Strongly coupled complex plasmas under microgravity conditions on the International Space Station

H.M. Thomas

Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), 51147 Köln, Germany

The Coulomb coupling parameter Γ is defined as the ratio of the Coulomb interaction between neighbouring charged particles to their kinetic energy. Normal plasmas are weakly coupled with $\Gamma << 1$. Strongly coupled plasmas where $\Gamma > 1$ can be achieved either by very low temperatures, by very small distances or by very high charges of the interacting particles. The latter appears if small solid particles are injected into a normal plasma and therefore are charged to thousands of elementary charges on a micrometre-sized particle through the interaction with the surrounding electrons and ions. The charge is mainly determined by the kinetic temperature of the electrons and is proportional to the particles' radius. If the density of the charged particles is large enough so that the distance between neighbouring particles is of the order of the Debye screening length, the coupling can be very strong and the microparticle component can show liquid or even crystalline behaviour. This is the transition from a pure plasma to a classical condensed matter system – the complex plasma – where the charged microparticles surrounded by the plasma medium represent a new form of soft matter.

Gravity strongly influences the complex plasma, the microparticles sediment to the lower plasma sheath where they are levitated, if the electric field is strong enough to compensate gravity. To perform experiments in the homogeneous and charge neutral bulk of the plasma microgravity experiments are performed in specially designed plasma laboratories on the International Space Station ISS since 2001. The current lab PK-4, a bilateral project of Russia and Europe with science members from all over the world, uses a dc-discharge allowing to investigate fluid and flowing complex plasmas [1]. Recent results cover the transition from fluid to string fluid – the formation of electrorheological effects in complex plasmas – and its reaction on wave propagation and induced shear forces. All of this can be investigated at the most fundamental kinetic level due to the large size and mass of the microparticles. These slow down the microparticle plasma frequency to easily observable 10s of Hertz and allow the direct observation of individual particles by video microscopy.

In this presentation I will review important and the most recent results from 20 years of microgravity experiments on complex plasmas on the ISS and will discuss the perspectives for future research.

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[1] Pustylnik et al., Rev Sci. Inst. 87, 093505; doi: 10.1063/1.4962696 (2016)