ON THE PERIOD OF RR CANUM VENATICORUM

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Abstract

Observations of the RR Lyrae star, RR Canum Venaticorum, from 1932 to 1980 are satisfied by a constant basic pulsation period on which are superimposed fluctuations due to changes in the shape and amplitude of the light curve.

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RR Canum Venaticorum is an RR Lyrae variable of subtype ab, B magnitude 11.95 to 13.55, with a variable period, according to the General Catalogue of Variable Stars (Kukarkin et al. 1969). Published periods range from $0^d.5585$ to $0^d.55861$; the more precise of the determinations are confined to the smaller range $0^d.5586057$ to $0^d.558609$ (Kukarkin 1932; Kinman et al. 1966; Butler et al. 1979).

The field appears on about 200 plates taken with the 7½-inch Cooke telescope at the Maria Mitchell Observatory in 1964 through 1980. We have used these, supplemented by 50 Harvard 3-inch Ross patrol plates, as part of a project to survey the constancy of pulsation periods (Belserene 1979).

Magnitudes were estimated relative to the sequence given in the first of a pair of Lick reports on RR Lyraes in high galactic latitudes (Kinman et al. 1966; Butler et al. 1979). Phases were computed according to the heliocentric elements from those reports:

$$JD_{max} = 2424370.624 + 0.558609\ n,$$

and light curves were plotted, one or two for each year. A logical next step would have been to note the phase at which the star was brightest on each of the plots. Elements predict maximum at phase zero, so these phases, traditionally called O-C (observed minus computed), test the validity of the assumed elements.

For two reasons it is unwise, in precise period analysis, to look only at the top of the light curve:

1) Observations at or near the actual maximum may be lacking, and

2) Even when it is possible to sketch a curve through the observations nearest maximum, the time at which the highest point is reached is poorly defined. The curve is necessarily horizontal there.

Various techniques have been developed to deal with this problem. We chose to define a mean light curve by combining several years of observations and to mark a nominal maximum on it. When a tracing of this curve is superimposed over each of the separate ones, the phase of the adopted, nominal maximum can be read off quite precisely.

In the case of RR CVn an additional complication arose. The shape and amplitude of the light curve are not constant. Apparently the variation in light is not adequately described by a single period. It seems likely that the star is subject to the Blazhko Effect, a periodic variation in amplitude and shape, but the observational material is not sufficient to demonstrate periodicity. We plotted not only the Maria

Mitchell and Harvard observations, but also the Lick data and found it impossible to use a single mean light curve for all cases. We chose a modification of a technique used by W. C. Martin (1938) in his classic study of period changes in the globular cluster, Omega Centauri. In common with other workers, he concentrated on the steep rising branch instead of the horizontal section near maximum. He had originally chosen the time where the rising branch reaches a preassigned magnitude, but he was concerned about possible changes in the magnitude system, which would affect the observed phase defined in this way. So, he determined the phases of "three or four points on the ascending branches, having a difference in phase with the points of the same magnitude on the descending branches of respectively .2, .3, .4, and .5 period."

We found that the nominal maximum of our mean light curve came just about one-third of the way between points on the ascending and descending branches at the level where the phase difference is 0.3 cycle. We redefined nominal maximum as the mean of three points defined this way, including the levels where the phase difference between the branches is 0.2 and 0.4 also. This nominal maximum can be and was used with light curves of different shapes and amplitudes.

Our resulting values of O-C are plotted in Figure 1 against the mean JD of the group of observations. The smaller dots are for the Maria Mitchell data. The large dots are from the Harvard patrol plates, and the open circles are from our rediscussion of the Lick data (Kinman, et. al. 1966; Butler, et al. 1979). The line segments at the left represent elements quoted by Kukarkin (1932), derived by himself (long dashes), Blazhko (short dashes) and Tsesevich (dots). The large cross is the phase of Kukarkin's epoch of maximum calculated with the elements used for the O-C diagram. It is not closely comparable to our nominal maximum because he drew the part of the curve near maximum rather sharper than ours. The light curve is illustrated in his paper and we found that nominal maximum, by our definition, comes $0^{d}.017$ later than his epoch. Both are consistent with the actual observations. The size of the difference is indicative of the uncertainty that can creep in when period analysis uses maxima that may be defined somewhat differently. The smaller cross in Figure 1 is the phase of the nominal maximum of Kukarkin's observations.

The steady decrease in the observed phase of maximum shows that the period adopted for the O-C diagram was too long, as more recent maxima have been seen at earlier phases than those in the past.

A least-squares line through the points is shown. Weights had been assigned inversely proportional to the squares of the lengths of the error bars, which had been estimated to represent the range of acceptable values of O-C. Kukarkin's epoch was included in the solution, weighted as the best of the later points. The line corresponds to the revised heliocentric elements:

$$\begin{aligned} JD_{max} = &\ 2443670.6126 + 0.55860758\ n \\ &\pm \qquad .0038 \pm .00000028 \end{aligned}$$

The mean error of an O-C of highest weight is $\pm .0136$ cycle. A second least-squares solution, for the best parabola, produced no improvement. It implied a rate of change of period of

$$\begin{array}{l} -.0000023\ \%\ \text{per year} \\ \pm .0000078 \end{array}$$

which is not significant. Residuals from the parabola imply a mean error of $\pm .0139$ cycle. The line comes reasonably close to agreement with Blazhko's and Tsesevich's elements considering the difficulties in drawing and defining maximum. Deviations of some of our points from the line are larger than the error bars would lead one to expect, but this is not surprising in view of the instability of the light curve.

We conclude that this RR Lyrae star has been very close to constant in its basic pulsation period, although individual cycles differ appreciably from each other. The physical inference is that at least one overtone is excited along with the fundamental period, but that any secular changes in the internal structure of the star are too slow to have had a measurable effect on these periods. It seems likely that the variation in period referred to in the General Catalogue (Kukarkin 1969) reflects the difficulty of finding, and in fact of defining, the period when the variation is not strictly periodic. One has only to imagine putting lines through pairs of points chosen at random from Figure 1 to realize how different the slope - and, therefore, the implied period - could be.

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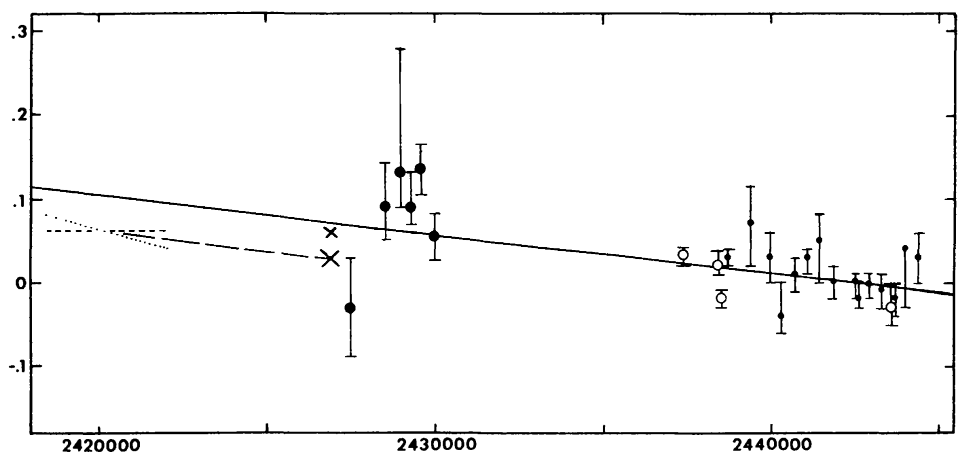

Figure 1. O-C diagram for RR CVn. Abcissa is Julian Date. Ordinate is observed minus computed phase of maximum, in fractions of the cycle. The elements used for the computation, and the meanings for the symbols are in the body of the text. The heavy line represents the least-squares solution for revised linear elements.