Transient Growth in Magnetized Vlasov Plasma

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Tokamak physics is rich in various types of instabilities. The physical origin, triggering mechanisms and fundamental understanding of many tokamak instabilities, however, is still an open problem. Aiming to gain a better insight into this question, we investigate the stability properties of a collisionless Vlasov plasma in a stationary homogeneous magnetic field. We narrow the scope of our investigation to the case of a plasma with an initial Maxwellian equilibrium (Maxwellian plasma) and examine its evolution with an electrostatic approximation. We prove that the linearized Vlasov operator is non-normal leading to the local instability of its eigenvalues. We find that the non-normality of the operator leads to an algebraic growth of perturbations in a magnetized plasma followed by exponential decay, i.e., classical Landau damping behaviour (see Fig. 1). This is a so-called transient growth phenomenon, developed in the framework of non-modal stability theory in the context of hydrodynamics. The typical time scales of the obtained instabilities are of the order of several plasma periods. The first-order distribution function and the corresponding electric field are calculated and the dependence on the initial conditions is studied. Our result offers a new scenario of the emergence and development of tokamak instabilities on the kinetic scale.

Figure 1: Evolution of the electric field demonstrating transient growth