I Coupled Rippling and g-Mode Turbulence

In previous work, electrostatic fluctuations that couple the free energy sources of resistive interchange turbulence (resistive g mode) and resistivity gradient driven turbulence (Rippling mode) were studied analytically and numerically. From the appropriate fluid model, the renormalized eigermode equation was constructed in order to determine amplitude and spatial structure of steady state turbulent fluctuations. Evaluation of the predicted fluctuation levels using realistic MST parameters and the best estimates of equilibrium profiles yielded levels that appeared to be too small to agree with experiment. Recent experimental measurements of electrostatic fluctuations and electrostatic fluctuation induced transport provide the basis for a more careful and quantitative comparison. In particular, the measured frequency spectrum allows for comparison of the spectrum integrated fluctuation level over the frequency range of g modes. While it was thought that the higher frequencies of the g mode would put it in a region of the spectrum where the amplitudes are sufficiently low to agree with theory, it was found that the g mode, rippling mode, and the coupled turbulence of g/rippling fluctuations all yield spectrum integrated electrostatic potential amplitudes (ω/Te≈0.01) that are at least an order of magnitude below the levels measured in MST in the comparable frequency range. This work calls into question the standard scenario in which g modes (or rippling modes) are presumed to govern edge transport and account for the high frequency fluctuation activity in the RFP. This work will presented at the upcoming IAEA conference.

II Anomalous Ion Heating in the RFP

It is well known that ion temperatures in the RFP are frequently higher than electron temperatures, a condition observed from early in the discharge. Elevated ion temperatures also seem to characterize the edge of Ohmically heated tokamaks. Because the Ohmic induction process heats electrons, it is presumed that classical thermalization processes would lead to equal ion and electron temperatures at best. Therefore, a study of anomalous ion heating mechanisms is in order. Ion heating is correlated with flux jumps and concomitant spectrum broadening, and these, in turn, are correlated with generation of reversed toroidal field. This has suggested an examination of the role of m = 1 tearing modes associated with the RFP dynamo as the source of anomalous ion heating. Analytical work performed indicates that anomalous ion heating is not viscous in nature, as previously thought, but results
from ion cyclotron resonant interaction with short scale fluctuations excited in the turbulent cascade driven by unstable $m = 1$ modes. In the calculation, energy through-put in the cascade is related to the inverse helicity cascade required to maintain the reversed toroidal field against resistive decay. The cascaded energy is damped on the ions and electrons via ion cyclotron and electron Landau resonances. Electron and ion heating rate predications are given, as is a prediction for the ratio of anomalous loop voltage to Spitzer loop voltage. This work has been accepted for publication in Comments on Plasma Physics and Controlled Fusion, and a longer paper is in preparation.

III Feedback of Resistive Wall Instabilities

A well-recognized RFP problem is that MHD predicts and experiments indicate that a close-fitting conducting shell is necessary for stability. During this fiscal year we have completed a comprehensive nonlinear MHD study of replacement of a conducting shell by feedback of specific helical fluctuations. In the computational study (in collaboration with SAIC, La Jolla) the radial magnetic field of specific targeted modes is forced to vanish at the boundary. It was found that such feedback of a relatively small number of modes (about equal to the aspect ratio) restores RFP behavior (loop voltage, fluctuation level) nearly to that with a perfectly conducting shell. This result strongly encourages an experimental test. A paper has been submitted to Nuclear Fusion.

IV Fluctuation Suppression By Edge Feedback

In the RFP a relatively small number of helical modes contain most of the fluctuation power. Hence, a computational MHD study (with SAIC) has been initiated to test whether the fluctuation level can be reduced below that with a conducting wall by feedback of a small number of helical modes. The feedback would, for example, impose a nonzero value of the edge radial magnetic field, to produce a perturbation which is more stable than that obtained with a conducting wall (which forces the edge radial magnetic field to vanish). Tests with one helical mode are encouraging. However, for a full nonlinear run with multiple interacting modes, the advantages do not appear to survive.

V Electrostatic Helicity Injection

Electrostatic helicity injection has been proposed by Ho as a means to flatten the current density profile and thereby reduce the fluctuation level. An experimental test of the concept is under development in MST. A parallel computational study is beginning, with the initial goals of examining the effects of various current injection configurations, and the effects on current diffusion and field line stochasticity.
VI Bi-Spectral Analysis of Magnetic Fluctuations of Tearing Fluctuations

Bi-spectral analysis is a technique to directly detect three-wave nonlinear mode coupling. A coordinated MHD computational and MST experimental effort has been completed. The identical analysis is applied to both computational and experimental data, with good semi-quantitative agreement. Many details of nonlinear coupling are revealed. A paper describing the results has been accepted for Phys. Rev. Lett.

References


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