Axisymmetric Modes in Thin Accretion Disks: Limits on β

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Abstract

A central problem in the study of accretion disks is the process by which angular momentum is transported outward at a rate sufficient to explain the observed luminosity of accretion-powered astronomical sources, which is far higher than conventional gas viscosities can account for. Current research focuses on plasma-physics instabilities, since conditions around accreting objects are likely to consist of ionized, magnetized material whose viscosity is dominated by collective modes rather than collisions.

In particular, one possibility that has been considered relies on axisymmetric modes such as the Magneto-Rotational Instability[1,2] to generate an effective viscosity through the excitation of turbulence in the disk. These modes use magnetic fields to couple matter orbiting with relative velocities in a differentially-rotating plasma, and were originally derived for the case of long-cylinder geometry. However, our previous work[3] showed that when vertically confined in a thin accretion disk due to a density profile across the height of the disk, the MRI modes become of the ballooning type instead, with radial oscillations, reduced growth rates, and strong limitations on the magnetic field strengths compatible with their excitation.

We review the relevant analytical approaches and expand our previous results with numerical studies of the axisymmetric modes to identify the limits on β, the ratio of the magnetic energy density to the plasma pressure, above which marginally-stable modes and unstable modes disappear. The present state of our analysis confirms our conclusions given in Ref. 3, that unstable axisymmetric modes in thin accretion disks require quite low values of the magnetic pressure relative to the plasma pressure and have growth rates that are insufficient[4] to provide the rate of momentum transport needed to explain the luminosities of a significantly large variety of objects.

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