Would Earth look like a habitable planet from afar?

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A zoomed-in image of Earth from the perspective of NASA's Lunar Crater Observation and Sensing Satellite (LCROSS). The small dot below it is the moon. Credit: NASA Ames

Even when a distant world has the trademarks of habitability—it's Earth-sized, it's in the zone around its star where liquid water is possible—finding signs of life is tricky. The telescope technology of

today falls short of being able to distinguish clues of life.

But readying the tools to find life now will help astronomers when telescopes get better in the next few decades. Sometimes, this requires looking at a planet that we already know has life—that would be Earth, the only confirmed one so far—and pretending that we are looking at it as a visiting extraterrestrial.

When viewing Earth from space, how could you tell that this planet is well-suited for life? Are there telltale signatures in the atmosphere or from our oceans? These are some of the questions that controllers of a lunar spacecraft sought to answer when it took a bit of a side mission. Instead of observing the Moon, NASA's Lunar Crater Observation and Sensing Satellite (LCROSS) briefly looked at Earth.

"The LCROSS spacecraft observed the Earth and made statements about ozone in Earth's atmosphere and also liquid water," said lead researcher Tyler Robinson, a postdoctoral researcher at the NASA Ames Research Center in Mountain View, Calif. "We also used it to validate a tool to simulate how a distant Earth would appear."

A paper on the research, "Detection of Ocean Glint and Ozone Absorption Using LCROSS Earth Observations," is available now on the pre-publishing site *Arxiv* and has been accepted in the *Astrophysical Journal*.

Searching for water

LCROSS, which was smashed into the Moon as planned in 2009, had a primary mission to look for the signature of lunar water. About a decade before, NASA's Lunar Prospector mission found hints of hydrogen in craters at the Moon's poles. The divots are permanently shadowed from the heat of the Sun.

LCROSS was to follow up on those observations, and it repaid the investment in spades. It tracked what happened after its spent Centaur rocket stage crashed into the crater Cabeus near the Moon's south pole, and found signs of hydrogen in spectroscopic measurements spanning infrared and ultraviolet light.

When LCROSS crashed into the moon itself, observations with NASA's Lunar Reconnaissance Orbiter and others revealed about 100 kilograms of water in the crater it punched in the regolith, which was about 20 meters (66 feet) across.

The spacecraft was indeed successful in finding (and helping other spacecraft find) water on the Moon. But could it also find water on our ocean-rich Earth at a distance? Scientists became curious about the prospect, especially after seeing that our oceans make a mirror-like reflection, called "glint," when a distant Earth appears as a crescent from the perspective of the Moon.

LCROSS did three observation sessions of Earth in 2009. Interestingly, the spacecraft was not originally tasked to look at Earth as an exoplanet. Instead, scientists were evaluating how accurately the spacecraft was pointing after launch, said co-author and NASA astrophysicist Kimberly Ennico-Smith. The data was later repurposed for the exoplanet modeling used in this research.

Three-quarters of Earth’s surface is ocean. Designing procedures to detect the water from afar could help scientists do the same thing for exoplanets. Credit: NASA

"You never know what else another pair of eyes looking at data can bring you," she wrote in an e-mail. "That's why having and maintaining archives is so important."

For example, finding hydroxyl—a type of water—on the Moon came from combining sets from India's Chandryaan-1 lunar spacecraft, and NASA's Cassini spacecraft on its way to Saturn. Both missions were using the Moon to calibrate their instruments; ocean examinations were not the main objective.

Seeing a glint

Looking at the repurposed data yielded a surprise. Not only did LCROSS see a glint, but it was a lot different than what researchers expected.

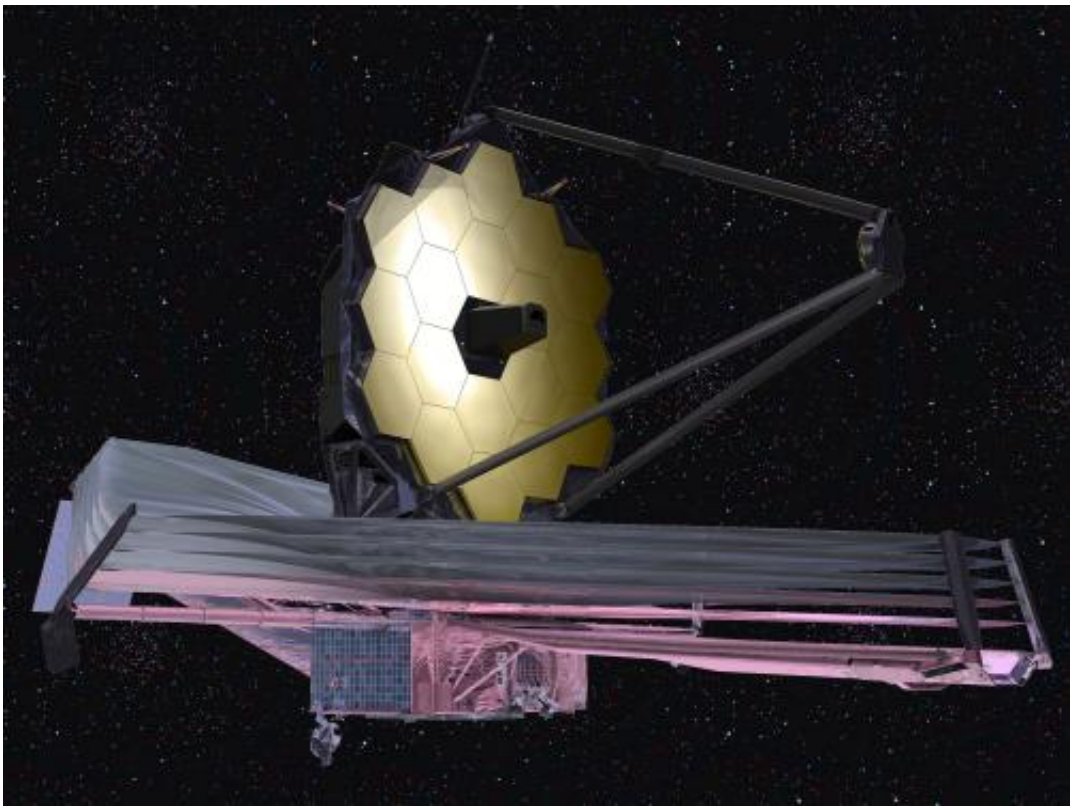
"The glint detection I found to be surprising for a couple of reasons," Robinson said. "The spacecraft observation of glint was in disagreement with some previous observations that were done from the ground."

Specifically, some researchers had tried to make predictions of the Earth's glint based on gazing at the Moon. When looking at the Moon outside of full phase, it's possible to see the Earth's light shining faintly off of it in a phenomenon called "Earthshine."

By comparing Earthshine data from a crescent-phase Earth with data from other phases, it's possible to get measurements of how significant glint is in observations of Earth's crescent sliver. These measurements predicted a much stronger glint than what Robinson's team saw using the LCROSS data.

What also surprised researchers was how different the glint appeared in different wavelengths of light. At some wavelengths, glint dominated Earth's appearance, while at other wavelengths, the glint effect was more muted, as it was masked by certain atmospheric phenomenon.

"Also, the Earth at crescent phase, thanks to the ocean, can be twice as bright. If it's something you look for in exoplanets, it can be a significant effect," added Robinson.



Artist's conception of NASA's James Webb Space Telescope, which is expected to launch in 2018. While this will be an able planet-hunting telescope, it will likely take a future generation of telescopes to seek oceans from afar. Credit: NASA

Designing future telescopes

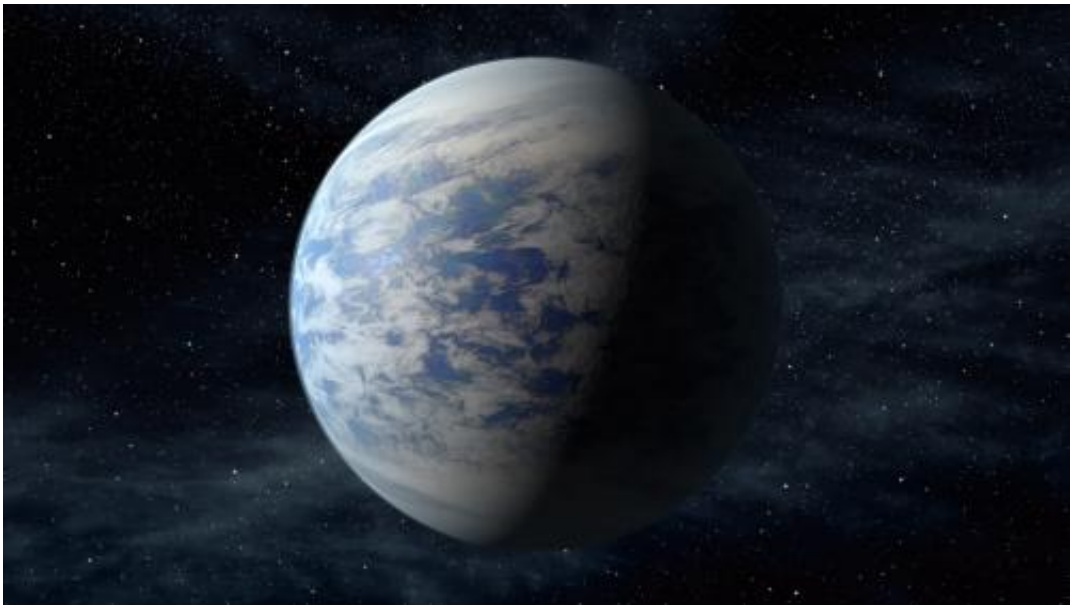
If over the course of several orbits, a planet is observed as more reflective at crescent phases and less reflective at other phases, then can it be assumed that ocean glint is the cause? Robinson cautions that the answer is not that simple.

"There could be other explanations," he said. "Clouds have a tendency to reflect better at crescent phases than at other phases, and recent work has shown that, under some circumstances, the ice-covered polar regions can

mimic certain glint effects."

But there could be other indications of habitability and life as well. One thing they noticed from a distance was ozone, which was not as much of a surprise to scientists but still a useful tool for observations. Ozone especially showed up in ultraviolet light, and it could be a "bio-indicator," or sign of life, on distant planets, Robinson said.

"Ozone is a key potential indicator of life, and it appears most strongly in ultraviolet observations of Earth," he said. "So, future telescopes could look to the ultraviolet as a place to more easily detect biosignature gases."



Artist's conception of Kepler-69c, a rocky planet larger than Earth that orbits in what could be a habitable region of its star. Credit: NASA

Such a telescope, however, will be a couple of decades down the line. While NASA's James Webb Space Telescope will be an able planet-

hunter, it will take the resolution of something like the cancelled NASA Terrestrial Planet Finder project to make better progress in searching these worlds, he said. There were a few different ideas for what it would look like, but one design had intended to combine four, 3.5-meter telescopes in space to look at parameters such as temperature and atmosphere, among others.

Another important aspect of the observations performed by LCROSS is that they become the basis for new telescope designs. NASA's work allows researchers to gather data on which designs would best pick out certain features of planets, such as the reflectivity or ozone that LCROSS observed.

"It's using current tools to predict and understand what future telescopes might one day see. By studying Earth now, you can ensure that we don't accidentally engineer the telescope of the future and find out we didn't build it strong enough," Robinson said.

More information: "Detection of Ocean Glint and Ozone Absorption Using LCROSS Earth Observations." Tyler D. Robinson, Kimberly Ennico, Victoria S. Meadows, William Sparks, D. Ben J. Bussey, Edward W. Schwieterman, Jonathan Breiner. *arXiv*:1405.4557 [astro-ph.EP]. DOI: 10.1088/0004-637X/787/2/171

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