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Impact of energetic geodesic acoustic modes on transport in fusion plasmas

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Energetic particles are ubiquitous in tokamaks due to either fusion reactions or external heating such as ICRH or NBI. These energetic particles need to be well-confined in order to transfer their energy to thermal particles before leaving the discharge and achieve this way a regime with self-sustained fusion reactions. However, energetic particles may excite modes that tend to de-confine the particles themselves. This is the reason why energetic particle mode excitation and saturation need to be understood and controlled. In this presentation we focus on a special class of energetic particle modes, called energetic geodesic acoustic modes (EGAMs) [1, 2]. Because these modes are axisymmetric, they are believed to play little role in the transport in a tokamak. Nevertheless, it was observed experimentally [1] and numerically [3] that particles can be de-confined in the presence of EGAMs. We explain in this presentation the underlying mechanisms of the impact of EGAMs on transport and show that they can actually have an impact, both directly on particle trajectories and indirectly on turbulent transport. We start with a brief insight into the theory of the linear excitation of EGAMs as presented in Refs. [4, 5, 6]. We will explain how EGAMs can be linearly excited in the state-of-the-art gyro-kinetic codes GYSELA [6] and ORB5 [7]. Quantitative agreement between theoretical predictions and numerical results will be presented [4, 5] and the nonlinear saturation of EGAMs analyzed [4], with the observation of islands in phase space. These islands can induce transport of energetic particles, and when the islands are large enough to interact with the trapping domain, counter-passing particles become trapped and eventually de-confined, in agreement with previous observations [3]. The nature of the transport in phase space from counter-passing to trapped trajectories is analyzed [9]. Finally, when non-axisymmetric modes are allowed to develop, it is found that EGAMs can interact nonlinearly with non-axisymmetric modes, enhancing turbulent transport and degrading the confinement [10, 11, 12].

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