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Instability of the Parallel-Propagating Alfvén/Ion-Cyclotron Wave Driven by Drifting Alpha Particles in High-Beta Solar Wind Streams

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Alpha particles are known to drift with respect to the protons along the background magnetic field in the fast solar wind. Their typical drift speed is observed to be limited to a value of order the local proton Alfvén speed v_{A} as long as collisional deceleration can be neglected. Since v_{A} decreases with increasing distance from the Sun, a continuous deceleration takes place converting the drift energy to other forms of energy such as thermal energy or wave energy.

We derive an instability of the parallel-propagating Alfvén/ion-cyclotron mode driven by drifting alpha particles in a high-beta plasma ($\beta \gtrsim 2$). To the best of our knowledge, this alpha-particle-driven drift instability has not been described previously, although it is similar in several respects to the well-studied cosmic-ray streaming instability. Using quasilinear theory, we derive an approximate analytic expression for the instability threshold. We compare this expression with numerical solutions of the full hot-plasma dispersion relation and find good agreement. The described instability is a result of the competition between driving by resonant alpha particles and damping by resonant protons.

Other drift instabilities are known to set “speed limits” to the relative drift of ion species in the solar wind depending on the required plasma parameters. We present a comparison with measured drift speeds and show that the instability threshold of the parallel Alfvénic drift instability indeed limits the alpha particle drift in high-beta fast-solar-wind streams.