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Physicists improve understanding of heat and particle flow in the edge of a fusion device

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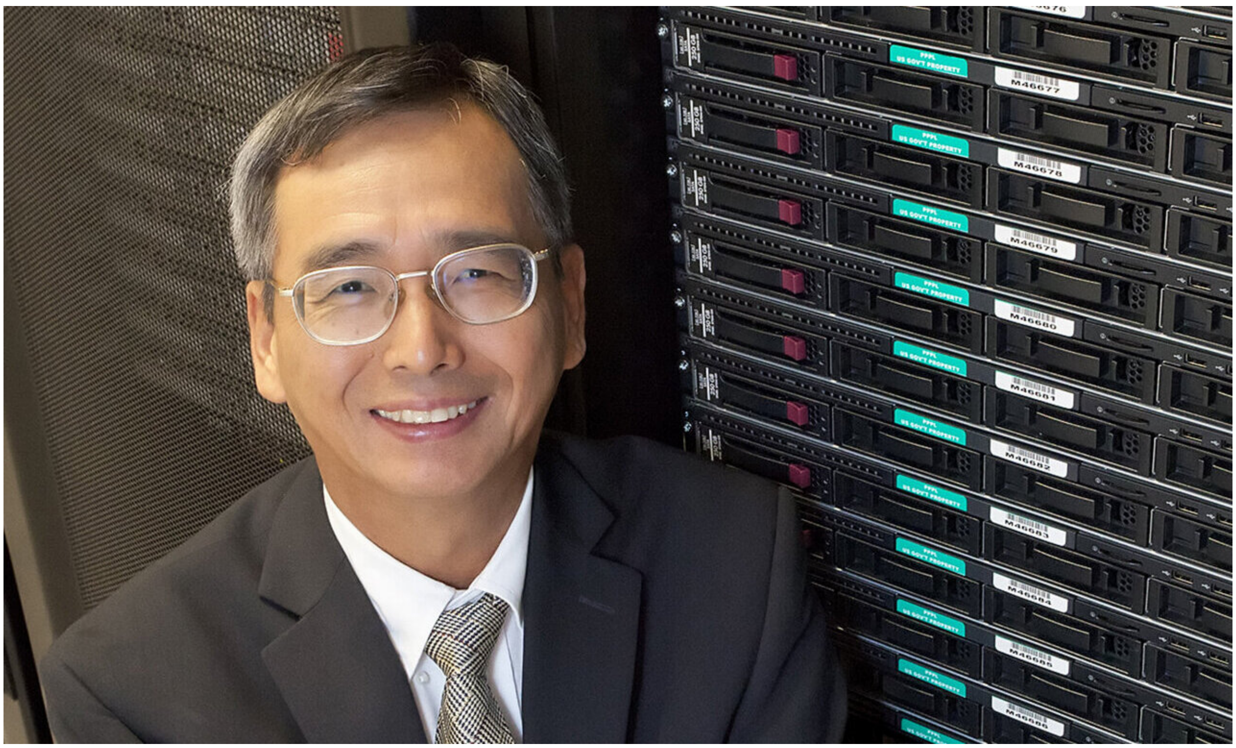

PPPL physicist C.S. Chang. Credit: Elle Starkman

Physicists at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) have discovered valuable information about how electrically charged gas known as "plasma" flows at the edge inside doughnut-shaped fusion devices called "tokamaks." The findings mark an encouraging sign for the development of machines to produce fusion energy for generating electricity without creating long-term hazardous waste.

The result partially corroborates past PPPL findings that the width of the heat exhaust produced by fusion reactions could be six times wider, and therefore less narrow, concentrated, and damaging, than had been thought. "These findings are good news for ITER," said PPPL physicist C.S. Chang, lead author of a description of the research in *Physics of Plasmas*, referring to the international fusion experiment under construction in France. "The findings show that the heat exhaust in ITER will have a smaller chance of harming the machine," Chang said.

Fusion, the power that drives the sun and stars, is the fusing of light elements in the form of plasma—the hot, charged state of matter composed of free electrons and atomic nuclei—that produces energy. Scientists around the world are seeking to replicate fusion on Earth for a virtually inexhaustible supply of power to generate electricity.

The superhot plasma within tokamaks, which can reach hundreds of millions of degrees, is confined by magnetic fields that keep the plasma from the walls of the machines. However, particles and heat can escape from the confinement fields at the "magnetic separatrix"—the boundary between the magnetically confined and unconfined plasmas. At this boundary, the field lines cross at the so-called X-point, the spot where the waste heat and particles escape and strike a target called the "divertor plate."

The new findings reveal the surprising effect of the X-point on the exhaust by showing that a hill-like bump of electric charge occurs at the X-point. This electrical hill makes the plasma circulate around it, preventing plasma particles from traveling between the upstream and downstream areas of the field lines in a straight path. Instead, like cars maneuvering around a construction site, the charged plasma particles take a detour around the hill.

The researchers produced these findings with XGC, an advanced computer code developed with external collaborators at PPPL that models the plasma as a collection of individual particles rather than as a single fluid. The model, which showed that the connection between the upstream plasma located above the X-point and the downstream plasma below the X-point formed in a way not predicted by simpler codes, could lead to more accurate predictions about the exhaust and make future large-scale facilities less vulnerable to internal damage.

"This result shows that the previous model of the field lines involving flux tubes is incomplete," said Chang—referring to the tubular areas surrounding regions of magnetic flux—"and that the current understanding of the interaction between the upstream and downstream plasmas is not correct. Our next step is to figure out a more accurate relationship between the upstream and downstream plasmas using a code like ours. That knowledge will help us develop more accurate equations and improved reduced models, which in fact are already in progress."

More information: C. S. Chang et al, X-point ion orbit physics in scrape-off layer and generation of a localized electrostatic potential perturbation around X-point, *Physics of Plasmas* (2019). DOI: 10.1063/1.5072795

Provided by Princeton Plasma Physics Laboratory particle-edge-fusion-device.html