

Join Today

And receive our stunning
Mars Panorama Poster!



[Society Information](#)

[Publications](#)

[Planetary](#)

[Learning Center](#)

[Links](#)

[The Store](#)

[Sign up for Planetary News Updates](#)



[Explore Mars!](#)

[Mars News Archives](#)

[▶ Mars Express/Beagle 2](#)

[▶ Mars Exploration Rovers](#)

[Mars Facts](#)

[Mars Images](#)

[Missions to Mars](#)

[Mars on Planetary Radio](#)

[Send this page to a friend!](#)



Buy a "Top 3 reasons Why I Want To Move To Mars" mug and support The Planetary Society

\$16 [Order](#)

Mars: The Case for Methane Expands, but Theories about Abundance, Sources, and 'Sinks' Diverge

By A.J.S. Rayl

With Emily Lakdawalla reporting from DPS

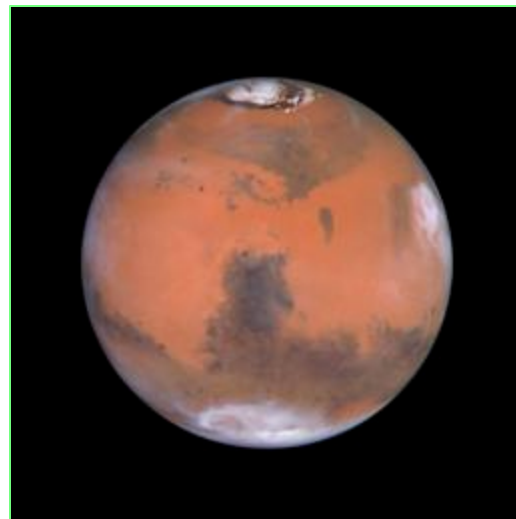
19 November 2004

The case for the presence of methane in Mars' atmosphere expanded, but the theories about its abundance, sources, and 'sinks,' floated in different directions as Sushil K. Atreya, Director of the Planetary Science Laboratory at the University of Michigan, Vladimir A. Krasnopolsky, of Catholic University of America, and Michael J. Mumma, of NASA, updated and expanded on their previous findings at the American Astronomical Society's Division for Planetary Sciences (DPS) annual meeting held in Louisville, Kentucky last week.

Using Earth as the analogue, Krasnopolsky maintained that the methane (CH₄) is uniformly distributed in the atmosphere of Mars, and took the hypothetical leap that living bacteria under the surface are "a plausible source" of the odorless and colorless gas. Mumma, on the other hand, reported the methane to be significantly "enhanced" in some areas, and veered out of the (Earth) box, suggesting that distinctly Martian processes may be in play. And Atreya presented new research on what one of those distinctly Martian processes may be, explaining how hydrogen peroxide "dust" produced in dust devils and dust storms can help "break apart" the methane molecules by oxidation, thereby serving as an important loss mechanism or 'sink' for methane near the surface of the planet.

During the past year or so, the teams of Krasnopolsky (1), Mumma (2), and Vittorio Formisano (3), principal investigator of the Planetary Fourier Spectrometer (PFS) onboard the European Space Agency's *Mars Express*, independently announced detection of methane in the Martian atmosphere. Atreya is a member of the Formisano team. The finding is significant because no one had ever measured methane there before, and because the gas is not stable in the Martian atmosphere. That means it has to be coming from somewhere on the planet. And -- whether the source is life in the form of tiny Martian microbes or physical geothermal processes or something else altogether -- it may well mean Mars is not the dead and desolate planet scientists have long thought it to be.

With the latest reports of further analyses from the three teams, the spectral evidence for methane at Mars seems secure. From there, the calculations, projections, and hypotheses as to just how much methane there is swirling about the Martian atmosphere and where and from what it's originating and where it's going are diverging dramatically.



Mars
Image: NASA/Hubble Space Telescope

Each team is analyzing spectra, data collected by spectrometers or instruments that measure the composition and properties of the atmosphere from the wavelengths of sunlight absorbed by the molecules there. How methane appears in these spectra (from infrared radiation it emits) is distinct, producing a kind of 'signature.' Even though the teams are looking at the same infrared spectrum of Mars for the telltale signature of methane, each is varied in its approach. Additionally, the spectrometers feature different resolution capabilities and sensitivity values. In other words, while all three teams are looking for the same thing, each is going about it in slightly different ways, with slightly different instruments. As a result of those and other factors, the measurements and the interpretations of what is being seen can be different.

Since both the Mumma and Krasnopolsky teams used ground-based telescopes to search for methane on Mars, they must also factor in the methane in Earth's atmosphere. Telescopes aimed through Earth's atmosphere at Mars will inevitably pick up strong absorption lines from the local methane.

Krasnopolsky, research professor at the Department of Physics of Catholic University of America, confirmed his team's earlier detection of around 10 parts per billion (ppb) methane from observations recorded in 1999 using the Fourier Transform Spectrometer (FTS) spectrometer on the Canada-France-Hawaii telescope, in Mauna Kea, Hawaii. "That spectrometer had the highest spectral resolution which is critical for ground-based detection of methane," Krasnopolsky stated. "The measured abundance agrees with the upper limits of 20, 50, and 40 ppb established by three other teams who tried but did not succeed to detect methane on Mars." The Krasnopolsky team has since conducted other inquiries into potentially influential factors. Consideration and analyses of those investigations led the team, Krasnopolsky said, to conclude that methanogenic bacteria, are a "plausible source" for the methane production on Mars.

The team determined, for example, the production of methane on Mars to be about 270 tons per year. Presupposing that photolysis [decomposition by the sunlight] and photochemistry determines the lifetime of methane, Krasnopolsky estimated that the lifetime of methane on Mars to be around 340 years, "much longer than the time of global mixing in the Martian atmosphere," and said that the gas should be uniformly distributed across planet. If methane varies from place to place on Mars, then there should be some rocks which are extremely effective in removal of methane. "Their efficiency should exceed that of the atmosphere by more than 1000 times, and such rocks are currently unknown," he concluded.

Of the total 270 tons of methane produced every Martian year, the production of volcanic methane on Mars, and the amount of methane delivered by comets, meteorites, and interplanetary dust, account for but a small part of the methane present.

The amount of volcanic methane on Mars is low, because Martian volcanism is more than 12 million years old and any released methane "must be photochemically destroyed since that time," Krasnopolsky stated. Additionally, he pointed out that the thermal emission imager (THEIMS) data from *Mars Odyssey*, which has been studying the composition of the planet from orbit since 2001, does not reveal any 'hot spots' indicative of volcanic or geothermal activity.

Krasnopolsky also reported on a recent search for sulfur dioxide (SO₂) on Mars, which he conducted with M.J. Richter, J.H. Lacy, and T.K. Greathouse, using TEXES spectrograph at NASA's Infrared Telescope Facility (IRTF), in Mauna Kea, Hawaii. They found that the most abundant volcanic gas (on Earth) is absent in the Martian atmosphere with an upper limit of 0.5 ppb, therefore seepage of the volcanic gases is "ineffective" on Mars and "cannot be a significant source" of methane. "This is a crucial argument against volcanic methane," Krasnopolsky told the DPS crowd.

As for the amount of methane that may be delivered to Mars by the impacts of comets, meteorites, and interplanetary dust, "each of these processes has been calculated, and the total delivery is 6% of the required production," the team wrote in its abstract (4).

In putting forward methanogenic bacteria as "a plausible source of methane on Mars," Krasnopolsky went on to suggest --assuming the biochemical efficiency of Martian biota is similar to biota on Earth -- that biomass production of methane could actually range from 170 to 3000 tons per year depending on efficiency. "This is much lower production than on Earth," he said, and Mars is "generally sterile," except for some "small oases" of these miniscule Martian lifeforms. Any search for this tiny underground biota, he cautioned, will be difficult because of the uniform distribution of the methane. The team's paper on the detection of methane on Mars will be published in the December issue of the journal *Icarus* (5).

In contrast, Mumma presented a different picture of the methane on Mars. The Chief Scientist for Planetary Research in the Laboratory for Extraterrestrial Physics at NASA's Goddard Space Flight Center (GSFC) presented data from observations in which his team detected methane and water in the same spectral regions on Mars, and found eye-brow raising evidence of strong gradients of methane between the equator and the poles (6).

Since last year's DPS poster presentation in which the team showed spatial variation in methane at Mars recorded using NASA's IRTF on Mauna Kea, and the Gemini South telescope in Chile, Mumma said he has applied "rigorous models to extract the column density and the mixing ratio for methane" to get a quantitative look at the gas. The team found that specific regions near the equator on Mars were showing an "intense enhancements" of methane, "implying the existence of local sources where methane is currently being released."

In observations using the CSHELL spectrometer at IRTF and the Phoenix spectrometer at Gemini South, the team found water in the same spectra as methane. With Phoenix, two lines of methane and four lines of water were detected simultaneously, and the abundances retrieved independently from the methane lines were in agreement. They then compared their water measurements with independent data from the thermal emission spectrometer (TES) on board *Mars Global Surveyor* (MGS). "The measuring approach we apply is somewhat different from TES, which measures water at 40 microns -- long wavelengths that are not sensitive to dust and ice opacity. We're measuring water at 3.3 microns where one can be affected by extinction due to ice in the atmosphere -- airborne ice on aerosols."

While the two methods should give results that agree with one another, "the proof in the pudding is to make those measurements and then show that they do," Mumma acknowledged. "After we apply a correction factor for extinction (based on TES/MGS measurements on the same date) the agreement in absolute abundance is satisfactory, and our measured latitudinal variation in water also agrees with TES results. This validates the process and our method for extracting column densities."

The good agreement with TES and the detection of multiple spectral lines of methane constitute "unequivocal evidence" for the detection of methane on Mars," Mumma concluded. "The methodology is correct. The detection of methane is secure, and the equatorial enhancements are very clear."

Focusing on Syrtis Major Planitia near the equator -- with a reference point in the mid latitudes (24-30 S) between the equator and the Hellas Basin -- Mumma said the team found a substantial increase up to 250 parts per billion [ppb] in the equatorial-latitudes, as compared to relatively low amounts visible in the high latitudes, around 50 ppb, with the range from 20 to 60 ppb. "That's an enormous difference. We didn't expect that," he told the gathering of planetary scientists.

"We'll make some refinements, but our quiescent [reference] levels -- levels measured at the high latitude regions but well away from the equatorial zone where we think we're seeing discrete sources - were in the range of 20 ppb to 60 ppb, as I reported last week, but they're going to drop a little bit because of a technical detail," Mumma told The Planetary Society later. "Our equatorial readings, however, will not come down -- they'll probably go up a bit because 250 ppb is the difference between the reference position and the equatorial region, and there is some methane in the reference position," he continued. "We have to add that back into the equatorial value in order to get the absolute value at the equator. So when I say 250 ppb -- I mean that there's 250 ppb more in the column density at the equator than there is at the reference position, which by the way didn't have a lot."

The equatorial enhancements of methane require "discrete" -- not widely distributed -- source regions, Mumma submitted at the meeting. While he agreed with Krasnopolsky that "volcanism" is probably not the source of the methane for the simple reason that "there is no independent evidence for current volcanism at all," like most Mars scientists, he wasn't ready to zero in on just Martian microbes as the methane producers, despite the fact that the discovery of methane and water together would appear to lend credence to the notion that perhaps biotic life may be the most obvious source. "[Water] certainly does help the idea that methanogens are responsible, but it is not definitive in any way," he noted. "Most water at this season (late Northern summer) is water released from the north polar cap; our measurements don't reveal the amount (if any) being released with methane."

Mumma considered other working hypotheses in his presentation, including serpentinization of basalts -- a geothermal process wherein carbon dioxide combines with water to alter basalt to serpentine and thus freeing methane, clathrate methane hydrates deep below the surface, and, yes, Martian methanogens -- and explained how the methane could travel underground wending upward through fissures extending to the surface or emerging through a scarp face [cliff] -- all of which was presented by Atreya, at the International Mars Conference last September (7), and in the *Science Online* paper by the PFS team (8), which is forthcoming soon in the print edition of the journal.

"We don't really have much more to go on yet, except we know that the two regions where we did find enhancements are regions where there are known to be pronounced scarps," Mumma said.

During the data collection process, Mumma said the team on occasion received a strong signal from a given area and then at another time would only get a very weak signal from the same area. The anomalies were created by interference or, more to the point, blockage, what he calls the "opacity effect" of Mars' notorious and tumultuous dust storms. "There are times when we observed during a dust storm, for example, and ultimately realized that this raises the reflecting surface up to about 10 to 20 kilometers, depending on the strength of the storm," Mumma elaborated. "It can actually mean that you're not looking down through the entire atmosphere, but just down to the cloud top level -- and yet most of the atmospheric gas lies below that level. It was in those situations that we would see a very weak signal. There may also be seasonal effects influencing the methane cycle at Mars." Mumma has not yet published any of his findings. But, he said, "getting a paper written and submitted" is now "the number one priority."

Those monster Martian dust storms -- and not photolysis -- may also have a lot to do with how methane is destroyed in the Martian atmosphere, Mumma said, another point of contention with Krasnopolsky's theory. "There are other sinks for methane that Krasnopolsky has not accounted for. We think that there has to be something much faster than photochemistry; otherwise, we wouldn't see these strong gradients from the equator to the poles because they should disappear in a matter of months in the absence of continued release, not in 300 years, which is the photochemical lifetime."

Enter the dust storms. The peroxide peppered dust particles, which make up the gusts that can envelope the entire planet at times, may well be a major 'sink' for the methane, helping the molecules of methane gas break apart. Hydrogen peroxide (H₂O₂) in the "gas phase" has been recently detected in the Martian atmosphere by two ground-based observations, in the sub-millimeter range (9) and in the infrared range (10), using the TEXES high-resolution spectrometer at IRTF. However, Atreya, who is also a member of the TEXES team, pointed out in his DPS presentation (11) that the measured abundance of hydrogen peroxide, 20-40 parts per billion by volume [ppbv], which is also predicted by global average photochemical models, is too low to account for the loss of methane or other organics on Mars.

Atreya then went on to show that substantially greater quantities of H₂O₂ can be produced by triboelectric fields in dust devils and dust storms and through saltation. In fact, the amounts are so immense, he said, that a large fraction of H₂O₂ would "snow out" of the atmosphere onto the Martian surface, using dust particles as condensation nuclei. "Bound to dust particles and impregnating the grains in the regolith, hydrogen peroxide can survive for long periods of time, unlike the gas phase that has a relatively short lifetime of a few days - an important consideration in the methane cycle," he contended.

"It is a simple mechanism for getting oxidants from the surface up into the atmosphere, distributing them uniformly over the first 20 kilometers and providing a wonderful set of surfaces with which methane can collide and eventually be destroyed - and be destroyed more rapidly than can be done with photochemistry," Mumma mused.

There remain many unanswered questions of course, not the least of which is the considerable concern over the lack of quantitative abundance agreement. But the one thing that does appear certain is that methane is present in the atmosphere of Mars.

The notion that something -- tiny Martian microbes or hydrothermal activity deep underground -- is "pumping" out methane, is "a very attractive hypothesis," as Atreya put it, but the scientists still don't know if the methane on Mars is in a "steady state." If it is, the above scenarios of some type of active 'producer' is/are likely. "But, in view of methane's 300-600 year lifetime, we cannot and will not be able to say anytime soon whether or not methane is in steady state," Atreya pointed out. "In fact, its source could very well be exogenous, and the methane we are seeing today may simply be a relic of a past cometary impact, with the methane abundance declining with time."

Each of the teams will continue research, with the objective of unraveling the mystery of the methane on Mars. "We plan to continue our study of methane on Mars by using the TEXES spectrograph at the Stratospheric Observatory for Infrared Astronomy (SOFIA)," Krasnopolsky told The Planetary Society later. "This aircraft observatory will be in operation in the nearest months. However, the TEXES will be at SOFIA in 2007. Most of the terrestrial methane will be below the aircraft facilitating measurements of Martian methane," he said.

"These findings suggest many directions for both confirmation and future work and they provide great directions for theoretical exploration, laboratory science and astronomical remote observations," Mumma offered. "The key thing is to identify critical tests of each hypothesis so that we have a plan to go forward and evaluate which of these may be working and which are not viable. By identifying regions where methane is currently being released, these new insights are likely to profoundly affect the direction and planning of the in situ search for life on Mars."

Krasnopolsky suggested that laboratory study of interaction of methane with rocks may also help to solve the controversial problem of variations of methane on Mars.

"The PFS has already collected more than 10,000 spectra that show a non-uniform

distribution of methane over Mars, and by the end of the nominal mission in November 2005 we plan to have a nearly complete map of methane over the entire planet," Atreya offered. "Barring any unforeseen difficulties, the Mars Express mission is planned to be extended for another Martian year [two Earth years]. In addition to methane, the PFS team is working hard to identify other molecules in the spectra that could shed light on the sources and sinks of methane on Mars, while at the same time carrying out modeling studies."

For now, the only thing upon which everyone agrees is that the methane is coming from somewhere on the Red Planet. Finding out where and from what will command the attention of Mars scientists until the answer is known, because the possibility that the Red Planet is not 'dead' is just too exciting to ignore.

Citations:

1. V.A. Krasnopolsky, J-P. Maillard, T. C. Owen, "First Detection of Methane in the Martian Atmosphere: Evidence for Life?" Geophysical Research Abstracts, Vol. 6 06169, European Geosciences Union, 26-30 April 2004.
2. M.J. Mumma, R.E. Novak, M.A. DiSanti, B.P. Bonev, "Sensitive Search for Methane on Mars." Abstract submitted to American Astronomical Society's Division for Planetary Sciences (DPS) annual meeting in Monterey CA, September 2003.
3. V. Formisano, S.K. Atreya, T. Encrenaz, N. Ignatiev, M. Giuranna, "Detection of Methane in the Atmosphere of Mars," *Science Online*, Oct. 28, 2004.
4. V.A. Krasnopolsky, J-P. Maillard, T.B. Owen, "First Detection of Methane in the Martian Atmosphere: Evidence for Life?" Abstract submitted to American Astronomical Society's Division for Planetary Sciences (DPS) annual meeting , Louisville, KY, 8-12 November 2004
5. V.A. Krasnopolsky, J-P. Maillard, T.B. Owen, "First Detection of Methane in the Martian Atmosphere: Evidence for Life?" In press. *Icarus*, December 2004.
6. M.J. Mumma, R. E. Novak, M. A. DiSanti, B. Bonev, N. Dello Russo, T. Hewagama, and M. Smith, "Detection and Mapping of Methane and Water on Mars: Evidence for local enhancements in Methane." Abstract submitted to American Astronomical Society's Division for Planetary Sciences (DPS) annual meeting, in Louisville, KY, 8-12 November 2004.
7. S. K. Atreya, T. Encrenaz, V. Formisano, A-S. Wong, "Methane on Mars - sources, sinks, implications for life." Presented as keynote speech by Atreya at the International Mars Conference in Ischia, Italy, 19-23 September 2004.
8. V. Formisano, S.K. Atreya, T. Encrenaz, N. Ignatiev, M. Giuranna, "Detection of Methane in the Atmosphere of Mars," *Science Online*, Oct. 28, 2004.
9. R.T. Clancy, B.J. Sandor , G.H. Moriarty-Schieven, "A measurement of the 362 GHz absorption line of Mars atmospheric H₂O₂," *Icarus*, January 2004.
10. T. Encrenaz, B. Bezard, T.K. Greathouse, M.J. Richter, J.H. Lacy, S.K. Atreya, A.S. Wong, S. Lebonnois, F. Lefevre, F. Forget, "Hydrogen peroxide on Mars: evidence for spatial and seasonal variations," *Icarus* , August 2004.
11. "Oxidant Enhancement in Martian Dust Devils and Storms," S.K. Atreya, A-S. Wong, N. Renno, W. Farrell, G. Delory , D. Sentman, S. Cummer, J. Marshall, S. Rafkin, and D. Catling, Abstract submitted to American Astronomical Society's Division of Planetary

Sciences (DPS) annual meeting, Louisville, KY, 8-12 November 2004.

▶ [Sign up for Planetary News Updates](#)

▶ [Send this page to a friend!](#)

▶ Visit [The Planetary Society's Exploring Mars website](#)

▶ For other news stories, visit [The Planetary Society's Mars News Archives](#)

▶ [Send us your comments](#) ▶ [Planetary Society Site Map](#) ▶ [Join The Planetary Society](#)

Copyright (c) 1993-2005 The Planetary Society. All rights reserved.