Topology, Weyl physics and quartets in multi-terminal superconducting structures

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Topology ultimately unveils the roots of the perfect quantization observed in complex systems. The 2D quantum Hall effect is the celebrated archetype. Remarkably, topology can manifest itself even in higher-dimensional spaces defined by control parameters playing the role of synthetic dimensions. However, so far, a very limited number of implementations of higher-dimensional topological systems have been proposed, a notable example being the so-called 4D quantum Hall effect. In this talk show how to engineer non-trivial topological signatures like Weyl-nodes in synthetic dimensions created by multi-terminal superconductors and how Berry spectroscopy can be used to extract information about the systems quantum geometry [1]. Furthermore, I will show that mesoscopic superconducting systems can implement higher-dimensional topology and represent a formidable platform to study a quantum system with a purely nontrivial second Chern number [2]. I discuss that these systems also admit a non-Abelian Berry phase. Hence, they also realize an enlightening paradigm of topological non-Abelian systems in higher dimensions. Furthermore, such systems can host exotic topological signatures like tensor monopoles [3]. Finally, I comment on recent experimental progress to implement synthetic dimensions in semiconductor-superconductor heterostructures [4] and the analysis revealing Cooper pair quartet [4].

[1] R. L. Klees, G. Rastelli, J. C. Cuevas, and W. Belzig Microwave spectroscopy reveals the quantum geometric tensor of topological Josephson matter Phys. Rev. Lett. 124, 197002 (2020)

[2] H. Weisbrich, R.L. Klees, G. Rastelli and W. Belzig Second Chern Number and Non-Abelian Berry Phase in Superconducting Systems PRX Quantum 2, 010310 (2021)R. L. Klees, G. Rastelli, J. C. Cuevas, and W. Belzig Microwave spectroscopy reveals the quantum geometric tensor of topological Josephson matter Phys. Rev. Lett. 124, 197002 (2020)

[3] H. Weisbrich, M. Bestler, W. Belzig, Tensor Monopoles in superconducting systems, Quantum 5, 601 (2021)

[4] M. Coraiola, D. Z. Haxell, D. Sabonis, H. Weisbrich, A. E. Svetogorov, M. Hinderling, S. C. ten Kate, E. Cheah, F. Krizek, R. Schott, W. Wegscheider, J. C. Cuevas, W. Belzig, and F. Nichele, Phase-engineering the Andreev band structure of a three-terminal Josephson junction, Nat. Commun. 14, 6784 (2023); David Christian Ohnmacht, Marco Coraiola, Juan José García-Esteban, Deividas Sabonis, Fabrizio Nichele, Wolfgang Belzig and Juan Carlos Cuevas, Quartet Tomography in Multiterminal Josephson Junctions, [arXiv:2311.18544]