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Observations of a Parallel Force Balance Breaking Instability in Non-neutral Plasmas Confined on Magnetic Surfaces

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The Columbia Non-neutral Torus (CNT) is a simple stellarator devoted to the study of non-neutral plasmas confined on magnetic surfaces. At low neutral pressures pure electron plasmas in CNT are stable [Physical Review Letters **97**, p. 095003 (2006)], and have a long confinement time (up to 190 ms), but the plasma goes unstable in the presence of a finite ion fraction ($n_i/n_e \sim 0.04$). The equilibrium of pure electron plasmas in CNT is determined by parallel force balance between the pressure and the electrostatic field in each magnetic surface, and it was thought that this force balance condition would prevent low frequency oscillations from developing in the plasma, unless the perturbation had a mode structure that resonated with a rational surface of the magnetic field. However, the instability has a measured poloidal mode number of $m = 1$ [Phys. Rev. Letters **100**, p. 065002 (2008)], which does not correspond to any rational surfaces in CNT. It is likely that this violation of parallel force balance comes about because CNT has a large (65%) fraction of electrons that are mirror trapped. The frequency scaling and the ion density threshold of this instability are similar to an instability found in pure-toroidal non-neutral plasmas [Phys. Fluids **12**, 2616 (1969)]; however, the magnitude of the instability in CNT saturates at a level where electron confinement is only weakly reduced. We present an overview of the CNT experiment and a detailed look at key experimental observations related to the instability, including the dependence on neutral pressure, magnetic field strength, and ion species. This work was supported by the NSF-DOE Partnership in Basic Plasma Science, Grant No. NSF-PHY-06-13662, and the NSF CAREER program, Grant No. NSF-PHY-04-49813.