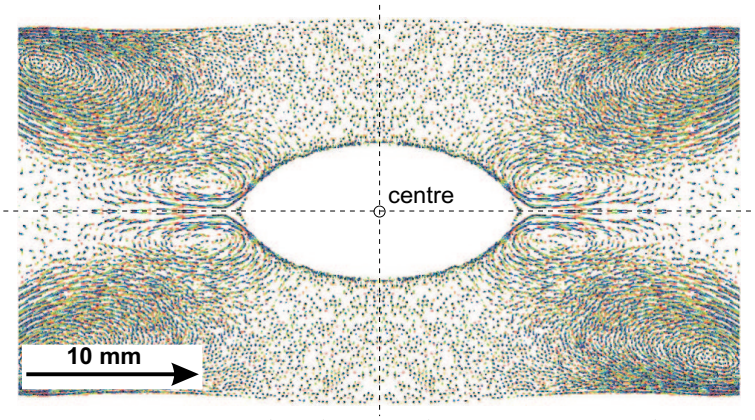
Plasma Crystal Experiments on the International Space Station

ABSTRACT:

The Plasma Crystal Experiment PKE-Nefedov, the first basic science experiment on the International Space Station (ISS) was installed in February 2001 during the assembly phase of the ISS by the first permanent crew. It is designed for long-term investigations of complex plasmas under microgravity conditions. "Complex plasmas" contain ions, electrons and small solid particles - normally in the micrometer range. These microparticles obtain thousands of elementary charges by their interaction with the free electrons and ions and interact with each other via a "screened" Coulomb potential. (The Coulomb field is screened by a spatial rearrangement of ions and electrons.) These complex plasmas are of special interest, because they can form strongly coupled liquid and crystalline plasma states, ther so-called plasma crystals, and are observable at the kinetic level. In experiments on Earth the microparticles are usually suspended against gravity in strong electric fields e.g. in the sheath of the plasma. This creates asymmetries, stresses and pseudo-equilibrium states with sufficient free energy to become unstable readily. Under microgravity conditions the microparticles move in the bulk of the plasma [3], experiencing much weaker volume forces than on Earth. This allows investigations of the thermodynamics of strongly coupled plasma states under substantially stress free conditions.

The first set of experiments, the so-called "basic experiments", performed during three missions in March, May and October 2001 by the first permanent crew and two taxi mission crews on the ISS, were designed to study the complex plasmas over a broad range of parameters. Monodispersive systems and binary mixtures were investigated at different Argon pressures and rf-powers. The neutral gas pressure was adjusted between 0.1 and 1.0 mbar in five steps where it was kept constant by a pressure control system. At each pressure, measurements were performed at five rf-power (forward) steps below 0.3 W. Typical trajectories of the microparticles are shown in the Figure. The form of a complex plasma under microgravity depends strongly on the conditions of the surrounding and the adjusted parameters. In most cases the complex plasma forms around a particle free region, the so-called void (Figure), in the center of our experimental system. Here, the boundary layer is of particular interest - the complex plasma acts as a "porous wall" (solid surface component 0.1%), creating a complicated transition to the particle free plasma via the electrostatic interaction. Along the main vertical axis of the experimental setup the complex plasma forms regular crystalline structures, while at the edges vortex flows can be found.



Trajectories of a complex plasma under microgravity conditions. Clearly visible is the central void, the regular order of the micro particles along the principal axis of the system below and above the void and different vortex flows at the edges.

Besides the intrinsically, with PKE-Nefedov planned experiments on complex plasmas, very interesting phenomena on microparticles in an uncharged gas can be investigated. It was determined, for example, that particles, although injected in a neutral gas, attain positive and negative charges and therefore agglomerate electrostaticly and form large objects which can grow in short times. This could have great influence on the understanding of processes which occur in the early phase of planet formation, for example, or in the mesosphere of our Earth (aerosols).

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