Mobile impurity dynamics in one-dimensional quantum gases

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The purpose of my visit was to initiate a collaboration with the LPTMS research group on the problem of dynamics of the mobile quantum impurity in one-dimensional (1D) quantum gases. This problem has attracted a lot of attention in the recent years. Being interesting by itself, it also constitutes a part of two fundamental subjects: the threshold behavior of the spectral function in 1D models and the dynamical properties of 1D itinerant ferromagnets. I, myself, have been working on both these subjects (M.B. Zvonarev *et. al.*, Phys. Rev. Lett. **99**, 240404 (2007)) by using non-perturbative many-body techniques: integrability, bosonization, and first-quantized path integrals. I have focused mostly on the investigation of the physics of low-energy excitations, for which these techniques are very suitable.

There is, however, another very hot topic where the mobile impurity problem is encountered: the physics of ultracold atomic gases. Indeed, loading ultracold atoms (*e.g.* ^{87}Rb) into a highly anisotropic magneto-optical trap one gets a 1D interacting system with the possibility of accessing and reading out the internal ("spin") state of the particles (A. Widera *et. al.*, Phys. Rev. Lett. **100**, 140401 (2008)). Making the concentration of the atoms in one of the spin states very low, one arrives naturally at the a problem of a mobile impurity interacting with a 1D quantum gas. What is specific about the latter problem is that one very often probes the physics of intermediate and high-energy rather than low-energy excitations in the ultracold atomic gases experiment. The theoretical analysis should be adapted properly in order to take this into account.

And so I came to LPTMS planning to investigate the mobile impurity dynamics at all energy scales. At the same time the group at LPTMS was working on the closely related problem of impurity dynamics in the few-body problem (D. Petrov *et. al.*, unpublished). Given the similarities between these problems, we had a lot of useful discussions and exchanges of ideas. The difference between the theoretical methods used to investigate the many-body and few-body problems was an additional advantage which allowed us to enrich our intuition about the physics of these problems.

A significant part of my preprints (M.B. Zvonarev *et. al.*, arXiv: 0811.2676 and arXiv: 0812.4059) was written during to and as a result of my visit to LPTMS. In these preprints I am presenting an approach to investigate the dynamical properties of the 1D itinerant ferromagnet. More specifically, in the preprint arXiv: 0812.4059 I am deriving the propagator of transverse spin waves in the form of the Fredholm determinant. The determinant representation allowed me to investigate the corresponding spectral function at all energies and momenta. The results of the investigation are summarized in the preprint arXiv: 0811.2676. The approach developed in the above preprints allows me to study the mobile impurity dynamics at all energies and momenta since the Hamiltonian of the 1D itinerant ferromagnet could be mapped onto the one for a mobile impurity problem. The investigation of the properties of the observables in the mobile impurity problem is the subject

of my current research, and the results of this research will most probably be reported in the joint work with my LPTMS collaborators.

In summary, given the scientific success of my visit to LPTMS, our collaboration will definitely be continued, primarily targeting the subject of the dynamical properties of one-dimensional quantum gases.