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NON-EQUILIBRIUM PHENOMENA IN SOFT MATTER AND COMPLEX FLUIDS (NESTEX)

Abstract

Non-equilibrium phenomena in soft matter and complex fluids typically involve the development of large amplitude density fluctuations or macrostructures that span large spatial scales. This interplay significantly influences the static and dynamic statistical properties of out-of-equilibrium systems, especially in complex fluids where processes such as crystallization, aggregation, sedimentation, and convection are strongly impacted by Earth's gravitational force. The ESA-CMSA NESTEX project aims to conduct experiments on complex fluids under non-equilibrium conditions through a collaboration between European and Chinese partners, utilizing platforms on the International Space Station and the Chinese Space Station. ESA's "Colloidal Solids" and "Giant Fluctuations" projects will contribute innovative optical diagnostics to be deployed on the ISS from 2025.

The Giant Fluctuations project's flight instrumentation will include four two-color quantitative shadowgraph diagnostics coupled with thermal gradient cells. Its main goal is the investigation of nonequilibrium fluctuations in complex liquids under conditions not adequately described by current theoretical models. This involves exploring transient states, concentrated samples, and large gradients.

The Colloidal Solids diagnostics will integrate "standard" wide and small angle scattering lines with newly developed scattering lines, based on Time Resolved Correlation (TRC) and Photon Correlation Imaging (PCI) techniques. These diagnostics will be coupled with an infrared laser capable of optothermally stimulating water-based samples. These tools will be employed to investigate growth kinetics,

microscopic dynamics, and restructuring processes in ordered and disordered systems like colloidal crystals, glasses, and gels.

On the Chinese side, projects such as "Colloid aggregation and phase transition study under microgravity" and "Study on the glass transition and rheological behavior of colloids under microgravity" are developing a multi-diagnostic platform. This platform includes techniques like visible light spectrometry, wide-angle light scattering, turbidity, microscopy, and rheometry.

Beyond giving a general introduction to the international ESA-CMSA project, in this presentation we will provide an overview of the on-ground research activities funded by the Italian Space Agency (ASI). These ground-based activities focus on comprehensively understanding Earth's gravity's influence on the nonequilibrium processes studied in space. Exploratory experiments with colloidal and polymeric samples, along with flight-like optical diagnostics, aim to characterize the effect of Earth's gravity on samples under nonequilibrium conditions.

Enhancing our understanding of complex fluids under non-equilibrium conditions will not only contribute to fundamental scientific knowledge, but is also strategically vital for space exploration with long-term space missions, affecting the processing of fluid materials like food, fuels, chemical reagents, and detergents.