LONG-TERM V/R VARIATIONS OF BE STARS DUE TO GLOBAL ONE-ARMED OSCILLATIONS OF EQUATORIAL DISKS

ATSUO T. OKAZAKI
College of General Education, Hokkai-Gakuen University, Toyohira-ku, Sapporo 062, Japan

Abstract. We study the long-term variations of Balmer line profiles due to global one-armed oscillations in Be-star disks. In order to examine the qualitative effects of oscillations on line profiles, we assume that the eigenfunctions of one-armed nonlinear oscillations are similar to those of linear oscillations. Computing the line profiles for various values of disk parameters, we find that in small disks or in disks with steep density gradients the one-armed fundamental modes cause remarkable variabilities similar to the observed V/R variations.

The long-term V/R variation is one of the most puzzling phenomena in Be stars. Periods of the variations range from years to decades; they are much longer than the dynamical time-scales in the central stars and the envelopes. In addition behaviors of the profile variations are bizarre: a profile as a whole shifts blueward (redward) when the red (violet) component is the stronger (e.g., McLaughlin 1961).

Recently, Okazaki (1991) proposed a model based on a theory of global oscillations in nearly Keplerian disks. According to this theory of oscillations (e.g., Kato 1983), the model suggests that the long-term V/R variations are phenomena caused by the global one-armed oscillations in the equatorial disks of Be stars. Studying the eigenmodes of linear one-armed isothermal oscillations in isothermal disks with finite radial sizes ($r_* \leq r \leq r_{\rm out}$), Okazaki (1991) found that the one-armed oscillation model naturally explains observed periods of the V/R variations.

In the present paper we examine the qualitative effects of the one-armed oscillations on line profiles. For this purpose we adopt a simplified treatment: we assume that the eigenfunctions of one-armed nonlinear oscillations are similar to those of linear oscillations found in Okazaki (1991); the eigenfunctions are normalized so that the maximum value of the perturbed part of the angular velocity is 5% of the unperturbed part. In addition we assume that the source function is constant over the entire disk region. On these assumptions we compute the optically-thick line profiles emitted from the entire disk by integrating fluxes along a bundle of line-of-sights penetrating the disk; neither the radiation from the central star nor the continuum radiation from the disk are included. The thermal broadening is taken into account as the line broadening mechanism. The density profile adopted is

Astrophysics and Space Science **210**: 369–370, 1993.

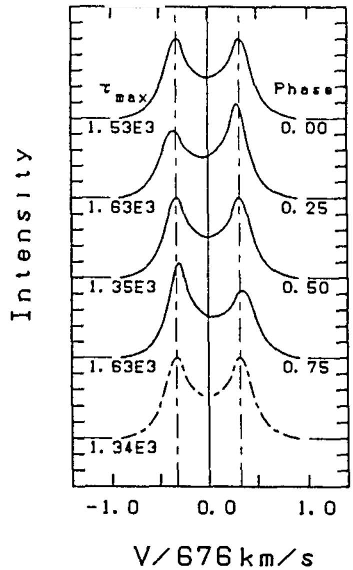

Fig. 1. Variability caused by the one-armed fundamental mode for $r_{out}/r_* = 10$ and $\alpha = 3$. The central star is in B0 main-sequence and the inclination angle is 60°. The four solid profiles denote the profiles at the different phases and the dash-dotted profile denote the profiles from the unperturbed disk. The line optical depth is given on the left side of each profile. The vertical dash-dotted lines represent the peak velocities of the unperturbed profiles.

a simple power-law form: the equatorial density of the unperturbed disk is proportional to $r^{-\alpha}$.

Examining the line profile variabilities for various values of disk parameters, we obtain the following conclusions: In small disks ($r_{out}/r_* \sim 2$) or in disks with steep ($\alpha \gtrsim 3$) density gradients (see figure 1), the one-armed fundamental modes cause remarkable variabilities similar to the observed V/R variations. These variabilities result mainly from the eccentric deformation of the region through which the optical depths along line-of-sights are of order unity.

References

Kato, S.: 1983, *Publications of the ASJ*, **35**, 249.
McLaughlin, D. B.: 1961, *J. Roy. Astron. Soc. Canada*, **55**, 73.
Okazaki, A. T.: 1991, *Publications of the ASJ*, **43**, 75.