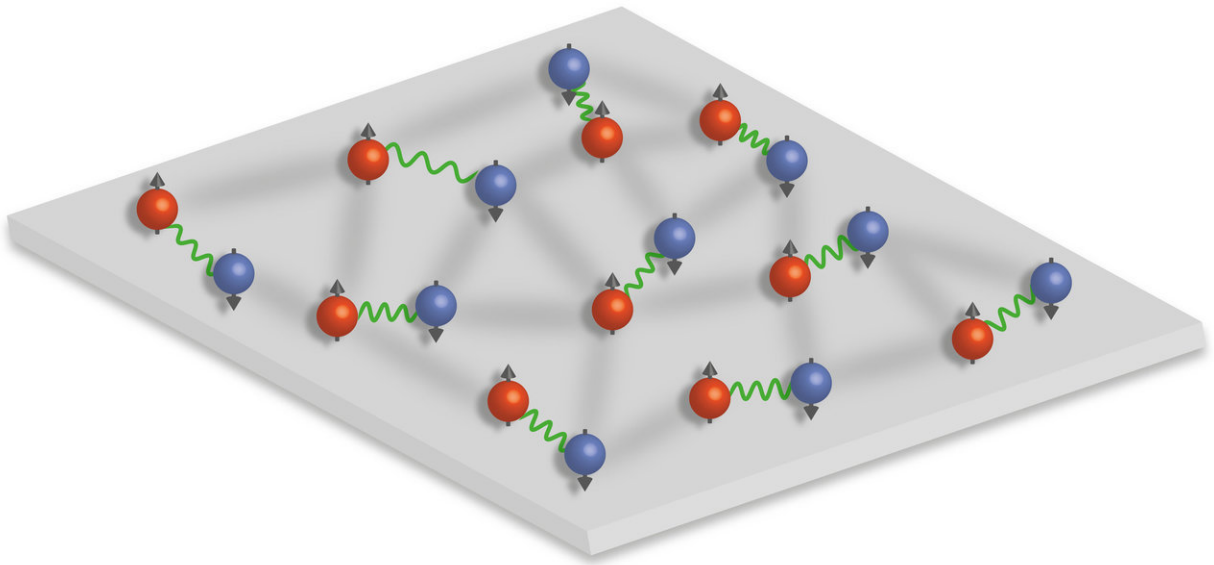


# Physicists find evidence of an exotic state of matter

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In a known and well-understood scenario, pairing is caused solely by the attraction between two fermions (green lines). However, Heidelberg scientists found that with strong interactions between the fermions, a different type of pairing takes place, which strongly depends on the density of the surrounding medium (gray shaded regions). This suggests that in this state, each particle is not only paired with one other particle, but that there are additional correlations with other particles in its surroundings. Credit: Puneet Murthy

Using ultracold atoms, researchers at Heidelberg University have found an exotic state of matter where the constituent particles pair up when

limited to two dimensions. The findings from the field of quantum physics may hold important clues to intriguing phenomena of superconductivity. The results were published in *Science*.

Superconductors are materials through which electricity can flow without any resistance once they are cooled below a certain critical temperature. The technologically most relevant class of materials, with exceptionally high critical temperatures for superconductivity, is poorly understood so far. There is evidence, however, that in order for superconductivity to occur, a certain type of particles – the [fermions](#) – must pair up. Moreover, research has shown that materials which become superconducting at relatively high temperatures have layered structures. "This means that electrons in these systems can only move in two-dimensional planes", explains Prof. Dr. Selim Jochim of Heidelberg University's Institute for Physics, who heads the project. "What we did not understand until now was how the interplay of pairing and dimensionality can lead to higher critical temperatures."

To explore this question, researchers at the Center for Quantum Dynamics performed experiments in which they confined a gas of ultracold [atoms](#) in two-dimensional traps which they created using focused laser beams. "In solid-state materials like copper oxides, there are many different effects and impurities that make these [materials](#) difficult to study. That is why we use [ultracold atoms](#) to simulate the behaviour of electrons in solids. This allows us to create very clean samples and gives us full control over the essential system parameters", says Puneet Murthy, a Ph.D. student at the Center for Quantum Dynamics at Heidelberg University and one of the lead authors of this publication.

Using a technique known as radio-frequency spectroscopy, the researchers measured the response of the atoms to a radio-wave pulse. From this response, they could tell exactly whether or not the particles

were paired and in what way. These measurements were also performed for different strengths of interaction between fermions. In the course of the experiments, the researchers discovered an exotic state of matter. Theory states that fermions with a weak interaction should pair up at the temperature at which they become superconductive. However, when the scientists increased the interaction between fermions, they found that pairing occurred at temperatures several times higher than the critical [temperature](#).

"To achieve our ultimate goal of better understanding these phenomena, we will start with small systems that we put together atom by atom", says Prof. Jochim.

**More information:** Puneet A. Murthy et al. High-temperature pairing in a strongly interacting two-dimensional Fermi gas, *Science* (2017).

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