FINAL REPORT, ESF SHORT VISIT GRANT: M. HAQUE

Short visit grant

Visitor: M. Haque
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Host Institute: H.H. Wills Physics Laboratory, University of Bristol
Tyndall Avenue, Bristol BS8 1TL, United Kingdom.

Grant reference number: 2652.

Started from Dresden Oct 30, 2008, returned Nov 12, 2008.

Purpose of the visit

The purpose of my visit was to start collaborative work with Dr. N. Shannon, on the topic of using entanglement measures to distinguish between valence-bond-solid (VBS) and resonating valence bond (RVB) states of lattice spin-1/2 systems.

One particular aim is to formulate a *quantitative* version of the loose statement that RVB states are "more entangled" than VBS states.

Description of the work carried out during the visit + main results obtained

During the visit, we

1. analyzed some aspects of the problem that could be treated through analytic reasoning.
2. settled on a numerical framework, to be implemented.
3. discussed entanglement in spin systems with members of the quantum information group at Bristol (Noah Linden, Sandu Popescu).

In more detail:

1. *Analytical.* Bipartite entanglement measures, quantifying the entanglement between partitions A and B of a many-particle system, depend on the choice of partitioning. We identified partitionings such

that the entanglement between these would necessarily distinguish between VBS states breaking the lattice symmetry, and RVB states not breaking the same symmetry.

2. *Numerical.* In the absence of a simple physical model known to have an RVB ground state, we decided to construct 'toy' states on finite lattices, starting with the periodic 4x4 square lattice. For this lattice, there is only one choice each for 'staggered' VBS and 'columnar' VBS states.
   For RVB states, we have decided to use two states:
   (a) the equal-weight superposition of all short-range singlet coverings, similar to the RK point of quantum dimer models;
   (b) the equal-weight superposition of coverings of *all* singlet dimers, including singlets of two distant spins, as envisaged in Anderson's original proposal of a (gapless) RVB state.
   The first step of the numerical implementation will be to convert these wavefunctions into a computational basis. I will implement this representation in the next phase of the project.

Future collaboration with host institution

This project has just moved beyond the planning stage toward concrete calculations. In addition, several other promising directions have been identified with other researchers at the host institution (Bristol University).

Collaboration with the host institution is thus very likely to continue.

Projected publications/articles resulting from grant

A successful outcome in this research would almost certainly lead to a high impact publication.

Other comments

I thank the ESF and the HFM program for providing this grant, especially at an early stage of the research project.