Unstable evolution of electron holes and their effect on plasma turbulence

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One essential element for the turbulence theory is nonlinearity, which controls the energy cascading in different modes. In collisional plasmas the nonlinearity arises at higher amplitude limit due to presence of nonuniformity in positional space, where as in collision-less limit the kinetic nonlinearity arises at any amplitude due to modification in both position and velocity space profile of the particle distribution. The turbulence theory in collisional plasmas is based on the interaction between different plasma modes which are also derived from a linearised formulation of collective plasma excitations, these are 'linearised plasma modes'. But in collisionless limit the collective plasma excitations are different which are controlled by the trapped particle nonlinearity. These collision-less phase space coherent structures are frequently observed in collision-less electrostatic and magnetized plasmas. They are formed due to strong wave-particle resonance, which generates a potential that can hold particles together in a trough. Once formed, such structures can grow by extracting free energy and by momentum exchange, or velocity scattering by other species. Such mechanisms allow a hole to be displaced up the phase space density gradient which leads to the growth of the hole. Therefore the existence of these structures can stir turbulence and enhance fluctuation level, and the turbulent flow. One of the striking features of the growth, which is identified in our recent simulation[1-3], is that it can be subcritical, namely structures can extract free energy even when plasmas are predicted to be linearly stable. In this present study the generation mechanism of these collision-les collective plasma excitations, and their stability criterion have been investigated using Vlasov-Poisson simulation. The coherent structures are exited inside the subcritical regime of plasma instability, and depending on ions response they may accelerate or propagate with constant velocity. At cold ion temperature $T_i<T_e$, the stability of electron holes are accompanied by an ion compression that yields phase velocities above C_s (ion acoustic genre) and accelerates them, forcing a jump over a forbidden velocity gap, and settle on the high velocity tail of the electron distribution. In the observed ultraslow structures having $T_i>T_e$, however, the warm ions begin to supplement the electron response and show Boltzmann-like behavior (electron acoustic genre), transforming the ion compression to decompression (rarefaction) at the hole location. In the presence of sufficient drift (above the critical value) two stage growth of electron hole observed. In the first stage EH accelerates to higher velocity and in the second stage EH starts to grow in amplitude. These new findings about the stability criterion of the coherent structures will help to enhance the understanding of collisionless turbulence theory.

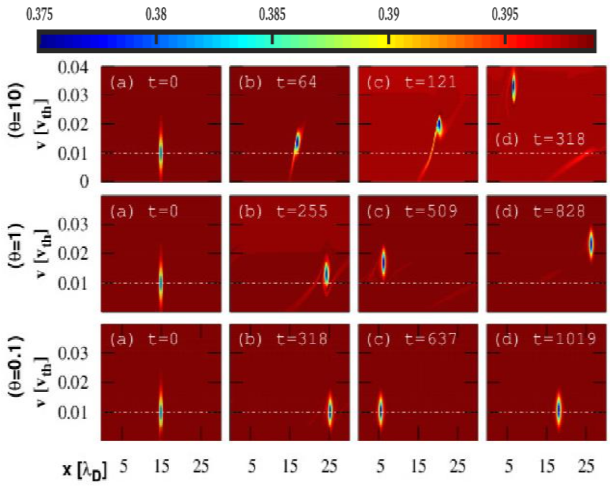

Fig.1: Acceleration of electron hole to higher velocity at cold ion temperature $\Theta \geq 1$, and stable ultraslow propagation of EH at hot ion temperature $\Theta < 1$.

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