Attracting Fixed Points and Strong-drive Compression of Single-Component Plasmas

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The rotating wall (RW) technique has proven to be an excellent method to create high-density, single-component plasmas in Penning-Malmberg traps. It is now useful, and sometimes critical, for applications such as antihydrogen production and the tailoring of ion crystals and positron beams. Azimuthally phased rf fields are used to produce a torque on the plasma, thereby injecting angular momentum and producing radial compression.

A recently discovered “strong-drive” regime provides new capabilities, including the ability to produce high-density steady states with plasma rotation frequencies, \( f_E = n e c / B \) (with \( n \) the plasma density), very close to the applied RW frequency [1-3]. Experiments are done with electron plasmas using a 4.8 tesla magnetic field for strong cyclotron cooling. The protocol for these experiments is such that the two control parameters of the system, the RW frequency and amplitude, are set to fixed values; then the system is allowed to evolve freely to a new steady state in which \( f_E \) approaches closely the applied RW frequency. This is in contrast to many previous experiments where either the RW was tuned to a plasma mode or the amplitude was changed slowly as the system evolves. These results raise a number of questions, including the nature of the bifurcation and hysteresis that are observed in the transition between low- and high-density steady states.

Here, we present a model of the transition to the strong drive regime, describing it as a competition between attracting fixed points of the system [3]. Key ingredients are a drag torque due to a plasma-mode resonance driven by static trap asymmetries and a RW drive torque that passes rapidly through zero as the plasma rotation frequency approaches the RW frequency. A number of tests of the model are described, including perturbation experiments to confirm the nature of the RW torque and to measure its magnitude near the high-density fixed point. Open questions for future research, including what limits the maximum achievable plasma density and a possible thermodynamic model of the compression process, will be discussed.

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