Conditions for quantized transport in the Thouless pump

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Abstract. The topological Thouless pump [1] is a quantum device which transfers charge in a quantized manner by performing a cycle in the parameter space of its Hamiltonian. The simplest model of the Thouless pump is the integrable Rice-Mele model describing N fermions on a one-dimensional lattice. In the original paper by Thouless, ref. [1], the quantization was proved under the assumption of adiabaticity, however, the adiabatic conditions were not discussed. A *necessary* adiabatic condition for the Rice-Mele model proven in ref. [2] stated that the cycle duration, T_N, should scale with the system size at least as fast as $\sqrt{N}$ in order to maintain adiabaticity. Here we point out that in fact the *necessary and sufficient* condition for adiabaticity is even more restrictive, $T_N = O(N)$.

Quite remarkably, the quantization is not necessarily broken simultaneously with the many-body adiabaticity. While the genuine many-body adiabaticity is sufficient for the quantization of transport [1], it may not be really necessary. In fact, two distinct modes of operation of the pump realized by the Rice-Mele model should be distinguished [2]. The first mode is a continuous one, when the pump performs one cycle after another, approaching a stationary state. In this mode the genuine many-body adiabaticity is indeed mandatory for quantization of the transferred charge per cycle. The second mode can be called a transient one: One measures the transferred charge immediately after a single cycle is completed, and then initiates the pump back in its ground state (such initialization requires some sort of external cooling). In this latter mode the quantization is present even when the many-body adiabaticity has gone completely. What is required instead is local adiabaticity independent on the system size [3].

If the Thouless pump is described by a non-integrable model, the elementary excitations propagate diffusively, not ballistically. We discuss how this fact modifies the time scale at which the quantization can be maintained despite the breakdown of many-body adiabaticity.

[1] DJ Thouless. Quantization of particle transport. *Physical Review B*, 27(10):6083, 1983.

[2] Oleg Lychkovskiy, Oleksandr Gamayun, and Vadim Cheianov. Time scale for adiabaticity breakdown in driven many-body systems and orthogonality catastrophe. *Phys. Rev. Lett.*, 119(20):200401, 2017.

[3] Sven Bachmann, Wojciech De Roeck, and Martin Fraas. The adiabatic theorem for many-body quantum systems. *Phys. Rev. Lett.*, 119:060201, 2017.