Gyrokinetic Pedestal Transport Studies

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The quality of ITER's H-mode pedestal is crucial in determining whether ITER can achieve its fusion power targets. A pedestal height of about 4 KeV may be required to meet its performance goals. If MHD stability were the principal determinant of pedestal properties, as is the case in the most widely invoked pedestal paradigm (the EPED model [1]) current machines, it is asserted, may have provided a solid basis for making optimistic projections for ITER. [aside from the fact that these predictions put ITER dangerously close to ELMs]

Although EPED-like models broadly capture major trends observed in H-mode pedestals, they are unable to reproduce the detailed properties of some discharges [2-4] suggesting that physics beyond MHD stability may, often, affect Pedestal properties.

Apart from these experimental "anomalies", it is conceivable that pedestals in future devices, operating in quite different regimes, may be subject to some other physical process that will arrest pedestal development below the maximum limits set by MHD [5].

One such parameter that sets ITER apart from current machines is ρ*(= ρ/a). Since ρ* is intimately connected to the E × B shear rate that is believed to be responsible for turbulence suppression (for suppression $\gamma_{E\times B} \sim \frac{d}{dr}\frac{E_r}{B} > \gamma$, the growth rate), smaller ρ* could have a profound effect on the level of turbulence, and hence, on the quality of the pedestal. It is likely that in low ρ* machines like ITER (and prospective future reactors), turbulence could emerge as a strong determinant of the pedestal characteristics.

The suppression factor, the ratio of the shear rate to linear growth rates, scales as $\frac{\gamma_{E\times B}}{\gamma_{inst}} \sim \rho^* \frac{a}{L_p}$, and places the present day experiments in a regime where shear rates are much larger than linear growth rates; turbulence is, then, suppressed, and profiles can evolve to reach the bounding MHD limits. This is, of course, the best scenario for a high quality H-mode pedestal [aside from ELM issues (on the negative side) and potentially broadened and heightened pedestals (on the positive side)]. At the other extreme, in the $\rho^* \to 0$ limit shear suppression will clearly fail. Typical ITER ρ* lies somewhere in between, and the crucial question is whether there will be sufficient velocity shear to sustain a high-enough quality pedestal.

In order to find answers to this question, fundamental to fusion energy, a major program to model the turbulence and transport in pedestals representative of present-day machines as well as plausible ITER scenarios is strongly and urgently called for.

At IFS, we have already begun the process of pedestal investigations employing two "state of the art" codes—the VMEC for constructing detailed equilibria, and the widely used gyrokinetic code GENE to explore the nature and extent of turbulence in these equilibria. To establish that our tools reproduce transport levels consistent with power balance in observed H-mode pedestals, we have first studied profiles and equilibria very close to those diagnosed in a recent JET H-mode discharge. Then we go to investigate ITER profiles obtained by appropriately scaling upwards the studied JET-like profiles. Our realistic MHD equilibria are built on current profiles that are the sum of Ohmic and bootstrap contributions, and self-consistently calculated shear-flow profiles.

Preliminary nonlinear global gyrokinetic simulations 1) identify an electromagnetic mode with tearing parity as a major component of pedestal transport, 2) find that transport in JET-scale pedestals is roughly consistent with experimental expectations, and 3) predict that transport (in particular transport attributable to electrostatic fluctuations) scales much less favorably than GyroBohm—as one would expect from the arguments above. The latter indicates that we must thoroughly explore what will be needed to create a robust and healthy pedestal in ITER.

We expect to identify the salient dynamics determining pedestal transport and determine its ρ^* scaling. We are also undertaking a vigorous validation effort aimed at substantiating the ability of our tools to rigorously model pedestal transport.

We are hoping that our working relationships with theoretical groups and experimentalists at NSTX, CMod and ASDEX Upgrade will be strengthened as combined effort elucidates more and more pedestal physics. With C-Mod, we share an additional special interest in trying to understand the I-mode discharges.

References:

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