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From supercritical transition of dusty plasmas to diffusion mechanism of 2D fluids

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We first claim the supercritical nature of dusty plasma fluid, due to the pure Yukawa repulsion between dust particles. From computer simulation data, we confirm that the dynamical transition point between the liquidlike and gaslike states of dusty plasmas perfectly matches the salient features of the Frenkel line, using several diagnostics. All these diagnostics lead to the same transition point of about 20 times of the corresponding melting point for both 2D and 3D dusty plasmas [1], which can be used as a new criterion to distinguish the strongly and weakly coupled regimes. Next, we focus on the general mechanism of shear viscosity of 2D dusty plasmas at the individual particle level. By combining Frenkel's liquid description, we find a simple formula for the kinematic viscosity that is solely determined by lifetime of local atomic connectivity and the average kinetic speed of particles [2]. Moreover, we discover that the lifetime of local atomic connectivity in 2D liquids is universally determined by the effective potential difference between the first peak and valley of the pair correlation function, implying a direct connection between macroscopic shear transport and microscopic structure. Finally, we demonstrate that the characteristic length scale governing the macroscopic shear viscosity aligns with the elastic length-scale that defines the propagation limit of collective shear waves in liquids. These findings are also valid for 2D Lennard-Jones and one-component plasma liquids, clearly indicating that shear viscosity in 2D liquids arises from the diffusive transport of average particle momentum across the elastic length scale. The obtained mechanism above means that shear dynamics of 2D systems are fundamentally governed by localized configurational excitations within the atomic connectivity network.

References

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