A shallow-water theory of annular sections of cold astrophysical disks

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A scaling argument is presented that leads to a shallow water theory of non-axisymmetric disturbances in annular sections of thin Keplerian disks. To develop a theoretical construction that will aid in physically understanding the relationship of known two-dimensional vortex dynamics to their three-dimensional counterparts in Keplerian disks. Using asymptotic scaling arguments, varicose disturbances of a Keplerian disk are considered on radial and vertical scales consistent with the height of the disk while the azimuthal scales are the full angular extent of the disk. The scalings lead to dynamics which are radially geostrophic and vertically hydrostatic. It follows that a potential vorticity quantity emerges and is shown to be conserved in a Lagrangian sense. Uniform potential vorticity linear solutions are explored and the theory is shown to contain an incarnation of the strato-rotational instability under channel flow conditions. Linearized solutions of a single defect on an infinite domain is developed and is shown to support a propagating Rossby edgewave. Linear non-uniform potential vorticity solutions are also developed and are shown to be similar in some respects to the dynamics of strictly two-dimensional inviscid flows. Based on the framework of this theory, arguments based on geophysical notions are presented to support the assertion that the strato-rotational instability is in a generic class of barotropic/baroclinic potential vorticity instabilities. Extensions of this formalism are also proposed. The shallow water formulation achieved by the asymptotic theory developed here opens a new approach to studying disk dynamics.

Brief Bio for the Speaker: Professor Umurhan did his graduate work in Astronomy at Columbia University, after his undergraduate studies at UCLA. He has been teaching at the City College of San Francisco since 2002.