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Novel orbital physics with fermions in optical lattices[1]

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Orbitals, a degree of freedom characterized by orbital degeneracy and spatial anisotropy and independent of change and spin, play important roles in magnetism and superconductivity in transition metal oxides. In this talk, we will show that the rapid progress of cold atom physics has opened up an opportunity to study novel features of orbital physics, which do not appear usual solid state systems. In particular, the $\mathrm{p}_{x;y}$-orbital system of the honeycomb lattice exhibits amazingly rich and fundamentally different behavior from that in the p_z-orbital system of graphene. Its flat band structure dramatically amplifies interaction effects, providing a natural way to study non-perturbative strong correlation phenomena such as Wigner crystallization, and ferromagnetism which is an important field in condensed matter physics but has not attracted much attention in the cold atom community. Furthermore, in the Mott-insulating states, the orbital degree of freedom enables superexchange interactions as spin does. We will show how spatial anisotropy generates frustration in such systems, which leads to a promising way to the exciting orbital liquid states. At last, we will present that a topological insulating phase occurs in the presence of the lattice rotation, as an orbital analogy of the quantum anomalous Hall effect of electron systems.

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