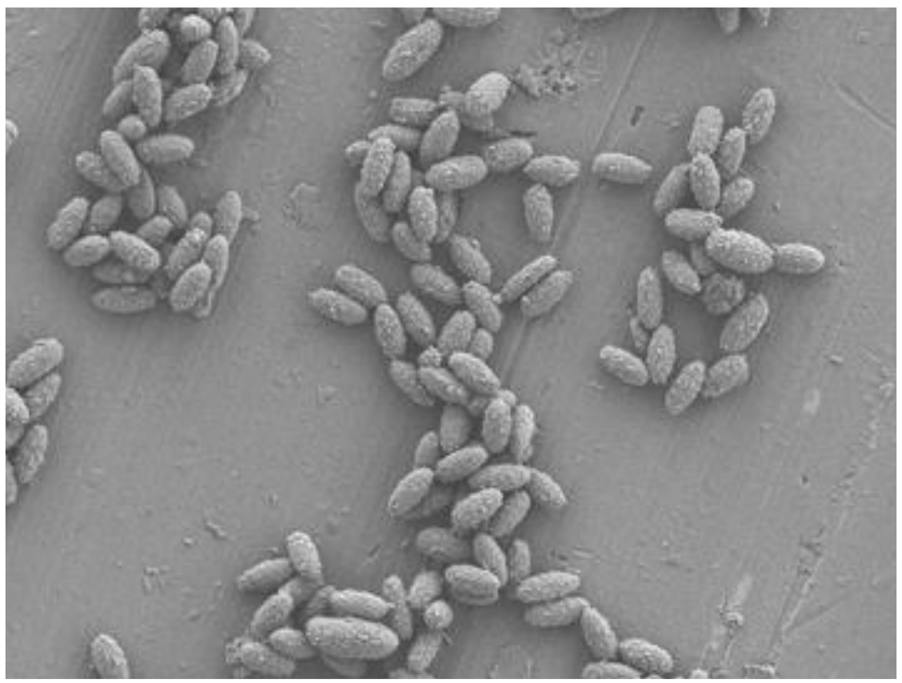
InSPACE-3 | Investigating Structure of Paramagnetic Aggregates from Colloidal Emulsions



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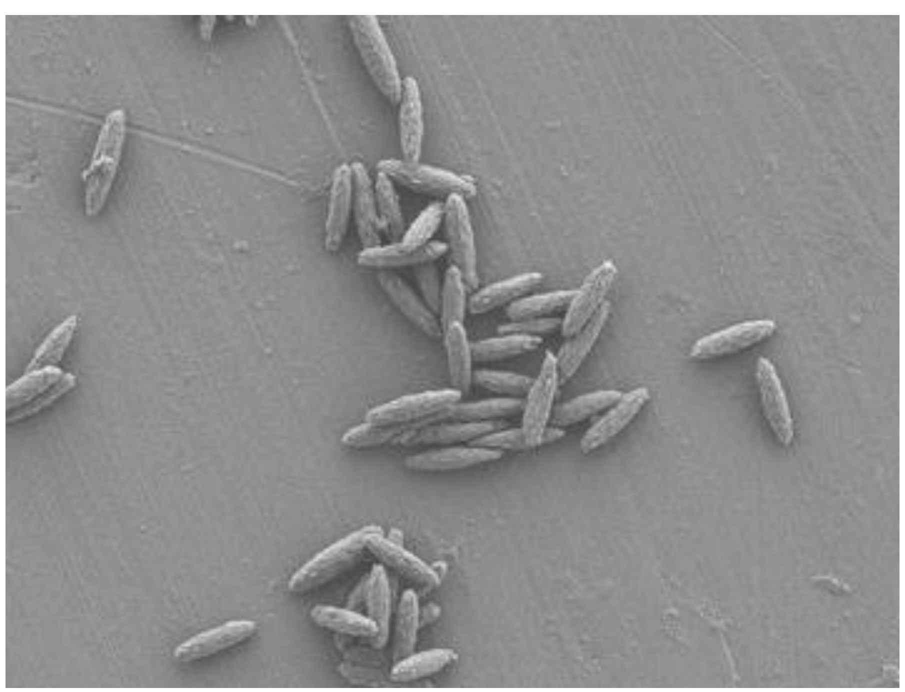
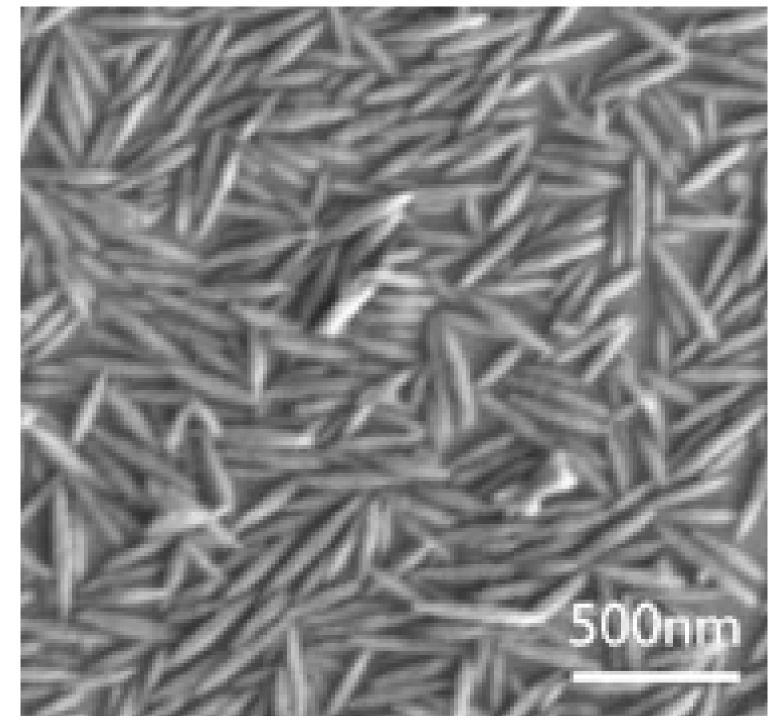
PM: Robert D. Green, NASA Glenn

Increment 31/32 Science Symposium
December 8, 2011

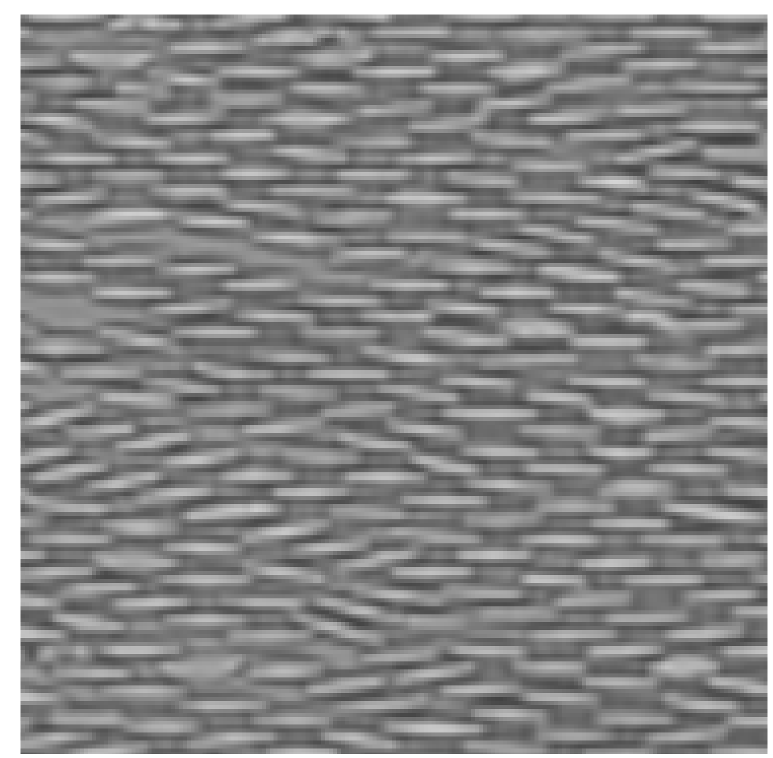


InSPACE-3 goal

Investigate the three-dimensional, directed assembly of polarizable, anisotropic colloids in steady and pulsed external fields



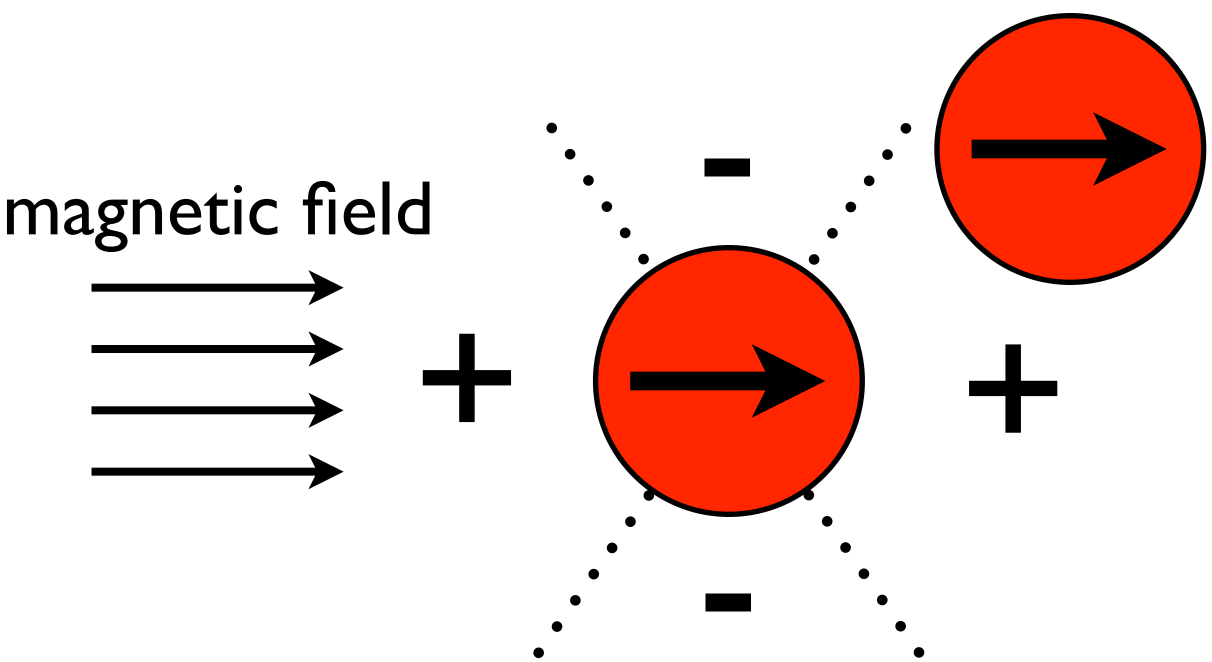
- assembly of novel materials
- exploring transitions from disorder to order (condensation)
- overcoming inherent kinetic limitations (percolation)

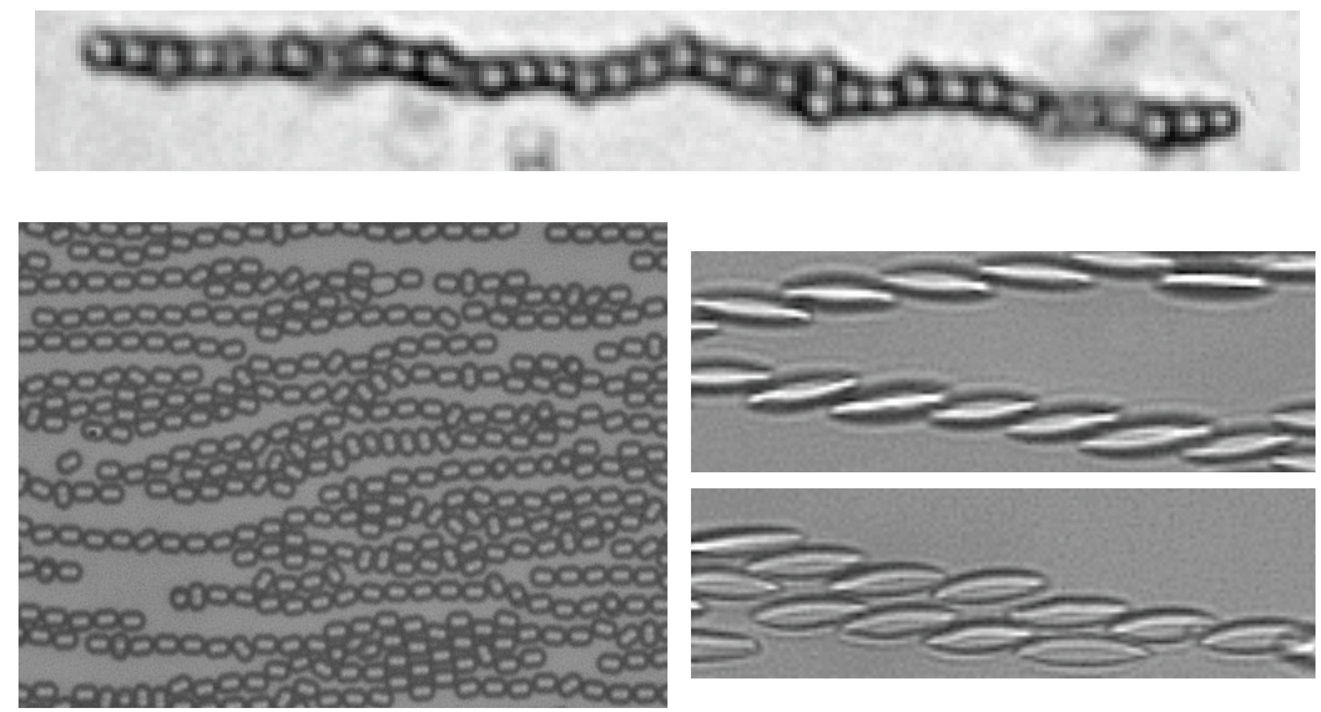


InSPACE-3 background

A magnetic field will induce a dipole moment in a ferromagnetic colloid. Induced dipoles cause particles to attract (+) and repel (-) forming chains aligned with the field

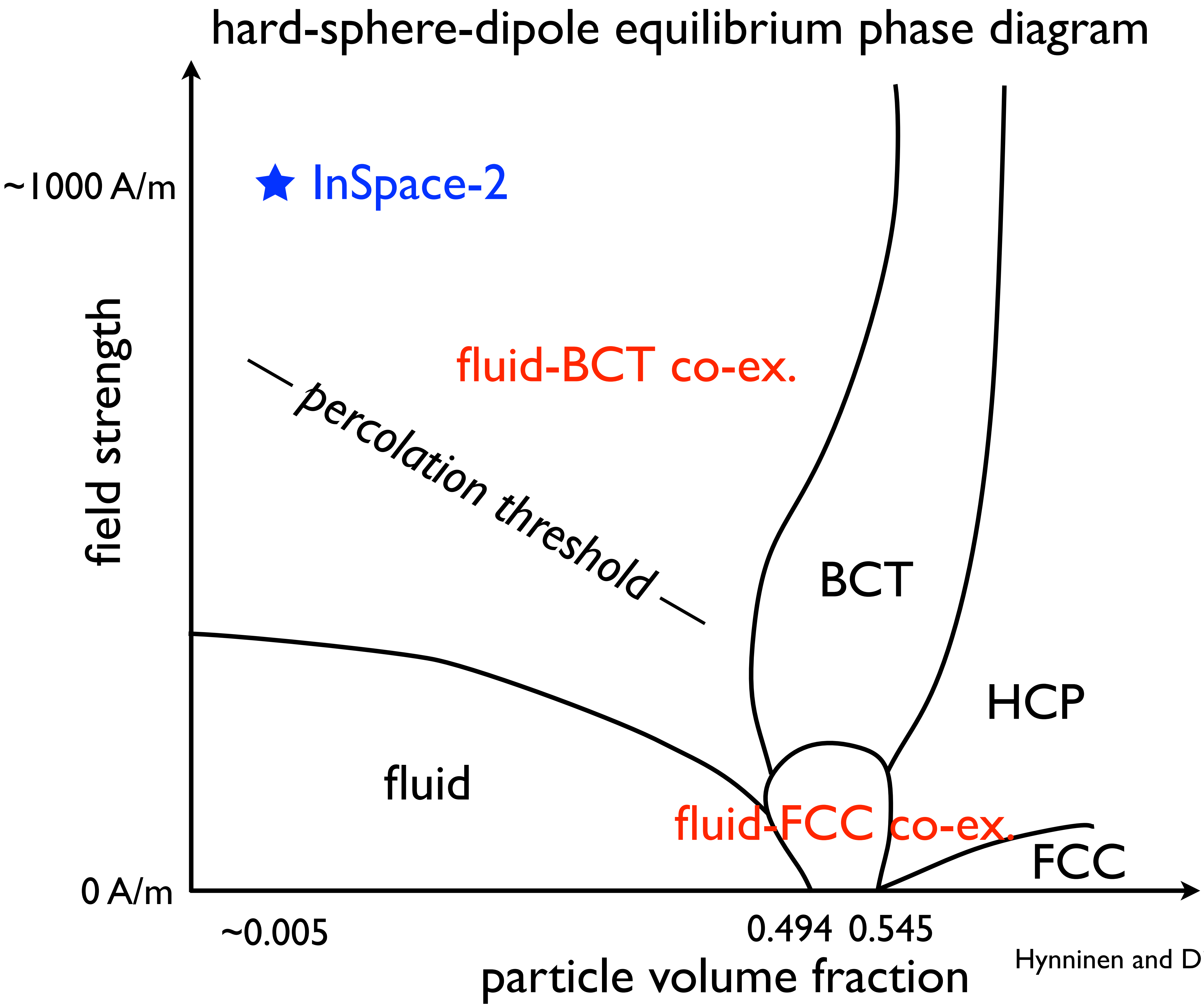
force ~ $(\text{field strength})^2 / (\text{separation})^4$





At high enough field strengths, chains interact forming percolated networks which are kinetically arrested.

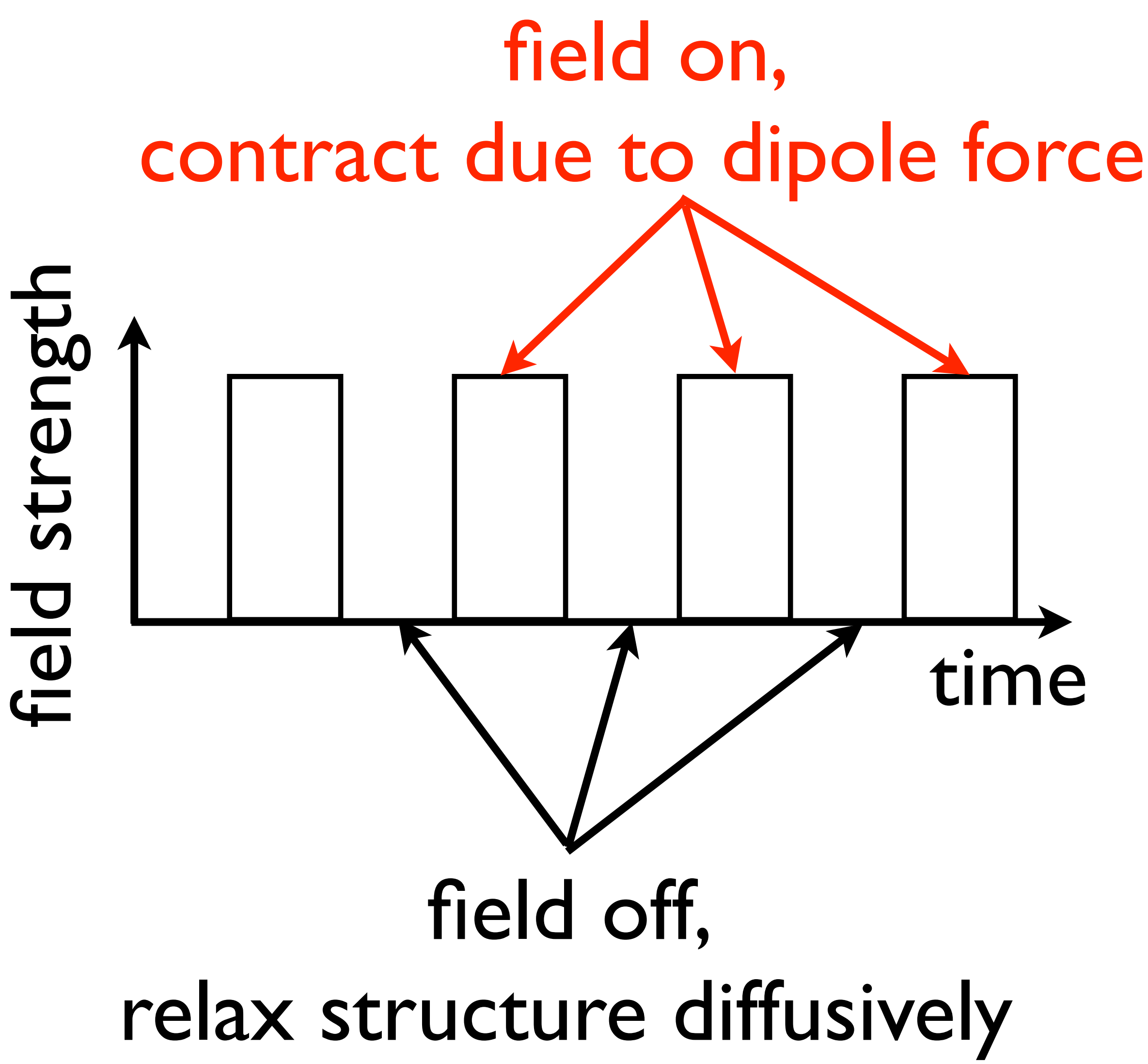
InSPACE-3 background (cont.)

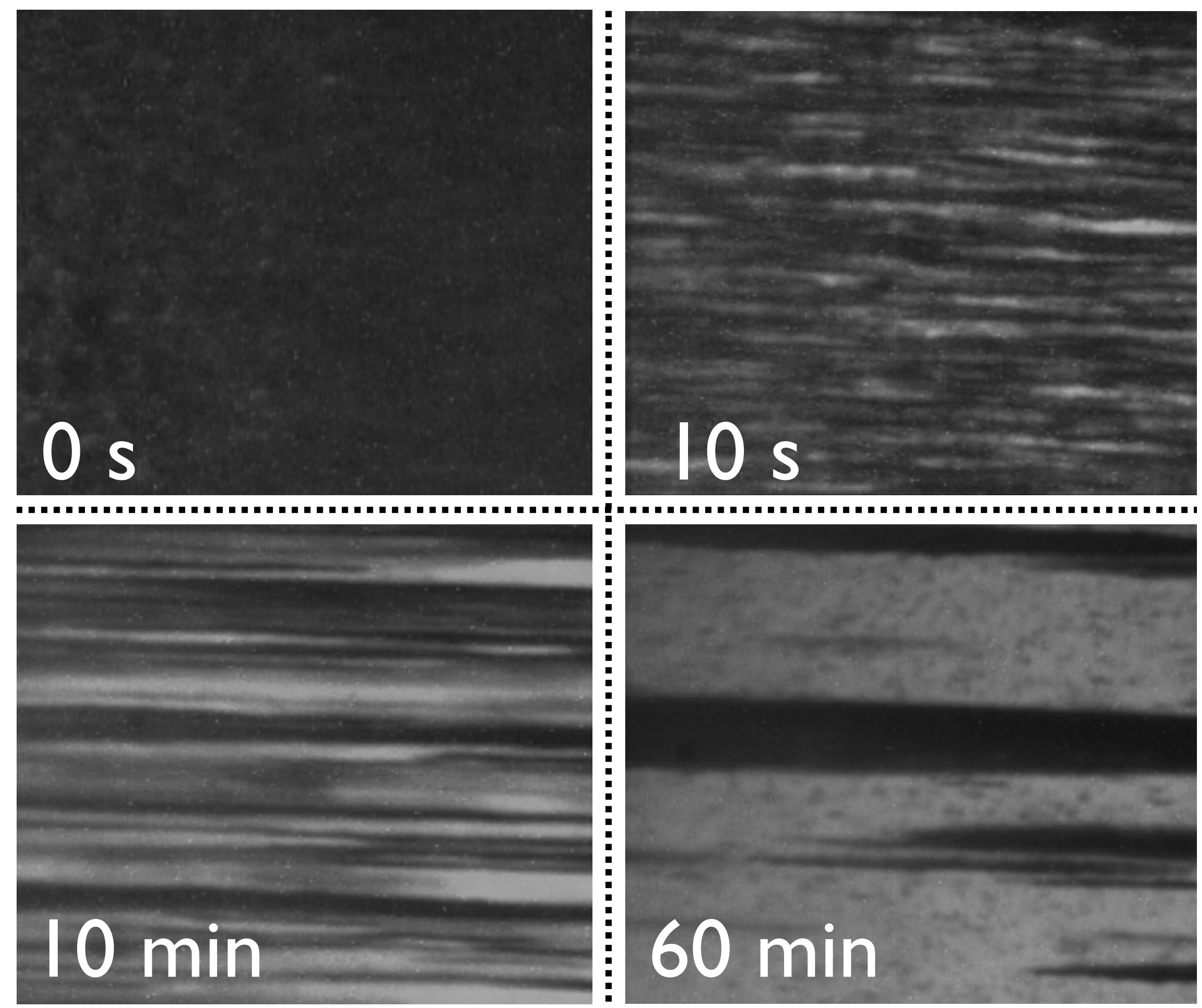


Hynninen and Dijkstra PRL, 2005

InSPACE-3 background (cont.)

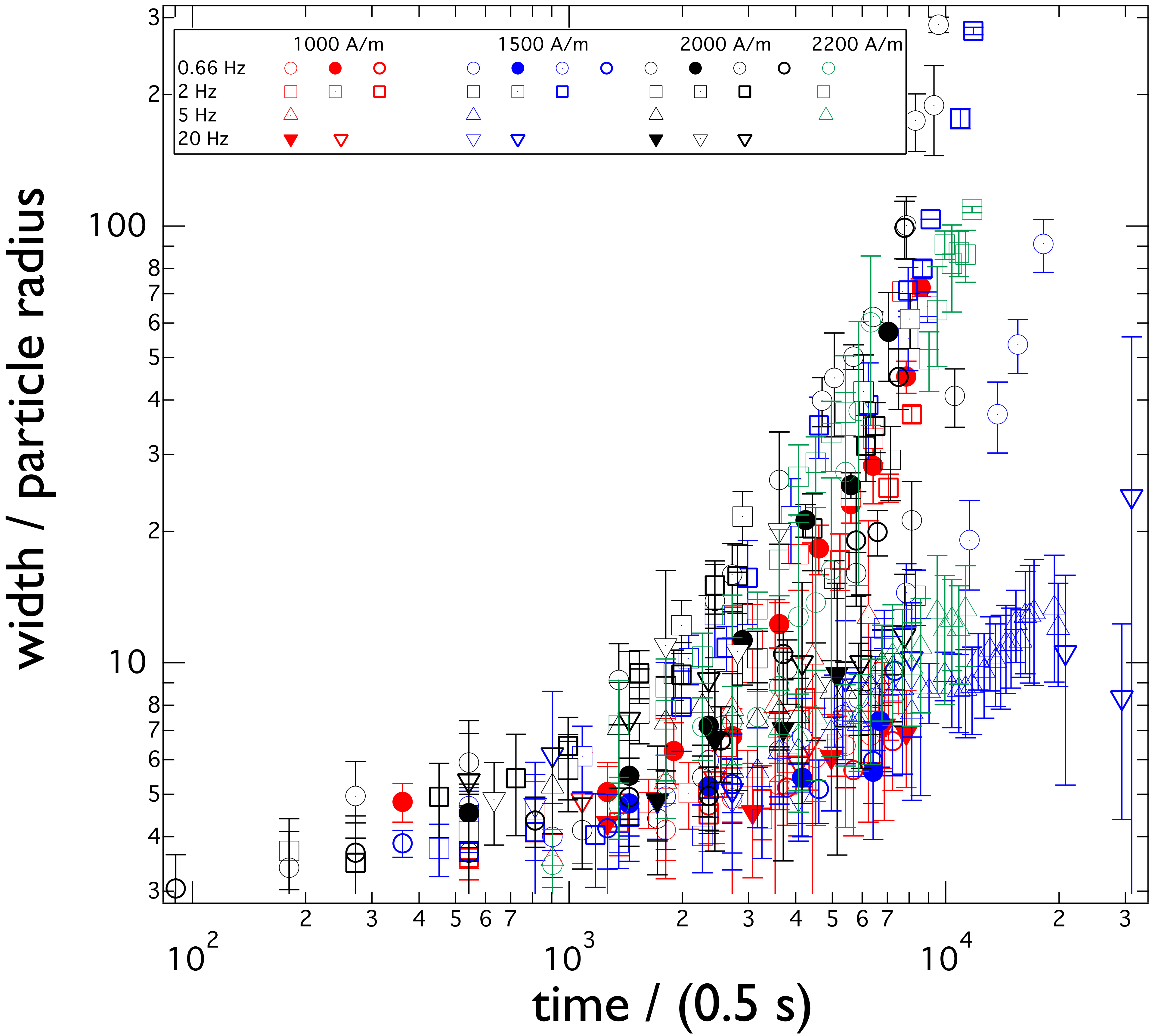
By periodically actuating the magnetic field (on/off), the suspension microstructure is annealed towards its equilibrium state.

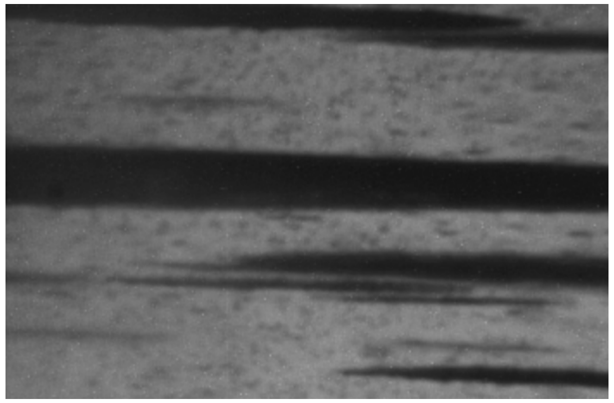




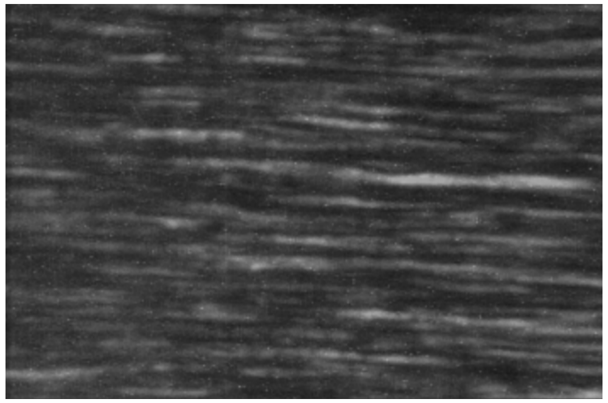
Will the material relax completely? At what frequency does it begin to relax? What structures ultimately form?

Past results



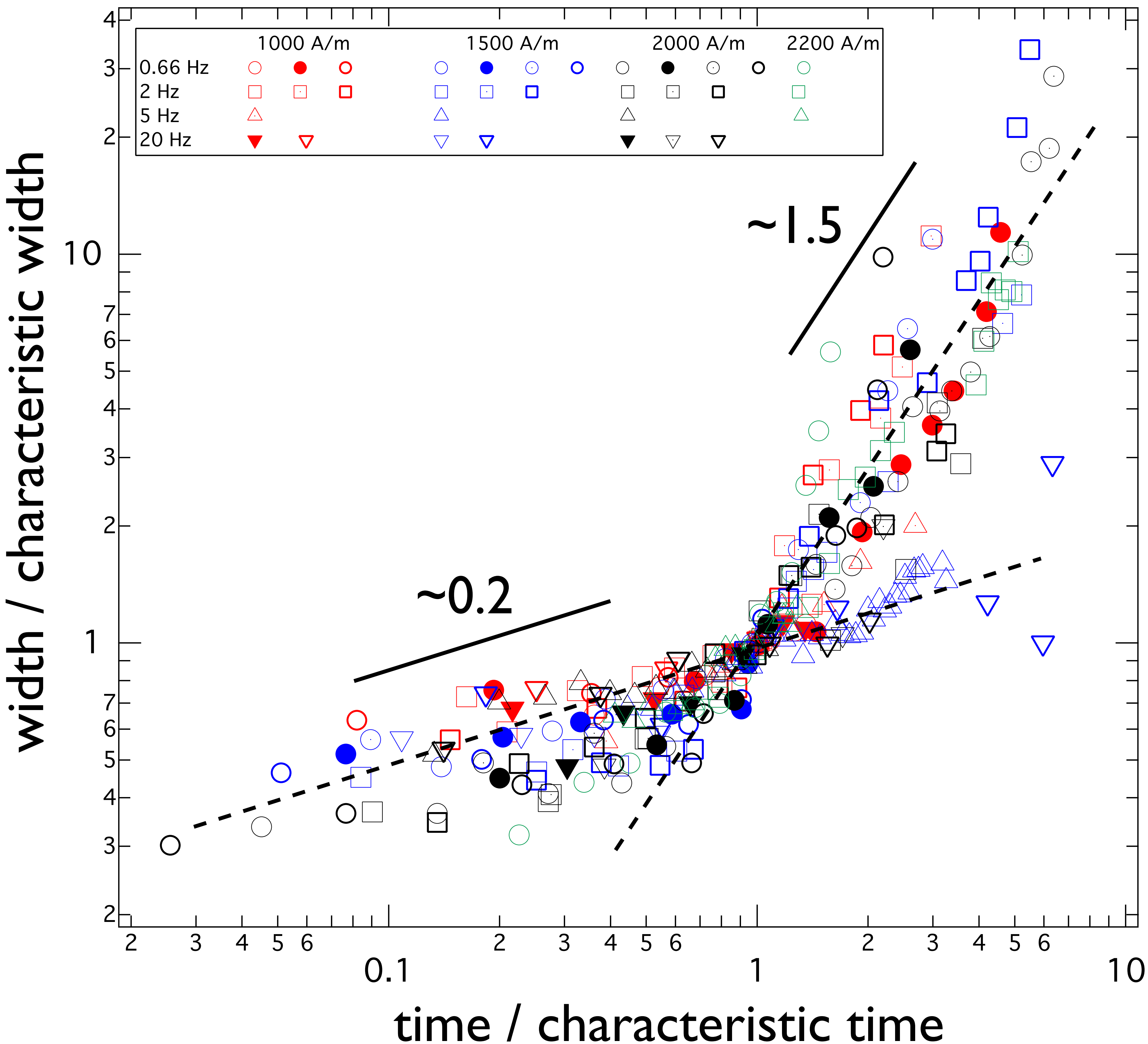


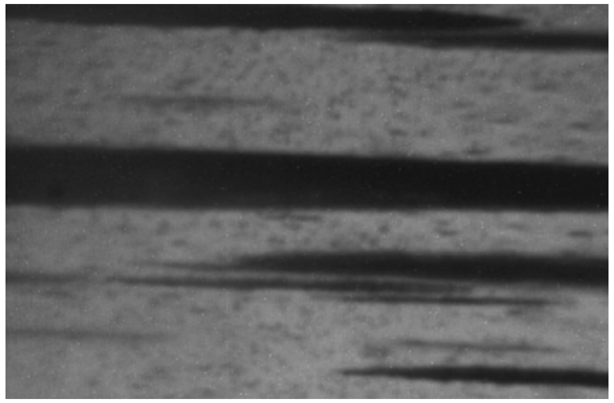
condensed



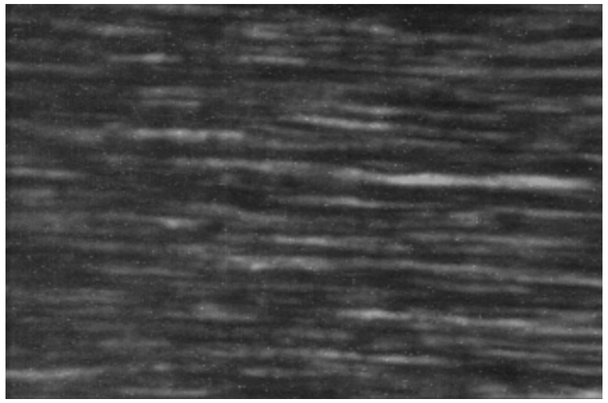
percolated

Past results (cont.)



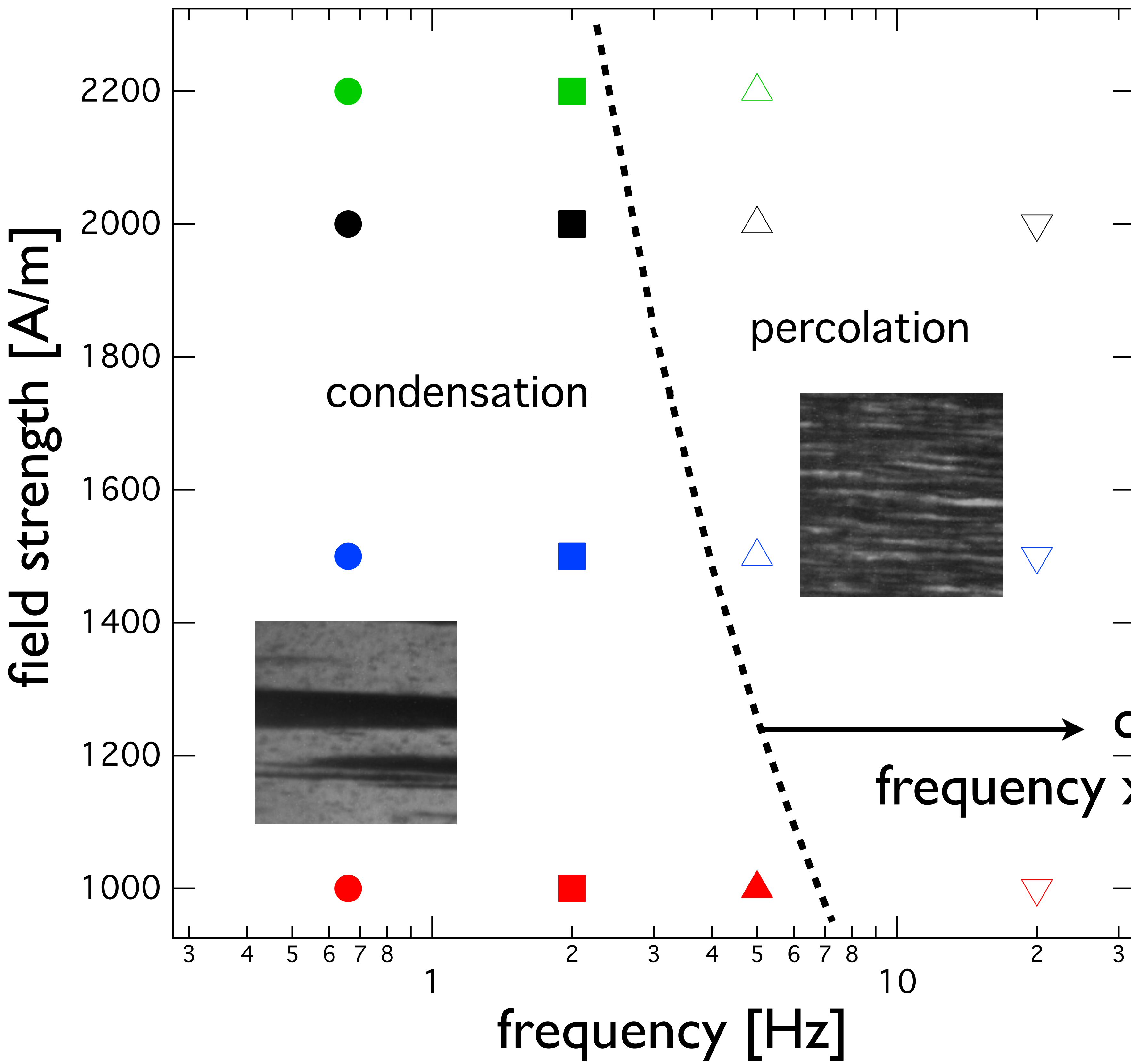


condensed



percolated

Past results (cont.)



time with field off:
~ 1/frequency

time for particle to diffuse capture radius:
~ (field strength)$^{4/3}$

constant:
frequency x (field strength)$^{4/3}$

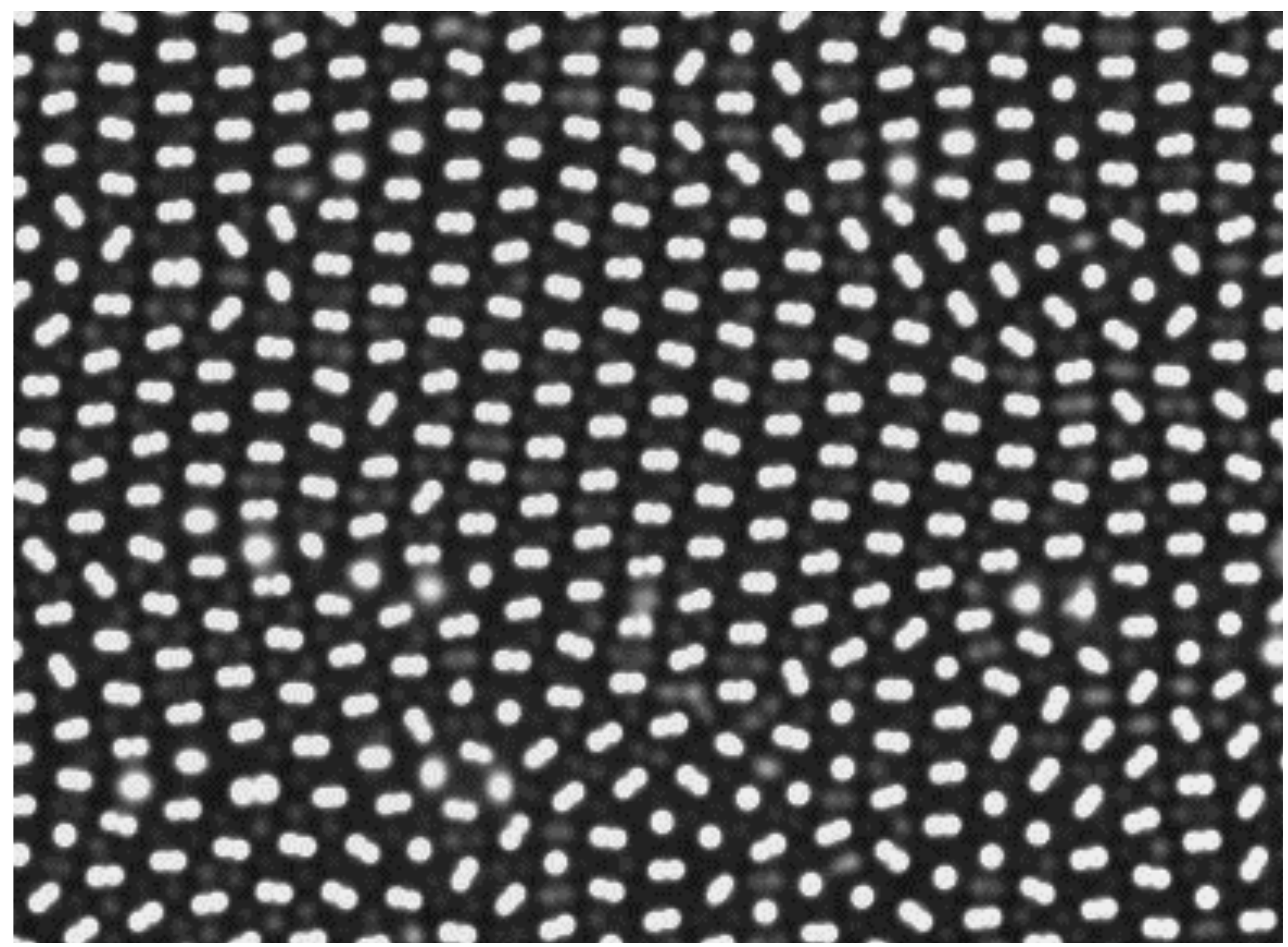
State of the art

directed assembly of colloids

- shear
- evaporation
- sedimentation
- surface templating
- *directing fields*
- *particle anisotropy*

field strength and frequency: energetic

size and shape: entropic



Objectives

- Identify structures formed by ellipsoidal suspensions in steady fields
- Pulse field at low frequency to allow suspension to relax. *Are new structures formed?*
- Test predictions of condensation-percolation transition from InSpace-2.
- Determine the growth rate of aggregates as function of time. *Does particle anisotropy stimulate field directed assembly?*

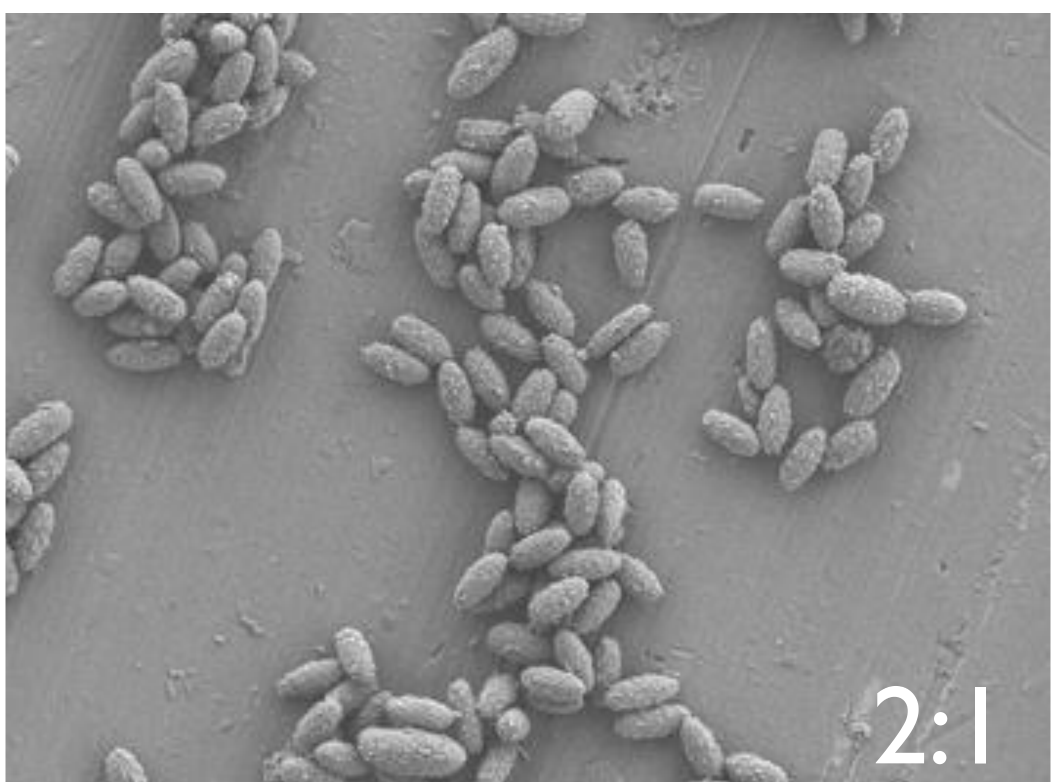
Variables

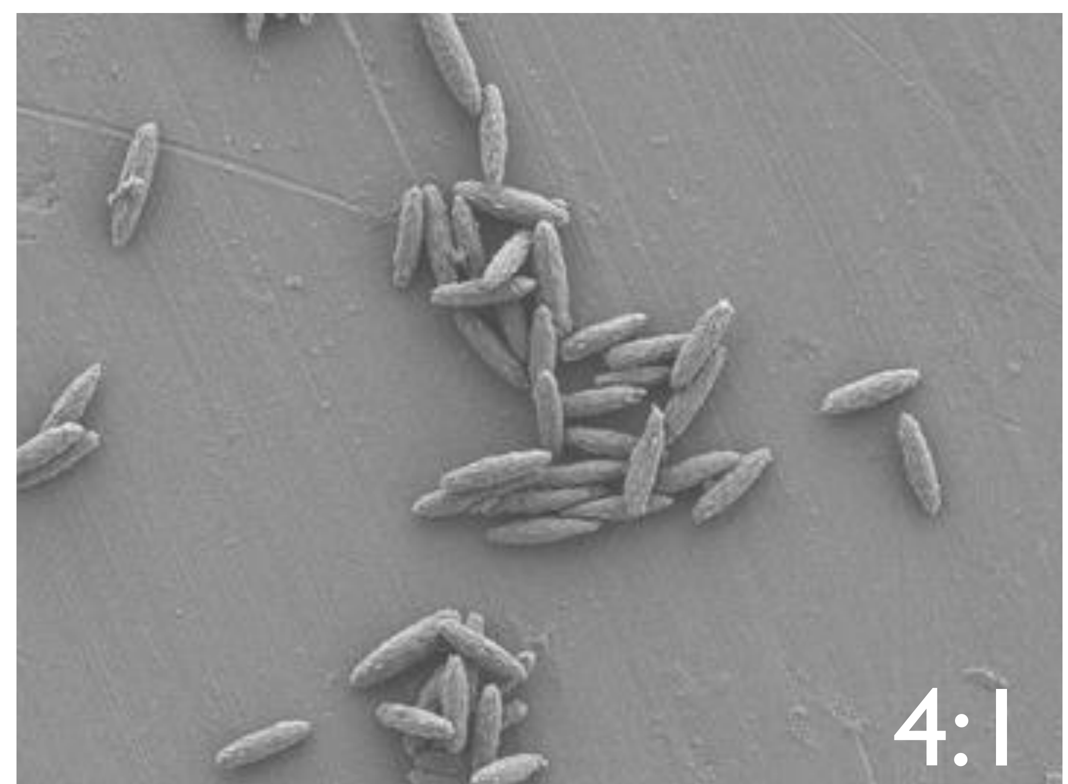
- magnetic field strength: 800-2000 A/m
- pulse frequency: 0.66-20 Hz
- concentration: 0.52% by volume
- *aspect ratio*: 2:1, 3:1, 4:1

2:1, L=3.96 μm

3:1, L=5.20 μm

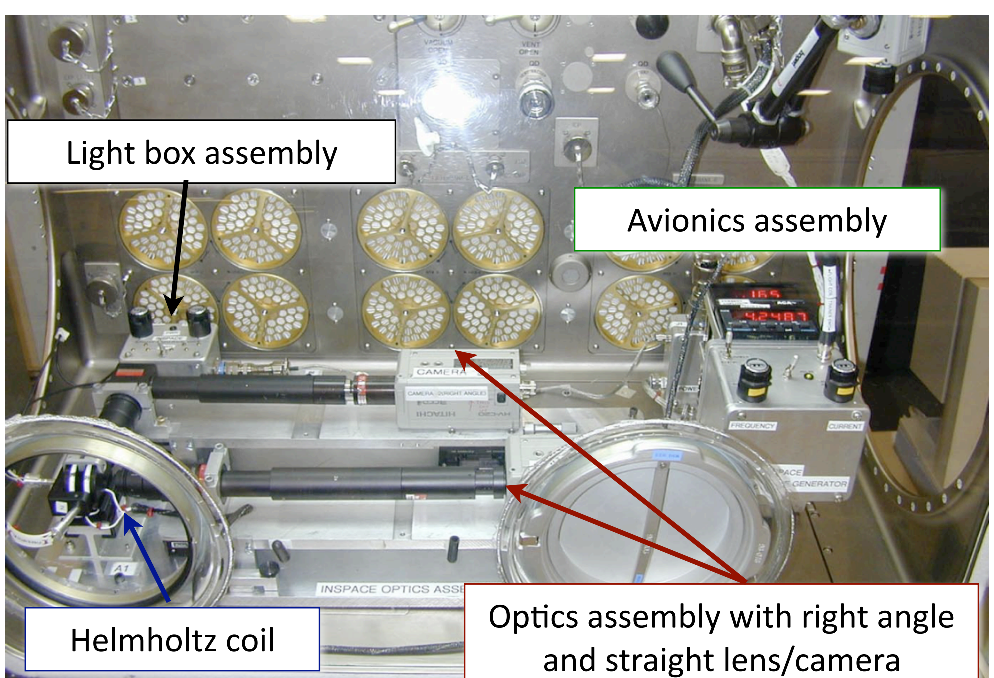
4:1, L=6.30 μm

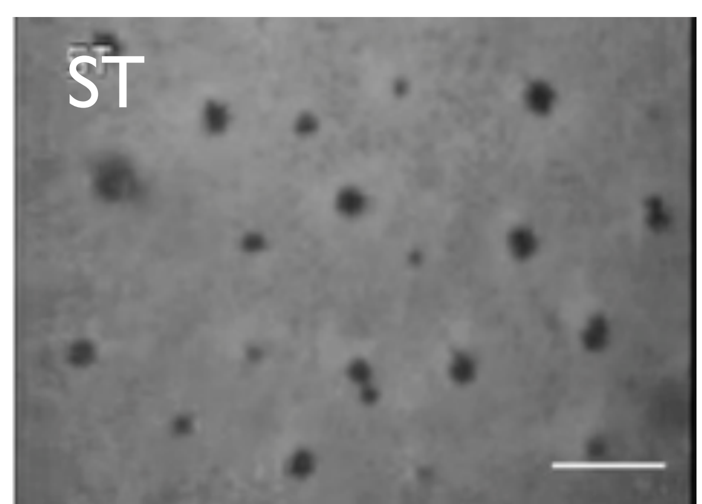


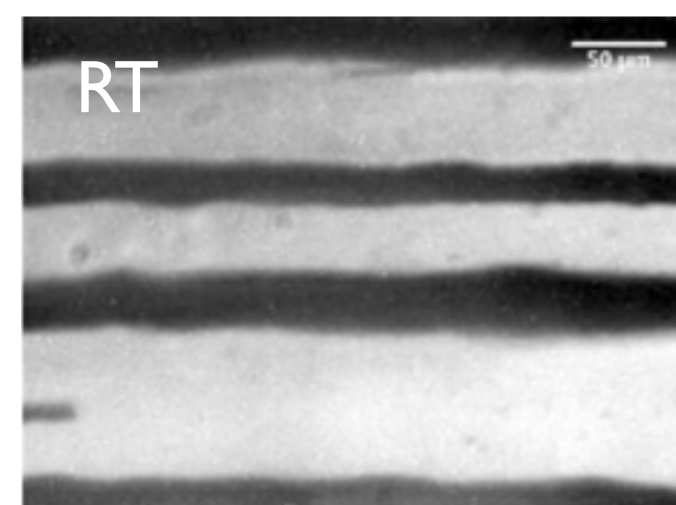


Measurements

- *in situ*: microscopic observations of suspension structure during assembly recorded to DV tape
  - ST: field-aligned view
  - RT: field-normal view
- ex situ: video analysis of micrographs to determine growth rate field assembled structures







Why the ISS?

- Colloids seeded with iron nano-particles undergo sedimentation in typical solvents:
  - The weight of field assembled aggregates grows faster than the drag resisting sedimentation!
  - Nearly density-matched suspension may be achieved with emulsion droplets, but these assume a spherical shape due to high Laplace pressures
- The time required to transition from percolation to coalescence is typically more than 45 minutes.

Terrestrial benefits

- Improved control over the mechanical response of field-actuated suspensions in electro-mechanical devices: dampers, actuators, magnetically sealed bearings, transducers, etc.
- Routes to creation of novel, responsive materials with unique mechanical and optical properties.
- Uncover fundamentals of percolation and order-disorder transitions in driven and complex media.