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Interchange mode growth rate and frequency merging due the perpendicular heat conductivity in stellarator plasmas

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The linear stability against interchange modes of heliotrons like the Large Helical Device has not been fully understood yet. The interchange mode is the dominant instability in nearly current-free 3D configurations. Recently, experiments in the so-called inward-shifted configuration have shown the machine can be operated safely up to $\langle\beta\rangle \sim 5\%$ without major MHD event [1]. Here $\langle\beta\rangle$ is the volume averaged ratio between kinetic and magnetic pressure. The rotation of the mode, which seems to play a role in the stability [2], is also not understood. Namely, the modes are observed to rotate in the electron direction [3], whereas extended MHD theory without heat conductivity but including electron and ion diamagnetic effects predicts rotation in the ion direction for Mercier unstable modes and almost no rotation for Mercier stable modes. [4].

In this contribution, we present a new effect on the linear Mercier unstable interchange growth rate caused by the perpendicular heat conductivity $\chi_\perp$. When $\chi_\perp$ is equal to a critical value χ_c, the growth rates of the two most unstable modes become equal. For $\chi_\perp > \chi_c$, the two modes have same growth rate and opposite frequency, as shown in Fig. 1. This degeneracy is removed by the diamagnetic effects. In the domain $\chi_\perp > \chi_c$, the diamagnetic effects can be destabilizing and the rotation can be in the electron direction. The rotation direction is determined by the value of perpendicular viscosity.

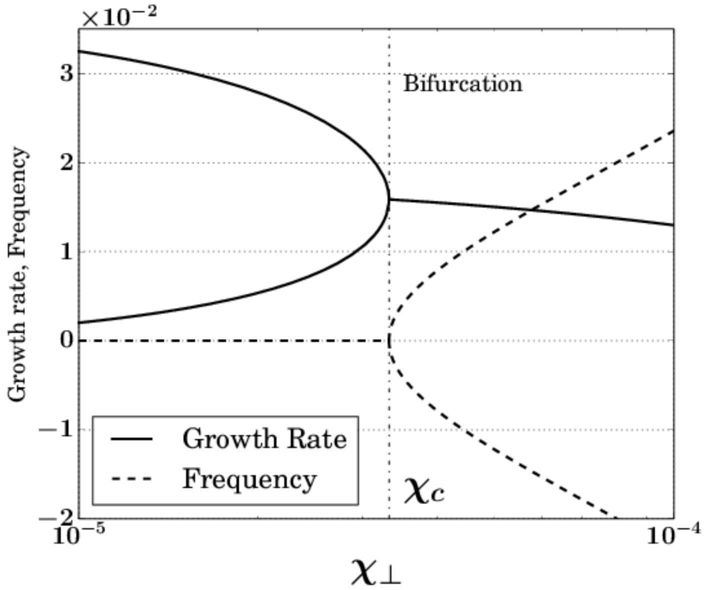

Fig. 1: Frequency and growth rate of the first two most unstable modes

This effect, which sheds a new light on the stability of the interchange mode in stellarators, is found analytically and confirmed both with a 3 field linear eigenvalue solver and with 3D non-linear MHD simulations utilizing the MIPS code [5, 6].

References

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