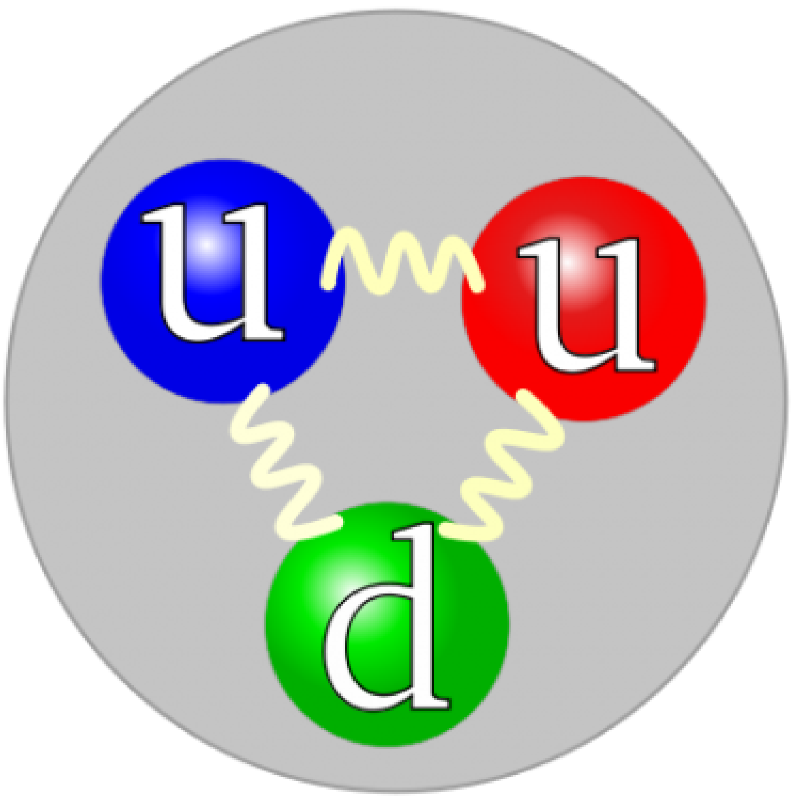
Are scientists finally on the brink of understanding where proton spin comes from?

June 1 2015, by Sophie Hetherton



The quark structure of the proton. There are two up quarks in it and one down quark. The strong force is mediated by gluons (wavey). The strong force has three types of charges, the so-called red, green and the blue. Note that the choice of green for the down quark is arbitrary; the "color charge" is thought of as circulating among the three quarks. Credit: Arpad Horvath/Wikipedia

For nearly three decades, physicists have been unable to answer a seemingly simple question: where does proton spin come from?

Summing the spins of the three quarks that make up the proton seems, in principle, straightforward, however, physicists have been faced with a particularly stubborn imbalance. In 1988 the European Muon Collaboration (EMC) at CERN shocked the physics community by announcing that the sum of the spins of the three quarks that make up the proton is much less than the spin of the proton itself. This discovery questioned the fundamental idea in physics that the amount of any physical quantity on one side of an equation must equal that on the other side.

EMC researchers discovered that the net spin of the three quarks actually accounted for no more than 24% of the proton's spin and may even contribute as little as 4% – in other words, practically none.

This discovery sparked the beginning of the "spin crisis". Gerhard Mallot, a senior physicist at CERN, recalls how nervous people were and how there were conjectures that the experiment was flawed or even that the underlying theory, known as quantum chromodynamics (QCD), might not be correct.

Further scattering experiments at the Stanford Linear Accelerator Center (SLAC), CERN and the DESY laboratory in Germany eventually confirmed that quark spin contributes 30% (+/-5%) of the total proton spin, but that still leaves 65–70% unaccounted for.

In the June 2015 issue of *Physics World*, science writer Edwin Cartlidge describes how researchers have since devoted their energy to finding alternative possible sources of the proton spin, such as the momenta that quarks and gluons – particles that mediate the strong nuclear force by bonding together quarks of various types – acquire as they rotate around the proton's spin axis, or perhaps the spin of the gluons themselves.

The hot debate between theorists is just how much each of these components contributes to the overall proton spin, and the latest round of data from the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory on Long Island in New York suggests that gluon spin may be the chief culprit.

Werner Vogelsang, a theorist at the University of Tubingen in Germany, says that these results pinning down the gluon spin contribution to 40% have lifted the "crisis mood" surrounding the hunt for the missing spin.

With these confident estimates in, one might expect that only a third of the proton's spin remains up for grabs. However, some physicists believe that the spin problem is far from being solved and are calling for a new machine, the Electron–Ion Collider (EIC), which would combine the punch of proton-beam experiments with the precision of electrons and reach collision energies in the region of 140 GeV.

Vogelsang points out that more data are needed to settle the issue and adds that "The only thing to do is push experiments down to these scales and see what happens there. There might still be surprises lurking."

Provided by Institute of Physics

proton.html