Study finds small solar eruptions can have profound effects on unprotected planets

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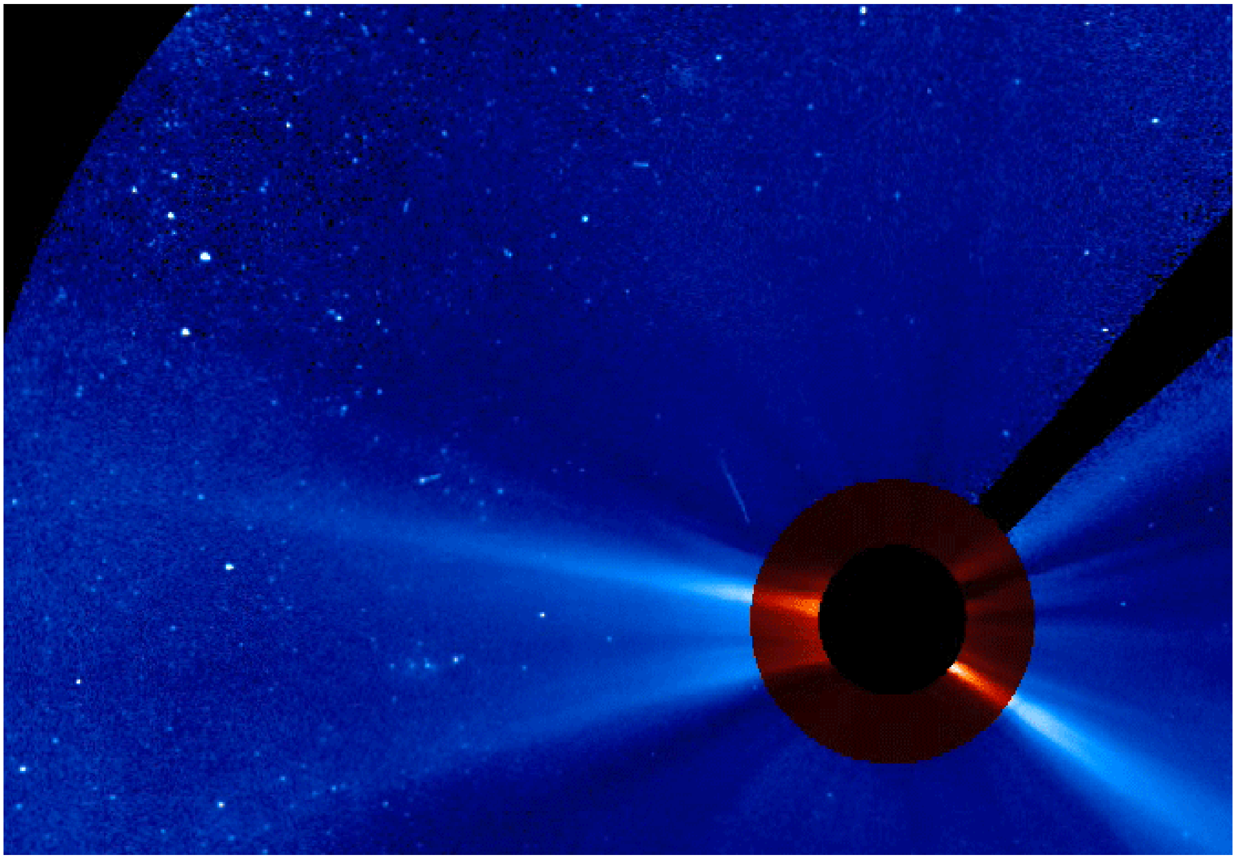

A relatively small puff of solar material can be seen escaping the sun on the upper left of this movie from ESA and NASA's SOHO on Dec. 19, 2006. This slow ejection was nevertheless powerful enough to cause Venus to lose dramatic amounts of oxygen from its atmosphere four days later. Credit: ESA/NASA/SOHO/JHelioviewer

While no one yet knows what's needed to build a habitable planet, it's clear that the interplay between the sun and Earth is crucial for making our planet livable - a balance between a sun that provides energy and a planet that can protect itself from the harshest solar emissions. Our sun steadily emits light, energy and a constant flow of particles called the solar wind that bathes the planets as it travels out into space. Larger eruptions of solar material, called coronal mass ejections, or CMEs, occur too, which can disrupt the atmosphere around a planet. On Earth, some of the impact of these CMEs is deflected by a natural magnetic bubble called the magnetosphere.

But some planets, such as Venus, don't have protective magnetospheres and this can be bad news. On Dec. 19, 2006, the sun ejected a small, slow-moving puff of solar material. Four days later, this sluggish CME was nevertheless powerful enough to rip away dramatic amounts of oxygen out of Venus' atmosphere and send it out into space, where it was lost forever.

Learning just why a small CME had such a strong impact may have profound consequences for understanding what makes a planet hospitable for life. These results appear in the *Journal of Geophysical Research* on April 9, 2015.

"What if Earth didn't have that protective magnetosphere?" said Glyn Collinson, first author on the paper at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "Is a magnetosphere a prerequisite for a planet to support life? The jury is still out on that, but we examine such questions by looking at planets without magnetospheres, like Venus."

Collinson's work began with data from the European Space Agency, or ESA's, Venus Express, which arrived at Venus in 2006 and carried out an eight-year mission. Studying data from its first year, Collinson noted that on Dec. 23, 2006, Venus' atmosphere leaked oxygen at one of the highest densities ever seen. At the same time the particles were escaping, the data also showed something unusual was happening in the constant solar wind passing by the planet.

To learn more, Collinson worked with Lan Jian, a space scientist at NASA Goddard who specializes in identifying events in the solar wind. Using data from Venus Express, Jian pieced together what had hit the planet. It looked like a CME, so she then looked at observations from the joint ESA and NASA Solar and Heliospheric Observatory. They identifed a weak CME on Dec. 19 that was a likely candidate for the one they spotted four days later near Venus. By measuring the time it took to reach Venus, they established that it was moving at about 200 miles per second - which is extremely slow by CME standards, about the same speed as the solar wind itself.

Scientists divide CMEs into two broad categories: those fast enough to drive a shock wave in front of them as they barrel away from the sun, and those that move more slowly, like a fog rolling in. Fast CMEs have been observed at other planets and are known to affect atmospheric escape, but no one has previously observed what a slow one could do.

"The sun coughed out a CME that was fairly unimpressive," said Collinson. "But the planet reacted as if it had been hit by something massive. It turns out it's like the difference between putting a lobster in boiling water, versus putting it in cold water and heating it up slowly. Either way it doesn't go well for the lobster."

Similarly, the effects of the small CME built up over time, ripping off part of Venus's atmosphere and pulling it out into space. This observation doesn't prove that every small CME would have such an effect, but makes it clear that such a thing is possible. That, in turn, suggests that without a magnetosphere a planet's atmosphere is intensely vulnerable to space weather events from the sun.

Venus is a particularly inhospitable planet: It is 10 times hotter than Earth with an atmosphere so thick that the longest any spacecraft has survived on its surface before being crushed is a little over two hours. Perhaps such vulnerabilities to the sun's storms contributed to this environment. Regardless, understanding exactly what effect the lack of a magnetosphere has on a planet like Venus can help us understand more about the habitability of other planets we spot outside our solar system.

The researchers examined their data further to see if they could determine what mechanism was driving off the atmosphere. The incoming CME had clearly pushed in the front nose - the bow shock - of the atmosphere around Venus. The scientists also observed waves within the bow shock that were 100 times more powerful than what's normally present.

"It's kind of like what you'd see in front of a rock in a storm as a wave passes by," said Collinson. "The space in front of Venus became very turbid."

The team developed three possibilities for the mechanism that drove the oxygen into space. First, even a slow CME increases the pressure of the solar wind, which may have disrupted the normal flow of the atmosphere around the planet from front to back, instead forcing it out into space. A second possibility is that the magnetic fields traveling with the CME changed the magnetic fields that are normally induced around Venus by the solar wind to a configuration that can cause atmospheric outflow. Or, third, the waves inside Venus' bowshock may have carried off particles as they moved.

Collinson says he will continue to look through the collected eight years of Venus Express data for more information, but he points out that seeing a CME near another planet is a lucky finding. Near Earth, we have several spacecraft that can observe a CME leaving the sun and its effects closer to Earth, but it's difficult to track such things near other planets.

This was a rare sighting of a CME that provides a crucial insight into a planet so foreign to our own - and in turn into Earth. The more we learn about other worlds, the more we learn about the very history of our own home planet, and what made it so habitable for life to begin with.

Provided by NASA's Goddard Space Flight Center

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