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Summary

The thesis describes the influence of dipolar interactions on the properties of many-body systems from a theoretical point of view. Its main goal is to analyze the consequences of the interplay between the local and non-local parts of interactions between atoms. The thesis puts special attention on stronger interactions beyond the applicability of the usual mean-field approaches. The presented study focuses mainly on one-dimensional models.

In Chapter 1, we briefly review the history of studies on ultracold gases with emphasis on dipolar atoms examples. We embed the subjects of the thesis in the context of ongoing research in the field.

Chapter 2 introduces the theoretical framework needed in the later parts of the thesis. That includes discussion of some general properties of the many-body systems and two-body interactions in the ultracold limit. It recalls the well-know mean-field description of ultracold gases.

Chapter 3 presents properties of two dipolar atoms moving in a harmonic trap without an external magnetic potential. It is possible to adiabatically pump the system from the s-wave to the d-wave relative motion.

Chapter 4 compares the mean-field dark solitons and the lowest energy states for fixed total momentum of the corresponding many-body system of weakly interacting bosons. The bosonic symmetrization is responsible for emergence of solitonic features even in the limit of vanishing interactions.

Chapter 5 studies bosons interacting via attractive short-range and repulsive dipolar forces. It shows that the lowest excitations of the system may be smoothly transformed from the typical states of collective character to the celebrated roton state by simultaneous tuning short-range interactions and adjusting a trap geometry.

Chapter 6 describes a transition between droplet-like and bright soliton-like states at the border of net attractive and repulsive interactions for a small number of atoms and strong interactions. Based on that, it introduces a new version of the Gross-Pitaevski equation.

Chapter 7 presents a microscopic model of two-body wave function diagnosis based on atom-light interactions. In particular, it discusses the influence of pulse properties on the absorption of photons by two identical atoms moving in a trap.

The last Chapter 8 summarizes the thesis and outlines some possibilities of extending the presented results.

Rafał Ołdziejewski