

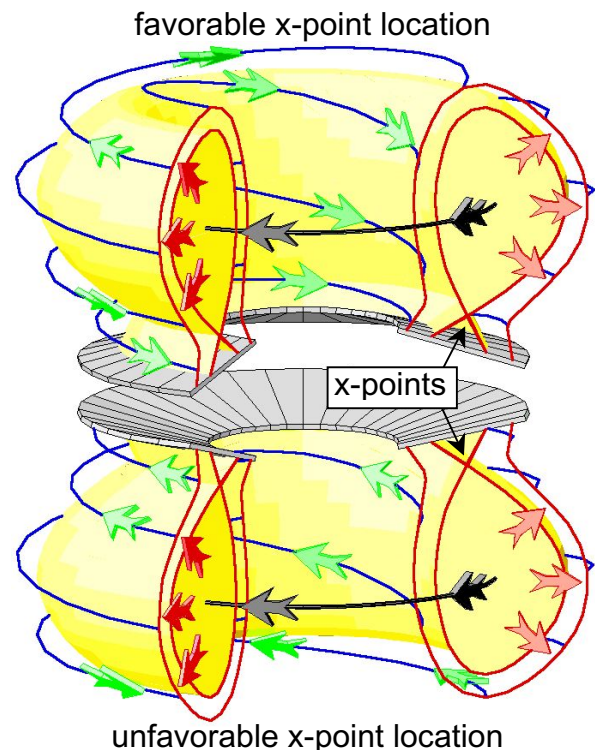
## Fusion plasmas go with the flow

*High performance fusion plasmas in a tokamak reactor are easier to obtain when the boundary layer flows with the plasma current*

Magnetically confined fusion plasmas exhibit low and high energy confinement modes (L- and H-mode, respectively), with the latter being essential for attaining a self-sustained nuclear fusion reaction. The H-mode can be achieved in a tokamak – a torus or donut-shaped “magnetic bottle”– if sufficient heating power is applied to the plasma. However, the required power varies strongly with the topology of the magnetic field, depending specifically on whether the magnetic field structure has an “x-point” at the top or bottom of the device. The physics behind this effect has been a long-standing puzzle for researchers: Why and how does the location of the x-point influence the amount of heating power needed to access the H-mode?

Recent research on the Alcator C-Mod Tokamak has uncovered a possible explanation involving the behavior of plasma flows in the boundary layer near the material walls. Plasma continuously leaks into the boundary and exhausts along magnetic field lines toward the walls in a helical pattern. It turns out that most of this leakage occurs where the magnetic field is weakest, i.e., at the outside of the torus. Consequently, the location of the x-point (top or bottom) influences the overall direction of the boundary-layer flow. Measurements indicate that these flows directly influence the toroidal rotation of the confined plasma; as the x-point is systematically moved toward the favorable location (i.e., with the lowest H-mode threshold power) the toroidal rotation shifts toward the direction of plasma current. Concurrently, stronger radial electric fields and electric field gradients are detected at the boundary, consistent with the expected interaction of the rotating plasma with the

confining magnetic fields. Based on experiments in other devices, it is thought that radial electric field gradients and associated plasma flow shear at the boundary suppress turbulence and play a key role in accessing the H-mode. Thus a potential explanation for the H-mode puzzle is born: x-point topology regulates boundary-layer flows, which affect flow shear, turbulence, and ultimately the heating power required to achieve H-modes in fusion plasmas.



*Plasma leakage on the outside of the torus (red arrows) causes a flow along magnetic field lines (green arrows) toward wall surfaces. Depending on the location of the x-point, this flow ‘spins’ the confined plasma (yellow) with or against the plasma current (black arrows), affecting access to high-performance regimes.*

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