Comment on "Absence of the Mott Glass Phase in 1D Disordered Fermionic Systems"

In Refs. [1,2] we predicted a novel phase for interacting fermions (or bosons) in presence of quenched disorder, intermediate between the Mott Insulator (incompressible with a gap in the optical conductivity) and the Anderson glass (compressible with a pseudo-gap in the optical conductivity). In this phase, called the Mott Glass, the system is incompressible but exhibits only a pseudo gap in the optical conductivity. This prediction was based on semiclassical arguments, excitonic arguments, and supported by a variational replica calculation and a functional RG calculation. It required finite extent repulsive interactions, at least nearest neighbors.

In Ref. [2], it is claimed that such an intermediate phase cannot exist. The analysis is based on an extension of the semiclassical treatment [1] of the Anderson insulator to the case of a Mott insulator with disorder. In Ref. [3] the energy of kinks (i.e. topological excitations) are computed. Ref. [3] argues, based on their Eq. (4), that a non-zero optical conductivity requires a zero-energy gap to kink formation in the system and thus a non-zero compressibility.

Although Eq. (4) is technically correct, we want to point out in the present comment that the subsequent argumentation in insufficient to rule out the existence of the Mott glass. Indeed as was already shown in [2] (see Fig. 5), in the phase representation, the Mott glass phase is characterized by a Hessian matrix with a positive spectrum extending down to zero and a kink gap remaining strictly positive. As shown in Sec. III A of [2], the incompressibility stems from the strictly positive kink gap, while the source of the non-vanishing conductivity is the spectrum of the Hessian matrix extending down to zero. As in Ref. [2], it is claimed that such an intermediate phase cannot exist. The analysis is based on an extension of the semiclassical treatment [1] of the Anderson insulator to the case of a Mott insulator with disorder. In Ref. [3] the energy of kinks (i.e. topological excitations) are computed. Ref. [2] argues, based on their Eq. (4), that a non-zero optical conductivity requires a zero-energy gap to kink formation in the system and thus a non-zero compressibility.

Examples of contributions of non-topological excitations to optical conductivity besides kink contributions are known to occur in several related situations. For instance in the non-disordered sine-Gordon model, which corresponds to the pure Mott insulator, non-topological excitations (breathers) with lower energy than the kinks (solitons) can exist. Applying the reasoning of [3] to the sine-Gordon model would lead to the conclusion that the conductivity gap in this model is always larger than the soliton gap, which is clearly not the case for sufficiently small parameter $K$ in the sine-Gordon model [4,5]. For the non-commensurate disordered case, non topological excitations do also lead to a non-zero absorption at finite frequency, and thus a non-zero optical conductivity, even if kinks are totally excluded such as in the extreme classical limit [6].

For the commensurate disordered case, as pointed out in Ref. [1,2] the non-topological excitations are thus at the root of the existence of the Mott glass phase. In a direct fermionic language they correspond to particle-hole bound pairs, similar to excitons, while kinks correspond to independent particles. An explicit example is given in Section IV B of Ref. [2]. While excitons, being neutral particles, do not contribute to dc transport they can and do give a contribution to the optical conductivity.

Besides the derivations given in Ref. [1,2], it is also interesting to point out that a real space renormalization procedure on disordered commensurate bosons, controlled in the limit of strong disorder, also leads to a similar conclusion to ours on the existence of a gapless incompressible phase [6]. There it is shown that this phase can be viewed as a chain of non-interacting finite superfluid grains; as the thermodynamic limit is taken, the lowest charging gap (i.e., kink energy) vanishes as $1/\log(L)$, due to essentially a single anomalously large grain. Adding particles to this grain hardly affects the density, and thus the compressibility is only: $\kappa \log(L)/L \to 0$ as $L \to \infty$, disproving the statement in Ref. [3] (page 3 under table 1) that zero compressibility implies a finite gap.

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