Magnetic phase transitions in 1D spinor Fermi gases

X.-W. Guan[1], M. T. Batchelor[1], and C. Lee[2]

[1] *Department of Theoretical Physics, Research School of Physical Sciences and Engineering, Australian National University, Canberra ACT 0200, Australia*

[2] *ACQAO and Nonlinear Physics Centre, Research School of Physical Sciences and Engineering, Australian National University, Canberra ACT 0200, Australia*

Atomic Fermi gases with internal spin degrees of freedom are tunable interacting many-body quantum systems featuring novel and subtle magnetic phase transitions. Recent experimental efforts on two-component Fermi atomic gases have explored the quantum phase transition between BCS superfluid and normal Fermi liquid. These experiments have revived interest in one-dimensional (1D) integrable model of multi-component fermions.

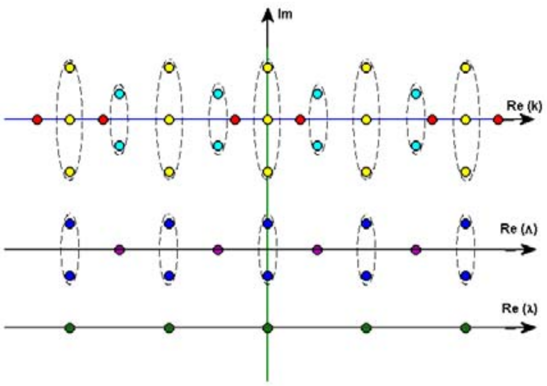

Fig. 1: Schematic configuration of Bethe ansatz quasi-momenta k, spin momenta Λ, and λ in the complex plane. For strongly attractive interaction, the unpaired and paired quasimomenta can penetrate into the central region occupied by trions.

More spin degrees of freedom involve more complex symmetries and will reveal more exotic features, such as color superfluid and baryonic phase. Three-component Fermi gases may exhibit $SU(3)$ symmetry and support novel color superfluid of three different types of BCS pairs. In particular, strongly attractive atom-atom interaction in a three-component system can cause the appearance of spin neutral three-body bound states called *trions*. Therefore, magnetic phase transitions are expected to occur between color superfluids and trionic phases. The $N-$component systems could display a group chain $SU(N) \supset SU(N-1) \supset \cdots SU(2) \supset U(1)$ symmetries associated, correspondingly, with exotic quantum phases of the N-body bound states, $(N-1)$-body bound states, $\cdots$, BCS pairs, and normal Fermi liquid.

In recent years, we developed an exact analytical method for 1D many-body quantum systems based upon the Behte ansatz (BA). With this method, we have not only studied Bose gases in a 1D hard-wall box [1], but have also investigated both, two- [2] and multi-component [3, 4] 1D spinor Fermi gases. Most recently, by solving the BA equations and the equations for corresponding dressed energies, we explored the precise nature of all bound states, and calculated critical fields and the full phase diagram. These results provide useful benchmarks for experiments with ultracold spinor fermions. A three-component system, arising from Zeeman splitting [3], shows exotic phases of trions, BCS pairs, a normal Fermi liquid, and four mixtures of these states. In particularl, a smooth phase transition from a trionic to pairing phase occurs as the highest hyperfine level separates from the two lower energy levels. In contrast, a smooth transition from the trionic phase into the normal Fermi liquid occurs as the lowest level separates from the two higher levels.

References

[1] M. T. Batchelor, X. W. Guan, N. Oelkers, and C. Lee, J. Phys. A **38**, 7787 (2005).

[2] X. W. Guan, M. T. Batchelor, C. Lee, and M. Bortz, Phys. Rev. B **76**, 085120 (2007).

[3] X. W. Guan, M. T. Batchelor, C. Lee, and H.-Q. Zhou, Phys. Rev. Lett. **100**, 200401 (2008).

[4] X. W. Guan, M. T. Batchelor, C. Lee, and J. Y. Lee, in preparation (2008).