THERMOPHORETIC FORCE INFLUENCE ON INTER-PARTICLE DISTANCE IN DUSTY PLASMA CRYSTALS

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Dusty plasma is ionized gas containing highly charged nanometer to millimeter sized particles of condensed matter – dust particles [1]. High values of particles' charge lead to a high degree of non-ideality of the system thus to formation of various structures. Strict theory of these structures is not developed due to the difficulty of simultaneous accounting of a variety of forces acting on dust particles.

Inter-particle distance in dusty plasma structures is chosen in this work as the parameter sensitive to all important effects. Its behavior is analyzed by the method of molecular dynamics. In the model it is suggested that particles are placed in the stratum head in a glow discharge. Gravitational force is counterbalanced by the strong vertical electric field gradient causing two-dimensional structures appearance. Particles are kept from drifting to the walls of the discharge tube by the parabolic trap existing near the axis. Particle interaction is Yukawa-like.

The work is divided into two parts: (i) numerical experiments with the model system without any suggestions about parameters' dependence on temperature, (ii) then using obtained results to study influence of different effects on inter-particle distance in dusty plasma structures.

In the first part of the work no assumptions about the nature of particle charging, screening length in dusty plasma system and trap appearance. It is found that inter-particle distance dependence on the number of particles in the structure is given by the following formula:

$$r(N) = b(q, \lambda_{scr}, \alpha)(1 - 0.25N^{0.16})$$

where $b(q, \lambda_{scr}, \alpha)$ does not depend on the number of particles. Inter-particle distance dependence on the particle charge, screening length and trap parameter is well described by power functions in conditions close to experimental ones:

$$r(q, \lambda_{scr}, \alpha) = (3.5 \pm 0.2)q^{0.15\pm0.01}\lambda_{scr}^{0.55\pm0.01}\alpha^{-0.17\pm0.01}$$

In the second part it is assumed that particle charge equals $1500\,e$, screening length equals Debye length in plasma. Electrostatic trap is suggested to be a result of two effects: ambipolar diffusion which does not change with temperature and thermophoretic force which increases at low temperatures. Simulations without thermophoretic force give inter-particle distance dependence on temperature similar to the one observed in [2]. Accounting thermophoretic force gives the dependence with a minimum at low temperatures and provides an explanation of anomalous inter-particle distance increase observed in dusty plasma crystals in [3,4].

References

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