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Collective modes and interacting Majorana fermions in topological superfluids

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Topological phases of matter are characterized by the absence of low-energy bulk excitations and the presence of robust gapless surface states. A prime example is the three-dimensional (3D) topological band insulator, which exhibits a bulk insulating gap but supports gapless 2D Dirac fermions on its surface. This physics is ultimately a consequence of spin-orbit coupling, a single-particle effect within the reach of the band theory of solids. The phenomenology of topological superfluids (and superconductors, which are charged superfluids) is rather similar, with a bulk pairing gap and gapless 2D surface Majorana fermions. The standard theory of topological superfluids exploits this analogy and can be thought of as a band theory of Bogoliubov quasi-particles. In particular, this theory predicts that Majorana fermions should be noninteracting particles. Band insulators and superfluids are, however, fundamentally different: While the former exist in the absence of interparticle interactions, the latter are broken-symmetry states that owe their very existence to such interactions. In particular, unlike the static energy gap of a band insulator, the gap in a superfluid is due to a dynamical order parameter that is subject to both thermal and quantum fluctuations. In this talk, I will argue that order parameter fluctuations in a topological superfluid can induce effective interactions among surface Majorana fermions. Possible consequences of these interactions will be discussed.

Author: MACIEJKO, Joseph (University of Alberta)

Presenter: MACIEJKO, Joseph (University of Alberta)

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