DPP AUTHOR SUMMARY

Reference papers:
[NP1.038] IMAGING MAGNETIC CHAOS REDUCTION IN MST, by P. Piovesan et al. (RFX and MST groups)
[NP1.037] UPGRADED SXR TOMOGRAPHY IN MST by P. Franz et al. (RFX and MST groups)

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CAT scanning of chaos reduction in a fusion plasma

Tomography reveals tiny structures and chaos reduction in a hot fusion plasma.

Since 1979, when the two physicists Cormack (USA) and Hounsfield (UK) were awarded the Nobel Prize for "*the development of computer assisted tomography"* (**CAT**) (http://nobelprize.org/medicine/laureates/1979/), this diagnostic technique has diffused to many fields of pure and applied science and technology. Tomography has become one of the main diagnostic techniques for medicine, particularly with the advent of such techniques as Positron Emission Tomography (PET). Tomography is also widely used for non-destructive diagnosis of metal components, like those used in airplanes, bridges, and ships. It is also used in seismology, astronomy, chemical and pharmaceutical plants, and environmental science.

Tomography also plays a crucial role in plasma science, since it allows, for example, a detailed reconstruction of the interior of a fusion plasma. However, while plasma tomography is based on the same principle as medical tomography, taking tomographic pictures of an energetic plasma with a temperature of 10 millions degrees centigrade is a significant challenge! Since, by definition, the patient in a hospital PET scanner can be asked to be "patient" (not moving), a limited number of detectors can be rotated around the patient in a reasonable time, allowing millions of well controlled measurements, which in turn allow reconstruction of details of the patient's body. A fusion plasma is less "patient." Plasma phenomena can last only a fraction of a second, requiring very rapid measurements which precludes the detector rotation technique used in medicine.

A joint collaboration between scientists working at the Physics Department, University of Wisconsin-Madison (http://sprott.physics.wisc.edu/mst.htm) and at Consorzio RFX, Padova, Italy (http://www.igi.cnr.it), has allowed the development of a novel tomography system, which has been installed in the Madison Symmetric Torus (MST), a donut-shaped fusion plasma experiment referred to as a reversed field pinch. The MST tomography system is comprised of four miniaturized photocameras based on strips of solid-state silicon detectors, which provide an image of the plasma up to 100,000 times each second. The photocameras are miniaturized, flexible and portable, to enable their use in many different plasma devices. For example, they have also been used with success to diagnose the plasma in a Magneto-Plasma-Dynamics thruster for space applications at the Centrospazio Laboratory in Pisa, Italy. Advanced new tools for high resolution tomographic image reconstructions have also been developed within this project.

X-ray tomographic measurements in MST have revealed a strong reduction of magnetic chaos in plasmas where plasma energy containment is improved ten fold.

In normal MST plasmas, the magnetic field that confines the plasma is chaotic, and in that field lines wander from the plasma interior to the plasma boundary, rapidly carrying with them plasma energy. A technique has been developed to reduce this chaos and the loss of energy. In the best cases, energy loss rates are reduced ten fold. Magnetic field measurements confirm that field fluctuations are reduced in these plasmas, and this indirectly implies a reduction in the magnetic chaos.

Now, x-ray tomographic imaging of the plasma has directly confirmed the hoped-for reduction of magnetic chaos [PHYSICAL REVIEW LETTERS. vol. 92, pp. 125001-125004]. We show in Fig. 1 a tomographic reconstruction of a vertical slice of the MST plasma at one instant in time in both standard plasmas (left) and in plasmas with reduced energy loss (right). In the standard plasma, there is little structure due to the strong wandering and overlap of field lines. The emission pattern is basically poloidally symmetric and rather smooth in shape, as one would expect because of the high turbulent thermal transport. In the improved plasmas, one observes individual structures, referred to as magnetic islands. The orange-red regions represent locations of maximum x-ray emission. These structures are very small, and the tomography scanning provides rather detailed images due to its high spatial resolution.

An "artistic" three-dimensional view of the two islands, based on the tomography measurements, is shown in Fig. 2, which shows the island structures winding around the inside of the MST device.

The emergence of such islands is a hallmark of magnetically confined plasmas with reduced magnetic chaos, since magnetic field lines remain confined to a small radial domain. This is the first time such chaos reduction has been observed in the reversed-field pinch.

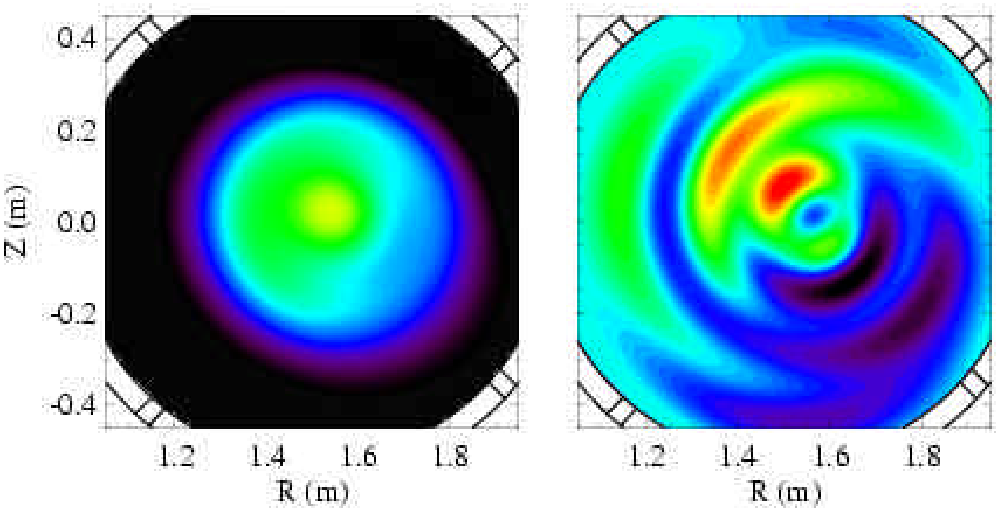

Figure 1

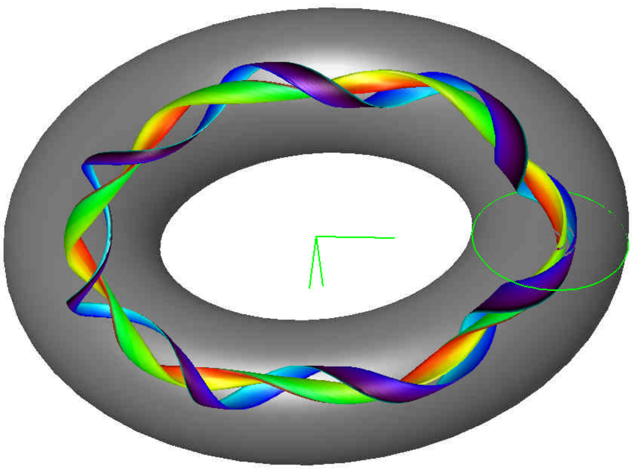

Figure 2