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Ultra-cold Fermi gases enter new regime

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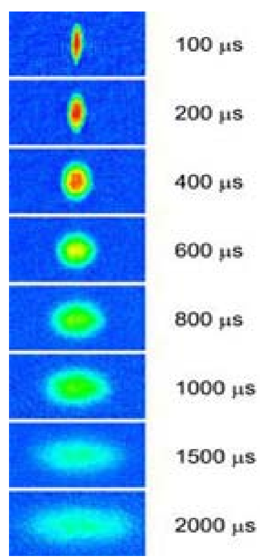
Physicists have created the first Fermi gas of atoms that is both strongly interacting and highly degenerate. John Thomas and co-workers at Duke University in the US think that the gas might even exhibit a new type of superfluidity because of its unusual expansion characteristics - see figure (K M O'Hara *et al*. 2002 *Science* 298 2179).



All atoms are either fermions -- particles that have a spin quantum number of 1/2, 3/2, 5/2 and so on -- or bosons, which have integer quantum numbers for spin. Fermions obey the Pauli exclusion principle, which means that two identical fermions cannot occupy the same quantum state. Therefore, if a Fermi gas could be cooled to absolute zero, the atoms would fill up all the available energy levels up to a level known as the Fermi temperature. If all or most of these levels are occupied the gas is said to be degenerate.

The Pauli exclusion principle prevents identical atoms from approaching each other too closely. However, if the atoms can be placed in different internal states, then the exclusion principle does not apply. Thomas and co-workers therefore cooled a gas in which half of the lithium-6 atoms were in the

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lowest hyperfine state, and half were in the second lowest hyperfine state. Atoms in different internal states can be made to approach each other unusually closely in the presence of an applied magnetic field.

Physicists have predicted that a Fermi gas of atoms could become superfluid -- in other words, it could flow without friction -- at temperatures lower than the Fermi temperature. In a superfluid, atoms at relatively long distances from one another are "locked" together and behave as a single quantum system. If lithium-6 is a superfluid, Thomas says it is a special type of superfluid that would be analogous to a very high-temperature superconductor.

"The very strong attraction in our atomic system leads to a particularly strong locking together of pairs of atoms. It is in this way that our atoms behave as a superconductor," Thomas told *PhysicsWeb*. Superconductivity -- the flow of currents without resistance -- arises from the locking together of pairs of electrons.

The team now hopes to unambiguously determine that they have observed superfluid behaviour in their system. They also plan to perform further experiments to study the general behaviour of strongly interacting Fermi gases. "This, we feel is a much broader and ultimately more important area of investigation," says Thomas.

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