Planetary News: The Moon (2009)

LCROSS Lunar Impactor Mission: "Yes, We Found Water!"

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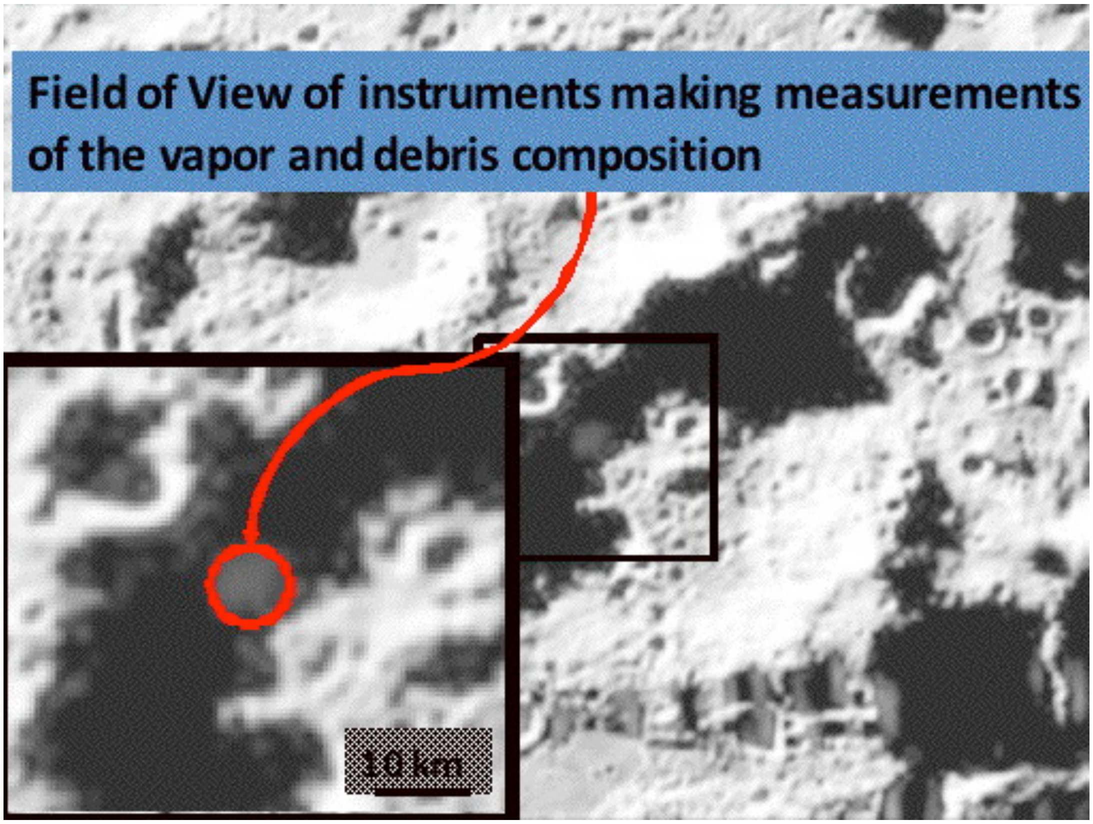
More On The Moon
More about Earth's Moon

Members of the LCROSS science team were evidently delighted to be able to report at last that when the spacecraft's spent Centaur upper stage smashed into the Moon on October 9, it excavated a crater into a spot on the lunar surface that contained "a significant amount" of water, the mission's principal investigator, Tony Colaprete, said in a press briefing today. The ejecta plume from the impact contained at least 100 kilograms of water. But the same data that conclusively identifies water also indicates that the plume contained a surprisingly complex cocktail of other elements and compounds that the team is now struggling to identify.

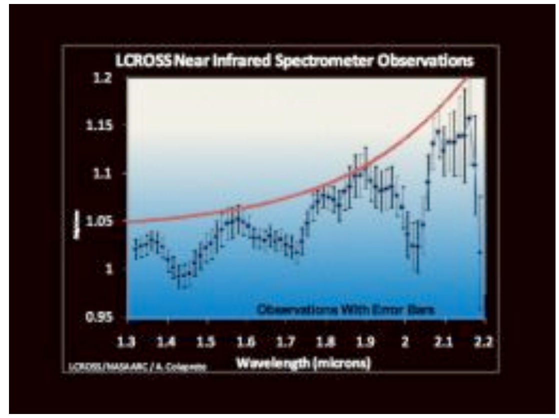
Preliminary analysis of the LCROSS mission data had already proven that the LCROSS team had been completely successful in the mission's execution. The Centaur upper stage was guided to within 200 meters of its intended target, a flat, smooth area on the floor of a permanently shadowed crater named Cabeus near the lunar south pole. And in the minutes after the impact, as the shepherding spacecraft plunged toward its own crash, it successfully aimed its instruments at the impact crater formed by the Centaur. In fact, it performed beyond the mission's expectations, snapping an infrared image into the permanently shadowed area that revealed the extent of the crater, about 20 to 30 meters in diameter. Its ultraviolet and infrared spectrometers were perfectly targeted to gather the data the science team needed to identify what kinds of materials were thrown up out of the lunar surface.



Ejecta Plume
The visible camera image showing the ejecta plume at about 20 seconds after impact. The field of view of the spectrometers are indicated by the red circle. Credit: NASA

Independent measurements from two different instruments confirmed the presence of water. Both are spectrometers, instruments that divide incoming light into hundreds of wavelength slices and measure the brightness of a target at each wavelength. The data from such spectrometers is usually self-deprecatingly referred to as "squiggly lines" by spectroscopists. In fact, the "squiggly lines" represent a fingerprint of all the different materials present in the spectrometer's view, each of which absorbs light at certain specific wavelengths.

Colaprete began by showing a spectrum from the near-infrared spectrometer, an average of measurements taken over a period from about 20 to about 60 seconds after the impact. Overlaid on the spectrum is a red line that indicates what the surface would look like if it were a gray, colorless body, heated to 400 or 500 degrees Celsius by the energy of the impact. "The data comes up and meets the line, but then it has all these notches taken out of it. Each of those notches is a compound, some kind of material absorbing infrared light," he said.



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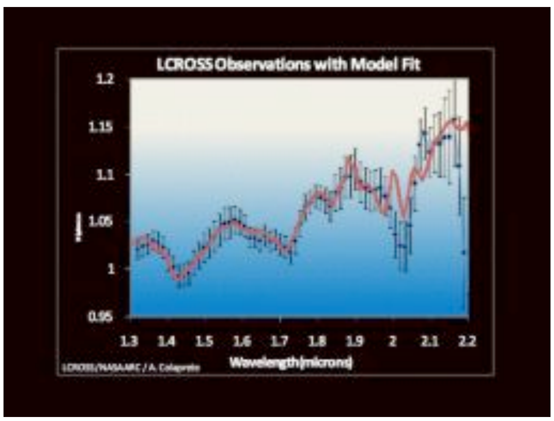
LCROSS Near Infrared Spectrometer Observations

Data from the down-looking near-infrared spectrometer. The red curve shows how the spectra would look for a "grey" or "colorless" warm (230 C) dust cloud. The smooth curve shows no compounds being absorbed. Credit: NASA

Next, Colaprete showed the same spectrum, but this time the red line included a "model," a synthetic spectrum generated by assuming that a certain abundance of water was present in the plume. The model fits well in two locations where water vapor and water ice are known to absorb infrared radiation, at wavelengths of approximately 1.4 and 1.9 microns. The quantity of water required to produce that fit would amount to 100 kilograms within the spectrometer's field of view, which encompassed most but not all of the plume.

Although the model that included water fit a few of the absorption bands well, there were still many other absorption bands present that the model did not account for. So Colaprete showed a model fit that contained numerous other materials and fit the observations much better. He declined to identify the materials whose spectra composed the model fit shown below.



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LCROSS Observations with Model Fit

Data from the down-looking near-infrared spectrometer with a model that contains more compounds. A continued effort going forward will be to uniquely identify the various compounds responsible for the spectral features. Credit: NASA

The second instrument that gathered spectral information on the plume was an ultraviolet spectrometer, which detected emission from various elements and molecules in the plume. Atoms can absorb energy to be kicked up to higher energy levels; when they drop down to their ground state, they emit photons with very specific wavelengths. Such emission results in the diagnostic red color from neon signs, or the orange color from sodium lamps. LCROSS's ultraviolet spectrometer detected an emission peak at a wavelength of 306 to 310 nanometers that comes from the hydroxyl group, OH-, which is formed when water molecules are ionized. Colaprete said that seeing this emission line was "the eureka moment" that confirmed the presence of water.

But Can We Drink It?

The water absorption band strengths (the amount by which the spectra dipped from the perfect black-body spectrum) indicate that there is so much water that some of it had to be in the form of ice; it wasn't just adsorbed as single-molecule layers on mineral grains. In other words, if an astronaut were to visit this lunar crater, they could produce lunar water from the soil simply by warming it enough to melt. Although water has long been suspected to exist in these permanently shadowed polar regions in the Moon, it was not until the LCROSS impact that scientists achieved direct measurements of its presence and abundance. This is clearly a game-changing discovery for the future of lunar science and exploration.

But "we have not had time to enjoy" the water confirmation, Colaprete said, "because we are so interested in everything else that's there." The spectra indicate that the composition of the lunar subsurface is "a lot more complicated than we had anticipated." He said they compared the spectra to "primitive icy bodies like Centaur or Trojan asteroids, and there were a considerable amount of similarities." Such bodies contain materials such as carbon dioxide, methane, sulfur dioxide, and more complex molecules like methanol, ethanol, and even organic compounds. "It is certain that some of these species are in there, but which ones?" Colaprete asked.

Which ones are certainly relevant to future lunar exploration. A reporter at the press briefing asked whether the water produced by melting the regolith could be drunk. "If there's methanol in there, I wouldn't drink it, because you could go blind," Colaprete laughed. Data from the LAMP instrument on the Lunar Reconnaissance Orbiter spacecraft has indicated there may be even nastier materials, such as Mercury, present in lunar polar meltwater. But "If you could clean it, it would be drinkable water."

Determining for sure which other chemicals are present in the LCROSS data will be challenging. One reason the data are so complex is because the signals evolved over the several minutes that LCROSS observed them. Immediately after the impact there was a flash of emission followed by the blast of the ejecta, the solid material that was tossed out of the crater. Along with the ejecta came vapors of various compounds that had been solid or adsorbed but were turned to gas by the shock and heat of the impact. But long after the impact, more vapor continued to emanate from the still-hot floor of the crater, and solid grains of ice in the initial plume also turned to gas as they flew out of the crater. Each of these would contribute different and changing signals to the spectrometers. "It's very complicated and very dynamic and very fun to study," Colaprete said. "We have to piece together the whole storyline of everything that occurred."

In the end, today's briefing was merely a "status update" on the LCROSS results, intended to allow the LCROSS mission scientists to openly discuss the presence of water in their data in advance of next week's Lunar Exploration Analysis Group (LEAG). The second day of the meeting, November 17, will be devoted to the latest results from Lunar Reconnaissance Orbiter and LCROSS, and the LCROSS team may discuss their model results in more detail then. Following the LEAG meeting, the LCROSS team plans to present many more results at the fall meeting of the American Geophysical Union, on December 14-18.