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## Tippy Superfluids: Glimpsing off-kilter quantum clouds

Peter Weiss

Physicists last year created an exotic state of matter previously unattainable in the laboratory but whose characteristics theorists have debated for more than 40 years. The latest probes of the new state suggest that the material—a cloud of ultracold atoms that's imbalanced with regard to a quantum property known as spin—behaves differently than most theorists had anticipated.

The new findings promise physicists a deeper understanding of superfluidity, a condition in which a fluid flows without resistance. The results may also provide insight into superconductivity, a form of superfluidity in which paired electrons flow without resistance.

The studies apply, in particular, to superfluids made up of particles known as fermions. The fermion-particle family includes electrons, protons, neutrons, quarks, and many atoms. All fermions have spin, a magnetic trait analogous to the spinning of a top. When two similar fermions meet and have opposite spins—designated as spin-up and spin-down—they'll often form a pair.

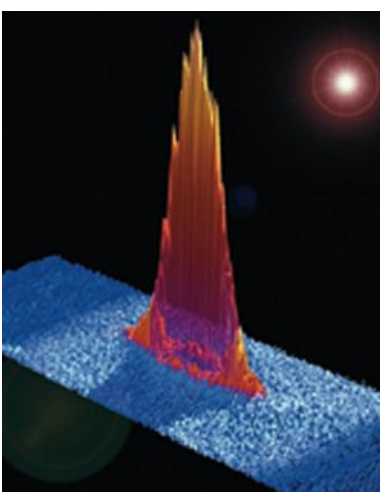
Scientists have long wondered whether superfluidity in a fermionic fluid could persist in the face of a spin imbalance, when there are more fermions with one spin than with the other. Many theorists had expected that if this condition came about, the superfluid would contain alternating bands of superfluid and normal fluid.

Spin imbalance in nature is difficult or impossible to study. For instance, the mismatch occurs in complex, poorly understood, extremely unusual compounds known as heavy-fermion superconductors, which are both magnetic and superconductive. A similar discrepancy is expected in such celestial objects as neutron stars.

However, since the late 1990s, laboratory researchers have confined fermionic atoms, such as lithium-6, in traps and then chilled the particles to nearly absolute zero, so that the particles coalesced into what are known as superfluid fermionic condensates (SN: 9/11/99, p. 166). Physicists can then use these condensates as models of experimentally inaccessible substances such as the innards of neutron stars (SN: 9/18/04, p. 186: <http://www.sciencenews.org/articles/20040918/bob9.asp>).

At the American Physical Society meeting in Baltimore last week, several physicists discussed the latest twist on such studies—making fermionic condensates from unequal numbers of spin-up and spin-down lithium-6 atoms.

Independent teams led by Wolfgang Ketterle of the Massachusetts Institute of Technology (MIT) and by Randall G. Hulet of Rice University



**MISMATCH MAKER.** In this density plot of a spin-imbalanced lithium cloud, the transparent center of the plot depicts a region of paired atoms that lies within a shell of excess, unpaired atoms.  
G. Partridge/Rice Univ.



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11. Bright Lights, Big Cancer
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14. Self-Serve Brains
15. Don't look now, but is that dog laughing?



in Houston recently explored polarization in condensates by using radio waves to flip the spins of varying portions of the condensates' atoms. Both teams have reported evidence that some superfluidity persists even if the condensate is skewed so that as many as 70 percent of its atoms are of one spin type.

Yet none of the experiments observed signs of the banded superfluid—normal fluid that theorists have anticipated since the 1960s, notes theorist Tin-Lun (Jason) Ho of Ohio State University in Columbus—a finding he calls "great progress."

The Rice team reports additional findings that the MIT group disputes. For example, the Houston scientists say that they've observed evidence of a superfluid with unpaired atoms interspersed among paired atoms. That finding is "astounding," Ho says. "This state is not supposed to exist according to conventional theory."

Although the disputed Rice results "are really intriguing and exciting," says Harvard University theorist Eugene Demler, "we don't understand them so well yet."

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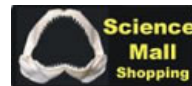
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Eugene Demler  
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Lyman 329  
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Tin-Lun Ho  
Department of Physics  
Ohio State University  
191 W. Woodruff Avenue  
Columbus, OH 43210-1117

Randall G. Hulet  
Department of Physics and Astronomy  
Rice Quantum Institute  
Rice University  
Houston, TX 77251

Wolfgang Ketterle  
Department of Physics  
Massachusetts Institute of Technology  
Cambridge, MA 02139

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