Sniffing for Life on Mars

Edmond W. Wilson, Jr., P.I.†
Department of Chemistry, Harding University, Searcy, AR 72149
Edward W. Tunstel
Advanced Robotics Controls Group, Jet Propulsion Laboratory, Pasadena, CA 91109
and
Gary T. Anderson, Department of Applied Science, University of Arkansas at Little Rock, Little Rock, AR 72204

There has been a great deal of speculation about the possibility of past or present life on Mars. However, missions to Mars, starting with the Viking Landers and continuing to the present day, including early data from latest satellite, the Mars Reconnaissance Orbiter (MRO), have failed to yield direct or indirect evidence for life in this hostile world. The current consensus of those studying the astrobiology of Mars is that the surface is too hostile for life to exist because of the lack of liquid water and the deadly radiation from Solar and cosmic radiation. Those that hope there may be life on Mars argue that it would be found protected underground where there is liquid water.

There are tantalizing results that do not carry the weight of evidence but hint that there might have been life on Mars and even that there may be life there today. These include the Viking experiments to detect life; the famous Mars meteorite, ALH84001 and the European Space Agency Mars Express Satellite that found methane at low levels in the Martian atmosphere. The latter is particularly interesting because the methane seems to be localized in certain regions where there is also water present.

What kind of unmanned space mission could be designed to find life underground on Mars? The obvious answer would be one that included drilling into the surface to examine samples for clues that life was there. At the present time, this type of mission has not been attempted because of the difficulties involved in a drilling operation, particularly one that involves a substantial penetration of the Martian surface. Until the drilling operations become feasible, we propose another approach that is cost effective and can be implemented with present technology. Our approach is to carry out wide-area Mars surface surveys by means of an absorption spectrometer that would detect localized emissions of biogenic gases escaping into the atmosphere from colonies of microbes buried below the surface.

What gases should be monitored in the search for microbial life on Mars? In 1999, researchers at Jet Propulsion Laboratory and California Institute of Technology formed a committee to identify chemical signatures of life from in-situ measurements of biogenic gases and their isotopic ratios. This team, led by Christopher Webster, considered fourteen known biogenic gases of Earth origins. These are listed in Table 1.

Table 1. Biogenic Gases found on Earth

H_2	O_2	CO_2	CO	CH_4
N_2	N_2O	NO_X	$(CH_3)_2SO$	COS
H_2S	CH_3Br	CH_3Cl	$CHCl_2$	

†Edmond W. Wilson, Professor, Department of Chemistry, Box 10849 Harding University, Searcy, AR 72149-0849. Phone: 501 279 4513, FAX 501 279 4706 E-mail wilson@harding.edu

A measurement of isotopic ratios for these gases would be very valuable because enzymes which produce these gases are selective towards the lighter isotopes during metabolism.

We have constructed a prototype diode laser absorption spectrometer specifically designed to detect and locate the source of biogenic gases while mounted on a mobile rover when operating on the surface of Mars or other Solar System body. This instrument is being tested to see if it can accurately measure isotopic ratios of these gases. While detection of biogenic gases is our primary goal, the instrument will also prove to be a valuable addition to the arsenal of Mars sensory instruments. Studies of the diurnal and seasonal variation of water vapor would be extremely important. The knowledge of accurate isotope ratios for gases making up the Mars atmosphere is also a goal of geologists in order to more fully understand the geologic history of Mars.

Figure 1. Robotic system searching for biogenic gases [Anderson, 2006].

Figure 1. illustrates the operation of the spectrometer. A diode laser beam, tuned to the frequency of methane, is collimated and focused on a highly reflective surface of the Mars Lander located some distance from the rover. The light reflected from the mirror surface is collected and focused onto a sensitive photo detector. At the present position of the rover, no methane is detected. The laser makes a measurement and then moves forward. Another measurement for methane is made. At some point the laser beam will encounter the methane gas escaping from underground out into the Martian atmosphere. This is pictured as some plumes of methane on the right side of the illustration. The methane gas spectrum will be detected and measured. The rover will then begin a series of movements to pin point the origin of the methane gas on the surface. Other robotic agents will then arrive and begin digging, drilling, sampling the location for the source of the methane.

By use of diode lasers that emit in the near-infrared region of the electromagnetic spectrum, a very compact, sensitive absorption spectrometer can be designed to detect biomarker gases. Diode lasers are ideal sensors for space exploration because they are the size of a pencil eraser and require only a few milliwatts of power. They can be operated sequentially, to minimize power requirements. Although diode lasers emit at a specific wavelength for a specific current through the laser and temperature of the laser, the wavelength of this emission can be varied over small wavelength ranges by variation in current and temperature. With careful selection, diode lasers can be obtained that are capable of scanning through spectral peaks, from baseline to baseline, of any gas that absorbs radiation in the near-infrared region (0.700 to 2.500 μm wavelengths).

The lasers are mounted in the thermally protected interior of the mobile rover and connected to the laser aiming device through fiber optic cables. The fiber optic cables are terminated with collimating lenses that focus the beam onto the reflective target located on the rover. The tilt and pan aiming device must have a resolution of 5 arc seconds per step in order to be able to strike a 20 square target at 1000 meters. This resolution is achieved with high resolution mini-linear actuators. An efficient algorithm must be developed to cause the laser beams find and to strike center of the target.

The detector is mounted collinearly with the laser beam. Studies are being carried out to determine the best material for the reflective surface on the Mars Lander. The reflected laser light is captured with a small telescope and focused onto an InGaAs photo-detector. The electrical signal from the photo detector is conditioned and amplified and digitized with a high resolution digitizer. The digitized signal is processed to determine the amount and direction of the detected biogas.

Studies have been made and are being made to determine the optimum trajectory for the mobile rover mounted spectrometer to traverse. The trajectory favored at this time is a spiral pattern for initial surveys of the area. Included in the trajectory algorithm is a plan to recover from a situation where the line of site between rover and Lander is blocked.

Successes thus far include laboratory measurements of ammonia vapor, water vapor and oxygen. Outdoor static measurements have been made for ammonia. It was found that variations in ambient light and variations in wind gusts degrade the accuracy of the measurements. Steps have been taken to reduce the ambient light problem through notch optical filters that only allow the wavelengths to be measured into the detector. Improvements in rapidity of measurements should take care of some of the wind gust problem. Oxygen measurements over a path length of 80 meters have been carried out. At this distance, the signal to noise ratio is large and field measurements of longer path lengths are in progress.

Plans are being made to survey buried land fills with the instrument to see if the various biogenic gases can be detected at the sensitivity needed for work on other Solar System bodies. The tests will include gas sampling by gas chromatography/mass spectrometry (GC/MS) to validate the results obtained from the laser spectrometer.

We feel that these studies will show that the diode laser absorption spectrometer method of biogenic gas detection and location will be a valuable addition to a future Mars rover mission or a mission to one of the Solar System Moons where this method of survey would be applicable.

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Acknowledgment

Funds for this project are being provided by the NASA Astrobiology Science and Technology Instrument Development Grant Number NNG04GO25G.