Weakly magnetized dust vortex flow analysis in the absence of non-conservative fields

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Quasi neutral electron-ion plasmas with highly charged dust particles, provide a setup where the vortex flow of the charged dust fluid is often present and can be studied at a very accessible spatio-temporal scale. Dust vortex flow structures that are driven by non-conservative force fields, like the ion drag force, and neutral flow have been observed in both theory and experiments [1]. Rotating dust structures [2] have been extensively studied in weakly magnetized plasmas where dust dynamics is again interpreted as governed by the non-conservative force fields. Dust vortex structures in a purely conservative force fields environment are yet to be explored. It would be interesting to see whether such dust vortex solutions are possible to obtain in the absence of any non-conservative force fields.

For this, the 2D hydrodynamic model in a Cartesian setup [3], as described in Figure (1), is applied to the confined dust cloud in a non-uniform magnetic field in order to recover the dust vortex flow driven in a conservative force field setup, in the absence of any non-conservative fields or dust charge variation. Vortex structures in dust flow field has been observed which are driven by the background weakly magnetized plasma. Considering a linear variation of magnetic field perpendicular to the sheath electric field, dynamical equilibrium of such dust vortex flow with weakly magnetized background plasma is analyzed. It shows that non-uniform field (ambiploar electric field) associated with the sheared E×B drift of electrons, produced by the combination of conservative fields (magnetic and sheath electric field), drive the vortex structures in dust flow field. This sheared E×B drift flow is facilitated by the magnetic field gradient. The unipolar and multipolar cases of the ambiploar electric field are discussed and analyzed, in the linear limit, for the magnetic field strength and its gradient value. The topology of the surface plot in Figure (2) indicating that the ambipolar electric field can act as a source of finite vorticity in the dust flow dynamics. The obtained results shows that the macroscopic dust vortex flow would be possible only by a non-zero value of magnetic field gradient and vorticity vector is pointing along the magnetic field direction.

The solutions obtained are, generally, agreeing with the experimental results [4], especially reproducing the reversal of the dust flow direction when varying the strength of the magnetic field. The presented analysis (in EMHD regime) applies to systems like MDPX (Magnetized Dusty Plasma Experiment), where non magnetized to weakly magnetized ion (and dust) regimes are very relevant.

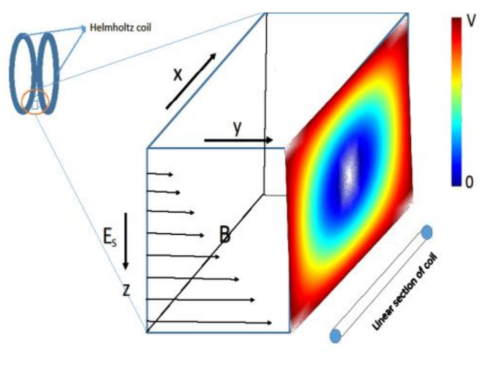

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Figure 1: Schematic of the set up in Cartesian geometry with the contour plot showing the strength of confining potential and $\mathbf{B}$ **and** $\boldsymbol{E_s}$ are representing the magnetic field and sheath electric field, respectively.

References:

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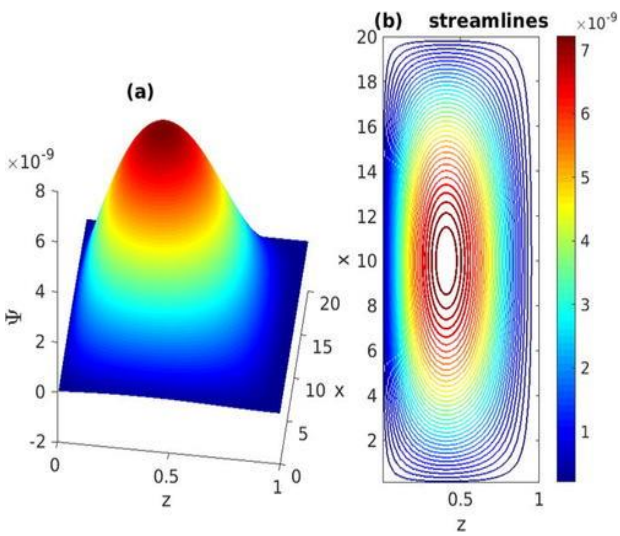

Figure 2: 2D-functions for dust flow profiles, (a) dust stream function, and (b) dust streamlines