



Advanced Colloids Experiment (ACE)

Science Overview

(ASGSR Meeting – Orlando, FL)

Friday, November 8, 2013
Crystal Room, 4:40 – 5:00 pm



Bill Meyer - presenting
(a.k.a. – William V. Meyer, Ph.D.)
BCAT and ACE NASA Project Scientist
USRA at NASA-GRC
Email: William.V.Meyer@NASA.Gov,
Tel.: (216) 433-5011

BCAT-5 Slow Growth Sample Module in a window of the International Space Station (ISS)



A 3-minute movie on BCAT-5 science follows:



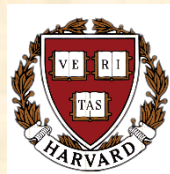
Why Microscopy?

Fundamental science and colloidal engineering can be pursued and understood directly at both the macroscopic level and the microscopic level - the particle level. For example: BCAT vs. ACE.

We call the bridge between the macroscopic and microscopic theory – or understanding in theory.



Advanced Colloids Experiment (ACE)



Procter & Gamble





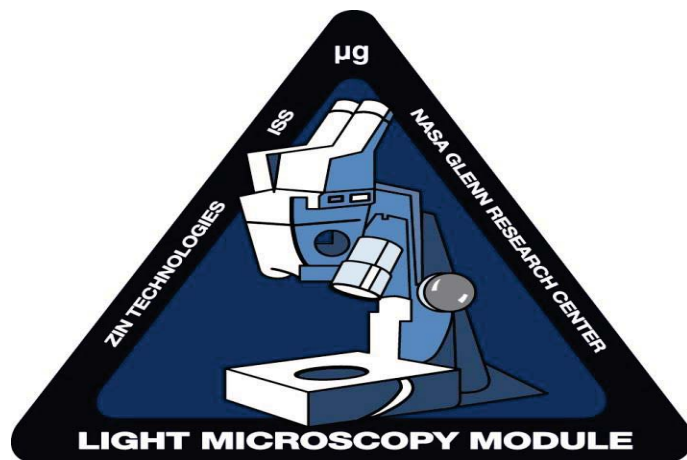
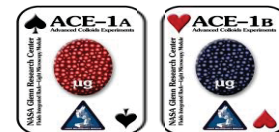
Enabling Soft-Condensed Matter Microgravity Research Fundamental Science and Engineering Research at the Particle Level



Advanced Colloids Experiment (ACE)



Light Microscopy Module (LMM) and the Advanced Colloids Experiment (ACE)



Fluid Integrated Rack (FIR) and Light Microscopy Module launched Aug 2009.

Assembly and checkout complete January 2011.

Then used for the CVB experiment.

LMM is being built-up in phases and used for colloids and biology research.



Previous ACE-1 Science Team Members (1/4)

Science Team Members:

Key Personnel [Affiliation] / Role	Contact Information (Contacts listed in alphabetical order)
Prof. Paul Chaikin [NASA Team: NYU] PI / Provide flight samples, science requirements, and data analysis	Professor of Physics, Department of Physics New York University, 607 Meyer Hall 4 Washington Place at Broadway; New York, NY 10003 Tel: 212-998-7694; Fax: 212-995-4016; chaikin@nyu.edu
Dr. Andrew Hollingsworth [NASA Team: NYU] Co-I / Provide flight samples, science requirements, and data analysis	Research Scientist, Department of Physics New York University 4 Washington Place - Office 826; New York, NY 10003 Tel: 212-998-8428; andrewdh@nyu.edu
Prof. David Pine [NASA Team: NYU] Co-I / Provide flight samples, science requirements, and data analysis	Professor of Physics, Department of Physics New York University, 601 Meyer Hall 4 Washington Place at Broadway; New York, NY 10003 Tel: 212-998-7744; Fax: 212-995-4016; Pine@nyu.edu
Dr. Stefano Sacanna [NASA Team: NYU] Co-I / Provide flight samples, science requirements, and data analysis	Research Scientist, Department of Physics New York University 4 Washington Place - Office 826; New York, NY 10003 Tel: 212-998-8460; S.Sacanna@nyu.edu
Prof. Nadrian (Ned) Seeman [NASA Team: NYU] Co-I / Provide flight samples, science requirements, and data analysis	Professor of Chemistry, Department of Chemistry New York University New York, NY 10003 Tel: 212-998-8395; Ned.Seeman@nyu.edu



Previous ACE-1 Science Team Members (2/4)

Science Team Members (continued):

Key Personnel [Affiliation] / Role	Contact Information (Contacts listed in alphabetical order)
Dr. Matthew Lynch [NASA Team: P & G] PI / Provide flight samples, science requirements, and data analysis	Principal Scientist, Colloid and Surfactant Laboratory Procter & Gamble Company Beckett Ridge Technical Center 8256 Union Centre Boulevard, West Chester, OH 45069 Tel: (513) 634-9644; Fax: (513) 634-9944; lynch.ml@pg.com
Thomas Kodger [NASA Team: P & G and Harvard] Co-I / Provide flight samples, science requirements, and data analysis	Research Scientist, Department of Physics Harvard University, McKay 517 17 Oxford Street; Cambridge, MA 02138 Tel: 617-460-7659; tkodger@fas.harvard.edu
Prof. David Weitz [NASA Team: Harvard] PI / Provide flight samples, science requirements, and data analysis	Mallinckrodt Professor of Physics and of Applied Physics, Department of Physics Harvard University, Pierce 231 29 Concord Street; Cambridge, MA 02138 Tel: 617-496-2842; weitz@physics.harvard.edu
Dr. Peter Lu [NASA Team: Harvard] Co-I / Provide flight samples, science requirements, and data analysis	Research Scientist, Department of Physics Harvard University, McKay 517 17 Oxford Street; Cambridge, MA 02138 Tel: 216-337-4981; plu@fas.harvard.edu
Prof. Arjun Yodh [NASA Team: U. Penn] PI / Provide flight samples, science requirements, and data analysis	James M. Skinner Professor of Science Director, Laboratory for Research on the Structure of Matter Department of Physics and Astronomy University of Pennsylvania; Philadelphia, PA 19104-6396 Tel: 215-898-6354; Fax: 215-898-2010; yodh@physics.upenn.edu
Dr. Peter Yunker [NASA Team: U. Penn] Co-I / Provide flight samples, science requirements, and data analysis	Research Scientist, Department of Physics & Astronomy University of Pennsylvania Philadelphia, PA 19104-6396 Tel: 832-545-8561; peter.yunker@gmail.com



Previous ACE-1 Science Team Members (3/4)

Science Team Members (continued):

Key Personnel [Affiliation] / Role	Contact Information (Contacts listed in alphabetical order)
Prof. Roberto Piazza [ESA Team: Milan and Montpellier] Co-PI / Provide flight samples, science requirements, and data analysis	Professor of Condensed Matter Physics Politecnico di Milano Dipartimento di Ingegneria Nucleare Ponzio 34/3 -20133 MILANO Tel: +39-02-2399-6386; Fax: +39-02-2399-6309; roberto.piazza@polimi.it
Dr. Stefano Buzzaccaro [ESA Team: Milan and Montpellier] Co-PI / Provide flight samples, science requirements, and data analysis	Professor, Dipartimento di Chimica, Materiali e Ingegneria Chimica Politecnico di Milano - Sede Ponzio Edificio Ce.S.N.E.F. - Soft Condensed Matter Lab via Ponzio 34/3, 20133 MILANO (Italy) Tel: +39-0223996361/6337; Fax +39-0223996309; stefano.buzzaccaro@mail.polimi.it
Prof. Luca Cipelletti [ESA Team: Milan and Montpellier] Co-PI / Provide flight samples, science requirements, and data analysis	Professor, Laboratoire des Colloïdes Verres et Nanomatériaux (UMR CNRS-UM2 5587), CC26, Université Montpellier 2, 34095 Montpellier Cedex 5, France Tel: +33 4 67 1 435 89; luca.cipelletti@univ-montp2.fr



Previous ACE-1 Science Team Members (4/4)

Science Team Members (continued):

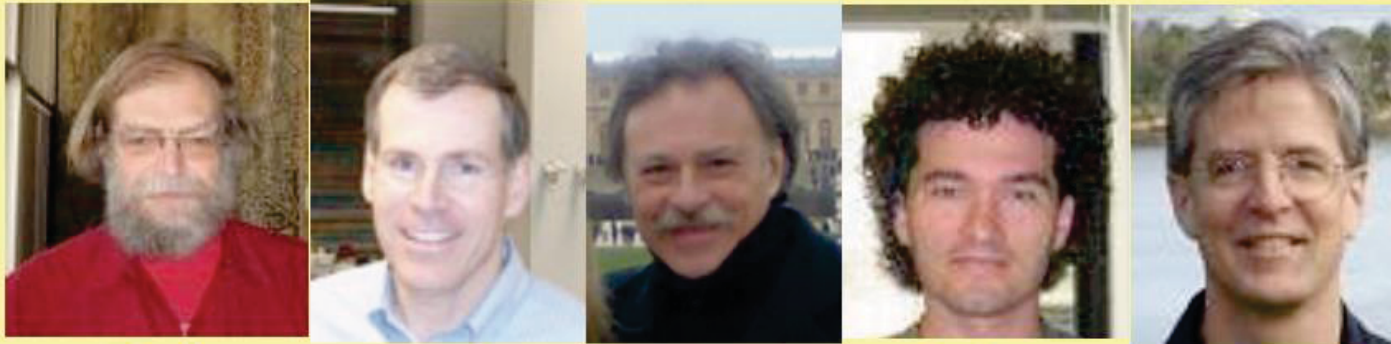
Key Personnel [Affiliation] / Role	Contact Information (Contacts listed in alphabetical order)
Prof. Peter Schall [ESA Team: UvA and Milan] Co-PI / Provide flight samples, science requirements, and data analysis	Professor of Physics, <i>Van der Waals-Zeeman Institute</i> Universiteit van Amsterdam, Science Park 904, C2 Room 228 1098 XH Amsterdam, The Netherlands Tel: +31-20-525-6314; Fax: +31-20-525-5788; ps@peterschall.de
Dr. Marco A. C. Potenza [ESA Team: UvA and Milan] Co-PI / Provide flight samples, science requirements, and data analysis	Research Scientist, Dipartimento di Fisica Università di Milano and INFN, Via Celoria, 16, Milano I-20133, Italy Tel: +39-02-503 17209 - v. Celoria, 16; Fax: +39-02-503-17712; marco.potenza@unimi.it
Dr. Sandra Veen [ESA Team: UvA and Milan] Co-PI / Provide flight samples, science requirements, and data analysis	Research Scientist, <i>Van der Waals-Zeeman Institute</i> Universiteit van Amsterdam, Science Park 904, C4 Room 226 1098 XH Amsterdam, The Netherlands Tel: +31-20-525-5966; Fax: +31-20-525-5788; s.j.veen@uva.nl
Prof. Gerard Wegdam [ESA Team: UvA and Milan] Co-PI / Provide flight samples, science requirements, and data analysis	Professor of Physics, <i>Van der Waals-Zeeman Institute</i> Universiteit van Amsterdam, Science Park 904, C4 Room 239 1098 XH Amsterdam, The Netherlands Tel: +31-20-525-6313; Fax: +31-20-525-5788; g.h.wegdam@uva.nl
Prof. Chang-Soo Lee [S. Korean Team: CNU] PI / Provide flight samples, science requirements, and data analysis	Professor of Chemical Eng., Department of Chemical Engineering School of Engineering, 1-258 Chungnam National University Daejeon, Korea Tel: 82-42-821-5896; rhadam@cnu.ac.kr



The investigation goals and
objectives
for 7 **ACE** science teams follow:



New York University (NYU) ACE-1 science team



Ned
Seeman

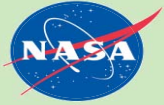
Andy
Hollingsworth

Paul
Chaikin

Stefano
Sacanna

Dave
Pine

Center for Soft Matter Research – New York University (NYU)



NYU investigation goals and objectives (1/2)

In General:

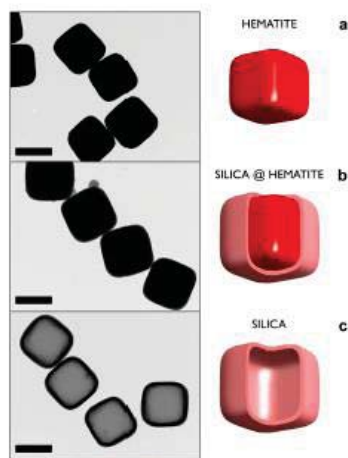
- Fundamental studies of Order, Frustration: the role of shape on structure.
- Technologies for complex processes: self-assembly, motility, toward self-replication.

In Detail:

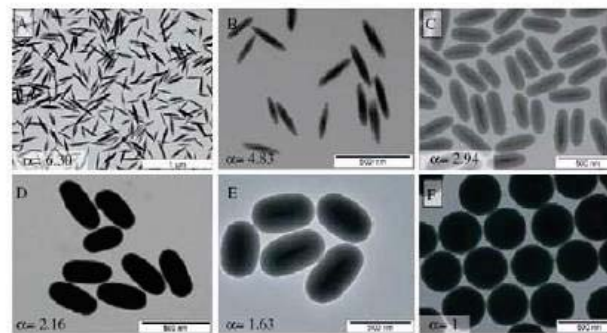
- Ellipsoids, Cubes, DNA functionalized particles, Lock and Key particles, 2-3-4 particle clusters.
- Order-disorder phase diagrams.
- Exotic Phases - Cubatic, Rotator, Quasicrystal, Soft rotation mode glass, Colloidal polymer w & w/o branching.
- Self-assembly - Crystals designed from specific DNA mediated interactions, Assembly of dissimilar particles with Lock & Key, Swimmers as active mixers and superdepletants, Self-replication of sequenced colloidal seeds.

NYU investigation goals and objectives (2/2)

particles with shape and specific attractions

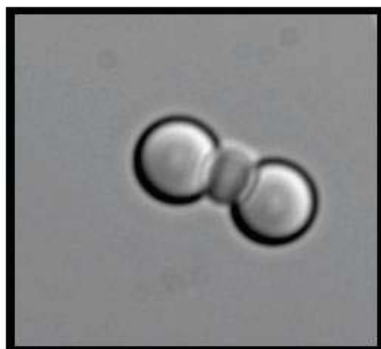
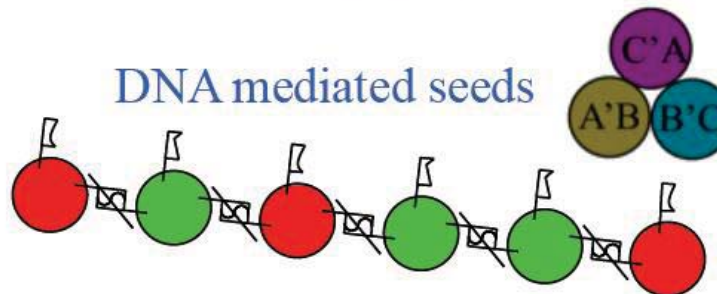


Cubes

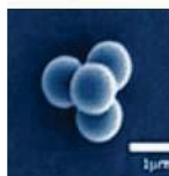


Ellipsoids

DNA mediated seeds



Pacmen

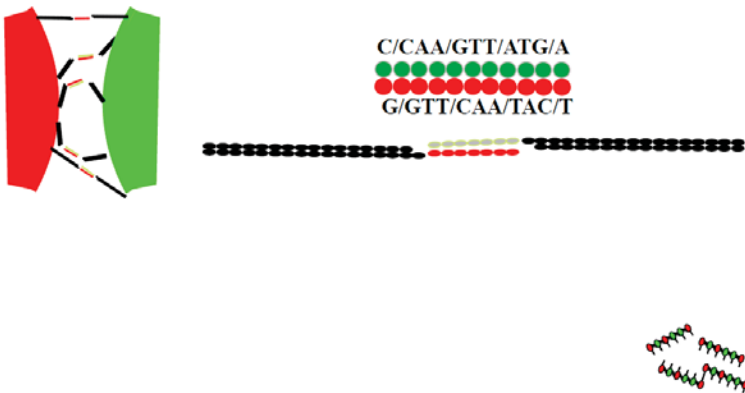


Tetra clusters

Expected results and how the expected results will advance the field

We want specificity, control and reversibility in interactions

Specific Interactions with DNA

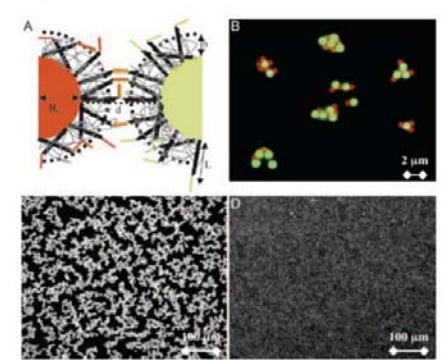


PNAS | March 22, 2005 | vol. 102 | no. 12 | 4225-4229

Reversible self-assembly and directed assembly of DNA-linked micrometer-sized colloids

Marie-Pierre Valignat^a, Olivier Theodoly^a, John C. Crocker^a, William B. Russel^b, and Paul M. Chaikin^{a,c}

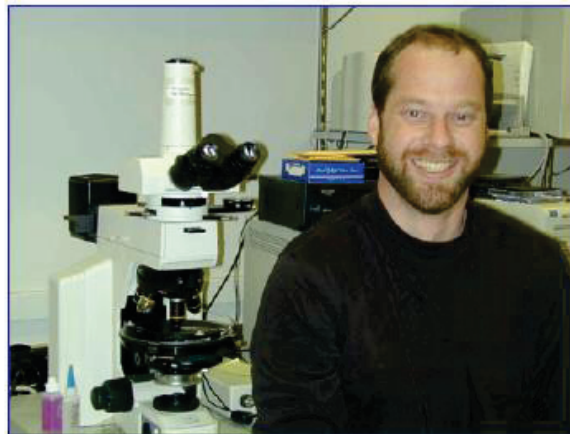
Departments of ^aPhysics and ^bChemical Engineering, Princeton University, Princeton, NJ 08544; ^cComplex Fluids Laboratory, Unité Mixte de Recherche 166 Centre National de la Recherche Scientifique/Rhodia, CN 7500, Cranbury, NJ 08512; and ^dDepartment of Chemical and Biomolecular Engineering, University of Pennsylvania, Philadelphia, PA 19104



Developing the understanding and know-how needed to get “billions” of particles to self-replicate and self-assemble in a controlled fashion.



Procter & Gamble (P&G) ACE science team

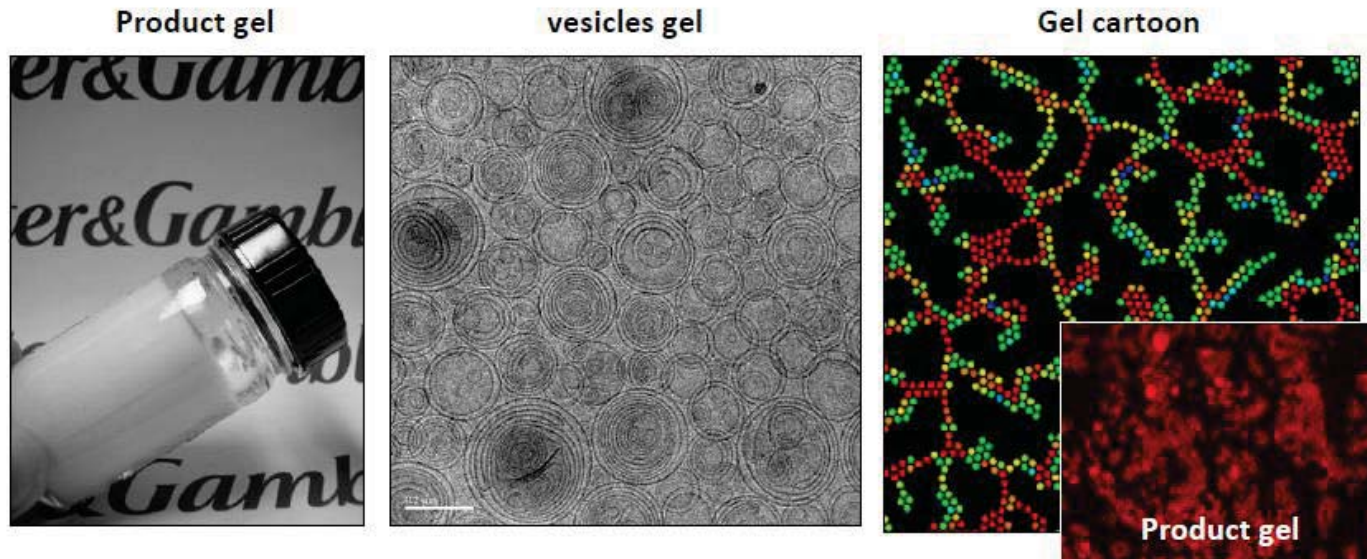


Dr. Matt Lynch
Corporate Research Division
Procter & Gamble Company



Tom Kodger
Applied Physics
Harvard University

P&G investigation goals and objectives



Colloidal gels define the microstructure of materials, including consumer products. This often determines the product shelf life.

Polydisperse (real-world) systems are complicated and not well understood. To control these systems, an understanding of the evolution (coarsening) of microstructure is required.

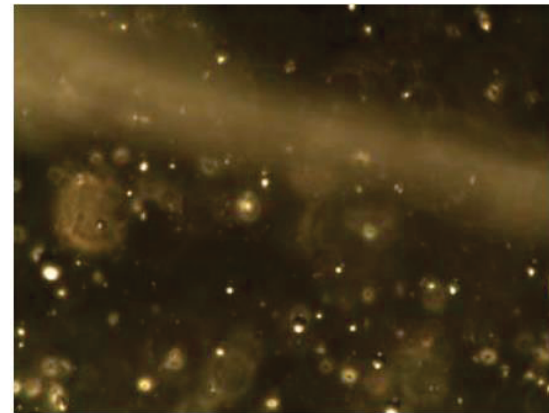


Earth benefits/spin-off applications

For Procter & Gamble (P&G):

- Product shelf-life extended
- Product quality enhanced
- Production cost lowered (stabilizers are expensive)
- Transportation cost reduced (by concentrating essence)

Dispersed 1-micron spheres in water



P&G spent 2 plus years with LANL and UCSB with high-powered computers to model this behavior ... no luck!

Why this work with colloids is important: we have

- Weakly-attractive systems - phase separation
- Strongly-attractive systems - gelation or crystallization
- Frontiers of soft-squishy colloids (soft - very cool)

Dr. Matt Lynch
Principal Scientist
Corporate Research Division
Procter & Gamble Company



Advanced Colloids Experiment (ACE)-M1

Science Objective

(Decadal Survey Area Complex Fluids, FP1 and AP 5):

To remove gravitational jamming and sedimentation and then use a microscope to observe

- colloidal engineering (the effects of polydispersity),
- to control phase separation to improve product shelf-life and quality.

Application:

ACE-M-1 – Launch SPX-2:

- Extending product shelf-life is a multi-billion \$ concern for P&G. (Lynch, P&G Principal Scientist works with NASA through a Space Act Agreement)
- Colloidal gels define the microstructure of materials, including consumer products. This often determines the product shelf life.
- Polydisperse (real-world) systems are complicated and not well-understood. To control these systems, an understanding of the evolution (coarsening) of microstructure is required.



Above: Dr. Matthew Lynch (P&G Principal Scientist), and ACE-M1 NASA Principal Investigator (PI), along with Chris Lant (ZIN-Technologies optics engineer), ground-testing the ACE-M1 hardware and software, while also testing a next generation confocal microscope for possible use in microgravity aboard the International Space Station(ISS).

icle level:

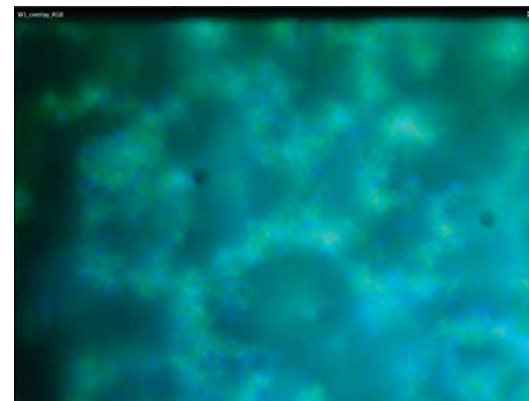


ACE-M-1

Advanced Colloids Experiment-M-1 (ACE-M1)

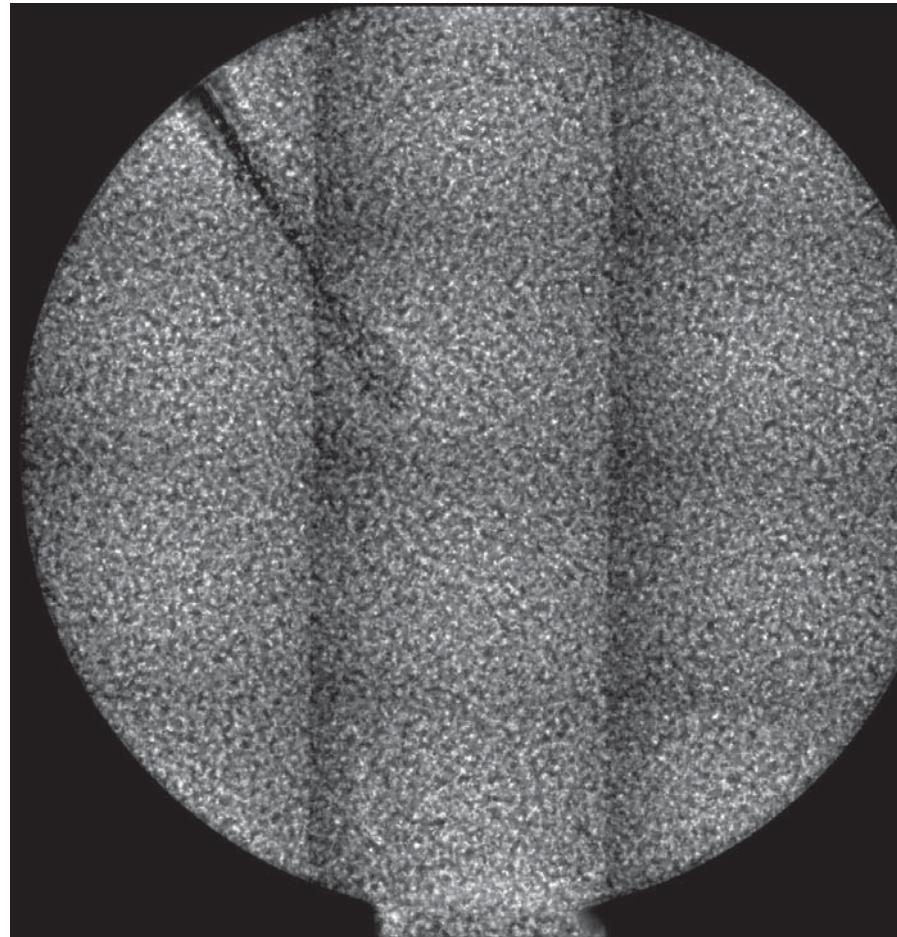
PI: Dr. Matthew Lynch -
The Procter and Gamble Company (P&G)
Co-I: Tom Kodger - Harvard

The present experiment on ISS is returning pleasant surprises. Two sizes of stabilizer particles with a size difference of 20% are behaving quite differently in microgravity. The larger particles are building scaffolding (they are product stabilizers) and the 20% smaller particles are swarming about. This is visible in 37MB movie, which is provided on jump drive to keep this document from swelling. On Earth, in normal gravity, this behavior is not evident.



Above: Single frame from short movie showing different behavior visible in microgravity for two sizes of P&G product stabilizer. Each of the two sizes has been fluorescently dyed a different color (false-colored blue and green by Co-I, who made the particles, and who is color-blind for other colors.)

*10X/0.3 mosaic of S5
at 75 μm depth
5 h after mix, FITC
filter, Flight GMT/274*



10/30/2013



FITC, 63X oil

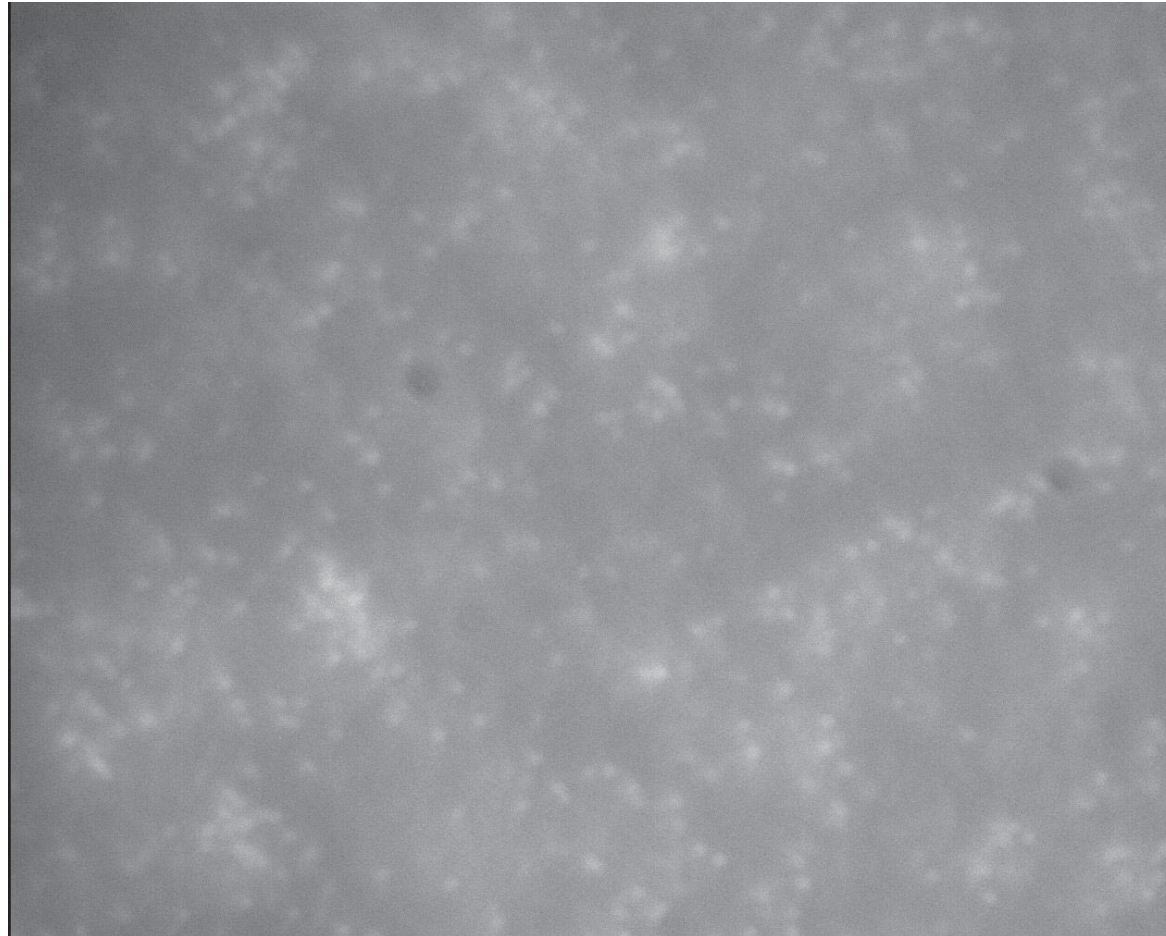
Flight LMM 9/17/13 - S4 FITC.00001_00490





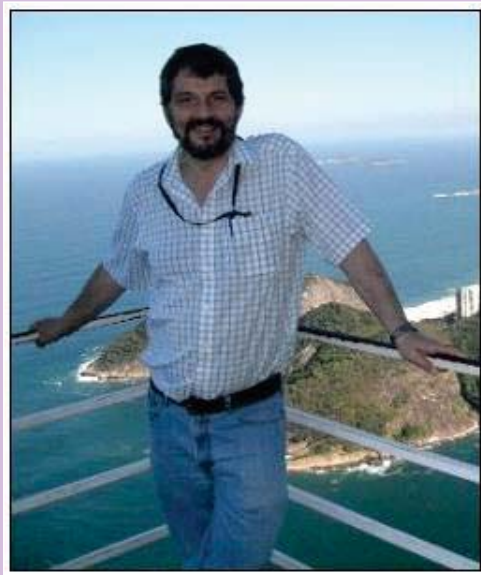
Flight LMM 9/17/13 - S4 TxR.00001_00990

TxR, 63X oil





Harvard ACE science team





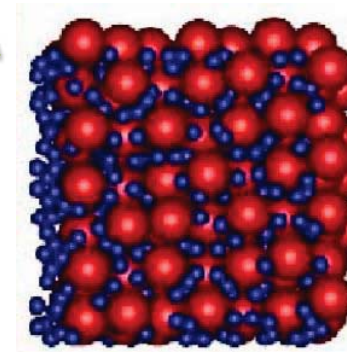
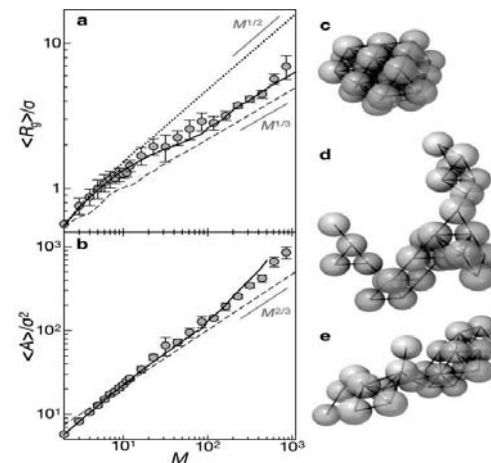
David Weitz



Peter Lu

Harvard investigation goals and objectives (1/2)

- **Crystal nucleation** 
Nucleation rates orders of magnitude different from simulation
Proper kinetics require no sedimentation
- **Binary crystallization**
Cannot buoyancy-match two types of spheres in the same solvent
- **New material crystals**
Photonic band-gap crystals require high refractive index (high density)
- **Phase separation beyond BCAT**
Morphological characterization of interfaces
- **Gels in μg (picture on next page)** 



Harvard investigation goals and objectives (2/2)

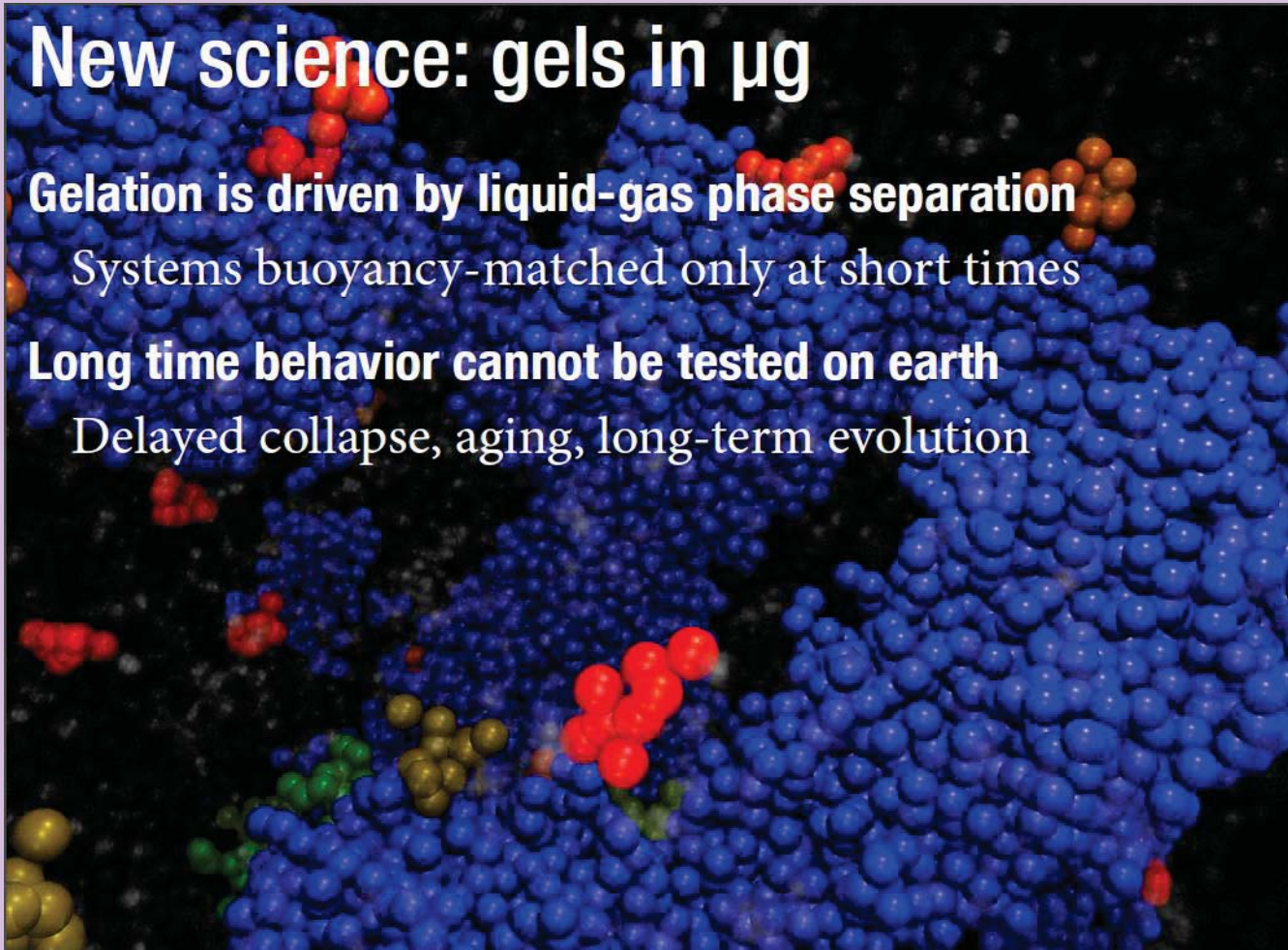
New science: gels in μg

Gelation is driven by liquid-gas phase separation

Systems buoyancy-matched only at short times

Long time behavior cannot be tested on earth

Delayed collapse, aging, long-term evolution





University of Pennsylvania (U. Penn) ACE science team



Arjun Yodh



Matthew Lohr



Matthew Gratale



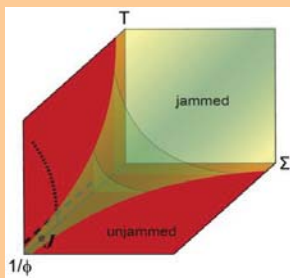
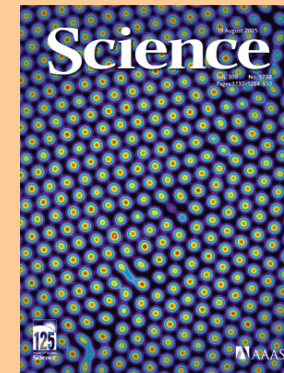
U. Penn investigation goals and objectives (1/2)

- Assembly of Anisotropic Particles
- Disorder-induced Crystal-Glass Transitions
- Jamming Phenomenology
- Without temperature-sensitivity (ACE-M), use index-matched (core-shell/soft) particles at various volume fractions to map basic effects (dynamical and structural).
- With temperature-sensitivity (ACE-H), use index-matched core-shell PS/PMMA-NIPA particles to much more fully map basic effects.

U. Penn investigation goals and objectives (2/2)

Swellable Particles are Swell

- **Melting in 3D, 2D, Thin Films, & quasi-1D (cylinders)**
(Science, 2005; PRE, 2008; PRL, 2010; PRE, 2010)
- **Freezing Criteria in 2D (JCP, 2010)**
- **Colloidal Antiferromagnets (Nature, 2008)**
- **Aging in Glasses (PRL, 2009)**
- **Crystal-Glass Transition (PRL, 2010)**
- **Jamming: Structural Signatures (Nature, 2009)**
- **Jamming: Shadow Systems, Phonon Density of States (PRL, 2010)**





Earth benefits/spin-off applications



“The coffee ring effect is very common in everyday experience,” Yunker said. “To avoid it, scientists have gone to great lengths designing paints and inks that **produce an even coating** upon evaporation. We found that the effect can be eliminated **simply by changing the shape of the particle.**”

[Peter J. Yunker](#), [Tim Still](#), [Matthew A. Lohr](#) , and [A. G. Yodh](#),

Nature 476, 308–311 (18 August 2011).

http://penn.museum/events-calendar/details/599-penn-science-cafe-the-coffee-ring-effect.html?utm_source=twitter&utm_medium=tweet&utm_campaign=socialmedia



Milan / Montpellier ACE science team



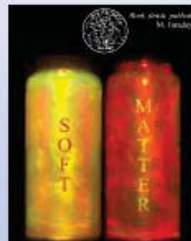
Roberto Piazza



Stefano Buzzaccaro

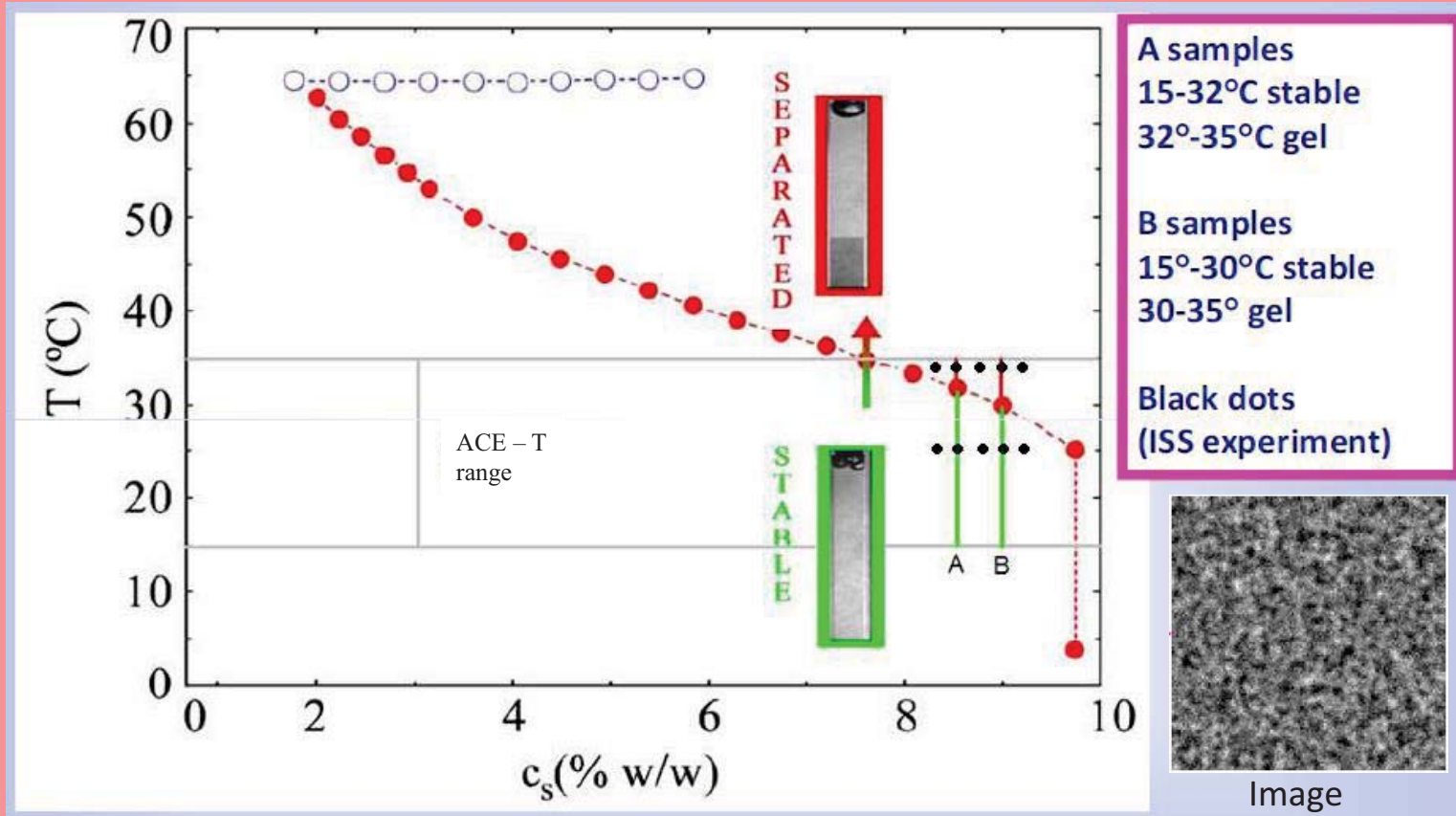


Luca Cipelletti



Milan / Montpellier investigation goals and objectives

Birth, structure and evolution of depletion gels in μ -gravity





University of Amsterdam (UvA) and Milan ACE science team



Dr. Sandra Veen
(Amsterdam)



Dr. Marco Potenza
(Milan)



Prof. Gerard Wegdam
(Amsterdam)



Prof. Peter Schall
(Amsterdam)

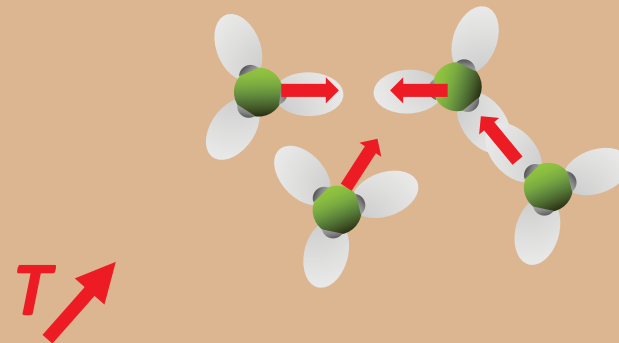


UvA / Milan investigation goals and objectives

Study Critical Casimir effect

Use temperature control

- Attraction on/off
- Follow structure formation
- "Reaction kinetics"



Vary Temperature → Vary attraction strength

Vary Rate of change → Equilibrium vs. out-of-equilibrium

Reverse Temperature → Repeat Experiment

Image in real + reciprocal space



Chungnam National University (CNU) ACE science team



Prof. Chang-Soo Lee
Department of Chemical Engineering,
Chungnam National University (CNU),
South Korea



Group members involved in this project

- Chang-Hyung Choi
- Jae-Min Jung
- So-Young Han

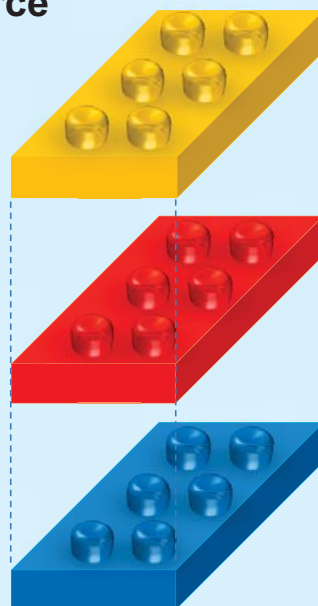
CNU investigation goals and objectives

Microscopic self-assembly

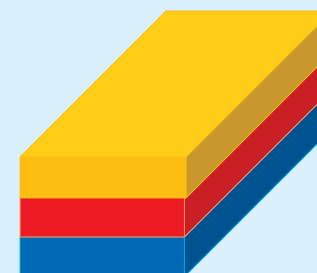
1. Combination of force

2. Shape

3. Topology



Particle assembly



New Functional Materials

Novel building block
“atoms” & “molecules” of tomorrow’s materials

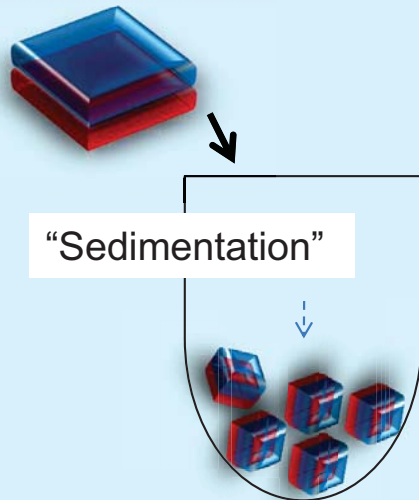
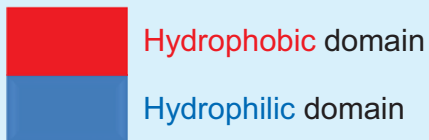
Ref.: Science, 306, 2004

Nature materials, 10, 2011

Microscopic self-assembly

Plan 1

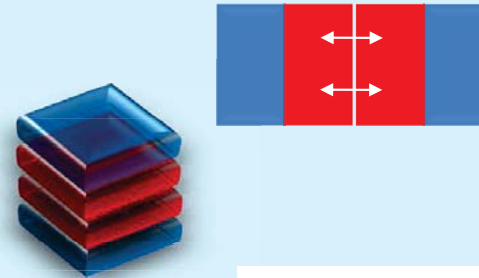
Anisotropic building blocks
(Janus amphiphilie)



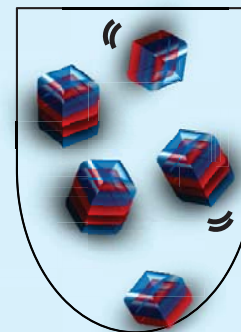
Ground state

Low probability of assembly in the ground state

Programmed assembly for dimers



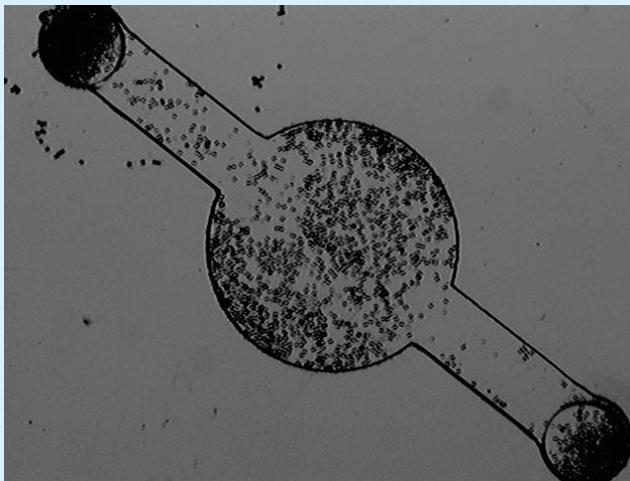
"Self-assembly"



Microgravity

ACE-1A Workhorse wells filled with cylindrical Janus particles

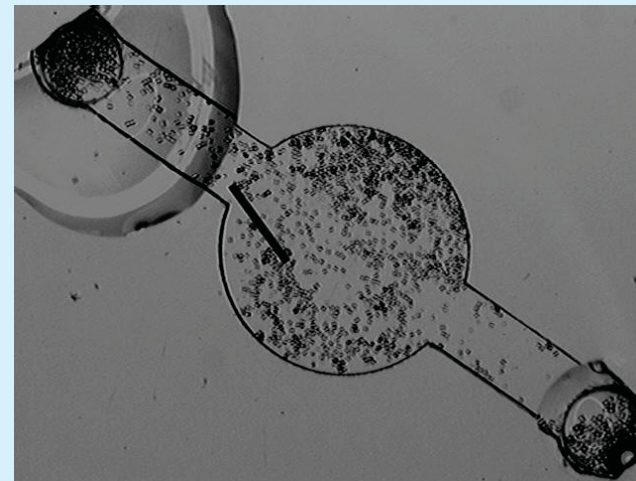
Test filling Professor Lee's samples (CNU – S. Korea)



E111122-5.2ndFill: $\phi = 4\% \pm 1\%$

Fill Notes

- 127,000 particles in 100 μL water
- Swirl-draw bottom
- No bubbles
- Sample well not sealed (practice fill)



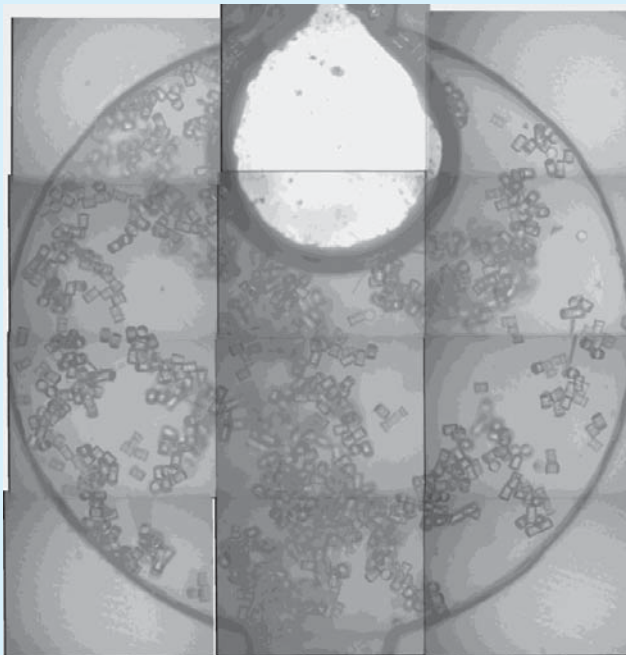
E111122-6: $\phi = 4\% \pm 1\%$

Fill Notes

- 127,000 particles in 100 μL water
- Swirl-draw bottom
- No bubbles
- Sample well not sealed (practice fill)

Successful fill with repeatable volume fraction close to target of (2 - 4%) and clean.

Lock-and-key two-sided (Janus) particles self-assemble in 3D in microgravity



Depicted in the adjacent composite image (on the left) are Janus particles (one of the CNU experiments), which forms unique 3-d structures in microgravity. On Earth, their configurations are confined by gravity to form 2-d structures (when the particle concentration is not so high that they stack). Janus particles are named after the Roman god with two faces. For these Janus particles, one-half of their surface is composed of [hydrophilic](#) groups and the other half of [hydrophobic](#) groups. This lays the foundation for Future ISS work that will use smaller particles to study the kinetics driving self-assembly (in the absence of sedimentation).



NASA Research Announcement (NRA) - 2013 Complex Fluids



Zhengdong Cheng
Texas Engineering
Experiment Station

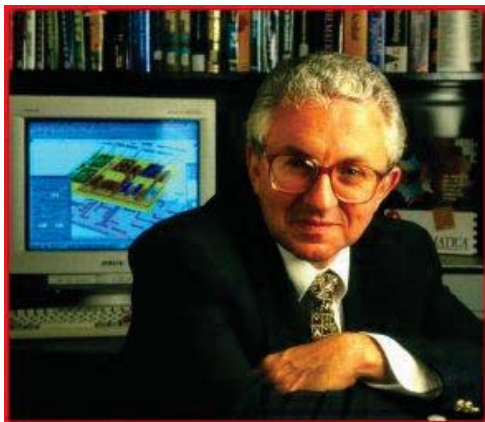
Liquid Crystals of Nanoplates

Investigate the crystallization and self-assembly of disk-shaped particle suspensions, especially the ones that are highly anisotropic in shape, in microgravity and comparing the results with that in gravity.

“Discotics are very interesting systems that offer a rich spectrum of applications once the properties are well understood. A rich set of liquid crystal structures can be obtained through self-assembly of colloidal disks. Claims to be able to make disks of controlled size and aspect ratios. An excellent materials-oriented proposal.”



NASA Research Announcement (NRA) - 2013 Complex Fluids



Boris Khusid
New Jersey Institute of
Technology (NJIT)

Kinetics of electric field-driven phase transitions in polarized colloids

Develop and conduct experiments to elucidate the fundamental microscopic mechanisms and create new strategies and predictive tools to control electrically driven processes in a suspension of interacting colloidal particles.

“This proposal takes full advantage of understanding electric-field induced colloidal assembly in a microgravity environment. The large international team is excellent, with expertise in experiment, theory, and simulation.”



NASA Research Announcement (NRA) - 2013 Complex Fluids

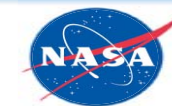


David Marr
Colorado School
of Mines

Fabrication, Crystallization, and Folding of Complex Colloidal Molecules under the Influence of Applied External Fields

Fabricate colloidal molecules of prescribed composition and architecture (on ground); Determine the role of applied electric field in the assembly of achiral and chiral building blocks (on ground and at ISS); Co-assemble, by self- and directed-methods, colloidal chains and tetrameters to produce open double networks with non-linear mechanical properties (on ground and at ISS).

“An extremely creative proposal to study the self-assembly of macromolecules using colloids as molecular analogs. The investigators use anisotropic building blocks and anisotropic fields to generate structures with complex symmetries ...”



NASA Research Announcement (NRA) - 2013 Complex Fluids



Ali Mohraz
University of
California – Irvine
(UCI)

Understanding the Morphology and Stability of Bijels Using Microgravity

Gain a better fundamental understanding of the relationship between the microstructure, rheology, stability, and processability of bijels [bicontinuous interfacially jammed emulsion gels] through synergistic ground-based and microgravity experiments and theoretical calculations.

“Understanding the underlying mechanism for the formation of bijels could lead to a robust synthesis platform for bulk micro-structured hybrid materials. Bijel systems using particle stabilization are quite novel; it is very probable that experiments in microgravity along with ground-based experiments will lead to materials with very significant applications.”



NASA Research Announcement (NRA) - 2013 Macromolecular Biophysics



Larry DeLucas
U. Alabama – Birmingham
(UAB)

The Effect of Macromolecular Transport on Microgravity Protein Crystallization

Compare incorporation of protein aggregates into growing protein crystals on ISS and on earth; Measure crystal growth rates in 1g versus μg for different size aggregates of proteins; compare the defect density and crystal quality via fluorescent-based atomic force microscopy and x-ray diffraction quality of crystals grown at different rates in a 1g environment.

“A highly specialized international team proposes to investigate systematically the impact of microgravity on the quality and size of protein crystals. Several characterization methods are considered. The proposal has several innovative aspects”



NASA Research Announcement (NRA) - 2013 Macromolecular Biophysics



Amir Hirs
Rensselaer
Polytechnic
Institute (RPI)

Amyloid fibril formation in microgravity: Distinguishing interfacial and flow effects

Investigate the influences of flow and fluid interfaces on the amyloid formation process. The study of protein amyloid fibrils formation also provides a model for studying biomolecular transport phenomena. Furthermore, the experiments can be performed aboard the ISS with essentially no container [using a ring sheared drop flow apparatus.] "... could have a high impact on the understanding of neurodegenerative diseases such as Alzheimer's and Parkinson's. Expertise in both theory and experiments as well as strong preliminary data suggest the proposed work will be successful. ..."

[May use OASIS flight hardware]



NASA Research Announcement (NRA) - 2013 Macromolecular Biophysics



Edward Snell
Hauptman Woodard
Medical Research
Institute, Inc.

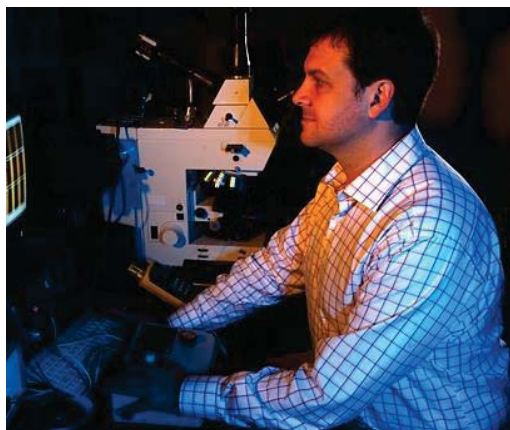
Growth Rate Dispersion as a Predictive Indicator for Biological Crystal Samples Where Quality Can be Improved with Microgravity Growth

Test the hypothesis that the presence of growth rate dispersion in macromolecular crystals grown on the ground is an indicator of crystals that can be improved when grown in microgravity.

“Aims to perform a systematic investigation of the effect of growth rate dispersion on crystal quality, with the goal of predicting which proteins may benefit from microgravity crystallization. ...”



NASA Research Announcement (NRA) - 2013 Macromolecular Biophysics



Peter Vekilov
University Houston (UH)

Solution convection and the nucleation precursors in protein crystallization

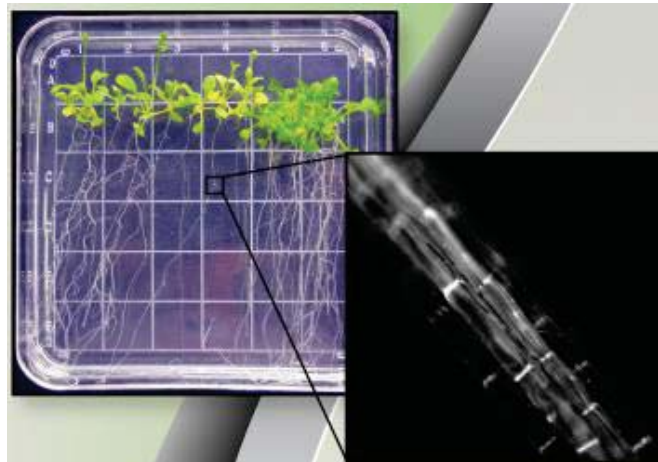
Explore the effects of a hitherto unstudied factor for the nucleation of protein crystals: solution shear flow: Test if shear flow affects the concentration and properties of the nucleation precursors and establish the mechanisms of these effects; Test if shear flow assists nucleation inside the dense liquid clusters; Test if the perfection of protein crystals can be improved by controlling nucleation via solution flow.

“Address nucleation and the role of solution flow on the process of nucleation, a key problem in protein crystallization. ...”

CARA/Petri Plant use of the LMM to see the expression of fluorescent tags.



Anna-Lisa Paul and Rob Ferl
U. of Florida



Fluorescent image of Arabidopsis (stem) taken during LMM ground-testing for CARA/Petri Plant demonstration planned for the SpaceX-3 mission.⁸



NASA Research Announcement (NRA) Biology

- Space Biology NRA (2014,2015,2016 ...)
Research Opportunities in Space Biology.
- The ILSRA is untitled as of yet.... But it's the solicitation that falls under: International Space Life Science Working Group (ISLSWG)-- Space Life Sciences. We anticipate this to be out in 2014.

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Space Life and Physical Sciences Research Division
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Space Processes and Experiments Division

Several teams of international partners are planning experiments using the Light Microscopy Module (LMM) for colloids research on the International Space Station (ISS).

For more information regarding these international collaborations with NASA, please contact:

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