Lin and Goldman Reply:

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Lin and Goldman reply: The Comment of Conduit and Meir [1] presents an alternative explanation of the experimental results on the magnetoresistance (MR) of amorphous bismuth films reported in on our recent letter[2]. They employ numerical simulations to calculate the transport and magnetotransport properties of disordered superconducting films using a microscopic theory[3] based on the disordered negative-U Hubbard model which includes thermal fluctuations but not quantum fluctuations[4]. They find a giant MR peak which exhibits a temperature independent MR at a certain magnetic field B_c similar to that found in the experiments. The values of the MR at different temperatures near B_c, can also be collapsed using the scaling form $R = R_c F(|B - B_c|/T^{1/\nu z})$ with $vz = 0.89$ and 0.94, in strong and weak disordered respectively. Furthermore, they state that B_c corresponds to $T_A(B = B_c) = T_A(B = 0)$, where $T_A(B)$ is the activation energy of the electrical resistance at a magnetic field B. By expanding T_A around B_c, they find that the scaling function for the MR can be fit with $vz = 1$. They then predict that the same behavior can be found in less disordered films.

We acknowledge that Conduit and Meir have provided a possible alternative to the explanation of of the data as evidence of a quantum phase transition as suggested in our letter. Their microscopic model may very well provide an explanation for the activated conduction behavior attributed to transport through Coulomb blockade islands[3]. Their simulations may also capture the evolution of the activation energy with magnetic field, and the appearance of the huge MR peak found in strongly disordered superconducting films. However, we find some features of our results cannot be explained by their model. We will enumerate them in the following.

First, they do not explain why the prefactor R_0 of the activated transport at B_c is equal to $h/4e^2$, which is the quantum resistance of an electron pair. Despite very different values of B_c, we found this strange feature for the two different thicknesses of films as reported in our letter. Furthermore, the first appearance of a positive MR coincides with the zero-field prefactor falling below $h/4e^2$. These observations suggest that $R_0(B) = h/4e^2$ delineates a boundary for the value of MR in the zero temperature limit, which is not found in their model.

Second is the issue of the value of critical exponent product in the scaling analysis of the MR data. In Figs. 1 (a) and 1 (c) we scale, using $vz = 0.89$, the same MR data presented in our letter, for the 20.91Å and 21.12Å films. One can clearly see that the collapse of the data is clearly better with $vz = 0.65$, the original value presented in our letter. This is shown in Figs. 1(b) and (d). We note that $vz = 0.89$ came from their simulation result of strongly disordered insulating film and $vz = 1$ came from expansion of the activation energy T_A around B_c, where the dependence of prefactor $R_0(B)$ on B is neglected. From our experimental data, the value of $R_0(B)$ actually

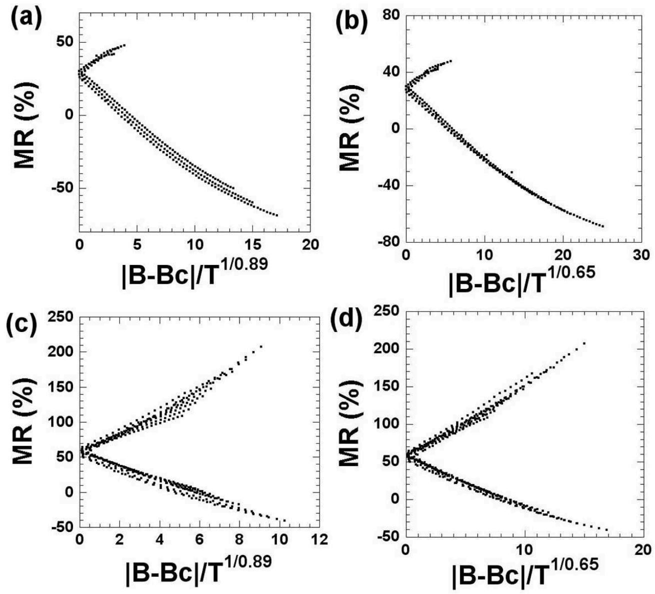

Figure 1: Scaling of the MR of the 20.91Å thick amorphous Bi film with (a) $vz = 0.89$ and (b)$vz = 0.65$ and 21.12Å thick film with (c) $vz = 0.89$ and (d)$vz = 0.65$.

changes by nearly a factor of two in the range of data used in the scaling analysis. Therefore, the prefactor $R_0(B)$ should also affect the result of a scaling analysis. For our less disordered or thicker films, this crossing point of MR happened at B_c higher than 10 Tesla, which is the highest field that we could access. Therefore, we can't verify whether MR has the same properties in less disordered films from our data.

We also reported the temperature dependence of the peak magnetic field, B_{peak}, of the the MR. The form, $B_{peak} = B_0 + \alpha T^{\beta}$, was found for films of different thicknesses. This has not been explained well by any theory. We wonder whether the numerical simulations of Conduit and Meir would be able to reproduce the same form.

In summary, we agree that the microscopic theory and numerical simulations of Conduit and Meir may possibly explain the activated transport behavior and origin of MR peak. However, this theory does not explain the value of the prefactor $R_0 = h/4e^2$ and the scaling behavior with critical exponent product $vz = 0.65$. The values of the prefactor of the activated conduction may be the key to the identification of the explanation of the data. Another constraint on theory would be the need to reproduce the form of temperature dependence of the peak field.

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[1] Comment
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[3] G. J. Conduit and Y. Meir, arXiv 1111.2941.
[4] G. J. Conduit and Y. Meir, Phys. Rev. B **84**, 064513 (2011).