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On statistics of electric field amplitudes in Langmuir turbulence

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A systematic study of the properties of Langmuir wave turbulence generated by electron beams via bump-on-tail instabilities in strongly non-homogeneous plasmas is presented. A statistical analysis of the Langmuir waves' fields' amplitudes using numerical simulations based on two different theoretical models is performed : a probabilistic one and a dynamical one. The former describes the self-consistent dynamics of wave-particle and wave-wave interactions in inhomogeneous plasmas. The latter is a modified version of the standard quasi-linear theory which requires much less computational resources. To analyze the simulation data provided by the probabilistic model, a Pearson technique is used to classify the calculated probability distribution functions (PDFs) of the logarithm of the wave fields' intensities. It is demonstrated that the core parts of the PDFs belong to the Pearson types I, IV and VI distributions, depending on the spatial profiles of the density fluctuations, rather than to the normal distribution. Moreover it is shown that the high-amplitude parts of the PDFs follow power-law or exponential decay distributions, depending on the type of the corresponding cores' distributions. The PDFs of the fields' amplitudes calculated using the numerical simulations based on the dynamical model are in the whole consistent with those provided by the probabilistic model. Moreover, these simulations lead to a series of additional results. First, in the small fields' amplitudes' parts of
the PDFs (i.e. in the linear stage of the system's evolution), an universal scaling parameter is found, with a value not depending on the average levels of the density fluctuations and of the Langmuir turbulence. Second, the PDFs are obtained in the presence of wave
28 decay processes, which are not taken into account in the probabilistic model. When those are weak, the PDFs show at large fields' amplitudes an exponential asymptotic behavior; during the time evolution, the corresponding scaling parameter decreases until a universal probability distribution is reached, what is realized when the wave decay processes are sufficiently strong. This distribution is analogous to that obtained for a quasi-homogeneous plasma. Such exponential type of distribution is a specific signature of transition states in the Langmuir turbulence. Third, the square of the statistical field amplitude maximum is found to be proportional to the average energy of the Langmuir waves.