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Nonlinear dynamics of soliton gas with application to “freak waves”

Ekaterina Shurgalina

Institute of Applied Physics, Department of Nonlinear Geophysical Processes, Nizhniy Novgorod, Russian Federation (eshurgalina@mail.ru)

So-called “integrable soliton turbulence” attracts much attention of scientific community nowadays. We study features of soliton interactions in the following integrable systems: Korteweg – de Vries equation (KdV), modified Korteweg – de Vries equation (mKdV) and Gardner equations. The polarity of interacted solitons dramatically influences on the process of soliton interaction. Thus if solitons have the same polarity the maximum of the wave field decreases during the process of nonlinear interactions as well statistical moments (skewness and kurtosis). In this case there is no abnormally large wave formation and this scenario is possible for all considered equation. Completely different results can be obtained for a soliton gas consisted of solitons with different polarities: such interactions lead to an increase of resulting impulse and kurtosis. Tails of distribution functions can grow significantly. Abnormally large waves (freak waves) appear in such solitonic fields. Such situations are possible just in case of mKdV and Gardner equations which admit the existence of bipolar solitons.
New effect of changing a defect’s moving direction in soliton lattices and soliton gas is found in the present study. Manifestation of this effect is possible as the result of negative phase shift of small soliton in the moment of nonlinear interaction with large solitons. It is shown that the effect of negative velocity is the same for KdV and mKdV equations and it can be found from the kinematic assumption without applying the kinetic theory. Averaged dynamics of the “smallest” soliton (defect) in a soliton gas, consisting of solitons with random amplitudes is investigated. The averaged criterion of velocity sign change confirmed by numerical simulation is obtained.