Correlational approach to study interparticle interactions in complex plasmas

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A general approach to the correlational analysis of Brownian motion of strongly coupled particles in open dissipative systems is described [1]. This approach can be applied to the theoretical description of various non-ideal statistically equilibrium systems (including non-Hamiltonian systems), as well as for the analysis of experimental data. In this report, we consider an application of the correlational approach to the problem of experimental exploring the wake-mediated nonreciprocal interactions in complex plasmas. For this, we derive simple analytic equations, which allows one to calculate the derivatives of the nonreciprocal interaction forces in a strongly coupled many-particle system as well as the gradients of external field. These calculations use data on time-averaged correlations of particles displacements and velocities, which are easily measured in an experiment. In the examples of numerical simulations, we demonstrate that the proposed approach could be an effective instrument in exploring the wake of a dust particle in a plasma. Unlike the previous attempts to study the wake-mediated interactions in complex plasmas, our method does not require a special design of the experimental setup and any external influences on a system, pre-measurements and any assumptions about the form of interaction. It is based on Brownian motion analysis only and can be used to study many-particle chain-like structures in complex plasmas [1].

We also show the importance of taking dissipative and random processes into account, without which consideration of a system with a nonreciprocal interparticle interaction as linearly coupled oscillators leads to significant errors in determining the characteristic frequencies in a system. We show that dissipative and random processes determine the minimum value of the force derivative to which the particle “reacts”.

References

[1] E.A. Lisin, O.S. Vaulina, and O.F. Petrov, Physics of Plasmas 25(1), 013702 (2018)