

Quantum Geometry in Superconductivity, Päivi Törmä

Quantum geometry tells about distances between quantum states and the structure of the Hilbert space manifold, for example Bloch states of an energy band. The concepts of Berry curvature and Chern number have been known to be relevant for physics for decades, while the understanding that the concept of quantum metric is relevant for condensed matter systems is somewhat more recent. One aspect where quantum geometry plays a crucial role is superconductivity. My lectures give an in-depth view on that aspect of quantum geometry, complementing other lectures which describe the role of quantum geometry for some other physical phenomena. My lectures start with a very brief reminder of the BCS mean-field theory of superconductivity, and the basics of quantum geometry. The latter will be taught in many other lectures of the school too. You will get background material on this, so you can recap these concepts, especially if you don't actively work on superconductivity and have forgotten what you learned about them in courses. Then I will go through the basics of the role of quantum geometry, in a pedagogical style. I will follow this review article: : Quantum geometry in superfluidity and superconductivity S.~Peotta, K.-E.~Huhtinen, P.~Törmä, Proceedings of the International School of Physics "Enrico Fermi", Ebook Volume 211: Quantum Mixtures with Ultra-cold Atoms, Pages 373-404, DOI 10.3254/ENFI250023 (2025) (also arXiv:2308.08248). Then I will present various recent research results related to the topic.

Here some extra reading: P. Törmä, Phys.~Rev.~Lett. 131, 240001 (2023); P. Törmä, S. Peotta, B.A.~Bernevig, Nature Reviews Physics 4, 528 (2022); J. Yu, B.A. Bernevig, R. Queiroz, E. Rossi, P. Törmä, B.J. Yang, arXiv:2501.00098 (2025)

The original article where we showed how quantum geometry affects superconductivity and allows flat band superconductivity: Superfluidity in topologically nontrivial flat bands, S. Peotta, P. Törmä, Nature communications 6, 8944 (2015)

An important recent follow-up: Revisiting flat band superconductivity: Dependence on minimal quantum metric and band touchings, K.-E- Huhtinen, J. Herzog-Arbeitman, A. Chew, B.A. Bernevig, P. Törmä, Physical Review B 106 (1), 014518 (2022)