Stable, Polarized Impurity in the Unitary Fermi Gas

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Spin-Imbalanced UFG

When the numbers of spin-up and spin-down fermions are different the Fermi surfaces do not match. It opens possibility for various pairing scenarios including LOFF phase, Sarma phase, interior pairing gap phase.

Spin-Imbalanced Impurity in UFG

We investigate the scenario when the spin-polarized impurity is created dynamically in otherwise unpolarized UFG. By applying the gaussian potential the spherical impurity is created possessing a peculiar internal pairing structure shown below:

The potential is on only for a limited amount of time.

After the external potential is applied and the polarized region is created the pairing field gets modified. Due to the fact that Fermi surfaces do not match locally the pairing field start to oscillate developing eventually the structure visible on the right figure. It resembles the behavior of pairing field at the superconductor-ferromagnet junction.

Consequently the nodal surface of the pairing field is trapped within the region where the polarization attains maximum and forms the shell surrounding the weakly paired interior. The localized Andreev states within the polarized shell are responsible for the trapping.

In 3D the expansion of the impurity is not possible as it would correspond to the expansion of the polarized shell which is energetically not favoured.

On the other hand the collapse of the impurity is also prohibited by the existence of the pairing field inside (with reversed phase) which would have to be destroyed in such a case.

Lifetime of The Impurity

As a consequence the impurity is practically stable once its size is large enough to admit the phase oscillation inside (see Fig. below).

In reality the stability may be affected by phonon excitations and two-body scattering effects. Depending on the rate of switching on/off of the external potential one may reduce the phonon excitations in the system.

Time Dependent Density Functional Theory with a local pairing field (TDASLDA).

Asymmetric Impurities

It is also possible to generate stable deformed impurities or of different shape.

Collision Experiments

Head-on Collision:

Collision With an Angle:

Summary:

- We predict the existence of the suprisingly long-lived, spatially-localized, spin-polarized excitation mode of UFG characterized by the peculiar pairing field structure.
- The stability of this excitation, resembling polarized impurity, is due to the pairing field which acquire nodal structure within the spin-polarized shell.
- The effect can be realized experimentally using currently available techniques of inducing local spin-imbalance with laser beams.