AMERICAN Scientist

Water Fight

Fenella Saunders

It's one of the first chemical formulas taught in school: A water molecule is made up of one oxygen atom and two hydrogen atoms, the familiar H_2O. But a few years ago, C. Aris C. Dreismann, a physicist at the Technical University of Berlin, began to question that simple ratio. At time scales of less than a femtosecond, Dreismann and his colleagues reported observing about 30 percent less hydrogen in water samples than expected.

Could water be, say, $H_{1.5}O$ at these brief scales? A crop of news articles suggested so. But now a team at Ben-Gurion University in Israel and Rensselaer Polytechnic University in New York has performed an experiment similar to Dreismann's. They report in the journal *Physical Review Letters* (May 13) that they find no anomalous hydrogen levels in water and conclude that water should be H_2O at all times. Both groups are standing by their results.

Previously in *Physical Review Letters* (13 October 1997) Dreismann and his colleagues reported on their use of neutrons, pumped up to high energies at the Rutherford Appleton Laboratory in England, to probe water samples containing various mixtures of hydrogen and its isotope deuterium (D), which has a neutron in addition to a proton (a combination called a deuteron) in its nucleus. In the same journal in 2003, they repeated the experiment with a thin film of a hydrogen-laden polymer called formvar, which they also bombarded with high-speed electrons at the Australian National University. In both cases, they fired the subatomic particles at extremely high energies at the hydrogen-containing molecules and detected how much the particles scattered.

When they found that the particles scattered from the protons (that is, the hydrogen nuclei) much less than expected, the physicists surmised that the neutrons and electrons were somehow unable to "see" the protons. At the extremely short time scales of a neutron whizzing past—in this case 0.1 to 1 femtosecond—the theory developed that the protons might be constantly popping in and out of a wavelike state of quantum entanglement with their local electrons, so that on average, the neutrons were only able to interact with the protons about half the time.

If this new type of quantum entanglement existed, it would change many of the basic tenets of atomic physics, so the finding was enough to make nuclear physicists—such as Raymond Moreh of Ben-Gurion University—fall out of their chairs. Moreh felt that Dreismann's results didn't sound right, so decided to see for himself. He and RPI colleagues Robert C. Block, Yaron Danon and Matthew Neuman repeated the neutron-scattering experiment with shorter interaction times—from 0.001 to 0.01 femtosecond—as the proton-quantum-entanglement theory predicted that the effect should be even more pronounced at shorter time scales. In another modification, the group compared their H_2O-D_2O mixture's scattering results to the expected scattering rate for D_2O. Dreismann's group had compared the mixture to heavier atoms such as oxygen. Moreh found no deviation from the expected scattering results: "We tried very hard to find the anomaly, but we couldn't," he says.

Dreismann responds that Moreh's results do not disprove the original finding, a deficit in scattering from protons; rather, since Moreh compared protons to deuterons, the experiment shows that deuterons undergo the same kind of entanglement. "This experiment does not prove that protons are normal, it proves that the ratio is normal. If you assume that the deuterons are normal, then of course the protons are normal, but this is an assumption," says Dreismann. "In this energy range, there is no reason, in principle, to have a different scattering behavior for protons and deuterons."

Moreh counters that neutrons scatter from every atom differently, and that the scattering depends more on how nuclei are oriented than on their atomic weights. "A neutron has a very strong scattering intensity with hydrogen, but with deuterium it has lower scattering intensity, closer to that of oxygen," he says. "You really have to be extremely creative to believe that deuteron and oxygen will show a drop in the scattering intensity exactly like hydrogen."

The disagreements go further, with the two investigators challenging each other's calculations and questioning whether anomalies may have arisen from equipment choices. Although Moreh considers the matter closed, Dreismann is planning more follow-up studies, so there may be more rough water ahead. "In the end I am very thankful that Professor Moreh did this work, because I learned something new that I did not know," says Dreismann. "Now I can expand my work into faster time scales and with deuterons."—*Fenella Saunders*

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