

Zeitschrift: Helvetica Physica Acta
Band: 65 (1992)
Heft: 2-3

Artikel: Magnetic properties of the Hubbard model with infinite interaction
Autor: Krivnov, V.Ya. / Ovchinnikov, A.A. / Cheranovskii, V.O.
DOI: <https://doi.org/10.5169/seals-116480>

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

Download PDF: 06.08.2025

ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>

MAGNETIC PROPERTIES OF THE HUBBARD MODEL

WITH INFINITE INTERACTION

V.Ya.Krivnov, A.A.Ovchinnikov and V.O.Chernovskii

Institute of Chemical Physics of USSR Academy of Sciences

Moscow, USSR

Abstract. The problem of the ground state multiplicity of the Hubbard model with the infinite interaction is considered for the systems of segments of length n .

Introduction.

The simplest model of strong correlated systems is the Hubbard model with the infinite repulsion described by the Hamiltonian

$$H = \sum_{ij} t_{ij} (c_{i\sigma}^+ c_{j\sigma} + c_{j\sigma}^+ c_{i\sigma}) (1 - c_{i,-\sigma}^+ c_{i,-\sigma}) (1 - c_{j,-\sigma}^+ c_{j,-\sigma}) \quad (1)$$

One of the most important problems is to find the dependence of the ground state multiplicity on the electron density ρ . (Nagaoka problem [1]). We consider this problem for special kind of systems, consisting of ladders of n -sites segments with different intra- and intersegment hopping integrals, t and t_{\perp} .

Spin Hamiltonian (SH).

If $\alpha = t_{\perp}/t \ll 1$ one can make use of the perturbation theory in α . For $t_{\perp} = 0$ energetic levels are spin degenerated. The resolve of degeneracy (up to α^2) leads to Hamiltonian acting upon the spin variables of the neighbouring segments [2]. It turns out that the energy of two neighbouring segments with equal (inequal) non-zero numbers of electrons is minimal at total minimal (maximal) spin. Thus, SH describes the competing interactions of ferro (F)- and antiferromagnetic (AF) types. For $\rho < 1/n$ there cannot be more than one electron at each segment and the ground state is singlet. For $\rho > 1/n$ the competition interactions leads to a separation of phases with F and AF ordering. For example, for the system with $n=2$ (ladders of dimers) and for $\rho > 1/2$ F-polaron is created. Its size is proportional to $\alpha^{-1/3}$, and at $\rho_c = (2\pi)^{-1} (3\pi\alpha \ln 2)^{1/3}$ is equal to the ladder length. Thus, the system is saturated ferromagnet. For the case with $n > 2$ polarons may be both F- and AF-type leading to the "cascade" of transitions with the alteration of total spin. Equally to the ladders a more complicated system may be considered. It

consists of dimers packed up a 2d lattice. For $\rho \leq 1/2$ SH is equivalent to Hamiltonian of the 2d t-J model which magnetic properties have been discussed in [3]. As in the case of the ladder model for $\rho > 1/2$ the F polaron appears as well as the critical density ρ_c above which the system becomes a saturated ferromagnet. The variational approach.

For ladders with arbitrary α we seek the wave function Ψ in the following form (for simplicity we consider the model with $n=2$):

$$\Psi = \prod_i N_{i\alpha} N_{i\beta} (x_i + y_{i\alpha} \psi_{\alpha\alpha}(i) + y_{i\beta} \psi_{\beta\beta}(i) + \psi_{\alpha\beta}(i) b_{i\alpha}^+ b_{i\beta}^+ + b_{i\alpha}^+ \psi_{\beta}(i) + b_{i\beta}^+ \psi_{\alpha}(i)),$$

where

$$\psi_{\sigma\sigma}(i) = c_{1\sigma}^+ c_{2\sigma}^+; \quad \psi_{\alpha\beta}(i) = \lambda_s \varphi_s(i) + \lambda_t \varphi_t(i); \quad \varphi_{s,t} = (2)^{-1/2} (c_{1\alpha}^+ c_{2\beta}^+ \mp c_{1\beta}^+ c_{2\alpha}^+); \quad \psi_{\sigma}(i) = (2)^{-1/2} (c_{1\sigma}^+ + c_{2\sigma}^+).$$

1,2 are the numbers of sites of a i -th segment; λ_s, λ_t are the variational parameters at $\lambda_s^2 + \lambda_t^2 = 1$; $x_i^2 + y_{i\alpha}^2 + y_{i\beta}^2 = 1$ ($y_{i\sigma} = 0$ or 1). $N_{i\sigma} = b_{i\sigma}^+ b_{i\sigma}$; $b_{i\sigma}^+$ are the operators of pseudo-fermi-particles.

Effective Hamiltonian for pseudoparticles is $H_{\text{eff}} = \langle \Psi | H | \Psi \rangle$ where $\langle \dots \rangle$ means an average on c -operators. Analysing H_{eff} we have reproduced the results obtained by SH method for $\alpha \ll 1$. In isotropic case, $\alpha=1$, and for $\rho < 1/2$ a ground state is singlet. At $\rho \rightarrow 1$ a ground state spin is maximal. At $\rho=0.67$ this state becomes unstable with respect to overturning single up-spin electron. However, it turns out that at $\rho=0.73$ F state is unstable against multimagnon excitations. Note that in Gutzwiller approximation F state in this model is stable at all values of ρ .

We also studied the dependence $S(\rho)$ using the exact diagonalization of small ladders of dimers (up to 16 sites). The agreement between analytical and numerical results is fairly good.

References.

1. Y. Nagaoka. Phys. Rev. 147 (1966) 392.
2. V. Ya. Krivnov, A. A. Ovchinnikov and V. O. Cheranovskii. Lecture Notes in Physics, Springer (1991), (in press).
3. L. B. Ioffe and A. I. Larkin. Phys. Rev. B37 (1988) 7530.