Ad hoc Workshop on Magnetized Dusty Plasmas

October 19 – 21, 2009
Auburn University, Auburn, Alabama

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Agenda – Wednesday, October 21

- 8:00 am Continental breakfast
- 8:30 am Session 5: Workshop summary
  - Revisiting physics goals
  - Prioritizing experiments
  - Outline of workshop report
  - Plans for next steps
- 10:45 am End of workshop – return to hotel

Day 2 - Summary

- Discussion on project motivation and goals
  - What is the organizing principle for pursuing a magnetized dusty plasma experiment?
    - Naturally occurring plasmas at all scales have both magnetic fields and dust.
    - Because the addition of the charged dust modifies the properties of the plasma current experiments have all focused on the dust – plasma interaction.
    - These experiments are operated in regimes without magnetic fields or with magnetized electrons only.
    - With the knowledge gained from the last two decades of research, it is now possible to explore the true behavior of a dusty plasma in nature – a system that includes both charged microparticles and magnetic fields.
    - Therefore, to advance the complete understanding of dusty plasmas, it is necessary to study fully magnetized plasmas – where first the electrons, then the ions, and finally the charged dust are confined by the magnetic field.
    - The presence of the magnetic field modifies all of the properties of the plasma by adding an additional degree of freedom; a magnetized dusty plasma will, likewise, be completely transformed by the magnetic field – leading to an entirely new regime of dusty plasma physics.
    - This facility will lead to a new era of discovery for dusty plasmas:
      - Verify existing theories of dust interactions with magnetized ions
      - Verify theories of new collective modes arising from magnetized dust
      - Allow experiments with magnetic particles where B and grad-B is a control parameter

Day 2 - Summary

- Discussion on project motivation and goals
  - What is the organizing principle for pursuing a magnetized dusty plasma experiment?
    - A magnetized dusty plasma can be used to study the fundamental processes that play a role in many plasma environments.
    - For example, magnetic field may affect the agglomeration of particles in proto-stellar and proto-planetary clouds – altering the properties of comets, stars, planetary rings, and atmospheres.
    - A magnetized dusty plasma can also give new insights into processes such as phase transitions, waves, and para- and ferro-magnetic condensed matter systems by enabling macroscopic modeling of complex processes at a kinetic level.

    - This facility will lead to a new era of discovery for dusty plasmas:
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Day 2 - Summary

- Theoretical and experimental considerations (Rosenberg)
  - Diagnostic approaches
    - Surface plasmon resonance – for metallic nanoparticles
    - May allow experiments to be performed for either enhanced scattering or absorption.
    - Using different particle shapes could allow tuning of the resonance.
  - Wave studies
    - Magnetized ions, unmagnetized dust
      - Dust modified E x B driven instabilities (Hall current)
      - Dust modified diamagnetic drift instabilities
      - Magnetized ion in charged dust beams (?)
    - Magnetized dust
      - Electrostatic dust cyclotron instability + higher harmonics
      - Modified longitudinal and transverse waves in crystals (assuming crystals still form)
  - Using paramagnetic ($\mu > 1$) and superparamagnetic ($\mu >> 1$, ~3) particles
    - Moderate gradients (6 G/cm -> 0.06 T/m) can be used for controlling particles.
    - Forces are independent of particle size (for spherical particles).
    - Can use particles with different values of μ and a variable grad-B to add additional control to experiments
    - Forces are attractive along B, repulsive perpendicular to B – use to “tune” the behavior of waves, crystals, etcl.

Day 2 - Summary

- Theoretical and experimental considerations (Rosenberg, cont.)
  - Crystals
    - Tune the spacing and structure of a dust cloud or a dust crystal by using mixtures of paramagnetic, super-paramagnetic and non-paramagnetic particles in a varying magnetic field
    - Create true binary crystals using a combination of electric and magnetic forces on two particle types to bring the particles together.

Day 2 - Summary

- Some decisions
  - Diagnostics
    - Visible lasers (red, green) – micron sized particles
    - UV camera / UV laser – down to 100 nm
    - PMT or speckle detection – down to 10’s of nm
    - Laser induced incandescence (?) – nm scale?
    - Multi-pass extinction measurements
  - Plasma source
    - Start using RF parallel plates
    - Make early test of DC discharge (Sato?)
    - Begin development of ICP system (perhaps operating at high frequency – 100’s of MHz, matching network design?)
    - Filaments, heated cathode – force issues; thermophoresis
  - Chamber design
    - Add Peltier elements for thermophoresis control (?)
    - Design wider diameter extension pieces
    - Possibly reduce the main chamber diameter slightly (to allow re-orientation of coils).

Day 2 - Summary

- Education and outreach discussion
  - Conventional activities
    - Undergrad and grad student training
    - Possibility for REU activities
    - Work with PPPL to become a NUF site
  - New initiatives
    - Use cyberinfrastructure to provide N% run-time to local/regional schools
    - Partner with Alabama Math, Science, Technology Initiative (AMSTI) for developing new lessons using magnetism and magnetic fields
    - Expand discussions with regional schools for use of facility for education and training.

Day 2 - Summary

- Role of magnetized dusty plasma in space and astrophysics
  - Does the presence of charged dust in magnetic fields affect the formation of proto-planetary and proto-stellar objects?
    - Specifically, does the magnetic field affect the coagulation rate of charged fractal precursors – modified transport, enhance or slow growth?
    - Does the fractal dimension of the precursors change?
    - Can shocks or nonlinear density waves in the presence of charged particles or charged para-/ferro- magnetic dust alter the coagulation rate.
    - Does B affect how charge is deposited onto the fractal particles? Generation of charge distributions on grains, dipole?
  - Experiments
    - Use growing nano-particles – drop into a region for particle to become charged – then let fall into region with grad-B (and/or grad-E)
    - Use grad-B to do size selection? Mass selection?
    - Actively produce shocks parallel / perpendicular to magnetic fields in a region with growing particles – again using grad-B to select particles.
    - Fundamental experiment - what is the resistivity of a dusty plasma?