Contribution ID: **6** Type: **Invited (Plenary Session)**

Effects of spatial channeling on the structure of Alfvén eigenmodes

Tuesday 3 September 2019 16:35 (35 minutes)

The energy and momentum transfer across a magnetic field realized by destabilized magnetohydrodynamic (MHD) eigenmodes - the phenomenon named Spatial Channeling (SC) - can be an important factor affecting the plasma performance [1]. It takes place when sources and sinks (s&s) of energy are located in different regions, i.e., when the region where particles (e.g., fast ions) drive the plasma instability does not coincide with the region where the destabilized waves are damped. Depending on the location of these regions, the SC can be directed outwards (see, e.g, [1, 2]) or inwards [3, 4]; the former leads to degradation of the plasma energy confinement, and the latter improves the confinement. The eigenmodes in toroidal systems can be treated as a superposition of two travelling waves, one of them moving outwards and the other moving inwards. In the absence of s&s, the energy flux densities across the magnetic surfaces of the traveling waves exactly compensate each other. The presence of s&s breaks the balance, leading to the flux across the magnetic field, $S_\perp$, which affects the mode spatial structure. The presence of the transverse energy flux, in addition to the longitudinal flux, $S_\parallel$, implies that the total flux is oblique and the wave front is curved. However, when s&s are weak, the mode "survives".

To study these effects of the SC, an equation for TAE modes with the s&s radially separated was solved. It was found that both the mode structure and the mode frequency (ω) changed. In addition, a radial spiral mode structure was obtained, see Fig. 1. This took place even when the plasma was marginally stable ($\gamma/\omega \approx 0$, with γ the instability growth rate), but the energy source was sufficiently strong, γ_α^L⊠0.1 (γ_α^L is the local instability growth rate in the region where drive dominates). It seems possible that the SC might be responsible for the radial spiral mode
structure observed in DIII-D and NSTX [5,6]. The SC can also be a factor playing a role in saturation of Alfvén modes.

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Figure 1: Spiral structure of a driven TAE mode with the mode numbers $m = 1/2$, $n = 1$, when the region where particles drive the plasma instability does not coincide with the region where the mode is damped. Φ is the scalar potential of the electromagnetic field.

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Work supported by STCU and NASU Project #6392.

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Session Classification: Plenary

Track Classification: Collective Phenomena