NSTX News Release, APS 2002

Spinning Fusion Plasmas Shed Light on Energy Production and Distant Astrophysical Mysteries

Recent fusion experiments bode well for future energy production, as well as an increased understanding of astrophysical phenomena. The National Spherical Torus Experiment (NSTX) at the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL) produced plasmas — hot, ionized gases — with high ratios of plasma pressure to magnetic pressure, or beta. This result indicates greater efficiency in magnetic field use, which is favorable for achieving efficient energy production in future fusion devices.

The desirable geometry of the spherical torus and the presence of a conducting wall around the plasma stabilize magnetohydrodynamic (MHD) instabilities that can destroy plasma. Local beta values of 75 percent — 1.5 times the previous record for plasmas in this temperature range — occurred with the injection of up to 7 megawatts of energetic neutral atoms. The injected particles also spun the plasma at 3 million revolutions per minute at 300 kilometers per second, which corresponds to 30 percent of the speed of magnetic sound. As predicted by theory, the wall functions like a superconductor at these speeds in the frame of the spinning plasma. The image currents in the wall induced by the rotating magnetic perturbations counteracted the destructive effects of these instabilities to make the high-beta values possible.

The creation of these high-beta plasmas opens the door for controlled laboratory studies relevant to plasmas in astrophysics. These investigations may significantly improve our understanding of phenomena such as solar wind, turbulence in the diffuse gas that exists between stars in the Milky Way Galaxy, and black hole accretion disks. For the latter, electromagnetic effects in the magnetic sound turbulence of the scale of ion gyration radius are predicted to determine the amount of radiation produced by plasma falling into the black hole. These effects should be measurable for the first time in order-unity beta plasmas on NSTX, which could be applied to interpreting astronomical observations by facilities such as NASA's Chandra X-ray Observatory.

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Gates, D., et al., “High-beta, Long-Pulse and Bootstrap-Sustained Scenarios on NSTX,” invited talk at 2002 APS DPP meeting.
Sabbagh, S., et al., “The Resistive Wall Mode and Beta Limits in NSTX,” contributed oral at 2002 APS DPP meeting.
Quataert, E. & Gruzinov, A., “Turbulence and Particle Heating in Advection-Dominated Accretion Flows,” Astrophys. J. 520 (1999) 248.
Rees, M. J., Phinney, E. S., Begelman, M. C., & Blandford, R. D., “Ion-supported Tori and The Origin of Radio Jets,” 1982, Nature, 295, 17.

Fig.2. Artist’s model of the NSTX device, which is designed to test and investigate plasma conditions with highly efficient utilization of magnetic field (i.e., high beta).

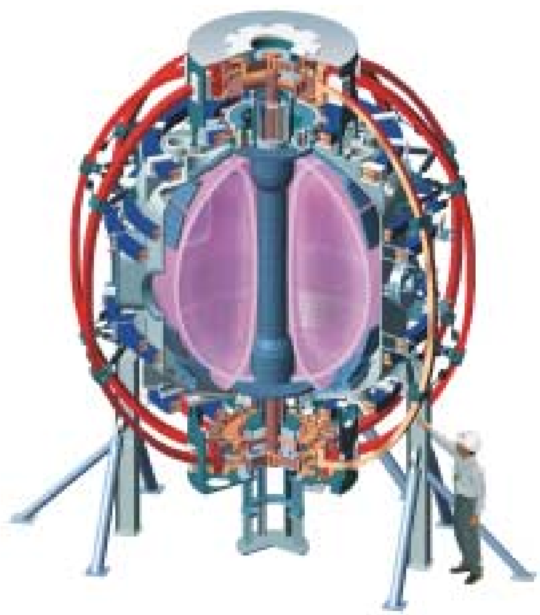

Fig. 2

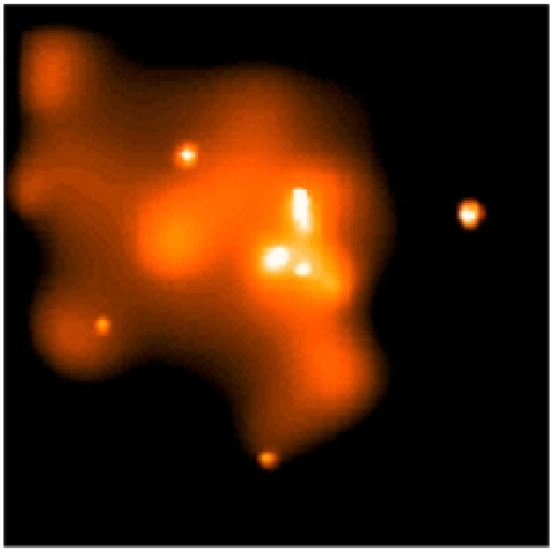

Figure 1: *This image from the Chandra X-ray Observatory shows the central 10 light-years of our Galactic Center in 0.5-10 keV X-rays. The leftmost white source near the center of the image is coincident with a 3 million solar mass black hole, which is also a prominent radio source. The diffuse emission (orange) is from an extended cloud of hot plasma surrounding the black hole.*