Quantum physicists identify „fingerprints“ of fundamental physical effects

A thrilling crime plot and modern solid-state physics have more in common than one would think: In the first case, all aspects of the crime scene must be carefully examined in the hope of finding possible clues. These are crucial to identify the perpetrators and hence to solve the case. Similarly in solid-state physics: Instead of crime scenes, it is many-electron systems that leave the researchers puzzled. These are complex quantum systems in which 100,000,000,000,000,000,000,000 electrons interact with each other.

This interaction is established through microscopical processes, through which the electrons exchange energy and momentum, in technical jargon they are referred to as "scattering processes". Among other properties, they determine the mobility of the charge carriers and thus control, whether the system ultimately exhibits a metallic, insulating or even superconducting behavior. With the help of extensive computer simulations, it is attempted to nail down the physical properties of these complex systems. However, instead of searching for perpetrators, condensed matter researchers aim at finding answers to fundamental questions, for example: *“How do unconventional superconductors work”* or *“How do quantum physical phase transitions take place at absolute zero”*?

An international research team of Prof. Sabine Andergassen at the Institute for Theoretical Physics at the University of Tübingen, Patrick Chalupa, Matthias Reitner, Dr. Daniel Springer and Prof. Alessandro Toschi from the TU Wien and Dr. Thomas Schäfer (meanwhile research group leader at the Max Planck Institute for Solid State Reserach in Stuttgart) from the École Polytechnique in Paris has achieved an important progress in this respect. An in-depth analysis of the scattering processes and their comparison in different physical situations allowed for the identification of clear-cut “fingerprints”. The results of the study were published in the journal Physical Review Letters.

Similarly to forensic scientists at a crime scene, the researchers tried to connect many small details to see the bigger picture. They succeeded in identifying characteristic structures in the complex mathematical quantities that describe the scattering processes and to relate these structures to two fundamental phenomena of solid-state physics. These turned out to be the formation of local magnetic moments as well as their screening due to the so-called Kondo effect, phenomena that crucially control the mobility of electrons. By determining these “fingerprints” it was even possible to discover a new alternative criterion for determining one of the most fundamental energy scales in theoretical solid-state physics: the Kondo temperature.

Eventually, these findings could shed new light on a for decades unsolved crime in solid-state physics: unconventional superconductivity in strongly correlated quantum materials. The correct determination of the underlying quantum fingerprints could put research on the right track to understand these systems at a fundamental level.

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