Mars Lost Atmosphere to Space

By: **Camille M. Carlisle** | March 30, 2017

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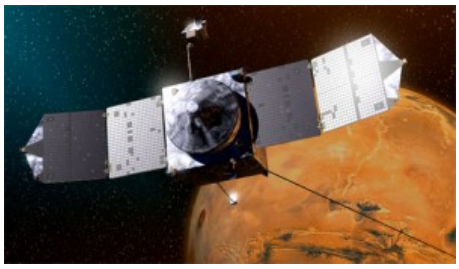
NASA's MAVEN mission has confirmed that the solar wind stripped the Red Planet of its atmosphere.



This image shows an artist concept of NASA's Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft, which reached the Red Planet on September 21, 2014.
Lockheed Martin

Mars is the little planet that couldn't. Its landscape, transformed by rivulets and lakes, has dried up. Its atmosphere is a wisp of what it once was. Based on the ratio of various elements' isotopes — which aren't currently what they should be if Mars always looked like this — planetary scientists suspect that the Red Planet has lost anywhere from 25% to 90% of its atmosphere over the last 4-ish billion years, with the estimates favoring at least 50%.

One popular explanation among planetary scientists has been that Mars's atmosphere was stripped away by the solar wind, the barrage of charged particles that stream out from the Sun at 400 km/s (900,000 mph) and up. Now, scientists with NASA's MAVEN orbiter mission have confirmed this hypothesis.

The MAVEN spacecraft loops around Mars, dipping in and out of its upper atmosphere. Using the craft's measurements, Bruce Jakosky (University of Colorado, Boulder) and colleagues determined the levels of two isotopes of argon, argon-36 and the heavier argon-38. Argon is a noble gas (in the rightmost column of the Periodic Table of elements), which means it doesn't interact chemically with the surface. The only way to get rid of it is to strip it from the atmosphere into space.

Argon's heavier isotope naturally settles lower in the Martian air than the lighter one, creating a predictable ratio of argon-36 to argon-38 in the upper atmosphere. This differentiation leaves the lighter isotope more susceptible to being torn away by the solar wind in a process called *sputtering*.

In sputtering, the atmosphere colludes with the

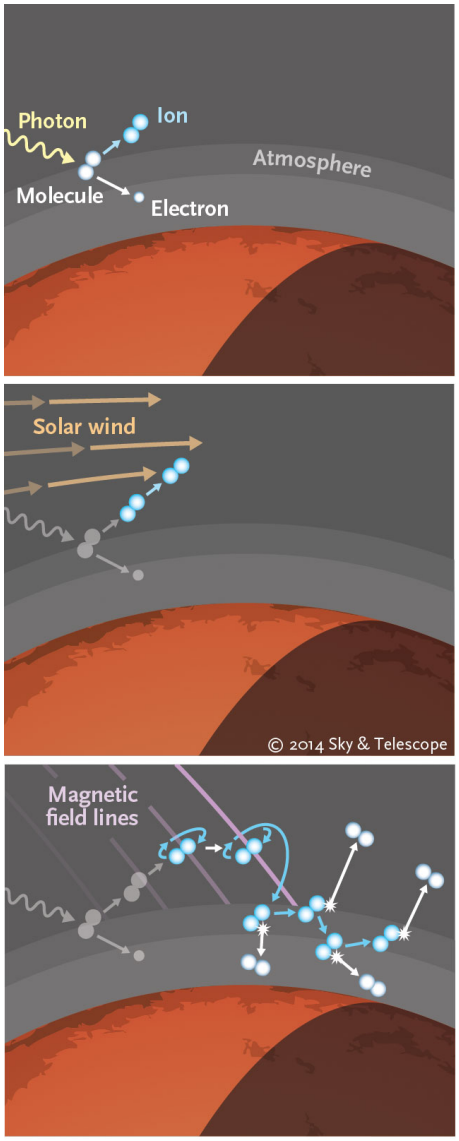
solar wind against the planet. Ultraviolet photons from the Sun first knock electrons from the atmosphere's atoms and molecules, forming ions. The solar wind then picks up these ions, whirling them around and flinging some of them back into the atmosphere, where they collide with neutral atoms and molecules there — such as argon-36 —and "sputter" them every which way, including out of the atmosphere entirely.

MAVEN's observations show that today's Mars has far too little argon-36, if it started out with levels similar to Earth and other solar system objects. To explain current levels, the planet has lost roughly two-thirds of its atmospheric argon to sputtering over its history, the team concludes in the March 31st *Science*.

This result agrees with previous Mars studies, including a 2013 study by Sushil Atreya (University of Michigan) and others using Curiosity rover data. (Incidentally, the MAVEN result incorporates Curiosity's measurements.) The percentage itself is not the news; rather, MAVEN's notable contribution is the evidence for how the argon isotopes separate and how the argon is lost.

Although argon is a loner element, it wouldn't have left alone. Other atmospheric constituents would have escaped Mars when it did. Jakosky's team estimates that, based on the argon ratio, Mars has lost at least half a bar (where 1 bar is the atmospheric pressure at sea level on Earth) of its primary atmospheric molecule, carbon dioxide. That's enough to at least partially explain the loss of the planet's ancient warmer, wetter climate.

Thus, MAVEN confirms that modern Mars is a frozen desert world in part because the solar wind blew off its insulation.



One of the ways the solar wind can steal a planet's atmosphere is by a process called sputtering. First, ultraviolet sunlight knocks electrons out of atmospheric atoms and molecules in the upper Martian atmosphere, forming electrically charged ions (top). These ions are picked up by the solar wind (middle), which is infused with the Sun's magnetic field. As the field-carrying solar wind moves by, it drags these ions with it. Some of these ions are flung back into the upper atmosphere at high velocity (bottom). There, they collide with neutral atoms and molecules and knock them every which way, like the cue ball scatters balls in a break shot in pool. Some of the atoms are knocked upward without enough velocity to escape Mars — in other words, they're "sputtered."

References:

Bruce M. Jakosky et al. "Mars' Atmospheric History Derived from Upper-atmosphere Measurements of $^{38}Ar/^{36}Ar$." *Science*. March 31, 2017.

Learn more about the MAVEN mission in our September 2014 cover story.

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Science Editor Camille M. Carlisle covers science news for *Sky & Telescope*. She specializes in black holes, galactic cosmology, and whatever she happens to be writing about at the time. She and Robert Naeye co-edited *S&T*'s special issue *Mars: Mysteries and Marvels of the Red Planet*.

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