

DPhil Project (2012-16, 3.5 years CASE EPSRC funding expected)

Ion-scale turbulence in MAST spherical tokamak: experimental data analysis and nonlinear gyrokinetic models

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Magnetically confined plasma is a complex nonlinear non-equilibrium system, where the temperature gradient provides free energy to feed plasma instabilities at the scale of ion Larmor motion and the turbulence driven by these instabilities in turn gives rise to heat transport, striving to flatten the temperature gradient. The nature of this turbulence, the interplay between it, large-scale gradients, plasma flows and magnetic geometry, and the practical methods of suppressing the turbulent transport constitute what perhaps is the main unsolved fundamental-physics problem in fusion science.

It is only recently that ion-scale turbulence in tokamaks has become directly measurable. This year, a new Beam Emission Spectroscopy (BES) diagnostic has come into operation on the MAST spherical tokamak (ST) at CCFE, which is able to image turbulence with a spatial resolution of a few centimetres and very high (MHz) time resolution. This and other high-resolution diagnostics (a state-of-the-art Thomson scattering system for measurement of the electron kinetic profiles, Motional-Stark-Effect system for measuring the magnetic geometry, etc.) make of MAST one of the best-diagnosed turbulent laboratory plasmas in the world. Spherical tokamaks are particularly interesting because they hold the promise of a more compact and versatile confined plasma than huge machines like ITER; it is also much easier to try new ideas on them than on big machines. A key feature of ST plasmas is that strong sheared flows driven by the neutral beam injection are more effective at suppressing the turbulence and transport than in conventional tokamaks – the resulting transport bifurcations, states of reduced transport, new kinds of turbulence (driven by the shear flows themselves) are all largely unexplored and fascinating phenomena, understanding which is a first-class intellectual challenge as well as a practical imperative.

The primary theoretical vehicle for developing such an understanding is the gyrokinetic theory and numerical simulations. The starting objective of this DPhil project is to combine data analysis from the MAST BES system with gyrokinetic modelling of turbulence both to test simulation results and to explore new turbulence regimes and parameter dependences. This could take the form of utilising calculations of the spatial response of the BES diagnostic to generate synthetic data from nonlinear simulations; the synthetic data would then be analysed in the same way as the actual measurement data, allowing a direct comparison of derived statistical measures, e.g., spatio-temporal correlation functions. One of the challenges will in fact be to identify which of such measures provide the most stringent tests of theory or the most physically relevant characterisation of turbulence.

Further physical phenomena amenable to study with the BES data (via measurement of mean and fluctuating flows using statistical analysis techniques) are, e.g., propagation of waves, self-generation of localised oscillating flows (so-called zonal flows and Geodesic Acoustic Modes), which are thought to be involved in the regulation of the saturated level of turbulence. The actual direction that this research takes will depend to an extent on the preferences and inclinations of the candidate.

Application: via standard Oxford route, to **Theoretical Physics** (deadline 20 January 2012; see <http://www2.physics.ox.ac.uk/study-here/postgraduates/theoretical-physics>; inquiries to Ms Michelle Boshier, Michelle.Boshier@physics.ox.ac.uk).