Scientific report on my visit to Trieste from May, 05 to May, 20, 2008 – Francesco Zamponi

Quantum computing is a field of research motivated by the exciting perspective of computers that intrisically take advantage of the law of quantum mechanics. A lot of activity has been concerned with the development of the « software »: the quantum adiabatic algorithm (or quantum annealing) is a versatile approach that in principle can be applied to any combinatorial optimization problem. As detailed in my application, a crucial question is of course to understand how slow the evolution should be for the adiabatic condition to be fulfilled.

The quantum version of spin glass models defined on random graph structures are natural test models for the quantum adiabatic algorithm and indeed many recent numerical studies focused on them.
A team in Paris, composed by myself, Guilhem Semerjian, Florent Krzakala and Alberto Rosso is starting to work on these models. We believe that interacting with people having a specific expertise on the quantum adiabatic algorithm is crucial for the success of our project. One of the leading groups on this subject, led by G.Santoro and E.Tosatti, is present in Trieste. Starting a collaboration between these two groups is therefore the main objective of my visit.

In this respect I believe that my visit in Trieste was very successful. I had the opportunity to discuss in detail with G.Santoro on their recent work and to share with him some of the ideas that we want to develop in the next future. In particular, we discussed a possible implementation of the quantum adiabatic algorithm that shares some similarities with the so-called “parallel tempering” algorithm, a powerful algorithm to simulate classical spin glass models. We discussed a possible way of “interpolating” between these two algorithms that might be of help in shading light on the main features of the energy landscape of these problems that influence the behavior of algorithms.

Beside this, I continued working on the extension to the quantum case of analytical methods developed in the classical case to compute the phase diagram of models defined on random lattices.
We have now an almost complete control of the solution in the simplest case of the Ising ferromagnet on a Bethe lattice; we found a good numerical implementation of the quantum cavity equations that allow for a reliable solution in fast time. The extension to more complicated and interesting models should now be possible. This research activity should result in a publication by the end of the year.

A related field of research is that of quantum glassy phases in particle systems. I am currently writing a paper in collaboration with G.Biroli and C.Chamon on this problem, and during my visit I had the opportunity to discuss with people working on quantum Monte-Carlo approaches to these problems. In this quite new and complex field, the interaction between analytical methods and numerical simulations is crucial and these discussion were very helpful for the redaction of our paper and to find new research directions.

Finally, I had the opportunity to discuss with A.Ramezanpour, who is currently working on the problem of packing spheres in the Hamming space. His work follows a paper by myself and G.Parisi on the same subject, that is of wide interest for the computer science community as it is related to the theory of error-correcting codes. The work of Ramezanpour constitutes an important advance over our previous work; the final objective is to give strong arguments supporting the conjecture that the Gilbert-Varshamov lower bound for the maximal packing density is tight. I think that such a result is not out of reach and could be obtained in the near future.