A disappearing feast: Mean flows remain slim after eating eddies

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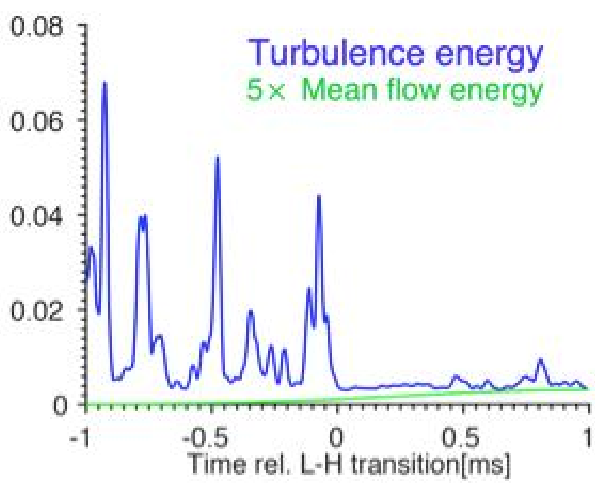

Plasma physics experiment shows that the reduction in turbulence energy can't be explained by the increase in the mean flow energy, ruling out the predator-prey model in magnetic confinement fusion machines. Credit: Princeton Plasma Physics Laboratory

Magnetic confinement fusion holds the promise of almost limitless amounts of energy, available on demand and producing zero carbon dioxide. But in order to harness that energy, we must trap plasma—an ionized gas—hotter than the center of the sun inside a donut-shaped magnetic facility called a tokamak that measures just a few yards across. As you might guess, the confined plasma becomes turbulent, and that turbulence leaks energy out from the ultra-hot core to the room-temperature wall.

But a slight increase in heating power can reduce the turbulence near the edge of the tokamak and cause the energy to leak much less. This new state of high confinement, known technically as "H-mode" and discovered in Germany in 1982, opened a promising new avenue towards the production of fusion energy.

Yet there is still no conclusive explanation for the disappearing turbulence. One popular contender, the "predator-prey" model, posits that the turbulence spontaneously dumps all of its energy into a benign spinning of the plasma called "mean flow" that does not transport heat. According to this model, the spinning acts as a predator that feeds on eddies (prey) in the turbulence. If the predator is too successful, the population of eddies plummets and the mean flows (predators) grow accordingly. The predator-prey model suggests that the energy in the mean flows must increase by roughly the same amount that the energy in the turbulence drops. But does this really happen?

At the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL), researchers have found that it does not. They used a gas puff imaging (GPI) diagnostic that let them directly see turbulent plasma fluctuations in the edge region of PPPL's National Spherical Torus Experiment (NSTX), the laboratory's flagship fusion facility, which has since been upgraded.

Pumping small amounts of neutral gas into the plasma caused the neutrals to interact with the plasma and glow. A fast camera recorded movies of that glow and revealed how the turbulence evolved in space and time. Researchers were also able to infer the velocity of the plasma. This enabled evaluation of both the energy in the turbulent fluctuations and in the mean flows, providing a direct check on whether the evolution of these conditions satisfies the expectations of the predator-prey model.

Surprisingly, the answer was a resounding "no." By carefully evaluating the energy in the flows and turbulence, keeping all the important terms, they found that on NSTX the energy in the mean flows was never—even in H-mode—bigger than about 1 percent of the energy in the turbulence before the transition (Figure 1) to H-mode. This clearly showed that the reduction in turbulence energy couldn't be explained by the increase in the mean flow energy, ruling out the predator-prey model.

With this result, the mystery of the H-mode deepens again. However, by ruling out one explanation, the results from NSTX may refocus efforts on other contenders, raising the chances of identifying the physics behind the mysterious "H-mode" and facilitating the ability to employ it for the success of future fusion reactors.

More information: meetings.aps.org/Meeting/DPP16/Session/GO6.10

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