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Turbulence, Waves, Transport (and perhaps Dynamo) in Laboratory Model Cores

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Our group's search for dynamo action in an earthlike geometry has not yet (as of this writing) resulted in a laboratory dynamo. However, the investigations in our rapidly rotating model cores, with and without differential rotation, yield results that are likely to be relevant to planetary cores and other geophysical and astrophysical problems. Of particular note is the importance of large scale inertial modes and Rossby waves in the high Reynolds number rapidly rotating turbulence driven by steady differential rotation. In our hydrodynamic results from the three meter spherical Couette apparatus, the Ekman number $E = \nu/(\Omega_o R^2)$ approaches 10^{-8} and the magnitude of the boundary Rossby number $Ro = (\Omega_i - \Omega_o)/\Omega_o$ ranges from about 0.05 to 100. Much of this Rossby range is beyond what is expected, measured, or inferred in planetary cores and atmospheres, though direct flow measurements show that the fluid differential rotation for some of the most interesting boundary Ro ranges is comparable to that which could result from tidal forcing (Tilgner PRL 2007), convection, or other processes. Differential rotation in the rapidly rotating three meter system leads to a wide variety of states, including excitation of three dimensional inertial modes for $Ro<0$ and a number of turbulent flow transitions involving inertial modes and Rossby waves for $Ro>0$ that result in large changes in rotation profiles and angular momentum transport. Even when the fluid Rossby number is well beyond what is plausible for planetary cores and atmospheres, the results demonstrate the important influence of strong rotation on the shear-driven turbulence at all Ro, and highlight the importance of Ro in defining the boundaries of different strongly turbulent states.

In addition to the rich interplay of waves and turbulence driven by differential rotation, we measure the flow driven by the precession of the three meter experiment as its axis rotates in space due to Earth's rotation. Observations include the internal shear layers expected in a precessing spherical shell at low Ekman number.

At the time of this writing, we are approaching our next attempt at laboratory dynamo action. The hydrodynamic experiments in the three meter system are finished and the three meter experiment is 73% full of sodium metal. We expect to have hydromagnetic results in hand before the meeting, and we will report our progress toward observation of dynamo action and other MHD phenomena in the Maryland three meter experiment.