Theorists probe the relationship between 'strange metals' and high-temperature superconductors

21 November 2019, by Glennda Chui

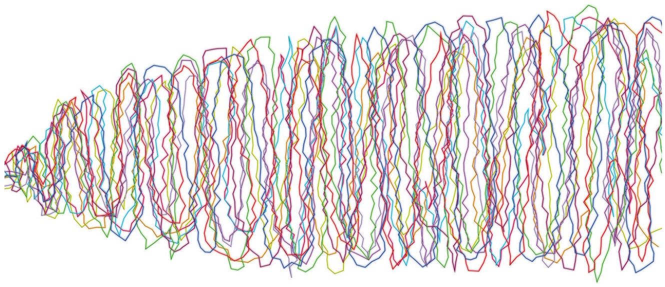

Illustration of a Monte Carlo simulation, where a calculation is run billions of times in slightly different ways to arrive at a range of possible results (far right), which are then averaged to determine the exact result. Each colored line represents a different run. A study at SLAC and Stanford used Monte Carlo simulations to make the first unbiased observations of a phenomenon called 'strange metallicity' in a model that describes correlated materials, where electrons join forces to produce unexpected phenomena such as superconductivity. Credit: Greg Stewart/SLAC National Accelerator Laboratory

Strange metals make interesting bedfellows for a phenomenon known as high-temperature superconductivity, which allows materials to carry electricity with zero loss.

Both are rule-breakers. Strange metals don't behave like regular metals, whose electrons act independently; instead their electrons behave in some unusual collective manner. For their part, high-temperature superconductors operate at much higher temperatures than conventional superconductors; how they do this is still unknown.

In many high-temperature superconductors, changing the temperature or the number of free-flowing electrons in the material can flip it from a superconducting state to a strange metal state or vice versa.

Scientists are trying to find out how these states are related, part of a 30-year quest to understand how high-temperature superconductors work so they can be developed for a host of potential applications, from maglev trains to perfectly efficient power transmission lines.

In a paper published today in *Science*, theorists with the Stanford Institute for Materials and Energy Sciences (SIMES) at the Department of Energy's SLAC National Accelerator Laboratory report that they have observed strange metallicity in the Hubbard model. This is a longstanding model for simulating and describing the behavior of materials with strongly correlated electrons, meaning that the electrons join forces to produce unexpected phenomena rather than acting independently.

Although the Hubbard model has been studied for decades, with some hints of strange metallic behavior, this was the first time strange metallicity had been seen in Monte Carlo simulations, in which billions of separate and slightly different calculations are averaged to produce an unbiased result. This is important because the physics of these systems can change drastically and without warning if any approximations are introduced.

The SIMES team was also able to observe strange metallicity at the lowest temperatures ever explored with an unbiased method—temperatures at which the conclusions from their simulations are much more relevant for experiments.

The scientists said their work provides a foundation for connecting theories of strange metals to models of superconductors and other strongly correlated materials.

More information: "Strange metallicity in the doped Hubbard model" *Science* (2019). science.sciencemag.org/cgi/doi … 1126/science.aau7063

Provided by SLAC National Accelerator Laboratory