Diffusive correlations and quantum-classical correspondence in integrable dynamics - popular summary

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Every day, we observe and experience phenomena related to the flow of liquids and gases. The range of these phenomena is very broad: from ordinary, such as water flowing from a tap or wind moving leaves, to the more violent and extreme, like flood waves or tornadoes. The richness of behaviors exhibited by fluids and gases is described by one physical theory—hydrodynamics.

Although we know that matter is actually composed of a large number of molecules moving at high speeds and bouncing off each other, hydrodynamics simplifies this picture. The characteristic length scales needed to describe phenomena in fluids are much larger than the average distances between particles. The efficiency and success of hydrodynamics lie in leveraging this scale disparity. It allows for averaging the density and velocities of particles and treating the system as a *continuous medium*. This simplification bypasses the problem of tracking the movement of vast numbers of particles and enables a quantitative description of the dynamics of fluids on scales we observe daily. In particular, hydrodynamics allows to predict the so-called dynamical correlation functions, which are experimentally measurable and directly related to transport coefficients such as thermal conductivity or viscosity. Hydrodynamics is a theory with over three centuries of tradition, yet its fundamental ideas are so general that they also prove effective in describing systems drastically different from classical fluids. In particular, this theory is also adequate for describing light in nonlinear optical fibres.

Among many-body systems, we can distinguish a special class—these are the so-called *integrable systems*. They occur in one-dimensional geometries, such as nanowires, optical fibres or specially prepared traps that restrict the movement of gas to a straight line. A distinctive feature of these systems is the existence of additional conservation laws (beyond mass, energy, and momentum). These additional conservation laws significantly influence the dynamics of integrable systems, for example, by making it difficult for them to reach the standardly understood thermal equilibrium. This difference also affects the hydrodynamic theory of integrable systems, which is known as *generalized hydrodynamics*. The theory was proposed by two independent research groups in 2016 and experimentally verified later in experiments with one-dimensional quantum gases and with optical fibres. Despite its recent birth, generalized hydrodynamics has an established status as the standard theory describing the dynamics of integrable systems on large scales.

The central aim of the project is to extend the generalized hydrodynamics theory describing nonlinear optical fibers by determining dynamic correlation functions on the so-called diffusive scale. The primary tool will be the use of the classical-quantum correspondence, which allows one to derive a theory describing such systems from the theory of one-dimensional quantum gases known as the Lieb-Liniger model. The outcome of the project will be a set of new theoretical tools with direct applications to experiments currently being conducted in optical laboratories.