

Pseudogap theory puts physicists closer to high temperature superconductors

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Physicists are one step closer to developing the world's first room-temperature superconductor thanks to a new theory from the University of Waterloo, Harvard and Perimeter Institute. Right to left: Prof. David Hawthorn, Prof. Roger Melko, and Lauren Hayward. They are pictured in front of Waterloo's SHARCNET supercomputer which they used to perform the calculations. Credit: University of Waterloo

(Phys.org) —Physicists are one step closer to developing the world's first

room-temperature superconductor thanks to a new theory from the University of Waterloo, Harvard and Perimeter Institute.

The theory explains the transition phase to superconductivity, or "pseudogap" phase, which is one of the last obstacles to developing the next generation of superconductors and one of the major unsolved problems of theoretical [condensed matter physics](#).

Their work was published in this week's issue of the prestigious journal *Science*.

Superconductivity is the phenomenon where electricity flows with no resistance and no energy loss. Most materials need to be cooled to ultra-low temperatures with liquid helium in order to achieve a superconductive state.

The team includes Professor Roger Melko, Professor David Hawthorn and doctoral student Lauren Hayward from Waterloo's Physics and Astronomy Department, and Harvard Physics Professor Subir Sachdev. Roger Melko also holds a Canada Research Chair in Computational Quantum Many-Body Physics.

"This amazing scientific collaboration actually came about by chance over lunch at the Perimeter Institute between Subir and myself," said Hawthorn.

Hawthorn showed Sachdev his latest experimental data on a superconducting material made of Copper and the elements Yttrium and Barium. The material, $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$, had an unexplained temperature dependence. Sachdev had a theory but needed expert help with the complex set of calculations to prove it. That's where Melko and Hayward stepped in and developed the computer code to solve Sachdev's equations.

Melko and Sachdev already knew each other through Perimeter Institute, where Melko is an associate faculty member and Sachdev is a Distinguished Research Visiting Chair.

"The results all came together in a matter of weeks," said Melko. "It really speaks to the synergy we have between Waterloo and Perimeter Institute."

To understand why [room-temperature superconductivity](#) has remained so elusive, physicists have turned their sights to the phase that occurs just before superconductivity takes over: the mysterious "pseudogap" phase.

"Understanding the pseudogap is as important as understanding superconductivity itself," said Melko.

The cuprate, $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$, is one of the few materials known to be superconductive at higher temperatures, but scientists are so far unable to achieve superconductivity in this material above -179°C . This new study found that $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ oscillates between two quantum states during the pseudogap, one of which involves charge-density wave fluctuations. These periodic fluctuations in the distribution of the electrical charges are what destabilize the superconducting state above the critical temperature.

Once the material is cooled below the critical temperature, the strength of these fluctuations falls and the superconductivity state takes over.

Superconducting magnets are currently used in MRI machines and complex particle accelerators, but the cost of cooling materials using Helium makes them very expensive. Materials that achieve [superconductivity](#) at a higher temperature could unlock the technology for new smart power grids and advanced power storage units.

The group plans to extend their work both theoretically and experimentally to understand more about the fundamental nature of cuprates.

More information: "Angular Fluctuations of a Multicomponent Order Describe the Pseudogap of $\text{YBa}_2\text{Cu}_3\text{O}_{6+x}$ " *Science*, 2014.

Provided by University of Waterloo

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