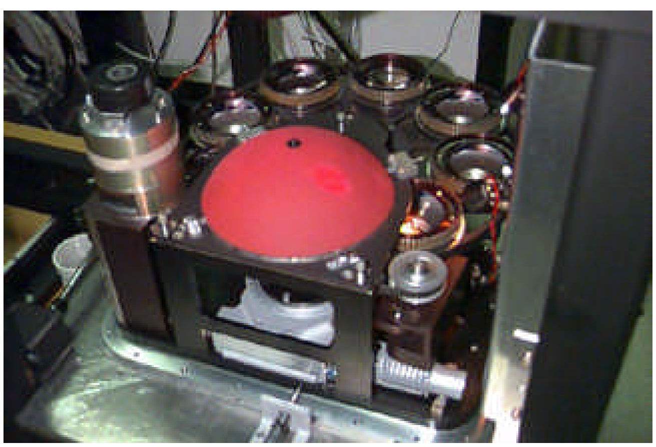
Physics of Hard Spheres Experiment (PhaSE) or "Making Jello in Space"

The Physics of Hard Spheres Experiment (PHaSE) is a highly successful experiment that flew aboard two shuttle missions to study the transitions involved in the formation of jellolike colloidal crystals in a microgravity environment. A colloidal suspension, or colloid, consists of fine particles, often having complex interactions, suspended in a liquid. Paint, ink, and milk are examples of colloids found in everyday life. In low Earth orbit, the effective force of gravity is thousands of times less than at the Earth's surface. This provides researchers a way to conduct experiments that cannot be adequately performed in an Earth-gravity environment. In microgravity, colloidal particles freely interact without the complications of settling that occur in normal gravity on Earth. If the particle interactions within these colloidal suspensions could be predicted and accurately modeled, they could provide the key to understanding fundamental problems in condensed matter physics and could help make possible the development of wonderful new "designer" materials. Industries that make semiconductors, electro-optics, ceramics, and composites are just a few that may benefit from this knowledge.

Atomic interactions determine the physical properties (e.g., weight, color, and hardness) of ordinary matter. PHaSE uses colloidal suspensions of microscopic solid plastic spheres to model the behavior of atomic interactions. When uniformly sized hard spheres suspended in a fluid reach a certain concentration (volume fraction), the particle-fluid mixture changes from a disordered fluid state, in which the spheres are randomly organized, to an ordered "crystalline" state, in which they are structured periodically. The thermal energy of the spheres causes them to form ordered arrays, analogous to crystals. Seven of the eight PHaSE samples ranged in volume fraction from 0.483 to 0.624 to cover the range of interest, while one sample, having a concentration of 0.019, was included for instrument calibration.

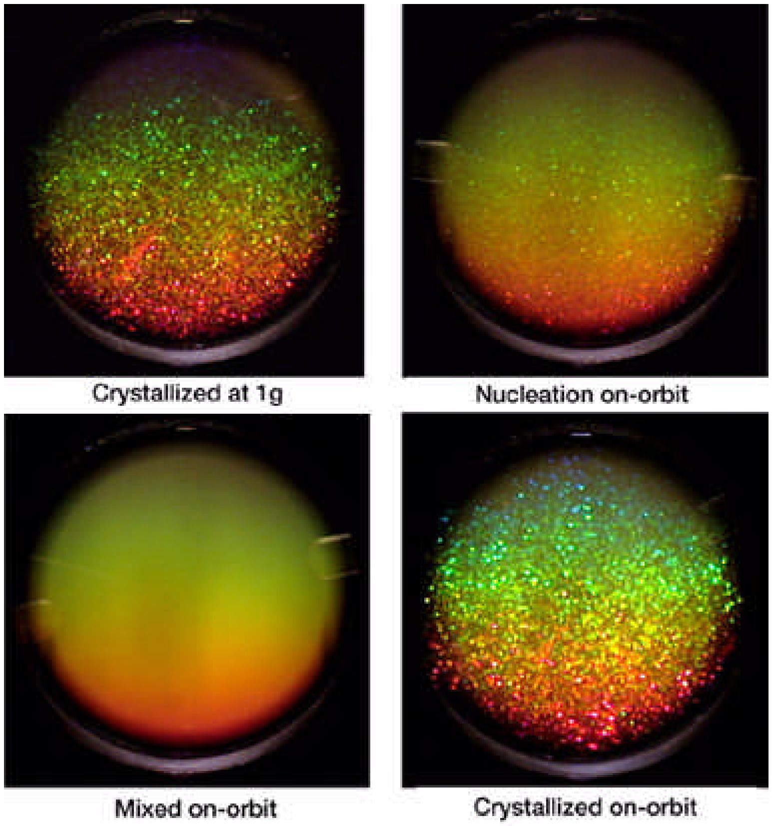


Interior view of PHaSE test section.

The hardware that housed the experiment included a complex state-of-the-art optics system, the experiment samples, cameras, fiber optics, temperature sensors, and the motor drives necessary to control the experiment. The preceding photo shows an interior view of the test section, including the carousel of eight sample cells, a Bragg imaging screen, cell mixing and positioning motors, and lights for photography. Not visible are the dynamic and static light-scattering systems, the color CCD (charge couple discharge) camera for digital imaging, and the avionics.

PHaSE flew in an EXPRESS rack (EXpedite the PRocessing of Experiments to Space Station) on the first Microgravity Science Laboratory (MSL-1), onboard Columbia during shuttle missions STS-83 and STS-94. The experiment was conceived by Professors Paul M. Chaikin and William B. Russel with Research Scientist Dr. Jixiang Zhu, all of Princeton University. The hardware and software were designed, built, and tested by NYMA, Inc., and Aerospace Design & Fabrication (ADF) at the NASA Lewis Research Center in Cleveland, Ohio.

Several novel light-scattering techniques were used to gather data from experiment samples. The investigative team compared these data with measurements performed under normal gravity to discern the equilibrium behavior from the effects due to gravity, as well as to determine the structure of the crystalline phase, the dynamics of crystal growth, the viscosity of the disordered phase, the elasticity of the ordered phase, and the nature and appearance of the glass transition. The following illustration shows a chronological series of digital images of a sample in various stages of crystallization both on Earth in normal gravity and in microgravity. In normal gravity, the dominant crystal structure appears to have a face-centered cubic orientation with irregularities in successive layers. In microgravity, however, the dominant structure appears to have a random hexagonal-close-packed orientation with very little face-centered cubic orientation present. Preliminary data also suggest that the crystallization process is accelerated in microgravity at lower sample concentrations. Because of the quantity of data obtained during this very successful experiment, postflight data analysis will continue during the next year.



Digital images of an STS-94 PHaSE sample with a volume fraction of 0.528.

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Headquarters program office: OLMSA
Programs/Projects: HEDS, Microgravity Science, STS-83, STS-94, MSL-1