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Precession direction reversal and rapid energetic particle pressure redistribution in a Large Helical Device Plasma

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The understanding of energetic particle (EP) dynamics in plasmas is crucial for the conception and operation of magnetic confinement devices. These energetic particles have an energy much higher than the thermal energy of the bulk plasma, and despite their low density, can destabilize magnetohydrodynamics (MHD) modes. These modes can provoke the rapid ejection of energetic particles from the plasma core, rendering them unable to deposit their energy on the bulk plasma, and thus reducing the fusion efficiency rate. These energetic particle modes have been observed and found to cause transport such as the fishbone instability, EP driven Alfvén Eigenmodes.
In the Large Helical Device (LHD), an Energetic particle driven InterChange mode (EIC) was observed in 2015 [1]. This mode, destabilized when a perpendicular neutral beam injection was active, has an $m/n = 1/1$ mode structure (m and n being poloidal and toroidal mode numbers respectively) and is located close to the plasma edge at the $\iota = 1$ surface, and it caused significant energetic particle losses from the plasma core. Its observation motivates the present numerical study of energetic particle driven by majority trapped energetic particles in the LHD.
This work, done using the kinetic-MHD hybrid code MEGA [2], focuses on an $m/n = 2/1$ mode observed numerically. It is shown to grow with a high growth rate and finite frequency, before experiencing a rapid frequency chirping at saturation, that leads to a frequency sign inversion during a short time. At the same time, a reversal in the precession drift direction of the trapped particles that interact strongly with the mode is observed, and is shown to be responsible for the rapid energetic particle pressure redistribution.
A free boundary condition is implemented in this model to allow studying the $m/n = 1/1$ EIC mode located at the plasma edge, as well its interaction with the previously discussed $m/n = 2/1$ mode located more inward.

[1] X. D. Du et al., Phys. Rev. Lett., 114, 155003 (2015)
[2] Y. Todo, Phys. Plasmas 13, 082503 (2006)

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