One-dimensional Optical Turbulence

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One dimensional Non-Linear Schrödinger Equation (1D NLSE), which governs different non-linear systems (optical fibers, liquid crystals, Bose-Einstein condensation), was proven to be integrable by Zakharov and Shabat in 1971 [1]. They used the Direct Scattering Transform (DST) method, a computation of the non-linear spectrum, equivalent of Fourier Transform. 1D NLSE is however just a model for most systems, the real equations contain high-order corrections. These new terms often break its integrability, allowing these systems to have a turbulent behaviour. The system studied here is the propagation of a laser beam into a liquid-crystals medium, governed by an non-integrable equation corresponding to a modified 1D NLSE. This system is thus turbulent and present interactions between linear waves and solitons. The main idea of our work is that we can apply DST to characterize solitons and thus study this turbulent system.

To understand these interactions, we run Direct Numerical Simulations and process the data obtained by using different methods to characterize the solitons, including the DST. We compare the results given by DST to the $x-t$ plot of the simulation and to $k-\omega$ plots. Doing this, we have three ways to identify solitons and to obtain their speeds and amplitudes. It appeared that the information given by DST is consistent with $x-t$ and $k-\omega$ plots which makes it a useful tool to study a non-integrable system. With these tools, we observed different sets of sech-profile solitons evolving with modified 1D NLSE and obtained interesting results, (i) these solitons move with an oscillating amplitude, (ii) some new solitons can be created and some annihilated, (iii) we saw evidences of soliton turbulence [2], a series of non-elastic collisions that leads to a big single soliton.

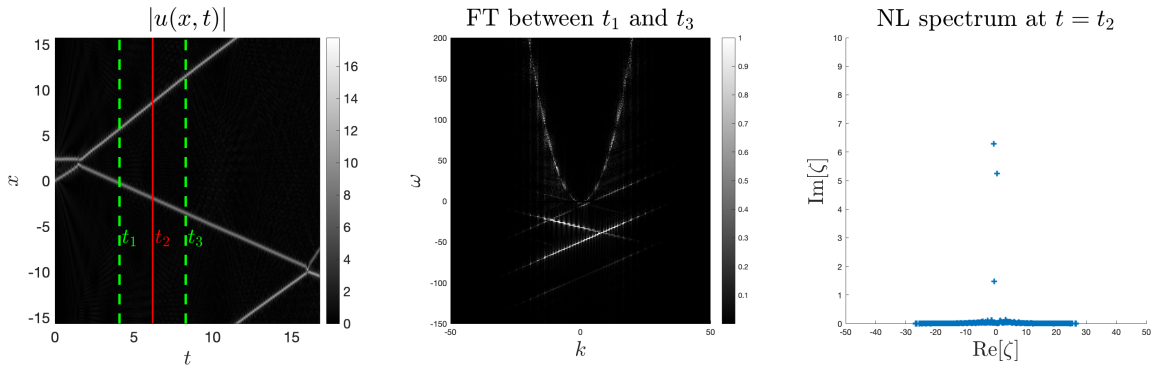

Figure 1. Study of a 2-solitons collision with appearance of a new soliton

Références

1. V. E. Zakharov, A. B. Shabat, *Journal of Experimental and Theoretical Physics*, **34**, 62-69, (1970).
2. J. Laurie, U. Bortolozzo, S. Nazarenko, S. Residori, *Physics Reports*, **514**, 121-175, (2012).