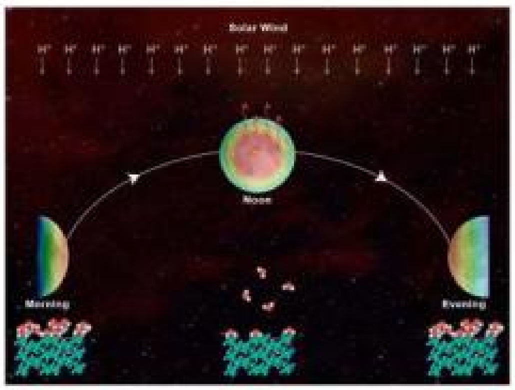
Deep Impact, Moon Mineralogy Mapper find clear evidence of water on moon

September 23 2009



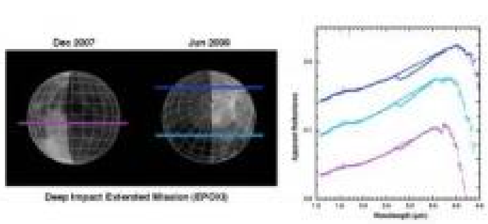
This schematic shows the daytime cycle of hydration, loss, and rehydration on the lunar surface. In the morning, when the moon is cold, it contains water and hydroxyl (OH). One theory holds that the water and hydroxyl are, in part, formed from hydrogen ions in the solar wind. By local noon, when the moon is at its warmest, some water and hydroxyl are lost. By evening, when it is colder, the surface returns to a state equal to that seen in the morning. Thus, regardless of location or terrain type, the entire surface of the moon is hydrated during some part of the lunar day. Credit: University of Maryland/O. Groussin/McREL.

New data from the Deep Impact spacecraft and the Moon Mineralogy Mapper (M3), an instrument aboard India's recently ended Chandrayaan-1 spacecraft, provide, for the first time, clear evidence that water exists on the surface of the Moon.

"The Deep Impact observations of the Moon not only unequivocally confirm the presence of OH/H_2O on the lunar surface, but also reveal that the entire lunar surface is hydrated during at least some portions of the lunar day," write University of Maryland astronomer Jessica Sunshine and co-authors in a paper on the Deep Impact data published online in the September 24 issue of the journal *Science*.

Small Amount of Water Yields Big Excitement "Finding water on the Moon in daylight is a huge surprise, even if it is only a small amount of water and only in the form of molecules stuck to soil," said Sunshine, lead author of the Deep Impact paper and a co-author of a companion *Science* paper based on data from the M3 instrument that first detected the presence of lunar water. Prevailing scientific opinion long has been that there probably is no water on the Moon and that, even if it does exist, it would be only in permanently cold, shadowed craters at the lunar poles.

"In the Deep Impact data we're essentially watching water molecules form and then dissipate right in front of our eyes," said Sunshine, who said her first reaction to the M3 data was skepticism.



Since successfully carrying out its spectacular impact experiment at comet Tempel 1 on July 4, 2005, the Deep Impact spacecraft has been on an extended mission (EPOXI), which culminates in a flyby of comet Hartley 2 on November 4, 2010. En route to the comet, the Deep Impact spacecraft observed the moon for calibration purposes on several occasions. In June 2009, the northern polar regions were observed and average spectra were collected (blue and cyan). These data unambiguously include the entire OH/H2O absorption feature (hashed regions; 2.7 to 3.6 μm). This water signature varies in strength. In particular, data acquired over the warm equator (purple; Dec 2007) have a distinct but weaker water signature. Credit: NASA/University of Maryland

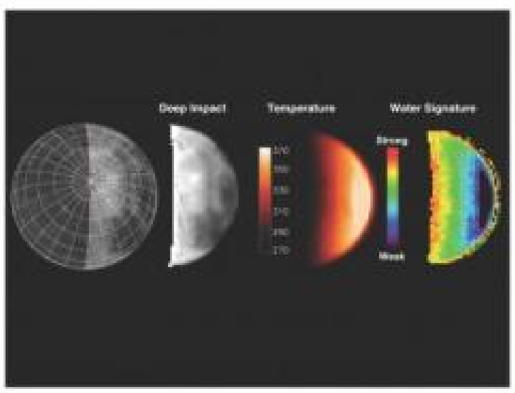
"We aren't certain yet how this happens," she said, "but our findings suggest a solar driven cycle in which layers of water only a few molecules thick form, dissipate and reform on the surface each lunar day. We postulate that hydrogen ions from the sun are carried by the solar wind to the Moon and there interact with oxygen rich minerals in lunar soil to produce the water [H20] and hydroxyl [OH] molecules that spectral analysis unequivocally show us are there. In a cycle that occurs entirely in daylight, this water is formed in the morning, substantially lost by lunar mid-day, and re-formed as the lunar surface cools towards evening.

"If this is correct, then such hydration via solar wind would be expected to occur throughout the inner Solar System on all airless bodies with oxygen-bearing minerals on their surfaces," Sunshine said.

"Within the context of lunar science, this is a major discovery," Paul G. Lucey, a planetary scientist with the University of Hawaii, said in a Los Angeles Times article. "There was zero accepted evidence that there was any water at the lunar surface, [but] now it is shown to be easily detectable, though by extremely sensitive methods. As a lunar scientist, when I read about this I was completely blown away," said Lucey, who was not involved in the current research.

"Water ice on the moon has been something of a holy grail for lunar scientists for a very long time," Jim Green, director of the Planetary Science Division at NASA Headquarters in Washington said in a NASA release.

Another reflection of the scientific significance of finding water on the moon was simply that it generated three papers in the current issue of Science and a NASA press conference. In addition to the M3 and Deep Impact articles, a third Science paper presented evidence collected by NASA's Cassini spacecraft.



These are deep impact observations of the northern polar regions (~60 km/pixel; June 9, 2009). Left to right: Clementine basemap (with 15° grid) of observed area; Brightness image generated from Deep Impact (at 1.2 µm); Temperature map (in K) derived from >4 µm spectra; Map of the strength of the water signature (continuum-removed 2.8 µm band depth). There are significant variations in the water signature across the lunar surface. While the strength of the water signatures is not correlated with terrain type (bright highland vs. dark maria), but is dependent on temperature. Credit: NASA/University of Maryland

Lunar H_2O Latest in UM-Led Deep Impact Science

Although the M3 instrument and its science team made the initial discovery of water in certain areas of the lunar surface, Sunshine and co-authors on the Deep Impact paper said the conclusiveness of the finding of water, the realization it was a surface-wide phenomenon, and the insight into the temperature dependent nature of the process were only possible because of data collected by the Deep Impact spacecraft during its current extended mission (EPOXI).

Deep Impact was not designed to study the Moon, but for a famous 2005 mission in which it successfully knocked a hole in comet Tempel 1 to find out what was inside. Its data on lunar water were obtained as part of calibration opportunities that occurred during June 2009 and December 2007 flybys of the Earth and Moon needed to get adequate gravity boosts to travel on its EPOXI mission to a second comet, Hartley 2, which the spacecraft will encounter in November 2010.

"Without the spectral range of Deep Impact's instruments the M3 discovery of surface water would not have been nearly so definitive, and because the Deep Impact spacecraft took observations at different times of the lunar day, the effect of temperature became very apparent," Sunshine explained.

University of Maryland Astronomer Michael A'Hearn, Deep Impact and EPOXI science team leader and one of Sunshine's four Maryland co-authors on the Deep Impact paper in Science, said "I think it is tremendous that the Deep Impact spacecraft, which was the first to detect ice on a cometary nucleus, has now demonstrated the existence of adsorbed water on the Moon.

"This great spacecraft and its instruments continue to make important, unexpected discoveries long after the prime mission has ended," he said.

Moon Mineralogy Mapper (M3) Results

It turns out the moon is a lot wetter than we ever thought. When Apollo astronauts returned from the moon 40 years ago, they brought back souvenirs in the form of moon rocks to be used for scientific analysis, and one of the chief questions was whether there was water to be found in the lunar rocks and soils.

The problem was they faced was complicated by the fact that most of the rock boxes containing the lunar samples had leaked. This led the scientists to assume that the trace amounts of water they found came from Earth air that had entered the containers. The assumption remained that, outside of possible ice at the moon's poles, there was no water on the moon.

Forty years later, a team of scientists including Larry Taylor of the University of Tennessee, Knoxville, has found evidence that the old assumption may be wrong. To do so, they used a high-tech instrument on a satellite in orbit around the moon.

"To some extent, we were fooled," said Taylor, a distinguished professor of earth and planetary sciences, who has studied the moon since the original Apollo missions. "Since the boxes leaked, we just assumed the water we found was from contamination with terrestrial air."

The team of researchers used a NASA instrument called the Moon Mineralogy Mapper - M3 for short - housed on the Indian Chandrayyan-1 satellite, India's first lunar expedition, which was launched into orbit around the moon late last year.

M3 analyzes the way that light from the sun reflects off the lunar surface to understand what materials comprise the lunar soil. Light is reflected in different wavelengths off of different minerals, and scientists can use those differences - mostly imperceptible to the human eye - to know what is present in the thin layer of upper soil - so-called reflectance spectrometry.

In this case, the instrument detected wavelengths of reflected light that would indicate a chemical bond between hydrogen and oxygen. Given water's well-known chemical symbol, H_2O, which represents two hydrogen atoms bonded to one oxygen atom, this discovery was a source of great interest to the researchers.

The instrument can only see the very uppermost layers of the lunar soil - perhaps to a few centimeters below the surface, but what it saw, according to the scientists, was water, previously theorized but not proven to exist only in permanently shadowed craters at the lunar poles. What scientists did not understand, though, was where this newly observed water came from.

There are potentially two types of water on the moon: exogenic, meaning water from outside sources, such as comets striking the moon's surface, and endogenic, meaning water that originates on the moon. Taylor and his colleagues suspect that the water they're seeing in the moon's surface is endogenic.

Since the rocks and soils that compose the moon contain about 45 percent oxygen, mostly combined in silicate phases, the question before researchers is where the hydrogen component of the water they're seeing with M3 came from. In this case, they believe it may have come from an astronomical phenomenon called the solar wind.

As the sun undergoes nuclear fusion, it constantly emits a stream of particles, mostly protons, which are positively charged hydrogen atoms. On Earth, the atmosphere and magnetism prevent us from being bombarded by these protons, but the moon lacks that protection, meaning the oxygen-rich minerals and glasses on the surface of the moon are constantly pounded by hydrogen in the form of protons, moving at velocities of one-third the speed of light.

When those protons hit the lunar surface with enough force, suspects Taylor, they break apart oxygen bonds in soil materials, and where free oxygen and hydrogen are together, there's a high chance that trace amounts of water will be formed. These traces are thought to be about a quart of water per ton of soil.

"The isotopes of oxygen that exist on the moon are the same as those that exist on Earth, so it was difficult if not impossible to tell the difference between water from the moon and water from Earth," said Taylor. "Since the early soil samples only had trace amounts of water, it was easy to make the mistake of attributing it to contamination."

Taylor and other M3 team members believe their findings will be of particular significance as mankind continues to plan for a return to the moon. The maps created by M3 could provide mission planners with locations prime for extraction of needed water from the lunar soil.

The M3 team, made up of scientists from the U.S. and India, reported its findings in this week's edition of the online journal *Science Express*. The team, funded by NASA, is led by researchers at Brown University, which collaborates with Taylor and UT Knoxville's Planetary Geosciences Institute.

Source: University of Maryland, University of Tennessee, Knoxville