Parametric decays of electromagnetic waves in electron-positron nonextensive plasmas

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Wave propagation in relativistic plasmas is a subject of interest in many astrophysical and space systems, where electromagnetic fields may accelerate particles up to relativistic velocities, which in turn modifies the physics of wave propagation. Besides, kinetic effects further modify the dispersion properties of waves and their nonlinear interactions with the plasma particles. Thus, it is of interest to study wave propagation, and its nonlinear decays, considering both relativistic and kinetic effects. However, the traditional approach of equilibrium statistics, where kinetic effects are described by Maxellian velocity distributions, is not satisfactory in several environments where long range correlations, or memory effects, may lead the distributions to deviate from the Maxwellian case. Here, the proposal to describe plasma distribution functions in terms of nonextensive distribution functions, either of the Tsallis (where deviation from the Maxwellian case is given by a parameter q) or the kappa type (where deviations are parametrized by a κ factor), allows to extend the traditional formalisms, to study wave linear and nonlinear propagation for systems out of thermodynamical equilibrium. Following these ideas, in this work, parametric decays of an electromagnetic wave in an electron-positron plasma are studied. Kinetic effects are considered by means of the collisionless Vlasov equation, which is coupled to Maxwell equations. Relativistic effects on the particle motion are also taken into account. Perturbation of the system's equations lead to dispersion relations for the pump wave and for its parametric decays, which is numerically studied by considering a velocity distribution function which maximizes the nonextensive Tsallis entropy which, in the extensive limit, reduces to the Maxwell-Boltzmann-Jüttner distribution. In the weakly relativistic case, although some of the instabilities involve strongly damped, electroacoustic pseudomodes, all instabilites (of the decay and modulational type) found using fluid theory are present as well in the kinetic regime. For ultrarrelativistic temperatures and transverse velocities, the resonant decay and modulational instabilities are studied. The decay instability involves an electroacoustic pseudomode, and nonextensive effects are shown to be mainly relevant for the instability rate, whereas the real frequency of the unstable mode is essentially unchanged. Both the growth rate and the instability range are modified as the temperature and as the pump wave amplitude increase. The dispersion relation for the parametric decays is solved numerically for various values of the nonextensive parameter q. As expected, results reduce to the Boltzmann-Gibbs statistics for q close to 1.

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