Magnetoresistance of disordered superconductors

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ABSTRACT

Disordered superconducting thin films have a magnetoresistance peak of several orders of magnitude

To exploit the magnetoresistance peak in electronic devices it is vital to have a thorough understanding of the mechanism behind its emergence

We develop and exploit a new and exact tool to study the conductance of superconductors, and draw maps of the microscopic current and chemical potential to explore the emergence of the magnetoresistance peak

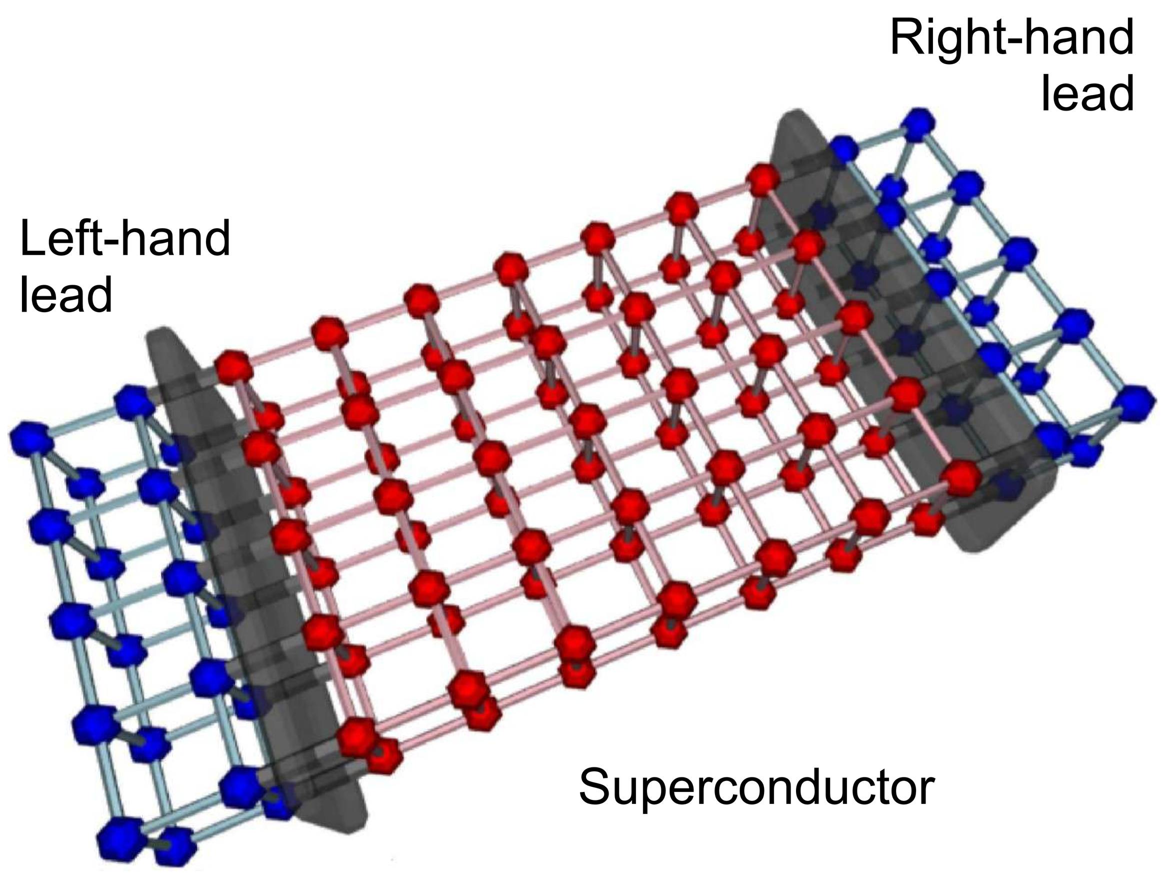


Fig. 1. Setup: The disordered superconductor (red) sites is connected between the two metalic leads (blue).

FORMALISM

To study the conductivity of mesoscopic superconductors we use the Meir-Wingreen formula for the current.

We model the superconductor with the disordered negative-U Hubbard model shown in Fig. 1, and attach two metalic leads to apply a potential across the system.

To take full account of the phase and amplitude fluctuations that drive the system resistive we use a Monte Carlo summation.

We also develop tools to plot the microscopic current flow though the system that provides a window onto the underlying physics.

MAGNETORESISTANCE PEAK

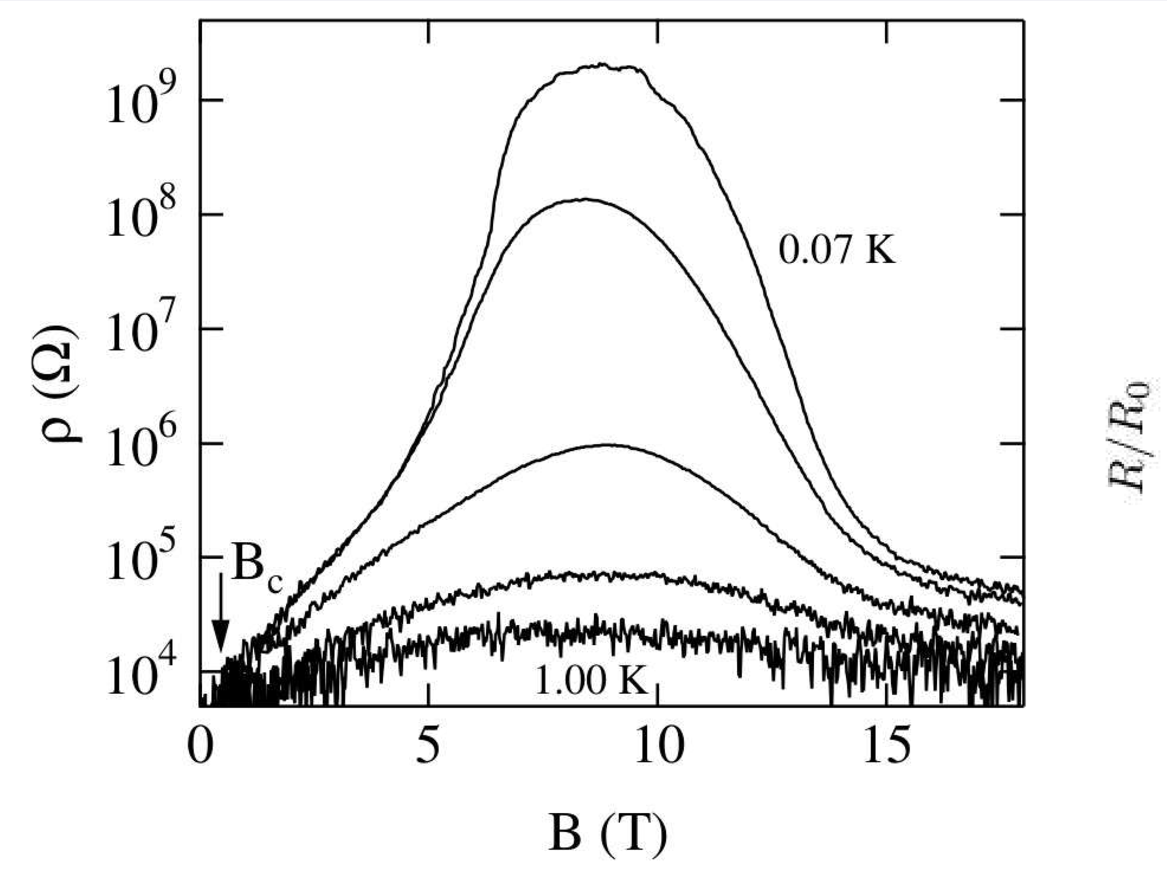


Fig. 2. Experimental magnetoresistance peak with magnetic field B at different temperatures. From Sambandamurthy *et al*. PRL **92**, 107005 (2004).

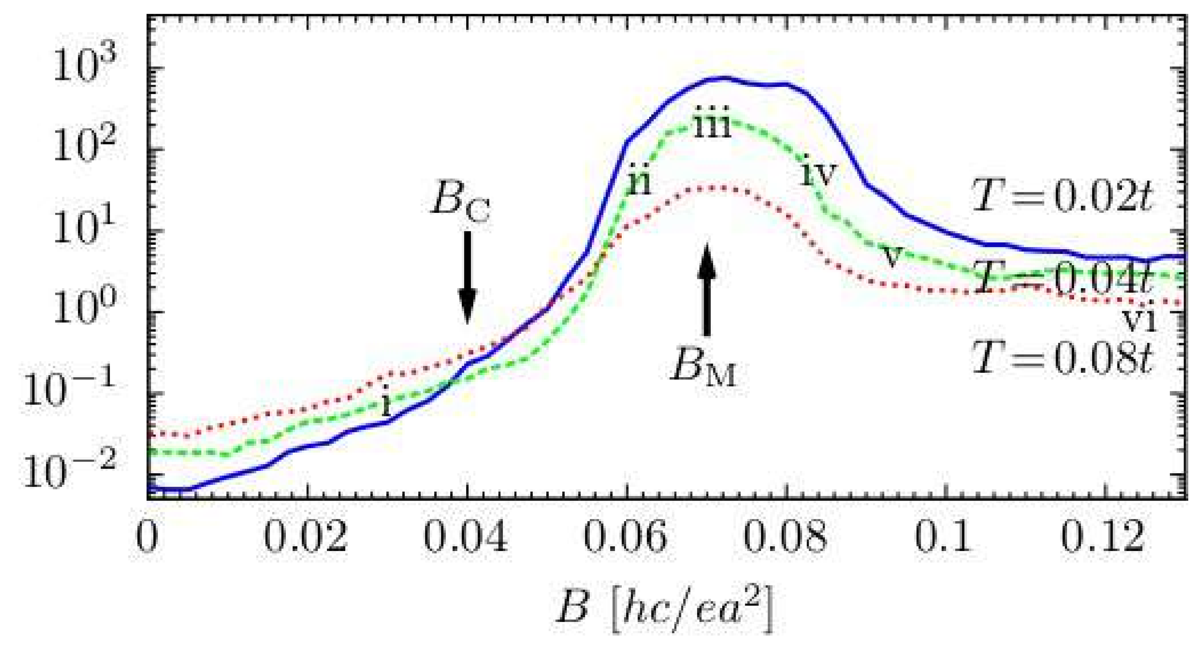


Fig. 3. Magnetoresistance peak seen in numerical simulations with magnetic field B and temperature T. Points (i-vi) correspond to the maps below.

The experimental magnetoresistance peak in Fig. 2 emerges as the normal magnetic field destroys the superconducting state.

In Fig. 3 we recover a similar magnetoresistance peak from our *ab initio* numerical simulations.

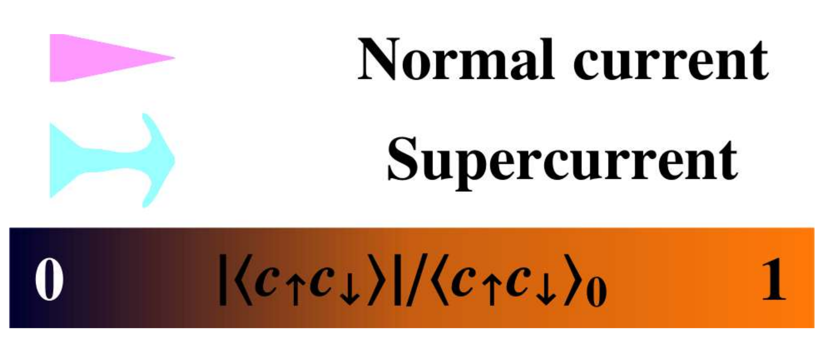
Below B_C the system is superconducting and the low temperature sample has the lowest resistance. Above B_C the system displays activated transport and the low temperature sample has the highest resistance.

CURRENT MAPS

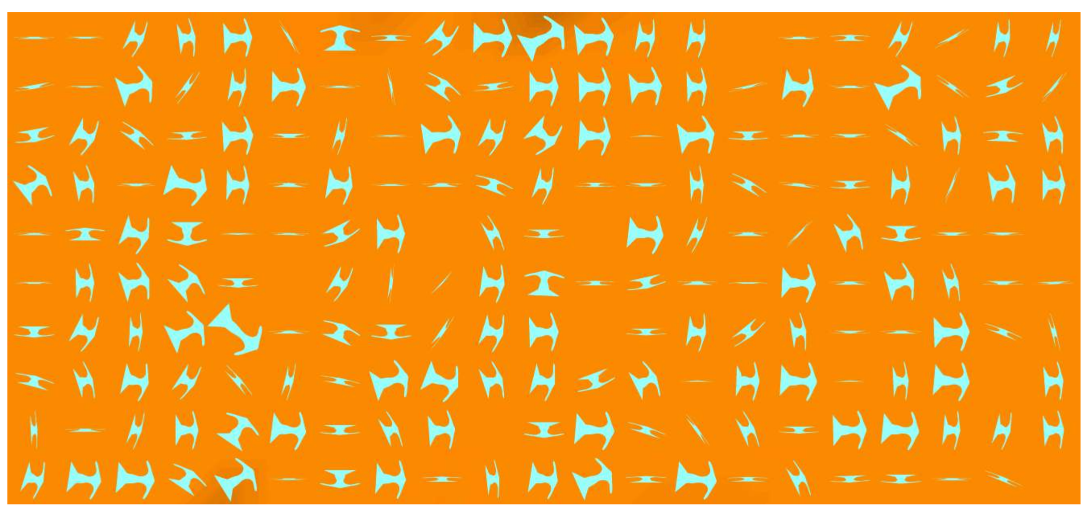
We now examine maps of the current flow to determine that activated transport through superconducting islands in a normal sea drives the emergence of the magnetoresistance peak. Six maps are plotted with increasing magnetic field at the points shown in Fig. 3.

The maps demonstrate that the transition proceeds through the emergence of weak superconducting links, that cause the current to flow down a single channel.

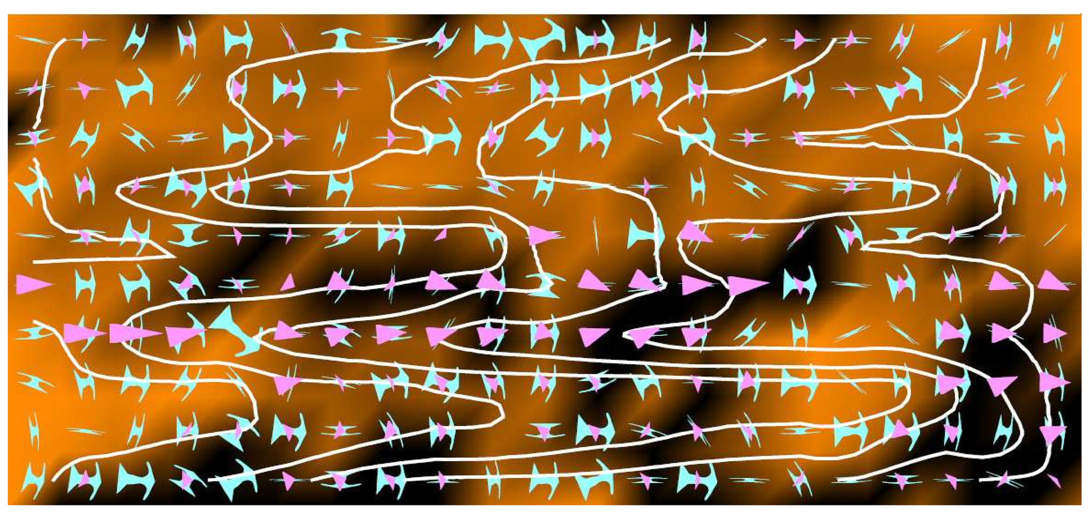
The magenta pointers denote normal current flow, the cyan arrows supercurrent, the white lines denote equipotentials dropped across the sample, and the background shading shows the superconducting order parameter.



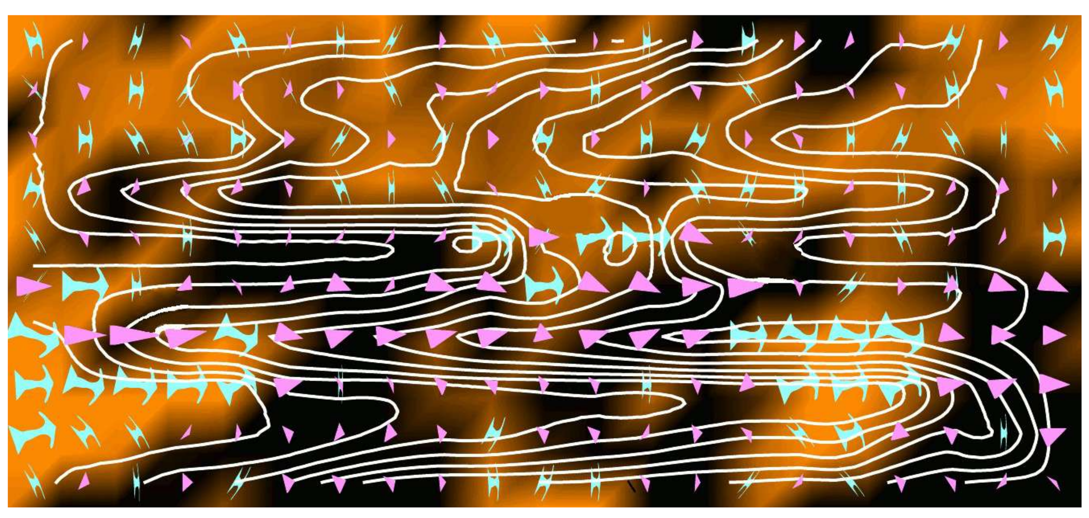
(i) At low magnetic field only supercurrent flows and no potential is dropped across the sample.



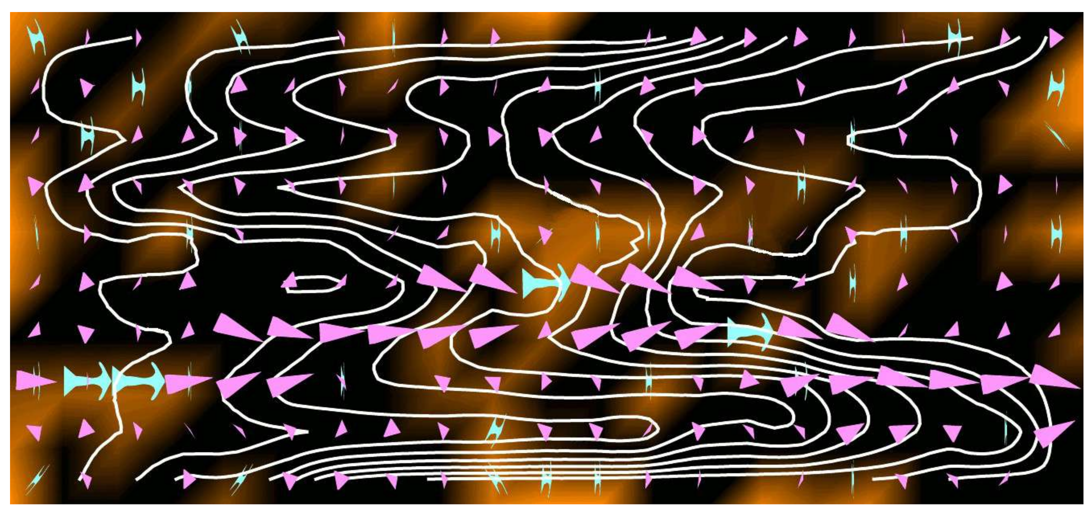
(ii) With rising magnetic field current flow is predominantly superconducting though small normal regions start to emerge.



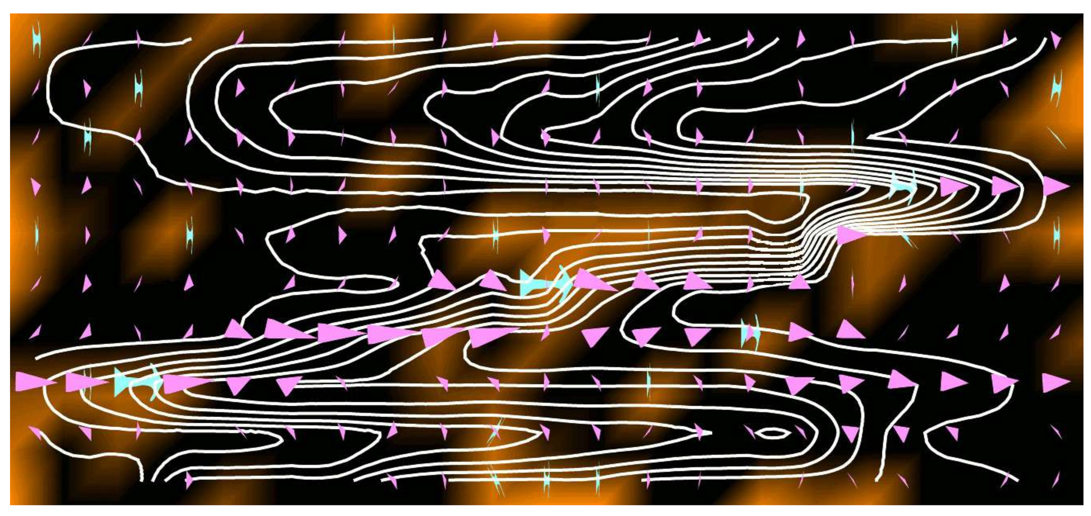
(iii) A single conduction channel starts to dominate with equal contributions from super and normal current, and weak links emerge.



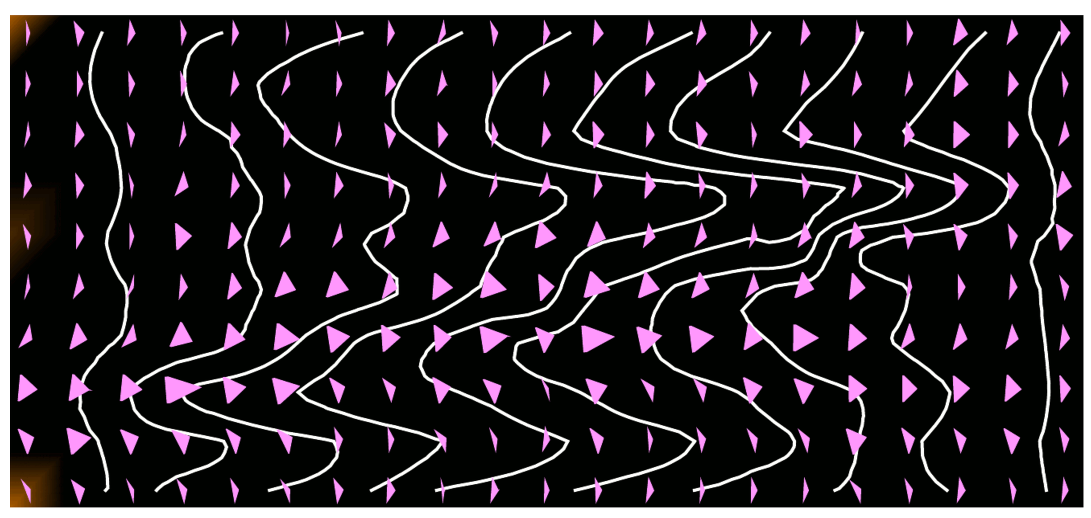
(iv) Current flows through a single normal channel, with superconducting islands that act as weak links.



(v) The remaining superconducting islands are destroyed, and current flow is almost entirely normal.



(vi) Only normal current flows, and it is relatively uniform across the sample.



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