Topological Transitions and Topological Insulators

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Symmetry breaking transitions and topological transitions provide us with completely different concepts of quantum phase transitions. However, recent renewed understanding allows us more comprehensive perspective for quantum criticality. Topological transitions under electron correlation effects are now understood from a framework distinct from Gnzburg-Landau-Wilson (GLW) scheme. Examples that follow non-GLW framework are Mott transitions and Lifshitz transitions under electron correlation.

Recently discovered topological insulators have been regarded that electron correlation effects do not play major roles because of the topological protection. However, we discuss that some class of theoretical models realize an interaction-driven insulating phase with nontrivial Z2 invariants. In several examples of lattices such as the pyrochlore lattice, we show that the topological insulator phase is stabilized even in the absence of the spin orbit interaction when electron correlation satisfies some conditions. In this case, the topological insulator emerges as a consequence of the spontaneous symmetry breaking. Nevertheless quantum phase transitions between the topological insulators and (semi)metals follow not the conventional GLW scheme but the non-GLW scheme for the topological transition characterized by the marginal quantum criticality.

We discuss detailed structure of its quantum criticality.

We next discuss roles of electron correlations on topological insulators and emergence of a novel phase within the topological insulator. Accurate variational Monte Carlo calculations with a large number of variational parameters show that increasing electron correlations on the honeycomb lattice (Kane-Mele-Hubbard model) cause a strong suppression of the charge Drude weight in the helical-edge metallic states leading to a presumable Mott transition (or strong crossover) from a conventional topological insulator to an edge Mott insulator before a transition to a bulk antiferromagnetic insulator. The intermediate bulk-topological and edge-Mott-insulator phase has a helical spin-liquid character with time-reversal symmetry.