Waves and solitons in complex plasmas

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Complex or dusty plasmas are plasmas with added microparticles (or dust grains). The microparticles collect electrons and ions and become highly charged. Their charges are usually negative due to higher mobility of the electrons. The grains interact with each other electrostatically via a Yukawa (or Debye-Hückel, or screened Coulomb) potential and often form ordered structures. Similar to colloids, complex plasmas can exist in solid, liquid or gaseous states and exhibit phase transitions [1].

Complex plasmas can be found in space, e.g. in planetary rings, comets or interstellar clouds. In plasma technology, dust contamination has negative effects on the yield of semiconductor devices. As the grains are weakly damped by gas friction and are traceable individually, dynamic phenomena such as shocks [2], Mach cones [3], solitons [4], and waves [5] can be observed at the kinetic level in real time.

The experiments were performed in a capacitively coupled radio-frequency discharge. A powered lower electrode was placed in a grounded vacuum chamber. Monodisperse plastic micro-spheres (9.19 μm in diameter) were levitated in the plasma sheath above the lower electrode. They were confined radially in a bowl shaped potential formed by a rim on the outer edge of the electrode and formed a monolayer hexagonal lattice. A horizontal thin sheet of laser light illuminated the particles, which were imaged by a digital video camera. Electrostatic pulses were applied to wires stretched above the electrode in order to excite waves and solitons.

We simulated monolayer complex plasmas consisting of 3000 negatively charged microparticles with the help of molecular dynamics simulations in three dimensions. The equations of grain motion were solved using the 5^{th} order Runge Kutta method taking into account the interaction of each grain with every other. Their motion was damped by the friction force. The grains were confined more strongly in the vertical direction than in the horizontal one. After seeding the grains randomly, the code was run until equilibrium was reached and a monolayer crystal lattice was formed. Varied excitation forces were then applied to produce nonlinear waves and solitons.

Here we report on the experimental and numerical results of our study of wave phenomena in complex plasmas. We investigated the structural changes of the lattice due to wave propagation, properties of compressional nonlinear waves and solitons, as well as interaction of colliding solitons and the influence of the lattice inhomogeneity on the soliton propagation.

Références

1. H.M. Thomas and G.E. Morfill, Melting of a plasma crystal, *Nature*, **379**, 806-809 (1996) ; C.A. Knapek, D. Samsonov, S. Zhdanov, U. Konopka, and G.E. Morfill, Recrystallization of a 2D plasma crystal, *Physical Review Letters*, **98**, 015004 (2007).
2. D. Samsonov, S.K. Zhdanov, R.A. Quinn, S.I. Popel, and G.E. Morfill, Shock melting of a two-dimensional complex plasma, *Physical Review Letters*, **92** (25), 255004 (2004).
3. D. Samsonov, J. Goree, H.M. Thomas, and G.E. Morfill, Mach cone shocks in a two-dimensional Yukawa solid using a complex plasma, *Physical Review E*, **61** (5), 5557-5572 (2000).
4. D. Samsonov, A.V. Ivlev, R.A. Quinn, G. Morfill, and S. Zhdanov , Dissipative longitudinal solitons in a two-dimensional strongly coupled complex (dusty) plasma, *Physical Review Letters*, **88** (9), 095004 (2002), T.E. Sheridan, V. Nosenko, and J. Goree, Experimental study of nonlinear solitary waves in two-dimensional dusty plasma, *Physics of Plasmas*, **15**, 073703 (2008).
5. D. Samsonov, S. Zhdanov, and G. Morfill , Vertical wave packets in a crystallized hexagonal monolayer complex plasma, *Physical Review E*, **71**, 026410 (2005).