GLOBAL DISK OSCILLATIONS AND KINEMATICS OF MEGAMASER SOURCES

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1. Introduction

Megamasers provide a powerful tool to probe the innermost few parsecs of active galactic nuclei (AGNs). In particular, for AGNs with large inclination angles, only maser sources enable to directly study the structure and dynamics of the region inside the supposed obscuring tori, which are considered to be optically thick from the infrared to the X-ray bands. For example, the VLBI observations of the water megamaser sources at the center of NGC 4258 have provided not only the compelling evidence for the presence of a central supermassive black hole but also the detailed information on the spatial and velocity distribution of the maser sources (Miyoshi et al. 1995; Nakai et al. 1995).

Hitherto, the dynamics of megamaser sources have been discussed under the assumption of circular rotation. It is known, however, that near Keplerian disks can be perturbed by global $m = 1$ oscillations (e.g., Kato 1983). If $m = 1$ modes exist in maser disks, the velocity field can deviate from the Keplerian one. It is, therefore, important to study the characteristics of $m = 1$ modes in maser disks and their effect on kinematics of maser sources.

2. Disk Model

As an unperturbed equilibrium disk, we take a non-self-gravitating, axisymmetric disk rotating around a black hole. To simulate the weak general relativistic effect, we use the pseudo-Newtonian potential (Paczyński & Wita 1980). We assume that the gas obeys a polytropic relation with an index of 5/3, adopt a simple toy model for the density distribution adopted by Okazaki (1996), and consider a linear, adiabatic $m = 1$ perturbation.

3. Global $m = 1$ Eigenmodes

Both z-symmetric (eccentric) modes and z-antisymmetric (warping) modes are present in magamaser disks. The velocity field associated with the modes is sensitive to disk parameters as well as the disk model adopted. The assumption of circular rotation of maser disks holds well only for warping modes.

3.1. WARPING (Z-ANTISYMMETRIC) MODES

The velocity field associated with the warping mode is approximately vertical. The amplitude of the vertical component of the perturbed velocity is roughly constant in the z-direction and decreases with radius. These features of the warping mode agree well with the observed spatial and velocity distribution of maser sources of NGC 4258. [See Okazaki (1996) for more details.]

3.2. ECCENTRIC (Z-SYMMETRIC) MODES

The perturbed velocity field associated with the eccentric mode is approximately horizontal. Due to the presence of the eccentric mode, the disk center is offset and the velocity field becomes non-circular. Then, it is necessary to take account of the perturbed velocity field to study the kinematics of maser sources and estimate the galaxy distances and the black hole masses of AGNs.

References

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