

## *Oxygen on Mars Adds to Atmospheric Mysteries*

After a perplexing methane burst was measured by NASA's Curiosity rover earlier this year, scientists were surprised again by variations in atmospheric oxygen.



By **Kenneth Chang**

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There is not much air on Mars — the atmospheric pressure there is less than one one-hundredth of what we breathe on Earth — but what little is there has baffled planetary scientists.

Oxygen, which makes up about 0.13 percent of the Martian atmosphere, is the latest puzzler.

In a paper published this month in the *Journal of Geophysical Research: Planets*, scientists working with data gathered by NASA's Curiosity rover reported that levels of oxygen unexpectedly varied with the seasons on Mars, at least in the neighborhood that Curiosity has been driving around since 2012.

That follows the rover's reading earlier this year of a large burst of methane, another gas emitted on Earth by living things and which perplexingly disappeared almost immediately.

"It's confusing but it's exciting," said Sushil K. Atreya, a professor of climate and space sciences and engineering at the University of Michigan who works on Curiosity's atmospheric measurements. "It keeps us on our toes. Mars is certainly not boring."

A Mars year lasts 687 days, so the scientists studying the oxygen variations were able to examine the behavior over almost three Martian years, through December 2017.

The level of oxygen "rises relatively higher in the spring," said Melissa G. Trainer, a research space scientist at the NASA Goddard Space Flight Center in Greenbelt, Md., and lead author of the new paper, "and then it comes down lower, below what we would expect later in the year."

Carbon dioxide is the main ingredient of Martian air, and scientists have understood for decades its ebb and flow. At the poles in winter, it falls out of the air and freezes to ice, then wafts back into the atmosphere as temperatures warm in the spring.

High in the Martian atmosphere, ultraviolet light breaks apart carbon dioxide into carbon monoxide and oxygen atoms and then closer to the ground, interactions with water shepherd the oxygen atoms into molecular pairs.

Because oxygen molecules should be pretty stable, persisting about a decade, researchers expected that the amount of oxygen molecules would remain almost constant.

Curiosity's atmospheric measurements showed exactly that pattern for nitrogen and argon, two other trace gases in the Martian atmosphere. But, for oxygen, the concentrations shot up by a third during spring.

"This was a very unexpected result, an unexpected phenomenon," Dr. Trainer said. "There's a lot we don't know about the oxygen cycle on Mars. That's become apparent."

Adding to the mystery, the cycle was not the same each year, and the scientists could not find an obvious explanation — like temperature, dust storms or ultraviolet radiation — for what changed from year to year.

On Earth, most oxygen is generated by the photosynthesis of plants. But so far, for the Mars scientists, that is far down on the list of explanations.

“You’ve got to rule out all of the other processes first before you go there,” Dr. Atreya said.

More likely sources are chemicals like hydrogen peroxide and perchlorates known to exist in the Martian dirt. “It’s pretty clear you need a flux from the surface,” Dr. Atreya said. “Nothing in the atmosphere is going to create this kind of rise.”

But how these chemicals might release and absorb enough oxygen to explain the seasonal rise and fall is difficult to figure out, especially as there are only 19 oxygen measurements over five and a half years.

An intriguing possibility is that the oxygen mystery might be tied to another trace gas, methane, that is also acting strangely in the Martian atmosphere.

“It’s not entirely clear if there is a correlation or not,” Dr. Trainer said.

Since 2003, several teams of scientists have reported large bursts of methane based on measurements from Earth-based telescopes, orbiting spacecraft and the Curiosity rover. Other times, the methane has been largely absent.

The presence of methane was a surprise to scientists, because the known processes to create the gas are either biological — methane-producing microbes — or geothermal, which would be a promising environment for life to exist on present-day Mars.

Now scientists want to know not only how methane is generated on Mars but how it quickly disappears. In June, Curiosity observed a particularly strong burp of methane — 21 parts per billion by volume. But when it repeated the experiment a few days later, it came up empty — less than 1 part per billion.

The European Space Agency’s orbiting Mars Express spacecraft passed over Gale Crater, the site of the rover, just about five hours after Curiosity measured the burst — and did not detect anything. (The same instrument corroborated a 2013 methane burst observed by Curiosity.)

“I would say that it seems this spike measured by Curiosity was very short-lived and local,” said Marco Giuranna, a scientist at the National Institute for Astrophysics in Italy who is in charge of the Mars Express instrument.

Even between bursts, methane on Mars poses a mystery. Curiosity has measured a low but persistent presence of methane, about 410 parts per trillion, which rises and falls with the seasons. But a newer European orbiter, the ExoMars Trace Gas Orbiter, with the ability to measure as little methane as 50 parts per trillion, has yet to see any methane at all since it started taking measurements in April last year.

The Trace Gas Orbiter is looking at a region several miles above the ground and Curiosity is taking measurements at the surface. But scientists had thought that methane near the ground would mix through the higher atmosphere within a few weeks.

“The science puzzle is that these two lines of evidence just cannot be reconciled,” Oleg Korablev of the Space Research Institute in Russia wrote in an email. Dr. Korablev is also the principal investigator of one of the two Trace Gas Orbiter instruments making methane measurements.

Håkan Svedhem, the project scientist for the Trace Gas Orbiter, said: “We know no mechanism that could destroy methane completely in such a short time. So it is really a mystery unless Curiosity sits right on top of the only local source on the planet, and even if it would, that source has to be a small one.”

Scientists working on the three missions are planning to make near simultaneous observations of Gale Crater on Dec. 15 and again in late December, Dr. Giuranna said.

Next year, four missions are scheduled to be launched toward Mars. Three of those — built by NASA, China and jointly by the European Union and Russia — will attempt to place new rovers on the planet's surface. The fourth, a United Arab Emirates spacecraft, will enter orbit. But none of them will carry instruments to measure methane or oxygen.

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