Seminar

Institute for Plasma Research

Title : Dynamics of a confined dust fluid in sheared flow of streaming plasma

Speaker : Mr. Modhuchandra Laishram
Institute for Plasma Research, Gandhinagar

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Venue : Seminar Hall, IPR

Abstract :

Dust clouds are formed in many experiments when micron size dust particles introduced in a plasma are confined by spatial non-uniformities of an effective potential. In their fluid-like phase, the dust clouds show self-organized flow dynamics like formation of vortex, boundary layers, and their interesting nonlinear dynamics. Essentially driven by non-conservative force fields arising either from the background plasma or other sources and stabilized by a dissipation, this system allows examining fundamental characteristics of many complex systems surviving away from the thermodynamic equilibrium.

Considering the unbounded sheared flow of the background plasma as a driver, the dynamics of dust clouds is studied by the first application of two-dimensional hydrodynamic model using its vorticity-stream function formulation. The characteristics of vortex and boundary flows in dust clouds are investigated for a range of system parameters, namely, the kinematic viscosity, ion drag co-efficient, neutral friction, boundary conditions and the driving field. In the low Reynolds number liner regime, the problem is treated as a non-homogeneous eigen value problem in a 2D domain with toroidal symmetry that confirms with the experimental set up in IPR laboratories. The collective flow is characterized by formation of vortices with induced multiplicity and departure of dust vorticity length scale spectrum from the driver eigen mode spectrum because of distinct scales introduced by the boundary layer structure. The boundary layer width and Reynolds number were recovered to scale as $\Delta r_b \approx \mu^{1/3}$ and $Re \approx \mu^{-2/3}$ with the kinematic viscosity μ. The nonlinear regime, allowing coupling across multiple scales, is addressed by iterative numerical solution of the nonlinear stream function formulation in the limit of small dust kinematic viscosity. The primary vortex in nonlinear regime are recovered scaling with the most dominant spacial scales of the domain, having a uniform vorticity core and developing virtual boundaries with highly convective flow of vorticity. This separation of boundary is triggered beyond a critical dust viscosity value μ^* and identified as a structural bifurcation. The boundary layer scaling in the nonlinear regime is transformed into a velocity dependence form, $\Delta r_b \approx (\mu L_{||}/u_{||})^{1/2}$, prescribing estimates of dust kinematic viscosity for experiments using velocimetric methods in both linear and nonlinear regimes. A unique multiplicity of co-rotating nonlinear vortices is recovered for the larger domain aspect ratio (L_z/L_r), explaining the recent experimental observations of such structures in IPR. Emergence, in the nonlinear regime, of uniform vorticity core and secondary vortices with a newer level of identical dynamics highlight the applicability of the dust dynamics to giant vortex flow in nature, like Great red spot of Jupiter, to microscopic biophysical intracellular activity.