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Press Release

Heisenberg uncertainty frustration - Quantum systems torn between liquid and solid states

Tübingen and Konstanz researchers discover a quantum mechanism unparalleled in classical physics

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Phase transitions in physics are common everyday occurences, for example melting: when a solid is heated, its atoms move more freely, and the solid abruptly becomes a liquid. In contrast, quantum phase transitions are not visible to us in our daily lives and pose many questions for science. Now Professor Sabine Andergassen and Dominik Maile at the University of Tübingen, working with Professor Wolfgang Belzig and Dr. Gianluca Rastelli at the University of Konstanz have used theoretical calculations to investigate what effects and mechanisms determine the physical behavior in the proximity of a quantum phase transition.
They discovered strange behavior linked to Heisenberg's uncertainty principle - and which could affect data processing in a proposed quantum computer. Their findings have been published in *Physical Review B*.

At the absolute zero there is no motion due to temperature, only quantum fluctuations. Phase transitions in a quantum system may be set off by changes in pressure or magnetic field. These have a comparable effect to that of heat on atoms in condensed matter. “This dynamic is influenced by the interaction of the quantum system with its environment. It is generally described as dissipation,” Sabine Andergassen explains. Dissipation means that the potential of the system is restricted by energy loss or by the particles’ inability to move. Dissipation quenches some quantum fluctuations, favoring an ordered state - the “solid” - instead of a disordered state - the “liquid,” she says.

“As Heisenberg’s uncertainty principle dictates, this leads to an increase of the fluctuations of the momentum,” Wolfgang Belzig adds. When the system interacts with two environments trying to quench the fluctuations of two conjugate variables simultaneously, Heisenberg’s principle prohibits this. You could say the system becomes frustrated, because it fundamentally cannot satisfy both demands at the same time,” says Dominik Maile. Gianluca Rastelli adds: “At a quantum phase transition un unexpected behavior may emerge.” In the comparison with melting in classical physics, the quantum system would be torn between the solid and the liquid states.

“This competition between different dissipative mechanisms leads to a peculiar behavior at the transition,” Gianluca summarizes. This represents a genuine quantum signature and paves the way to study novel aspects of dissipative quantum phase transitions using engineered environments. This newly-discovered characteristic could have an influence in the field of information processing, for example by a quantum computer, the researchers say.

Publication:

D. Maile, S. Andergassen, W. Belzig, and G. Rastelli: Quantum phase transition with dissipative frustration. *Physical Review B 97, 155427 (2018)*
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