Please fill in each element in square brackets.
Refer to http://science.energy.gov/discovery-and-innovation/highlights/ for examples.

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Spinning on its own: selecting the direction of intrinsic rotation

Collisionless ion damping, discovered more than 70 years ago, may explain the mysterious 'rotation reversals.'

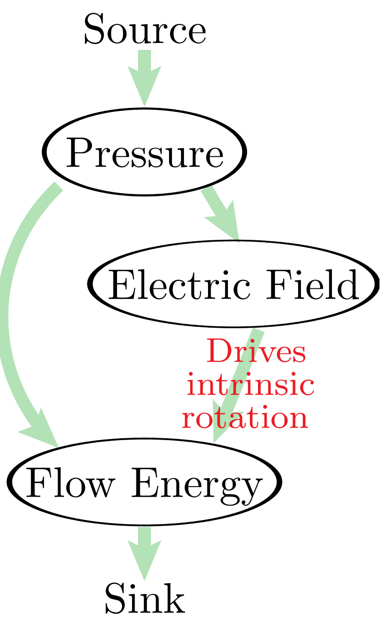

Image courtesy of Timothy Stoltzfus-Dueck (PPPL)

Fluctuation energy from plasma instabilities (the Source) drives pressure fluctuations and is dissipated from plasma flows along the magnetic field (Flow Energy). In turbulence, fluctuation energy must flow from its source to its sink, just like water in a basin flows from the tap to the drain. This forces energy to be transferred from the Electric Field to the Flow Energy. The direction of this transfer determines the direction of the resulting intrinsic rotation.

The Science

A fusion reactor will have little to no applied torque to spin up its plasma, but the plasma will still need to rotate fast enough to avoid dangerous instabilities and disruptions. How will it know which way, and how fast, to rotate? Careful analysis of tokamak geometry and symmetry shows that the transfer of energy from the electric field to flow energy is inextricably linked to the spatial transfer of momentum between the core and edge of the tokamak. This transfer of momentum causes the core of the tokamak to rotate differently from the plasma edge.

The Impact

A nonrotating plasma can be driven unstable by magnetic interactions between plasma fluctuations and the metal vessel wall, causing disruptions that are very dangerous for ITER. When the plasma rotates, it weakens or eliminates the plasma-wall interaction that can drive these disruptions. Since ITER will not have much external torque available to spin the very large plasma, we need to understand the so-called intrinsic rotation to see if it will be strong enough. This work evaluates a contribution to the intrinsic rotation that may play an important role in answering this question.

Summary

Quite surprisingly, tokamak plasmas rotate spontaneously without applied torque. The core rotation may equal the edge rotation or be more counter-current than the edge rotation. The core rotation can also transition suddenly between these two states — an unexplained phenomenon referred to as rotation reversal. This work demonstrates the existence of a robust, fully nonlinear symmetry-breaking spatial transfer of plasma momentum that enables the transition. This transfer follows from the simple fact that turbulent energy flows from its source to its sink. Basically, the very same electric field that transfers energy to flows also causes a spatial transfer of momentum, which drives the core to rotate counter-current relative to the edge. This process is unusually robust, since it relies only on conservation properties and symmetry, which hold even in strongly nonlinear turbulence. The calculations lead to a concrete formula for the resulting difference between the core and edge rotation, a key step in estimating plasma rotation profiles expected for ITER and the resulting implications for stability.

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Publications

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