Adiabatic nonlinear waves with trapped particles: II. Wave dispersion

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A general nonlinear dispersion relation is derived in a nondifferential form for an adiabatic sinusoidal Langmuir wave in collisionless plasma, allowing for an arbitrary distribution of trapped electrons. The linear dielectric function is generalized, and the nonlinear kinetic frequency shift $\omega_{\rm NL}$ is found analytically as a function of the wave amplitude a. Smooth distributions yield $\omega_{\rm NL} \propto \sqrt{a}$, as usual. However, beam-like distributions of trapped electrons result in different power laws, or even a logarithmic nonlinearity, which are derived as asymptotic limits of the same dispersion relation. Such beams are formed whenever the phase velocity changes, because the trapped distribution is in autoresonance and thus evolves differently from the passing distribution. Hence, even adiabatic $\omega_{\rm NL}(a)$ is generally nonlocal.

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