Short Visit Grant - Scientific Report

Kareljan Schoutens, Inst. for Theoretical Physics, University of Amsterdam
Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands
+ 31 20 525 5664 - kjs@science.uva.nl

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The purpose of this visit has been to work with Liza Huijse and Paul Fendley on a project where we study charge frustration and quantum criticality for strongly correlated fermions. This project constitutes the core of the PhD project of Liza Huijse at the Institute for Theoretical Physics of the University of Amsterdam. On a separate INSTANS grant, Liza Huijse traveled to Oxford to work on this with Paul Fendley; I joined them for a short period. This report largely coincides with the one by Liza Huijse as both concern the same work.

The project concerns the properties of strongly interacting fermions on a lattice with tuned interactions, such that the Hamiltonian is supersymmetric [1]. These models generically exhibit, what we call, superfrustration, which manifests itself in an extensive groundstate entropy. Thanks to the supersymmetry, a lower bound to the number of groundstates: the Witten index can be found exactly in many cases. In a remarkable series of work [2], J. Jonsson, has shown that the Witten index is typically a lower bound, since supersymmetric groundstates occur at different filling fractions. His proof involves an intriguing relation between the Witten index and tilings. Fendley has conjectured that for the square lattice the number of these tilings is one-on-one with the actual number of groundstates. For several kinds of periodic boundary conditions this conjecture has proven to hold. We have focussed on three such cases, where the boundary conditions are such that the resulting lattice is a ladder. These cases are particularly interesting since they do exhibit superfrustration, which is a typical 2D feature, but formally they are 1D, which makes them much more tractable. We investigated the spectra of these ladders via exact diagonalisation and we have found compelling evidence that these ladders are quantum critical.

During my visit we discussed the results we have obtained and prepared a publication. We also discussed new ideas and possible follow up research on the subject. We investigated what happens when free boundary conditions are imposed. The effective geometric picture that arises from the tilings allows one to understand that such a system will have gapless modes that correspond to the ends of defect lines. This new insight allows us to present the obtained results on criticality in the ladder models in a much broader physical picture. We are currently writing an article [3] on this, which we hope to submit in due course.

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References

[1] P. Fendley, K. Schoutens, and J. de Boer, Phys. Rev. Lett. **90**, 120402 (2003) [arXiv:hep-th/0210161].

[2] J. Jonsson, Electronic Journal of Combinatorics **13**(1), #R67 (2006); J. Jonsson, *Hard Squares on Grids With Diagonal Boundary Conditions*, Preprint (August 2006).

[3] L. Huijse, J. Halverson, P. Fendley, and K. Schoutens, *Charge frustration and quantum criticality for strongly correlated fermions*, manuscript in preparation.