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Strongly interacting soliton gas and the noise-induced modulation instability

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We investigate the statistically stationary state of spontaneous noise-driven modulation instability of a plane wave (condensate) background. As a model we use the integrable focusing one-dimensional nonlinear Schrodinger equation (NLSE). The fundamental statistical characteristics of the stationary state of the modulation instability obtained numerically by Agafontsev and Zakharov in 2015 [1] have not been explained so far. When the condensate is spatially wide the inverse scattering transform (IST) theory predicts that interacting solitons play the dominating role in the system evolution. Here we explain statistical characteristics of the modulation instability by using N-soliton solutions (N-SS, here N means the number of solitons) of the NLSE. We determine parameters of the N-SS corresponding to the statistically stationary state of the integrable turbulence produced by the instability development. These N-SS are strongly interacting bound states of solitons having specific distribution of the IST eigenvalues and random phases. The condensate is a coherent state of the N-SS and initial stage of the modulation instability development represents the loss of coherence of the soliton phases. We use a special approach to construct ensembles of the multi-soliton solutions with statistically large number of solitons N ~100 [2]. Our investigation demonstrates complete agreement in spectral and statistical properties of the long-term evolution of the condensate perturbed by noise and the constructed multisoliton bound states [3]. Our results can be generalised to the broad class of integrable turbulence problems in the cases when the wave filed dynamics is strongly nonlinear and driven by solitons.

[1] D. Agafontsev and V. E. Zakharov, Nonlinearity 28, 2791 (2015)

[2] A. A. Gelash and D. S. Agafontsev, Phys. Rev. E 98, 042210 (2018).

[3] A. Gelash, D. Agafontsev, V. Zakharov, G. El, S. Randoux and P. Suret, Bound state soliton gas dynamics underlying the noise-induced modulational instability, In preparation.

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