Collapses in Optical Turbulence

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We consider turbulence in the framework of Nonlinear Schrodinger Equation with focusing nonlinearity, dissipation, and forcing. Dissipation saturates catastrophic growth of collapses, causing their break down into almost linear waves. These waves form a random field which seeds new collapses. We analyse statistics of the amplitude fluctuations in the turbulent filed and connect it to the evolution and structure of individual collapses and the statistics of collapses in the field.

In the first part of our study, we focus on the regularization of isolated collapses due to dissipation and non-linear saturation. Using numerical simulations, we find that the time dependence of collapse height, $h(t)$, scales as a power law both during the growth and the decay of the collapse. During the growth, $h \sim t^{-(1/2+\alpha)}$, where α is small number which depends on a particular combination of stabilization parameters. During the decay, $h \sim t^{-1}$, for all collapses with the same stabilization parameters, $h(t)$ can be rescaled to the same function. We have obtained an empirical correction for the ODE model (Fibich and Levy, 1998) which describes $h(t)$ in the limit of small stabilization parameters.

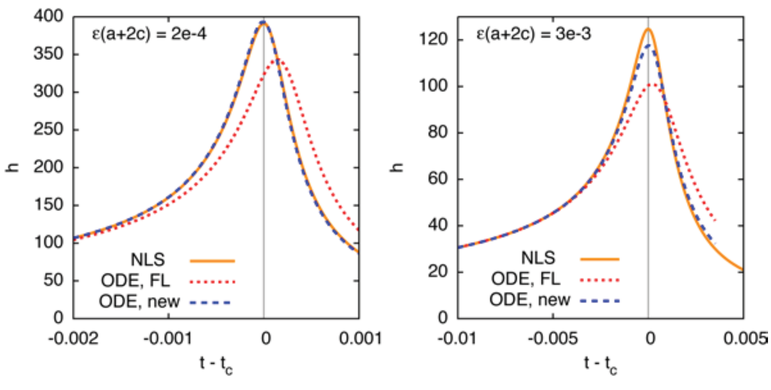

Fig.1. Comparison of original and proposed ODE models to direct solution of NLS equation for a single collapse.

In the second part of our study, we perform numerical simulations of turbulent systems with different stabilization parameters. A forcing maintains the total optical power (number of waves) at the level of hundreds of the critical power of a single collapse. We show that the evolution of a single collapse in turbulence follows the same rescaled $h(t)$ as in isolation. The dependence $h(t)$ combined with probability of collapse to reach a certain maximum, h_{max}, can be used to estimate amplitude fluctuations in the turbulent filed. In numeric simulations, we find that the statistics of collapse maxima has exponential tails at large h_{max}. We show that the estimate for probability of amplitude fluctuations based on $h(t)$ and statistics of h_{max} agrees with direct measurements.

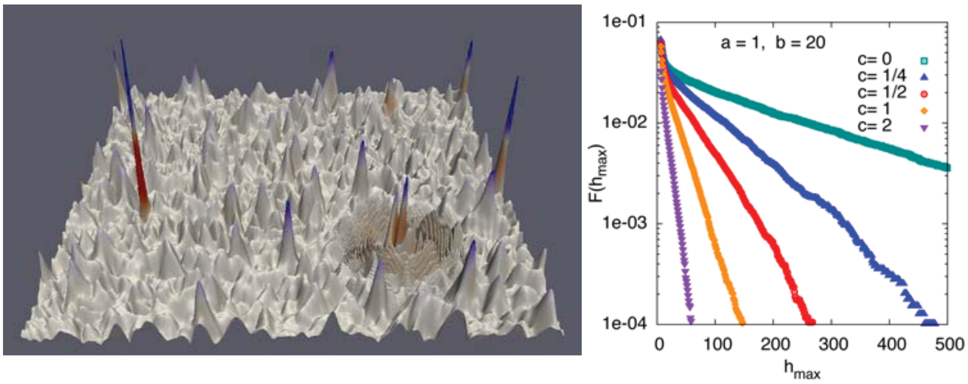

Fig. 2. Left: A snapshot of amplitude in a turbulent system. Right: frequency of collapses with $h > h_{max}$ per unit area in five simulations with different coefficient of non-linear saturation.

References

[1] G. Fibich and D. Levy, "Self-focusing in the complex Ginzburg-Landau limit of the critical nonlinear Schrödinger equation", Physics Letters **A** 249: 286-294 (1998).

[2] P.M. Lushnikov and N. Vladimirova, "Non-Gaussian Statistics of Multiple Filamentation", Optics Letters A 35, 1965 (2010).