THE PHOTOMETRIC BEHAVIOUR OF RU CAM FROM 1966 TO 1977

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Two-colour photoelectric light curves of RU Cam, obtained from 1973.0 to 1977.6, are presented. The variable appears to maintain the same photometric behaviour as during the years after 1964, when the pulsations died down. The period, which up to 1965 was relatively constant, excluding the secular and continuous lengthening, during the following years shows a strong instability without any systematic behaviour in the fluctuations. An analysis of the light curves confirms that a random component is superimposed on a sinusoid.

Considering all the observations obtained at Merate after 1966 we conclude that: 1) RU Cam after 1964 has maintained substantially the same brightness; 2) a correlation seems to exist between the best fitting period for single cycles and the amplitudes of oscillations. The hypothesis that RU Cam underwent strong modifications in the outer layers is confirmed.

Key words: pulsating stars – population II cepheids

1. INTRODUCTION

The W Vir type variable RU Cam has already been observed photometrically at the Merate Observatory from December 1966 to 1972 with the aim of monitoring the variable light curves and the period, after the well known strong amplitude reduction in the summer of 1964. The study of these measurements gave evidence of the following facts (Broglia and Guerrero 1972, 1973):

a) the light curves have roughly a sinusoidal shape, whereas before 1964, when the amplitude was large, the minimum was much sharper than the maximum. The total amplitude moreover, never in excess of a few tenths of magnitude, varies remarkably during a few cycles and can reduce nearly to zero;
b) a search to detect a possible modulation effect over the light curves gave no conclusive findings. At times a random component seems to prevail, followed then by a recovering of a regular light oscillation;
c) the period changed slightly around the value 22 days, in particular during the well-observed fifteen year interval before 1964. Afterwards the period instability strengthened together with the occurring peculiar photometric behaviour, but with a delay of about one year. The residual \( O - C \) of the epochs of maximum or minimum light moreover, calculated with a linear ephemeris, have an irregular course and bear out the uncertainty of the search for a beat phenomenon;
d) no correlation appears between the variation of the period and the changes of the light curve amplitude;
e) after 1966 RU Cam did not alter its mean luminosity, within the observational uncertainty;
f) the epochs of maximum or minimum light in \( V \) colour are on the average 0.5 days later than the \( B \) ones.

The exceptional behaviour of this pulsating star, which has several characteristics of the W Vir stars, but shows also some peculiarities like the colour, the spectral type cooler and some spectral features at the minimum, did not give rise to specific theoretical studies or detailed calculations. To the best of our knowledge, only qualitative explanations have been put forward till now (Wallerstein 1968; Zaitseva et al. 1973b). As the observational facts mentioned above did not indicate a certain persistence of small oscillations or a possible growing to the larger ones and since this alternative can involve significant modifications for the model of the variable, we thought it useful to continue the photometric monitoring. In this note new observations are reported, spanned over a five year interval from 1973 through July 1977 and a new analysis is made based on all the photometric material gathered after 1966.

2. LIGHT CURVES AND PERIOD VARIATIONS

The \( B \) and \( V \) measurements of RU Cam, altogether 2051 for \( B \) and 2624 for \( V \) colour, were made differentially with respect to \( a_2 = BD + 70^\circ.448 \) as comparison star \((V = 9^\circ.09, B - V = +1^\circ.10)\) and \( a_1 = BD + 70^\circ.477 \)
and 3 = BD + 70°450 as check stars, during 222 nights spread over the intervals: 1973.0–1973.5, 1975.1–1975.4, 1975.8–1976.3, 1976.8–1977.6. The equipment and observing technique were those used by the authors in the previous photometric studies of RU Cam. The measurements have been corrected for the differential extinction using mean extinction coefficients. The normal points are listed in tables 2 and 3 with the corresponding mean errors and the number N of observations concurring to the normals. In table 1 the Δm's between a and the check stars are given. We notice a small difference between the ΔB's obtained in the interval 1973.0–1973.5 and those of subsequent seasons, but it is not clear which star varied. Part of the disagreement can be accounted for as mean colour extinction coefficients were used. Moreover this possible effect should have a minor influence on the magnitude of RU Cam since the variable has a small colour difference in comparison with the star a.

The light and the colour curves are plotted in figures 1a, b, c, d. RU Cam appears to maintain the same photometric behaviour as during the years after 1964: the variability remains around some tenths of magnitude at the most, and after some cycles the oscillations grow less and disappear; afterwards a new group of oscillations rises. The light variation can be thought of as the sum of a sinusoid and of a random component since the amplitude and the shape are slightly irregular from cycle to cycle.

To know more about the mechanism of pulsation at work after 1964 some epochs of maximum and minimum light have been derived by least squares fitting. In table 4 these values, mean of the B and V determinations, are listed. It appeared that the epochs in the two colours are not in phase, but the V minima occur on the average 0°7 later than the B ones, as happened also during the past observing seasons.

During the last few years two notes have appeared reporting on new observations of RU Cam obtained during the intervals 1971.0–1972.5 and 1973.5–1974.5 (Zaitseva et al. 1973a; Kovalenko 1974), which are in part complementary to the intervals of our observations. Unfortunately the measurements are not listed in these reports, but the light curves only are represented. It has been possible however to estimate some epochs of minimum and maximum light so that an almost complete coverage of the variation of the period over the recent years was obtained. As has already been noted by the observers of RU Cam and in particular by Zaitseva et al. (1973b), intervals when the brightness fluctuations of the variable are near regular alternate with periods when the amplitude nearly cancels out. Since during the last few years the pulsations suffered a phase drift even of half a period between two consecutive groups of oscillations, it is not possible to link all the epochs with an ephemeris because an uncertainty of one cycle in the counting of cycles can occur. On the contrary a period can be derived separately for each group of oscillations and the variation of the period can be monitored. In figure 2 the results of this analysis are represented. Disregarding the slow and continuous lengthening of the period in the course of the last half century, it appears clearly that whilst just before 1965 the period was relatively constant, soon after a strong instability arose and that no systematic behaviour can be assumed in the period fluctuations.

3. DISCUSSION

A qualitative indication of the characteristics of the pulsation now at work in RU Cam can be sought by trying to correlate between the parameters that define a single oscillation: amplitude, period, mean magnitude and by looking for their possible dependence in time. To this end all the observations obtained at Merate Observatory after 1966 have been examined. As already has been seen (Broglia and Guerrero 1972) no substantial gain in accuracy can be obtained by representing the light curves by means of Fourier terms superior to the first. Therefore, since the sine-component in the light variation is sometimes seriously disturbed by an irregular component, a sine-fitting by least squares to the measurements included in single cycles has been performed. The period of the sinusoid was changed step by step till the best representation was obtained. The fitting generally was only approximate because of the effect of the irregular component or because the observations in some cycles are few or unfavourably distributed. In very few cycles indeed the sine-fitting error was reduced to the level set by observational uncertainty.
In figure 3 the mean magnitudes $\bar{B}$ and $\bar{V}$ are represented versus J.D. The variable after 1964 has maintained substantially the same brightness; the random character of the small fluctuations for $\bar{B}$ and $\bar{V}$ is prevalent even if a cyclic variation at times seems to be rising.

No correlation exist between $\bar{B}$ and $\bar{V}$ and the best fitting period $P_t$. On the contrary a correlation seems to exist between the sinusoidal amplitudes $A_B$ and $A_V$ and $P_t$ (figure 4). When a pulsation aims to take place in the variable the period of the light variation tends to adjust to values near the period before 1964, but when conditions in the star hamper the normal pulsation and give rise to oscillations with period longer or shorter than this value, the amplitude decreases to zero. The remarkable dispersion of the amplitudes corresponding to a given period is only in part due to the uncertainties in the fitting, but chiefly reflects the presence of a random component in the physical process now at work in the variable.

Taking all the photometry of RU Cam into consideration it appears that some results found in the preceding notes and summarized in the introduction have been confirmed. In particular the mean colour, practically the same before and after 1964, and the mean brightness, constant within two tenths of magnitude during the same interval, prove that the flux emerging from the core kept substantially constant. The phenomenon is probably due to a mass loss or to a mixing (Wallerstein 1968), so the conditions for the dissipation of energy coming from the core are now unstable.

Some few measurements of linear polarisation in $V$ light have been performed during cycles when the pulsation had a 0.2 mag. total amplitude, to look for time-dependent changes due to a non-uniformity of temperature on the surface of the star associated with mass loss or with mixing processes. No dependence of polarisation on the phase was detected at the level of the internal consistency of the measurements, of the same order of the precision of a normal point.

The attempts made to recognize some regularities in the light variations post the 1964 event, like the appearance of a beat phenomenon or a cyclic variation of amplitude, or a progression in the number of pulsations belonging to a group or in the length of quiescent phases, were disproved gradually as more observations were obtained. So an irregular activity seems at times to prevail over the 22-days reduced pulsation mechanism.

REFERENCES


Table 1: $\Delta m$ between comparison and check stars

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Table 4: Observed epochs of minimum or maximum light

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### Table 2 Normal V points

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RU Cam from 1966 to 1977

Figure 1a Light and colour curves of RU Cam from 1973.0 to 1973.5.

Figure 1b Light and colour curves of RU Cam from 1975.1 to 1975.4.
Figure 1c  Light and colour curves of RU Cam from 1975.8 to 1976.3.

Figure 1d  Light and colour curves of RU Cam from 1976.8 to 1977.6.
RU Cam from 1966 to 1977

Figure 2  The trend of the period of RU Cam during the last thirty years. The figures indicate the number of epochs by which the period has been derived.

Figure 3  Small irregular fluctuations in the mean brightness of RU Cam, calculated by means of sinusoid fitting to single cycles.

Figure 4  The amplitudes of pulsation of RU Cam after 1964 rise when the period approaches the value before 1964 and fall to zero as the period deviates from this value.