

Summer school schedule

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7/12/2012 Lecture 1: Overview of tools in cold atom experiments

Here I will review two experimental tools in cold atom research that enable the transition of weakly-interacting atomic gases into strong coupling and strong correlation regimes: Feshbach resonances and optical lattices.

Particular emphases will be given on the development of analytic models that easily link to experimental observables, as well as innovative uses of the tools in recent experiments.

7/12/2012 Lecture 2: In situ imaging: density, fluctuations, correlations and equation of state

A wealth of new observables is revealed from in situ images of atomic gases. A brief overview of imaging approaches and issues regarding imaging distortion and nonlinear optical response will be discussed. Furthermore, we will comment on a proper calibration of the atomic density, as well as fluctuations and correlations.

The measured density and fluctuations provide the key to determine essential properties of the system. Among others, equation of state and static structure factor will be discussed in detail as the foundation to explore new quantum phases and to study quantum non-equilibrium dynamics and transport.

7/13/2012 Lecture 3: Scale invariance, universality and quantum criticality of 2D quantum gases

The collective behaviour of a many-body system near a continuous phase transition is insensitive to the details of its microscopic physics; for example, thermodynamic observables follow generalized scaling laws near the phase transition. Here we show that *in situ* density and density-fluctuation measurements of two-dimensional Bose gases of cesium confirm the scale-invariant, universal behaviors of the sample. When the atoms are loaded into an optical lattice, we further observe quantum critical behavior with two-dimensional Bose gases at sufficiently low temperatures, as well as locate the quantum critical point, and constrain the critical exponents.

7/17/2012 Talk: Exploring Universal Quantum Physics in few- and many-body atomic systems

Recent cold atom researches are reaching out far beyond the realm that was conventionally viewed as atomic physics. Many long standing issues in other physics disciplines or in Gedanken-experiments are nowadays common targets of cold atom physicists. Two prominent examples will motivate this talk: BEC-BCS crossover and Efimov physics. Here, cold atoms are

employed to emulate electrons in superconductors, and nucleons in nuclear reactions, respectively.

The ability to emulate exotic or thought systems using cold atoms stems from the precisely determined, simple, and tunable interaction properties of cold atoms. New experimental tools have also been devised toward an ultimate goal: a complete control and a complete characterization of a few- or many-body quantum system. We are tantalizingly close to this major milestone, and will soon open new venues to explore new quantum phenomena that may (or may not!) exist in scientists' dreams.