Michigan Institute for Plasma Science and Engineering Seminar

Dynamo Experiments: From Liquid Metals to Plasmas

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Abstract

Astrophysical plasmas often have high magnetic Reynolds number, turbulent, flowing plasmas in which the flow energy is much larger than that of the magnetic field. Examples include stellar interiors, accretion disks and the solar wind. Creating such conditions in lab plasma experiments is challenging as confinement is required to keep the plasma conducting and this is usually provided by strong magnetic fields. For this reason, recent experiments using liquid metals are addressing fundamental plasma processes in this unique parameter regime. In this talk a tutorial will be given of fundamental processes occurring in such plasmas and how lab experiments can be used to study them. The first is the self-generation of a magnetic field of energy comparable to the turbulent flow from which it arises--the dynamo process. A description will be given of how magnetic fields are generated in planets and stars, describing the "Standard Model" of self-exciting dynamos. The second process is the magnetorotational instability (MRI) that concerns how a weak magnetic field can act as a catalyst for transporting momentum, heat, etc. A weak magnetic field plays an important role in triggering instability in conducting fluids when neutral fluids are rigorously stable. I will then show how experiments have contributed to understanding such processes. Liquid metal experiments have demonstrated (1) self-excitation of magnetic fields, (2) two scale dynamos where a small scale flow drives a large scale magnetic field, (3) intermittent self-excitation and time dynamics including field reversals, (4) turbulent electromotive forces (mean-field current generation), and (5) MRI-like instabilities in Couette flow geometries. Liquid metals are, however, not plasmas: dynamos and MRI may differ in plasmas where the relative importance of viscosity, and resistivity can be interchanged, and new instability mechanisms, outside the scope of MHD may be critical in collisionless plasmas. A new dynamo experiment, under construction at the UW, will be described.

About the Speaker: Cary Forest is Professor of Physics at the Univ. of Wisconsin - Madison (UW). He received a BS in Applied Math, Engineering and Physics in 1986 from UW, and a Ph. D. in 1992 from Princeton Univ. His thesis demonstrated spherical tokamak formation by pressure driven currents on the CDX-U experiment and he received the APS DPP Outstanding Thesis Award. Moving to General Atomics in 1992, he measured non-inductive currents driven by rf heating and neutral beams on the DIII-D tokamak. In 1997 he moved to UW where his group has constructed experiments to study magnetically confined and astrophysical plasmas including a liquid sodium dynamo for self-generation of magnetic fields from plasma flow; a linear pinch for studying MHD instabilities; and a plasma Couette flow experiment studying magneto-rotational instability. His student Erik Spence received the DPP's thesis award for work on the sodium experiment. Forest received the Sloan and Packard Fellowships, and a Humboldt Research Award. He is an APS Fellow.