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Reducing small-scale turbulent filaments in a hot fusion plasma

Small-scale turbulence and temperature fluctuations are reduced in the core of high confinement (H-mode) DIII-D plasmas

Hot tokamak fusion plasmas confine energetic ions and electrons in a donut-shaped vacuum vessel using a strong magnetic field. Such plasmas can exhibit strong turbulence and large plasma flows. Locally, these turbulent filaments or bubbles of warmer, or more concentrated, plasma move about chaotically within an overall background plasma flow - in a manner similar to eddies observed during whitewater rafting. These filaments or bubbles exist on large and small scales (1/100th of an inch to ten inches). Understanding these turbulent filaments is critical in fusion plasmas, since they move particles and heat from the hot plasma core to the vessel wall and thereby deplete the stored plasma energy.

For the first time, UCLA researchers have shown experimentally on the DIII-D tokamak that smaller-scale turbulent filaments are greatly reduced or absent in the core of high-confinement mode plasmas. This research is an important step towards understanding anomalous energy transport in a regime that is relevant to future burning plasma experiments. Time-dependent plasma flows are found to interact with relatively small-scale (1/4”-1”) fluctuations, with strong flow shear observed to correlate with reduced turbulence level.

These small scale filaments affect mainly plasma electrons; however, their role in governing energy transport is not well understood. In the research reported here, UCLA researchers, together with DIII-D collaborative researchers, utilize microwaves to probe the magnitude and flow of turbulent density eddies with sizes between 1/4”-1”, in a manner similar to Doppler radar detection of approaching aircraft. Flows are known to reduce or suppress large-scale turbulent eddies by shearing them apart, if the plasma core flows much faster than the boundary plasma layer. It has been unclear until now how sheared flows affect smaller-scale eddies. In the current research it was found that the small-scale turbulence level is influenced by the time-dependent plasma flow pattern. Figures 1 and 2 show the smaller-scale turbulence level (radial eddy size ~ 1-2 cm) versus time. Four microwave beams were used to probe a radius range of ~ 2 cm. The turbulence level (shown in the upper panels) is seen to be reduced (darker colors) in high-confinement-mode (Fig. 2) compared to low-confinement-mode (Fig. 1), while the radial size of eddies is somewhat reduced. The radial flow shear (shown in the lower panels) is statistically larger in H-mode and more localized radially, correlated with reduced small-scale fluctuation levels and improved transport properties.

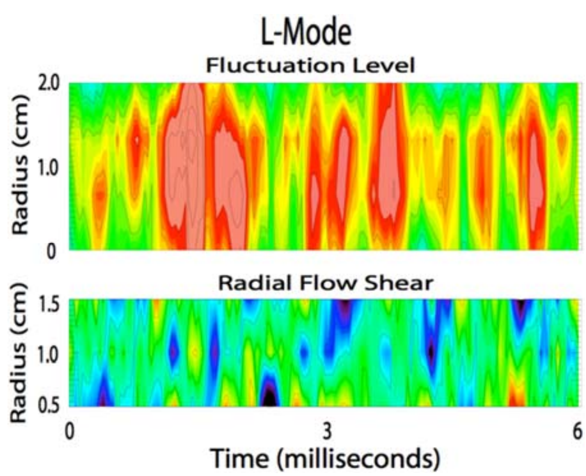

Fig. 1

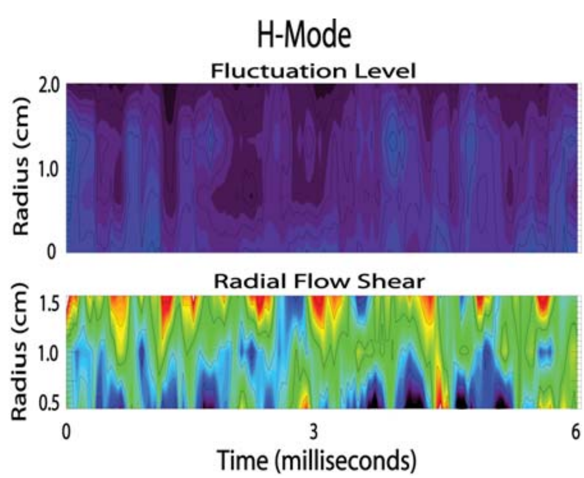

Fig. 2

Larger-scale electron temperature fluctuations, evaluated by collecting the natural plasma microwave emission, were also, for the first time, found to be greatly reduced in the core of these plasmas. Recent numerical simulations suggest that temperature fluctuations can account for a substantial part of the electron heat loss observed in tokamaks.

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