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RADIAL VELOCITY CURVES AND FIRST CALCULATIONS OF THE RADII FOR FOUR DOUBLE-MODE CEPHEIDS

Double-mode Cepheids form a specific group of Cepheids which includes a limited number of stars. The light and radial velocity curves of these stars show double-mode variations, whereas ordinary Cepheids show only one period. The ratio of periods is almost the same for most of these stars and is close to 0.71, in agreement with the theoretical ratio of periods of the first overtone P_1 to fundamental tone P_0. For CO Aur, unlike other stars, this ratio is close to 0.8; one can imagine (based on the theory of stellar pulsations) that this star pulsates both in the second and first overtone modes.

Berdnikov (1992, 1993) used a large number of original photoelectric observations of 14 double-mode Cepheids to decompose their light and color curves into two oscillations. Since 1987, we have carried out systematic measurements of radial velocities of northern Cepheids with a correlation spectrometer designed and made by Tokovinin (1987). Most part of these observations were included in our two catalogues (Gorynya et al., 1992, 1996). These data, combined with our unpublished observations, allowed us to derive separate radial velocity curves for two oscillations in five photometrically well-studied Cepheids (V367 Sct, EW Sct, BQ Ser, TU Cas, CO Aur).

Note that clear separation of radial velocity curves into two oscillations was made possible by long sets of observations resulting in good coverage of radial velocity curves.

Figures 1-5 show the decomposed radial velocity curves for each mode.

We used these curves to estimate the radii of the four double-mode Cepheids using Balona's method (1977), which is a modification of the well-known Baade–Wesselink technique (Wesselink, 1946). We were forced to simplify our analysis because the number of radial velocity observations is much less than that of photometric measurements, and radial velocities alone do not permit us to find the relation between the amplitudes and phases of the two modes found earlier in photometric data (Berdnikov, 1992, 1993). We therefore assumed that the two oscillations are independent of each other.

In this case the main least squares equation can be written as

$$V = A(B - V) - 5\lg(< R > + r_0 + r_1) + C$$

where V and $(B - V)$ are current magnitude and colour; $< R >$, mean Cepheid radius in $R_\odot$; and A and C, the constants to be found. The total pulsational radius variation $r = r_0 + r_1$ can be found by direct integration of radial velocity curves for two modes:

$$r = -pP_0/R_\odot \int V_{r0} d\phi_0 - pP_1/R_\odot \int V_{r1} d\phi_1$$

We use two color indices, $(B - V)$ and $(V - R)$, as the effective temperature indicators. Table 1 gives the Cepheid radii and their formal errors.

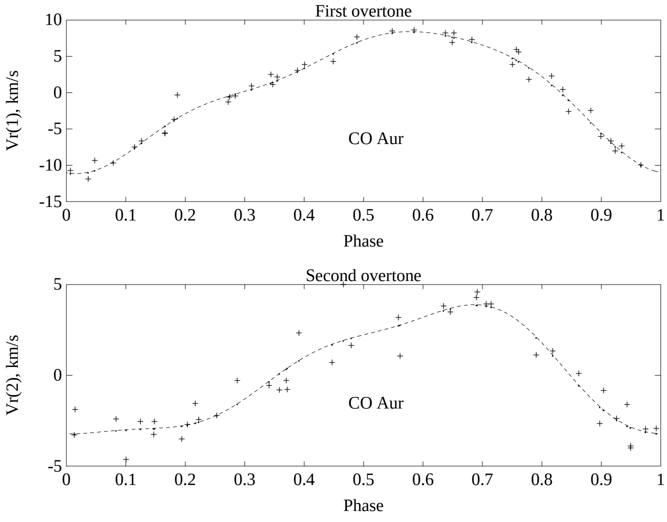

Figure 1

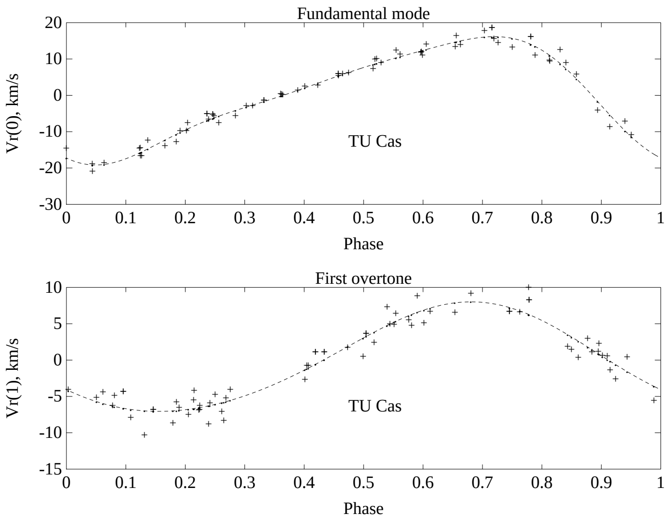

Figure 2

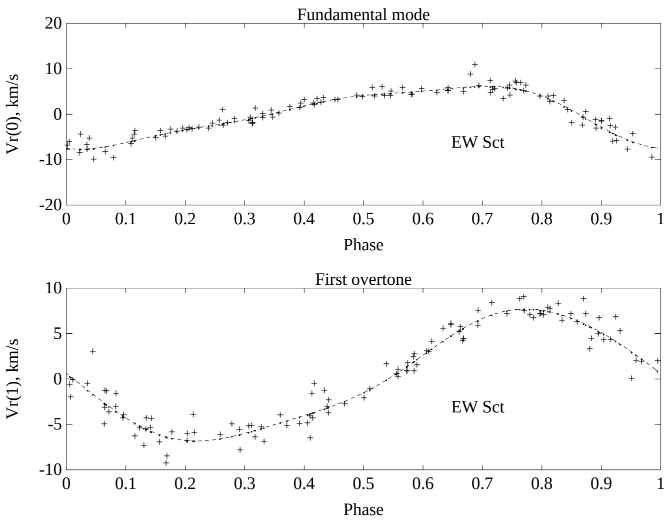

Figure 3

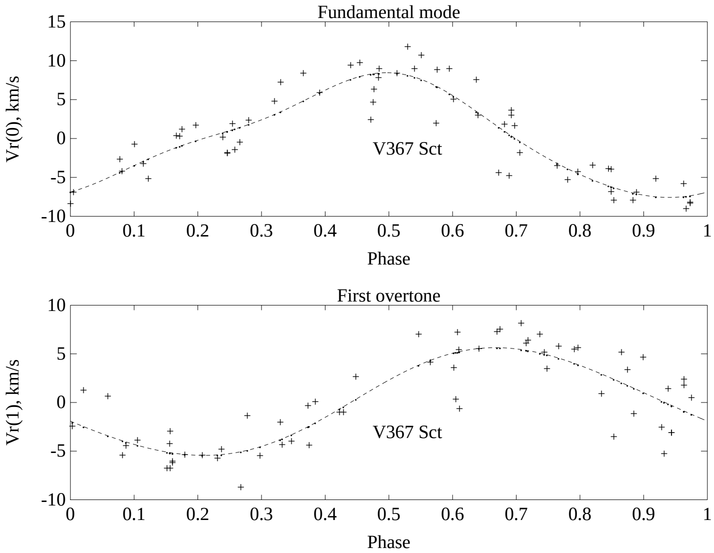

Figure 4

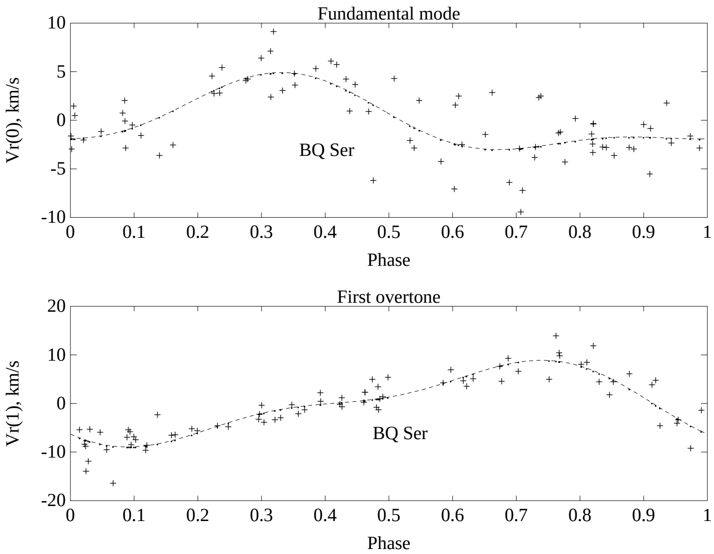

Figure 5

Table 1

Star	P_0	P_1	$R_{B-V}/R_\odot$	σ_R	$R_{V-R}/R_\odot$	σ_R
EW Sct	$5^{\rm d}\!.8233$	$4^{\rm d}\!.06714$	57	14	50	10
BQ Ser	4.2756	3.01191	56	19	35	14
TU Cas	2.1393	1.51827	31	2	25	3
CO Aur	2.5113	1.78300	40	10	30	5

Radial velocity data for the faintest star, V367 Sct, cannot be used for calculations because of large observational errors.

We derived the following period–radius relations for the four double-mode Cepheids assuming that CO Aur oscillates in the first and second overtones.

$$\lg R = 1.33 + 0.59 \lg P_0 \quad \text{for (B-V)}$$
$$\pm .08 \pm .14$$
$$\lg R = 1.21 + 0.61 \lg P_0 \quad \text{for (V-R)}$$
$$\pm .07 \pm .12$$

These relations agree well with that for single-mode Cepheids (Ripepi et al., 1997; Sachkov et al., 1997); we consider this agreement to be a justification of our technique applied to the double-mode Cepheids.

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