Physicists create guidelines for non-equilibrium measurements of many-body systems

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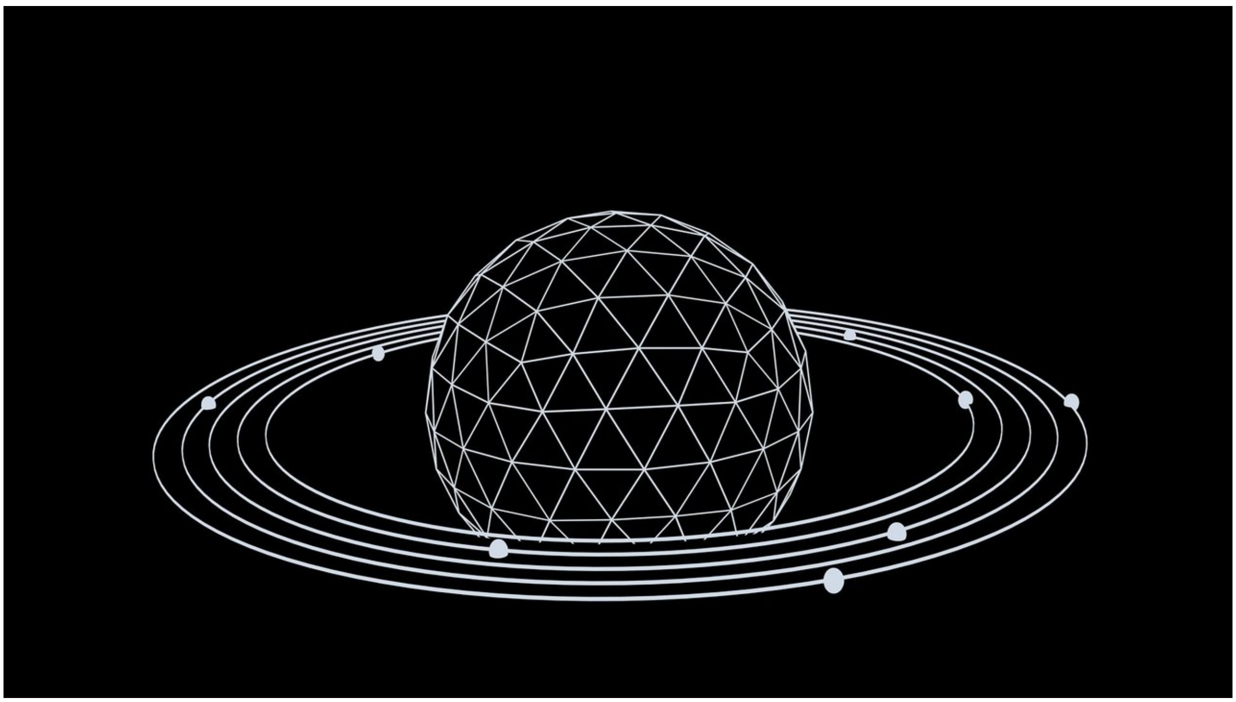

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When it comes to non-equilibrium physics, not all assumptions are created equal. At least, those are the latest findings from NC State physicist Lex Kemper and colleagues from NC State and Georgetown University.

Kemper studies non-equilibrium physics, which aims to understand complex materials by pushing their atoms and electrons out of equilibrium and then observing their interactions over time. In his latest work, published in *Physical Review X*, Kemper and his colleagues note that electrons in materials in a non-equilibrium state don't necessarily behave in the same way that materials in equilibrium do, which could affect experimental results.

"We have a very good understanding of equilibrium physics and that's what most of our understanding of non-equilibrium physics has relied on," Kemper says. "Essentially, physicists have used equilibrium analysis techniques to analyze experimental data from non-equilibrium materials. But we wondered whether these techniques should work in non-equilibrium cases. So we tested it and found that most of the previously held assumptions don't work generally – they can still work in some specific cases, but not all."

Why is this the case? It has to do with the way in which the electrons in a material in equilibrium relax from an excited state versus the way in which those in a non-equilibrium material relax back to their equilibrium state, which is what's measured in time domain experiments.

"When you observe an electron in a system that's sitting in equilibrium, for every motion that it makes in one direction, it makes another in the opposite direction," Kemper says. "Think of it like two small buckets, everything that goes into one is equal to the amount that goes out of the other. But when you've driven the system out of equilibrium, the net in and out are not the same anymore. When that system returns to equilibrium, the atoms and electrons could be in different states, which will affect interactions and thus the resulting observations."

Kemper and his colleagues looked at four different commonly held assumptions about behavior of equilibrium materials, and demonstrated how materials in non-equilibrium states can behave differently. Kemper hopes that his work will help other physicists studying materials out of equilibrium states consider these differences in their calculations and measurements.

"The idea that these systems behave differently isn't new, but [this viewpoint] hasn't really been quantified or written down anywhere," Kemper says. "Non-equilibrium physics is a growing field and we hope that we've provided some general principles to follow when researchers work with these systems."

More information: A. F. Kemper et al. General Principles for the Nonequilibrium Relaxation of Populations in Quantum Materials, *Physical Review X* (2018). DOI: 10.1103/PhysRevX.8.041009

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