ANALYSIS OF DUST PARTICLE DYNAMICS IN A VARYING GRAVITATIONAL FIELD, PART III

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ABSTRACT AND INTRODUCTION

In a dusty plasma, the predominant forces suspending the dust cloud within the plasma are the gravitational and electromagnetic forces. Once the effects of gravity are eliminated, the electromagnetic force dominates dust particle dynamics. Other, smaller forces such as the drag force should play a role on interparticle behavior and their effects should be visible in a zero gravity environment. To obtain data which could allow for a more thorough understanding of dust particle dynamics, an experiment which enabled the observation of these smaller forces in a zero gravity environment was created and flown as a part of NASA's Reduced Gravity Flight Program. Through modifications of previous year's experiments, the team was able to obtain data of a fully formed dust cloud in zero gravity during the 2010 flight campaign. A full analysis of the dust particle motion and cloud dynamics is currently being performed.

Dusty plasmas are very common within the visible universe, as well as on Earth. In space, dusty plasmas can be seen in Saturn's rings, young stellar objects, all kinds of nebulae, comet tails, and stellar ejecta or circumsolar dust. On earth, dusty plasmas are seen in natural phenomena like lightning bolts and flames. These dusty plasmas have an industrial importance as well, as they can be unintended creations inside of fusion devices and machines using plasma etching to create microchips [1-5].

In recent years, many ground-based experiments have been performed in an effort to learn more about dusty plasmas. In these ground based experiments, however, gravitational effects place restrictions on what complex phenomena can be observed. In an attempt to observe the effects of other, less noticeable forces on dust cloud dynamics, the Dusty Plasma Experiment (DPX) took dusty plasmas into a microgravity environment where the overwhelming force of gravity could be eliminated. Following-up and building on experiments performed in 2008 and 2009, Team DPX has attempted to further the understanding of dusty plasmas by observing their behavior in a microgravity environment. Dust dynamics in a varying gravitational field were observed and measurements relating to interparticle spacing, particle motion, and cloud dynamics as a whole will be made in a thorough analysis.

NASA'S REDUCED GRAVITY STUDENT FLIGHT OPPORTUNITIES PROGRAM

The Reduced Gravity Student Flight Opportunities Program provides undergraduate students with the unique opportunity to fly experiments on the "Weightless Wonder" in a zero gravity environment. Through a rigorous process, the students are able to propose, design, and build an experiment which meets the NASA quality and safety requirements. These experiments are then flown on a specially designed aircraft, which simulates zero gravity by flying in a series of parabolas. Each flight consists of 30 parabolas, and each team is given two flight days. As the plane climbs to the top of each parabola, the passengers experience about 30 seconds of hypergravity (1.8g). As the plane begins to maneuver over the top of each parabola and turn back towards the ground, the passengers experience about 25 seconds of microgravity (0g).

Another aspect of the Reduced Gravity program is the outreach plan, which requires that each team create a plan of proposed activities which will help the team members connect with the public. The purpose of this is to encourage an interest in the sciences, our experiment, and the Reduced Gravity program. Nearly all of our proposed outreach plans were fulfilled. A high school tour of our hometown and local high schools was completed, where 30-45 minute presentations were given to high school physics classes. This allowed us to share our own research as well as our experience with the Microgravity University Program with students preparing to start their undergraduate careers, hopefully encouraging the pursuit of careers in science.

Within The College of New Jersey, we were able to share our work and experience with our peers and faculty. During a "Women in Science" Panel, we were able to have our female team member speak about her own experience with the research and the program. At our annual student achievement presentations, our team was able to speak again about our work to our peers and faculty advisors.

In an effort to reach the general public, the team spoke with the public at a TCNJ as well as a Princeton Plasma Physics Lab (PPPL) open house. This allowed the team to speak with children and adults of all ages about the research that we were performing and the enriching experience that we had with Microgravity University.

EXPERIMENT HISTORY

This experiment was a continuation of two previous experiments performed with Microgravity University in 2008 and 2009. Previous experiments were performed with the same goal of obtaining a fully formed dust cloud in zero gravity. While the 2008 and 2009 experiments were unsuccessful in this final goal, the results did provide constructive data pertaining to dusty plasma sciences. The data also demonstrated what experimental modifications would be necessary in order to observe a fully formed dust cloud in zero gravity.

The 2009 experiment was able to obtain extremely useful data of dust particle dynamics. The data demonstrated that the dust cloud itself was dominated by the electromagnetic force in the absence of gravity, and that this force needed to be better understood in order to obtain a fully constructed dust cloud in a zero gravity environment. Figure 1 demonstrates the motion observed in the 2009 flight. The dust cloud deconstructs as gravity (z) is eliminated, and moves according to the projected electromagnetic field lines. As gravity begins to approach 1g again, the dust cloud is reconstructed in its initial position.

In order to solve this issue, many tests were performed prior to flying the experiment in the 2010 campaign. Computer simulations were created in order to map the electric field lines within the chamber. Based off of these simulations, a new experimental design was constructed in order to 'close' the electric field lines and contain the dust cloud during portions of zero gravity. This new design required the addition of a second electrode in the experimental setup. In order to test this new setup, a thermophoretic experiment was attempted. The goal of this ground based experiment was to balance the downward gravitational force with an upward thermal force, however, this experiment proved unsuccessful in the limited time before the flight. Ultimately, these preliminary tests did provide results that could be used to modify the experimental setup for flight.

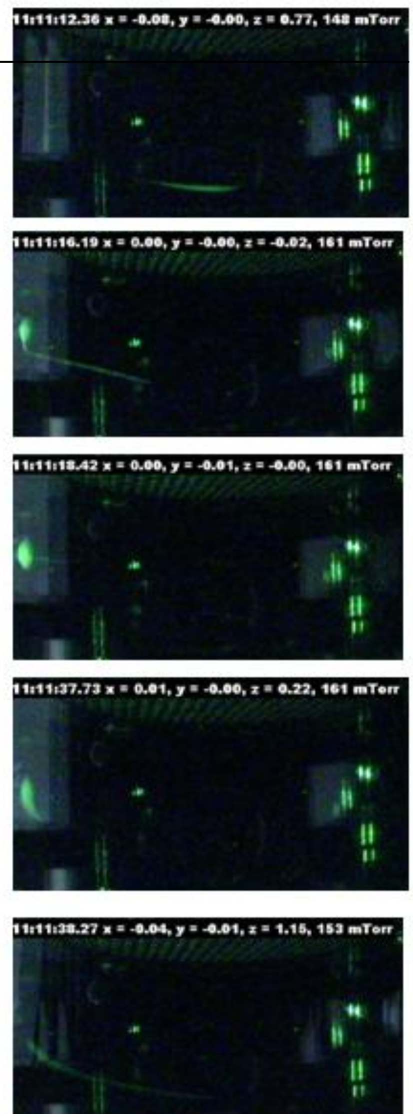

Figure 1: Dust cloud motion in 2009 DPX campaign

EXPERIMENTAL METHOD

The experimental setup consisted of a glass vacuum chamber of 6" in height and 3" in diameter. The plasma was created within this chamber by charging a stainless steel electrode which also acted as a vacuum flange. An electrically isolated stainless steel mesh suspended from this top electrode was charged to a positive voltage in order to contain the dust cloud in zero gravity. A lower stainless steel flange closed off the bottom of the vacuum chamber and acted as a ground for the system. Extending from this flange was a stainless steel grounded dust tray, surrounded by a small plastic lip to keep the dust in place during the flight. Extending from the lower flange were two ports. One port was for the baratron, to record the pressure within the chamber, and the second was attached to the vacuum pump. A Pfeifer XtraDry 150-2 Piston Vacuum Pump was used. Data was recorded using two CCD cameras, placed 180 degrees apart. The cameras recorded to a touch screen monitor mounted to the experiment box, which also recorded the time, accelerometer data, voltage and pressure. The cloud itself was illuminated using a 5 mW laser, directed through a diverging lens to create a thin sheath of light. This allowed us to record a two dimensional slice of the three dimensional dust cloud.

Before the parabolas began, the chamber was pumped down to vacuum and backfilled with argon gas. The pressure ranged from 120-300 mTorr over the two flights. A voltage of -100V was applied to the top electrode and a voltage of +400 V was applied to the mesh, creating a DC glow discharge argon plasma. A non-monodispersive silica dust was used. Once a dust cloud was obtained, the only varying components of the experiment were the internal pressure of the chamber, the voltages, and the gravitational field.

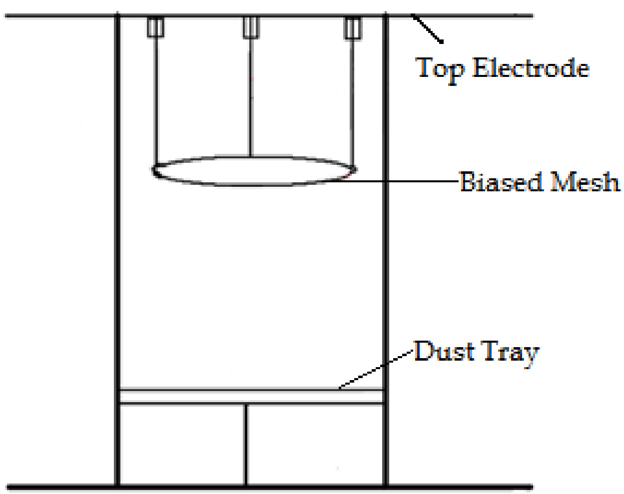

Figure 2: Experimental Set Up

RESULTS

The experiment was run successfully on both flight days. Through a voltage scan on the first flight day, a stable dust cloud was obtained in zero gravity. On the second flight day, a large amount of data of fully formed dust clouds in zero gravity was obtained. The stability and presence of the dust cloud in zero gravity was directly dependent upon the voltages of the electrode and mesh, confirming the hypothesis that a modified electromagnetic field would allow for the observation of a fully formed dust cloud in zero gravity. The dust clouds obtained in 1g and hyper-gravity were also very stable, as it has previously been predicted and observed that they would be.

The final run of the Dusty Plasma Experiment III proved to be a successful one. Data of a fully constructed dust cloud was obtained in regular, hyper, and zero gravity environments. The work of previous years provided useful data which guided the team towards a new and modified experimental setup which was able to achieve the initial experimental goals.

The experience of taking part in the Microgravity University program, over all, allowed the team members to get a taste for real world science and engineering. Working with NASA engineers and living up to the standards and regulations of NASA allowed the team to experience what it really takes to create and run a safe and successful experiment.

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