Visualizing Ring Currents with a Planeterrella Device. Ethan R. Ayari[1], Mihály Horányi[1], Jan Deca[1], Xu Wang[1], Robin Varrenes[1]
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Abstract: The dynamics of plasmas confined within dipole magnetic fields give insight into how planetary magnetospheres behave and evolve over time. A laboratory Planeterella setup, manufactured at the Institute for Modeling Plasmas, Atmospheres and Cosmic dust within the Laboratory for Atmospheric and Space Physics (IMPACT/LASP), is used to visualize ring currents through light emission generated by impact excitation, ionization, and recombination processes as illustrated in Figure 1.

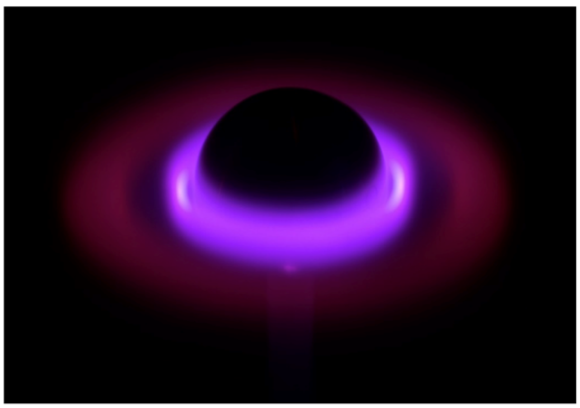

Figure 1: Light emission in Planeterrella device. Two distinct rings are observed.

The IMPACT Planeterrella device consists of a vacuum chamber that contains a .5 Tesla Neodymium bar magnet embedded within a highly biased aluminum sphere. Through using an oil pump, it is capable of fine-adjustable depressurization. The bar magnet's presence alongside the potential difference between the biased sphere and the grounded chamber subject the constituent charged particles to a radially inward electric field and azimuthally oriented magnetic dipole field. Low pressures (~400 mTorr) paired with sufficient applied voltage yield visible plasma ring currents.

To perform a simulation for such a plasma, a Runge-Kutta-based Monte Carlo Collisional (MCC) algorithm was developed to follow the motion of electrons within the electromagnetic fields and track their collisions with neutral N_2 and O_2 particles. Process-based parallel programming was implemented to expedite these simulations and improve statistics.

The duality of simulations and experiments reveals more information about the dynamics of trapped electrons. Using the laboratory Planeterrella, an ignition voltage and luminosity trends are established for the visible rings. Additionally, filling the chamber with pure Nitrogen gas (N_2) experimentally verified the nature of the outer ring. The MCC algorithm successfully reproduced the two visible rings. For discretized locations in the equatorial plane of the sphere, collision densities alongside average velocities and a ratio of electron gyrofrequency to collision frequency are given, as shown at the top and bottom of Figure 2, respectively.

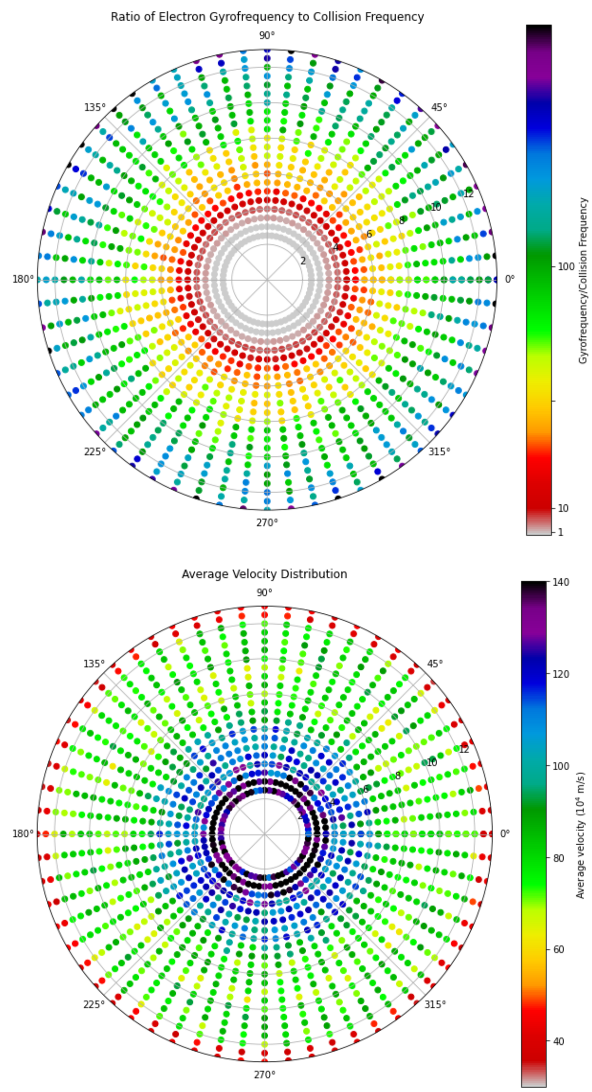

Figure 2: Ratio of electron gyrofrequency to collision frequency (top) and average velocity (bottom) by discretized location in a birds-eye view of the Planeterrella device. The ratio values indicate whether or not the motion of the electrons is adiabatic.