Field-angle-resolved Specific-heat Measurements of $YbRh_2Si_2$

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Quantum phase transition in the heavy fermion (HF) system has attracted much attention because of an emergence of exotic physics such as superconductivity near a quantum critical point (QCP). Typical antiferromagnetic (AFM) QCPs in the HF systems have been attributed to the competition between Kondo screening and magnetic interactions, which yields non-Fermi liquid (NFL) behavior in the QC region [1, 2].

A HF metal $YbRh_2Si_2$ has been intensively studied because it shows easily accessible field-induced AFM QCP, $H_{c,\perp c} \sim 0.06\,\mathrm{T}$ and $H_{c,\|c} \sim 0.7\,\mathrm{T}$ [3], and various exotic characteristics represented by coexistence of large ferromagnetic fluctuations in the AFM ordering side [4], which cannot be explained by the *conventional* picture of the QCP. A variety of scenarios for this exotic QCP has been proposed theoretically and experimentally, e.g., Kondo break-down scenario [5], quantum tricritical point [6], and two-fluid model of FL and NFL [7], but the origin of the QCP has remained an open question.

In this study, we aim to approach the question by means of the magnetic-field-angle-resolved specific-heat measurements because the preceding studies were limited just along the $H \perp c$ or $H \parallel c$ directions. The measurements were conducted on a single-crystal sample of $YbRh_2Si_2$ in a dilution refrigerator with the magnetic-field direction controlled in the *ac* plane. Highlight of the results is the difference of the field-angle ϕ dependence of C/T ($C(\phi)/T$) between the QCP for the *a*-axis ($H_{c,||a}$) and *c*-axis ($H_{c,||c}$) direction at $0.1\,\mathrm{K}$ (QC region). At the $H_{c,||a}$ ($\sim 0.06\,\mathrm{T}$), $C(\phi)/T$ shows broad maximum around *a*-axis, and it is suppressed drastically above the QCP. At the $H_{c,||c}$ ($\sim 0.7\,\mathrm{T}$), relatively sharp peak structure appears around *c*-axis, and the peak is gradually suppressed but remains at least up to $5\,\mathrm{T}$. On the other hand, when the $C(\phi)/T$ is replotted as a function of the *a*-axis component of the magnetic field, the peak structure can be scaled to the field-dependence of the C/T along the *a* axis except just around *c* axis. This implies that the out-of-*c*-axis structure can be explained only by the tetragonal crystallographic symmetry of $YbRh_2Si_2$ and the quantum critical behavior seems to be suppressed *isotropically*.

[1] S. Doniach, Physica B+C **91**, 231 (1977).
[2] T. Moriya and T. Takimoto, J. Phys. Soc. Jpn. **64**, 960 (1995).
[3] P. Gegenwart *et al.*, Phys. Rev. Lett. **89**, 056402 (2002).
[4] K. Ishida *et al.*, Phys. Rev. Lett. **89**, 107202 (2002).
[5] F. Steglich *et al.*, J. Phys. Soc. Jpn. **83**, 061001 (2014).
[6] T. Misawa *et al.*, J. Phys. Soc. Jpn. **77**, 093712 (2008).
[7] S. Kambe *et al.*, Nat. Phys. **10**, 840 (2014).