Spin-spin interactions in dilute magnetic topological materials

TOMASZ DIETL[1-3]

[1]*Institute of Physics, Polish Academy of Sciences, Warszawa, Poland*
dietl@ifpan.edu.pl
[2]*Institute of Theoretical Physics, University of Warsaw, Warszawa, Poland*
[3]*WPI-Advanced Institute for Materials Research, Tohoku University, Sendai, Japan*

ABSTRACT

Since magnetic impurities break time reversal symmetry, their presence was initially regarded as a source of backscattering that can destroy topological protection and preclude the observation of signatures of topological matter such as the quantum spin Hall effect. Surprisingly, however, topological insulators doped with transition metals show a number of remarkable properties, the striking example being the quantum anomalous Hall effect, predicted theoretically [1] and then observed in macroscopic samples by several groups. The development of materials in which charge transport occurs entirely *via* a single edge chiral channel in the absence of an external magnetic field offers a number of novel spintronic capabilities.

In the lecture, I will first discuss the role of relativistic effects in compounds of heavy elements and then survey the formal analogies between behavior of various type of fermions in vacuum--described by constrained Dirac equations--and properties of elementary excitations (Dirac electrons, Weyl fermions, and Majorana anyons) in particular families of topological materials. Particular attention will be paid to the role of exchange splitting of bands, which often changes the topological class of the system. I will then present the recent progress in the understanding of the nature of spin-spin interactions between magnetic ions in topological insulators, semimetals, and metals, i.e., in bismuth/antimonite and lead/tin chalcogenides, mercury chalcogenides, and cadmium arsenide, respectively. In particular, I will discuss the physics and the relative importance of ferromagnetic Ruderman-Kittel-Kasuya-Yosida, Bloembergen-Rowland, and superexchange interactions, and their competition with antiferromagnetic superexchange, depending on the location of magnetic impurities in the lattice and their charge state [2-4]. Finally, the role of topological boundary states in mediating exchange interactions between localized spins will be presented.

References

[1] Rui Yu, Wei Zhang, Hai-Jun Zhang, Shou-Cheng Zhang, Xi Dai, and Zhong Fang, *Science* **329**, 61 (2010).
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[3] see also, T. Dietl, K. Sato, T. Fukushima, A. Bonanni, M. Jamet, A. Barski, S. Kuroda, M. Tanaka, Phan Nam Hai, H. Katayama-Yoshida, *Rev. Mod. Phys.* **87**, 1311 (2015).
[4] C. Śliwa, J. A. Majewski, and T. Dietl, *unpublished.*