MAVEN solar wind ion analyzer will look at key player in Mars atmosphere loss

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The MAVEN Solar Wind Ion Analyzer will study ions in the Martian atmosphere, a key component for better understanding the planet's evolution. Credit: University of Colorado at Boulder LASP

This past November, NASA launched the Mars Atmosphere and Volatile Evolution (MAVEN) mission in the hope of understanding how and why the planet has been losing its atmosphere over billions of years.

One instrument aboard the spacecraft will study a special component of the Martian atmosphere to help solve this mystery. By studying ions, or small electrically charged particles, in and above the Red Planet's tenuous atmosphere, the Solar Wind Ion Analyzer will help answer why Mars has gradually lost much of its atmosphere, developing into a frozen, barren planet.

Once the MAVEN spacecraft is orbiting Mars, the Solar Wind Ion Analyzer (SWIA)—which was designed and built at the University of California, Berkeley Space Sciences Laboratory (SSL)—will spend much of its time measuring the ions in the solar wind. Released continuously from the sun's atmosphere, the solar wind travels toward Mars at speeds around a million miles per hour, carrying with it a magnetic field that originates inside the sun. It is composed of charged particles that interact with neutral gas particles in Mars' upper atmosphere, giving them the ability to escape from Mars' gravitational pull.

Scientists think the interactions between solar wind ions and Mars' atmospheric particles are a key factor allowing the particles to escape, a process that gradually strips the planet of its atmosphere and has done so for billions of years.

SWIA instrument lead Jasper Halekas of SSL said scientists could apply SWIA's measurements of solar wind ions with the measurements of the atmosphere's escaping gases the mission's other instruments make, making connections between the two that will paint the picture of how the atmosphere has evolved.

"By combining SWIA measurements with measurements of escaping gases we can parameterize the loss of atmospheric gases from Mars as a function of solar wind conditions," Halekas said. "Ultimately, we want to know where the atmosphere, especially water, went, how it left, and what Mars has looked like over its entire history."

SWIA will specifically be measuring the solar wind speed and density, two critical factors that determine how its ions interact with the planet's atmospheric particles. Halekas said although the solar wind itself isn't packed with ions, its blazing speed ensures that a huge number of ions are hitting the Martian atmosphere, and interacting with the atmosphere's particles, every second.

MAVEN deputy principle investigator Janet Luhmann, also at SSL, said by measuring the solar wind's density and velocity, SWIA could help determine whether gusts of denser, faster solar wind contribute to greater atmospheric loss. This information will be used to estimate losses in the past, when solar wind gusts may have been prevalent thanks to an early, more active sun.

Once they hit the planet's atmosphere, the solar wind's ions play several critical roles in aiding particles to escape from Mars' atmosphere. The solar wind is made up of both electrons, which are very small, negatively charged particles, and ions, which are larger positively charged particles like ionized hydrogen and helium.

Halekas said both ions and electrons could start the process of particle escape by transforming the atmosphere's neutral particles into charged ions. This can occur through processes called charge exchange and impact ionization. Ultraviolet sunlight also transforms many atmospheric particles into ions. Once the atmospheric particles become charged, they can interact with the solar wind's magnetic field and be accelerated and carried away from the planet; ions that have been removed like this are called pickup ions. The ionization step is critical, since the original neutral particles don't respond to the solar wind magnetic field and generally have too little energy to escape.

Halekas said although the solar wind electrons contribute to particle escape by stripping electrons from some of the neutral atmospheric particles, it's the solar wind ions that play the more critical role in giving the particles enough energy to escape.

The ionized gases in the solar wind—known as plasma—can interact with the wind's magnetic field to form an electric field, and accelerate the newly charged particles in the atmosphere with enough energy for them to escape. While both the electrons and ions form this plasma, Halekas said the ions are in some ways more important, thanks to their larger mass.

Although the solar wind ions are travelling at the same velocity as the electrons, they have a larger mass than the electrons. This gives them a greater momentum, which is created from an object's mass and velocity. Therefore, the solar wind ions are able to transfer more of the necessary momentum to the newly formed atmospheric ions themselves, providing them with more energy to escape.

"The electrons themselves probably don't do as much work in driving escape," Halekas said. "They can ionize some atmospheric gases through electron impact ionization, but they won't drive escape through momentum transfer as the ions can."

Because the solar wind's ions play key parts in interacting with other solar wind components, like the electrons and magnetic field, Halekas said SWIA complements several of the other MAVEN instruments.

In order to determine how solar wind ions work with the magnetic fields in the near-Mars environment to aid particle escape, SWIA will work with the MAVEN magnetometer. Together with the solar wind's magnetic field, the ions interact with Mars' upper atmosphere, forming a network of charged particles and magnetic field lines around Mars called a magnetosphere.

"If there were no solar wind ions or magnetic field, the Martian atmosphere would just be a big ball of partially ionized gas sitting in space," Halekas said. "It is the incoming solar wind ions and magnetic field that compress and warp the ionized gas into the teardrop-shaped structure we call a magnetosphere, which any escaping particles must travel through to leave the system."

Unlike Earth, Mars has no global magnetic field. Instead, it has many localized magnetic fields that can disturb the magnetosphere structure. But Halekas said the overall shape was still broadly similar to Earth's magnetosphere.

Since charged particles respond to magnetic forces, the newly charged atmospheric particles can follow paths that depend on the solar wind's magnetic fields. In addition, these magnetic field lines can connect with the planet's own magnetic fields generated in its crust, providing different routes for particles to travel either towards or away from Mars.

Halekas said SWIA was perhaps most complementary to the Suprathermal and Thermal Ion Composition instrument (STATIC), which will measure the planet's ions—including those escaping—while SWIA focuses on the ions from the solar wind. SWIA will also work closely with the Solar Wind Electron Analyzer (SWEA), which will measure the electrons in the solar wind and how they affect particle escape.

"Ultimately, all the instruments on MAVEN complement each other," Halekas said. "The payload was very carefully designed to work together."

Although SWIA will be operating continuously throughout the mission, Halekas said its most useful measurements would come from altitudes greater than 190 miles (305 km) above the planet's surface, outside of the main bulk of the atmosphere.

Equipped with a field of view that covers about 70 percent of the sky and is centered on the Sun, SWIA will be able to measure the entire distribution of solar wind ions.

Because SWIA will provide key insight into how solar wind behaves, MAVEN scientist Robert Lillis at SSL said the instrument would be critical in helping understand why Mars doesn't have the dense atmosphere required to maintain life-supporting properties like liquid water on its surface, and whether it ever did.

"The history of habitability and atmospheric loss on Mars are linked, and to decipher this history we need to understand how rates of loss of gas from Mars today depend on the properties of solar wind buffeting the upper atmosphere," Lillis said. "SWIA will be one of our sets of eyes aboard MAVEN, constantly monitoring the flow of charged particles from the sun that has helped shape the patterns of atmospheric escape from Mars over billions of years."

Since its development, Halekas said SWIA has undergone many tests and calibrations to ensure it works correctly in space Halekas is responsible for these calibrations, and said there are always unexpected things that will crop up when an instrument is first turned on in space.

"No matter how much testing we perform in advance, and we do a staggering amount, there are inevitably things that we just can't plan for or simulate in a lab," Halekas said. "I anticipate that the first few weeks after SWIA is turned on in flight and the first few weeks after arrival at Mars will therefore be especially exciting and challenging, as we learn how to best operate the instrument in the Martian environment."

Halekas said that no matter what unexpected challenges the SWIA team might face, he is confident that the instrument will perform well, and looks forward to seeing the instrument in action as it helps unlock the Red Planet's mysteries.

"Every stage of the mission has been, and will continue to be, a learning experience and a new and exciting challenge," Halekas said. "I'll be ramping up to support the team's scientists in their investigations of all of our observations, with the goal of answering all the big picture questions of MAVEN, and more."

MAVEN's principal investigator is based at the Laboratory for Atmospheric and Space Physics at University of Colorado, Boulder. The university provided science instruments and leads science operations, as well as education and public outreach, for the mission.

Goddard manages the project and provided two of the science instruments for the mission. Lockheed Martin built the spacecraft and is responsible for mission operations. The University of California at Berkeley's Space Sciences Laboratory provided science instruments for the mission. NASA's Jet Propulsion Laboratory in Pasadena, Calif., provides navigation support, Deep Space Network support, and Electra telecommunications relay hardware and operations.

More information: www.nasa.gov/maven

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