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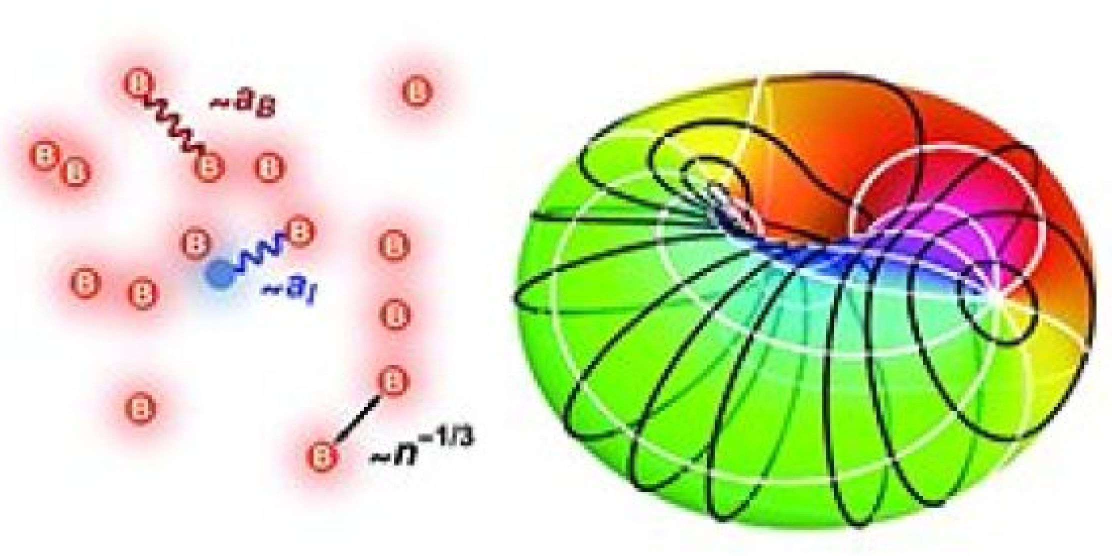


PhD Thesis Defense NILS-ERIC GUENTHER 'Dynamics of Quantum Mixtures'

NILS-ERIC GUENTHER

September 08, 2021
10:00
Online (Teams)

PhD Thesis Defense, September 8, 2021, 10:00. Online (Teams)

NILS-ERIC GUENTHER
Quantum Optics Theory
ICFO-The Institute of Photonic Sciences

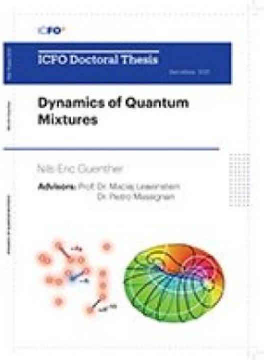
At sufficiently low temperatures, fluids of bosonic particles may undergo a phase transition, below which a Bose-Einstein condensate (BEC) forms. The BEC is one of the most fundamental concepts in many-body quantum physics and provides a paradigmatic example of a collective matter wave. The distinctive mixture of fluid-like and particle-like behavior this state exhibits leads to the emergence of unique features such as vortex quantization, but also to an often exotic interaction with other matter as well as its environment. The goal of my thesis is a further theoretical investigation of the latter, along two specific lines of research. Correspondingly, this manuscript is divided into two main parts.

In the first part, I studied the fundamental polaron problem in the case of a bosonic bath: A BEC interacting with a single distinguishable impurity, a quantum particle on the same scale as the constituent particles of the condensate, which can often be described as a 'dressed' quasiparticle, called the polaron. The focus of this thesis is textit{dilute} BECs of ultra-cold atomic vapors, where historically the BEC state was first observed experimentally and the underlying atomic interactions can be controlled to hitherto unprecedented degree via Feshbach resonances. Of particular interest is the case of strong interactions between the impurity and the bosons, the unitary-limited regime. Such impurity systems have been first probed experimentally in recent years, however due to the theoretical complexity and physical richness of the condensate state as well as experimental limitations, the nature of the compound system is not completely understood at strong interactions. I present two theoretical models in this part of the thesis which predict qualitatively new phenomena. In the first, I extended a scheme used in previous work unrelated to me, including the effect of finite temperature below the transition point to take into account the two-fluid nature of the bosons. This scheme predicts a textit{splitting} of a single quasi-particle branch at zero temperature into two branches upon heating, and a general strong temperature dependence of the quasi-particle properties. In the second work, I developed a new variational ansatz tailored for describing large dressing of the impurity. This ansatz predicts that for sufficiently weak intra-bosonic repulsion the impurity can bind a textit{macroscopic} but coherent and dilute cloud of bosons of sizes comparable to the healing length of the condensate.

In the second part of my thesis, I present work focusing on the interplay of a condensate and the geometry of its containment. Well known features of condensates are superfluidity and the quantization of vorticity. Considering a superfluid embedded on a two-dimensional surface, I studied the dynamics of point vortices on curved surfaces in the framework of potential flow theory, with a focus on non-simply connected geometry. In a work presented in this thesis revolving around cylinder- and related geometries I derived the generating potential of a single point vortex, which predicts that the dynamics are modified by the quantization of flow around the circumference of the cylinder. In particular, a single vortex is always forced to move along the longitudinal axis of the cylinder, providing a powerful marker for superfluidity. In a following work regarding a torus-shaped embedding as well as related more general surfaces, I derived the generating potential for a single and multiple vortex-anti vortex pairs and predicted a significant change of local dynamics due to the macroscopic quantization of flow and to the non-trivial curvature of the embedding surface.

PhD Thesis Defense, September 8, 2021, 10:00. Online (Teams)

Thesis Directors: Prof Dr. Maciej Lewenstein / Dr Pietro Massignan



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