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New insights into the experimental behavior of magnetized gas discharges

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Helicon discharges have been extensively researched for over 25 years, and over 700 papers have been published on this subject in that time. Helicons are different from other gas discharges because they exist in a dc magnetic field and depend on energy deposition from waves driven by an external radiofrequency (rf) antenna. They produce higher plasma densities than other rf plasmas, but the physics of how they do that turns out to be very complicated. This research has been like peeling an onion. Each layer reveals another layer deeper down. Though the properties of coupled helicon and Trivelpiece-Gould waves have been known for a long time, there has been no theory of the equilibrium profiles of density, electron temperature T_e, and neutral density. In tackling this problem, we found that the sheaths on the endplates are important. They allow electrons to cross the magnetic field via the Simon short-circuit effect. A radial electric field is then set up which drives the ions radially outward at a speed scaled to T_e. For fixed T_e, the density profile follows a "universal" profile which is independent of discharge radius and pressure. A physical reason is given for this universality. From this point forward, the theory goes into many details which give insights to the physics of all cylindrical gas discharges, with or without a magnetic field.

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