Reply to a Comment on “Nonequilibrium Electron Distribution in Presence of Kondo Impurities” (cond-mat/0105026)

In a recent paper [1] we have studied the energy relaxation of electrons in voltage biased mesoscopic wires in presence of magnetic impurities. The t-matrix approach by Kaminski and Glazman (KG) [2] was extended beyond the poor man’s scaling regime and shown to lead to results in quantitative agreement with experimental data by Pothier et al. [3] and Pierre et al. [4].

Kroha and Zawadowski (KZ) argue in a Comment [5] that the decomposition of the two particle t-matrix into two single particle t-matrices employed by KG and us is not adequate. As shown in [1], such a decomposition arises for the leading infrared divergent terms of the collision kernel. These terms display a $1/\omega^2$ behavior, where $\omega$ is the energy exchanged between the two electrons, which is responsible for the experimentally observed scaling of the nonequilibrium electron distribution function. As already noted by KG, the $1/\omega^2$ behavior is cut off at low energies by the decoherence rate $1/\tau_s$ of the impurity spin. On the other hand, in the collision integral the collision kernel is multiplied by a product of four distribution functions which vanishes for low energies so that the collision integral is in fact well behaved even in the absence of an infrared cutoff. As a consequence, the energy range $\omega < 1/\tau_s$ where our approach may overestimate the collision kernel gives only a negligible contribution to the collision integral, and the spin decoherence rate leads merely to secondary effects that do not influence the scaling behavior. Various tests with cutoffs based on estimates by KG have confirmed this conclusion.

While this was already explicitly mentioned in [1], KZ now argue that for typical experimental parameters an infrared regularization is required in about 10 to 30% of the relevant energy range and, therefore, summing the leading divergent terms in $1/\omega$ is not sufficient. However, KZ seem to have missed the selfconsistency of our approach. As can be seen from Fig. 3 in [1], the selfconsistently determined single particle spin-flip t-matrix $\tau(\varepsilon)$ does not vary much in magnitude in the relevant energy range since it depends on the smeared nonequilibrium electron distribution function and not on the distribution of noninteracting electrons with two sharp Fermi edges. For sufficiently smeared distribution functions the argument by KZ is not correct since nonleading divergent terms are suppressed. Even in presence of a cutoff the factorized graphs give the leading contribution and our approach is indeed adequate to describe the experiments in [3,4]. In fact, our fit of the gold data [4] has no adjustable parameters since the impurity concentration was extracted from the temperature dependence of the resistivity.

In [1] we point out that our result “is insensitive to the Kondo temperature $T_K$ as long as $T \ll T_K$”. $T_K$ can in fact be varied within a physically reasonable regime determined by the experimental conditions. KZ correctly point out that our approach does not describe the crossover to the Fermi liquid fixpoint behavior. This issue was already discussed by KG in some detail and is of no importance in the parameter regime of the experiments in [3,4].

In a last point KZ write “Göppert and Grabert claim that in the slave boson (SB) method employed in [3] algebraic behavior of $K(\omega, \varepsilon, \varepsilon')$ can only be obtained in infinite order perturbation theory (PT)”. This claim has never been made by us. Ref. [6] is even not cited in [1] and hardly could be mentioned, since it has appeared in cond-mat only 2 months later than [1]. In the published version of [1], we have added a reference to [3] in a sentence referring to the $1/\omega^2$-behavior and “the NCA techniques used in [2] where algebraic behavior only arises from a summation of an infinite series of logarithmic corrections.” Hence, it was not claimed that the SB approach a priori cannot reproduce the algebraic $1/\omega^2$ behavior in PT but rather that Kroha’s specific calculations do not yield algebraic $1/\omega^2$ terms. This is in complete accordance with Kroha’s own statements in [2] where he writes about the $1/\omega^2$ term responsible for scaling: “It must, therefore, be generated by an infinite resummation of logarithmic terms obtained in perturbation theory due to the presence of a Fermi edge.” Basically, we have just restated Kroha’s own words. Of course, our results can also be reproduced by other methods. This work was supported by grants from the DFG and the DAAD.

We wish to thank B. Altshuler, F. Pierre, and H. Pothier for valuable discussions.

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