Non-local Transport of Strongly Coupled Plasmas

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Collective motion of charged meso-scopic particles (i.e., particulates) immersed in a plasma (i.e., dusty plasmas) is of great interest with regard to improving our understanding of the fundamental nature of strongly coupled Coulomb systems. Observable phenomena in most laboratory dusty plasma experiments are often macroscopic in nature, i.e., phenomena whose scale lengths are significantly larger than the average interparticle distance and time scale much longer than the plasma frequency of charged particulates. In order to understand the relation between the dynamics of charged particulates in the meso-scopic level and such observable macroscopic phenomena, one needs a theoretical framework in which statistical properties of particulates are directly incorporated in the dynamical equations governing the macroscopic motion of the system. One of such models is hydrodynamic equations, where statistical properties of constituent particles are incorporated in their transport and thermodynamical coefficients.

In the case of moderately or strongly coupled dusty plasmas, one is also often interested in “less macroscopic” phenomena whose typical space scales are several times larger than or almost the same as the average interparticle distance, and equally whose typical time scales are several larger than or almost the same as the particulate plasma frequency. The hydrodynamics equations can also describe such phenomena approximately if one includes memory effects in their transport coefficients.

In the present work, we model dusty plasmas by the Yukawa system, i.e., the system of particles interacting through Yukawa potentials, and evaluate its memory effects and the relaxation time (i.e., time scale of memory effects) in the shear viscosity, using molecular dynamics (MD) simulations. We have found a phenomenological scaling of the relaxation time as a function of the system parameters. These results are used to construct the hydrodynamics equations (i.e., generalized hydrodynamics equations) applicable to moderately or strongly coupled dusty plasmas.