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UCSB Physicists Apply Einstein's Theory to Superconducting Circuits

In recent years, UC Santa Barbara scientists showed that they could reproduce a basic superconductor using Einstein's general theory of relativity. Now, using the same theory, they have demonstrated that the Josephson junction could be reproduced. The results are explained in a recent issue of the journal Physical Review Letters.

The Josephson junction, a device that was first discovered by Brian David Josephson in the early 1960's, is a main ingredient in applications of superconductivity.

Gary Horowitz, professor of physics at UCSB, said that Einstein's general theory of relativity -- which was developed as a theory of gravity and is extremely successful in explaining a wide variety of gravitational phenomena -- is now being used to explain several aspects of non-gravitational physics.

"The basic phenomenon with Josephson junctions is that you can take two superconductors, separate them by a little gap, and still find current going across it, in a specific way," said Horowitz. "And that has found many applications. So the Josephson junction is something we've reproduced using general relativity."

Horowitz said that he and his co-authors used tools from string theory to develop the gravity model of a superconductor. He explained that it was surprising to be able to link Einstein's general theory of relativity to a totally different area of physics. He said he hoped that the new tools would one day be able to shed light on new types of superconductors.

"Most materials, if you cool them down sufficiently, will actually conduct electricity without any resistance," said Horowitz. "These are superconductors. There is a standard theory of superconductivity, discovered about 50 years ago, that has worked well for most of the so-called conventional superconductors."

A new class of materials was discovered 25 years ago. These are superconductors that have zero resistance at somewhat higher temperatures. Physicists are still working on understanding the mechanism.

This new class of materials involves copper-oxygen planes. Another new class of superconductors, based on iron instead of copper, was discovered a couple of years ago. These materials, called iron nictides, also have the property of superconducting at a higher temperature.

"There is a lot of activity and interest in understanding these materials," said Horowitz. "Ultimately, the goal is to have a room-temperature superconductor, which, you can imagine, would have lots of interesting applications."

Horowitz and his research team found what could be called a gravitational model, or a gravitational dual -- a dual description of a superconductor using gravity, black holes, and all of the traditional ingredients of general relativity. "This came as quite a surprise because this is a totally different area of physics, which is now being connected to this condensed matter area," said Horowitz.

The co-authors of the paper are postdoctoral fellow Jorge E. Santos and graduate student Benson Way.

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[Gary Horowitz]

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