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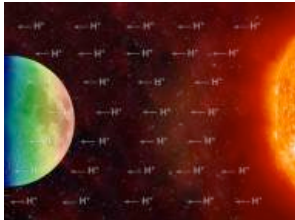
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## A DAMP MOON: WATER FOUND INSIDE AND OUT

### Spacecraft reveal higher than expected abundances of the liquid on the lunar surface and in volcanic rocks

By Ron Cowen

**Web edition** : Wednesday, September 23rd, 2009



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#### GO WITH THE FLOW

This illustration shows one scenario to account for the newly discovered water on the moon's surface. When a stream of hydrogen ions carried from the sun (extreme right) by the solar wind hits the moon (extreme left), it may liberate oxygen from lunar material to form water. At high temperatures (red-yellow), most of the newly formed water is released into space but at lower temperatures (green-blue) water accumulates on the surface. This scenario doesn't address the other new finding of water below the moon's surface.

F. Merlin/University of Maryland, McREL

Scientists' understanding of the moon could be all wet. Its surface is surprisingly dewy and its interior contains more water than previous analyses of moon rocks have indicated, according to new studies.

Observations from three spacecraft suggest that water is widely distributed over a thin layer of the lunar surface rather than locked up in icy enclaves predicted to lie at the moon's poles. The results, detailed in a trio of papers to be posted online September 24 in *Science*, suggest that liquid water may be more available to future moon explorers than had been thought.

Concentrations in sunlit soil might average about 1,000 parts per million, the equivalent of roughly a quart of water per ton of material. That water doesn't remain on the moon, but comes and goes each lunar day.

In contrast, water molecules bound to phosphate minerals within volcanic rocks — material that formed well beneath the lunar surface — date back several billion years, says Francis McCubbin of the Carnegie Institution for Science in

Washington D.C. A fourth, unpublished study led by McCubbin finds a surprisingly high abundance of this interior water, which may shed new light on how the moon formed.

The researchers who made the surface observations caution that their observations, which are based on low-resolution spectroscopy of minerals on the lunar surface, cannot clearly distinguish between water and the hydroxyl ion, which can serve as a marker for water.

Nonetheless, Roger N. Clark of the U.S. Geological Survey in Denver, Colo., asserts that “this is the first detection of water on the moon and we see it all over, not just in the polar regions.” Clark, a coauthor of two of the *Science* papers, led a team that found evidence of water in spectra taken by the Cassini spacecraft as it flew past the moon in 1999. Clark says he knew his team had a real signal a while ago, but he says he waited to publish because “the detection was so fantastic, I felt we needed confirmation.”

Confirmation has now come in the form of spectra taken by instruments aboard NASA’s Deep Impact spacecraft and Chandrayaan-I, India’s first mission to the moon. Each of the papers in *Science* reports data from one of the spacecraft.

Last week, other researchers reported that the Lunar Reconnaissance Orbiter spacecraft had found hydrogen on the moon’s surface, a possible marker of water (SN Online: 9/18/09).

The three *Science* papers “present a strong case for surficial water on the moon, and this could certainly be the result of delivery by icy impactors or solar wind interactions long after the moon formed,” comments Robin Canup of the Southwest Research Institute in Boulder, Colo., who is not a member of any of the teams.

Data collected by Deep Impact one-quarter of a lunar day apart reveal that layers of water only a few molecules thick form, evaporate into space and then reform each lunar day, notes Jessica Sunshine of the University of Maryland in College Park, lead author of the Deep Impact study.

An obvious driver of such a cycle would be hydrogen ions delivered by the solar wind. The ions could interact with oxygen-rich minerals on the lunar surface to produce water, Sunshine suggests. Heat from the sun could then vaporize the water each lunar noon. Although the long-term effects of this interaction on the moon are unknown, “this same process should be occurring on airless, silicate-rich bodies throughout the inner solar system,” she says.

In McCubbin’s study of the lunar interior, he and his colleagues calculate that phosphate minerals contain a concentration of water as high as several thousand parts per million. This result, combined with lower abundances of water in other volcanic material reported in 2008 by Alberto Saal of Brown

University in Providence, R.I., points to an average overall abundance of water in the lunar mantle significantly higher than the previous estimate of 1 part per billion.

It's been a long-standing assumption, notes Canup, that if the moon formed when a giant, Mars-sized impactor smacked into the young Earth, any water would have been vaporized by the high temperatures generated during such a cataclysm and that vapor would have escaped into space. However, that assumption "has yet to be evaluated with direct models," she adds.

McCubbin agrees that there may have been some way for water to be retained in this accepted model of the moon's formation. Any alternative explanation of moon formation will have to account for all the water now known to reside inside the moon.

On October 9, a NASA spacecraft called LCROSS will deliberately crash into a cratered area of the moon's south pole, where frozen water likely resides. The resulting plume of kicked-up soil should reveal the abundance of water there.

Says Canup: "Our picture of a bone-dry moon is clearly in need of updating."