PHASE STATES OF COMPLEX PLASMAS

Possible states of complex plasmas are classified in terms of the momentum transfer in binary grain-grain collisions.

Momentum transfer in binary grain-grain collisions is investigated assuming the repulsive screening Coulomb (Debye-Hückel or Yukawa) potential of interaction between the grains. The momentum transfer cross sections and rates are obtained. This allows us to obtain further insight into the possible states of complex plasmas. Figure 1 represents different "phase states" of complex plasmas as functions of the electrostatic coupling parameter $\Gamma_{\rm ES} = U(\Delta)/T$ [where $U(r)$ is the potential energy of interaction] and the mean grain separation Δ, normalized either to the grain size a or the screening length λ. The vertical dashed line at $\kappa = 1$ conditionally divides the system into Coulomb and Yukawa parts.

The following states can be identified [1,2]:

(i) Above the red solid line we have Coulomb or Yukawa crytals, the crystallization condition is $\Gamma_{\rm ES} > 106(1+\kappa+\kappa^2/2)^{-1}$ [3]. (ii) Above the blue solid line we have Coulomb or Yukawa non-ideal plasmas – the characteristic range of grain-grain interaction (in terms of the momentum transfer) is larger than the intergrain distance (in terms of the Wigner-Seitz radius), $(\sigma/\pi)^{1/2} > (4\pi/3)^{-1/3}\Delta$, which implies that the interaction is essentially multiparticle. (iii) Regions below blue solid line correspond to Coulomb or Yukawa ideal plasmas – the range of grain-grain interaction is smaller than the intergrain distance and only pair collisions are important. (iv) Below the lower dotted line the electrostatic interaction is not important and the system is like a usual granular medium. (v) In the region between the upper dotted line and the solid blue line the pair Yukawa interaction asimptotically reduces to the hard sphere limit and complex plasma forms a "Yukawa granular medium".

Next we investigate complex plasma properties in terms of competition between the momentum transfer rate in mutual grain-grain collisions ν_{dd} and the interaction with surrounding medium (neutral gas), characterized by ν_{nd}. Figure 2 shows that there is a broad range of parameters where complex plasmas have the properties of one-phase fluids ($\nu_{dd}/\nu_{nd} \gg 1$), and those of two-phase fluids $\nu_{dd}/\nu_{nd} \sim 1$. In the extreme limit of very small ν_{dd}/ν_{nd} we can also have "tracer particles" in the background medium.

The broad range of states that is accessible for complex plasmas and the possibility to study a variety of processes at the kinetic level makes these systems extremely attractive for further research. The reported results can be important for "engineering" experiments which aim to make use of special properties of complex plasmas.

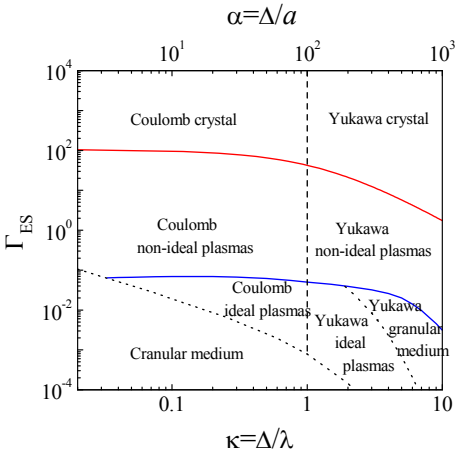

Fig. 1 Possible "phase states" of complex plasmas.

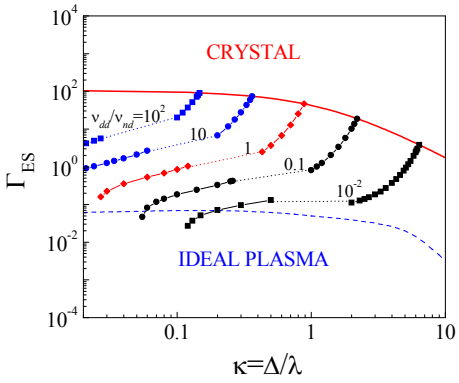

Fig. 2 Typical contours of constant ratios of the momentum transfer rates in grain-grain collisions relative to grain-background (neutral gas) collisions in (Γ,κ) parameter space. Also shown in the figure are the melting line and the boundary between ideal and non-ideal plasmas. The calculations are performed for a set of typical complex plasma parameters [2].

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[2] S. Khrapak, A. Ivlev, and G. Morfill, Phys. Rev. E (in press, 2004).
[3] O. Vaulina and S. Khrapak, JETP **90**, 287 (2000).

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