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Plasma Turbulence Generates Flow in Fusion Reactors

Heating the core of fusion reactors causes them to develop sheared rotation that can improve plasma performance

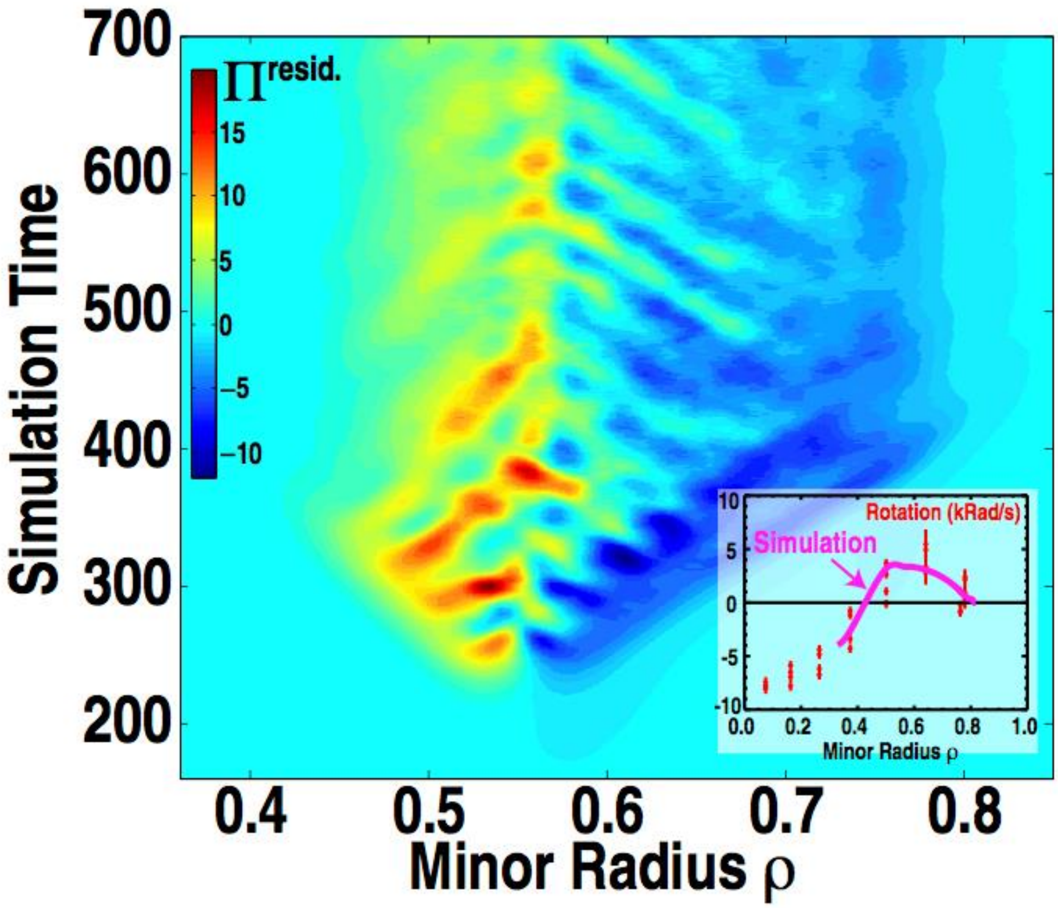

Image courtesy of W.X. Wang
Simulation of plasma turbulence generating positive (red) and negative (blue) residual stress that drives rotation shear. (inset) Comparison between measured and simulated rotation profile.

The Science

Improved stability and confinement in fusion reactors comes through generation of sheared flow, commonly driven by high energy particle beams. New simulations are showing how the plasma can self-organize to generate its own sheared flow, even when there is no auxiliary external drive.

The Impact

Rotation and rotation shear is beneficial for confinement in fusion plasmas. Such rotation is provided predominantly by injecting momentum into the plasma with energetic neutral particles in present day experiments. In future, larger fusion reactors like ITER, the amount of torque that can be applied to the plasma is more limited than in present devices. Current research is focused on understanding and developing plasma self generated flows that can be used in fusion reactors to improve confinement and stability. This research presents an important step towards quantitatively predicting the underlying physics of these self-generated flows. The potential impact of this research is increasing fusion reactor performance in terms of improved stability and increased pressure.

Summary

New measurements and simulations of plasma rotation in DIII-D show that self-organized “intrinsic rotation” in tokamaks is generated by turbulence. Such self-organized flow can be beneficial for fusion reactor performance by suppressing turbulent energy loss and magnetohydrodynamic instabilities. The present work shows that by simply heating the plasma core we can cause it to generate a sheared flow. The modeling shows that we now have a quantitative understanding of the amount of sheared flow that can be generated using this self-generated intrinsic torque. The plasma flow is generated by the variation of the turbulence strength across the radius of the plasma, which the plasma sees as a source of momentum flux. The plasma reacts to this momentum flux, causing acceleration from rest and driving differential flow, like the atmospheric jet stream or the bands of Jupiter. This final steady flow represents the balance between the intrinsic torque driven by the turbulence, and the viscosity of the plasma that keeps the gas from spinning arbitrarily fast. Theoretical simulations are able to predict the intrinsically generated torque and plasma rotation, in very good agreement with observations.

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Publications

B.A. Grierson, W.X. Wang, S. Ethier, G.M. Staebler, D.J. Battaglia, J.A. Boedo, J.S. deGrassie and W.M. Solomon, “Main-ion intrinsic toroidal rotation profile driven by residual stress torque from ion temperature gradient turbulence in the DIII-D tokamak”, *Physical Review Letters* **118**, 015002 (2017)