The FFLO state in superconductors: long sought after, finally found.

H.A. Radovan et al., *Magnetic enhancement of superconductivity from electron spin domains*, Nature **425**, 51 (2005)

H.A. Radovan et al., *Fulde-Ferrell-Larkin-Ovchinnikov superconductivity in heavy fermion $CeCoIn_5$*, Int. Conf. on Strongly Correlated Electron Systems 2005 (SCES'05), Vienna, to be published in Physica B

K. Kukuyanagi et al., *Texture in the superconducting order parameter of $CeCoIn_5$ revealed by nuclear magnetic resonance,* Phys. Rev. Lett. **94**, 047602 (2005)

K. Kumagai et al., *Microscopic evidence of the FFLO state in $CeCoIn_5$ probed by NMR*, Int. Conf. on Strongly Correlated Electron Systems 2005 (SCES'05), Vienna, to be published in Physica B

Recommended with a commentary by H. v. Löhneysen, Universität Karlsruhe, Physikalisches Institut, and Forschungszentrum Karlsruhe, Institut für Festkörperphysik, Germany

The experimental realization of the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state in superconductorsalthough predicted more than 40 years ago, has been enigmatic. In the FFLO state which is induced by a large magnetic field B, electrons pair with a finite momentum **q** with $q \sim 2\ \mu_B B/\hbar v_F$. This leads to a spatially oscillating order parameter with a wavelength $2\pi/q$ near the upper critical field B_{c2} and a corresponding oscillating spin polarization. Spin aligned Bloch walls form at the order parameter nodes. The requirements for the presence of such a state are rather stringent: one needs clean materials and at the same time rather high values of B_{c2}, such that the superconductivity is limited by the paramagnetic spin alignment of Cooper pairs rather than orbital effects. Many early attempts to demonstrate the FFLO state with thermodynamic measurements, i.e. magnetization, specific heat and thermal expansion, later proved to be ambiguous. For instance the peak effect in irreversible type-II superconductors gives rise to irreversible behavior that can be mistaken as a signature of the FFLO state.

Recently, the heavy-fermion superconductor $CeCoIn_5$ was reported to exhibit the FFLO state, inferred from thermodynamic signatures of a first-order transition just below B_{c2}. The intriguing phenomena associated with this state were explored subsequently by the two groups cited above. Radovan et al. explored the "substructure" of the FFLO phase arising from the interplay of orbital and paramagnetic effect, by heat capacity and magnetization measurements. The observed sequence of first-order transitions – unravelled with the tilt angle between the applied magnetic field and the two-dimensional planes of $CeCoIn_5$ as an additional control parameter – is due to successive transitions between Landau levels of the order parameter. Kukuyanagi, Kumagai et al. have demonstrated microscopic evidence by ^{115}In and ^{59}Co NMR studies for the spatially inhomogeneous superconducting state in $CeCoIn_5$. In addition, the NMR data provide evidence that in the FFLO state the vortex-core structure of $CeCoIn_5$ differs markedly from that of classical superconductors, as predicted theoretically.