Beyond electron pairing: fermion quadrupling condensates in multi-component superconductors

Ilaria Maccari[1], Johan Carlström[2] and Egor Babaev[3]

[1] *Institute for Theoretical Physics, ETH Zürich, 8093 Zürich, Switzerland*
[2] *Department of Physics, Stockholm University, Stockholm SE-10691, Sweden*
[3] *Department of Physics, The Royal Institute of Technology, Stockholm SE-10691, Sweden*

Beyond the BCS fermion pairing paradigm, multi-component superconductors can host novel kinds of fermion condensates, where electrons condense in quadruplets, or even sextuplets. These vestigial phases may appear both below and above the superconducting critical temperature as a result of the partial melting of the multiple broken symmetries of the ground state. Recently, experimental signatures of a non-superconducting fermion quadrupling condensate that spontaneously breaks time-reversal symmetry have been reported in a multi-band iron-based superconductor [1, 2]. From a theoretical standpoint, this is a beyond mean-field state whose onset is driven by the proliferation of topological phase excitations [3]. Single-band superconductors with unconventional pairing may also host fermion quadruplets. In a recent work [4], we studied a low-energy effective model proposed in [5] for magic-angle twisted-bilayer graphene. We found that, for all the model parameters investigated, a fluctuations-induced phase appear above the superconducting transition, where a condensate formed by four electrons breaks the time-reversal symmetry.

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