Physicists find new order in quantum electronic material

Two Rutgers physics professors have proposed an explanation for a new type of order, or symmetry, in an exotic material made with uranium—a theory that may one day lead to enhanced computer displays and data storage systems and more powerful superconducting magnets for medical imaging and levitating high-speed trains.

Their discovery, published in this week's issue of the journal *Nature*, has piqued the interest of scientists worldwide. It is one of the rare theory-only papers that this selective publication accepts. Typically the journal's papers describe results of laboratory experimentation.

Collaborating with the Rutgers professors was a postdoctoral researcher at Massachusetts Institute of Technology (MIT) who earned her doctorate at Rutgers.

"Scientists have seen this behavior for 25 years, but it has eluded explanation." said Piers Coleman, professor in the Department of Physics and Astronomy in the School of Arts and Sciences. When cooled to 17.5 degrees above absolute zero or lower (a bone-chilling -428 F), the flow of electricity through this material changes subtly.

The material essentially acts like an electronic version of polarized sunglasses, he explains. Electrons behave like tiny magnets, and normally these magnets can point in any direction. But when they flow through this cooled material, they come out with their magnetic fields aligned with the material's main crystal axis.

This effect, claims Coleman, comes from a new type of hidden order, or symmetry, in this material's magnetic and electronic properties. Changes in order are what make liquid crystals, magnetic materials and superconductors work and perform useful functions.

"Our quest to understand new types of order is a vital part of understanding how materials can be developed to benefit the world around us," he said.

Similar discoveries have led to technologies such as liquid crystal displays, which are now ubiquitous in flat-screen TVs, computers and smart phones, although the scientists are quick to acknowledge that their theoretical discovery won't transform high-tech products overnight.

Coleman, along with Rutgers colleague Premala Chandra and MIT collaborator Rebecca Flint, describe what they call a "hidden order" in this compound of uranium, ruthenium and silicon. Uranium is commonly known for being nuclear reactor fuel or weapons material, but in this case physicists value it as a heavy

metal with electrons that behave differently than those in common metals.

Recent experiments on the material at the National High Magnetic Field Laboratory at Los Alamos National Laboratory in New Mexico provided the three physicists with data to refine their discovery.

“We’ve dubbed our fundamental new order ‘hastatic’ order, named after the Greek word for spear,” said Chandra, also a professor in the Department of Physics and Astronomy. The name reflects the highly ordered properties of the material and its effect on aligning electrons that flow through it.

“This new category of order may open the world to new kinds of materials, magnets, superconductors and states of matter with properties yet unknown,” she said. The scient [1]ists have predicted other instances where hastatic order may show up, and physicists are beginning to test for it.

The scientists’ work was funded by the National Science Foundation and the Simons Foundation. Flint is a Simons Postdoctoral Fellow in physics at MIT.

Hastatic order in the heavy-fermion compound URu2Si2 [1]

Condensed-matter physics: Hidden is more [2]

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