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SIMULATIONS ELUCIDATE ATTRACTIVE FUSION POWER OPERATION REGIME

Bridging the gap in understanding the ionized-gas dynamics.

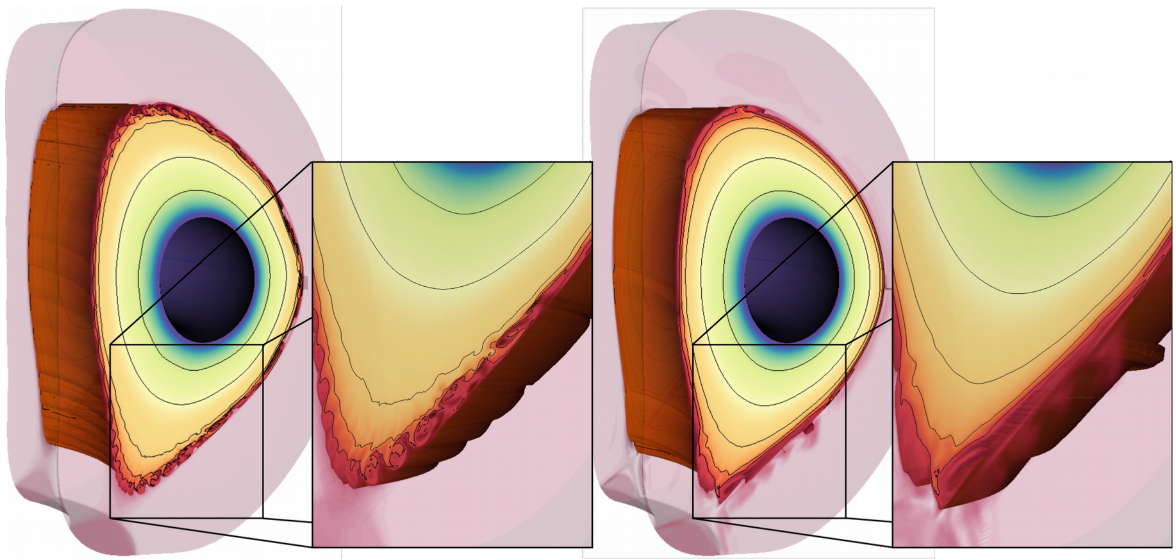

Image courtesy of Jacob King
Pressure contours as a cut of the full 3D torus at two different times demonstrate the development of a weakly turbulent steady-state that prevents wall-damaging bursts.

The Science

One of the outstanding challenges for the creation of fusion energy from tokamak plasmas is that the plasma confinement is *too good*. This leads to periodic bursts of plasma from the edge of the confined region. These bursts, in a future power reactor, could potentially damage the wall and significantly reduce its lifetime. Experiments show that attractive regimes exist without these bursts and that these regimes are enabled by specific 3D structures of the plasma's magnetic field. Understanding how to operate a fusion reactor in these burst-free regimes requires interpretation from three-dimensional simulations.

The Impact

Advanced simulations demonstrate that the 3D magnetic structures associated with these burst free regimes can be modeled; opening the door to computer-aided design and prediction for future burning plasma devices and path to identify high-performance fusion regimes without heat bursts.

Summary

As pioneered at the DIII-D National Fusion Facility, quiescent H-mode operation provides such a burst-free regime. Observations indicate that large, long-wavelength magnetic perturbations in the edge of confined region produce a steady-state exhaust of particles and energy. Extended-magnetohydrodynamic simulations with the NIMROD plasma-modeling code produce a saturated long-wavelength state where a bath of multiple unstable modes interact to provide energy and particle loss. This state is consistent with many aspects of DIII-D experiments. In particular, simulations saturate to steady-state only when the flow inferred from the experiment is included and the simulated particle transport is enhanced relative to the thermal transport. Both effects are observed in experiment.

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Publications

J. R. King, K. H. Burrell, A. M. Garofalo, R. J. Groebner, S. E. Kruger, A. Y. Pankin, and P. B. Snyder, "NIMROD modeling of quiescent H-mode: reconstruction considerations and saturation mechanism," Nuclear Fusion **57**, 022002 (2017) [10.1088/0029-5515/57/2/022002].

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J. R. King, A. Y. Pankin, S. E. Kruger, and P. B. Snyder, "The impact of collisionality, FLR, and parallel closure effects on instabilities in the tokamak pedestal: Numerical studies with the NIMROD code," Physics of Plasmas **23**, 062123 (2016) [10.1063/1.4954302].

J. R. King, S. E. Kruger, K. H. Burrell, X. Chen, A. M. Garofalo, R. J. Groebner, E. Olofsson, A. Y. Pankin, and P. B. Snyder, "MHD modeling of a DIII-D QH-mode discharge and comparison to observations," accepted for publication in Physics of Plasmas in association with an invited talk at the APS-DPP annual conference.

Related Links

https://nimrodteam.org/

http://w3.pppl.gov/cemm/

https://fusion.gat.com/global/DIII-D