A “theory of everything” is said to solve its first real-world problem

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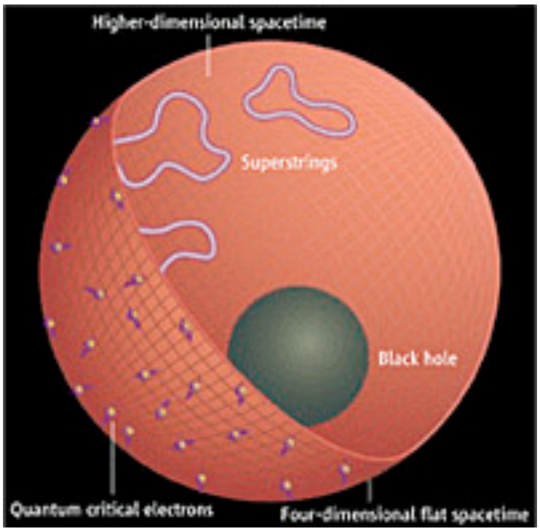
Courtesy University of Leiden and World Science staff



For the first time, researchers say they have solved a real-world problem using a very abstract “theory of everything” that often has been criticized as untestable.

Now, the scientists claim, the critics may have to rethink their position.

The scientists attempted to use the controversial doctrine, known as string theory, to explain an aspect of super-conductivity—a phenomenon in which electric current zooms through an object without meeting any of the normal resistance.

String theory is a bid to resolve almost all the mysteries of physics at a blow by bridging the gap between the two most successful theories of the 20th century, general relativity and quantum mechanics. Each has been successful at explaining how the universe behaves over vast distances and in tiny spaces, respectively. But they conflict in some ways; both can’t be right.

String theory claims all the particles of nature are actually different vibrations of unseen, tiny loops called “strings.” The theory mathematically fixes the major inconsistencies between the other two. In the process, if it’s correct, it would show the underlying unity of nature’s forces.

But it only works if the strings have several extra dimensions in which to vibrate beyond the dimensions we see. Different versions of string theory propose 10 or 26 dimensions, some of which are invisible because they are rolled up into tiny balls.

Scientists at the University of Leiden in the Netherlands used the mathematics of string theory to understand so-called high-temperature superconductivity. The effortless shooting of current through “superconducting” materials was once believed to occur only at temperatures so absurdly cold as to make practical applications of the phenomenon unlikely. But more and more examples are coming up where it also occurs at higher temperatures, according to the Leiden physicists.

Electrons, the subatomic particles that carry electric current, can form a special kind of state, a so-called quantum critical state, that plays a role in this high-temperature super-conductivity.

“It has always been assumed that once you understand this quantum-critical state, you can also understand high temperature super-conductivity. But, although the experiments produced a lot of information, we hadn’t the faintest idea of how to describe this phenomenon,” said Leiden physicist Jan Zaanen.

String theory now offers a solution, he added. “This is superb. I have never experienced such euphoria,” he remarked, explaining that the numbers fit so precisely that he was astonished. The finding is reported this week in the research journal Science.

Zaanen describes the quantum-critical state as a “quantum soup,” whereby the electrons form a collective independent of distances, where the electrons exhibit the same behaviour at small quantum mechanical scale or at macroscopic human scale.

Because of Zaanen’s interest in string theory, he and string theoreticist Koenraad Schalm became acquainted after Schalm’s arrival at Leiden University. Zaanen had an unsolved problem and Schalm was an expert in the field of string theory. Their common interest brought them together, and they decided to work jointly on the research.
The pair used the aspect of string theory known as AdS/CFT correspondence. This allows situations in a large, so-called relativistic, world to be translated into a description at minuscule, so-called quantum physics level. This correspondence bridges the gap between these two different worlds. By applying the correspondence to the theoretical situation where a black hole vibrates when an electron falls into it, they arrived at a description of electrons that move in and out of a quantum-critical state.

This is the first time a calculation based on string theory has been published in Science, even though the theory is widely known, Zaanen said.

“There have always been a lot of expectations surrounding string theory,” Zaanen explained, having himself studied the theory to satisfy his own curiosity. “String theory is often seen as a child of Einstein that aims to devise a revolutionary and comprehensive theory, a kind of ‘theory of everything’. Ten years ago, researchers even said: ‘Give us two weeks and we’ll be able to tell you where the Big Bang came from.’ The problem of string theory was that, in spite of its excellent maths, it was never able to make a concrete link with the physical reality—the world around us.”

“AdS/CFT correspondence now explains things that colleagues who have been beavering away for ages were unable to resolve, in spite of their enormous efforts,” he went on. “There are a lot of things that can be done with it. We don’t fully understand it yet, but I see it as a gateway to much more.”

I*mage: ‘AdS/CFT’ correspondence that relates a gravity - determined world in a higher dimension to 'quantum critical' worlds formed, for example, by electrons in a lower dimensional world on the 'out side' of the first world. (Courtesy Science)*