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Turbulent vortex rotation in diffused DC glow plasma

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Dusty plasmas consist of highly charged micron-sized particles suspended within the plasma. Dust particles interact via a shielded Coulomb potential, with electrons and ions providing the shielding. They allow easy tracking of dust particle trajectories due to their slow dynamics compared to electrons and ions. This characteristic makes dusty plasmas an ideal platform for studying flow, waves, instabilities, and turbulence at kinetic levels, even in fluid regimes. Studying these collective dynamics is important due to its relevance in astrophysical plasmas, fusion devices, charged colloids, and industrial plasmas. Turbulence in dusty plasmas can arise mainly either by the excitation of waves or by the formation of dust vortices. Vortices in dusty plasmas get induced by microparticle size dispersion, charge gradient, and non-zero curl of the forces exerted by plasma or by some external perturbation.

This talk will focus on the experimental observation of turbulence in a rotating dust cloud. The experiments are carried out in the newly commissioned Shivalik Plasma Device-I (SPD-I) [1] at IIT Jammu. A 3D dust cloud gets formed in the diffused region of a DC discharge experiment performed in an Argon plasma environment. We used poly-dispersive Kaolin microparticles of size ranging from 2-8 ⌈m for particle size dispersion which leads to a charge gradient in 3D dusty plasma. A thin sheet LASER of thickness ~ 150 ⌈m is used to illuminate a single layer of the dust cloud to observe and record the planar dynamics. The flow visualization and measurement of the dust rotation are done using the Particle Image Velocimetry (PIV) technique. The velocity field of the rotating dust vortex at all different regions is measured by using MATLAB based open source software PIVlab [2].

High ion drag force over the electrodes and sheath formation over the glass surface leads to the formation of a dust void. It causes the dust particles to levitate in the diffused plasma region far away from the cathode. We observed dust vortices at different locations of the device under specific discharge conditions, with dust charge gradient and ion drag force playing a major role in vortex formation.

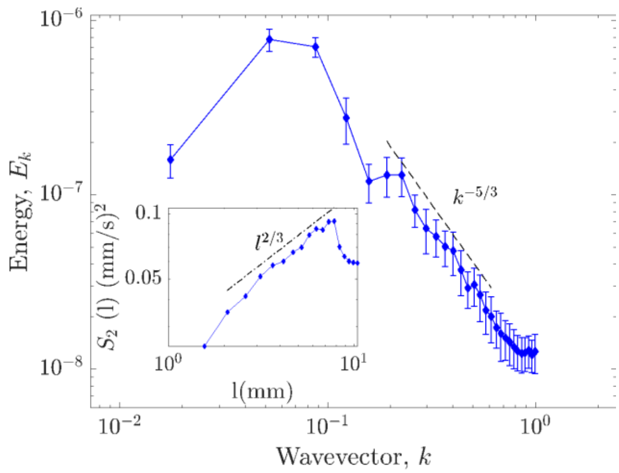

Figure 1: The time-averaged power spectrum of velocity fields obtained from PIV analysis. The slope of the spectra follows the Kolmogorov power law of -5/3 scaling. The figure shows the second-order structure function following the slope of 2/3, consistent with Kolmogorov's theory.

The power spectra for turbulence in our experiments followed the -5/3 power-law scaling of Kolmogorov turbulence [3] in both time and space domains. Our findings are further supported by analysis involving the second-order structure functions showing 2/3 scaling. Also, the Probability distribution functions (PDF) for velocity and velocity gradient exhibit the characteristics of 3D Kolmogorov turbulence. Our results demonstrate characteristic traits of Kolmogorov 3D turbulence within distinct diffused plasma regions. This underscores the universality of turbulence in laboratory dusty plasma.

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