ACE1

SCIENCE OVERVIEW

Peter J. Lu and David A. Weitz (Harvard University)

14 June 2011

Colloid Science Program Goals

Develop new discipline of “colloid engineering”

Fabricate new materials with colloidal precursors

Study fundamental behavior of colloids

Extend to earth-based applications

Train scientific experts in complex fluids

Enhance US competitiveness

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Harvard NASA colloids researchers

Urs Gasser, Suliana Manley, Rebecca Christianson, Peter J. Lu, Vikram Prasad

Peter J. Lu
(STS 134)

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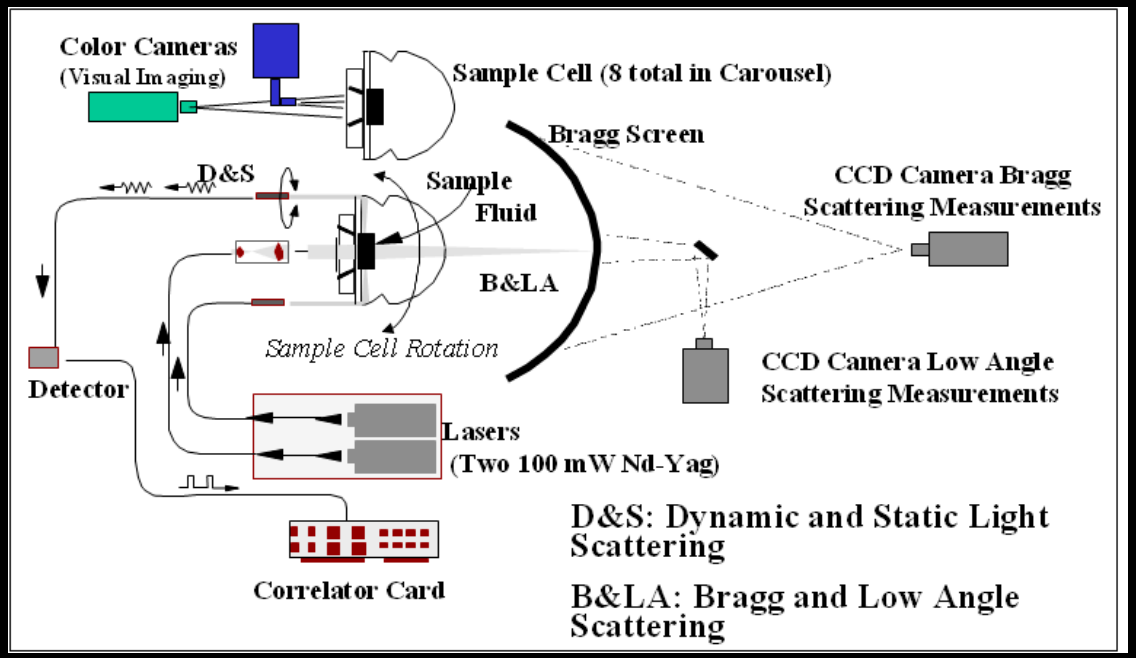
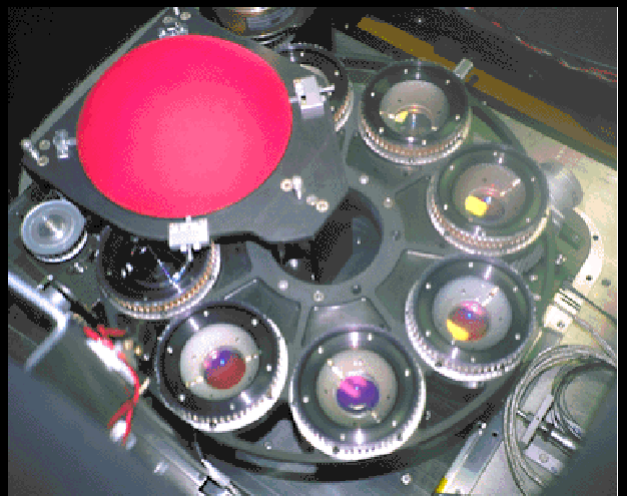
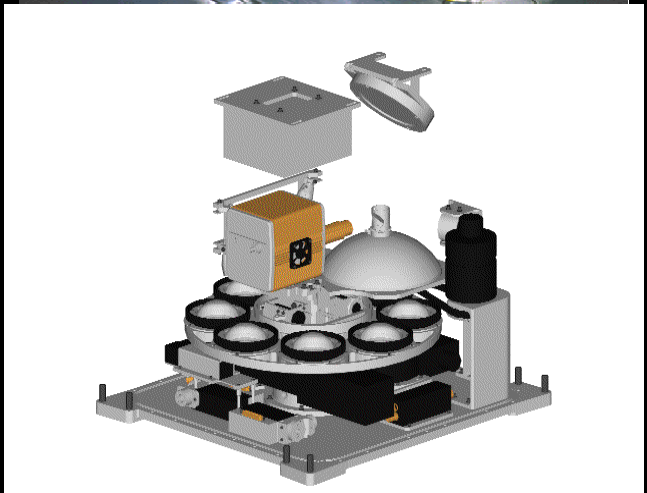
Physics of Colloids in Space (PCS)

Part of NASA fluids program, ISS Express Rack (2001-2)







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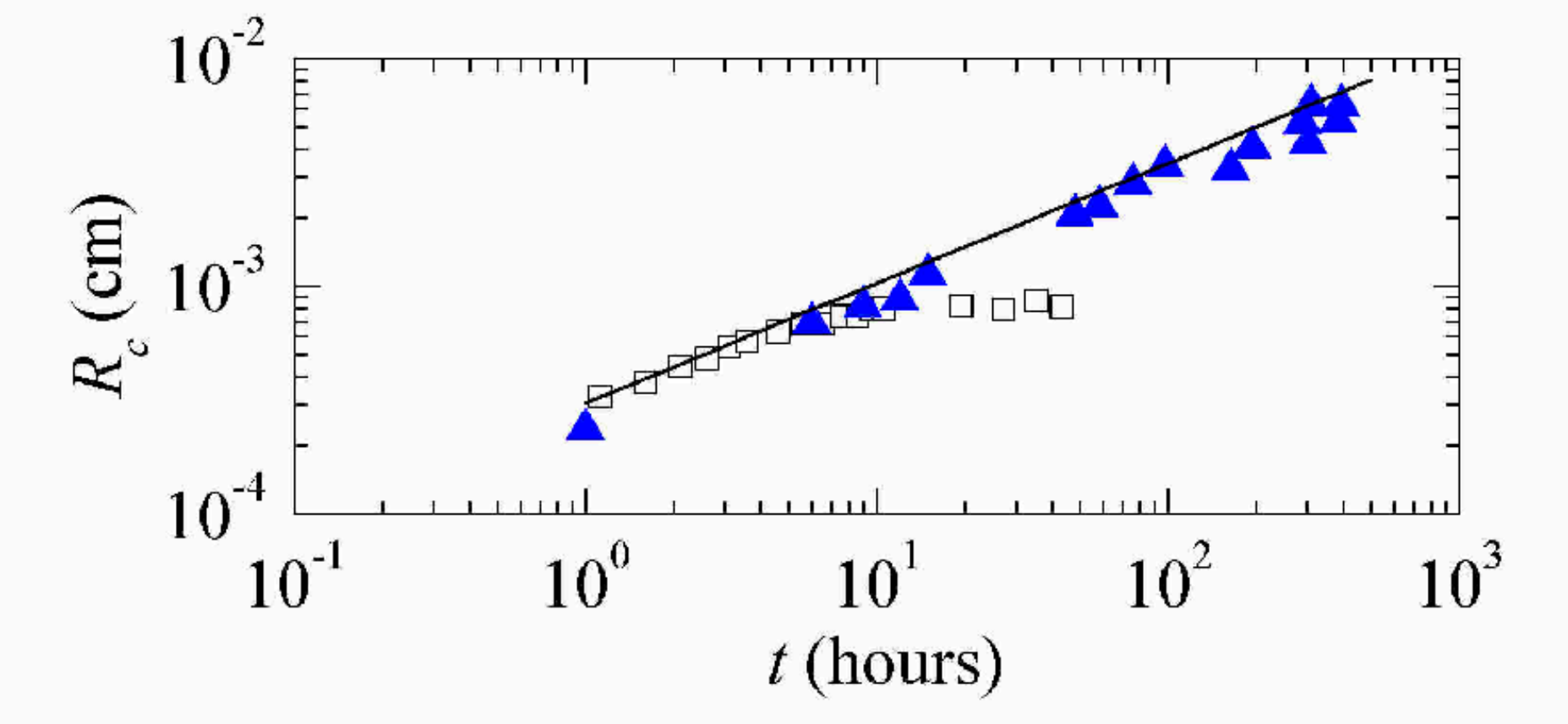
PCS: fractal gel clusters

Gravity disrupts growth



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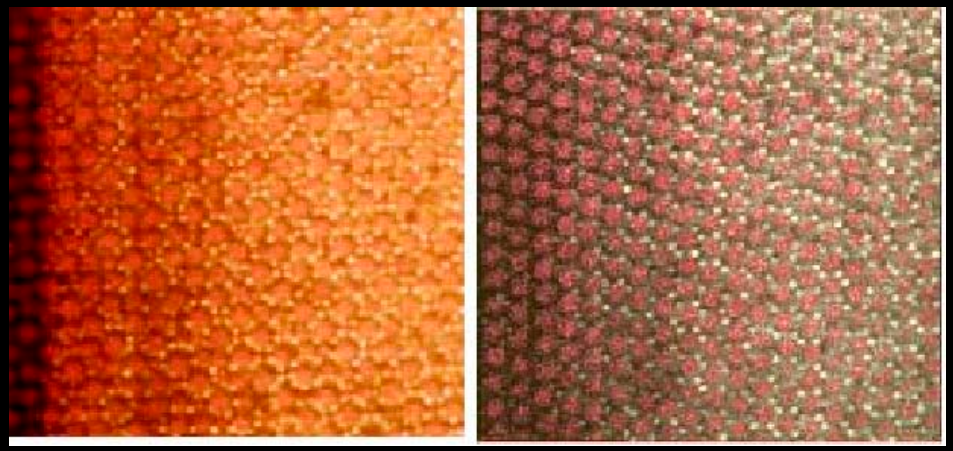
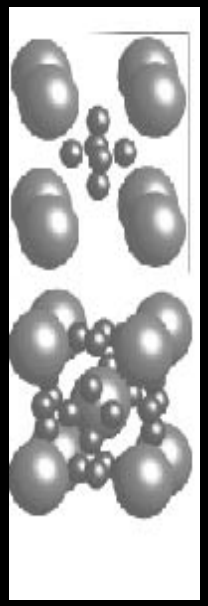
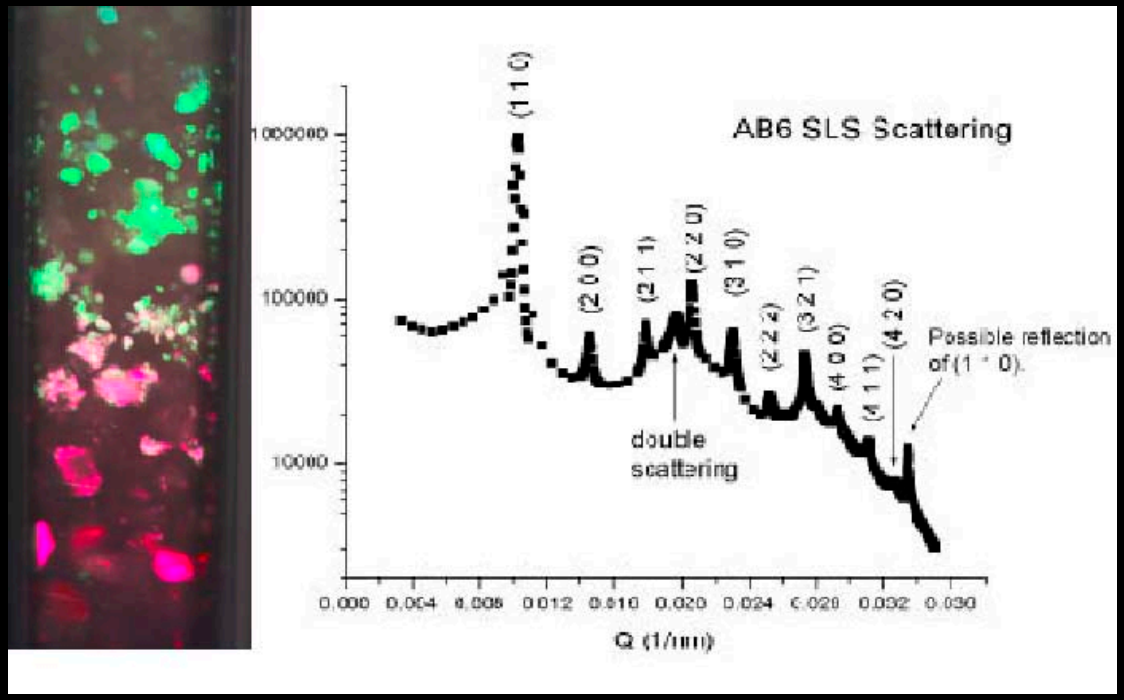
PCS: binary alloys

AB6 binary alloy crystal







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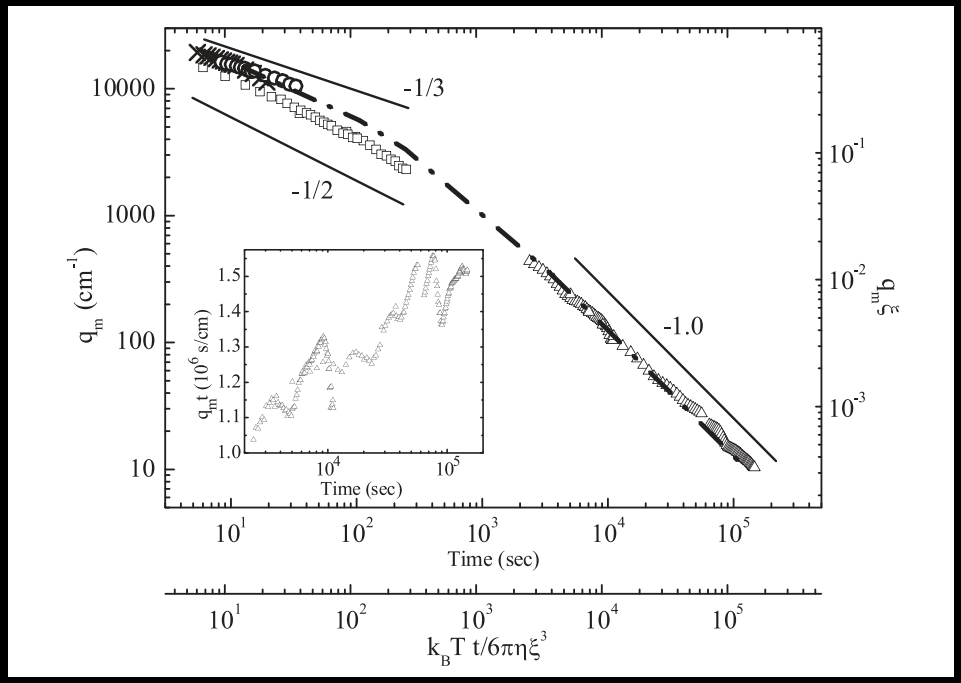
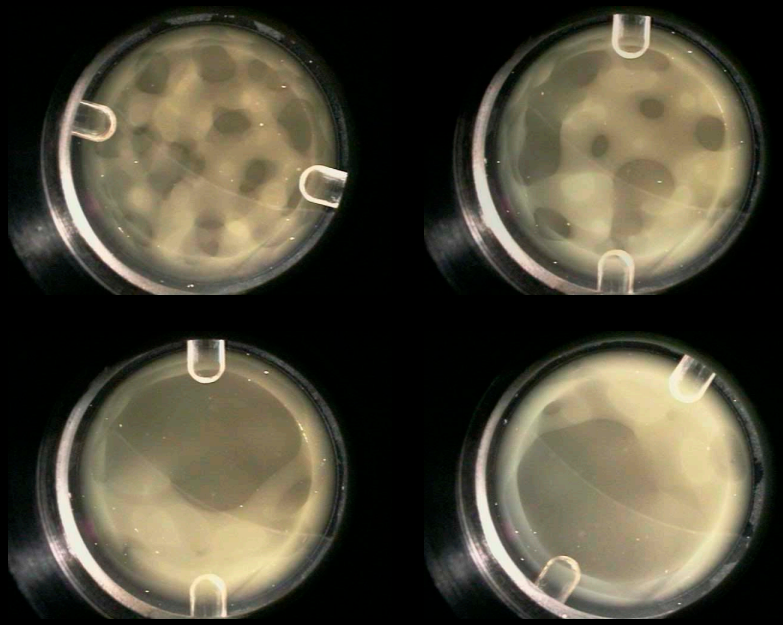
PCS phase separation

Combination of scattering (short time) and imaging (longer time)

No provision for imaging in original spec, modified on orbit: importance of flexibility in instrument design!





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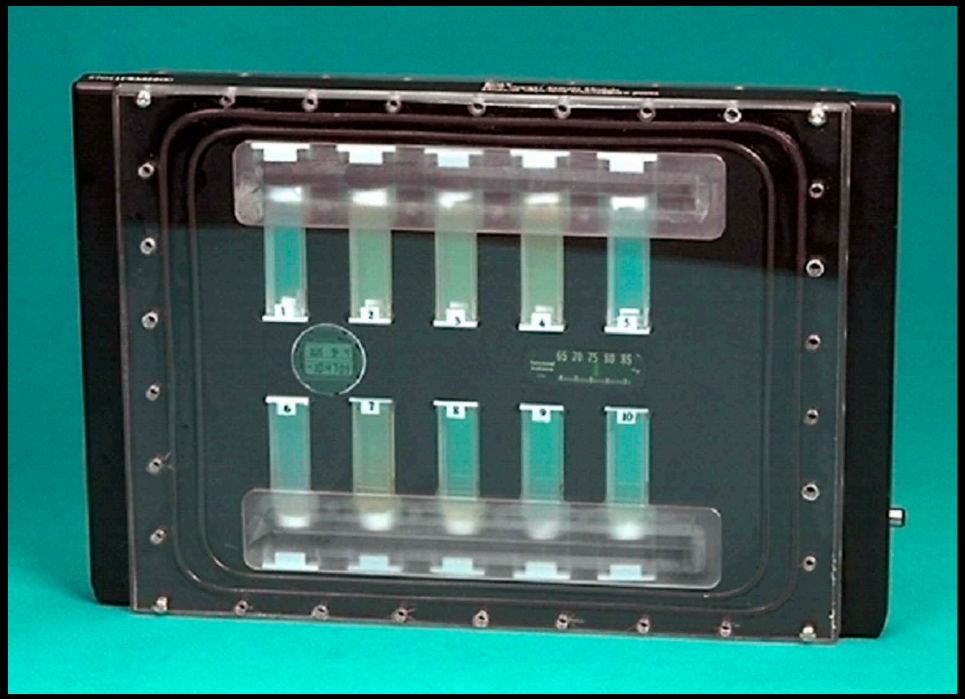
BCAT3 Experimental Apparatus



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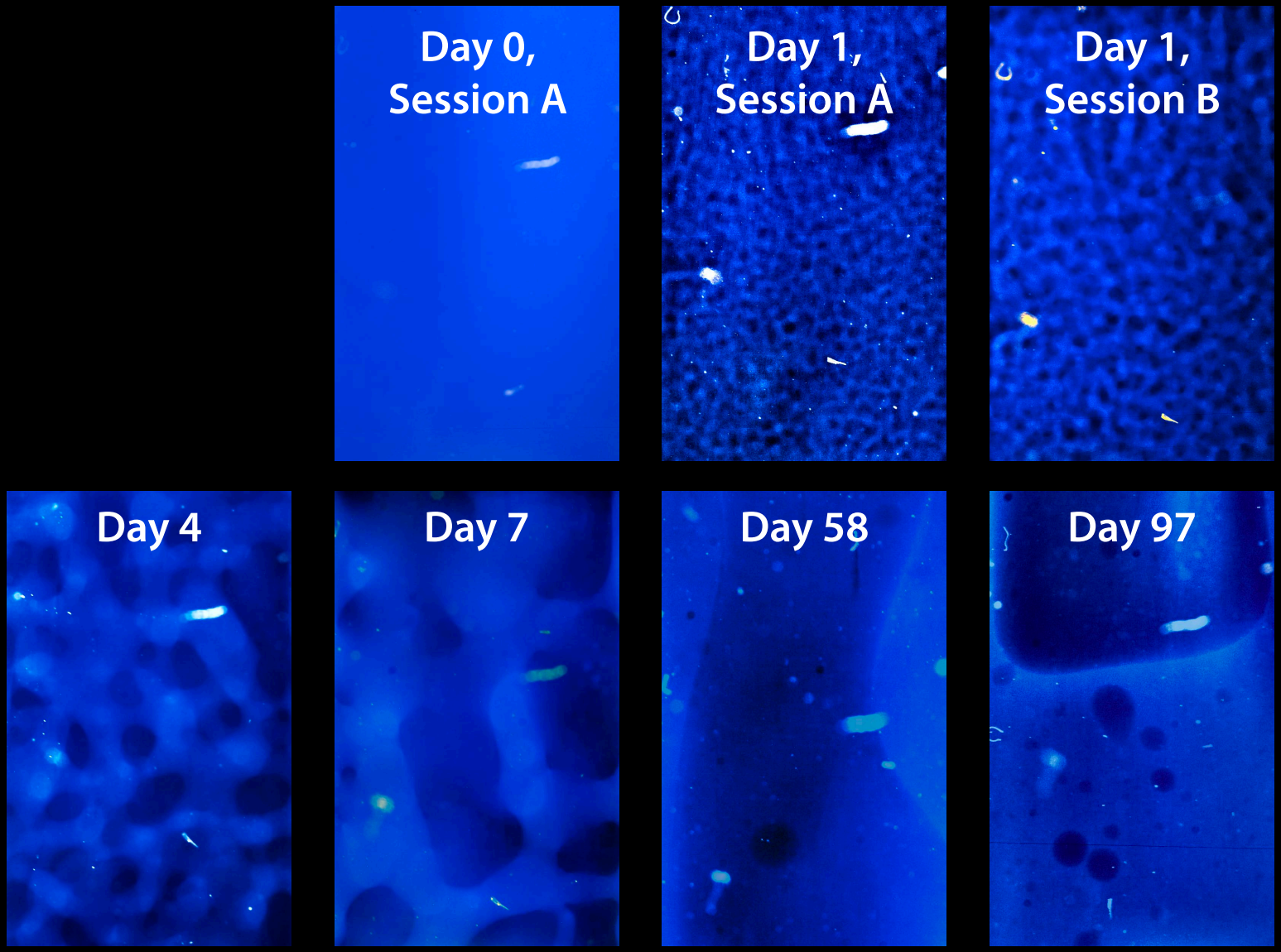
BCAT3, Sample 2: Phase Separation



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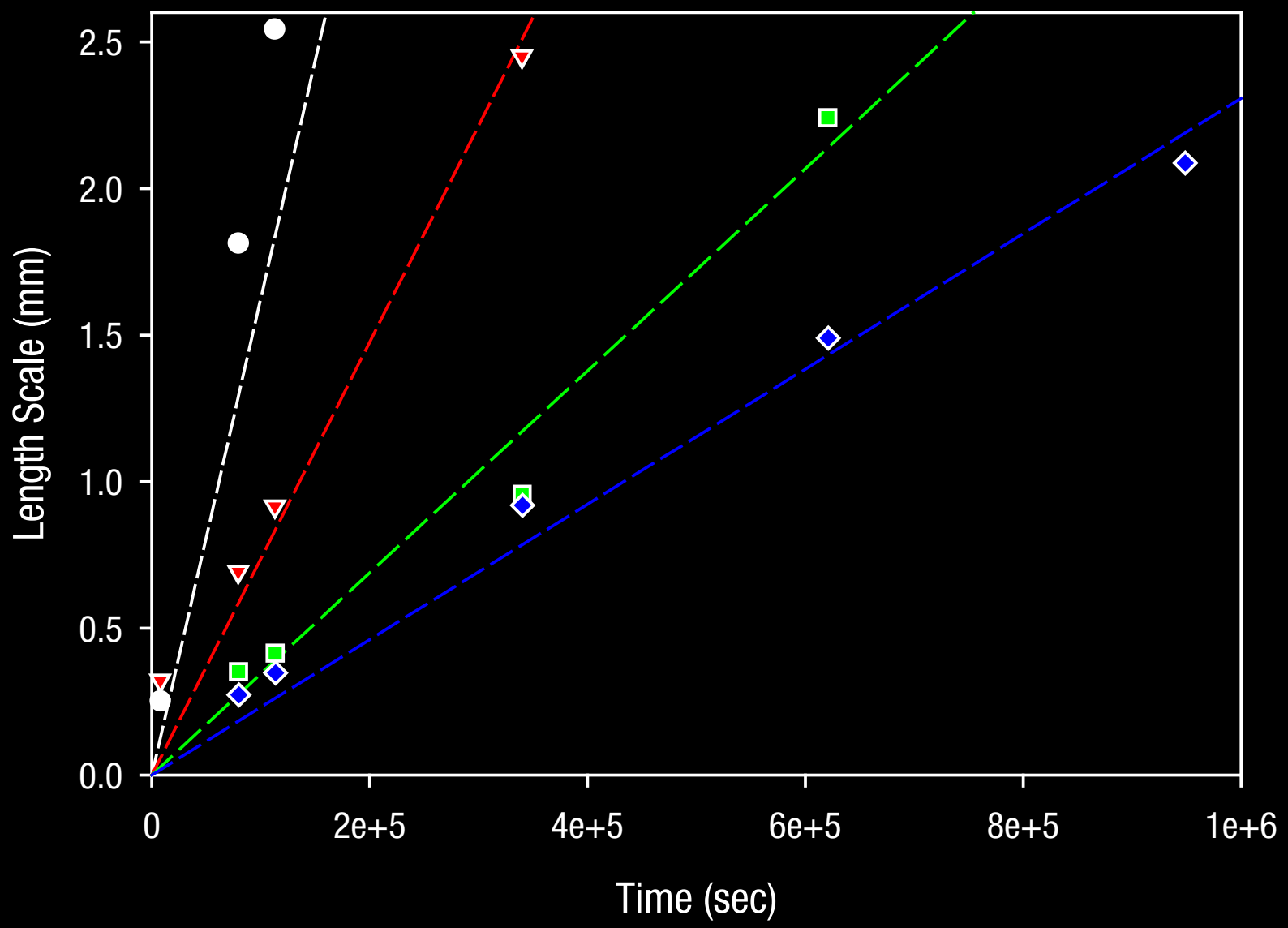
BCAT3: Original data



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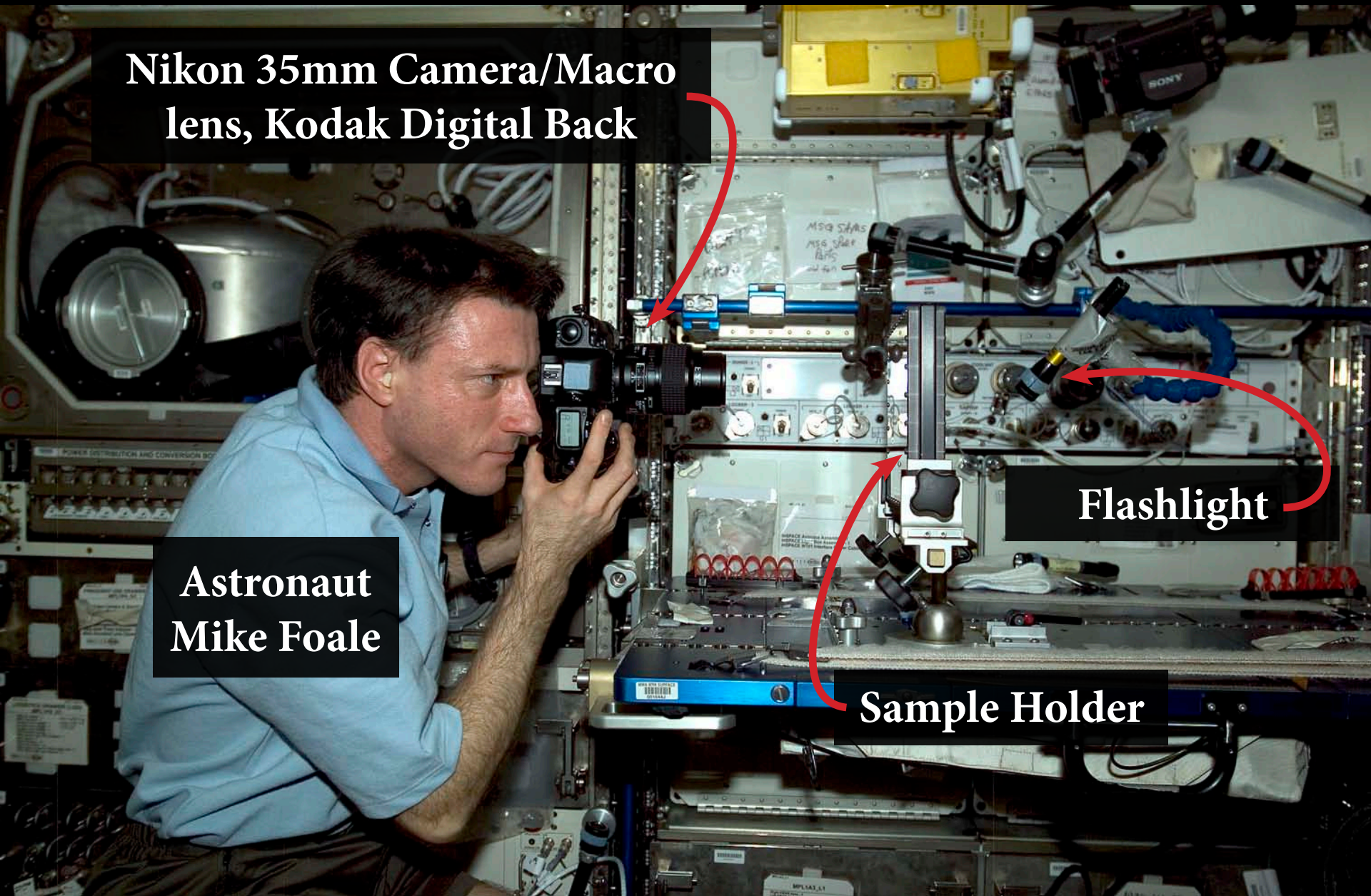
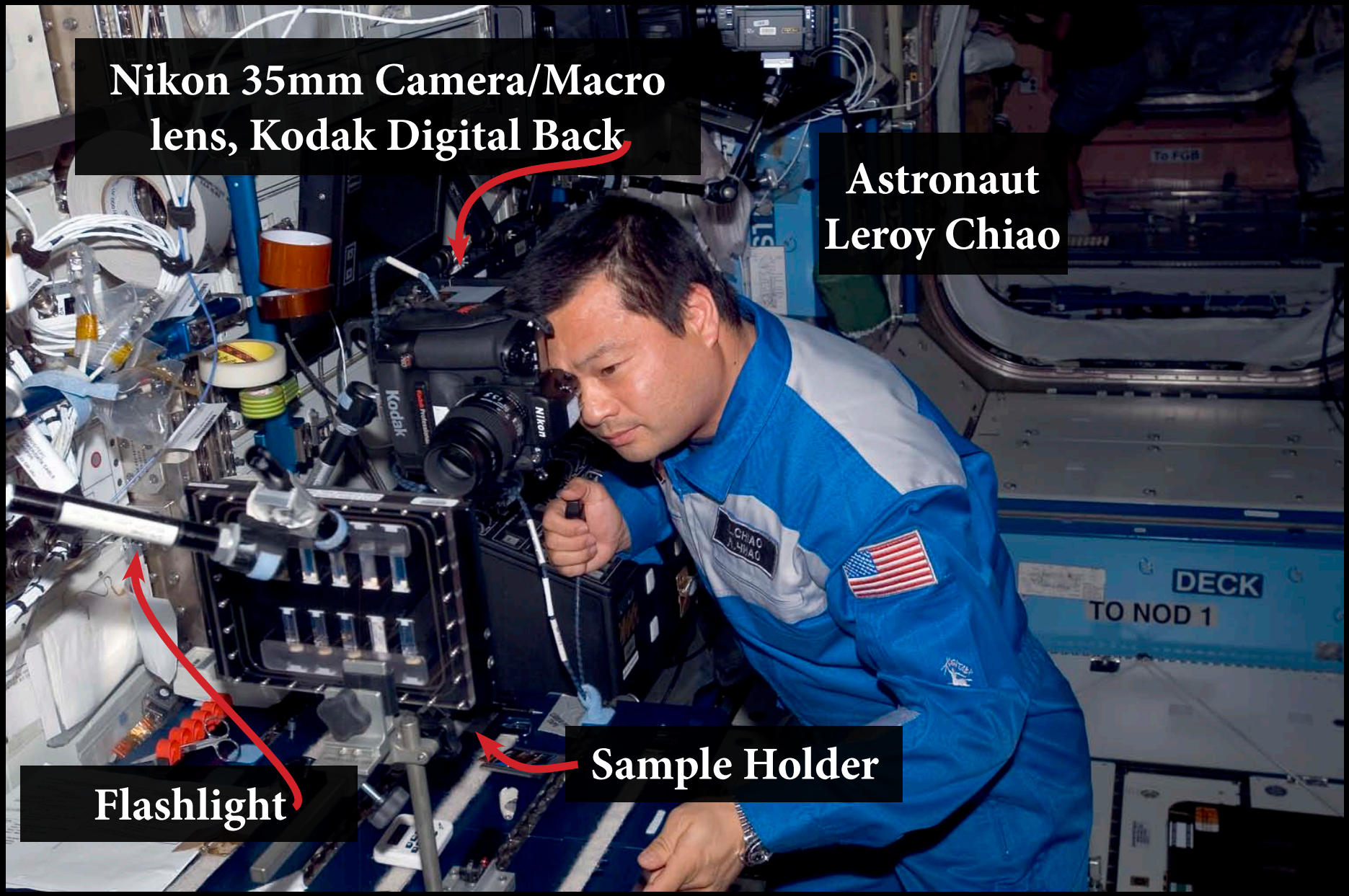
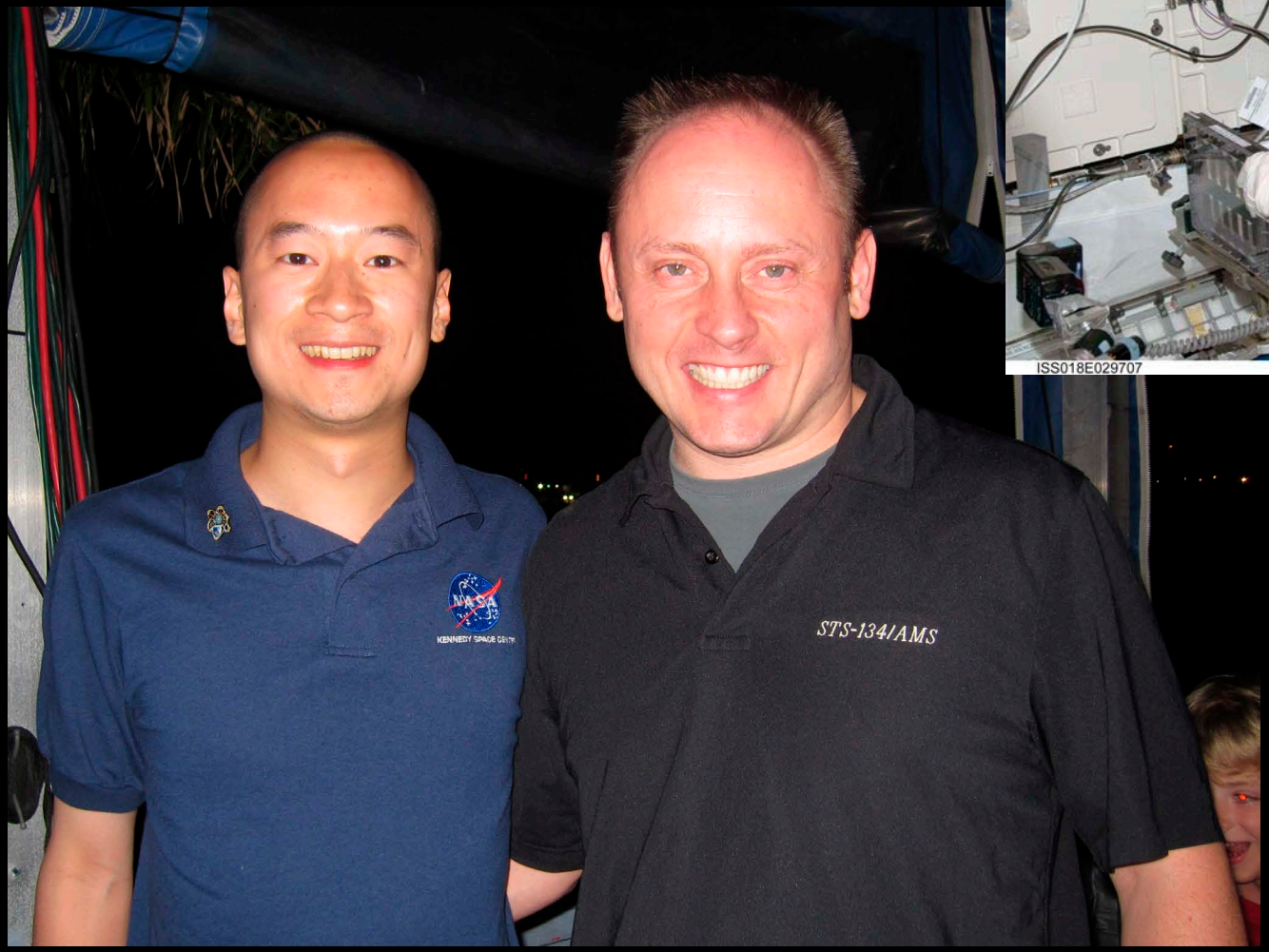
BCAT3 Experimental Setup



BCAT3 Experimental Setup



BCAT4 Experimental Setup



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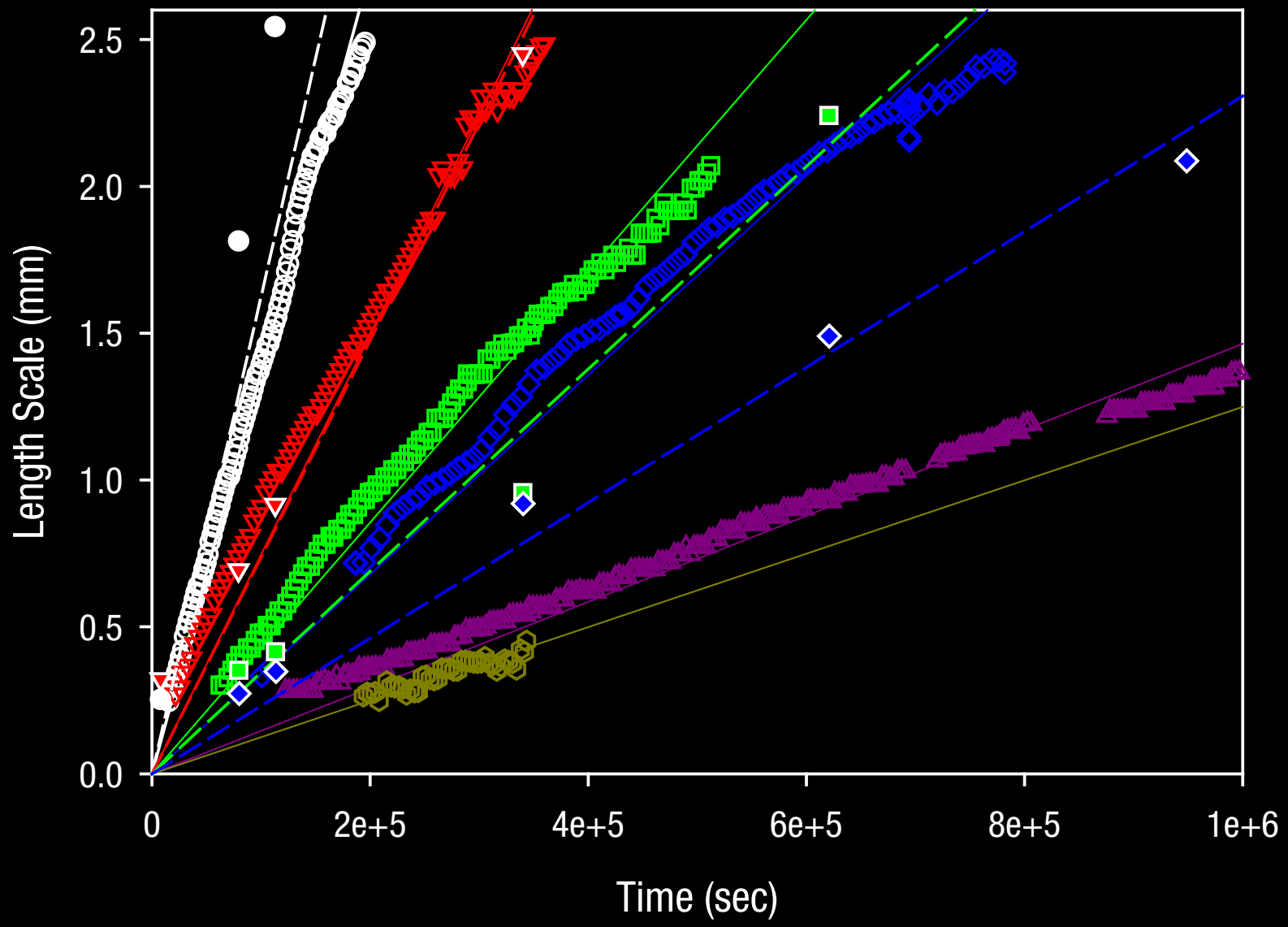
BCAT3: Automation with EarthKAM



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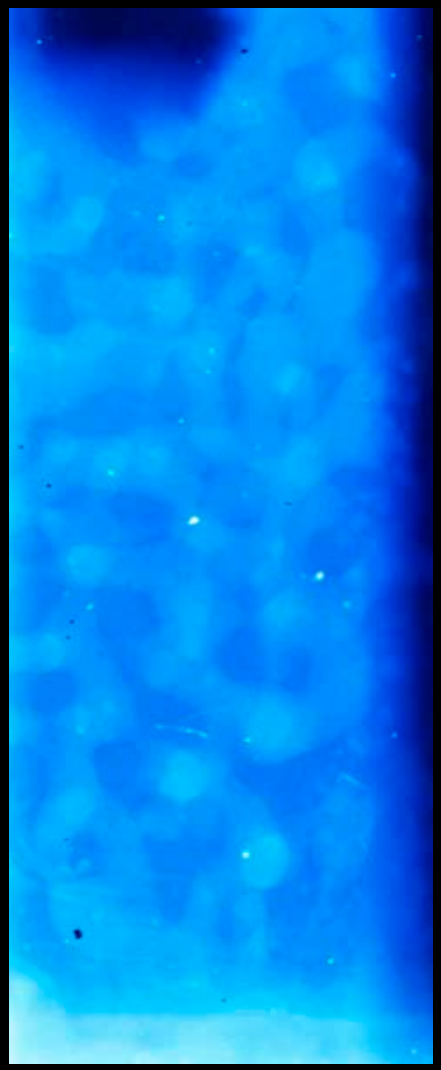
BCAT3: how were samples chosen?

Earth: 1g



ISS: µg

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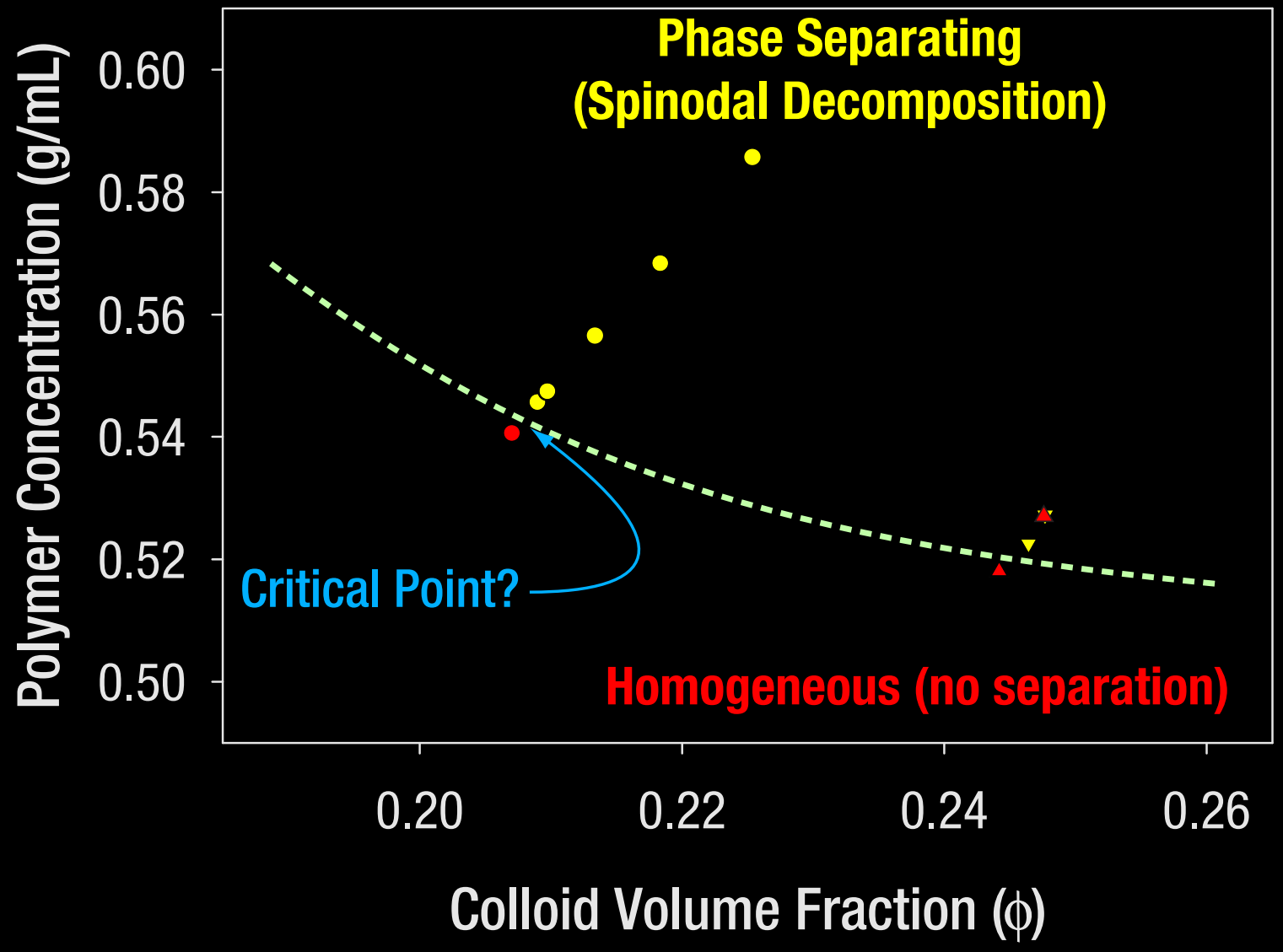
BCAT3/4 sample phase diagram?



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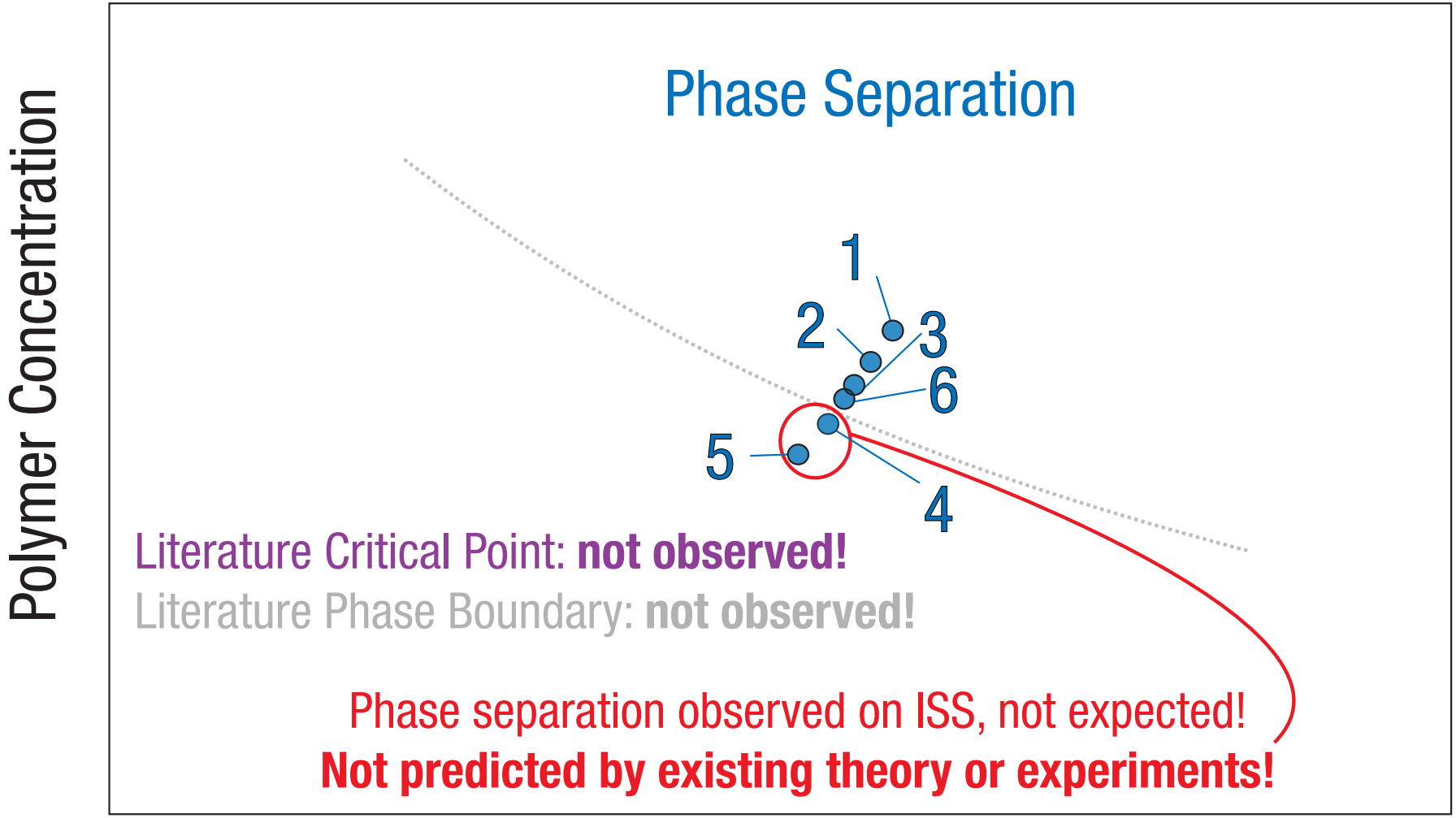
BCAT3/4 sample phase diagram?



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BCAT3-6: Macro photography limits

Effective resolution limit given by CCD

4 pixels required for sufficient contrast: ~50 μm

(particles are < 0.5 μm)

Increase resolution (~2x) with newer CCD

Cannot resolve individual particles!

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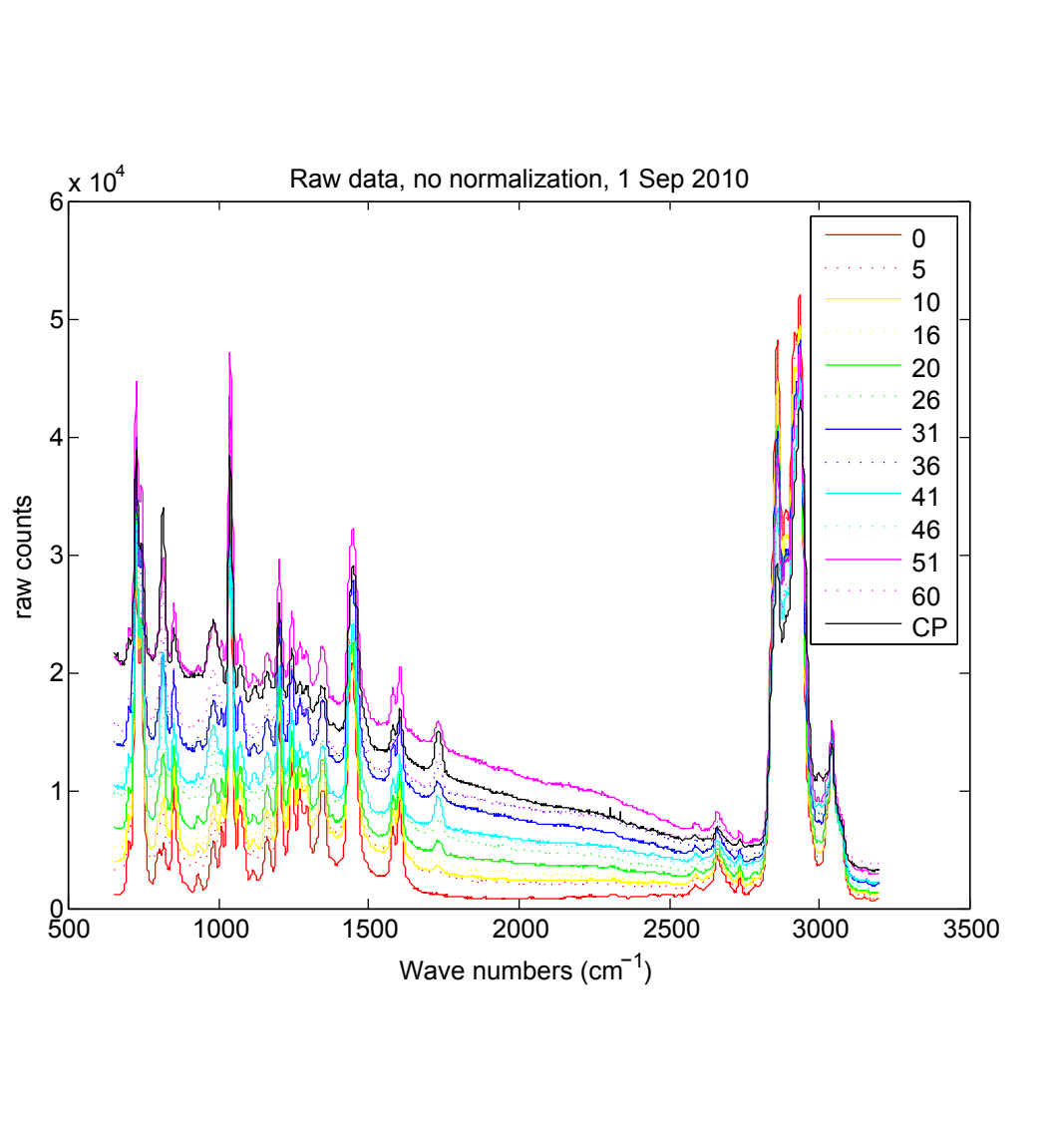
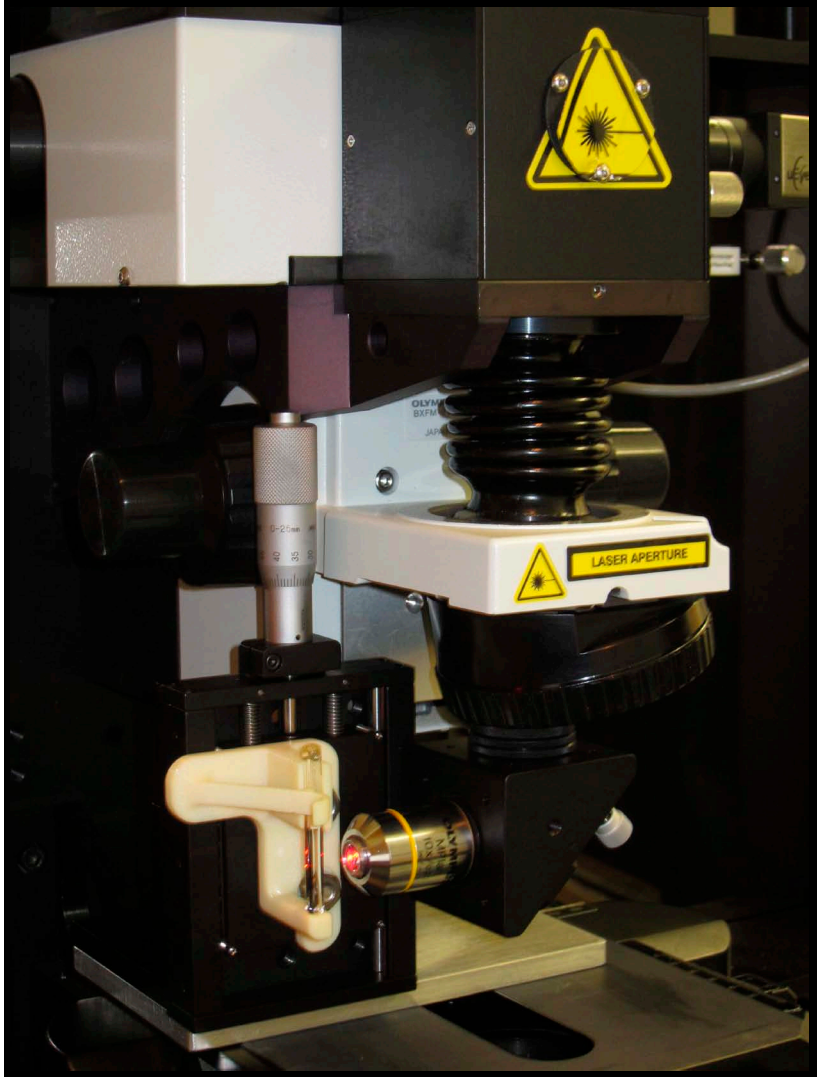
Bulk techniques on Earth: Raman





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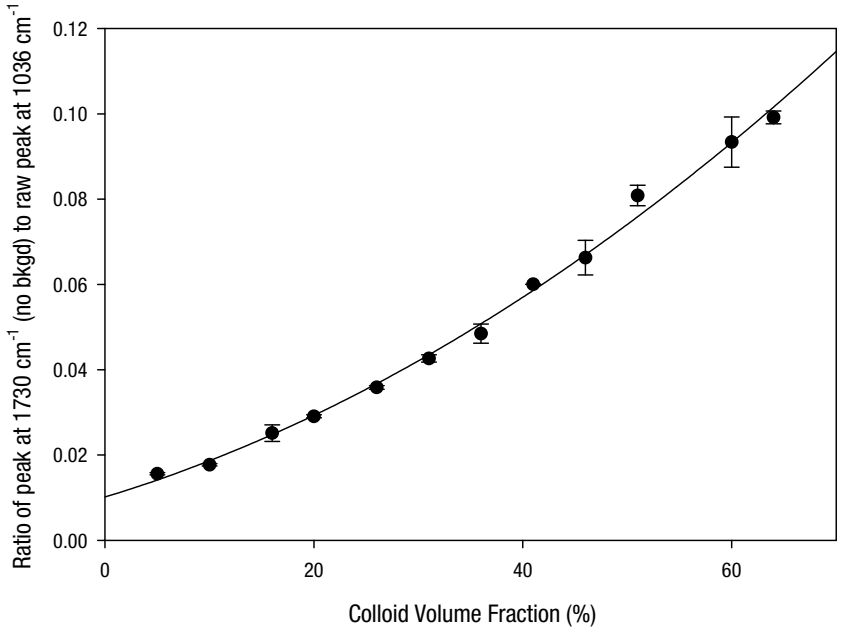
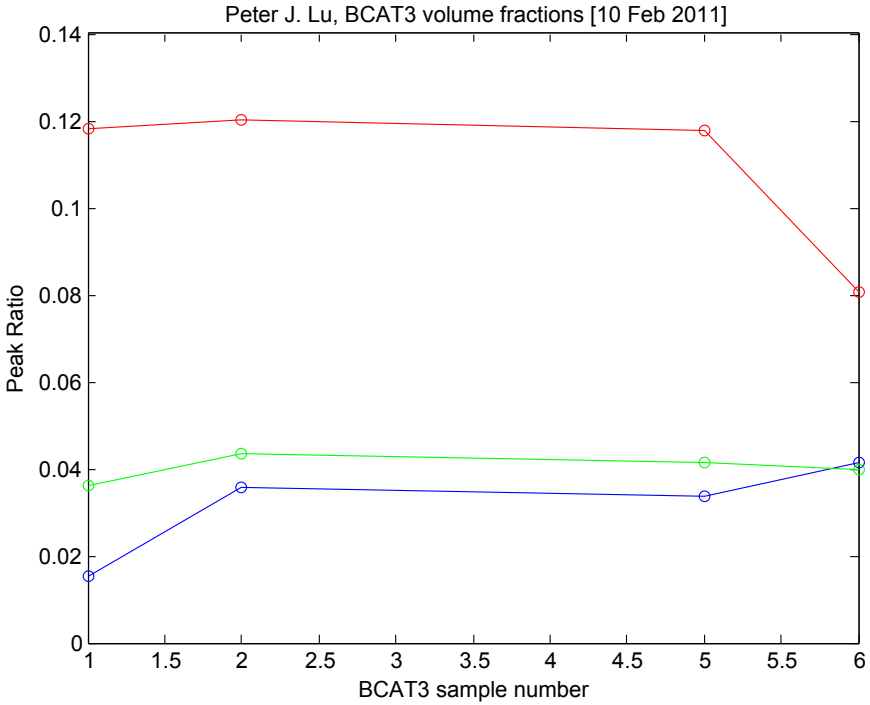
BCAT phase diagram not measurable!





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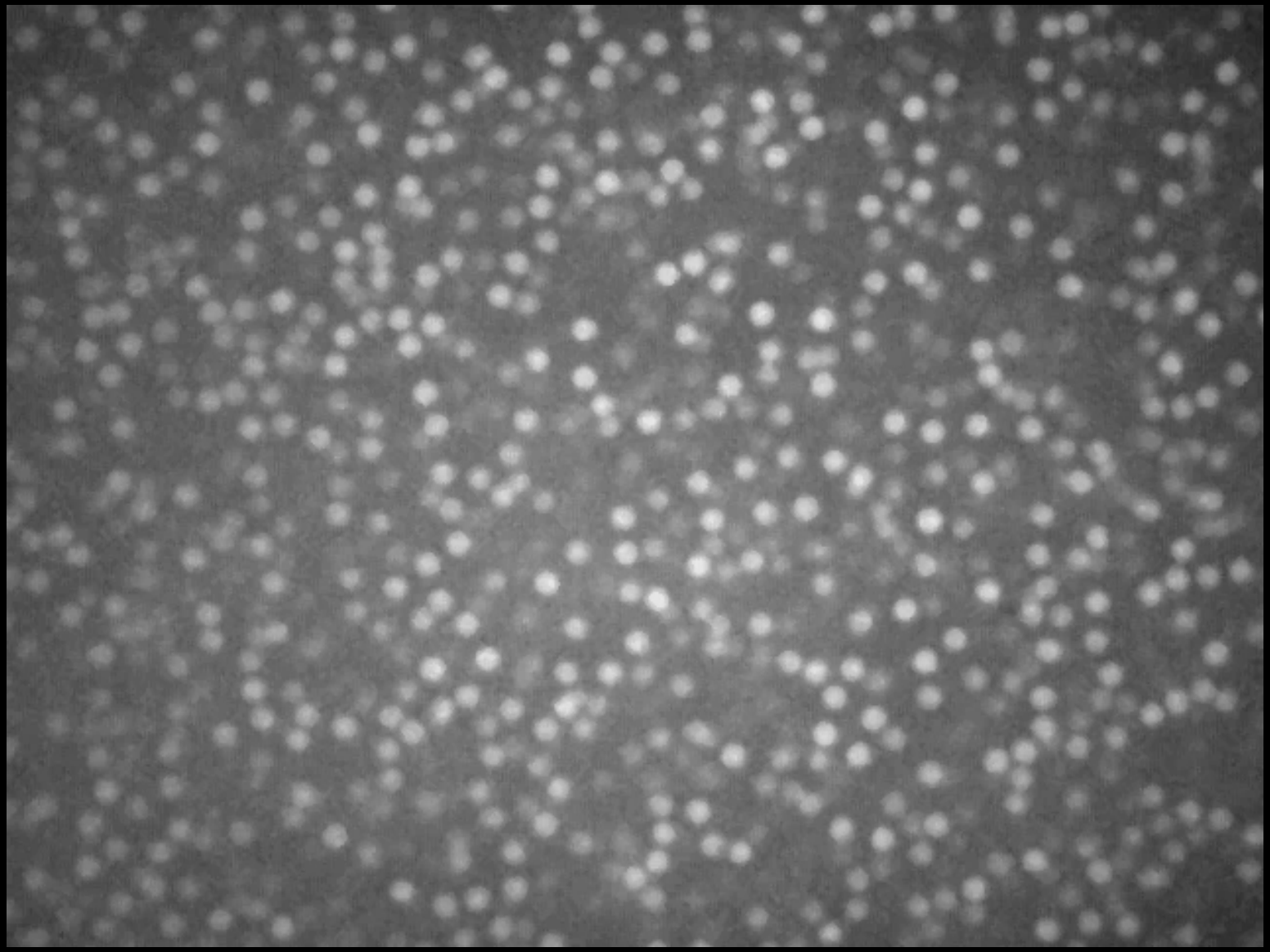
With microscopy, can simply count!



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BCAT to ACE: ISS microscopy

Can resolve individual particles, at high speed

sub-μm resolution, video rates (>25 frames/sec)

Can directly visualize and quantify many new things

particle count for phase diagrams!

interface width, rates, particle exchange

Can investigate predictions for atomic systems

not possible to investigate at single-atom level, especially with disordered liquids and gases

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Why ACE?

Stable (months) microgravity environment

- Not achievable on earth for this long
- Small temperature fluctuations do not change buoyancy
- ISS laboratory required

Removes need to match densities between particles and solvents

- Existing experiments with stable non-buoyancy-matched solvents
- New types of particles
- Mixtures of existing particle sizes

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New science: crystal nucleation

Homogeneous nucleation in simple hard spheres

Nucleation rates orders of magnitude different from simulation

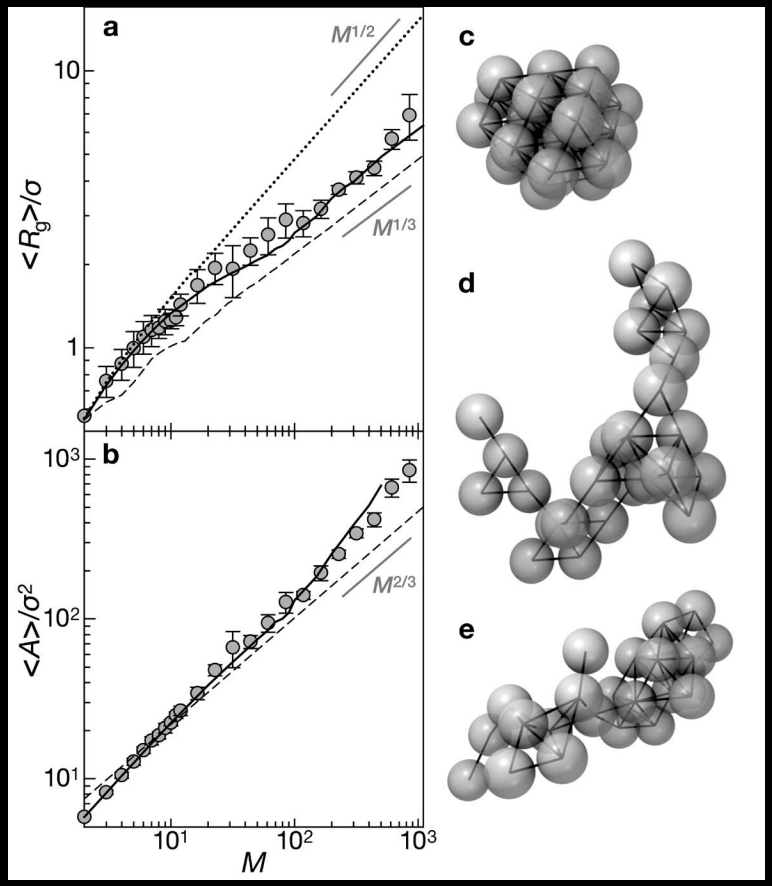
Proper kinetics require no sedimentation

Heterogeneous crystal nucleation

seed particles , templates (ACE specialty cells)

Experiments can be quite slow

days to weeks to crystallize: stable ISS required



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New science: binary crystallization

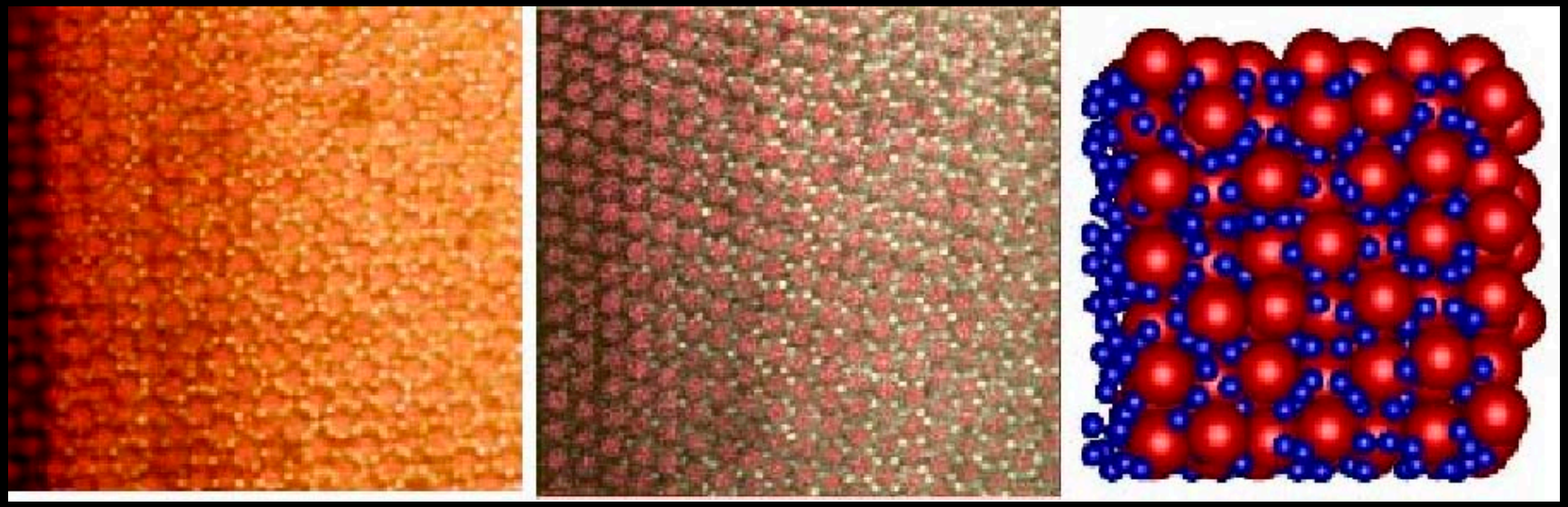
Cannot buoyancy-match two sphere sizes in same solvent

Microgravity environment required for careful studies

Does sedimentation affect phase behavior, kinetics?

Microscopy for phase identification

Scattering not possible for small crystallites



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New science: new material crystals

Photonic band-gap crystals require high refractive index

- High refractive index requires high atomic density
- Not possible to buoyancy match with solvents

Experiments not possible on earth, requires ISS μg

- Phase identification, kinetics, etc. all require density match, and therefore cannot be done on earth

Fundamental studies + real applications?

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New science: phase. sep. past BCAT

Morphological characterization of interfaces

- BCAT sees only macroscopic lengthscale and curvature
- No direct visualization of interfaces at single-particle level (width, roughness, escape times, etc.)

Experiment not possible with atomic systems

- Cannot visualize rapidly-moving, disordered atoms

Experiment not possible on earth, requires ISS μg

- Liquid and gas always have different densities

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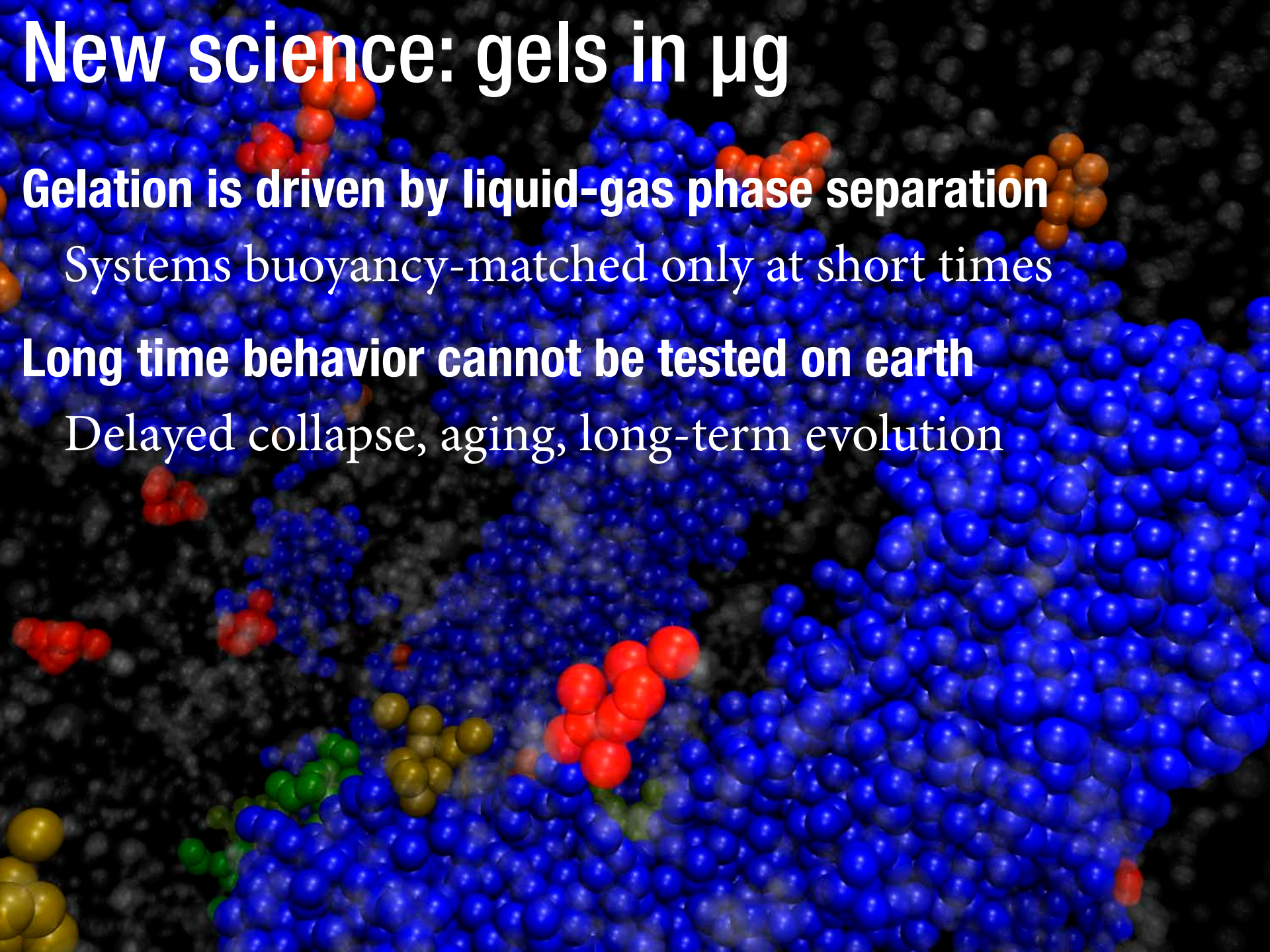
New science: gels in μg

Gelation is driven by liquid-gas phase separation

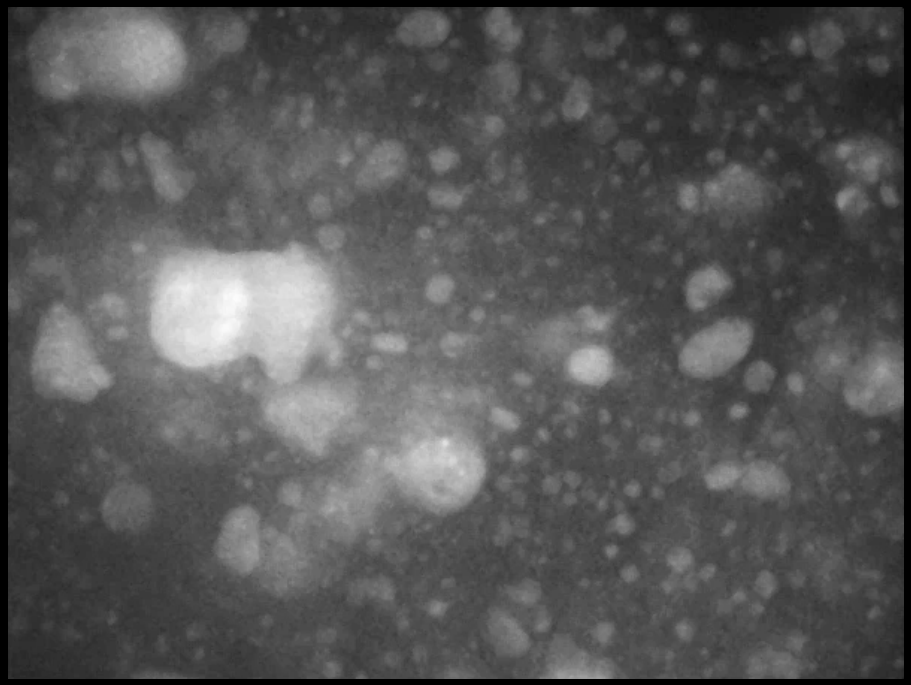
Systems buoyancy-matched only at short times

Long time behavior cannot be tested on earth

Delayed collapse, aging, long-term evolution



$1B consumer products



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