulsation was appearing in the star and in particular that a beat phenomenon was becoming evident.

For checking this occurrence we continued the photometric monitoring during the years 1970-72 and in this note we give the results obtained. The observations were performed in two spectral ranges close to the *B* and *V* system, with the same photometer and telescope used in the preceding campaigns. The comparison a_2 and the check stars a_1 and a_3 also are the same as in the previous years. The corrections for the differential extinction were computed using mean extinction coefficients. The Δm of Table I, compared also to those obtained in the previous seasons (Broglia and Guerrero 1972), confirm the constancy of the star a_2. Altogether during 141 nights, 3400 measures were obtained for the variable. For each night mean *B* and *V* magnitudes were calculated, with reference to the values for a_2: $V = 9^{m}.09$, $B = 10^{m}.19$. They are reported in the Tables II and III with the mean date, the variance and the number *n* of measures comprised in each normal. To monitor the variable with the greatest assiduity we have observed also during nights of poor quality and this circumstance explains the lower precision of some normals.

Table I - Δm between the comparison stars. The standard deviation of a single measure is given in parenthesis.

Observing season	ΔB		ΔV	
	$a_2 - a_1$	$a_2 - a_3$	$a_2 - a_1$	$a_2 - a_3$
1970.7 – 1971.2	$+\ 0^{m}.830$ ($0^{m}.019$)	$+\ 0^{m}.072$ ($0^{m}.013$)	$+\ 1^{m}.025$ ($0^{m}.021$)	$+\ 0^{m}.365$ ($0^{m}.013$)
	± 2	± 1	± 3	± 1
1971.6 – 1972.6	0 .817 (0 .020)	0 .064 (0 .012)	1 .020 (0 .018)	0 .359 (0 .012)
	3	2	3	2

Recently Zaitseva and Lyutyj (1971) have published a series of *U*, *B*, *V*, photoelectric observations of RU Cam, made at the Crimea Observatory during the years 1970-71. As the Authors have compared the variable to the same star as us, so the zero of the magnitude scales coincide with ours, we have esteemed useful to plot their measures together with ours in Fig. 1.

2. - THE LIGHT CURVES AND THE PERIOD.

The actual trend of the light curves resembles that of the years after 1966. The *B* oscillation is slightly greater than the *V* one; the color curve shows that at minimum light the star is redder. The oscillation with a period of about twenty-two days still persists.

Considering also the past series of measures it appears evident that the pulsation is strongly modulated and at intervals of time varying from five to eighteen cycles it practically disappears. In the Fig. 2, below, we have plotted, only for the V observations, the magnitudes at minimum and maximum light. It is undeniable that a strong irregular component is superimposed over the 22 days pulsation.

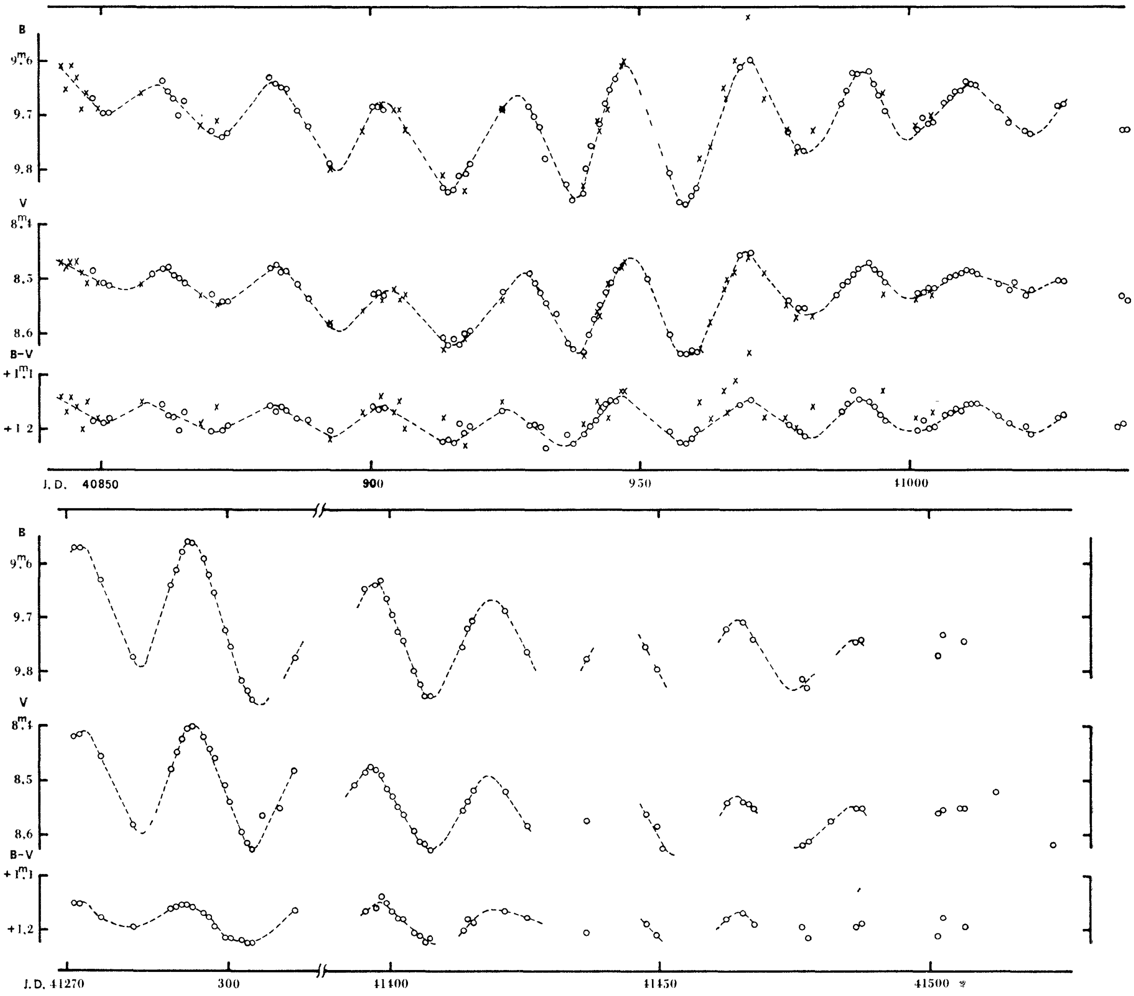

Fig. 1

Light and colour curves of RU Cam from September 1970 to March 1971 and from November '71 to July '72. The crosses represent the measures according to Zaitseva and Lyutyj, the circles are our ones.

For testing this behaviour more accurately it will be very useful to have available the very long series of photoelectric measures obtained after 1966 by Detre and Szeidl (private communication).

TABLE II - Normal *B* points

N°	J.D. 2440 000.+	B	e.m.	n
1	848.423	9.670	±0.002	10
2	850.380	.696	2	12
3	851.407	.693	4	10
4	861.384	.635	2	10
5	862.655	.655	1	11
6	863.632	.672	1	8
7	864.654	.702	4	13
8	865.648	.676	7	13
9	870.644	.731	7	20
10	872.566	.742	1	10
11	873.483	.733	3	15
12	881.530	.637	1	11
13	882.399	.642	3	12
14	883.450	.649	3	23
15	884.533	.653	3	14
16	886.516	.692	2	11
17	888.530	.722	4	16
18	892.516	.790	4	20
19	900.570	.687	2	14
20	901.479	.688	2	11
21	902.485	.691	2	11
22	913.476	.833	2	12
23	914.479	.841	2	10
24	915.461	.837	2	12
25	916.456	.811	4	17
26	917.454	.808	3	11
27	918.453	.790	2	10
28	924.540	.691	2	17
29	929.458	.684	2	14
30	930.420	.702	4	11
31	931.568	.722	1	9
32	932.432	.782	1	9
33	936.462	.829	3	15
34	937.427	.857	4	10
35	939.485	.844	2	11
36	940.492	.800	1	18
37	941.497	.757	3	15
38	942.518	.717	4	18
39	943.419	.680	2	11
40	944.441	.655	2	18
41	945.429	.635	1	10
42	955.394	.809	2	15

TABLE II - Normal *B* points (cont.)

Nº	J.D. 2440 000.+	B	e.m.	n
43	957.426	9.861	±0.002	13
44	958.484	.864	1	11
45	959.383	.850	4	18
46	960.396	.837	4	12
47	968.498	.613	2	26
48	970.307	.600	2	19
49	977.495	.734	4	17
50	979.394	.761	3	16
51	980.354	.769	3	17
52	987.266	.682	1	15
53	988.262	.658	2	11
54	989.304	.623	3	14
55	990.385	.627	4	15
56	992.418	.622	3	15
57	993.387	.644	1	12
58	994.417	.666	3	15
59	995.275	.696	3	14
60	1001.359	.729	2	12
61	002.430	.707	5	13
62	003.359	.719	2	16
63	004.372	.715	3	15
64	006.370	.680	2	16
65	007.318	.671	3	15
66	008.375	.659	2	10
67	009.381	.657	2	12
68	010.339	.640	4	7
69	011.329	.644	2	12
70	012.282	.647	3	13
71	016.387	.688	4	11
72	018.309	.714	2	17
73	021.312	.729	2	10
74	022.292	.733	2	17
75	027.484	.683	3	16
76	028.405	.679	3	18
77	039.317	.729	3	17
78	040.436	.728	2	14
79	271.491	.571	2	14
80	272.470	.569	1	16
81	276.456	.631	1	10
82	282.451	.775	2	14
83	289.502	.641	2	8

Table II - Normal *B* points (cont.)

N°	J.D. 2441 000.+	B	e.m.	n
84	290.449	9.608	±0.002	8
85	291.430	.578	2	12
86	292.461	.559	2	14
87	293.452	.561	2	12
88	295.440	.590	2	12
89	296.441	.621	3	16
90	297.458	.653	2	10
91	299.515	.725	14	5
92	300.474	.754	3	10
93	302.445	.817	1	10
94	303.420	.838	3	8
95	304.428	.852	3	15
96	312.404	.646	2	10
97	395.367	.649	1	12
98	397.345	.641	2	12
99	398.315	.631	6	10
100	399.333	.668	2	10
101	400.299	.697	3	10
102	401.295	.729	2	10
103	402.306	.745	3	11
104	404.310	.800	2	15
105	405.303	.825	1	11
106	406.305	.845	2	11
107	407.310	.845	2	17
108	413.366	.756	2	21
109	414.340	.720	6	16
110	415.322	.706	2	11
111	421.319	.688	1	10
112	425.351	.763	2	14
113	436.347	.777	2	17
114	447.447	.753	3	11
115	449.345	.797	2	10
116	462.365	.721	2	12
117	465.381	.708	1	10
118	467.393	.741	2	12
119	476.444	.814	3	11
120	477.380	.829	7	13
121	486.392	.747	3	10
122	487.397	.738	2	12
123	501.444	.772	3	10
124	502.413	.731	8	12
125	506.407	.746	4	10

TABLE III - Normal *V* points

N°	J.D. 2440 000.+	V	e.m.	n
1	848.414	8.486	±0.001	10
2	850.365	.508	5	13
3	851.396	.512	3	12
4	859.469	.491	6	9
5	861.375	.481	4	11
6	862.656	.479	3	9
7	863.642	.493	2	10
8	864.669	.498	5	14
9	865.661	.508	2	10
10	870.650	.527	9	17
11	872.550	.540	1	12
12	873.466	.538	2	15
13	881.519	.480	1	10
14	882.385	.475	3	11
15	883.426	.488	3	14
16	884.518	.486	2	10
17	886.504	.510	2	10
18	888.514	.538	3	14
19	892.493	.587	3	15
20	900.555	.528	1	12
21	901.464	.525	2	12
22	902.473	.530	1	10
23	913.461	.608	2	12
24	914.476	.622	1	10
25	915.449	.611	2	10
26	916.442	.621	3	12
27	917.443	.601	3	11
28	918.441	.595	2	11
29	924.521	.524	2	15
30	929.431	.491	1	16
31	930.401	.508	1	10
32	931.554	.526	1	10
33	932.414	.544	2	10
34	934.411	.564	2	10
35	936.443	.618	2	8
36	937.415	.629	2	9
37	939.457	.634	1	16
38	940.476	.603	2	16
39	941.484	.573	1	10
40	942.495	.549	3	15
41	943.402	.525	2	11
42	944.422	.507	2	15
43	945.418	.485	1	12

TABLE III - Normal *V* points (cont.)

N°	J.D. 2440 000.+	V	e.m.	n
44	951.371	8.501	±0.005	5
45	955.379	.603	1	14
46	957.412	.637	1	14
47	958.498	.637	1	12
48	959.403	.631	2	15
49	960.380	.636	2	12
50	968.471	.457	1	19
51	970.287	.452	2	15
52	977.477	.541	2	11
53	979.366	.555	4	14
54	980.339	.556	2	15
55	986.407	.532	9	5
56	987.252	.512	2	13
57	988.248	.504	2	10
58	989.279	.492	3	20
59	990.361	.481	3	15
60	992.381	.471	2	17
61	993.374	.484	2	12
62	994.397	.492	2	17
63	995.258	.509	3	13
64	1001.346	.527	2	16
65	002.406	.524	4	17
66	003.343	.519	2	15
67	004.353	.518	2	12
68	006.353	.505	3	16
69	007.302	.500	2	12
70	008.365	.495	2	12
71	009.366	.490	1	9
72	010.325	.484	1	12
73	011.316	.488	1	12
74	012.266	.492	2	12
75	016.368	.511	2	12
76	018.288	.523	3	17
77	019.298	.509	2	5
78	021.294	.531	1	11
79	022.275	.522	2	11
80	027.466	.502	2	15
81	028.386	.504	3	17
82	039.298	.531	3	14
83	040.421	.538	2	12
84	271.479	.419	1	14
85	272.456	.416	1	14

TABLE III - Normal *V* points (cont.)

N°	J.D. 2441 000.+	V	e.m.	n
86	276.446	8.453	±0.001	14
87	282.435	.580	1	14
88	289.496	.479	3	10
89	290.436	.449	1	8
90	291.416	.424	2	12
91	292.489	.405	1	13
92	293.436	.401	1	10
93	295.423	.421	2	13
94	296.424	.443	2	16
95	297.446	.460	2	10
96	299.500	.511	4	10
97	300.462	.539	2	12
98	302.432	.597	1	10
99	303.413	.614	1	8
100	304.414	.628	2	10
101	306.420	.565	4	9
102	309.471	.551	2	18
103	312.405	.483	1	10
104	343.383	.662	7	15
105	393.302	.508	4	14
106	395.349	.483	1	10
107	396.333	.475	4	22
108	397.330	.481	2	12
109	398.331	.491	3	14
110	399.322	.516	1	10
111	400.311	.530	2	8
112	401.307	.549	2	9
113	402.289	.565	2	14
114	404.294	.593	2	14
115	405.306	.613	1	12
116	406.293	.619	3	10
117	407.295	.629	2	17
118	413.349	.555	2	15
119	414.325	.538	2	10
120	415.309	.518	2	16
121	421.309	.522	1	8
122	425.338	.584	2	15
123	436.330	.573	2	15
124	447.411	.563	3	11
125	449.335	.586	1	9
126	450.390	.625	8	19

Table III - Normal *V* points (cont.)

N°	J.D. 2441 000.+	V	e.m.	n
127	462.348	8.540	±0.006	16
128	465.368	.539	2	16
129	466.371	.543	2	14
130	467.380	.552	2	11
131	476.435	.620	4	27
132	477.363	.612	3	9
133	481.375	.574	4	9
134	486.381	.550	1	16
135	487.385	.550	2	11
136	501.431	.560	2	12
137	502.396	.553	4	18
138	505.386	.550	2	15
139	506.394	.550	3	11
140	512.356	.520	13	6
141	523.352	.562	5	10

The mean luminosity of the variable, computed simply as the mean of the normals of the Tables II and III is as follows:

	B	*V*
1970.7 – 1971.2	9.715 ± 0.008 e.m.	8.531 ± 0.005 e.m.
1971.6 – 1972.6	9.714 .012	8.534 .008

In other words, comparing these values with those we obtained after 1966, the mean brightness of RU Cam during the years after the reduction of its pulsation was stable within a few hundredths of magnitude.

Then we have derived the dates of maximum and minimum light by fitting by least squares a parabola to the normals of Fig. 1 encompassing such instants and computing the abscissa of the vertex. The twenty nine values obtained, mean of *B* and *V* determinations, are given in the Table IV. Their mean variance computed from the *B* and *V* determinations is ± $0^d.3$. The square root of the weight $\sqrt{w}$ is esteemed according to the number and the location of the normals. At a first approximation the linear ephemeris:

$$\text{Min} = \text{Helioc. J. D. } 2440850.96 + 21.517\, n$$

can represent the observed epochs. However the residuals given in Table IV, on an average five times greater than the above variance, display a systematic oscillatory trend. It is more interesting to compare the actual behaviour of the period with that of the previous years. This is displayed in the Fig. 2 where we have plotted

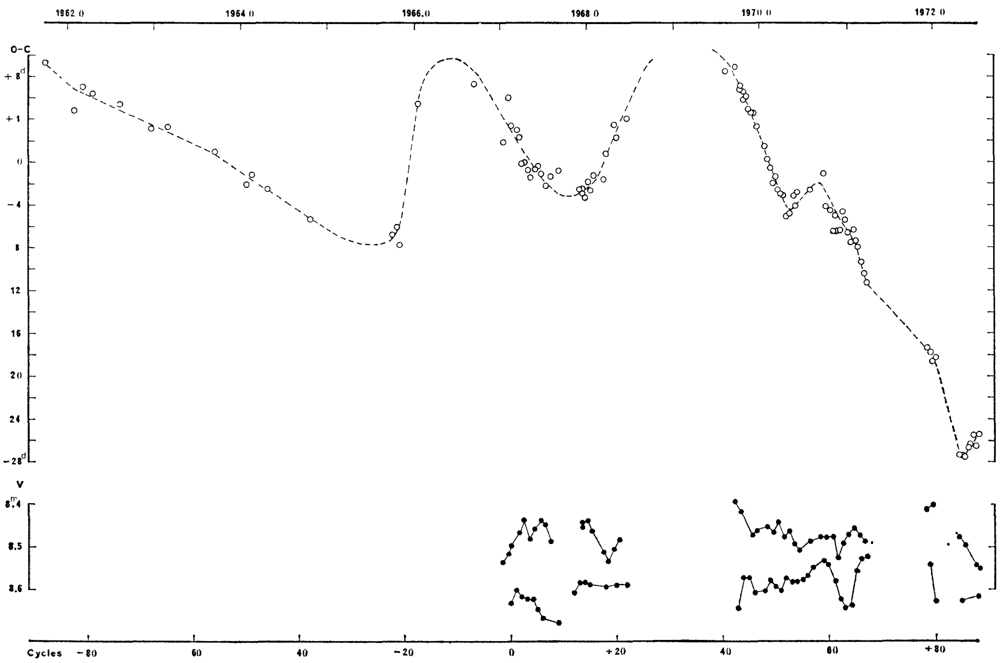

FIG. 2

The trendt of the period of RU Cam during the last ten years (upper part); in the lower part are given the V magnitudes at maximum and minimum light.

TABLE IV - Observed epochs of minimum or maximum light

n	J.D. 24. . .	$\sqrt{w}$	O-C	n	J.D. 24. . .	$\sqrt{w}$	O-C
0	40852.9	2	d +2.0	7.5	41011.2	3	d -1.1
0.5	861.0	3	- .7	8	021.6	3	-1.5
1	871.9	1	- .6	19.5	272.5	1	+2.0
1.5	881.1	2	-2.1	20	283.3	1	+2.0
2	893.8	1	- .2	20.5	293.6	4	+1.5
2.5	903.4	3	-1.4	21	305.2	2	+2.4
3	914.7	2	- .8	25.5	396.7	2	-2.9
3.5	927.7	3	+1.4	26	407.8	3	-2.6
4	938.1	4	+1.1	26.5	418.8	3	-2.4
4.5	948.0	2	+ .2	27	430.9	1	-1.0
5	958.3	3	- .2	27.5	442.4	1	- .3
5.5	970.7	2	+1.4	28	454.4	1	+1.0
6	980.8	3	+ .7	28.5	464.5	2	+ .3
6.5	991.3	4	+ .5	29	476.8	1	+1.8
7	41001.1	3	- .5				

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the residuals calculated with the linear ephemeris given in the previous note (BROGLIA and GUERRERO 1972):

$$\text{Min} = \text{Helioc. J. D. } 2439535.16 + 22.354\, n$$

It is evident that the quasi-sinusoidal variations of the *0-C* which occurred during the interval 1966-1970.5 are not stationary and that their amplitudes became smaller. In addition the period is shortened.

3. - CONCLUDING REMARKS

Taking into consideration all our photoelectric measures obtained after 1966, we arrive at the following conclusions:

a) The mean *V* and *B* brightness of the variable during the years after reduction of the pulsation in 1965-66 remained remarkably constant. As we have already noted (BROGLIA and GUERRERO 1972) also the luminosity during the years before 1965 was the same as it is now within two tenths of magnitude. In other words the mechanism of energy production in the core of the star worked normally during the last years and the phenomenon which produced the photometric peculiarities arose in the outer regions of the star.

b) The period oscillated at the most of 5% around its mean value. During the years 1966-1970.5 a systematic variation arose with an almost sinusoidal trend, as if in the regions of the star which pulsate a beat phenomenon was appearing. The successive observations proved that this was only a transient situation and that moreover these regions are not in a stable condition, as the irregular trend of the *0-C* shows (Fig. 2).

c) The more external layers of RU Cam are in a very unstable situation, as the fact that the spectacular variations of the light curves occurred in such a very short time shows. This situation has persisted also during the last few years, because from one season to the other the light variation can reach an amplitude of two tenths of magnitude at the most and a few cycles later it can almost completely disappear. This phenomenon is localized in the more external regions of the star as appears evident from the lack of correlation shown in the Fig. 2 between the changes of the period of pulsation and the light amplitude variation of the photosphere. The outer 30 to 50 per cent in radius of the star pulsates with a 22 days period. Over this component another erratic important one is superposed in the light curves, as if some new conditions for the dissipation of energy coming from the interior of the star are now at work. The spectroscopic observations also support qualitatively the existence of the atmospheric instability depicted by the light curves. FARAGGIANA and HACK (1967) and WALLERSTEIN (1968) have observed a phenomenon of convection in the atmosphere of RU Cam and the presence of an expanding atmosphere. The ejection of matter, which can be explained by the existence of shocks associated with the pulsation (CHRISTY

1966), and the convection likely have altered the stability of the envelope and of the underlying regions where the pulsational energy is stored and where the conditions are favourable for the maintenance of radial pulsations. In particular the convection in the driving regions influence the amplitude of pulsation since the energy carried out by convection will not be effected by the variations in opacity. Finally we stress the fact that a delay of about one year exists between the sudden quasi cancellation of the light curve amplitude and the starting of the period oscillation. This delay can be considered as the time of propagation of the perturbation from the atmosphere of RU Cam to the pulsating shell.

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