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Description limit for soliton waves due to critical scaling of electrostatic potential

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We provide a formulation that describes the propagation of solitons in a nondissipative, nonmagnetic plasma, which does not depend on the particular electron density distribution considered. The Poisson equation in the plasma sheath is expressed in terms of the Mach number for ions entering the sheath from the plasma and of a natural scale for the electrostatic potential. We find a class of reference frames with respect to which certain functions become stationary after arbitrary small variations of the Mach number and potential scale, that is, by determining the critical values of those quantities based on a variational method. It is shown that the critical Mach number defines the limits for the applicability of the reductive perturbation technique to a given electron density distribution. Based on our provided potential scale, we show that the Taylor expansion of the suprathermal electron distribution around equilibrium converges for all possible values of the spectral κ-index. In addition, owing to the admissible range for the critical Mach number, it is found that the reductive perturbation technique ceases to be valid for $3/2 < \kappa \leq 5/2$. In the sequel, we show that the technique is not valid for the deformation q-index of nonextensive electrons when $q \leq 3/5$. Furthermore, by assuming that the suprathermal and nonextensive solitons are both described with respect to the same critical reference frame, a relation between κ and q, which has been previously obtained on very fundamental grounds, is recovered.

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