Tokamak experiments come clean about impurity transport

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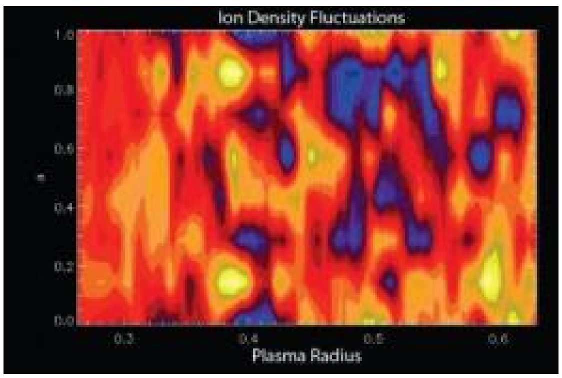

Results from a recent turbulence simulation reveal turbulent structures believed to be responsible for the measured levels of impurity transport. Credit: Nathan Howard, MIT

A fusion reactor operates best when the hot plasma inside it consists only of fusion fuel (hydrogen's heavy isotopes, deuterium and tritium), much as a car runs best with a clean engine. But fusion fuel reactions at the heart of magnetic fusion reactors also create leftovers—helium "ash." The buildup of this helium ash and other impurities can cool the hot plasma and reduce fusion power. Research at the MIT Plasma Science and Fusion Center is providing new insight into the transport of these impurities in fusion plasmas in an effort to improve on the natural impurity exhaust process, producing cleaner plasmas and higher fusion power.

On the Alcator C-Mod tokamak at MIT, researchers are using a novel set of plasma diagnostics and advanced computer simulations to better understand the physical processes that can either flush out impurities or allow them to stay. All fusion plasmas contain intrinsic impurities introduced by the unintentional interaction of very hot plasma with the reactor walls and the fusion reactions themselves. To study these phenomena, the scientists introduce a known source of impurities at a small level that will not adversely affect the plasma's performance. This is achieved using a high powered, pulsed laser to knock impurity atoms off a coated glass slide directly into the plasma edge. Once inside the plasma, the impurity is ionized and heated by the plasma and begins to emit soft x-ray radiation which is observed by a new high-resolution spectrometer that allows the impurities to be tracked as they are transported by plasma turbulence.

"It is not enough to simply observe results in existing experiments," says MIT graduate student Nathan Howard. "We also need to develop high resolution computer models to predict how impurities will behave in future larger, hotter fusion reactors. The process is much like developing accurate long-range weather forecasts."

The MIT scientists are developing and testing new computer programs which run on some of the world's fastest supercomputers. A single case can take up to 250,000 CPU hours to complete. For comparison, this is roughly equivalent to letting a home computer run for about 15 years. The latest simulations connect the behavior of small turbulent eddies and ripples in the plasma to new measurements showing the movement of impurities into and out of the plasma.

According to Dr. Martin Greenwald, Nathan's thesis advisor, "This work represents an important first step in gaining confidence in our ability to predict and control impurity transport in tokamaks."

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