Wave-particle interactions in plasmas: Alfvén waves, turbulence and blobs

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Interactions between waves and particles are at the heart of many phenomena in magnetized plasmas, and are studied both in their fundamental aspects and in their practical implications for the performance of fusion devices. Two classes of examples will be discussed: the interaction of fast ions with coherent Alfvén waves, and the development of turbulence from linear instabilities into blobs. The stability properties of Alfvén Eigenmodes (AEs) and their potential effect on the distribution of fast ions, including fusion generated α's, are among the most important building blocks for the physics of burning plasmas that can be addressed in present devices. A fundamental role for the stability, but also for the nonlinear developments, is played by the damping rate of the mode. Dedicated methods to measure the AE damping rate separately from the fast ion drive were pioneered at JET, using internal antennas, and were subsequently deployed on other devices, e.g. C-Mod and MAST. A new antenna system was installed at JET to cover the toroidal mode number range that is expected to be most unstable in ITER. Many stable modes with n~3-10 and low damping were excited in the plasma, and analyzed with the help of a sophisticated algorithm for mode-number recognition, also operated in real-time. The comparison of results from the different experiments, in the large volume, high performance JET plasma, in the high density, high magnetic field C-Mod scenarios, and in the relatively large beta plasmas of MAST, will improve the predictive capability of the theoretical models for the stability of ITER burning plasma scenarios.

Electrostatic turbulence, related structures and their effect on transport, of importance for the behavior and performance of the edge of fusion plasmas, are investigated on the TORPEX simple magnetized plasma device using high-resolution diagnostics and several control parameters, fluid models and numerical simulations. A critical pressure gradient to drive the interchange instability is experimentally identified, consistently with linear theory. Interchange modes nonlinearly develop blobs, radially propagating filaments of enhanced plasma pressure. Blob velocities and sizes are obtained from probe measurements using pattern recognition and are described by an analytical expression that includes ion polarization currents, parallel sheath currents and ion-neutral collisions. Limiter configurations with varying angles between field lines and the metal surface are explored. The effect of interchange turbulence on fast ion phase space dynamics is studied using movable fast ion source and detector in scenarios for which the development from linear waves into blobs is fully characterized.

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