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Superfluidity in an Ultracold Gas of Fermion Atoms

Superfluidity in an ultracold gas of fermion atoms has been demonstrated in an experiment at MIT, where an array of vortices has been set in motion in a molecular Bose Einstein condensate (BEC) of paired lithium-6 atoms. There have been previous hints of superfluidity in Li-6, for example, (**http://www.aip.org/pnu/2004/split/681-1.html (http://www.aip.org/pnu/2004/split/681-1.html)**) but the presence of vortices observed in the new experiment clinches the case since vortices manifest the most characteristic feature of superfluidity, namely persistent frictionless flow.

Wolfgang Ketterle and his MIT colleagues use laser beams to hold the chilled atoms in place and separate laser beams to whip up the vortices. In general the quantum behavior of bosonic atoms (those whose total internal spin---the spin of the nucleus added to that of the electron retinue---is an integral number of units) and fermi atoms (those with a half-integral-valued total spin) is very different. Gaseous Li-6 represents only the second known superfluid among fermi atoms, the other being liquid helium-3. (Superconductivity is also a form of fermion superfluidity, but in this case the constituents are charged particles, electrons, unlike the neutral atoms used in the experiments described here.)

There are great advantages in dealing with a neutral superfluid in dilute gas form rather than in liquid form: in the gas phase (with a material density similar to that of the interstellar medium), inter-atomic scattering is simpler; furthermore, the strength of the pairing interaction can be tuned at will using an imposed external magnetic field. According to Ketterle, one of those who won a Nobel prize for his pioneering work with boson BECs, the study of fermionic superfluidity is much richer than for bosons: control over forces will permit researchers to vary the strength and nature of the pairing (fermi atoms must pair up before falling into BEC form) and to load atoms into an optical lattice.

Additional pairing mechanisms can also be explored. One further superlative: the ultracold lithium gas represents, in a narrow sense, the first "high-temperature" superfluid. Consider the ratio of the critical temperature (Tc) at which the superfluid transition takes place to the fermi temperature (Tf), the temperature (or energy, divided by Boltzmann's constant) of the most energetic particle in the ensemble. For ordinary superconductors, Tc/Tf is about 10^{-4}; for superfluid helium-3 it is 10^{-3}; for high-temp superconductors 10^{-2}; for the new lithium superfluid it is 0.3. (Zwierlein *et al.*, **Nature (http://www.nature.com/index.html)** , 23 June 2005) T`

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