Kinetic Alfvén waves in tokamak plasmas

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In this talk the role of kinetic Alfvén waves (KAWs) in Tokamak plasmas is discussed. Although KAWs are difficult to measure directly due to their short wavelengths, it is clear from theoretical considerations that their impact on linear and non-linear phenomena is crucial for many aspects of tokamak physics (β<<1). Hand-in-hand with the underlying theory, the consequences of KAWs for simulations and the interpretation of experimental results are presented.

Specifically in burning tokamak plasmas, KAWs are predicted to couple alpha-particle driven global MHD-type instabilities to ion-gyro-radius scales via mode conversion processes. So-called 'radiative' damping and radial propagation are closely connected in this multi-scale physics problem. In addition, a kinetic description introduces electric fields along the magnetic field direction close to mode conversion layers that gives rise to collisionless wave dissipation processes. As a consequence, already for the quantitative predictions of linear mode properties the electron dynamics have to be well resolved, while at the same time global effects have to be retained in order to account for radial non-uniformity and toroidicity.

Theoretical frameworks, numerical examples and measurements from various tokamak experiments are discussed, in particular ASDEX Upgrade. Also the predictions for the stability of α-particle-driven modes in ITER plasmas including KAW physics are summarized. For these studies, linear gyrokinetic eigenvalue models (LIGKA), non-linear hybrid kinetic models (LIGKA/HAGIS) and non-linear gyrokinetic initial value codes (ORB5) are employed. Within their range of applicability, their comparison shows a consistent picture of non-linear saturation properties, in particular with respect to the role subdominant modes.

Furthermore, kinetic effects of both thermal and energetic species modify the symmetry of various global Alfvén waves with respect to their localization layer. As a consequence, the related transport of energetic ions shows also asymmetries with respect to co- and and counter-passing particles leading to modifications of the mean parallel flow with possible consequences for current drive and energetic particle transport in burning plasmas.

As outlined in the literature, the non-linear consequences of KAW physics are very broad: non-linear mode-mode coupling is enhanced as well as the excitation of zonal structures. Although global non-linear simulations are starting to capture the multi-scale aspects of the problem, the identification of the competing non-linear processes in various parameter regimes remains a challenge and is subject to ongoing research.

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