Journal Club 9.09.2014 (Paweł Szumniak)

Topological Shiba chain from spin-orbit coupling
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arXiv:1407.6345

We investigate the possibility of realizing a topological state in the impurity band formed by a chain of classical spins embedded in a two-dimensional singlet superconductor with Rashba spin-orbit coupling. In contrast to similar proposals which require a helical spin texture of the impurity spins for a nontrivial topology, here we show that spin-flip correlations intrinsic to the spin-orbit coupled superconductor produce a topological state for ferromagnetic alignment of the impurity spins. From the Bogoliubov-de Gennes equations we derive an effective tight-binding model for the subgap states which resembles a spinless superconductor with long-range hopping and pairing terms. We evaluate the topological invariant, and show that a topologically non-trivial state is generically present in this model.

Density of states at disorder-induced phase transitions in a multichannel Majorana wire
Maria-Theresa Rieder, Piet W. Brouwer
arXiv:1409.1877

An N-channel spinless p-wave superconducting wire is known to go through a series of N topological phase transitions upon increasing the disorder strength. Here, we show that at each of those transitions the density of states shows a Dyson singularity $\nu(\varepsilon) \propto \varepsilon^{-1} |\ln \varepsilon|^{-3}$, whereas $\nu(\varepsilon) \propto \varepsilon |\alpha|^{-1}$ has a power-law singularity for small energies ε away from the critical points. Using the concept of "superuniversality" [Gruzberg, Read, and Vishveshwara, Phys. Rev. B 71, 245124 (2005)], we are able to relate the exponent α to the wire's transport properties at zero energy and, hence, to the mean free path l and the superconducting coherence length ξ.

Tunneling spectroscopy of Majorana-Kondo devices
Erik Eriksson, Andrea Nava, Christophe Mora, Reinhold Egger
arXiv:1408.4937

We study the local density of states (LDOS) in systems of Luttinger-liquid nanowires connected to a common mesoscopic superconducting island, in which Majorana bound states give rise to different types of topological Kondo effects. We show that electron interactions enhance the low-energy LDOS in the leads close to the island, with unusual exponents due to Kondo physics that can be probed in tunneling experiments.

Tuning spin orbit interaction in high quality gate-defined InAs one-dimensional Channels
J. Shabani, Younghyun Kim, A. P. McFadden, R. M. Lutchyn, C. Nayak, C. J. palmstrøm
arXiv:1408.1122

Spin-orbit coupling in solids describes an interaction between an electron's spin, an internal quantum-mechanical degree of freedom, with its linear momentum, an external property. Spin-orbit interaction, due to its relativistic nature, is typically small in solids, and is often taken into account perturbatively. It has been recently realized, however, that materials with strong spin-orbit coupling can lead to novel states of matter such as topological insulators and superconductors. This exciting development might lead to a number of useful applications ranging from spintronics to quantum computing. In particular, theory predicts that narrow band gap semiconductors with strong spin-obit coupling are a suitable platform for the realization of Majorana zero-energy modes, predicted to obey exotic non-Abelian braiding statistics. The pursuit for realizing Majorana modes in condensed matter systems and investigating their exotic properties has been a subject of intensive experimental research recently. Here, we demonstrate the first realization of gate-defined wires where one-dimensional confinement is created using electrostatic potentials, on large area InAs two dimensional electron systems (2DESs). The electronic properties of the parent 2DES are fully characterized in the region that wires are formed. The strength of the spin-orbit interaction has been measured and tuned while the high mobility of the 2DES is maintained in the wire. We show that this scheme could provide new prospective solutions for scalable and complex wire networks.

The quantum pigeonhole principle and the nature of quantum correlations
Y. Aharonov, F. Colombo, S. Popescu, I. Sabadini, D.C.Struppa, J. Tollaksen
arXiv:1407.3194 + Comment http://www.math.umb.edu/~sp/pigeonco.pdf

The pigeonhole principle: "If you put three pigeons in two pigeonholes at least two of the pigeons end up in the same hole" is an obvious yet fundamental principle of Nature as it captures the very essence of counting. Here however we show that in quantum mechanics this is not true! We find instances when three quantum particles are put in two boxes, yet no two particles are in the same box. Furthermore, we show that the above "quantum pigeonhole principle" is only one of a host of related quantum effects, and points to a very interesting structure of quantum mechanics that

was hitherto unnoticed. Our results shed new light on the very notions of separability and correlations in quantum mechanics and on the nature of interactions. It also presents a new role for entanglement, complementary to the usual one. Finally, interferometric experiments that illustrate our effects are proposed.

Quantum imaging with undetected photons
Gabriela Barreto Lemos, Victoria Borish, Garrett D. Cole, Sven Ramelow, Radek Lapkiewicz & Anton Zeilinger
Nature 512, 409–412 (28 August 2014)

Information is central to quantum mechanics. In particular, quantum interference occurs only if there exists no information to distinguish between the superposed states. The mere possibility of obtaining information that could distinguish between overlapping states inhibits quantum interference. Here we introduce and experimentally demonstrate a quantum imaging concept based on induced coherence without induced emission. Our experiment uses two separate down-conversion nonlinear crystals (numbered NL1 and NL2), each illuminated by the same pump laser, creating one pair of photons (denoted idler and signal). If the photon pair is created in NL1, one photon (the idler) passes through the object to be imaged and is overlapped with the idler amplitude created in NL2, its source thus being undefined. Interference of the signal amplitudes coming from the two crystals then reveals the image of the object. The photons that pass through the imaged object (idler photons from NL1) are never detected, while we obtain images exclusively with the signal photons (from NL1 and NL2), which do not interact with the object. Our experiment is fundamentally different from previous quantum imaging techniques, such as interaction-free imaging or ghost imaging, because now the photons used to illuminate the object do not have to be detected at all and no coincidence detection is necessary. This enables the probe wavelength to be chosen in a range for which suitable detectors are not available. To illustrate this, we show images of objects that are either opaque or invisible to the detected photons. Our experiment is a prototype in quantum information—knowledge can be extracted by, and about, a photon that is never detected.

Protecting a spin ensemble against decoherence in the strong-coupling regime of cavity QED
S. Putz, D. O. Krimer, R. Amsüss, A. Valookaran, T. Nöbauer, J. Schmiedmayer, S. Rotter & J. Majer
Nature Physics (2014) doi:10.1038/nphys3050

Hybrid quantum systems based on spin ensembles coupled to superconducting microwave cavities are promising candidates for robust experiments in cavity quantum electrodynamics (QED) and for future technologies employing quantum mechanical effects. At present, the main source of decoherence in these systems is inhomogeneous spin broadening, which limits their performance for the coherent transfer and storage of quantum information. Here we study the dynamics of a superconducting cavity strongly coupled to an ensemble of nitrogen–vacancy centres in diamond. We experimentally observe how decoherence induced by inhomogeneous broadening can be suppressed in the strong-coupling regime—a phenomenon known as ‘cavity protection. To demonstrate the potential of this effect for coherent-control schemes, we show how appropriately chosen microwave pulses can increase the amplitude of coherent oscillations between the cavity and spin ensemble by two orders of magnitude.

Mapping the optimal route between two quantum states
S. J. Weber, A. Chantasri, J. Dressel, A. N. Jordan, K. W. Murch & I. Siddiqi
Nature 511, 570–573 (31 July 2014)

Floquet engineering of long-range p-wave superconductivity
Mónica Benito, Álvaro Gómez-León, Victor Bastidas, Tobias Brandes, Gloria Platero
arXiv:1409.0546

Detection of Majorana bound states by thermodynamically stable 4π-periodic D.C. Josephson current
Zhan Cao, Tie-Feng Fang, Hong-Gang Luo
arXiv:1409.0196

Coherent imaging spectroscopy of a quantum many-body spin system
C. Senko, J. Smith, P. Richerme, A. Lee, W. C. Campbell, C. Monroe
Science 25 July 2014: Vol. 345 no. 6195 pp. 430-433

Thermoelectric effect in the Kondo dot side-coupled to a Majorana fermion
Heunghwan Khim, Rosa Lopez, Jong Soo Lim, Minchul Lee
arXiv:1408.5053

Braiding Statistics of Loop Excitations in Three Dimensions
Chenjie Wang and Michael Levin
PRL 113, 080403 (2014)