MAR14-2013-030022

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

Theoretical Approaches to Correlated Electron Problems

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Theoretical studies of the electronic properties of strongly correlated materials can rarely be both realistic and controlled. Despite the lack of a small parameter, astonishing success has been achieved by realistic approaches using various generalized forms of mean field theory including, most notably, local density approximation. I will instead discuss some of what has been learned by studying simple paradigmatic models, such as the Hubbard model, in limits in which the existence of a small parameter allows asymptotic control of the theory, and of engineered models, that are amenable to exact solution. This approach is ideal for establishing, as points of principle, what behaviors can exist. In some cases, invoking the principle of adiabatic continuity, the results can be extrapolated to a physically reasonable regime so that contact with experiment becomes plausible.