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Plasma Kristall-4: Anomalous diffusion and vorticity in a multi-chain dusty plasma

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Understanding the thermodynamics of dusty plasmas requires knowledge of the energy transfer, or convection, in this open driven dissipative system. Convection is the global flow of heat due to particle transport, which includes the two subprocesses: advection (directed flow) and diffusion (random motion). The interaction with the ion flow and the presence of gradients in the dust charging can induce long-distance correlations, resulting in anomalous dust diffusion and global instabilities in the dust structure. The coexistence of subdiffusion (trapping) and superdiffusion (enhanced transport) in different regions of the same dusty plasma structure have been previously related to the onset of global cooperative motion in the form of a vortex flow.

Here we present a study of anomalous diffusion and vorticity in multi-chain dusty plasmas formed in the Plasma Kristall-4 facility on board the International Space Station. Video data from these experiments have been analyzed to characterize the diffusive behavior of dust chains throughout the cloud as well as the presence of global vorticity. The connection between the observed diffusion regime and global dynamics is investigated analytically using a spectral technique, where long-distance correlations within the system are modeled by a fractional Laplacian operator. As the analytical method relies on spectral analysis while the experimental results are kinetic in nature, the agreement between the two provides a new and powerful technique for the study of complex transport phenomena.

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