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Phase transition and emergence of active temperature in an active Brownian system in underdamped background

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Micron sized self-propelled particles, immersed in a background medium, are known as active Brownian particles. A group of bacteria in an experimental setup is a perfect example of active Brownian system[1]. Unlike passive driven systems, viz., sheared glassy systems, vibrated granular matter, or complex plasma under gravity, active systems consume and dissipate energy at the smallest possible length scale, i.e., at the individual particle length scale. Hence, active Brownian systems are out of equilibrium due to inherent activity.

In general, active Brownian particles are immersed in a background solvent like water. Due to the length and velocity scales associated with these particles, background becomes highly viscous or overdamped. But, in many cases background turns out to be underdamped. For example, dust or grain particles in dusty plasma, if styled as Janus particles[1,2], then become an active system that can go from inertia-less or overdamped to an inertial or underdamped limit by controlling the density of various components.

In recent past, it has been observed that a two-dimensional passive soft-disk system transits from a liquid phase at high temperature (or low density) to a solid phase at low temperature (or high density) via a narrow hexatic region[3]. Despite of inherent activity, active Brownian system has been shown to exist in equilibrium like liquid and solid phases[4], but there are substantial differences between active and passive phase transitions from liquid to solid phases. Unlike passive phase transition, active transition occurs at different values of coupling parameter, which is the ratio of potential energy to the thermal energy of the background solvent, for different measures of activity of the active Brownian particles. We have demonstrated[2] that an intermediate region, characterized by high structural fluctuations, between the liquid and solid phases exists in the overdamped limit, as observed in a previous study[4], but found to disappear in the underdamped limit.

Despite non-equilibrium nature, active Brownian system was shown[2,5,6] to possess equilibrium like temperature, which is different in value from that of the background solvent temperature. We call the temperature of the active Brownian system as active temperature[2]. We have demonstrated that active temperature depends not only on the activity of the active Brownian particles, but also on the interaction potential and the background dissipation strength. Moreover, we have demonstrated that the active temperature reduces with the increase in the strength of background dissipation and eventually vanishes in the overdamped background limit.

In this talk, we will present the detail of our mathematical model, elaborate all the associated terminologies and explain the simulation results of the various phases and active temperature of a system of active Brownian particles in two dimensions. We will also try to link some possible connection of our study of non equilibrium statistical physics with dusty plasma experiments.

References

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