EGU21-552, updated on 20 Jun 2021
https://doi.org/10.5194/egusphere-egu21-552
EGU General Assembly 2021

Soliton turbulence in weakly nonlinear and weakly dispersive media

Ekaterina Didenkulova[1,2]
[1]National Research University Higher School of Economics, Nizhniy Novgorod, Russian Federation (edidenkulova@hse.ru)
[2]Institute of Applied Physics RAS, Department of Nonlinear Geophysical Processes, Nizhniy Novgorod, Russian Federation

A short review on weakly nonlinear and weakly dispersive dynamics of soliton ensembles, the so-called soliton turbulence is given. Such processes take place in shallow water waves, internal waves in the atmosphere and the ocean, solid mechanics and astrophysical plasma; they are described by the integrable models of Korteweg – de Vries equation type (modified Korteweg – de Vries equation, Gardner equation). Here, soliton turbulence means an ensemble of solitons with random parameters. The property of solitons to interact elastically with each other gives rise to an obvious association with the gas of elastically colliding particles. Strictly speaking, soliton turbulence (soliton gas) is a deterministic dynamical system due to the integrability of equations describing the evolution of waves (solitons). However, due to the great complexity of its behavior (due to the large number of participating solitons and nonlinear nature of their interactions), the dynamics of the system can be considered random and, accordingly, may be investigated using methods typical for such problems.

Firstly, pair soliton collisions have been analyzed as an elementary act of the soliton turbulence for further understanding of their impact on multi-soliton dynamics. Different types of solitons have been considered: “thick” or “top-table” solitons, algebraic solitons, solitons of different polarities. From the point of view of the turbulence theory, the interactions of waves (particles) should be described by the statistical moments of the wave field. It was shown that the interaction of solitons of the same polarity leads to a decrease in the third and fourth moments characterizing the skewness and kurtosis. However, the interaction of solitons of different polarity leads to an increase in these moments of the soliton field. Then, the study of collision patterns of breathers (localized oscillating packets) with each other and with solitons has been carried out. The determination of conditions leading to an extreme scenario, as well as statistical properties, probability and features of large wave manifestation has been provided. As a result of numerical modeling of the multi-soliton field dynamics, the appearance of anomalously large waves in bipolar soliton fields has been demonstrated. Though most of the soliton collisions occur between the pairs of solitons, which may result in maximum two-fold wave amplification, multiple collisions also happen (they make about 10% of the total number of collisions). The long-term simulation of the soliton gas dynamics has shown a significant decrease in skewness and significant increase in kurtosis, confirming the fact of abnormally large wave (so-called “freak/rogue wave”) occurrence.

The reported study was funded by RFBR according to the research projects 19-35-60022 and 21-55-15008.