Potential new applications stem from controlling particles' spin configurations

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Fermions are ubiquitous elementary particles. They span from electrons in metals, to protons and neutrons in nuclei and to quarks at the sub-nuclear level. Further, they possess an intrinsic degree of freedom called spin with only two possible configurations, either up or down. In a new study published in *EPJ B*, theoretical physicists explore the possibility of separately controlling the up and down spin populations of a group of interacting fermions. Their detailed theory describing the spin population imbalance could be relevant, for instance, to the field of spintronics, which exploits polarised spin populations.

Imbalanced Fermi particle mixtures occur in matter like, for example, semiconductors placed in a magnetic field, in nuclear matter, and in the plasma of neutron stars, which combines the elementary sub-particles quarks and gluons. Pierbiagio Pieri and Giancarlo Calvanese Strinati from the University of Camerino, Italy, focused on an interacting fermion system where the up and down spin populations are imbalanced. They extended the proof of a theorem that was originally conceived for the exact theory of a Fermi liquid with equal populations of up and down spin, called the Luttinger theorem, to these imbalanced systems.

Previous experimental observations involved separately controlling the number of fermions with a given spin, leading to free movement with no viscosity in the gas particles, reaching a superfluid state. The work by Wolfgang Ketterle and his group at MIT, USA, in 2008, also demonstrated that the difference between two spin populations can be made so large that superfluidity is destroyed and the system remains

normal even at zero temperature.

In turn, this latest theoretical work introduces a constraint that is key to numerical calculations for such large quantum many-body systems, namely that the radii of the two Fermi spheres, which characterise the non-interacting systems of spin-up and spin-down fermions, are separately preserved when the interaction between the spin-up and spin-down fermions is initiated.

More information: Pierbiagio Pieri et al, Luttinger theorem and imbalanced Fermi systems, *The European Physical Journal B* (2017). DOI: 10.1140/epjb/e2017-80071-2

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