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Spin Meissner Effect in Superconductors and the Origin of the Meissner Effect

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The expulsion of magnetic flux from the interior of a metal that becomes superconducting (Meissner effect) was discovered experimentally in 1933. Contrary to conventional wisdom, I argue that it is impossible to explain this effect within the accepted framework of London-BCS theory: one would have to assume either violation of Lenz's law, or violation of angular momentum conservation, or both. Instead, I propose that the outward motion of magnetic field lines as a metal goes superconducting reflects and is a consequence of outward motion of electric charge, just like would happen in a classical plasma (Alfven's theorem). According to the theory of hole superconductivity[1], metals become superconducting because they are driven to expel excess negative charge from their interior. This is why high T_c occurs in the highly negatively charged $(CuO_2)^=$, B^- and $(FeAs)^-$ planes of cuprates, MgB_2 and iron arsenides respectively, and why NIS tunneling spectra are asymmetric, with larger current for a negatively biased sample. How to reconcile the resulting macroscopic charge inhomogeneity with the supposed non-existence of macroscopic electric fields in the interior of superconductors will be discussed in the talk. Charge expulsion is also associated with an expansion of the electronic wavefunction and a decrease in the kinetic energy associated with quantum confinement, consistent with observations[2]. In addition to explaining the Meissner effect, this physics gives rise to a "spin-Meissner effect"[3]: a macroscopic spin current is predicted to flow near the surface of superconductors in the absence of applied external fields, of magnitude equal (in the appropriate units) to the critical charge current of the superconductor. The orbital angular momentum of each electron in the spin current equals its spin angular momentum. This physics also provides a 'geometric' interpretation of the difference between type I and type II superconductors, and predicts that the macroscopic electric field in the interior of superconductors equals the thermodynamic critical magnetic field H_c or H_{c1} for type I and type II superconductors respectively. These predictions are theoretically and experimentally testable.

[1] References in http://physics.ucsd.edu/ jorge/hole.html
[2] H. J. A. Molegraaf et al, Science **295**, 2239 (2002).
[3] J.E. Hirsch, Europhys. Lett. **81**, 67003 (2008); Ann. Phys. (Berlin) **17**, 380 (2008).