Quantum Criticality at the Anderson Transition: a TMT Perspective

Mahmoudian,S; Tang, S; Dobrosavljevic,V.(FSU, PHYSICS, NHMFL)

Introduction - Although the original DMFT formulation adequately describes many features of strongly correlated electron systems, its original formulation was unable to capture Anderson localization effects, processes that cannot be neglected in presence of sufficiently strong disorder. A hint how to overcome this difficulty was provided by P. W. Anderson [1], who emphasized that the typical, i.e., geometrically averaged local density of states (TDOS) vanishes at the transition, in contrast to its algebraically-averaged counterpart. A self-consistent calculation of TDOS was recently formulated,“ Typical-Medium Theory ” (TMT) [2], which can be regarded as the conceptually simplest order-parameter approach for Anderson localization. The numerical solution of TMT self-consistent equations has been obtained for both the (noninteracting) Anderson, and the Mott-Anderson transition. However, so far the exact functional form of order parameter could not be obtained analytically near the mobility edge, except in the special limit of particle-hole symmetry. The outstanding remaining question is what are the possible types of quantum criticality that can be obtained within the TMT framework, and how are results affected by model-dependent aspects of the problem, such as the precise form of disorder or the electronic band structure in the clean limit. During this project, I answered all these questions both analytically and numerically.

Results and Discussion - We present a complete analytical and numerical solution of the Typical Medium Theory (TMT) of the Anderson metal-insulator transition. Although the exact TMT theory gives us non-analytic critical behavior, we showed that the offending logarithmic corrections to scaling are not very significant if we are not too close to the transition. We also demonstrated that, within TMT, two different universality classes for the critical behavior may exist, depending on the qualitative form of disorder Fig. 1(b). We explored the opening a soft gap in the single-particle density of states near the Fermi energy Fig. 1(a), which is shown to emerge when the disorder is chosen of the form appropriate for electrons interacting through long-range Coulomb interactions (pseudo-gap model). In relevant cases, our results are found to be in excellent agreement with recent experiments [3] on $Ga_{1-x}Mn_xAs$,as well as with large-scale exact diagonalization results [4].

Conclusions - In summary, we carried out a detailed TMT study of the critical behavior of Anderson transition both analytically and numerically. We conclude that TMT represents a flexible and practically useful tool to successfully describe the main qualitative trends for physical observables, in the vicinity of disorder-driven metal-insulator transitions.

Acknowledgements - The authors thanks Ali Yazdani and Stephan von Molnar for useful discussion. This work was supported by the NSF grants DMR-1005751 and DMR-1410132.

References –

[1] P. Anderson, Physical Review 109, 1492 (1958).
[2] V. Dobrosavljevic, A. A. Pastor, and B. K. Nikolic, Europh. Lett. 62, 76 (2003).
[3] A. Richardella, P. Roushan, and A. Yazdani, Science 327, 665 (2010).
[4] M. Amini, V. E. Kravtsov, and M. Muller, New Journal of Physics 16, 015022 (2014).

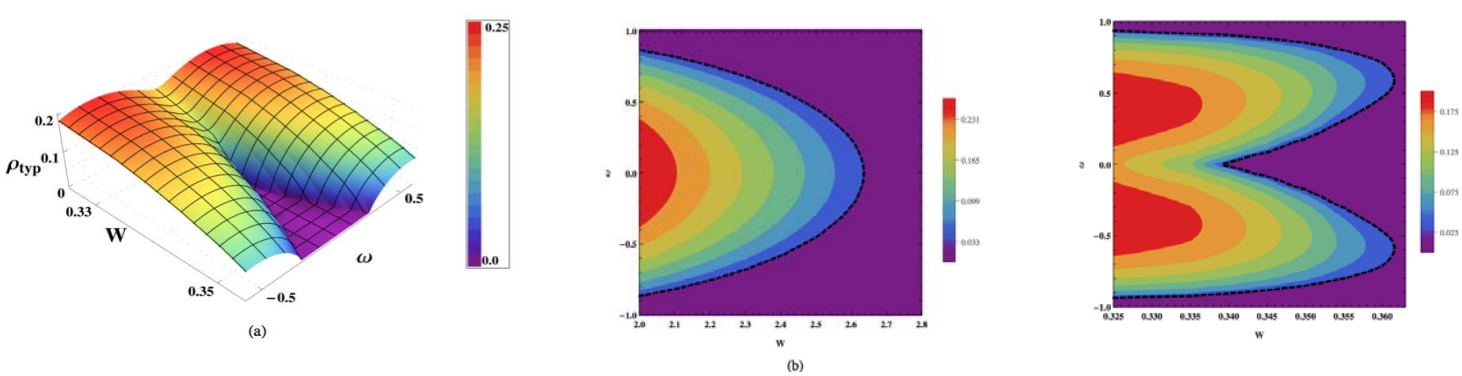

Fig. 1 : (a) The evolution of TDOS for pseudo-gap model of random site distribution. (b) phase diagram for flat (left panel) and pseudogap model (right panel) where the mobility edge (dashed line) separates the extended states (finite TDOS) from the localized states (TDOS=0).