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Accurate Fourier Decomposition of Cepheid Radial Velocity Curves

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Abstract. The shapes of light curves and of radial velocity curves are two main predictions of the hydrodynamical models of Cepheids. Of the two, the velocity curves are more robust numerically and therefore, more suitable for comparison with the observations. In this report, we present accurate Fourier parameters for an extensive set of classical Cepheid velocity curves. Published radiative models reproduce the observations very well, with only small discrepancies present. We estimate the center of the $\omega_2 = 2\omega_0$ resonance to occur at $P_{\rm r} = 9.947 \pm 0.051$ day.

We have collected from literature accurate velocity data for 131 classical Cepheids. The data have been fitted with the Fourier sum (sine decomposition), and standard Fourier parameters $R_{\rm n1} = A_{\rm n}/A_1$ and $\phi_{\rm n1} = \phi_{\rm n} - n\phi_1$ have been calculated. The errors are estimated with formulae of Petersen (1986). For 92% of stars $\sigma(\phi_{21}) < 0.15$, with the average of $\sigma(\phi_{21}) = 0.08$. The fit dispersion is typically ~ 1 km s^{-1}. Our new data supersede the previous sample of Kovács, Kisvarsányi, & Buchler (1990).

The behavior of the first overtone Cepheids is discussed in detail by Kienzle et al. (1999). Here, we focus on the fundamental-mode Cepheids. In Fig. 1 we present 82 stars with best-quality solutions. The selection criteria are: a) at least 25 data points, b) $\sigma(\phi_{21}) < 0.15$, and c) fit dispersion below 2 km s^{-1}. The trends displayed by the velocity Fourier parameters are very similar to those of the light curves (Simon & Moffett 1985). The progressions of ϕ_{21} and ϕ_{31} with the period are very tight, in agreement with the theoretical expectations (Buchler, Moskalik, & Kovács 1990). The trends seen in Fig. 1 are caused by $\omega_2 \approx 2\omega_0$ resonance, which occurs at $P_{\rm r} \approx 10$ day. The plot is the Fourier representation of the well-known *Hertzsprung progression.*

Open circles in Fig. 1 represent the Sequence "A" of hydrodynamical Cepheid models of Moskalik, Buchler, & Marom (1992). Its 2:1 resonance occurs at 10.2 d. The models reproduce the data quite well, especially considering that no fine tuning has been performed. The only significant discrepancy is seen at $P = 10.5 - 12.5$ day, where the observed ϕ_{21} seems to decrease, whereas the

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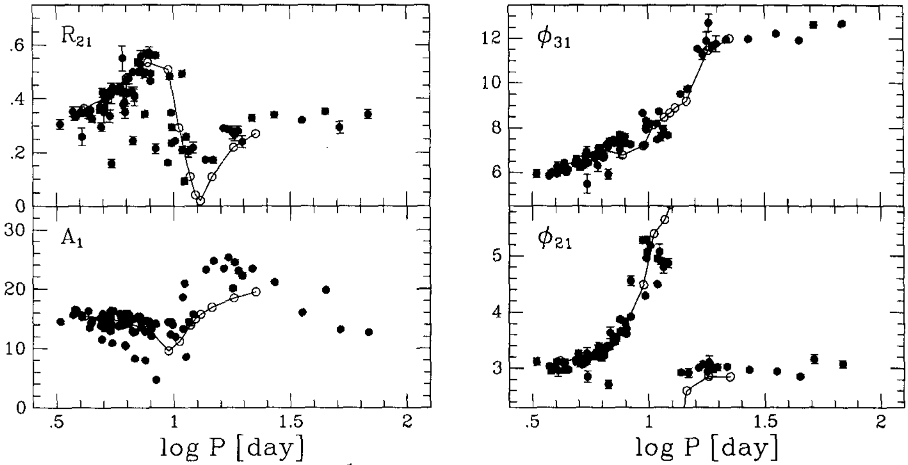

Figure 1. A_1 (in km s^{-1}), R_{21}, ϕ_{21} and ϕ_{31} for radial velocity curves of selected sample of fundamental-mode Cepheids (filled circles, see text). Hydrodynamical models of Sequence A of Moskalik et al. (1992) are plotted with open circles.

model ϕ_{21} increases. We note that the theoretical behavior of ϕ_{21} in this range of periods is highly model dependent: ϕ_{21} can either *increase* to 9.1 or *decrease* to 2.8 (2π ambiguity). Both behaviors have been encountered in the numerical simulations (see Moskalik et al. 1992 for discussion).

The data of Fig. 1 can be used to determine the exact position of the $\omega_2 = 2\omega_0$ resonance. This can be achieved by the least squares fitting of the models to the velocity data. As has been shown by Buchler et al. (1990), velocity ϕ_{21} is a unique function of the resonant period ratio P_2/P_0, viz. $\phi_{21} = f(P_2/P_0)$. Following the approach of Kienzle et al. (1999), we assume that along the instability strip the period ratio is given by the approximate expression $P_2/P_0 = 0.5(P/P_r)^{-\alpha}$. The fit of the above two formulae to the ϕ_{21} data yields the resonant period of

$$P_r = 9.947 \pm 0.051\,\text{day}.$$

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