

Workshop and Seminar

**Spin Orbit Entanglement: Exotic States of Quantum Matter in Electronic Systems**

15 July – 02 August 2013

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## Scientific Report Summary

The major aim of the international workshop and seminar on **Spin Orbit Entanglement: Exotic States of Quantum Matter in Electronic Systems** was to bring together some of the leading theoretical and experimental physicists that share a common interest in the complex interplay of strong spin orbit coupling, Coulomb interaction and other correlation effects in novel electronic systems. We achieved this aim by inviting experts from a variety of different fields of condensed matter physics with their respective focus areas spanning a broad range from material physics, such as iridium oxides or topological insulators, to spin liquid phases and chiral magnets as well as superconductors and fractional topological states.

The three weeks including the workshop and seminar were organized as follows: In the first and last week, we scheduled a light program with roughly six talks per week and a lot of discussion time. In the intermediate week, we organized an international workshop with roughly eight invited talks per day and excellent speakers/participants from all over the world. In addition we organized an evening session of contributed talks, offering three promising junior researchers – Tobias Meng (Basel University), Andreas Schnyder (MPI for Solid State Physics, Stuttgart), and Sebastian Huber (ETH Zurich) – an opportunity to present their latest scientific results. We were particularly happy to host the most promising young researchers in the field, including the beforementioned speakers but also e.g. Titus Neupert (Princeton).

Two very stimulating colloquia were given by Shoucheng Zhang (Stanford University) in the first week on the “Three cheers for the quantum Hall trio” and by Achim Rosch (University of Cologne) in the second week on “Skyrmions and monopoles in chiral magnets”.

During the conference, a significant number of inspiring talks were given on the physics of iridium oxides – both by theoretical and experimental researchers. A particular focus was on material systems believed to be well described by a Heisenberg–Kitaev model of spin–orbit entangled degrees of freedom. The deeper motivation to focus on these materials was the possible realization of rather exotic physics including, for instance, a quantum spin

liquid phase. To mention a few highlights along these lines, Giniyat Khaliullin (MPI for Solid State Physics, Stuttgart) spoke about magnetic order and excitations in layered iridium oxides. Radu Coldea (University of Oxford) gave an experimental talk on the spin dynamics of different iridium oxides based on inelastic neutron scattering. In addition, Roderich Moessner (MPI for the Physics of Complex Systems, Dresden) told us about the dynamical structure factor of the Kitaev model and Roser Valenti (University of Frankfurt) about an ab initio analysis of hexagonal iridates and rhodates.

The physics of topological superconductors and insulators also played a major role during our seminar and workshop. Stimulating presentations on topological metals in proximity to superconductors were given by Eun-Ah Kim (Cornell University) and Patrik Recher (University of Braunschweig). One-dimensional topological superconductors based on semiconducting nanowires were discussed in the presence of Coulomb interactions by Roman Lutchyn (Microsoft Research Station Q, Santa Barbara), in the presence of disorder by Pavel Ostrovsky (MPI for Solid State Physics, Stuttgart), and in the presence of hyperfine interaction by Daniel Loss (University of Basel).

The interplay of topological physics and Coulomb interactions was in the focus of a number of talks by Stephan Rachel (TU Dresden), Karyn Le Hur (Ecole Polytechnique, Lozere), Fakher Assaad (University of Würzburg), and Lars Fritz (University of Cologne). Laurens Molenkamp (University of Würzburg) gave an excellent presentation on his pioneering experiments on HgTe as a topological insulator. This high level was likewise met regarding the discussion of Heusler compounds presented by Claudia Felser (MPI for Chemical Physics of Solids, Dresden).

More general theoretical aspects of symmetry-protected topological phases were presented by Shinsey Ryu (University of Illinois at Urbana Champaign) and of statistical topological insulators by Anton Akhmerov (Harvard University). Gregory Fiete (University of Texas at Austin) told us about topological phases in transition metal oxides where interesting physics, for instance, that of Chern insulators and topological crystalline insulators, plays a substantial role.

Two leading experimentalists on the physics of skyrmions in chiral magnets – Christian Pfleiderer (TU Munich) and Peter Milde (TU Dresden) – presented their latest results on impressive experimental signatures of skyrmions such as a topological Hall signal and the appearance of quantized magnetic monopoles that can be detected by magnetic force microscopy.

Finally, fractional topological insulators and the fractional quantum Hall effect were the main topics of a series of excellent talks given by Nicolas Regnault (ENS Paris), Duncan Haldane (Princeton University), and Andrei Bernevig (Princeton University). In this research area, new conceptual and numerical developments allow to explore exotic models (such as Read–

Rezayi states and the Gaffnian state describing a critical quantum Hall scenario) by the determination of so-called entanglement spectra which can yield new insights in the unconventional physics of these systems.

In summary, we believe that the workshop and seminar on **Spin Orbit Entanglement: Exotic States of Quantum Matter in Electronic Systems** was definitely a great success – mostly due to the excellence and liveliness of its participants. The latter is also testimony of a field that is rapidly evolving and with a number of new collaborations generated during this event we expect to hear a lot more about new and fascinating physics in this area of research in the near future.