Eccentric Oscillations in Viscous Decretion Discs of Be Stars

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1 Transonic Outflow in Viscous Decretion Discs of Be Stars

Lee et al. (1991) proposed the viscous decretion disc scenario for Be stars, in which the matter ejected from the star drifts outward because of the effects of viscosity. In this paper, we examine the characteristics of outflow in viscous decretion discs around Be stars. For simplicity, we assume the disc to be isothermal, and adopt the α-description for the viscous stress. As the radiative force, we adopt the parametric form proposed by Chen and Marlborough (1994). We also include the quadrupole contribution to the potential around the rotationally-distorted central star, following to Papaloizou et al. (1992) and Savonije and Heemskerk (1993).

Solving the resultant wind equation for a wide range of parameter values, we found that a transonic solution exists for any α. The sonic radius is located at $r > 100r_{\rm s}$ for plausible values of parameters,where $r_{\rm s}$ is the stellar radius. It is smaller for higher temperature and/or larger radiative force. We found also that the topology of the sonic point is a node for $\alpha \gtrsim 0.95$, while it is a saddle for $\alpha \lesssim 0.9$. According to the theory of accretion, the sonic point in the former case is unstable, while that in the latter case is stable (e.g., Abramowicz and Kato 1989).

Figure 1 shows the typical structure of the viscous transonic decretion disc. We note that the outflow is highly subsonic in the inner part of the disc. We note also that, in the subsonic region, the outflow velocity increases as r and the local density decreases as $r^{-7/2}$. The angular velocity of the disc decreases as $r^{-1/2}$ in the inner subsonic region, while it decreases as r^{-1} in the outer subsonic region.

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Many Be stars exhibit long-term V/R variations, which are considered to be caused by the variations in the equatorial discs (e.g., Poeckert 1982). It is thus important to investigate the characteristics of the oscillation modes in viscous decretion disc discussed above. Since the possible global oscillations in near Keplerian discs are one-armed oscillations alone (e.g., Kato 1983), we restrict our attention to the one-armed oscillation mode. For simplicity, the oscillation is assumed to be linear.

Figure 2 shows an example of the one-armed fundamental mode confined in the inner part of the viscous transonic decretion disc. It is important to note that the characteristics of the one-armed spiral mode are consistent with the periodicity and line profile variability of the observed V/R variations. Note also that the mode is a leading one-armed spiral wave. This suggests that the V/R asymmetry in the individual lines would progressively shift with time from lower to higher Balmer members.

The one-armed oscillation modes in viscous decretion discs are, in general, overstable because of the viscous effect. The period and the growth time are roughly comparable.

References

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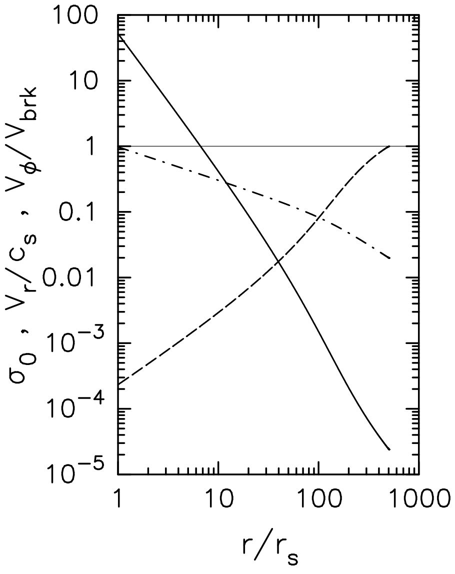

Figure 1: Structure of the viscous transonic disc around a B0V star. The disc temperature is assumed to be 2/3 of the effective temperatur e of the star. The value of α is 0.1. The solid, dashed, and dash-dotted lines denote the surface density in units of $\mathrm{g \cdot cm^{-2}}$, the Mach number of the outflow, and the angular velocity of the disc normalized by the break-up velocity. Though the surface density is calculated for the mass decretion rate of $10^{-9}\, M_{\odot}\mathrm{yr}^{-1}$, the velocity distribution is independent of the mass decretion rate. The other parameters are: the deformation factor $k_2 f^2 = 9.6 \times 10^{-4}$ and the weak line force in the form of $4.9 \times 10^{-2}\,(r/r_{\rm s})^{0.1}$.

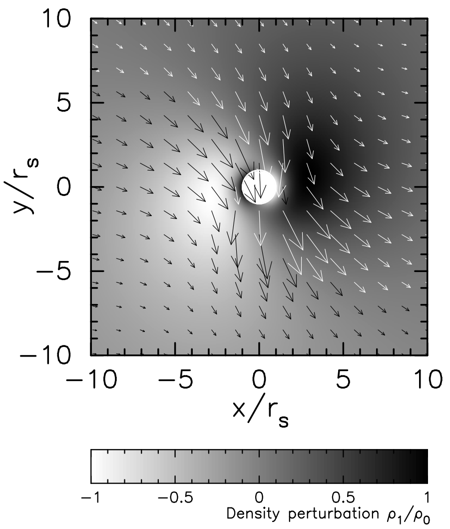

Figure 2: One-armed fundamental mode confined in the inner part of the viscous transonic decretion disc. The gray-scale plot denotes the density perturbation ρ_1/ρ_0 on the equatorial plane, while arrows denote the perturbed velocity vectors relative to the local angular velocity of the unperturbed disc.