Phillips Replies: Castner [1] has raised some interesting points regarding ionized impurity scattering in semiconducting impurity bands in the intermediate phase ($n_{c1} < n < n_{c2}$) or $E_c \leq E_F \leq E_2 < E_0$, where E_c is the Mott mobility edge and E_0 is the lowest energy of E_F in the Fermi liquid phase ($n > n_{c2}$). The intermediate phase (IP) [2] lies between the semiconductive phase [3] ($n < n_{c1}$), where the electronic structure is dominated by Coulomb interactions that fundamentally rearrange energy levels to create a pseudogap, and the Fermi liquid phase ($n > n_{c2}$), where Coulomb interactions are screened and have little effect on the spectrum. Castner suggests that a useful way to view Coulomb interactions in the IP is to separate the electron-impurity interactions from the electron-electron interactions, and to focus first on the former (which are generally several times larger than the latter anyway). One then takes a second step and separates the electron-impurity interactions into two components, localized and ionized. Similar separations are made for the two electron components ($E_l \leq E_c$ and $E_i \geq E_c$) and the impurities. (These separations are analogous to a first-order phase transition and cannot be derived perturbatively.) The ionized component is then used to define a subspace that is assumed to be percolative, so that it is effectively one dimensional. This procedure is analyzed for consistency with conventional full space single-ion scattering formulas, leading to the conclusion that for the percolative states indeed $d = 1$ and the conduction is diffusive. The reader should judge for herself the validity of the single-ion approximation.

This procedure has many appealing features, as it is known that the conductivity exponent $\alpha = 1/2$ only when the impurities are randomly distributed, so that there are no hidden correlations that would interfere with the two-component separation [4]. Similarly, in the presence of partial compensation y, which also introduces additional correlations, α increases rapidly, and approaches 1 for $y > 0.1$. Whatever picture one adopts, it is clear that in the IP some kind of percolative model is required, and the positions of, and electron interactions with, the dopants are central to the percolative process. Electron-phonon interactions with the (probably not randomly distributed) dopants apparently are also responsible for high temperature superconductivity in the IP of the cuprates [2,5,6]. There the relevance of the percolative picture is dramatized by photoemission measurements [7] of the doping dependence of the Fermi velocity, which changes by about a factor of 3 from underdoped to overdoped. The authors explained this change (their Fig. 1) with increased doping in terms of an exotic concept: electron fractionalization. With a two-component filamentary first-order nanoscale phase separation model these trends are explained much more simply. With increasing dopant density the filamentary density increases, and this implies an increasing density of states in the regime of states pinned to the dopants, which extends up to about 0.2 eV, in reasonably good agreement with an early estimate of dopant binding energies [8].

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