Condensed Matter Theory Center Seminar

Tuesday, March 28
11:00 am – 12:15 pm
2205 John S. Toll Physics Building

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"Novel orbital phases in optical lattices and solids – unconventional BECs and large gap topological states"

Abstract: Orbital is a degree of freedom independent of charge and spin, which plays an important role in the study of transition-metal-oxides. Recently, cold atom optical lattices have opened up a new opportunity to investigate orbital physics. In this talk, we will present its novel features in optical lattices, and also apply them for novel states in solids as well.

Orbital physics in solids typically studies electrons, which are fermions. In contrast, bosons in optical lattices, when pumped into high orbital bands, become orbital-active. We predicted a class of novel superfluid states of orbital bosons which spontaneously break time-reversal symmetry. These states are beyond the scope of "no-node" theorem which constrains many BECs including Helium and atomic systems.

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They exhibit unconventional symmetries (e.g. p-wave) in analogy to unconventional superconductivity. They have been experimentally realized by Hemerich's group at Hamburg, and their p-wave symmetry was observed through matter-wave interference and time-of-flight measurements. For fermions, we have studied the orbital active px/py-orbital bands in the 2D honeycomb lattice. Their physics is very different from graphene, and can be applied to both optical lattices and various solid state systems including organic-metal-frameworks, semiconductor quantum dots, and 2D materials like Stanene. The interplay between orbital structure and spin-orbit coupling gives rise to quantum spin Hall state and quantum anomalous Hall state with large topological gaps. The gap magnitudes are equal to the spin-orbit coupling strength at the atomic level, and thus are much larger than those based on the *s-p* band inversion. In the Mott-insulating state, orbital exchange is highly frustrated described by a quantum 120° model which is similar to but different from the Kitaev model. An f-wave Cooper pairing arises if the band is filled with spinless fermions exhibiting boundary Majorana edge modes. Although the pairing mechanism is conventional, the unconventional pairing symmetry is driven by the non-trivial band structure.

Ref.
1) C. Wu, "Unconventional Bose-Einstein Condensations Beyond the ``No-node'' Theorem", Mod. Phys. Lett. 23, 1 (2009), a brief review.

2) Gu-feng Zhang, Yi Li, C. Wu, The honeycomb lattice with multi-orbital structure: topological and quantum anomalous Hall insulators with large gaps ,Phys. Rev. B 90, 075114 (2014) .

3) Wei-cheng Lee, C. Wu, and S. Das Sarma, "F-wave pairing of cold atoms in optical lattices", Phys. Rev. A 82, 053611 (2010).

4) C. Wu, "Orbital analogue of quantum anomalous Hall effect in p-band systems", Phys. Rev. Lett. 101, 186807 (2008).

5) C. Wu, "Orbital orderings and frustrations of p-band systems in optical lattices", Phys. Rev. Lett. 100, 200406 (2008).

6) C. Wu, Doron Bergman, Leon Balents, and S. Das Sarma, "Flat bands and Wigner crystallization in the honeycomb optical lattice", Phys. Rev. Lett. 99, 70401 (2008).

Host: Xiao Li

Web: http://www.physics.umd.edu/cmtc/seminars.html