The non-resonant streaming instability: from theory to experiments

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Cosmic rays can power the exponential growth of a seed magnetic field by exciting a non-resonant instability, which has received growing attention as it can generate the necessary turbulence to help confine and accelerate high energy particles in supernovae remnants and young stellar jets shocks. In general, the instability can develop in a large variety of environments, ranging from the cold and dense molecular clouds to the hot and diffuse intergalactic medium. This work aims at elucidating the behaviour of the non-resonant cosmic rays streaming instability in such environments. To study the instability in hot plasma, where finite Larmor radius effects are important, we then resort to linear kinetic theory and extend the existing analytical results to the case of demagnetized ions. The linear theory results are confirmed, and extended to the non-linear evolution by multi-dimensional hybrid-Particle-In-Cell simulations (kinetic ions and fluid electrons). The simulations highlight an important reduction of the level of magnetic field amplification in the hot regime [1], indicating that it may be limited in hot astrophysical plasmas such as in superbubbles or the intergalactic medium. In colder and denser environments, such as H II regions and molecular clouds, particle collisions in the background plasma must be taken into account. We investigate numerically their impact by including Monte-Carlo Coulomb and neutral collisions in the simulations. We find that in poorly ionized plasmas, where proton-hydrogen collisions dominate, the instability is rapidly suppressed and our results from kinetic simulations confirm quantitatively existing, multi-fluid linear theory calculations. In contrast, we find that in fully ionized plasmas, Coulomb collisions unexpectedly favour the development of the instability by reducing self-generated pressure anisotropies that would otherwise oppose its growth [2]. The instability has never been observed in the laboratory. We describe the requirements on the plasma parameters to generate the instability in an experiment, and propose two possible setups based on existing high-power laser facilities, aiming at observing and characterizing the non-resonant mode for the first time in the laboratory.

References

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