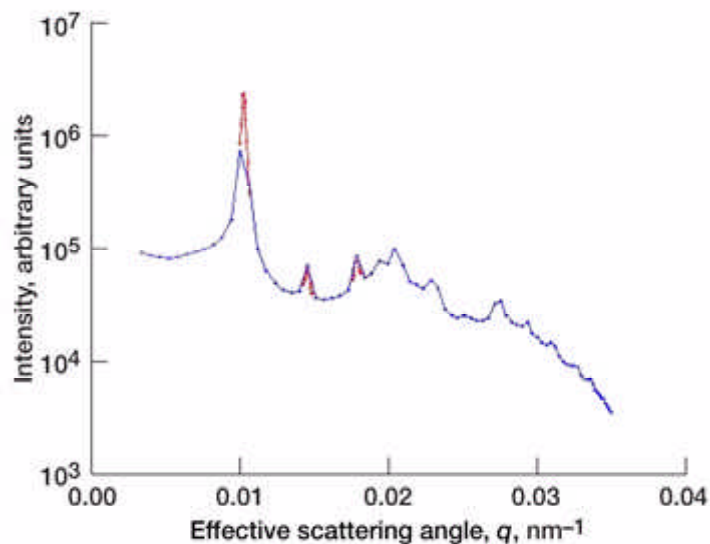
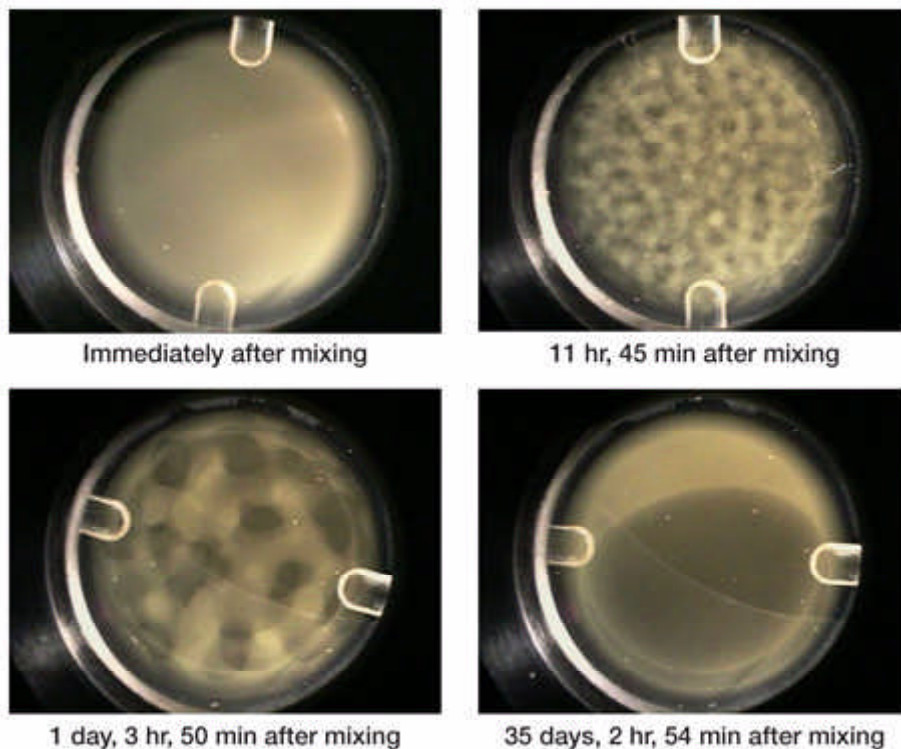


Physics of Colloids in Space (PCS): Microgravity Experiment Completed Operations on the International Space Station



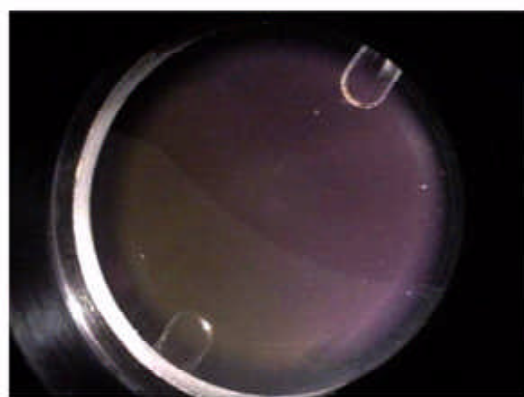
Diffraction pattern from the AB6 binary colloidal crystal alloy; 11 days, 4 hr after melting; q , effective scattering angle.

Long description of figure 1 A diffraction pattern of the AB6 binary colloidal crystal alloy was taken 11 days and 4 hours after sample homogenization (melting) using the fiber-static scattering diagnostic. Because of the large accessible q -range (corresponding to the 11° to 169° angular range for fiber scattering) many Bragg peaks are observable for this sample, enabling detailed structure analysis. Growth and coarsening of crystals is measured from the time evolution of the height and width of these peaks.

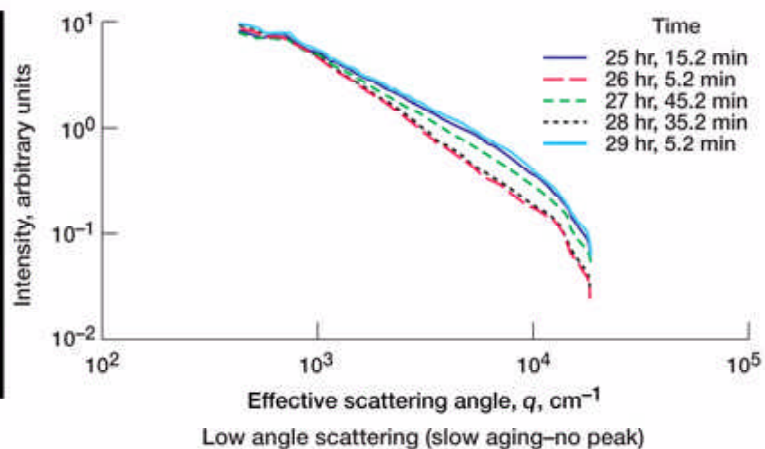


Phase separation of the colloid-polymer critical point sample.

Long description of figure 2 Immediately after mixing, the two-phase-like colloid-polymer critical point sample begins to phase separate, or de-mix, into two phases—one that resembles a gas and one that resembles a liquid, except that the particles are colloids and not atoms. The colloid-poor black regions (colloidal gas) grow bigger, and the colloid-rich white regions (colloidal liquid) become whiter as the domains further coarsen. Finally, complete phase separation is achieved, that is, just one region of each colloid-rich (white) and colloid-poor (black) phase. This process was studied over four decades of length scale, from 1 micrometer to 1 centimeter.

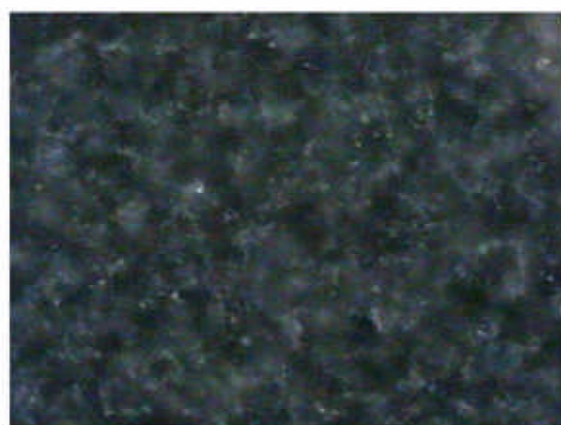


1 day, 23 hr, 40 min after mixing

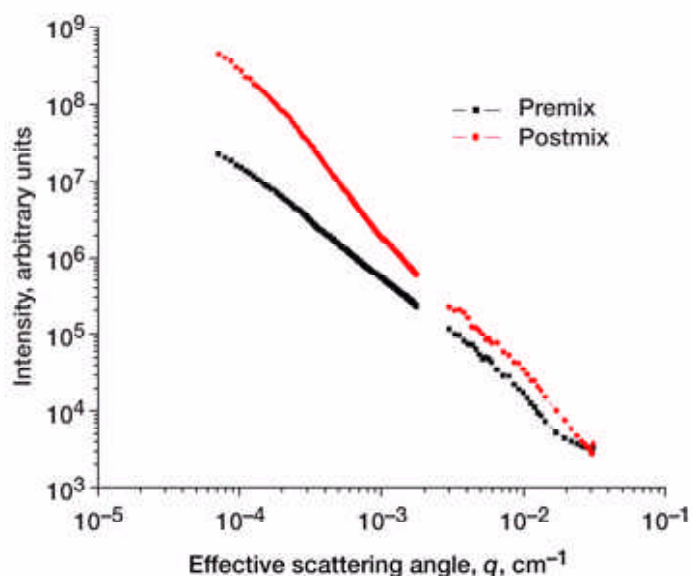


Gelation and aging of colloid-polymer gel sample.

Long description of figure 3 The study of the aging of the colloid-polymer gel reveals that once the gel network spans the sample cell and the fluid no longer flows (i.e., gelation is complete), the gel ages. Aging refers to the evolution of the gel's structure and to its internal motions during that time. This gelation and aging scenario is much like the hardening of jello on Earth-- the gel structure forms rapidly, but the gel network continues to evolve (become stiffer). The figure shows a photograph 1 day, 23 hr, 40 min after mixing, and a graph of low angle scattering (slow aging--no peak)--intensity versus effective scattering angle for times of 25 hr, 15.2 min; 26 hr, 5.2 min; 27 hr, 45.2 min; 28 hr, 35.2 min; and 29 hr, 5.2 min



Polystyrene gel



Aggregation behavior of polystyrene fractal gel sample. Left: Polystyrene gel-high-magnification image taken 10 days after constituent combination, showing aggregation occurring. Right: Polystyrene gel-static light scattering performed both before and after constituent combination; a tremendous increase in scattered light occurs.

Long description of figure 4 The fractal gel samples were composed of colloids that gel in an irreversible manner when a salt is added to initiate their on-orbit investigation. The polystyrene fractal gel, which had a very low volume fraction, produced very interesting results, allowing measurement of the internal vibrational modes of the fractal structure, even though it did not fully gel. The image on the left is a high-magnification image of the polystyrene gel taken 10 days after constituent combination, showing aggregation occurring, and the image on the right shows the increase in scattered light intensity in this sample upon constituent combination. This extremely dilute gel allowed an exploration of

the crossover from a gel to a fluid filled with large clusters--a regime impossible to study in 1g.

The Physics of Colloids in Space (PCS) experiment was accommodated within the International Space Station (ISS) Expedite the Processing of Experiments to Space Station (EXPRESS) Rack 2 and was remotely operated from early June 2001 until February 2002 from NASA Glenn Research Center's Telescience Support Center in Cleveland, Ohio, and from a remote site at Harvard University in Cambridge, Massachusetts. Remote operations enabled a significant number of hours of run time for this experiment with just a small number of ISS crew hours expended. PCS is an experiment conceived by principal investigator Professor David A. Weitz of Harvard University and coinvestigator Peter N. Pusey of the University of Edinburgh. It focused on the behavior of three different classes of colloidal suspensions (binary colloidal crystal alloys, colloid-polymer mixtures, and fractal gels). A colloidal suspension consists of fine particles (micrometer to submicrometer) suspended in a fluid, examples being paint, milk, salad dressings, and aerosols. The potential payoffs of PCS are improvements in the properties of paints, coatings, ceramics, and food- and drug-delivery products; improved manufacturing of products requiring either colloidal suspensions for processing or as precursors; and important first steps in the research and development of an entirely new class of materials that passively affect the properties of light passing through them. The sophisticated light-scattering instrumentation comprising PCS is capable of color imaging, dynamic and static light scattering from 11° to 169° , Bragg scattering from 10° to 60° , and laser light scattering at low angles from 0.3° to 6.0° . The PCS instrumentation performed remarkably well on orbit, demonstrating a flexibility that enabled experiments to be performed that had not been envisioned prior to launch.

While on-orbit on the ISS, PCS completed 2400 hours of science operations, and the principal investigator declared it to be a resounding success. Each of the eight sample cells worked well and produced interesting and important results. Crystal nucleation and growth and the resulting structures of two binary colloidal crystal alloys were studied, with the long-duration microgravity environment of the ISS facilitating extended studies on the growth and coarsening characteristics of the crystals. In another experiment run, the demixing of the colloid-polymer critical point sample was studied as it phase-separated into two phases, one that resembled a gas and one that resembled a liquid. This process was studied over four decades of length scale (from $1\ \mu\text{m}$ to $1\ \text{cm}$) to observe behavior that could not be seen in this sample on Earth because sedimentation would cause the colloids to fall to the bottom of the cell faster than the demixing process could occur. To acquire this data, the PCS science and operations teams codesigned and coexecuted a unique diagnostic sequence that captured and condensed the first 16 hr of this sample's demixing into a 7-s time-lapse movie. In addition, the study of the gelation and aging of another colloid-polymer sample, the colloid-polymer gel, provided valuable information on gelation mechanisms, as did investigations on the extremely low concentration silica and polystyrene fractal gel samples. In virtually all cases, we enhanced our understanding of the science being investigated.

The PCS experiment was developed, launched, and operated by Zin Technologies under

NASA contract NAS3-99154. PCS was deorbited in June 2002. The hardware will be replenished with another set of eight colloidal samples and is planned for relaunch in 2003.

Find out more about this research:

Glenn's PCS research (includes data on a sample-by-sample basis--being updated)

<http://microgravity.grc.nasa.gov/6712/pcs.htm>

David Weitz at Harvard (introduces the principal investigator)

<http://www.physics.harvard.edu/weitz.htm>

Principal investigator's group at Harvard (scientific focus areas of interest)

<http://www.deas.harvard.edu/projects/weitzlab/>

Glenn's microgravity research <http://microgravity.grc.nasa.gov/>

Glenn's fluid physics research <http://exploration.grc.nasa.gov/life/>

Glenn contact: Michael P. Doherty, 216-433-6641, Michael.P.Doherty@nasa.gov

National Center for Microgravity Research contact: Dr. Subramanian Sankaran, 216-433-9335, Subramanian.Sankaran@grc.nasa.gov

Authors: Michael P. Doherty and Dr. Subramanian Sankaran

Headquarters program office: OBPR

Programs/Projects: Microgravity Science