Project Summary - MRI: Development of a Magnetized Dusty Plasma Device

In many astrophysical and terrestrial laboratory plasmas, magnetic fields are present. The magnetic field fundamentally alters the plasma by shaping the spatial distribution of ions and electrons, modifying the number of degrees of freedom, and redistributing momentum. In a plasma with charged dust grains, the magnetic field will alter the interaction between the dust and plasma. Because of the ubiquity of plasmas, dust, and magnetic fields in cosmic and terrestrial environments, understanding the basic physics of a fully magnetized dusty plasma is of fundamental scientific interest. **This project proposes the development of a new research instrument – a *magnetized dusty plasma device* – that will enable laboratory investigations of phenomena relevant to plasma physics, astrophysics, fusion and fluid systems.**

Intellectual merit of the proposed research

The *intellectual merit* of this proposal is the design, construction, and operation of a device with the scientific mission to study the coupling between neutrals, ions, electrons, and charged microparticles in a fully magnetized plasma environment in which the magnetic force is comparable to electric, gravitational, or other inter-particle interaction forces. The two major scientific questions addressed by this project are:

1) As a dusty plasma is taken from an unmagnetized system through a progression of regimes where first the electrons, then the ions, and then charged microparticles become magnetized - how do the structural, thermal, charging, and collective properties of the system evolve?
2) If a dusty plasma is composed of microparticles that have paramagnetic or ferromagnetic properties, how do the properties of the dusty plasma evolve in the presence of uniform and non-uniform magnetic fields?

To resolve these questions, this proposal calls for the development of a new multi-user experimental instrument for the study of a magnetized dusty plasma. This project combines the integrated development of a superconducting, high magnetic field ($|B| \geq 4$ Tesla) system, a flexible, multi-configuration plasma chamber and plasma source, and a novel nanoparticle imaging system to create a unique, research device that will be the premier instrument of its type in the dusty plasma research community.

This proposal is the culmination of over two years of international development activity. This effort has leveraged the expertise of the entire dusty plasma research community as well as involving researchers with interests in fusion, astrophysics, and fluid mechanics. Moreover, this proposed project is transformational in that, once operational, this device will allow access to regimes of dusty plasma behavior that have previously been inaccessible – which provides additional motivation for broad community support for this project. Investigations of grain charging (e.g., ion/electron gyro-orbits less than inter-grain distances), wave phenomena (e.g., electrostatic dust cyclotron wave), magnetic field effects on dust transport (e.g., $\vec{g} \times \vec{B}$ drift), and the behavior of plasma with embedded paramagnetic particles are new scientific topics that will be enabled by this device.

Broader impact of the proposed research

The unique capabilities of this proposed magnetized dusty plasma device allows this project to have a *broad impact*. As a multi-user instrument, this proposed device will not only be a valuable tool for the dusty plasma research community, it will enable a wide variety of collaborative research projects in areas ranging from astrophysics to fluid mechanics. This project creates new training and research opportunities for the next generation of plasma scientists - including the creation of a new faculty position at Auburn University, the lead institution. Finally, because dusty plasmas are a highly visual phenomenon, they provide a highly effective platform for engaging students and the public in plasma science. This project will expand its long-running collaboration with the Princeton Plasma Physics Laboratory (PPPL) Science Education program to make use of dusty plasmas as a platform for introducing research skills at the K-12 and undergraduate student level.