IAF MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2)
Microgravity Sciences on board of Space stations (6)

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GRAVITATIONALLY TAPPING COLLOIDS IN SPACE (GTACS - SEDIMENTING COLLOIDS)

Abstract

Gravitational particle sedimentation is omnipresent in academia and industry. For non-Brownian particles, which are dominated by gravity rather than thermal forces, large nonequilibrium (NE) velocity fluctuations arise during sedimentation. Theory predicts their unbounded growth, whereas experiments find an upper limit to their size, as particles organize into swirls to screen out the long-range hydrodynamic interactions. This disagreement goes as divergence paradox, a conflict that remains theoretically unexplained.

On the other hand, NE concentration fluctuations can arise in fluids kept/brought out of equilibrium by the application of an external concentration (or temperature) gradient. It has been predicted, although not confirmed experimentally, that these fluctuations are reduced through the sedimentation of Brownian particles due to the quenching effect of the sedimentation flux on spontaneous equilibrium velocity fluctuations above a certain size.

The ESA-ESTEC GTACS - Sedimenting Colloids project aims to understand the connection between NE velocity fluctuations of non-Brownian particles and NE concentration fluctuations in Brownian particle suspensions during sedimentation exploiting the unique capabilities of the FLUMIAS (FLUorescence MIcroscopic Analysis in Space) platform on the International Space Station, which combines high-resolution imaging with a rotational platform enabling to tune the effective gravity between 1g and microgravity. This will allow investigation of the same particles across different sedimentation regimes, providing a comprehensive characterization of the interplay between equilibrium and NE fluctuations during transients and at steady state. The project aims at implementing and integrating in FLUMIAS complementary quantitative microscopy and image analysis methods like Differential Dynamic Microscopy, Particle Tracking, and Particle Image Velocimetry to study the NE fluctuations by acquiring time-lapse movies

of the fluctuations. Development and testing of the required image analysis software, optimization of the acquisition protocols, and fine-tuning of the microscope optical settings represent the focus of the ongoing ground-based research activity, funded by the Italian Space Agency.

Sedimentation is key in several important man-related activities ranging from water purification to phase separation. For this reason, understanding the role of fluctuations during sedimentation is crucial to planning processes and activities with the required degree of safety and reliability. This is more than a theoretical expectation, as the ESA-GRADFLEX experiment, devoted to the study of NE fluctuations in stressed fluids, showed how concentration fluctuations can become extremely long-lived in microgravity conditions, which may impact for example protein crystallization or aggregation. Similarly, the absence of gravity may impact the outcome of all processes that depend on sedimentation as an intermediate step.