Final Report, ESF Exchange grant: Ivan D. Rodriguez

Exchange grant

Awarded to Ivan D. Rodriguez, Dipartimento di Fisica, Università di Firenze, Italy.
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Note: The part of the staying exceeding the 26 weeks has been covered by other funding.

Purpose of the visit and results

The goal of my visit to the Universidad Autonoma de Madrid was the collaboration with Prof. German Sierra in different arguments:

a) One of them was the relationship, proposed in the pass by several authors, between the Fractional Quantum Hall Effect (FQHE) and the gapped spin systems. We diagonalized the real Hamiltonian of the FQHE (for until ten particles) and we obtained the ground states for the fillings $\nu = \frac{1}{3}$ and $\nu = \frac{1}{5}$, in the disk geometry. We found an interesting map between the angular momentum single particle states involved in the FQH ground states and an spin-1 chain; the ground state of the spin chain corresponding to the single particle state with higher probability. We also found squeezing rules (similar to that of Ref.[1]), connecting the most probably one particle states, that correspond to non-local operators acting on the spin chain. At present we are continuing with this collaboration.

b) Another topic (not planned at the beginning of the visit) in which we have worked along the grant is the topological entanglement entropy [2] in the QHE. The topological entanglement entropy in systems with topological order, such as the QHE, has been the target of several recent studies [3]. On this subject we wrote the following paper:

Ivan D. Rodriguez and German Sierra, *Entanglement entropy of integer Quantum Hall states*, [Cond-mat/08112188] (2008),

in which we computed the topological entanglement entropy (in the real space) for the integer Quantum Hall states for three different domains of the torus, the disk and the sphere. We established the validity domain of the area law for the entanglement entropy and we found that the entropy per unit length of the perimeter depends on the filling fraction but it is independent of the geometry. For $\nu = 1$, we have found a simple interpretation of the area law. In this case the entanglement entropy is given by the sum over the Lowest Landau Level (LLL) states, of the Shanon entropies associated to finding an electron or a hole in the domain. The area law arises from the contribution of the LLLs inside a correlation length of the boundary of the domain.

Actually we are writing another paper in which, using the analytical methods of our previous work we are able to analyze more interesting geometries, in particular those with curvature singularities where one may expect deviations from the area law. In this work we also apply the computational methods of a) to the torus and the sphere, and we calculate the topological entanglement entropy of the Hall ground states ($\nu = \frac{1}{3}, \frac{1}{5}$) in different geometries, like disks, annulus and casquettes on the sphere. On this subject the follow publication will appear soon:

Ivan D. Rodriguez and German Sierra, *Entanglement entropy in the Quantum Hall Effect for arbitrary geometries*, in preparation.

In the future we plan to extend our analysis to more general fillings such as the $\nu = \frac{5}{2}$ that presents anyons with non-abelian statistics [4].

At last, I have continued with the lines of research of my PhD in which I studied the effective matrix theories for the FQHE [5]. During the visit I started to study the edge excitations in the Chern-Simons matrix theory [5]. This theory capture the physics of the FQHE for fillings $\nu = \frac{1}{k}$, with k an integer. Recently I finished my calculations and I wrote the following paper:

Ivan D. Rodriguez, *Edge excitations of the Chern Simons matrix theory for the FQHE*, hep-th/08124531 (2008),

in which I integrated out the bulk degrees of freedom of the microscopical theory, obtaining the boson chiral theory on the circle that is a good description of the boundary physics of the Laughlin fluids, as shown in Ref.[6].

Other Comments

I wish to thank the ESF and in particular the INSTANS program for providing this grant.

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