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Levitating Magnet Brings Physics of Space to the Laboratory

By magnetically levitating a half-ton superconducting dipole magnet, physicists have created plasma with profiles characteristic of those seen in planetary magnetospheres

DALLAS, Texas—Recent experiments at the Massachusetts Institute of Technology (MIT) Plasma Science and Fusion Center (Cambridge, MA) have created and measured the properties of high temperature plasma confined by the strong magnetic field of a fully levitated superconducting dipole magnet. When the magnetic dipole floats without supports, the hot plasma is only lost in the radial direction by a mixing process that naturally creates plasma profiles similar to those found surrounding magnetized planets like Earth and Jupiter.

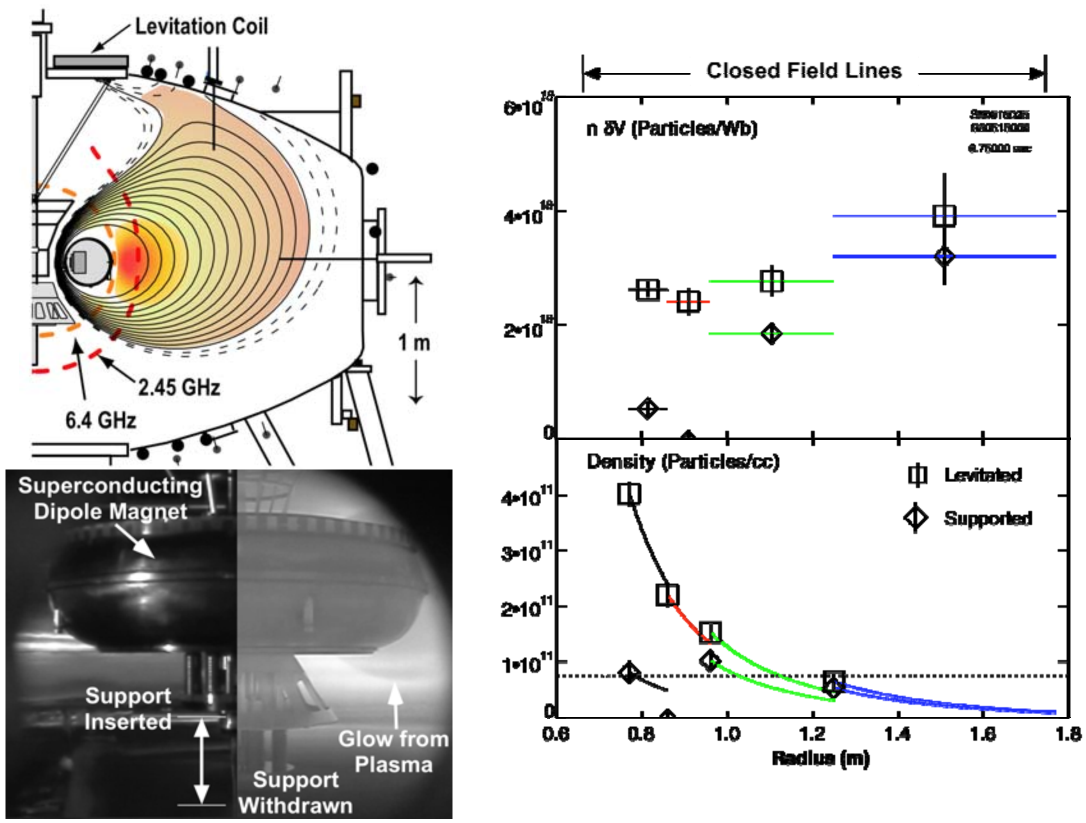
Scientists build plasma experiments with strong magnetic fields to confine plasma, made from ionized gas heated to many millions of degrees, and prevent it from coming into direct contact with the much colder surrounding structures. The most studied magnetic configuration in the laboratory is a torus, or doughnut, where the magnetic field wraps itself around within the torus and never strikes the walls. However, the most common magnetic field found in nature to confine hot plasma is the magnetic dipole, where the magnetic field emerges from the north and south poles of planets, like Earth.

Since the launch of America's first satellites, scientists have been studying plasma confined by natural magnetic fields. The plasma surrounding a planet is called a magnetosphere, and it is characterized by energetic charged particles and plasma profiles that result from dynamic processes driven by the sun. After fifty years of exploring plasma both in space and in the laboratory, scientists at MIT and Columbia University have succeeded in building a magnetic dipole that confines plasma like a magnetosphere while simultaneously preventing contact with the laboratory apparatus like a torus.

The experiments were performed in the Levitated Dipole Experiment (LDX). (See attached figures.) A joint project by MIT and Columbia University and sponsored by the U.S. Department of Energy, LDX consists of a superconducting magnet about the size and shape of a large truck tire. This half-ton magnet is levitated inside a huge vacuum chamber, using another powerful magnet above a large vacuum chamber. Earlier experiments, with the dipole mechanically supported, were used to investigate the formation of hot plasma containing energetic electrons that are magnetically confined like those particles within the Earth's radiation belts.

The new experiments reported here were conducted with a fully levitated coil and with a newly installed microwave interferometer array that provided the first-ever measurements of plasma density profile evolution. By eliminating the supports used in previous studies, cross-field radial transport dominates the dynamics of the plasma and the particle confinement dramatically improves. Strong plasma mixing processes are observed under several circumstances, such as the initial creation of plasma or when plasma-heating sources are switched on or off, and low-frequency fluctuations likely maintain centrally-peaked profiles at other times.

Whenever the dipole magnet is levitated, high-speed measurements of the plasma density with the interferometer array show the development of centrally peaked interchange stationary density profiles. These profiles correspond to an equal number of particles per flux tube and are observed in active magnetospheres like that found surrounding the planet Jupiter.



Figures: (Top Left) Schematic of the Levitated Dipole Experiment (LDX) showing the region of closed field lines that pass through the inner bore of the superconducting dipole magnet. (Bottom Left) Photographs of the dipole magnet when supported and when magnetically levitated surrounded by high-temperature plasma. (Right) Measurements of the density profiles of two high-power plasma discharges. When the dipole magnet is levitated, then plasma losses to the supports are eliminated, and the plasma density profile dramatically peaks in the central region coinciding to the profiles of active magnetospheres.

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Improved Confinement During Magnetic Levitation in LDX

Invited Session CI1: Magnetic Confinement 1
2:00 PM–5:00 PM Monday, November 17, 2008
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Further information:

Physics of Plasmas **13**, 056111 (2006) and http://www.psfc.mit.edu/ldx/

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