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$m = 1$ Oscillations of Accretion Disks in Close Binary Systems

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Abstract. We examine the two-dimensional structure of $m = 1$ modes in disks around white dwarfs in close binary systems. We find that the odd modes (warping modes) as well as even modes (eccentric modes) are confined to the outermost part of the disk. The period of the fundamental mode is of a few percent of the binary period, and is insensitive to the parity of the mode. These modes naturally explain the superhump periods of SU UMa stars.

1. Introduction

In SU Ursa Majoris (SU UMa) stars, which constitute a subclass of dwarf novae, the accretion disks are considered to be eccentric during superoutbursts (e.g., Osaki 1996, and references therein). It is natural to regard this eccentricity as the manifestation of global $m = 1$ modes. Using a vertically-integrated disk model, Hirose & Osaki (1993) analysed the $m = 1$ modes confined to the outermost part of the disk and found the eigenfrequencies consistent with the observed periods of superhumps. In this paper, we examine the two-dimensional structure of the $m = 1$ eigenmodes in disks of SU UMa stars.

2. $m = 1$ Eigenmodes in Disks of SU UMa Stars

We take a geometrically thin, axisymmetric, polytropic disk around a white dwarf as an unperturbed disk. We assume that the unperturbed disk, which is in hydrostatic equilibrium in the vertical direction, is truncated at $r = 3^{-2/3}D$ by the tidal instability, where D is the binary separation. We use the phase-averaged axisymmetric potential for the tidal potential. We neglect the radial advective motion and viscous effects.

We consider a linear, $m = 1$ adiabatic perturbation. We solve the resulting second-order partial differential equation for the enthalpy perturbation $h_1(r, z)$ only in the propagation region, which extends from the inner Lindblad resonance (ILR) to the disk outer radius. As the boundary conditions, we require that the Lagrangian perturbation of the pressure vanishes on the disk surface and the disk outer radius, and h_1 is regular at the ILR.

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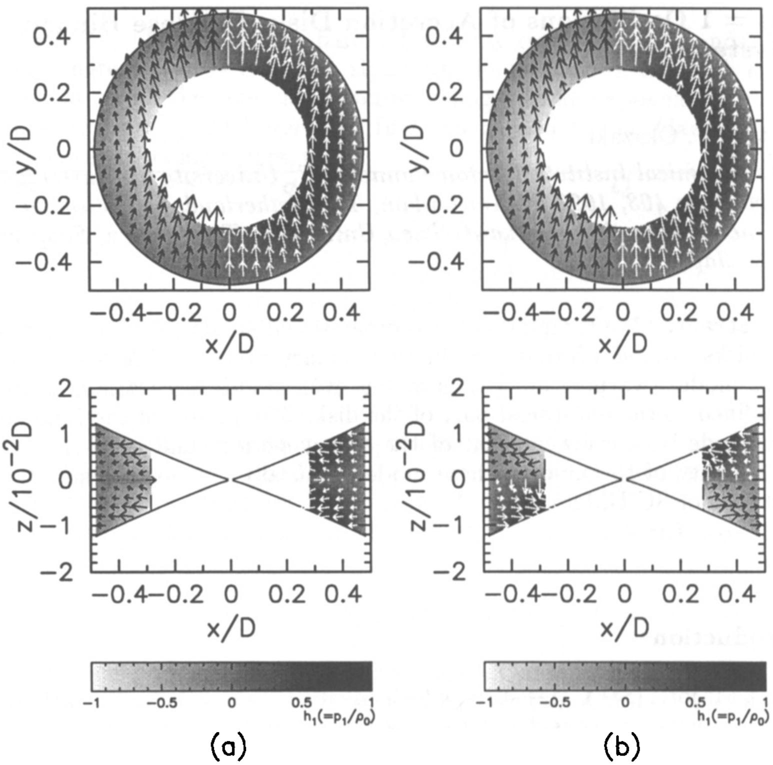

Figure 1. The fundamental mode confined to the outermost part of the disk: (a) the even mode and (b) the odd mode. The upper panel shows the (r, ϕ)-distribution of the perturbations averaged vertically over the upper half-thickness, while the lower panel shows the (r, z)-distribution of the perturbations. A gray-scale representation denotes the distribution of h_1. Arrows denote the perturbed velocity vectors

Figure 1 presents the even (eccentric) and the odd (warping) fundamental modes confined to the outermost part of the disk with parameters typical for SU UMa stars. These modes prograde and have periods of several percent of the binary period. Therefore, both modes naturally explain the superhump periods which are always longer by a few percent than the orbital period.

The eigenfunctions of the eccentric mode and the warping mode are quite similar, except for the parity of the mode and the perturbed velocity field near the equatorial plane. The difference in the disk geometry caused by these two kinds of modes may be detectable.

References

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