THE t-J MODEL IN ONE DIMENSION:
EXACT SOLUTION AT |t|=J.

P.-A. Bares
Theoretische Physik, ETH-Hönggerberg, CH-8093 Zürich,
Switzerland

Abstract

By means of the Bethe ansatz technique, we have diagonalized exactly the one dimensional t-J Hamiltonian for |t|=J.¹ We emphasize that the model we have solved can not be obtained as the large-U limit of the repulsive Hubbard model, for which the exchange constant J=4t²/U ≪ t, the hopping strength. The ground state properties and the low-lying excitation spectrum are discussed for the case t=J>0,² where the model becomes supersymmetric ³. For all values of the band filling, the ground state can be pictured as a liquid of singlet bound pairs. From a formal point of view, the structure of the ground state is similar to that of the attractive Hubbard model⁴. However, the physics is more like that of the repulsive Hubbard model⁵,⁶. In particular, the ground state involves pairs of electrons of arbitrarily weak binding energies, resulting in a gapless spectrum. The low-lying part of the spectrum is composed of two types of excitations:

1) Charge excitations occurring only away from half-filling. This mode is gapless and carries no spin. In Anderson's terminology ⁷, it corresponds to a holon-antiholon branch. It is the analogue of the particle-hole excitation in a Fermi liquid. The holons have an effective Fermi surface at 2k_F (k_F=πN/2N). (received December 8, 1989)
ii) Spin excitations which, at half-filling, reduce to the two-parametric family of states of Faddeev and Takhtajan.\textsuperscript{8} The excitation consists in breaking a pair with (triplet) or without (singlet) spin-flip and carries no charge. The spectrum is gapless: this is due to the presence of a continuum of asymptotically unbound pairs. Near half-filling, this mode can be identified as a double-spinon branch. The effective Fermi surface for spinons is at $k_F$.

In conclusion, we have determined the ground state and the elementary excitation spectrum of the $t$-$J$ model at $|t|=J$ for arbitrary band filling. We believe that the model for $t=J$ belongs to the same universality class as the repulsive Hubbard model and do not expect a phase transition in the interval $0<J/t<1$.\textsuperscript{9}

We are very indebted to T.M. Rice for illuminating discussions and for his continuous encouragement during this work. We are also very grateful to G. Blatter for numerous discussions and for performing all numerical calculations.

We thank G. Felder, M. Karowski, M. Luchini, M. Ogata, W. Puttika, J. Rhyner and P. Wiegmann for discussions.

References

1. P.-A. Bares, to be published.