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# Analysis of Nonaxisymmetric Modes in Accretion Disks at Marginal Stability with Nonlinear Diffusion and Dissipation*

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A class of unstable modes with azimuthal wavenumber, in accretion disks with an equilibrium magnetic field $\mathbf{B} \cong B_\phi(R,z)\mathbf{e}_\phi + B_z(R,z)\mathbf{e}_z$, that can transport angular momentum have the following properties: they are radially localized over distances much smaller than $R$; they require the effects of finite pressure for their excitation; they possess two sets of singularities in the MHD approximation; and they require a localized diffusion or dissipation operator to resolve the inner singularity [1, 2]. The spectrum of modes about marginal stability was analyzed numerically for linear operators and reported in Ref. 3, where the existence of separate classes of solutions with different numbers of nodes in the radial direction was demonstrated.

Nonlinear diffusion and dissipation operators have been proposed on the basis of the fact that within the inner singularity, pressures and densities tend to become infinite and therefore nonlinear effects become important [4]. The MHD equation describing the radially ballooning nonaxisymmetric modes [1, 2, 5] is modified into one that smoothly connects the solution within the transition regions to the MHD solution outside the transition regions [3]. The physical basis of nonlinear operators described in a previous report [4] is discussed. For the nonlinear operators, the marginal stability condition is analyzed by taking the ratio $\delta$ of the width of the transition layer to the radial extent of the mode to be much less than 1, and the growth rate to be of order $\delta$ relative to the orbital frequency. A spectrum of modes, with different numbers of radial nodes, is mapped for each of the nonlinear operators.

*Sponsored in part by the U. S. Department of Energy

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