Non-linear propagation of bright solitons in disorder

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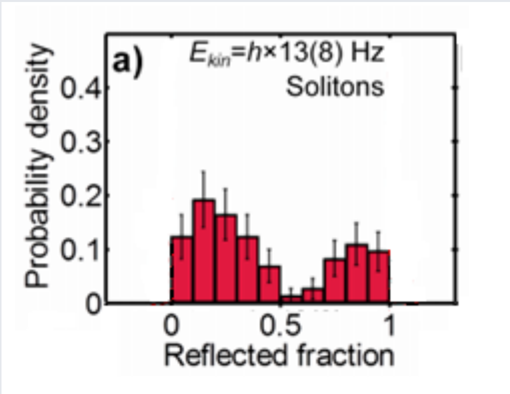
Whereas propagation of non-interacting particles or waves in disorder is relatively well understood with the well known phenomena associated to Anderson localization, the presence of interaction makes the situation more complex and also much richer. In particular, the competition between disorder and interaction leads to modifications of the transport properties. One may fro example ask wether Anderson localization survives in the presence of interaction or what amount of disorder is necessary to destry superfluidity in quantum systems.

In our project, we have attacked this broad open problem of transport in disordered and interacting systems with the study of propagation in disorder of bright soltions. These are produced in attractive one-dimensional Bose-Einstein condensates. We have thus produced the first bright soltions in potassium 39 using Feshbah tuning of the interaction. Second we have lauched these solitons in a disordered potential produced by a speckle light field. Such a disorder have the advantage to be controllable in strength with all statistical properties known.

The main experimental difficulty was to achieve a situation where the interaction energy between particules was sufficiently high as compared to the soliton kinetic energy in order to enter the regime where non-linear effect due to interaction are present. In this situation, we observe the tendancy of atoms to be reflected collectively, i.e. to be either mostly reflected or transmitted. 50-50 splitting of the solitons was on the contrary observed to be very unlikely unlike what is observed for independent particules. Our observations were nicely reproduced in a Gross-Pitaevskii simulations. This observation of non-linear behavior of bright soliton is unique and was only possible due to the help of PALM.

Interesting developments are now possible toward the observation of an interaction driven transport. For weak disorder, we expect the bright solitons to propagate without seeing the disorder while indepedent particles are localized by the Anderson mechanism. Furthermore, for low atom numbers, we may reach a regime where the whole soliton behave quantum mechanically, exhibiting macroscopic quantum superposition.



Histogram of reflected fractions when solitons are sent at a velocity of 0.5 mm/s is a disorder potential during 50 ms. The double peak structure of the histogram is a result of the attractive interaction between particles. The chances to have a 50-50 splitting of the solitons are greatly reduced, thus showing a strong non-linear behavior.

A. Boissé, G. Berthet, L. Fouché, G. Salomon, A. Aspect, S. Lepoutre, T. Bourdel, *Non-linear scattering of atomic bright solitons in disorder*, EPL, 117 10007 (2017).

S. Lepoutre, L. Fouché, A. Boissé, G. Berthet, G. Salomon, A. Aspect, and T. Bourdel, *Production of strongly bound 39K bright solitons*, PRA 94, 053626 (2016).

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