Core Concepts: Quasiparticle

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Physicists have identified dozens of different subatomic species in the particle zoo, but most physical and chemical interactions arise from only three: the proton, the neutron, and the electron. There are

a lot of those: solids and liquids contain on the order of 10^{24} particles per cubic centimeter.

Each of those quantum mechanical particles may interact with all of the others in

the material due to the long-range nature of the electromagnetic force, which adds up to one sprawling headache of a math problem for condensed matter physicists who want to study the properties of matter on the subatomic scale. The problem is particularly vexing for condensed matter physicists who study crystalline lattices or superconductors.

Enter the quasiparticle, a mathematical construct that makes near-impossible calculations not only possible, but also straightforward. Decades ago, researchers realized that they don't have to tackle the many-body problem that arises from the messy interactions of real quantum particles. Instead, a crystal solid can just as accurately be studied and analyzed as an averaged bulk object along with a collection of quasiparticles: disturbances in the solid that act just like well-behaved, nonrelativistic particles that barely interact at all. They're fictitious and easier to work with, and their collective behavior matches that of the real subatomic particles.

An electron quasiparticle, for example, includes both the real electron and the nearby particles it affects—and may therefore have a different mass. Another quasiparticle, a “hole,” represents the absence of an electron (i.e., a place where an electron recently passed) and has the opposite charge. It is particularly convenient in studies of the properties of superconductors. The “polaron,” a quasiparticle also related to electrons, helps describe how an electron disturbs nearby ions. In April 2012, physicists introduced the “orbiton,” a quasiparticle that's like an electron without spin or electric charge—representing a modern thrust to use quasiparticles to separate out the different mechanisms of an electron.

Closely related to quasiparticles are collective excitations, similarly fictitious entities that can be used to describe and quantify the overall behavior of a complex system. Plasmons, for example, are a collective excitation that can illustrate how the electron density of a foil changes in response to a bombardment of energy. Phonons describe the effects of a sound wave moving through a solid.

Some researchers even go so far as to argue that all particles are, in some way, quasiparticles—because they all arise from perturbations in an energy field.

In February, JILA physicists and German theorists described the dropletion (or “quantum droplet”), a quasiparticle made of a network of electrons and holes that combines quantum characteristics with some properties of a liquid. Image courtesy of the Cundiff group and Brad Baxley (JILA, Boulder, CO).