Complex Plasma Research in Microgravity

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Complex plasmas are considered the soft matter state of plasmas. They are generated by injecting micrometer-sized grains, typically made from plastic, into a low temperature noble gas discharge. Typical ionization fractions of the plasma are low, in the range of 10^{-7}-10^{-8}. As soon as the grains get in contact with the plasma, they get charged by the flows of electrons and ions to their surface. Due to the higher mobility of the electrons the particle charge is usually negative and can reach several thousand elementary charges. The neutral gas component provides a weak damping of the particle motion by friction.

The charged particles interact with each other via a screened Coulomb potential, and can form gaseous, liquid or solid states. Since the particles are individually visible, their atomistic dynamics are virtually undamped and it is possible to generate huge systems with up to 10^9 particles, complex plasmas provide a new experimental approach for fundamental studies of strong coupling phenomena with fully resolved dynamics at the individual particle level.

On ground, gravity compresses the system and prevents the generation of larger, three-dimensional particle clouds. Therefore, research in microgravity conditions, e.g. on parabolic flights, sounding rockets or the International Space Station (ISS) is necessary. Since 2001, complex plasma laboratories are operated on the ISS, starting with PKE-Nefedov (2001-2005), PK-3 Plus (2006-2013) and most recent PK-4 which was launched in 2014.

The research topics include, amongst others, studies of waves, fluid regimes and instabilities in complex plasmas. Here, some recent results of experiments on phase transitions and phase separation, conducted with the PK-3 Plus laboratory (Fig. 1) on board the ISS, will be presented: Phase transitions in three-dimensional complex plasmas, especially the fluid-solid transition observed during freezing and melting of a large particle cloud [1], could be observed and studied on the individual particle level, yielding insights into the underlying processes. Recently, the behavior of binary complex plasmas has been investigated, where particles of different sizes are inserted into the plasma simultaneously. This leads to phase separation [2], similar to the demixing of e.g. water and oil. With complex plasmas, demixing could now be studied on the “atomistic” level for the first time.

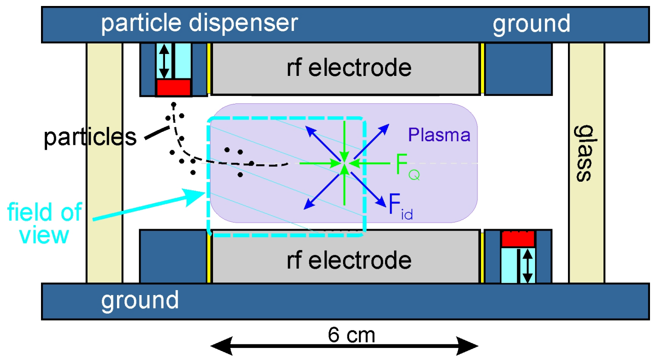

FIG. 1. The plasma chamber of the PK-3 Plus setup. Plasma is generated between two parallel electrodes by HF-signals to the electrodes. Particles are injected by dispensers build into the grounded guard-rings. The blue and green arrows inside the plasma indicate the confining electrical force and the ion drag force acting outwards on the grains.

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