Vortices and planetesimal formation in fully stratified protoplanetary disks

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We present the study of early stages of planet formation in protoplanetary disks. We shortly overview the theory of planet formation and focus on the early stages when planetesimal formation is thought to be a key factor. In particular we discuss the generation and dynamics of hydrodynamic anticyclonic vortices that play a crucial role in planetesimal formation in the core accretion model. We study the linear dynamics of differentially rotation fully stratified protoplanetary disks. Disks with sub-keplerial law of rotation and exponential vertical and radial power law stratification are considered. The mutual effect of radial and vertical buoyancy is studied in local shearing sheet frame. The generation of potential vorticity by thermal instability is discussed. Nonlinear balance that can be developed in turbulent disks is estimated. The role of spiral shock waves is studied numerically using direct numerical simulations. We show that initial flattering of the disk matter can be a key in vorticity generation and be a trigger for planet formation in protoplanetary disks.

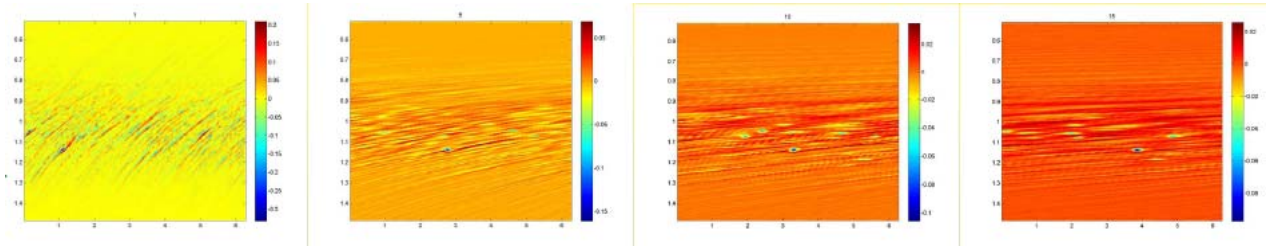

Figure: Results of direct numerical simulation of differentially rotating disk matter when only pressure perturbations are present initially. Perturbations of potential vorticity for different moments in time. Figure shows stochastic generation and nonlinear development of vortices mostly by developing spiral shock waves. After several disk revolutions strong coherent anticyclonic vortices that can accelerate the planetesimal formatioin are formed.