Exploring the Feasibility of Realizing Kondo Physics in Cold Atom Systems

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Motivated by the impressive recent advance in manipulating cold fermionic atoms it is interesting to explore the Kondo physics where magnetic impurities are immersed in cold fermionic atom systems. Experimental realization requires the preparation of a Fermi sea of cold atoms that are confined by a shallow harmonic potential, and the trapping of a few other atoms with non-zero spin (that serve as magnetic impurities) in specially designed optical potential (see figure). The new feature here is that fermionic atoms can have spin $F > \frac{1}{2}$. Two interesting physical scenarios can be explored (and hopefully be realized in experiment).

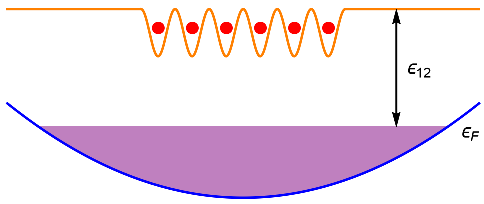

Figure 1: Illustration of a Kondo physics in cold atom system. Itinerant fermions (*e.g* ^{40}K with spin $F = \frac{7}{2}$) are trapped in a shallow Harmonic potential and form a degenerate Fermi sea (violet region). A few different atoms (with non-zero spin) (red circles) are trapped in specially designed optical potential (wavy line) and form a dilute concentration of localized magnetic impurities. When there is an antiferromagnetic exchange interaction between the itinerant atoms in the Fermi sea and a localized magnetic impurity, it gives rise to an overs-creened Kondo effect. If the Fermi sea is composed of Yb(^{1}S$_0$) atoms and the impurities are Yb(^{3}P$_0$) atoms, the underlying physics is described by the Coqblin-Schrieffer model.

The first scenario is based on the fact that when the spin of the itinerant fermions is large, then, in the standard SU(2) Kondo effect, the magnetic impurity is over-screened. At low temperature, such system displays a non-Fermi liquid behaviour.

The second scenario concerns the a realization of the Coqblin-Schrieffer model (implying an SU(N) Kondo physics), in a gas of cold fermionic ^{173}Yb atoms. This system is experimentally attractive because both the itinerant and the localized atoms are identical except for their electronic configurations. Making use of different AC polarizabillity of the electronic ground state (electronic configuration $^1S_0$) and the long lived metastable state (electronic configuration $^3P_0$), it is substantiated that the latter can be localized and serve as a magnetic impurity while the former remains itinerant. The exchange mechanism between the itinerant $^1S_0$ and the localized $^3P_0$ atoms is analyzed and shown to be antiferromagnetic. The ensuing SU(6) symmetric Coqblin-Schrieffer Hamiltonian is constructed. A number of thermodynamic measurable observables are calculated in the weak coupling regime $T > T_K$ (using perturbative RG analysis) and in the strong coupling regime $T < T_K$ (employing known Bethe ansatz techniques).