Experiments on the exchange-correlation hole in solids

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The concept of the exchange-correlation hole (xc-hole) is fundamental to solid state physics. It was introduced in the early 1930ies by Wigner and Seitz and Slater, and postulates, that each electron in a solid is surrounded by a region of reduced electronic charge, adding up to exactly one electron charge. Thus, each such "dressed" electron looks "neutral" to another one residing beyond a certain distance. This concept explained why electrons essentially behave like independent quasi-particles. Despite the success of this postulate it has never been directly tested experimentally for more than 70 years. In order to do this, one has to make a scattering experiment with electrons which, by the very nature of the dressed electrons, will have a rather small cross section.

We set up an (e,2e) experiment in which an electron (of some 10 eV kinetic energy) is sent to a sample, is elastically back reflected and on its way out may scatter with a valence electron. If the incident electron offer energy loss, and the hit electron have sufficient energy to overcome the surface barrier they may be detected in vacuum in coincidence. For a given emission direction of the one electron the electron-electron interaction manifests itself in the angular distribution of the second electron around this direction. We made such experiments and found that there is a depletion zone for the second electron within an angular range of about 1 rad, essentially independent of its energy. We tested this for alkali halides as well as for Cu, and Fe. The cause of this effect is the mutual repulsion of electrons by exchange interaction and Coulomb repulsion. Thus, one may eventually map the xc-hole. In order to disentangle the contributions from correlation and exchange, one may work with a spin-polarized target and spin-polarized primary electrons. Such an experiment has been carried out /1/, using Fe as the target and a GaAs photocathode electron source. We find that the "exchange hole" is significantly larger than the "correlation hole".

/1/ Spin-resolved mapping of spin contribution to exchange-correlation holes
   F. O. Schumann, C. Winkler, J. Kirschner, F. Giebels, H. Gollisch, and R. Feder