OASIS
Observation and Analysis of Smectic Islands in Space

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Observation and Analysis of Smectic Islands in Space

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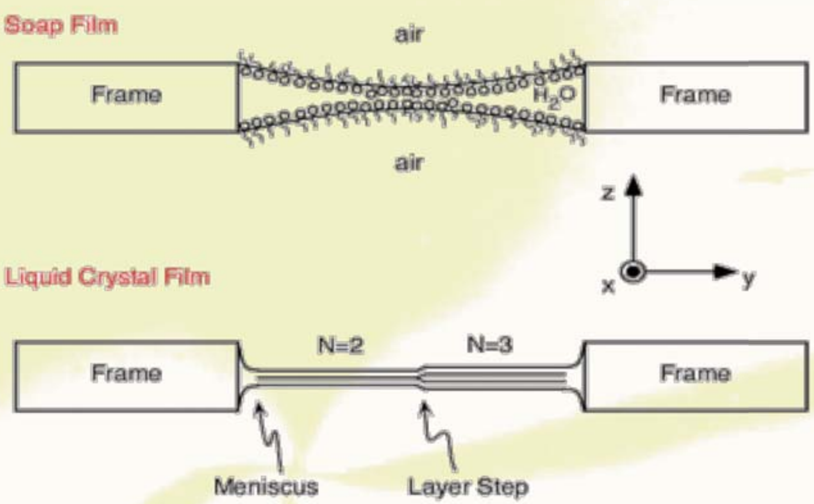
Freely Suspended Fluid Films



FSLC films exhibit a combination of physical characteristics systems for the study of

- ***Equilibrium and out-of-equilibrium phenomena in reduced dimensionality, example liquid crystal ordering and fluctuations in two dimensions, the effects of finite size on liquid crystal phase transitions.***

- ***FSLC films in microgravity present extraordinary opportunities for the study of fluid dynamic and thermodynamic behavior in reduced dimensionality, the exploration of fundamental nonequilibrium fluid interfacial phenomena.***

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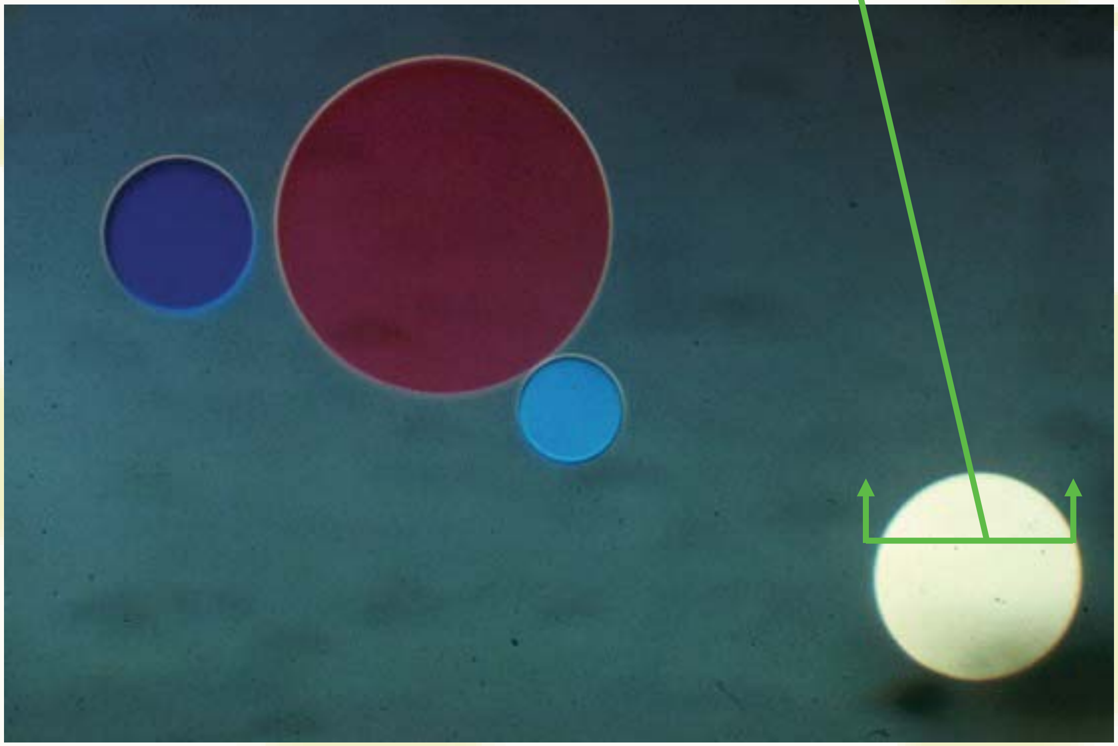
Smectic Islands

- **Thickness is Quantized**
  - Smectic layering
  - Profile
- **Shape**
  - Line tension
- **Interaction**
  - Barrier
- **Coalescence**
  - Dynamics
  - Collectivity



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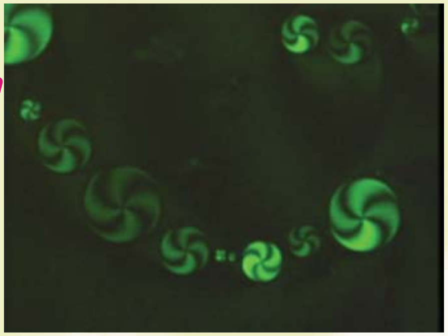
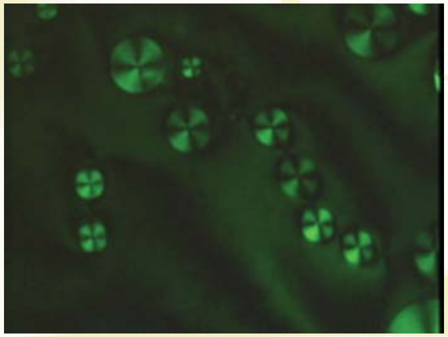
Chaining Behavior vs. Chiral Concentration

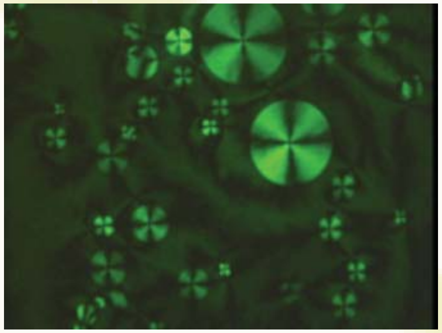
Chiral

Strong Interaction and Chain Formation



Weak Interaction

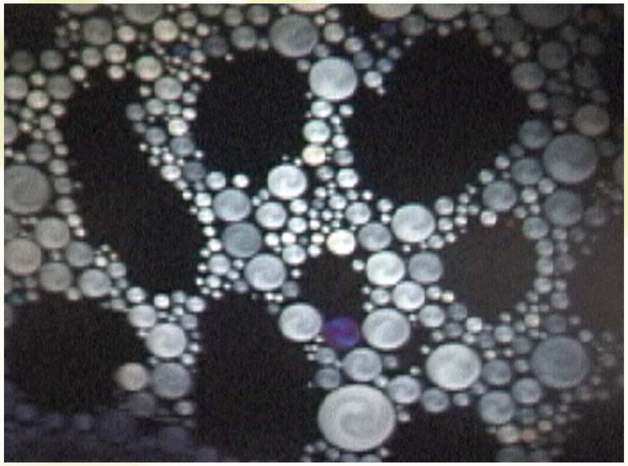


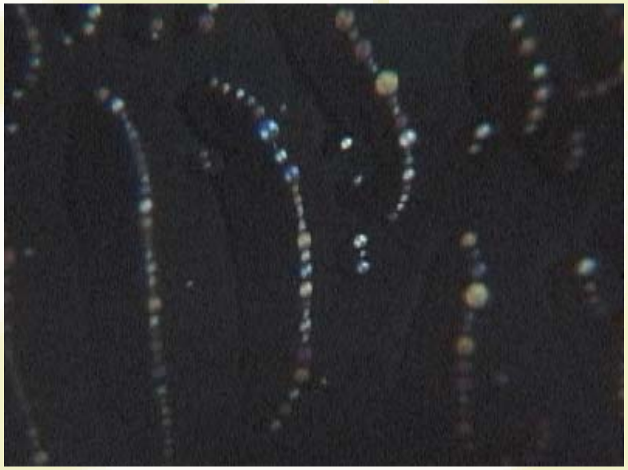


No Chain Formation at all

Racemic

External Electric Field Interaction





[1] A. Pattanaporkratana, C. S. Park, J. E. Maclennan, and N. A. Clark, Ferroelectrics 344, 71 (2006).

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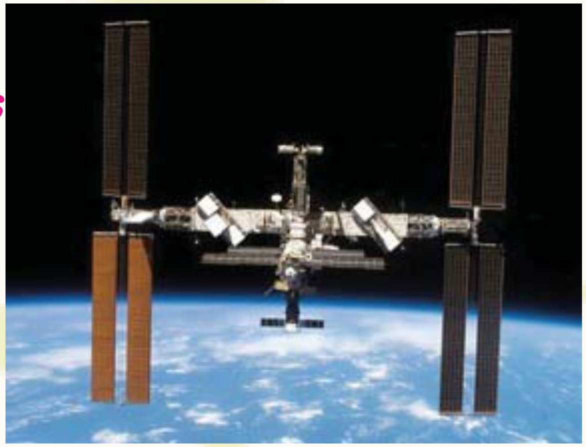
Science Objectives in Microgravity

To develop smectic bubbles as a experimental geometry for innovative studies of interface interactions and dynamics in ultra-thin fluid films



- ***2D Hydrodynamics***
  - *Hydrodynamics of islands and droplets*
- ***1D Interfaces in 2D Space***
  - *Coarsening & Ostwald ripening*
  - *Island interactions*
- ***Thermocapillary Effects***
  - *Marangoni effect*
- ***Surface and Line Tension***
  - *Dependence on film thickness*
- ***Textural Interactions***
  - *Interactions of islands/droplets and defects*
- ***Ultraweak Interactions***
  - *Interactions of islands*
  - *Effects of perturbing bubbles*

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Prioritized Experimental Objectives in Microgravity

- **Study of Collective Dynamics of 1D Interfaces on 2D Films**
  - Observation of the evolution of the island system over extended periods of time with no applied external field
  - Flow generation
  - Perturbation of the equilibrium state
  - External Electric field induced island interaction
  - Thermocapillary effects

- **Study of Dynamics & Organization of Droplet Arrays**
  - Generation & deposition of droplets using inkjet drop ejector
  - (Repeat the experiments with near identical islands)
- **Quantitative Measurements**
  - Bubble parameters
    - » thickness (spectrometry)
    - » diameter (imaging)
  - Island & droplet correlations (low, high resolution video image analysis)
  - Island & droplet distributions (low, high resolution video image analysis)
    - » island thickness (DRLM/ spectrometer)
    - » island & droplet size
  - Electric field strength, temperature

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Observation and Analysis of Smectic Islands in Space

Liquid crystal is everywhere today. Medical, education, energy, business, infrastructure, agriculture, space missions.

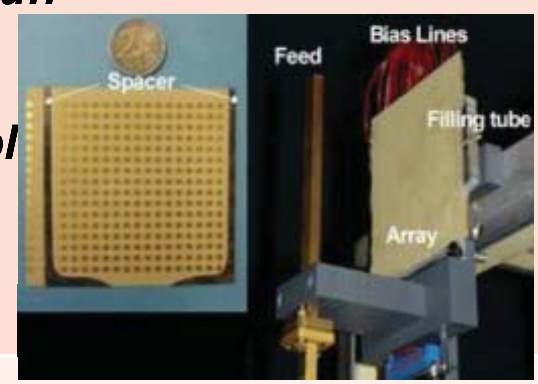
Inexpensive <u>Holographic</u> HD TV. (concerns of current 3d TV, medical/ophthalmological concern for children viewing current systems)

110 inch Ultra High Definition LC Displa

Hologram cellular phone (within 5 yrs.),

Smart windows (Eliminated need of window blinds and car sun shades)

Liquid crystal reconfigurabl antennas for deep space missions, satellite communications



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Today's Challenges of liquid crystal development:
Operation temperature range. (e.g.. Research expedition in the South Pole -50F)
Brightness, contrast ratio. (Using at day time outside).
Viewing angle, operation voltage, response time.

These challenges depend on liquid crystal materials and its control parameters;
Clearing point, melting point, birefringence,
dielectric anisotropy, elastic constants, rotational viscosity,
Discovery of new LC material structures.

Fig. Liquid Crystal defects grow and coalesce after 10 minutes at normal gravity and convective flow

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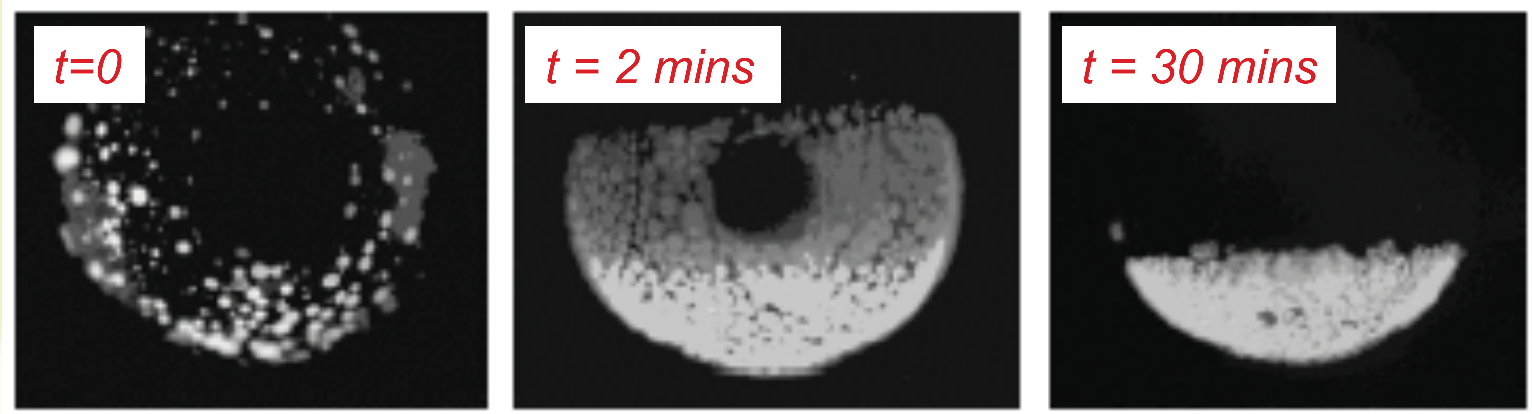
Justification for Microgravity



LC Material: 8CB

- **Limitations of Terrestrial Experiments**
  - Gravitational sedimentation of islands & drops
  - Convection of films and surrounding air
- **Limitations of Drop Tower & Parabolic Flight Experiments**
  - Coalescence & coarsening of islands, ordering of drops take a long time
- **Limitations of Modeling**
  - Lack of experimental data to test theory

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Science Requirement ➔ Hardware Development

- *Near 2 D system freely suspended film*

  ➔ Thin liquid crystal bubble ➔ making thin film lc bubble ➔ How to create thin LC bubble ➔. requirements, parameters, T control,
- *Thickness ?*

  ➔. Measurement techniques
- *Emulsions on the bubble (islands)*

  ➔. Creation methods and requirements
- *Global observation of bubble observation*

  ➔ macro view system
- *Island interactions*

  ➔ micro view capability
- *Interaction with external forces electric field interaction*

  ➔. Electric field
- *Gradient steps towards and away from phase transition*

  ➔ temperature measurement and control
- *Bubble Dynamics*

  ➔. Dynamic oscillation (inflation and deflation) of bubble ➔. Techniques
- *Droplet studies*

  ➔. Near identical (future proposed experiment) islands ➔. Size, distribution, material?? ➔. Inkjet nozzles

Bubble Study Approach

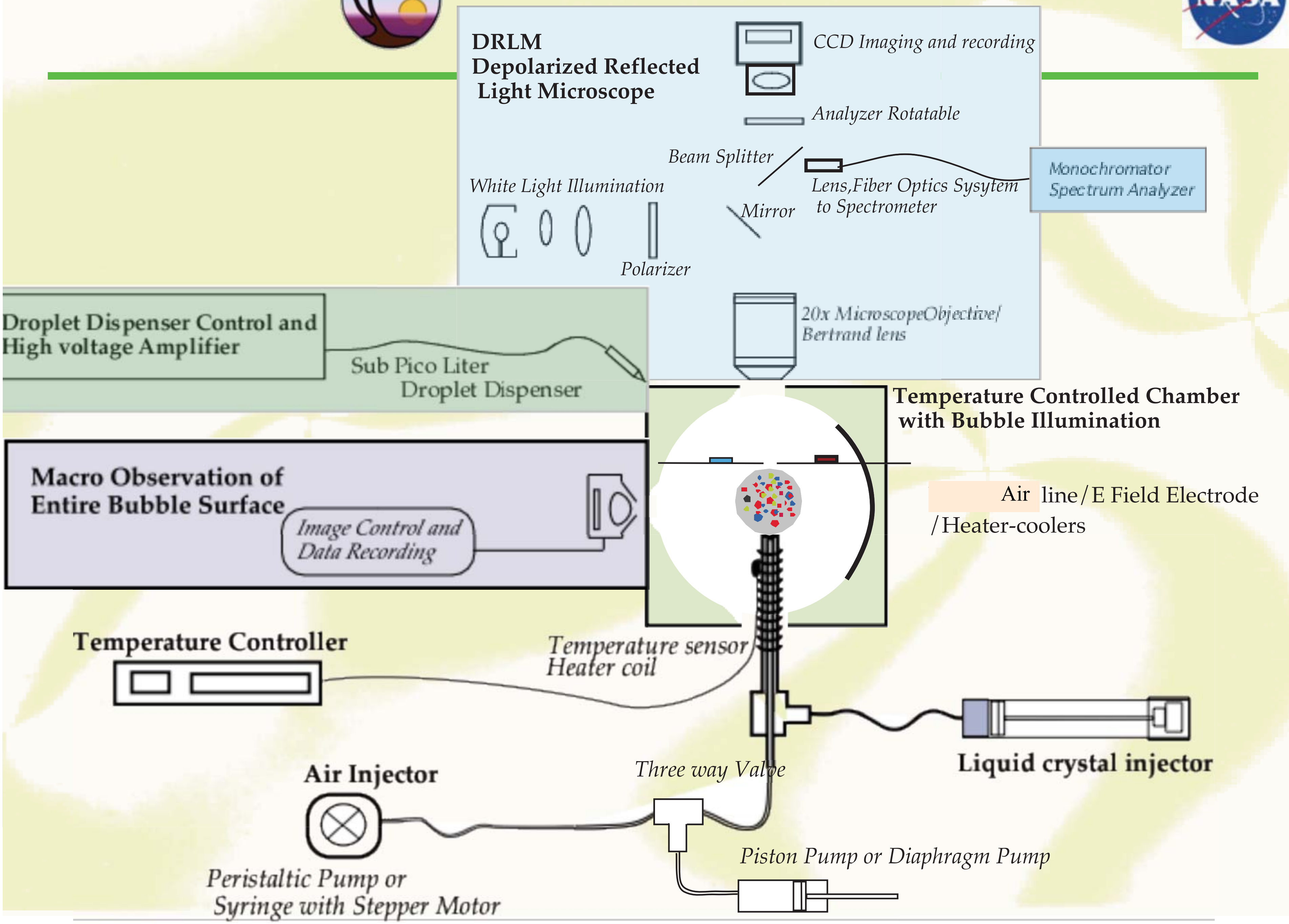
- **Observation by Reflected Light Imaging**
  - Low resolution video
    - » bubble inflation
    - » global bubble structure
    - » global interface organization
  - High resolution video microscopy
    - » island structure and dynamics
    - » orientational textures
- **Manipulation**
  - Electric field
    - » induced island interactions
    - » electrohydrodynamics
  - Air jets
    - » island generation
    - » film hydrodynamics
  - Optical tweezer manipulation of islands
    - » interactions
    - » elasticity
    - » hydrodynamics
  - Dynamic inflaton and deflation
    - » nucleation of islands and pores

OASIS Hardware in the Microgravity Science Glovebox

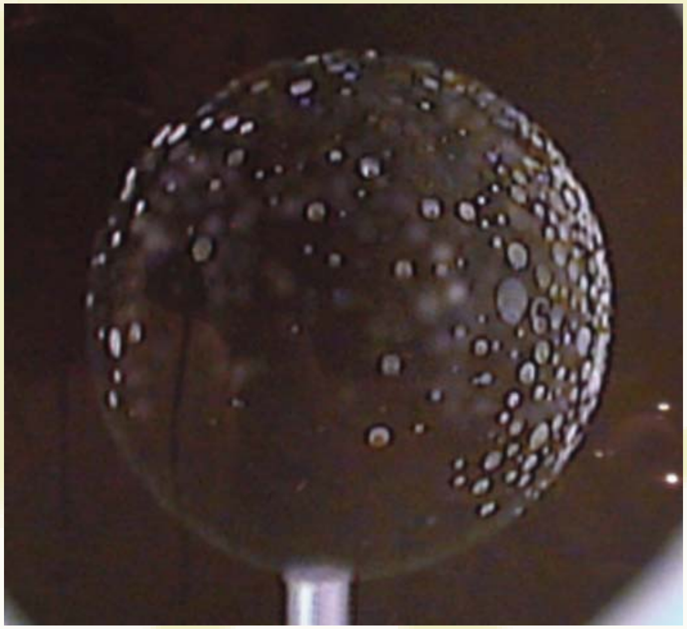
Hardware subsystems that meet Science Requirements

1. Create very thin liquid crystal bubble (sample dispenser, bubble maker)
2. Create micron size islands on the bubble (shearing with tangential gas, droplet dispensing device)
3. Macro view of entire bubble (illumination, macro lens, ccd camera)
4. Depolarized Reflective Light Microscope, Microscopic view of islands dispersion and interactions (illumination, microscope objectives, ccd camera)
5. Measurement of bubble film and island thickness (spectrometer)
6. Bubble dynamics (oscillation of bubble, inflate-deflating system))
7. Temperature control of ambient, and temperature steps
8. Temperature gradient system
9. Electric Field device and electrodes

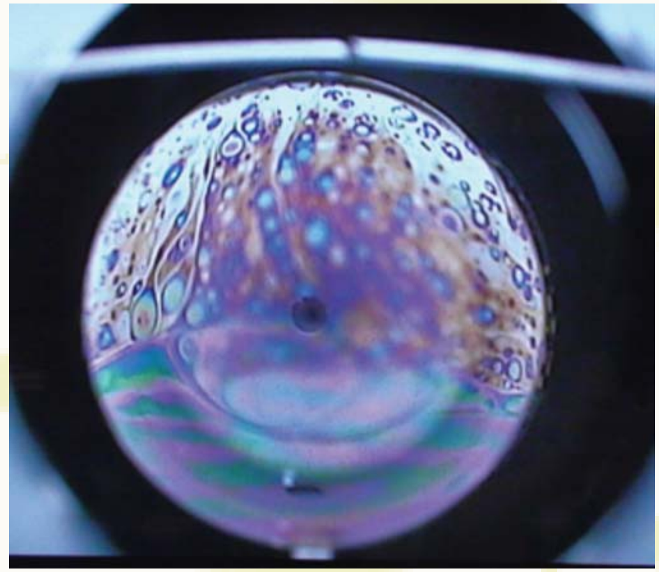
OASIS Instrumentation



Low Resolution Reflected Light Imaging



Islands on Smectic Bubble



Island Emulsion on Smectic Bubble

Global View of Structures on Bubble
Island Generation

after 5 minutes

after 1 hour old
(sedimented by gravity)

OASIS Hardware in the Microgravity Science Glovebox