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Crystallization in three-dimensional complex plasmas

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Complex plasmas are low-temperature plasmas in which microparticles are embedded. The microparticles are illuminated with a laser sheet, and their movement is traced in time and space using high speed digital cameras. This allows studying their dynamics on the most basic level, that of the individual particles. Moving the laser sheet through the system makes three-dimensional investigations possible by recording several slices in succession in a tomographic procedure.
The microparticles in the plasma get strongly charged by collecting unequal amounts of ions and electrons from the surrounding plasma. They acquire mean charges of several thousands of electrons. Thus, they strongly interact with each other. When the interaction strength is much larger than the microparticles' kinetic temperature, the microparticles arrange in ordered structures, and a 'plasma crystal' forms. Under gravity conditions, these crystals are stressed by the strong forces required to counteract gravity, and plasma-specific instabilities easily induce melting. Under microgravity, however, the microparticles are suspended in the bulk of the plasma, where the ion fluxes are small, and the fluid-solid phase transition is realized via a generic mechanism that is common to a wide range of materials [1].
Here, we give an overview over crystallization experiments in complex plasmas with an emphasis on data recorded with the PK-3 Plus Laboratory that was hosted on board the International Space Station until 2013 [2]. This laboratory was very versatile [3-5], but its main goal was to study crystallization, with 32 experiments dedicated to this topic. Crystallization or melting were typically induced by changing the neutral gas pressure, but could also be caused by changes in the particles charges [6], or, in the case of melting, by shaking a plasma crystal with an electric field.
This last method was applied to induce crystallization fronts by melting a preformed plasma crystal incompletely and studying the recrystallization process. We study the three-dimensional propagation of these crystallization fronts: By performing repeated short scans through the system, we find the three-dimensional position of the fronts and determine their propagation velocity. We use both conventional analysis of the microparticle dynamics and novel techniques developed by C. Dietz et al. [7] to accurately identify the crystalline and fluid regions. Figure 1 shows the borders of the crystalline regions recorded at two planes displaced by 0.8 mm. The colors indicate different instances of time, visualizing the spread of the crystallization front.

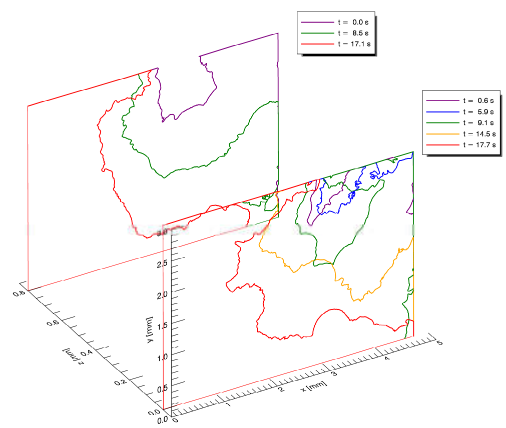

Figure 1: Borders of crystalline regions in a complex plasma. Two planes displaced in space are shown. The colors mark different instants of time.

References
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