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Abstract

Hydrodynamics and transport in low-dimensional interacting systems

By

Manas Kulkarni

Recent ground-breaking experiments realized a strongly interacting quantum degenerate Fermi gas in a cold atomic system with tunable interactions. This has provided a table-top system which is extremely hydrodynamic in nature. This experimental realization helps us to investigate several aspects such as the interplay between nonlinearity, dissipation and dispersion. We find, for instance, that the dynamics in such a system shows near perfect agreement with a hydrodynamic theory. In collaboration with the group of John Thomas at Duke we studied collision of two strongly interacting Fermi gases and observed shock waves which is a hallmark of nonlinear physics. Due to reasons such as the nature of interactions, higher dimensionality, these cold atomic systems are non-integrable and moreover the underlying field theory construction is mostly phenomenological in nature.

On the other hand there are certain one-dimensional systems which are not only integrable but also facilitate more formal and rigorous ways of deriving the corresponding integrable field theories. One such family of models is the family of Calogero models (and their generalizations). They provide an incredible insight into the field of strongly correlated systems and hydrodynamics. We study the collective field theory of such models and address aspects of nonlinear physics such as Spin-Charge Interaction, Emptiness Formation Probability, Solitons etc; We derive a two-component nonlinear, nonlocal, integrable field theory which is the only known example of its kind. We also show that this family which is integrable even in an external harmonic trap (usually unavoidable in cold atom setups) is relatively “short ranged” thereby qualifying as a toy model for cold atom experiments.

Transport in certain strongly correlated systems (impurity models) was studied using few low-dimensional techniques such as a 1/N diagrammatic expansion, Slave Boson Mean Field Theory and the Bethe Ansatz. A mesoscopic setup such as parallel quantum dots forms an ideal platform for such an investigation and comparison between different low-dimensional techniques. We studied transport, correlations and nature of the ground state of double quantum dots. We probed several non-perturbative aspects of this double-impurity model. For example, we showed that the RKKY interaction in closely spaced dots can be non-ferromagnetic in nature due to its non-pertubative nature. This study helped us to point some discrepancies between different methods (such as the Numerical Renormalization Group). We give possible reasons for these discrepancies.

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Robert. M. Konik