Nonlinear Landau damping of EMWs and its interdisciplinary applications

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One of the most important aspects of kinetic theory, especially from the viewpoint of instability, is the treatment of collision-less or Landau damping. As is well-known physical mechanism of Landau damping is related to the exchange of energy between wave and a particle. Nonlinear Landau damping or the nonlinear wave particle interaction however refers to mode coupling and involve interaction of two waves (beats) and one particle. Here the resonant condition is $(\omega_2 \pm \omega_1) = (k_2 \pm k_1) \cdot v$. Where "v" is the thermal velocity of particles.

We discuss the problem of nonlinear Landau damping of circularly polarized EM waves (helicons) in plasma, with particular emphasis on the acceleration of solitons. It's important to note that linear damping of such waves is very small.

Here we use kinetic equation for the slowly varying distribution function of the particles, which embodies a new time dependent (ponderomotive) force due to the intense EM field, in addition to the usual Lorentz force. Later we see that the the time dependence term in the ponderomotive force is of more significance than the usual space dependent term. Ignoring this may not lead to Landau damping

The wave-plasma interaction can be well described by two coupled dynamical equations of the generalized Zakharov type, with one extra nonlocal term coming from Landau damping.

Then we construct a kinetic nonlinear Schrödinger equation and obtain nonlinear decrement.
Additionally, we note that the nonlinear Landau damping leads to the amplitude modulation of helicon waves, and can trigger a modulational-type instability.

Kinetic nonlinear Schrödinger equation also allows soliton solitions and we study how the nonlinear Lanadu damping leads to the acceleration of which eventually slow down after transferring some of its energy to the wave.
We point out that the nonlinear Landau damping phenomena has application in both laboratory and astrophysical plasmas.

[1] A. F. Alexandrov, L. S. Bogdankevich, and A. A. Rukhadze, 1984 '*Principles of Plasmas Electrodynamics'* Springer, Heidelberg.
[2] R. Z. Sagdeev and A. A. Galeev, 1969 '*Nonlinear Plasma Theory'* New York Press.
[3] Z. Ehsan, N.L. Tsintsadze, J. Vranjes and S. Poedts, 2009 Phys. Plasmas 16, 053702 and references therein.