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Mesoscopic fluctuations of the local density of states in interacting electron systems

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In this paper, we review our recent results for mesoscopic fluctuations of the local density of states, $\rho(E)$, in the presence of electron-electron interaction [1–4]. Specifically, we focus on two cases: (i) a vicinity of Anderson–Mott transition and (ii) vicinity of the non-interacting critical point in the presence of a weak electron-electron attraction.

For Mott–Anderson transition we demonstrate that the strong mesoscopic fluctuations (multifractality) of the local density of states survive in the presence of electron-electron interaction. Within two-loop expansion in disorder we check that the multifractal spectrum in the presence of interaction is different from the multifractal spectrum known in the absence of interaction. In addition, we find that in some cases on the insulating side of Anderson–Mott transition the mobility edge for single particle excitations can exist (see Fig. 1a). The mobility edge has a nontrivial scaling with the distance from the interacting critical point: $E_c \sim (t-t_*)^{\nu z}$. Here t denotes dimensionless resistance, ν and z stand for the correlation length and dynamical exponents in the interacting critical point $t = t_*$, respectively.

For the case of vicinity of the non-interacting critical point in the presence of weak electron-electron attraction $\gamma < 0$ (see Fig. 1b) we found enhancement of mesoscopic fluctuations at temperatures close to the superconducting transition temperature $T_c^* \sim |\gamma|^{d/|\Delta_2^{\mathrm{n}}|}$. Here d denotes the spatial dimension and Δ_2^{n} stands for the multifractal exponent at the noninteracting critical point. At high temperatures the mesoscopic fluctuations of $\rho(E)$ are the same as in the non-interacting case.

The predicted strong mesoscopic fluctuations of local density of states imply strong point-to-point fluctuations of tunneling spectra which can be measured in scanning tunneling microscopy experiments. We note that our theoretical results are consistent with available data on scanning tunneling microscopy in disordered interacting systems, in particular, for a strongly disordered 3D system [5], for various 2D semiconductor systems and graphene [6–9], for a magnetic semiconductor $Ga_{1-x}Mn_xAs$ near metal-insulator transition [10], for metallic and insulating phases near superconductor-insulator transition in TiN, InO, and NbN films [11–16].

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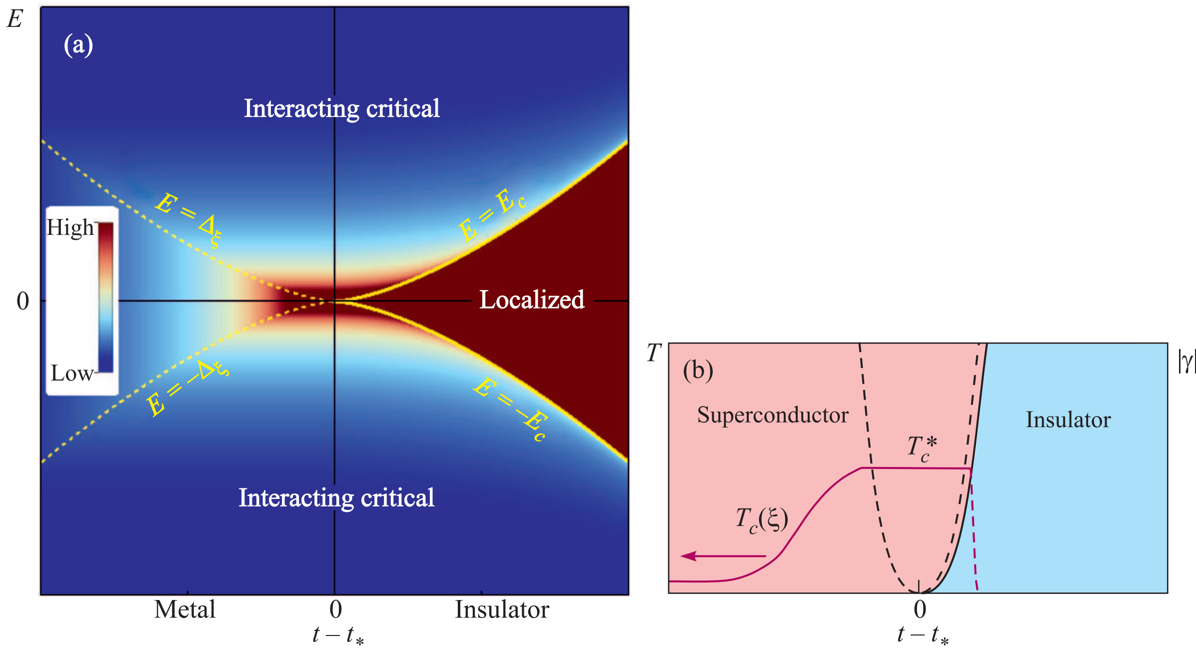

Fig. 1. (Color online) (a) – Sketch of the phase diagram in the energy (E) vs disorder (t) plane. The interacting critical point is situated at $t = t_*$ and zero energy, $E = 0$. The dashed yellow curves separate critical regime on metallic side. The solid yellow curves correspond to the mobility edge $E = \pm E_c$. The colour scheme indicates value of the ratio $\langle \rho^2(E)\rangle / \langle \rho(E)\rangle^2$ in different parts of the phase diagram. (b) – Sketch of the phase diagram in disorder (t) and interaction ($|\gamma|$) plane near the superconductor-insulator transition. The solid black curve denotes the transition. The dashed black curve corresponds to the condition $T_c^* \sim \delta_\xi$ and indicates the critical region. The red solid curve illustrates the dependence of the superconducting transition temperature on the distance from the critical point

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