Towards thermodynamics of flat-band electron systems

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The standard N-site repulsive Hubbard model with the Hamiltonian

$$H = \sum_{\sigma=\uparrow,\downarrow} H_{0\sigma} + H_U, H_{0\sigma} = \sum_{\langle i,j\rangle} t_{ij} \left(c_{i\sigma}^{\dagger} c_{j\sigma} + \text{h.c} \right), H_U = U \sum_i n_{i\uparrow} n_{i\downarrow}$$

is among simplest models of strongly correlated systems, although rigorous analysis of its properties is a difficult task. In the early 90s A. Mielke and H. Tasaki, while studying the origin of ferromagnetism in itinerant electron systems, considered a class of lattices, which have a special property that the lowest-energy one-electron band is completely dispersionless (flat), and proved rigorously the existence of ferromagnetism in this class of Hubbard models at zero temperature and certain electron filling factors (for review see [1]). Later on, low-temperature thermodynamics of the Hubbard model on some of these lattices was obtained rigorously around a particular value of the chemical potential μ_0 [2].

The aim of the present paper is to examine a region of validity of the method used in [2], i.e. to estimate until which particular (low) temperature and within which particular chemical potential region (around μ_0) the elaborated in [2] approach does work. To achieve this goal we consider some one-dimensional lattices, which support the lowest-energy flat one-electron band (sawtooth and two kagomé chains), assume $U = 0$, adopt a grand-canonical description, and perform *i)* exact calculation of thermodynamic quantities in a whole half-plane chemical potential μ – temperature $T > 0$ and *ii)* calculation of thermodynamic quantities using the method suggested in [2]. Comparing both results in the μ – T half-plane we discuss in detail to what extent the approach of [2] reproduces exact results in noninteracting limit. Our analysis refers to the entropy, specific heat, and the average number of electrons.

1. H. Tasaki, J. Phys.: Condens. Matter **10**, 4353 (1998).
2. O. Derzhko, A. Honecker, and J. Richter, Phys. Rev. B **76**, 220402(R) (2007); *ibidem* **79**, 054403 (2009).