QSS41 - Yoshiro Takahashi - Questions & Answers

Yoshiro Takahashi

Does the SU(N) physics you can explore in the laboratory also appear in solid-state physics or other systems? Or is it unique to cold atoms?

YOSHIRO: Solid-state systems like transition metal metal oxides and graphene's SU(4) spin-valley symmetry are discussed in the context of SU(N) symmetry. However, the introduction of the symmetry is just a rough approximation. In contrast, an intrinsic SU(N) nuclear spin symmetry is realized in fermionic isotopes of alkaline-earth-metal-like atoms owing to the nuclear-spin independence of the inter-atomic potential.

For N->infinity, we expect that SU(N) fermions behave more and more as bosons (or distinguishable particles?). On the one hand this is intuitive because the spin degree of freedom becomes more and more continuous. On the other hand, one finds more and more complex phases as you have shown for example for N=5. Could you say more about what you expect to happen in terms of magnetic order as you go to larger N?

YOSHIRO: For example, in the paper of Hermele et al., Phys. Rev. B 84 (2011), the phase diagram of SU(N) Heisenberg model in 2D square lattice for various filling and N including the large-N limit is discussed. Exotic phases like chiral spin liquid state and valence bond solid are predicted.

Are there limitations in the pomeranchuk cooling if N (in SU(N)) gets even larger?

YOSHIRO: I believe there is no fundamental limitation. In actual experiments, however, atom number per spin/flavor becomes small for too large N, given the total atom numbers fixed, which may introduce some difficulty in discussing the system in terms of statistical physics.

Pomeranchuk cooling allows you to reach lower temperatures in the system by increasing the number of components. But what happens for the critical temperature of the relevant phases? Do they stay unchanged, or are they also reduced?

YOSHIRO: In general, quantum fluctuation becomes important for large N in an SU(N) system, so magnetic ordered phases are not favored, which means the critical temperature would be also reduced. However, some other interesting phases are also expected, and the critical temperatures are not necessarily reduced.

Except for even higher singlet triplet imbalance and STO amplitude, what would you expect for experiments performed with SU(N) systems with N >6?

YOSHIRO: As for the STO signal, more complex form of STO signal with multiple frequencies associated with many more spin-pairs is expected, which makes analysis harder.

In your comparison of the singlet-triplet imbalance in 1D vs. 3D systems, the theory calculations seem to show that where the calculations can be done, we expect very similar results for 1D and 3D,but the experiment suggests that the 3D calculations are a factor of two smaller - do you know where this discrepancy might come from?

YOSHIRO: The existence of a heating process or nonadiabaticity during the lattice loading, which may differ between 1D and 3D, may explain the discrepancy.

Dissipative Hubbard model: Do you find that you can leave the dissipation on, and settle into a minimum atom number, i.e., is there a steady state atom number with losses switched on? How does this depend on the initial particle number?

YOSHIRO: In our experiment, the atom loss is almost saturated at the longest time of 1.5 ms of dissipation, and so the atom number almost reached the steady-state value. The remained atoms are mostly in the triplet state, and so the steady-state atom number depends on the initial spin correlation, rather than the initial atom number. Namely, the smaller the AFM correlations are in the initial states, the larger the remaining atom numbers are in the steady states.

What perspectives do you see to reach even lower temperatures in SU(N)Fermi gases, and what do you expect to see if you can? What is known about the potential for pairing or superconductivity in an SU(N) system? Is this expected to be similar to the spin-1/2 case?

YOSHIRO: We expect novel long-range spin correlations characterized by peaks at $k=2n\pi/N$ ($n=1, 2,..N-1$) in the spin structure factor in 1D case. Pairing in a 2D SU(N) system with doping and/or spin-imbalance, possibly quite different from spin-1/2 case, is very interesting but the theoretical effort along this line has just started quite recently.

What do you see as the future of SU(N) physics and 2-electron atoms over the course of the next 10 years? What can we expect to see in terms of new physics, new connections to solid state physics, or new applications of 2-electron atoms?

YOSHIRO: Two-electron atoms with nuclear spin degrees of freedom would be useful for building quantum computers with Rydberg atom tweezer array or SU(N) spin liquid. Another interesting possibility is to combine the abilities of quantum simulation with quantum gases and the precision measurement with ultranarrow optical transitions in the search of new physics beyond standard model.