Superfluidity and geometry of Bloch bands

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Abstract: Band structure theory and the BCS theory of superconductivity are two cornerstones of modern condensed matter physics. They have been used to explain many properties of crystalline solids and have found important practical applications. It is believed that the interplay between the atomic lattice and the attractive force between electrons, whose origin is still matter of debate, is at the root of the phenomenon of high-Tc superconductivity. In weakly-coupled superconductors the effect of the lattice amounts to a simple renormalization of the electron mass and of the density of states. On the contrary in high-Tc superconductors the coherence length is of the order of the lattice spacing and new phenomena may occur. An extreme example in this sense are "flat bands", namely bands where the electron effective mass diverges. As proposed in Ref. [1] flat bands are an attractive platform for high-temperature superconductors since the critical temperature is linear in the coupling constant rather than being exponentially suppressed as in conventional BCS theory. In this talk I will present our ongoing work on the problem of superconductivity and superfluidity in flat band systems with special emphasis on the transport properties. Naively one can expect that in a flat band, where the charge carriers are very heavy, transport is absent or at least strongly suppressed. However we have recently shown that in the flat band limit the superfluid weight D_s is not controlled by the effective mass but rather by a geometric invariant of the band, the quantum metric [2], which in a sense measures the overlap between neighbouring lattice wave functions [4,6]. This implies that the superfluid weight can be nonzero even for a band which is strictly flat, provided the quantum metric is nonzero. The quantum metric is intimately related to a topological invariant, the Chern number, and as a consequence we obtain the inequality $D_s \geq |C|$ between superfluid weight

and Chern number C [2]. We show that this geometric effect is important in a number of lattice models of current interest for material science and ultracold gases [2-5].

References

[1] N. B. Kopnin, T. T. Heikkilä, and G. E. Volovik, Phys. Rev. B 83 , 220503(R) (2011).

[2] SP and P. Törmä, Nature Communications 6 , 8944 (2015).

[3] A. Julku, SP, T. Vanhala, D.-H. Kim, and P. Törmä, Phys. Rev. Lett. 117, 045303 (2016).

[4] M. Tovmasyan, SP, P. Törmä, and S. D. Huber, arXiv:1608.00976.

[5] L. Liang, T. I. Vanhala, SP, T. Siro, A. Harju, and Päivi Törmä, arXiv:1610.01803.

[6] N. Marzari and D. Vanderbilt, Phys. Rev. B 56 , 12847 (1997).

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