北京大学量子材料科学中心

International Center for Quantum Materials, PKU

Weekly Seminar

Majorana fermions in a quantum spin liquid

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Time: 3:00pm, May. 17, 2023 (Wednesday)

时间：2023年5月17日 （周三）下午3:00

Venue: Room w563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

The intersection of topology and strong electron correlations has given rise to a plethora of exotic phenomena. One such phenomenon is the fractional quantum Hall effect, where quasiparticles carry fractions of electron charge. More recently, the Kitaev quantum spin liquid (QSL) has garnered attention due to the emergence of Majorana fermions and non-Abelian anyons resulting from the fractionalization of electron spins. The Kitaev model, which represents a spin-1/2 on a honeycomb lattice interacting through bond-dependent Ising ferromagnetic couplings, has been observed in the spin-orbit Mott insulator α-$RuCl_3$. Several measurements, including specific heat, Raman scattering, and inelastic neutron scattering, provide evidence for the spin fractionalization in α-$RuCl_3$. Moreover, the half-integer quantized thermal Hall conductance provides evidence for the formation of a topologically nontrivial state consistent with the Kitaev model [1].

The half-integer quantized thermal Hall conductance, which appears even for a magnetic field with no out-of-plane components (planar thermal Hall effect), supports the formation of a topologically nontrivial state consistent with the Kitaev model [2] . Recently, we performed low-temperature measurements of high-resolution specific heat [3] and planar thermal Hall conductivity with rotating in-plane fields. We find that a distinct closure of the low-energy bulk gap is observed concomitantly with the sign reversal of the planar thermal Hall effect. The general discussion of topological bands shows that this is the hallmark of an angle-rotation-induced topological phase transition of fermions, providing conclusive evidence for the Majorana-fermion origin of the thermal Hall [4].

These results provide direct signatures of topologically protected chiral currents of charge neutral Majorana fermions at the edge and non-Abelian anyons in the bulk of the crystal. The recent scanning tunneling microscopy measurements of monolayer α- and b- $RuCl_3$ will also be discussed if time allows.[5]

[1] Y. Kasahara *et al*., Nature **559**, 227 (2018).
[2] T. Yokoi *et al*. Science **373**, 568 (2021).
[3] O. Tanaka *et al*. Nature Physics **18**, 429 (2022).
[4] K. Imamura *et al*. a preprint.
[5] T. Asaba *et al*. Science Adv.**9**, eabq5561 (2023).

About the speaker

Yuji Matsuda received his Ph.D. in Physics from the University of Tokyo (Japan) in 1987 and became a research associate at the Department of Pure and Applied Science, the University of Tokyo. He became an associate professor in 1993 at Hokkaido University (Japan) after spending two years at Princeton University (USA) as a postdoctoral fellow. He moved to Institute for Solid State Physics, University of Tokyo, as an associate professor in 1997, and became a full professor at Kyoto University in 2003. He is a condensed matter experimentalist with an interest in the electronic and magnetic properties of solids. His current research interests include strongly correlated electron systems, in particular exotic superconductivity and quantum spin systems. He received Nishina Memorial Prize, Kamerlingh Onnes Prize, and Science and Technology Award from the Minister of Education, Culture, Sports, Science and Technology.

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