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Dynamical Phase Transitions in Active Complex Plasma

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Micron sized dust particles immersed in a low temperature plasma environment is known as Complex Plasma, where the background plasma shields the negatively charged dust particles. Depending on the ionization and the background neutral density, Complex Plasmas are known to exhibit liquid, solid, and hexatic phases [1] that are typically observed at thermodynamic equilibrium in two dimensions. Complex Plasmas are also known to exhibit several non-equilibrium phases, such as lane formation [2], depending on the external drives that are, in general, incorporated at the largest scales of the system. Nearly spherical, micron sized dust particles in Complex Plasmas are recently being started to be engineered as self-propelled particles, which is possible by breaking the rotational symmetry. For instance, one hemisphere of the dielectric dust particles are being coated with a metal, such as gold, thereby producing a local thermal gradient in the presence of an illuminating Laser [3]. Such self-propelled particles are known as Janus particles [3]. Janus particles coupled with appropriate driving mechanism, for instance thermophoresis [3], makes the particles self-driven or self-propelled at the shortest scales, unlike globally driven Complex Plasmas. Self-propelled particles in a low temperature plasma background is known as Active Complex Plasmas [4, 5], which is an emerging field of research. Few early investigations [4, 6, 7] show promising collective behavior in Active Complex Plasma that are not known to be observed in conventional driven Complex Plasmas. Large scale numerical studies [8] of the inherently non-equilibrium inertial system of self-propelled particles are found to be highly diffusive compared to their passive counterpart, that is Complex Plasma. Numerical investigations suggest that the non-equilibrium system is found to exhibit equilibrium-like homogeneous phases to coexistence of phase separated state of high density dynamical clusters and low density phase, known as motility induced phase separation (MIPS) [9], with variation of the softness of the Janus particles or the background charge density. Low density Janus particles have been recently found to exhibit various intriguing dynamic phases, such as MIPS [9] and flocking [8], and transition between the non-equilibrium phases has been reported [8, 10] with continuous variation of the system parameters. Inertia of the Janus particles, that is controlled by the background neutral density, is found to substantially alter the spatio-temporal dynamics of the system[8, 11]. Several of these numerical results will be explored, along with experimental possibilities of the observed results.

References

[1] E. V. Vasilieva, O. F. Petrov and M. M. Vasiliev, Scientific Reports 11, 523 (2021)
[2] K. R. Sütterlin et al., Phys. Rev. Lett. 102, 085003 (2009).
[3] C. Bechinger et al., Rev. Mod. Phys. 88, 045006 (2016).
[4] V. Nosenko et al., Phys. Rev. Res. 2, 033226 (2020).
[5] S. De Karmakar and R. Ganesh, Phys. Rev. E 101, 032121 (2020).
[6] K. Arkar et al., Molecules 26, 561 (2021).
[7] V. Nosenko, Physics of Plasmas 29, 123701 (2022).
[8] S. De Karmakar, Ph.D. Thesis, HBNI (2023).
[9] S. De Karmakar and R. Ganesh, Soft Matter, 18, 7301-7308 (2022).
[10] S. De Karmakar and R. Ganesh, Phys. Rev. E 106, 044607 (2022).
[11] S. De Karmakar, A. Chugh, and R. Ganesh, Scientific Reports 12, 22563 (2022).