MOMENTUM TRANSFER IN COMPLEX PLASMAS

Momentum transfer in complex plasmas is investigated assuming an interaction potential between the charged species of the screened Coulomb (Yukawa) type. Momentum transfer cross sections and rates are derived. The obtained results have a wide range of applications including calculations of different kind of drag forces, classification of possible complex plasma states and transport properties.

Momentum transfer between different charged components in complex plasmas is investigated. A detailed model analysis of grain-electron, grain-ion, and grain-grain collisions is performed (electron-ion collisions are well described within standard plasma theory). Assuming the screened Coulomb (Debye-Hückel or Yukawa) interaction potential (attractive or repulsive) the momentum-transfer cross sections are calculated numerically. In Fig. 1 these cross sections are shown as functions of the so called *scattering parameter* β, which is the ratio of the Coulomb radius to the screening length. It can be shown to be the unique parameter describing scattering of pointlike particles interacting via the Yukawa potential. For typical complex plasma parameters the characteristic value of β for different types of collisions are: For electron-grain $\beta \ll 1$, for ion-grain $1 < \beta < 30$, and for grain-grain $\beta \gg 1$. The standard Coulomb scattering theory is applicable only for electron-grain collisions, but for ion-grain and grain-grain collisions different approaches should be used. Based on our numerical calculations the required approaches are developed, the role of the finite grain size is investigated, and analytical approximations for the momentum transfer cross sections are proposed. The latter are used to estimate the characteristic momentum-transfer rates in complex plasmas. The obtained results have a number of applications, e.g., calculation of the ion drag [1-3] and electron drag [4] forces, development of criteria to classify the possible states of complex plasmas in terms of the momentum transfer [5-7], investigation of the hierarchy of the momentum transfer in grain-grain and grain-neutral collisions[7].

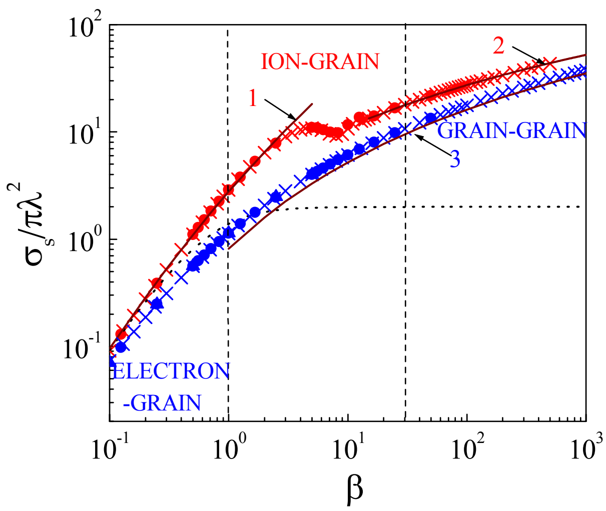

Fig. 1 Momentum-transfer cross section, σ_s, normalized to $\pi\lambda^2$ (where λ is the plasma screening length), versus the scattering parameter β. The upper (red) data are for attractive and the bottom (blue) data are for repulsive screened Coulomb potentials. Crosses correspond to our numerical calculation, circles and (blue) triangles are earlier numerical results by Hahn *et al.* and Lane and Everhart, respectively. Solid curves correspond to our analytical approximations. The dotted line corresponds to the Coulomb scattering theory. The later underestimates considerably the cross sections above $\beta \sim 1$. Vertical dashed lines conditionally divide β-axis into three regions: $\beta \ll 1$ is typical of electron-grain collisions; $1 < \beta < 30$ is typical of ion-grain collisions; $\beta \gg 1$ is typical of grain-grain collisions.

[1] S. A. Khrapak, A. V. Ivlev, G. E. Morfill, and H. M. Thomas, Phys. Rev. E **66**, 046414 (2002).
[2] S. A. Khrapak, A. V. Ivlev, S. K. Zhdanov, and G. E. Morfill, Phys. Rev. Lett. **90**, 225002 (2003).
[3] S. A. Khrapak *et al.*, IEEE Trans. on Plasma Sci. **32**, 555 (2004).
[4] S. A. Khrapak and G. E. Morfill, Phys. Rev. E **69**, 066411 (2004).
[5] G. E. Morfill *et al.*, Phys. Scripta **T107**, 59 (2004).
[6] G. E. Morfill *et al.*, Contrib. Plasma Phys. **44**, 450 (2004).
[7] S. Khrapak, A. Ivlev, and G. Morfill, Phys. Rev. E (in press, 2004).

S. Khrapak, A. Ivlev, S. Zhdanov, G. Morfill, and H. Thomas