STATISTICAL ANALYSIS OF THE SEMIREGULAR VARIABLE AR CEPHEI

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Abstract

A Fourier analysis of the light curve of AR Cephei indicates three periods: P = 2222, 364, and 87 days.

The first period estimations of AR Cephei were by Loreta (1939), who found it to be about 116 days and classified the star as a RV Tauri variable. Further attempts to estimate the period were made by Huebscher *et al.* (1985, 1986), who calculated the intervals between nearest minima and maxima; two values of the semi-period were obtained: 70 and 115 days. Preliminary analysis made by the author (Kučinskas 1985) showed the possible existence of two semi-periods: ~50 and ~365 days. However, the length of observational record and small density of data points in the light curve prevented concluding that they were real.

In the current work we used the standard Fourier analysis widely described in literature (e.g., Fitch 1967; Deeming 1975, 1976), based on the numerous visual observations made by amateur astronomers between 1961 and 1989. Fourier spectra were computed from ten-day means with the step of frequency df = 4×10^{-5} /day. (The influence of a trend in the data was not excluded.) The significance of the peaks in the periodogram was analysed using the methods suggested by Doroshenko and colleagues (Doroshenko *et al.* 1985). Two periods were detected at the significance level just slightly less than p = 1, which means that the probability of the stochastic peak with the same intensity occurring in the periodogram is about zero: P_1 = 2222 days and P_2 = 364 days. Periodic variations were also detected with the period of P_3 = 87 days at the level of p = 0.9852 (see Table 1). The ten-day mean light curve of AR Cephei is presented in Figure 1.

O-C values are plotted in Figure 2. These are the differences between the observed dates of maxima of AR Cephei in 1961 - 1989 and those calculated on the basis of a uniform period of P_2 = 364 days. The figure suggests that about the date of JD 2441400 a change occurred in the period, from an almost stable period of 324 days (linear regression coefficient k = 0.98) to a period of 364 days (linear regression coefficient k = 0.10), which likely had been varying in time, possibly reflecting relaxation effects after the period change. The traditional chi-squared test (e.g., Lacy 1973), however, when applied to test the stability of the period P_2=364 days in AR Cephei, indicates that the period change is significant at no more than p = 0.15 level. Therefore, it is concluded that the mean period of AR Cephei probably has changed, although a longer run of data is needed to confirm this.

Considering the rather high ratio of the periods P_1 and P_2, namely, P_1/P_2 = 6.10, it is most likely that in the case of AR Cephei we have a fundamental mode-overtone pulsator with second or higher overtone variations. Conclusions about the multi-periodicity of AR Cephei, however, should be accepted very cautiously, because the light curve clearly shows that a particular period acts only for a very short time interval. That is, the pulsation periods are changing and the star may display intervals of almost irregular variability. Such variations with smaller amplitudes and shorter time scales (from several tenths to tens of days) may result from oscillations in higher harmonics or from random surface disturbances (e.g., pulsational oscillations caused by shock waves, or a variability caused by star spots). The origin of variations with the period of $P_3 = 87$ days therefore is unclear; possibly it can be associated with rotational effects. On the other hand, random pulsation-like disturbances may result from non-radial local effects in a non-uniform continuous atmosphere. Strong convection, shock, and magneto-hydrodynamic waves probably occur in variable stars on the asymptotic giant branch. These stars clearly evolve near their stability limit, and when disturbed by some global force, the adiabatic exponent may drop below the value 4/3 for the sufficiently important region of the star atmosphere. This may cause a complex response in the stellar layers. Therefore, period changes or demonstrations of temporary irregular variability should probably be interpreted as a result of non-linear phenomena in stellar physics.

Table 1. Detected Periods in the Semiregular Variable AR Cephei

Period (days)	*Statistical Significance*
2,222	0.99999998
364	0.99999999
87	0.9852

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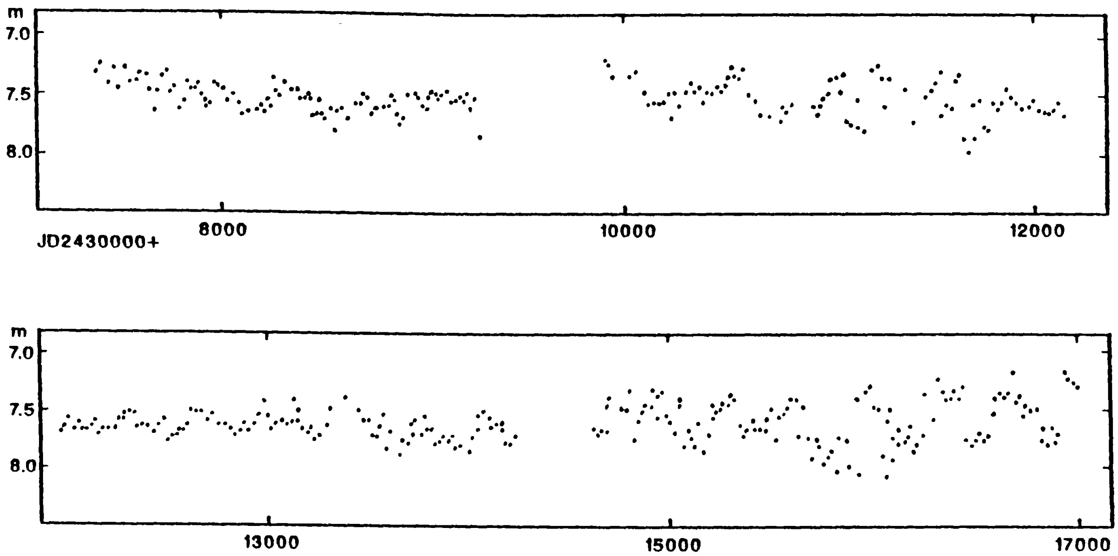

Figure 1. Ten-day mean light curve of the semiregular variable AR Cephei in 1961-1989.

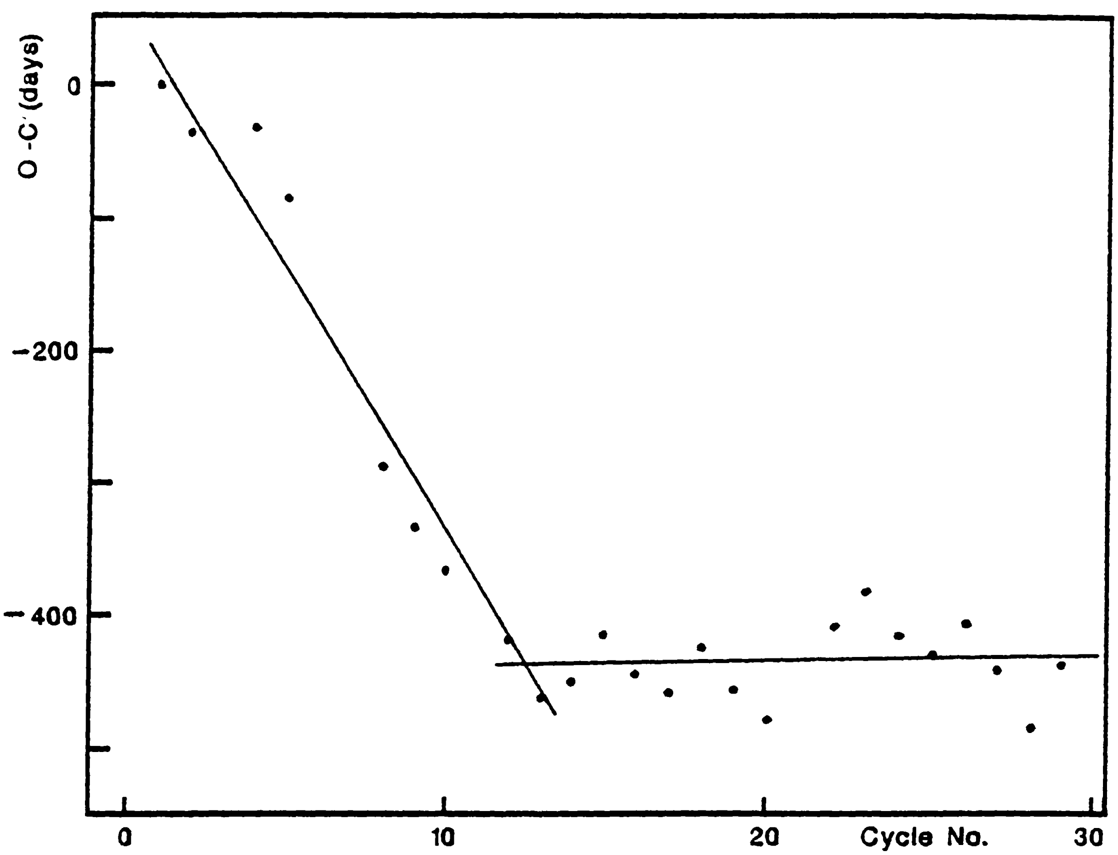

Figure 2. O-C diagram for maxima of AR Cephei in the interval 1961-1989 computed from a uniform period of 364 days.