

Phase transitions in colloids under microgravity

Qian Lei*, Boris Khusid, Lou Kondic

New Jersey Institute of Technology, Newark, NJ

Andrew D. Hollingsworth, Paul Chaikin

New York University, New York, NY

William V. Meyer

Universities Space Research Association at the NASA GRC, Cleveland, OH

Alton J. Reich

Streamline Automation LLC, Huntsville, AL



NASA Advanced Colloids Experiment (ACE) Program

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- Despite the fundamental and technological importance, the understanding of colloidal crystallization is still elusive. The origins and even the existence of a glass transition in monosized concentrated colloids remain poorly understood and hotly debated.
- Experiments ACE-T11 on spherical colloidal particles and ACE-TR-Ellipsoids on ellipsoidal particles apply high-resolution confocal microscopy to capture the suspensions structure over time.
- Understanding of how a disordered arrangement of particles self-organizes into a three-dimensional ordered structure at the particle level is vital for a variety of industries from 3D printing to photonics and electronics and to chemicals and pharmaceuticals.

MEASUREMENT APPROACH

LMM Implementation Philosophy

Philosophy: Maximize the scientific results by utilizing the existing LMM capabilities. Develop small sample modules and image them within the LMM

Light Microscopy Module (LMM)

Payload specific and multi-user hardware customizes the FIR in a unique laboratory configuration to perform research effectively.



Fluids Integrated Rack (FIR)

- Power Supply
- Avionics/Control
- Common Illumination
- PI Integration Optics Bench
- Imaging and Frame Capture
- Diagnostics
- Environmental Control
- Data Processing/Storage
- Light Containment
- Active Rack Isolation System

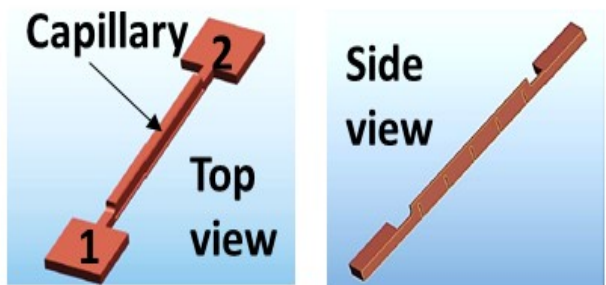
Multi-Use Payload Apparatus

- Test Specific Module
- Infrastructure that uniquely meets the needs of PI experiments
- Unique Diagnostics
- Specialized Imaging
- Fluid Containment

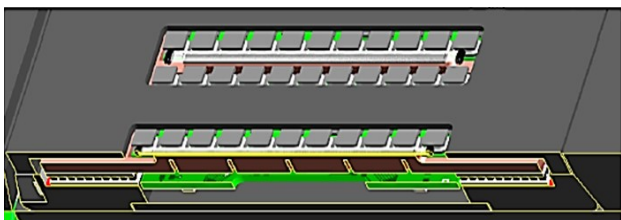
Payload Specific Hardware

- Sample Cell with universal Sample Tray
- Specific Diagnostics
- Specific Imaging
- Fluid Containment

NASA GRC & ZIN Tech images



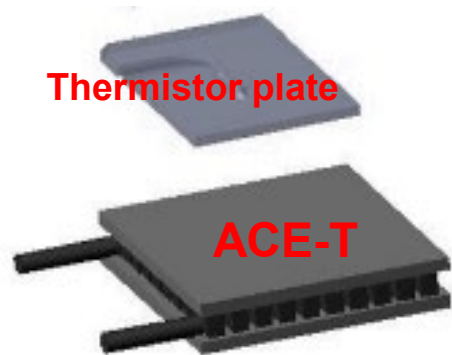
The capillary of diameter 0.140 mm and length 50, 100, or 300mm is mounted between hot and cold thermistors 1 and 2.



Capillary sample cells surrounded by inductors that are used for walking a turning stirring bar for mixing a sample.

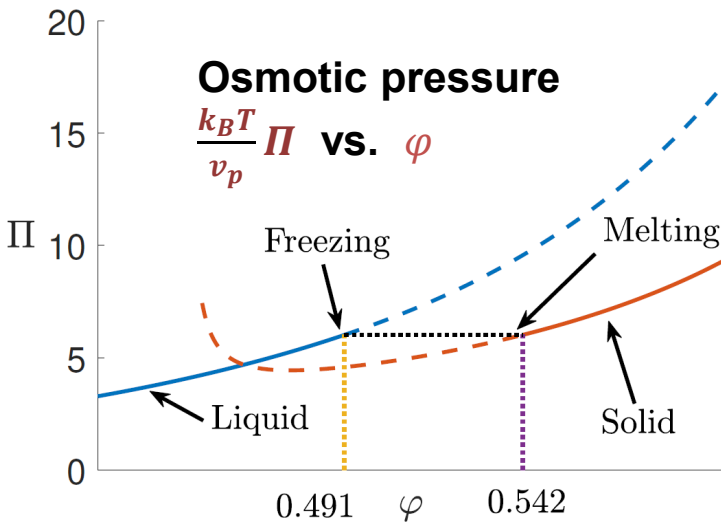
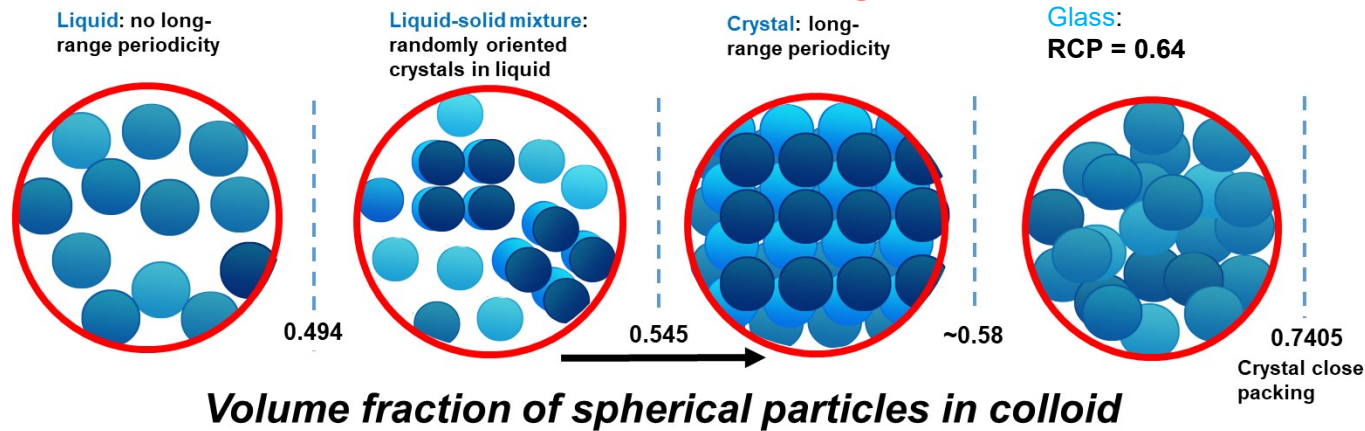


ACE-T11 SPHERES



ACE-T Cell, ZIN-
Technologies, OH

Observations at 1g



MD simulations Speedy 1997, 1998

MD simulations & Experiments

Liquid: $\phi < \phi_{fr} \approx 0.49$

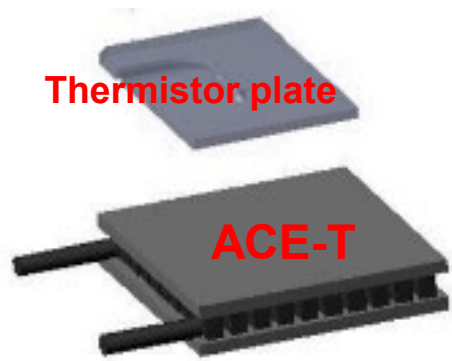
Crystalline up to maximum packing:
 $\phi_m \approx 0.54 < \phi < \phi_0 = \sqrt{2}\pi/6 = 0.74$

Coexisting liquid & crystalline phases:
 $\phi_m > \phi > \phi_{fr}$

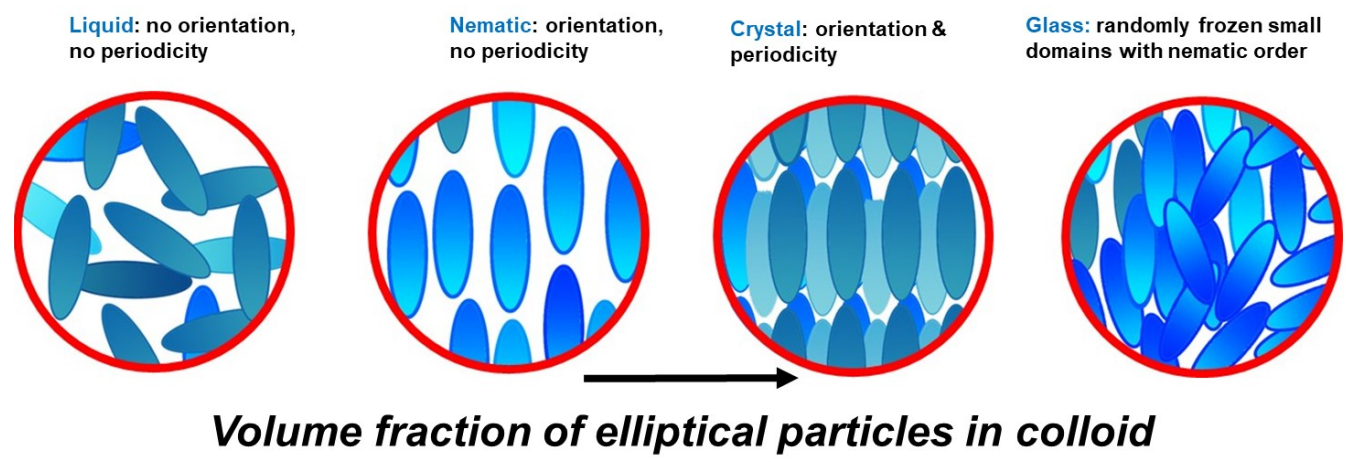
Reviews: Gasser 2004, Palberg 2014

ACE-TR ELLIPSOIDS

Observations at 1g



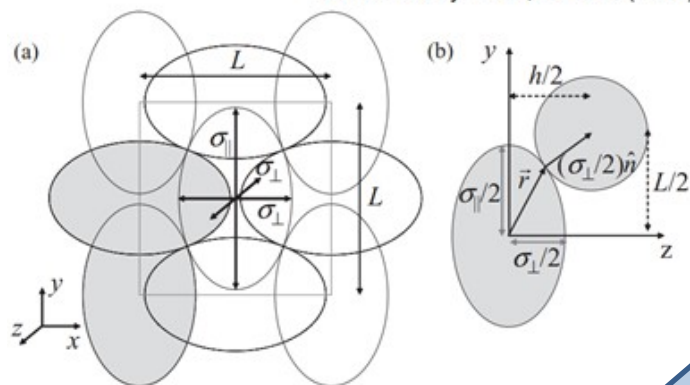
ACE-T Cell, ZIN-Technologies, OH

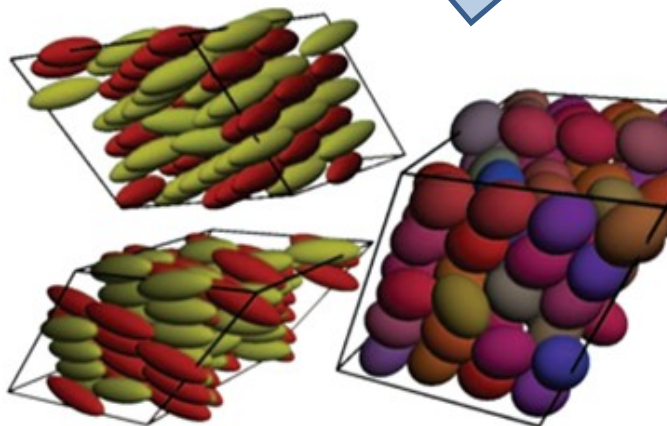
PHASE DIAGRAM HARD ELLIPSOIDS

MD simulations

Bautista-Carbajal, Moncho-Jordá, and Odriozola
J. Chem. Phys. **138**, 064501 (2013)

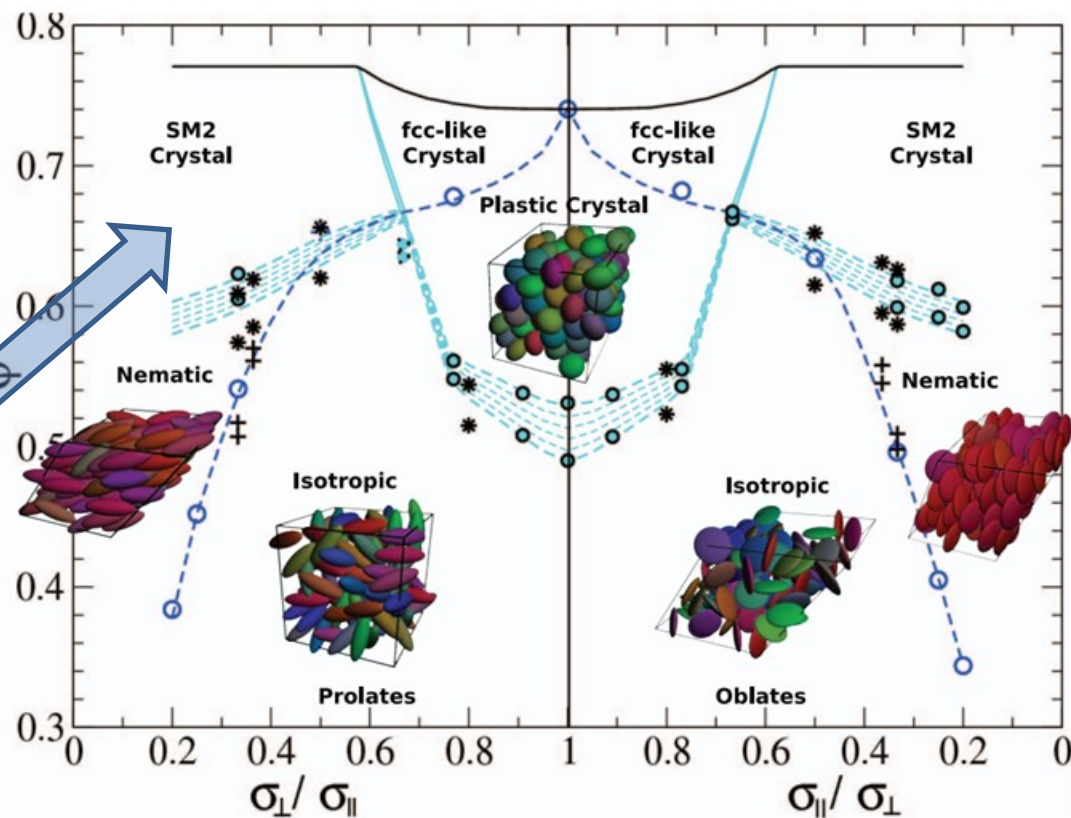


prolate sm2 structure



Prolate SM2
Crystal

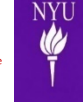
Prolate fcc-like
Crystal



Odriozola
J. Chem. Phys. **136**, 134505 (2012)



SYNTHESIS STRATEGY

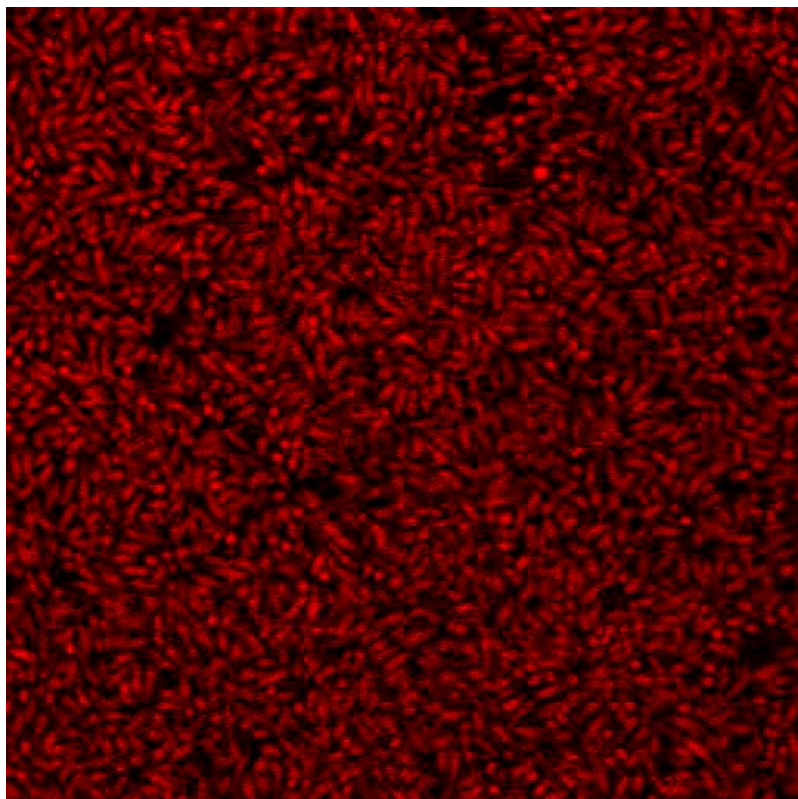


Andrew D. Hollingsworth, NYU

ELLIPSOIDAL COLLOIDS

- 1 to 2 micron dia. PHS-stabilized PMMA spheres
- fluorescent labeling
- disperse PMMA spheres in PDMS prepolymer
- cast/cure PDMS film
- thermomechanical stretching / T soak / quench
- harvest ellipsoids
- photocrosslinking
- post-processing

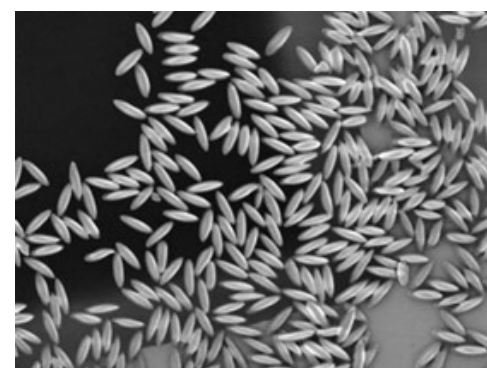
ELLIPSOIDAL COLLOIDS



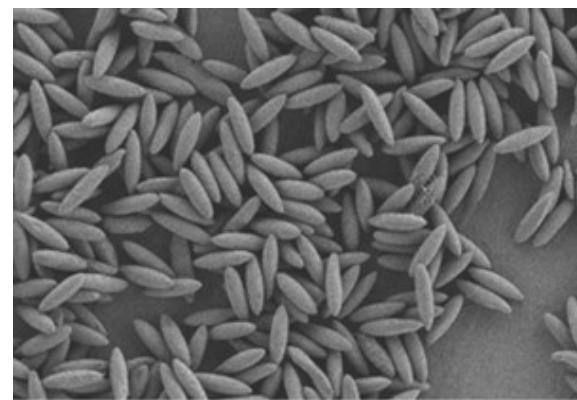
Leica SP5 confocal
63 X glycerol, 543 nm HeNe



CSF-02-139A pulls 5 6b 7 8 9
 $\alpha \approx 3.0$



CSF-02-139B pull 1
 $\alpha \approx 3.7$



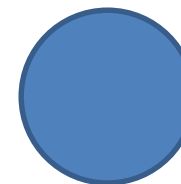
CSF-02-139C pull 10
 $\alpha \approx 3.8$



$$\alpha = 3.8$$



$$\alpha = 3.0$$



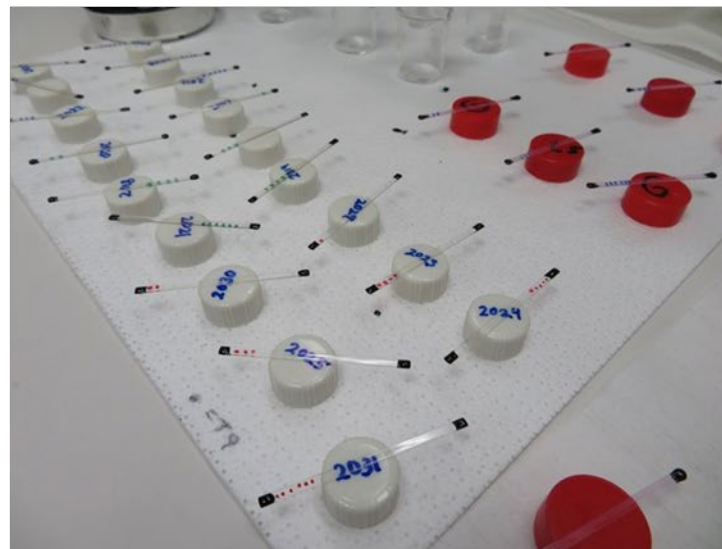
$$\alpha = 1.0$$

ACE-TR ELLIPSOIDS SAMPLE FILL

JAN 2, 2020

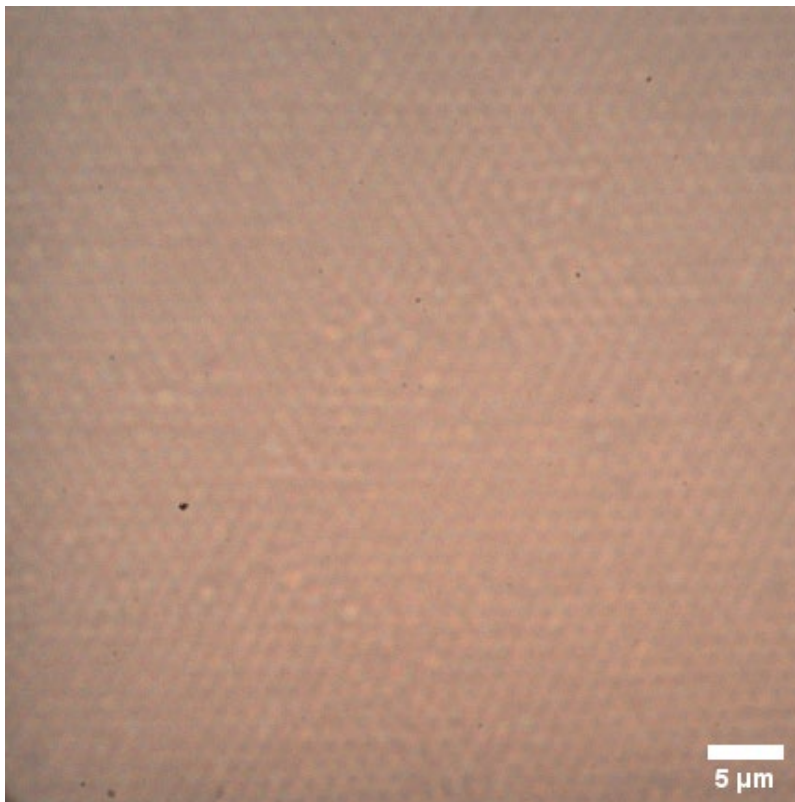
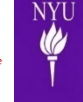


ZIN-Technologies



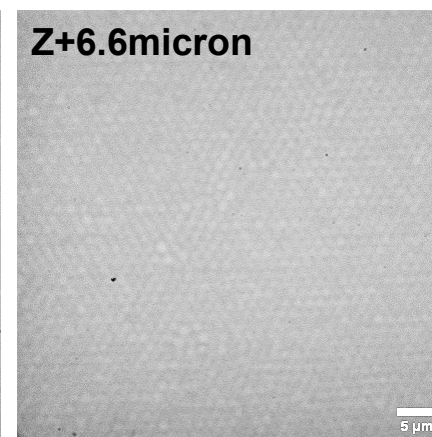
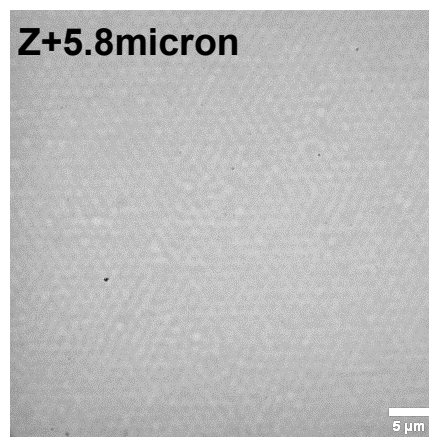
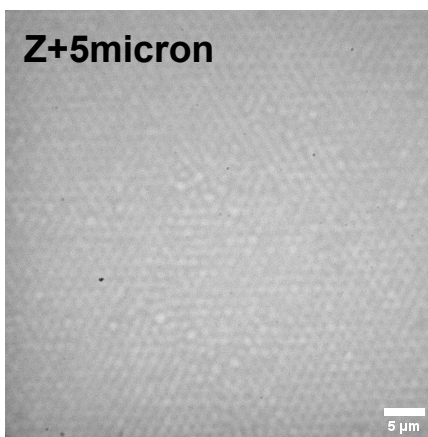


SPHERES

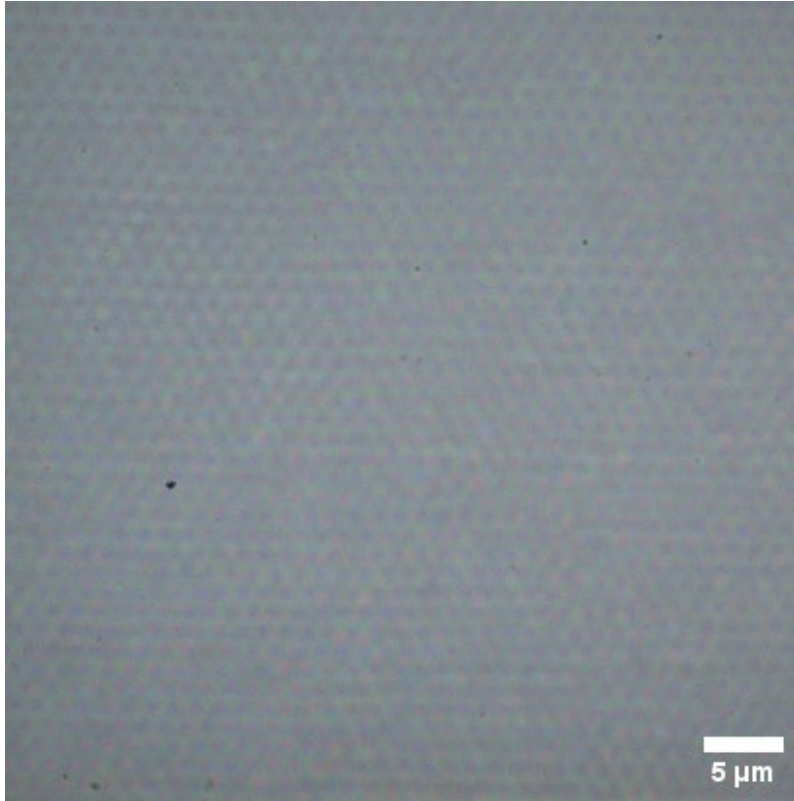


Large defect-free colloidal crystal

Three images taken with step **0.8micron** across the capillary gap overlap in RGB multi-color composite image

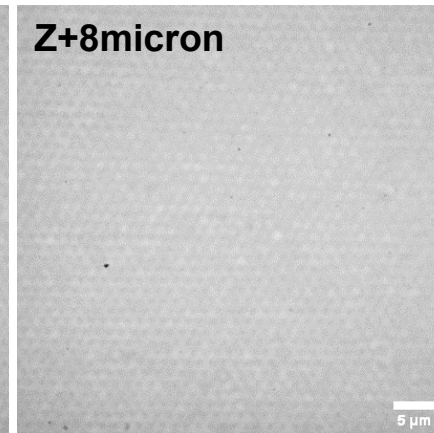
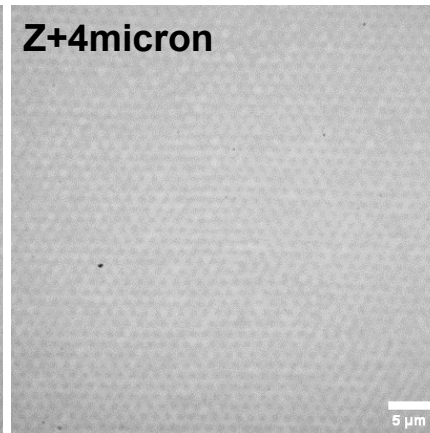
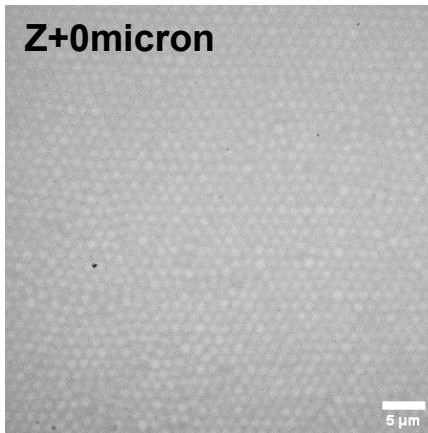


2020/11/22,
06:18:27.010, CnFcl,
ACET11, S2017,C3,
X100, DR1, X-9002,
Z0+5, Y1



Large defect-free colloidal crystal

Three images taken with step **4micron** across the capillary gap overlap in RGB multi-color composite image



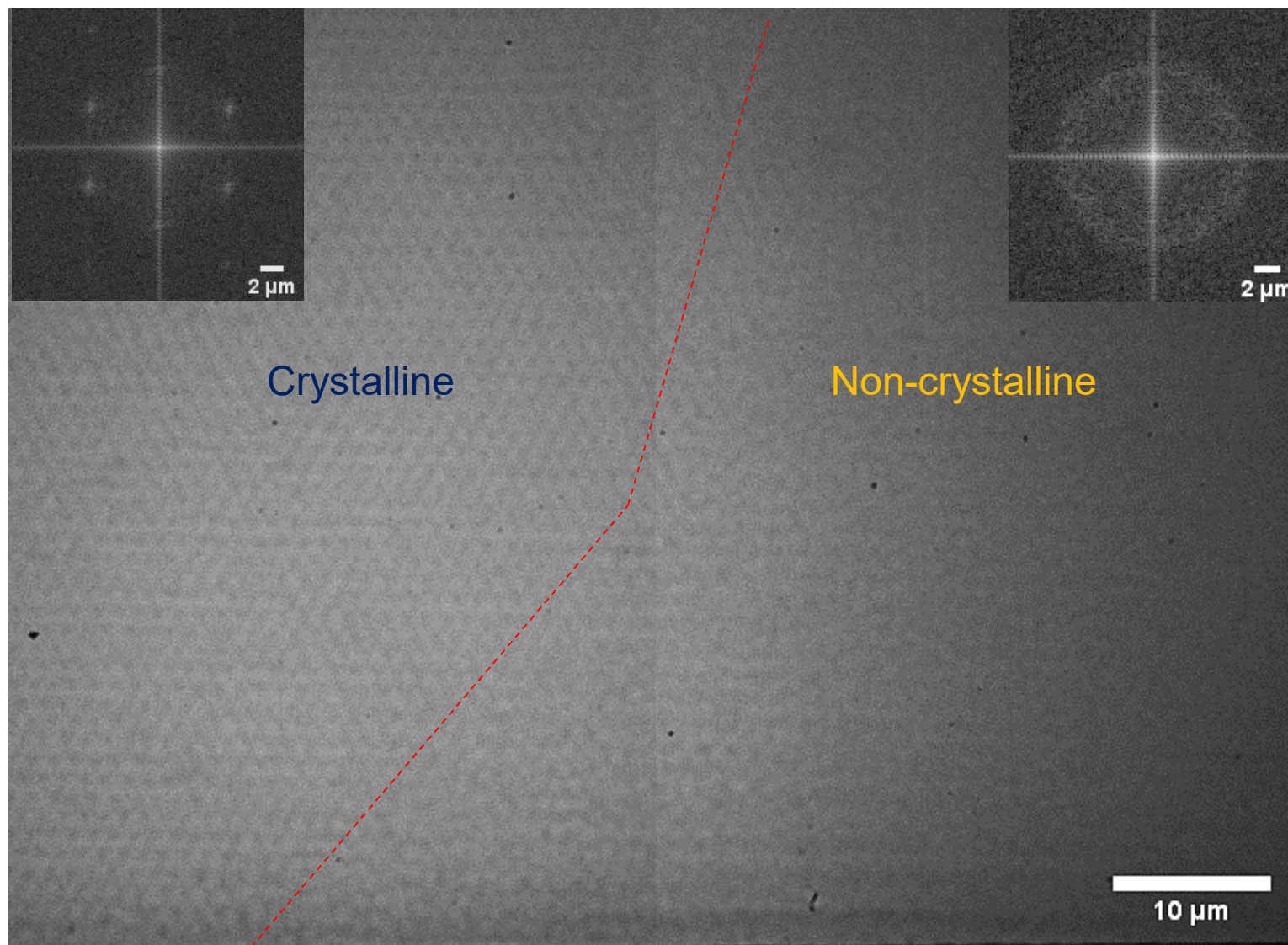
2020/11/21,
 17:42:55.624, CnFcl,
 ACET11, S2017, C3,
 X100, DR2, setup, Y1,



SPHERES



Coexistence of crystalline and non-crystalline structures

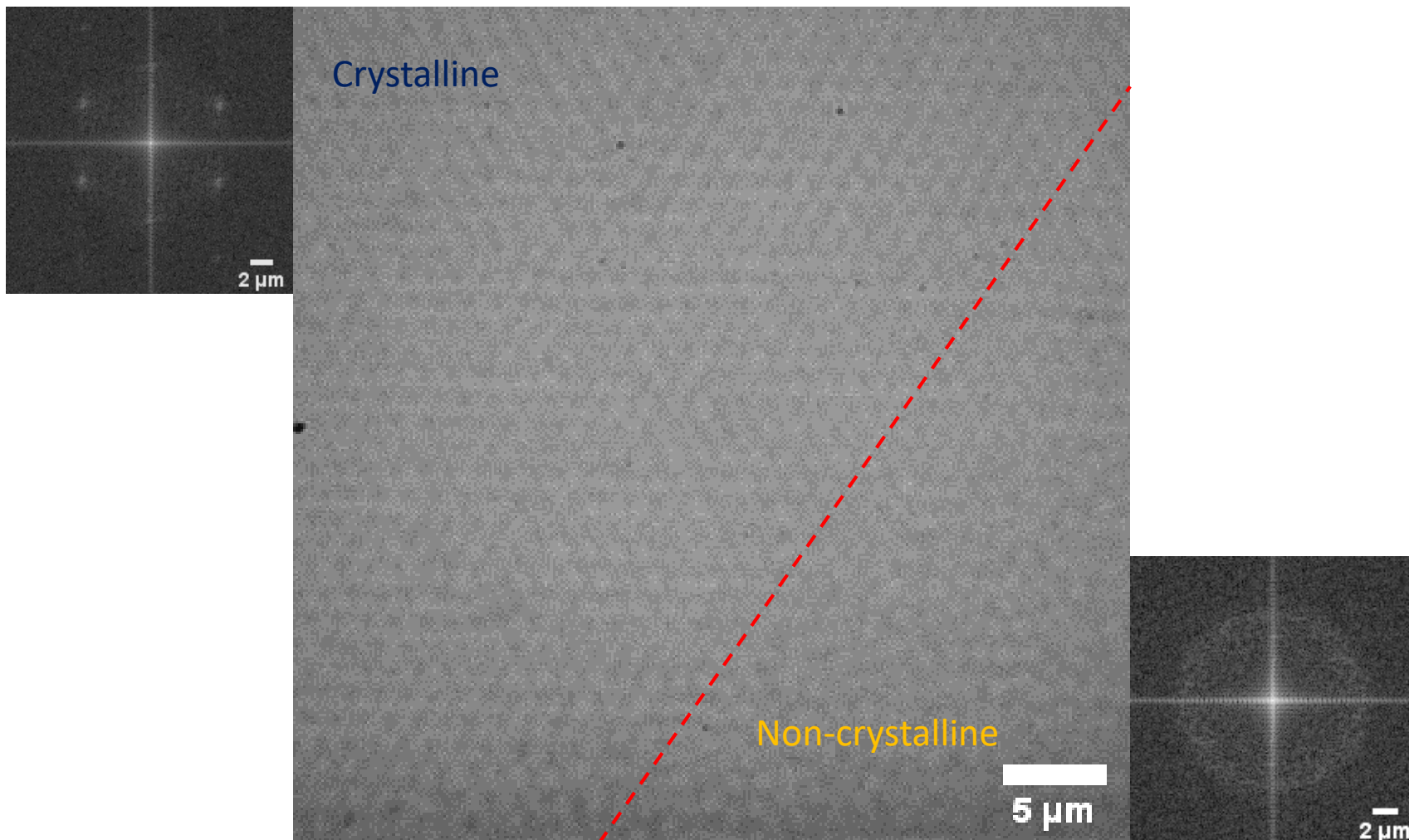




SPHERES



Coexistence of crystalline and non-crystalline structures



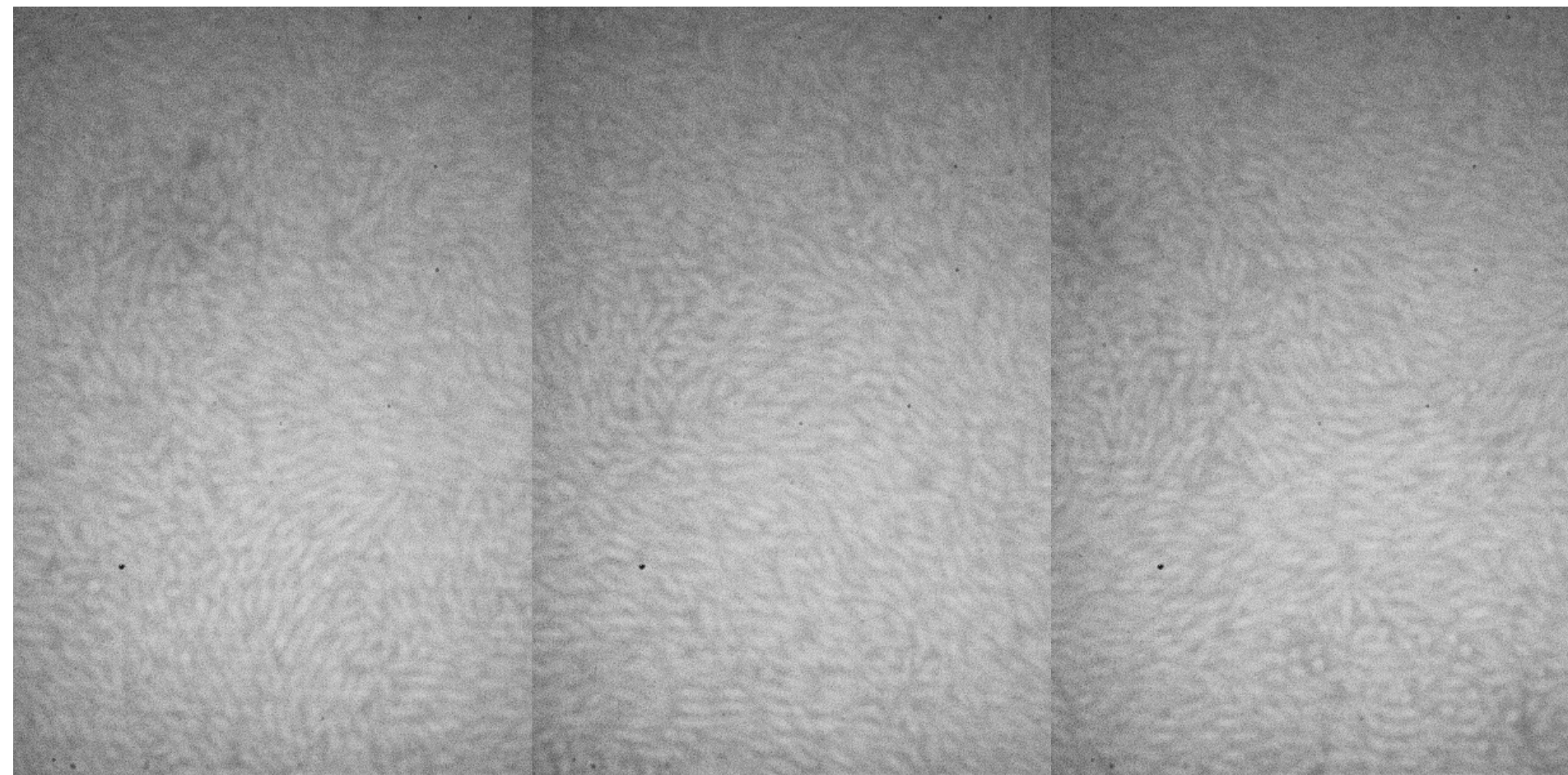
2020/11/21, 19:35:29.568, CnFcl, ACET11, S2017, C2,
Y+0, Z10uMr2, X100, X-8501, P16, E1052373, 00015



ELLIPSOIDS



Large nematic domains in scanning along the capillary axis

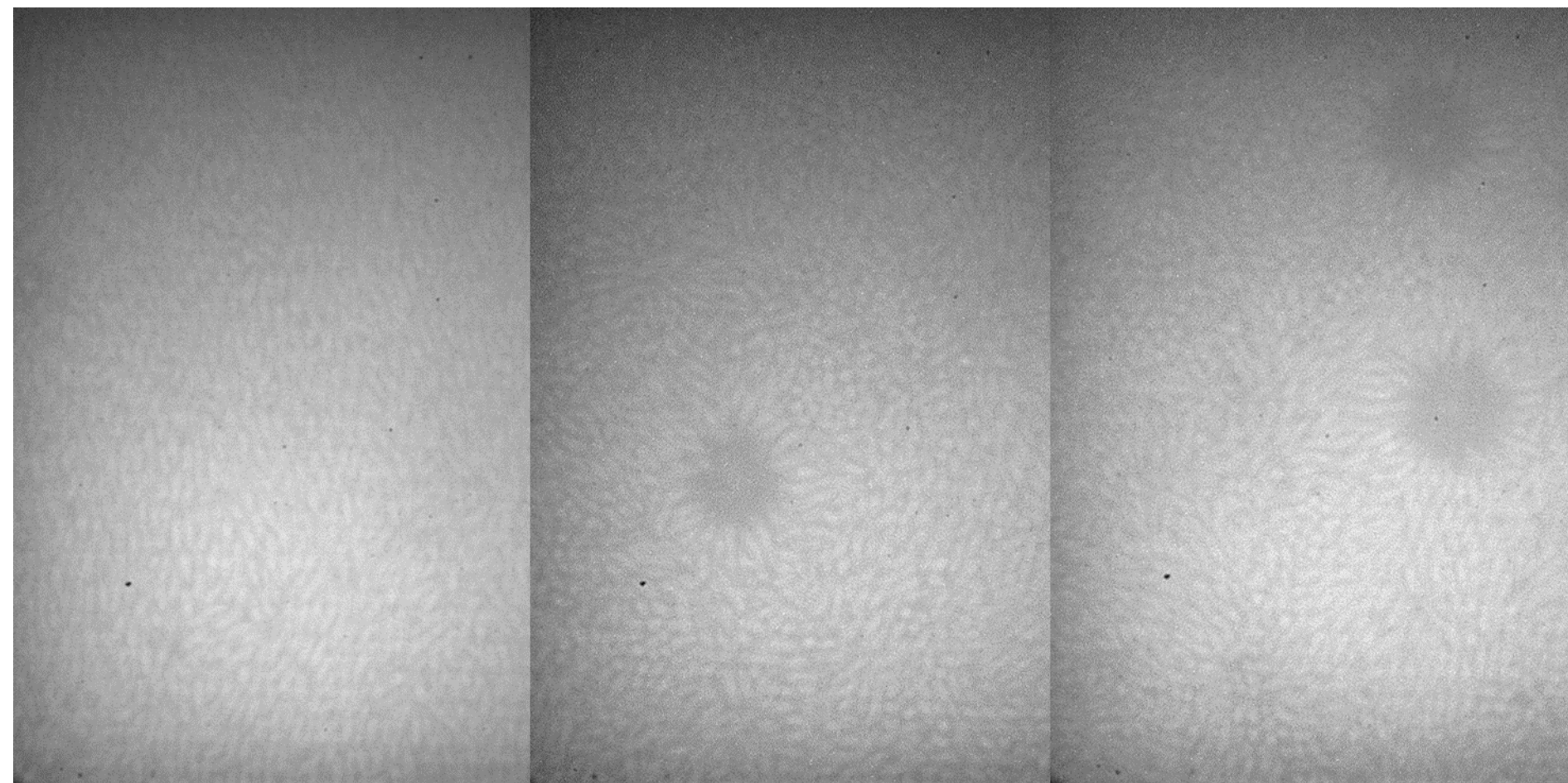


2020/10/05, 17:21:25.535, CnFcl, ACETR,
S3001, C3, X100, X-16674, **Z0+15**, P4,
E458961, 00945

2020/10/05, 17:21:29.535, CnFcl, ACETR,
S3001, C3, X100, X-16566, **Z0+15**, P5,
E458961, 00946

2020/10/05, 17:21:33.535, CnFcl, ACETR,
S3001, C3_X100, X-16457, **Z0+15**, P6,
E458961, 00947

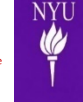
Nematic domains and associated “hedgehog” defects



2020/09/24, 22:14:56.768, CnFcl, ACETR,
S3001, C3, X100, X-13964, P29, E443412,
00250

2020/09/24, 22:16:56.833, CnFcl, ACETR,
S3001, C3, X100, X-10712, P59, E443412,
00280

2020/09/24, 22:15:40.701, CnFcl, ACETR,
S3001, C3, X100, X-12771, P40, E443412,
00261



SUMMARY OF PRELIMINARY DATA

Spheres

- Large crystal formed in microgravity
- Observed transition between crystalline and non-crystalline structures

Ellipsoids

- Large nematic domains formed in microgravity
- Associated “hedgehog” defects found

Questions

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Boris Khusid: khusid@njit.edu