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Steady equilibrium co-rotating dust vortices in a streaming sheared plasma

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Highly charged micron size dust particles suspended in a plasma often form clouds localized by electrostatic potential non-uniformities and gravitational field [1]. Force fields with nonvanishing curl in these clouds drive self-organized vortex flow motion [2] such that the setup replicates a wide range of volumetrically driven bounded natural and complex flow systems. Addressing their viscous fluid like regimes using 2D Navier-Stocks model allows to reveal various physical characteristics of a variety of volumetrically driven bounded flow equilibria and highly sheared vortex flows [3]. The 2D hydrodynamic formulation of the confined dust clouds and its nonlinear equilibrium solutions incorporating finite boundary effect shows a critical transition of the boundary flow from the laminar to a boundary layer separated (BLS) nonlinear regime. The scaling of boundary layer width $\Delta r^3 \propto \mu$, uniquely dependent on the kinematic viscosity μ in linear regime turn into velocity dependent form $\Delta r^2 (u_{\|} /L_{\|}) \propto \mu$ in the high Reynolds number nonlinear regime through a critical kinematic viscosity μ^*, influencing the velocimetric determination of the dust viscosity [4]. The nonlinear solutions recover development of vortex scales independent of finer structure in the boundary. The transition allows formation of sequence of corotating vortices separated by layers of high shear depending on varying depth-to-width called the aspect ratio (L_z/L_r) of the dust confined domain.

References

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