Neutrons uncover new density waves in fermion liquids

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Scientists working at the Institut Laue-Langevin, one of the world's leading centres for neutron science, have carried out the first investigation of two-dimensional fermion liquids using neutron scattering, and discovered a new type of very short wave-length density wave. The team believe their discovery, published in *Nature*, will interest researchers looking at electronic systems, since high temperature superconductivity could result from this type of density fluctuations.

Fermi liquids are composed of strongly interacting fermion particles, a group that includes quarks, electrons, protons and neutrons. They are common in nature, found in atomic nuclei, metals, semiconductors, and neutron stars.

They are also one of two types of quantum liquid used to model and explain the complex interplay between atoms or even sub-atomic particles that is governed by quantum mechanics in a field known as 'many-body physics'.

Fermion particles are defined by their adherence to the Pauli Exclusion Principle that states that no two identical fermions can exist in the same energetic state, making fermion systems particularly complicated. As a result, whilst the other types of quantum liquid, composed of bosons like gluons and photons, are well understood in terms of their underlying physics, fermion liquids remain more mysterious.

As part of this on-going investigation a team of researchers from the

Institut Néel (Centre national de la recherche scientifique and Université J. Fourier) in France and Aalto University in Finland (Microkelvin Collaboration), Oak Ridge National Laboratory and SUNY University at Buffalo in the US, Johannes Kepler University in Austria carried out the first direct investigation of these very short wave-length elementary excitations in a fermion liquid by inelastic neutron scattering. In their study, the neutrons were focused on a one atom thick layer of helium-3, a much rarer version of helium on Earth than helium-4 that is used in balloons and airships, which acts like a Fermi liquid at temperatures close to absolute zero.

Using this scattering technique the scientists were able to observe high frequency, very short wave-length density waves known as zero-sound oscillations. The results from the scattering experiments revealed the zero sound modes to be far longer lived in this two-dimensional fluid than those seen during previous experiments at the ILL in bulk liquids, where they were strongly damped.

The discovery of these oscillations in a fermion helium liquid is particularly interesting as it's thought that if this type of high frequency density oscillation is seen in another fermion liquid, composed of electrons, this could be a mechanism for high temperature superconductivity. Once the team have completed their investigation of the properties of the helium system, their next step is to extend this understanding to electron liquids.

Dr. Henri Godfrin, Director of research at CNRS, based at the Institut Néel, a leading laboratory for fundamental research in condensed matter physics:

"People working with electron systems will be very interested to see if this property exists in their own systems and this finding suggests it is entirely possible. This is an important discovery in the field of quantum

fluids, which has direct consequences in other areas of many-body physics, particularly in understanding the makeup of metals and the physics behind neutron stars."

Provided by Oak Ridge National Laboratory

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