Exploring the behavior of a gas as it transitions between quantum and classical states

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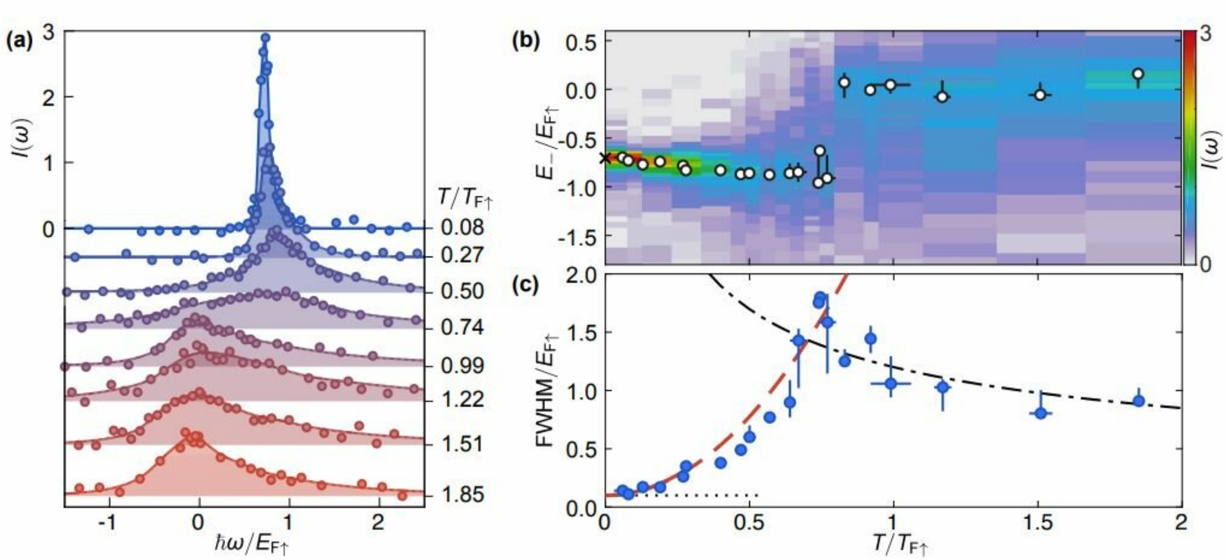

(a) Thermal evolution of the minority rf spectra. (b) 2D plot of the minority spectra with maxima highlighted by white points. Credit: arXiv:1811.00481 [cond-mat.quant-gas]

A team of researchers from the MIT-Harvard Center for Ultracold Atoms has developed a way to study and measure gases as they transition between quantum and classical states due to changes in temperature. In their paper published in the journal *Physical Review Letters*, the group describes experiments they carried out with clouds of lithium-6 atoms and what they found.

Boltzmann gases are made up of particles with negligible volume and perfectly elastic collisions—they are described, naturally enough, by Boltzmann's kinetic theory. In such a gas, particles move around in random fashion and frequently collide. Prior research has shown that if a Boltzmann gas is cooled sufficiently, it undergoes a transformation so radical that it can only be described in quantum terms. Furthermore, if the particles that make up the gas are fermions, the result can be described using Fermi liquid theory. Notably, the process can move in either direction. In this new effort, the researchers have developed a way to monitor and measure the changes that occur as the gas transitions between a quantum state and a classic one.

In order to study the transition, the researchers used quasiparticles as a way to measure the properties of the Fermi gas—more specifically, they created a cloud of lithium-6 atoms using what is known as a "laser box." They then cooled the box and its contents and monitored what happened inside using ejection spectroscopy, where photons flip the internal state of impurities such that they do not interact with the gas. They were then able to use the number of atoms that were flipped to gauge the energy of the photons, and then calculate the excitations of the gas. This allowed them to calculate the energy and decay rates of the quasiparticles.

The group also conducted an experiment to measure the quasiparticles at different temperatures, which allowed them to see what actually occurred as the gas transitioned. They note that as the temperature rose, the peak spectrum lost energy and became broader. Eventually, the quasiparticles lost their identity, and at this point, Fermi theory began to unwind. They also report that just below the point where Fermi theory became applicable, there was a sharp change in the energy of the spectrum peak, which eventually dropped to zero.

More information: Zhenjie Yan et al. Boiling a Unitary Fermi Liquid, *Physical Review Letters* (2019). DOI: 10.1103/PhysRevLett.122.093401 , arxiv.org/abs/1811.00481