第61回トポロジカル物質科学セミナー
Topological Materials Science Seminar (61)

Theories of topological spin-nematic excitonic insulators in graphite under high magnetic field and quantum multicriticality in disordered Weyl semimetal

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Place: **Room 1320, Faculty of Science Bldg. #4, Hongo Campus, Univ. of Tokyo (東大本郷キャンパス理学部4号館1320号室)**

Date: **July 19 (Thursday), 2018**

Time: **13:00-14:30**

Abstract:

In the first part of my talk, I will discuss our phenomenological theory for metal-insulator transitions in graphite under high magnetic field [1,2]. Graphite under high magnetic field exhibits consecutive metal-insulator (MI) transitions as well as re-entrant insulator-metal (IM) transition at low temperature. We explain these enigmatic insulator phases as manifestation of topological excitonic insulator phases with spin nematic orderings. We first argue that graphite under high magnetic field (> 20 Tesla) is in the charge neutrality region. Based on this observation, we employ models with electron and hole pocket(s), to construct a bosonized Hamiltonian that comprises of displacement field along the field direction and its conjugate fields. Using a renormalization group argument, we show that there exists a critical interaction strength above which a umklapp term becomes relevant and the system enters excitonic insulator phase with a long-range ordering of spin superfluid phase field, i.e. "spin nematic excitonic insulator (SNEI)". We argue that, when a pair of electron and hole pockets get smaller in size, a quantum fluctuation of the spin superfluid phase becomes larger and destabilizes the excitonic insulator phases, which results in the re-entrant IM transition. We explain field- and temperature-dependences of in-plane resistivity in graphite experiment by surface transports via novel surface states in topological SNEI phases [1,2].

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In the second part of my talk, I will discuss our recent theory on multicriticality in disordered Weyl semimetal [3,4]. In electronic band structure of solid state material, two band touching points with linear dispersion (called as `Weyl node') appear in pair in the momentum space (`Nielsen-Ninomiya' theorem). When they annihilate with each other, the system undergoes a quantum phase transition from three-dimensional Weyl semimetal (WSM) phase to a band insulator (BI) phase. The phase transition is described by a new critical theory with a `magnetic dipole' like object in the momentum space. We reveal that the critical theory hosts a novel disorder-driven quantum multicritical point, which is encompassed by three quantum phases, WSM phase, BI phase, and diffusive metal (DM) phase. Based on the renormalization group argument, we first clarify scaling properties around the band touching points at the quantum multicritical point as well as all phase boundaries among these three phases [4]. We argue that a localization-delocalization transition between the BI phase and a WSM phase is controlled by a clean-limit fixed point with spatially anisotropic scale invariance. We show that the anisotropic scale invariance is reflected on unconventional scaling function forms in the quantum phase transition between BI and WSM phases. We verify the proposed scaling function forms in terms of transfer-matrix calculations of conductance and localization length in the tight-binding model [3].

[1] Z. Pan, X.-T. Zhang, and R. Shindou, arXiv:1802.10253.
[2] in preparation
[3] X. Luo, T. Ohtsuki, and R. Shindou, arXiv:1803.09051.
[4] X. Luo, B. Xu, T. Ohtsuki, and R. Shindou, Phys. Rev. B 97, 045129 (2018).

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