Application of Picard iteration technique to self-consistent wave-particle interaction in plasmas

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The validity of quasilinear theory (QL) describing the weak warm beam-plasma instability has been a controversial topic for several decades (see the many references in the introduction of [1]). Simulations extending those in [1] brought an unexpected clue to understand why QL theory was found in [1] to remain valid in the strong chaotic diffusion regime: the variation of the phase of a given wave with time shows only small fluctuations with the random realizations of the initial wave phases [2].

This suggested revisiting the past analytical calculations of the wave phase and amplitude average evolutions which were performed by averaging over the initial particle positions. The new numerical result [2] suggests performing instead an average over the initial wave phases, which is compatible with a non uniform particle density. Furthermore, the previous calculations used a perturbative approach which made sense in the linear regime, but which might be unjustified for the chaotic regime of the instability. This is an incentive to use the Picard iteration technique which is one of the tools to prove existence and uniqueness of solutions to differential equations. Three successive iterations turn out to be analytically tractable when starting from the ballistic solution. Numerical calculations indicate that for the chaotic motion of particles in a prescribed set of waves such an iterated solution is already fairly good over the Lyapunov time-scale which plays the role of a decorrelation time. Surprisingly, this calculation shows that some of the results of the uniform particle density case remain correct even for a non uniform density. However, as for Langmuir wave amplitude evolution, there is a spontaneous emission by spatial inhomogeneities (turbulent eddies) on top of Landau growth or damping and of spontaneous emission by particles.

References

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