Unconventional Quantum Criticality

Masatoshi Imada

Department of Applied Physics, University of Tokyo, and JST-CREST, Hongo, Bunkyo-ku, Tokyo, 113-8656, Japan

Most of the quantum phase transitions are categorized either to the type of spontaneous symmetry breaking or to that of topological transitions. In case of the topological transitions, an unconventional quantum criticality, marginal quantum criticality apears in the proximity to first-order transitions as in Lifshitz transitions for $ZrZn_2$[1] and Mott transitions as observed in an organic conductor, κ-$(ET)_2Cu[N(CN)_2]Cl$[2]. The criticality necessarily takes on a symmetry-breaking character in the side of the first-order transition. The topological character shows up in the other side of the marginal quantum critical point extending along the quantum critical line. The interplay of the poles and zeros of the single-particle Green function substantiates the topological nature[3-5]. In case of the symmetry breaking, conventional quantum criticalities formulated for magnetic transitions[6] have been challenged by many experiments[7]. Some of them are accounted for again by the proximity to the first-order transitions, but here as quantum tricriticalities as in heavy-fermion compounds, $YbRh_2Si_2$, $CeRu_2Si_2$ and $YbAlB_4$[8]. In some cases, the origin of this proximity may be ascribed to the magnetic anisotropy or the valence instability. We overview these unconventional quantum criticalities also as important origins of novel non-Fermi-liquid properties.

[1] Y. Yamaji, T. Misawa and M. Imada: J. Phys. Soc. Jpn. **76** (2007) 063702.

[2] T. Misawa and M. Imada: Phys. Rev. B **75** (2007) 115121.

[3] I. Dzyaloshinskii: Phys. Rev. B **68** (2003) 085113.

[4] R. M. Konik, T. M. Rice, and A. M. Tsvelik, Phys. Rev. Lett. **96** (2006) 086407;
K.-Y. Yang, T. M. Rice, and F.-C. Zhang, Phys. Rev. B **73** (2006) 174501.

[5] S. Sakai, Y. Motome and M. Imada: Phys. Rev. Lett. **102** (2009) 056404.

[6] T. Moriya T *Spin Fluctuations in Itinerant Electron Magnetism* (Berlin: Springer-Verlag,1985).

[7] see for a review, H. v.Löhneysen, A. Rosch, M. Vojta and P. Wölfle: Rev. Mod. Phys. **79** (2007) 1015.

[8] T. Misawa, Y. Yamaji and M. Imada: J. Phys. Soc. Jpn. **78** (2009) 084707.