Laser-ion funnel mass spectrometry makes search for Martian life easier

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NASA's Mars Science Laboratory is part of one of many space exploration missions that have used mass spectrometry to analyze rocks and soils. But current techniques require samples to be heavily prepared, which can harm results. Recent research shows that adding a laser and an ion funnel to a mass spectrometer enables analysis on Mars' surface without handling samples. Credit: NASA/JPL-Caltech

Finding life on Mars could get easier with a creative adaption to a common analytical tool that can be installed directly on the robotic arm of a space rover.

In a recent paper published online in the journal *Planetary and Space Science*, a team of researchers propose adding a laser and an ion funnel to a widely used scientific instrument, the mass spectrometer, to analyze the surfaces of rocks and other samples directly on Mars' surface. The researchers demonstrated that the combined system could work on the spot, without the sample handling that mass spectrometry usually requires.

"There are a lot of exciting discoveries about Mars that have yet to be made," said the paper's lead author, Paul Johnson. "This technique could make understanding the composition of rocks and soils on Mars — possibly including evidence of life — much easier."

Johnson, of NASA's Jet Propulsion Laboratory in Pasadena, Calif., came up with the idea after reading about an ion funnel technology for mass spectrometry developed by Keqi Tang and Dick Smith of the Department of Energy's Pacific Northwest National Laboratory. William Brinckerhoff of NASA's Goddard Space Flight Center in Greenbelt, Md., contributed his expertise in miniaturizing scientific instruments to the project, while Robert Hodyss, also of JPL, provided hands-on expertise during experimentation and testing.

Here on Earth, mass spectrometry is a common analytical technique scientists use to identify molecules, their elements and their isotopes in samples ranging from rocks to proteins. It works by turning a sample's molecules into electrically charged ions. A mass spectrometer then precisely measures the mass of ions and ion fragments to identify the sample's contents at a detailed molecular level.

Mass spectrometry isn't new to space exploration. It was used to analyze Martian soil for the first time as part of NASA's Viking program in the 1970s. And it's planned to be part of the Mars Science Laboratory's Curiosity rover, which will lift off for the Red Planet this November. But each time it's been used in space, the samples had to be extensively prepared before they could be analyzed.

With Viking, for example, soil had to be scooped up, placed into a chamber and heated to make the sample a gas before it could be analyzed. The Mars Science Laboratory will be able to do a more thorough sample analysis than Viking could, but it will still need to prepare its samples beforehand. The more a sample has to be handled, the greater chance there is for the equipment to malfunction or the analysis to fail.

On Earth, scientists do mass spectrometry within a vacuum chamber. But that requires either finding a small enough sample, or cutting down the sample to fit into the chamber. Any such efforts on Mars have to be done with a robotic rover that's controlled by human operators millions of miles away.

"Cutting rocks, picking them up and moving them around, all this adds complexity," Johnson said. "Complexity makes it more difficult to conduct experiments with a robotic rover. Plus, adding new tools so the instrument can do these extra tasks increase size, weight and power consumption. All this makes sending a mass spectrometer into space even more challenging."

Trying to simplify this work, Johnson and Hodyss at JPL, which manages NASA's Mars Exploration Project, turned to a technique called laser ablation. The method involves shooting a laser at the sample's surface, which creates a plume of molecules and ions that can then be analyzed by the mass spectrometer.

But how do you get the sample ions to enter the mass spectrometer? Even on our planet, that problem has plagued researchers for years. A large percentage of a sample was traditionally lost at this stage — until recently, that is. PNNL researchers Dick Smith and Keqi Tang developed a new technology for mass spectrometers in the late 1990s to address that challenge.

Their electrodynamic ion funnel is a series of conductive, progressively smaller electric ring electrodes that efficiently pull in and focus more ions into the mass spectrometer than without the funnel. This makes mass spectrometers tremendously more sensitive. Fortunately, the ion funnel works best when its surrounding environment has an air pressure of about 5 torr, which also happens to be the atmospheric pressure on Mars.

"We didn't specifically design the ion funnel for space exploration, but we're excited that it and Mars are a good fit," said Tang.

JPL asked PNNL to help test whether the combination of laser ablation and an ion funnel could make in situ, or "in place," mass spectrometry possible on Mars. A standard laboratory mass spectrometer was equipped with laser and an ion funnel attachments, and the ion funnel end was placed inside a sealed chamber that matched Mars' atmospheric conditions. The researchers shot laser pulses at various samples, such as copper, stainless steel and gypsum. As they suspected, a small layer of each sample's surface atoms was transformed into ions and the ion funnel quickly pulled them into the mass spectrometer, which identified the samples.

"This system could be developed into a 'point and shoot' instrument for space analysis," Johnson said.

The results are promising, but further work is needed to develop ion funnel-equipped mass spectrometers ready for space. The next step is to make the system as small and light as possible so it could be used on a space exploration rover. The authors plan to pare it down enough to fit onto a rover's robotic arm.

More information: Paul V. Johnson, Robert Hodyss, Keqi Tang, William B. Brinckerhoff, Richard D. Smith, The laser ablation ion funnel: Sampling for In Situ mass spectrometry on mars, *Planetary and*

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