On the dynamics of plasma flows, gradients and transport in fusion plasmas

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Understanding the relation between free energy sources, flows and transport is a fundamental issue in systems far from thermal equilibrium that has been debated for years. Confined thermonuclear plasma is an extreme example of system far from thermal equilibrium due to strong external drives that maintain steep gradients in the plasma parameters. The heat and particle transport in fusion plasmas are generally due, in part, to turbulent process associated with small-scale instabilities driven by the in-homogeneity of density, temperature and pressure profiles in the direction normal to the magnetic surfaces. Therefore, clarifying the dynamical relation between plasma gradients, flows and transport is one of the key open issues confronting the magnetic fusion community.

The magnitude of radial transport in magnetic confinement devices for controlled nuclear fusion suffers spontaneous bifurcations when specific system parameter values are exceeded. The mechanism governing the development of this bifurcation, leading to the establishment of an edge transport barrier, is still one of the main scientific conundrums facing the magnetic fusion community after more than twenty years of intense research. Recent experiments in tokamaks and stellarators have shown that the paradigm of turbulence controlled by sheared flows should include both mean and oscillating (zonal flow like) sheared flows [1, 2, 3, 4, 5, 6, 7].

More recently, the dynamical coupling between gradients and transport has been investigated using similar experimental tools in the plasma boundary of tokamak and stelarator devices, showing that the size of turbulent events is minimum in the proximity of the most probable gradient [8]. The universality of these findings points out the importance of plasma self-regulation mechanisms.

These observations provide a guideline for further developments in plasma diagnostics and multi-scale transport studies in fusion plasmas.

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