Studying Micro-Climate Weather in a Working Model of a Fusion Reactor

DENVER—At airports in areas prone to dangerous wind conditions, Doppler radar and LIDAR (like radar with light instead of radio waves) systems are used to spot otherwise invisible trouble like "microbursts" and wind shear. At the DIII-D national tokamak facility at General Atomics in San Diego, somewhat similar kinds of instruments are used to make detailed observations of the "plasma weather" – turbulent fluctuations at spatial scales shorter than an inch. The fluctuations on these short scales is strongly affected by the equivalent of the large-scale "wind shear", which is the result of how rapidly the plasma flows around the doughnut-shaped "magnetic bottle". In this series of experiments, the plasma conditions in DIII-D are set up to be an accurately scaled-down version of those that will be achieved in ITER, the largest fusion reactor ever built, currently under construction in the south of France. Researchers believe that observations of how the plasma weather in present-day fusion machines like DIII-D depends on the "wind shear" can point to directions for more efficient confinement of energy in much larger fusion machines like ITER and beyond that, fusion reactors that will generate electricity without greenhouse gas emissions for the electrical grid.

DIII-D plasmas have been prepared in which powerful beams of particles are injected into the plasma, both heating the gas to truly stellar temperatures and controlling the plasma. Beams of microwaves at power levels similar to that of the particle beams, about 3 or 4 million Watts, are also injected to further heat the plasma without imparting any spin, similar to how fusion reactions will keep the plasma hot in a full-scale fusion reactor.

An example shows the quite different fluctuation level in plasmas with microwave heating compared with those in plasmas with solely particle beam heating, looking at turbulent eddies of characteristic size of a fraction of an inch. The case with combined particle beam and microwave heating shows significantly higher fluctuation levels than are seen in the case with particle bean heating alone, suggesting that the higher "wind shear" in the latter case effectively tears apart the fluctuations and minimizes the leakage of heat from the magnetic bottle.

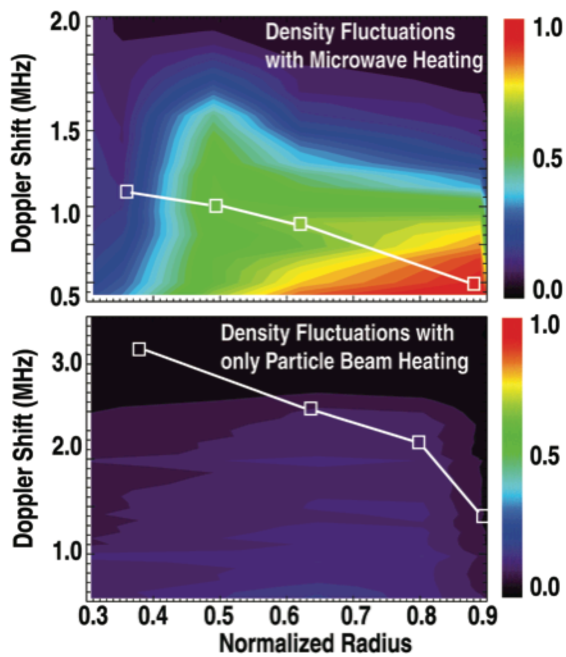

Fig. 1: "Doppler radar" measurements of turbulent eddies of characteristic size of 0.2-0.4 in. in the DIII-D tokamak plasma. The upper plot shows the level (color scale, with red being the highest fluctuation level and blue-to-black being the lowest fluctuation level) and location of turbulence in a case with combined particle beam and microwave heating, and the lower plot shows the much lower fluctuation levels in a case with only particle beam heating at a higher "wind speed" (flow rate around the machine).

Results from measurements like these are compared to sophisticated computer simulations, allowing researchers to gauge their level o understanding of the physical processes underlying the plasma "micro-climate weather", and thereby increase their confidence in predicting conditions in ITER and future power-producing fusion reactors.

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