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New turbulent transport modeling shows multiscale fluctuations in heated plasma

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Researchers at the DIII-D National Fusion Facility, a DOE Office of Science user facility operated by General Atomics, used a "reduced physics" fluid model of plasma turbulence to explain unexpected properties of the density profile inside a tokamak experiment. Modeling plasma's turbulent behavior could help scientists optimize the tokamak performance in future fusion reactors like ITER.

Applying heat in a tokamak produces many interesting phenomena such as changes in plasma rotation and density. DIII-D researchers modeled how different types of heating, like microwaves that produce electron heating or neutral beams that produce ion heating, influences the plasma density, behavior of impurities and turbulent transport. The different heating methods drive turbulence at the long (ion) scales and much shorter (electron) scales that are at the frontier of turbulence computer simulations.

Their findings, reported this week in *Physics of Plasmas*, showed that heating the electrons in a fusion reactor caused important changes in density gradients within the plasma. Their "trapped gyro-Landau fluid" (TGLF) model predicted that adding heat excited turbulence, at wavelengths between the ion and electron scales, and would produce a particle pinch that modifies the plasma's overall density profile. Additionally, in this paper, researchers used their reduced transport model to predict impurity transport in a fusion reactor.

Brian Grierson, a Princeton Plasma Physics Laboratory physicist working as a researcher at the DIII-D National Fusion Facility in San Diego, said that "when you heat the plasma, you don't just change the temperature, you change the type of turbulence that exists, and that has secondary implications on the transport of plasma density and the plasma rotation."

Generally, heat flowing from the hot plasma center to the cold plasma edge drives turbulent diffusion, which should act to flatten the density gradient. "But the fascinating thing is that sometimes applying heat in a fusion reactor causes it to produce a density gradient rather than flatten it," Grierson said. This density peaking is significant because the fusion reaction between deuterium and tritium particles in a tokamak increases as the density of the plasma increases. In other words, he said, "fusion power is proportional to the [plasma] density squared."

Grierson credits Gary Staebler, a co-author on the paper, as the General Atomics theoretician behind TGLF, the model tested in this paper. TGLF is a reduced physics model of the "full physics" gyrokinetic code GYRO for turbulent transport, which must be run on supercomputers. Using this more cost-effective TGLF model, researchers were able to execute the code with various experimental measurement and inputs hundreds of times to quantify how uncertainties in the experimental data affect the theoretical interpretation.

Going forward, Grierson hopes that these findings will help inform research to advance the fusion community's understanding of extremely small-scale fluctuations and impurity transport within a plasma.

"We need to understand transport under ion and electron heating to confidently project to future reactors, because fusion power reactors will have both ion and electron heating," Grierson said. "This result identifies what we need to investigate with the computationally challenging full physics simulations to verify the interaction of particle, momentum and impurity transport with heating."

More information: B. A. Grierson et al, Multi-scale transport in the DIII-D ITER baseline scenario with direct electron heating and projection to ITER, *Physics of Plasmas* (2018). DOI: 10.1063/1.5011387

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