Mars's rare disappearing solar wind event explained

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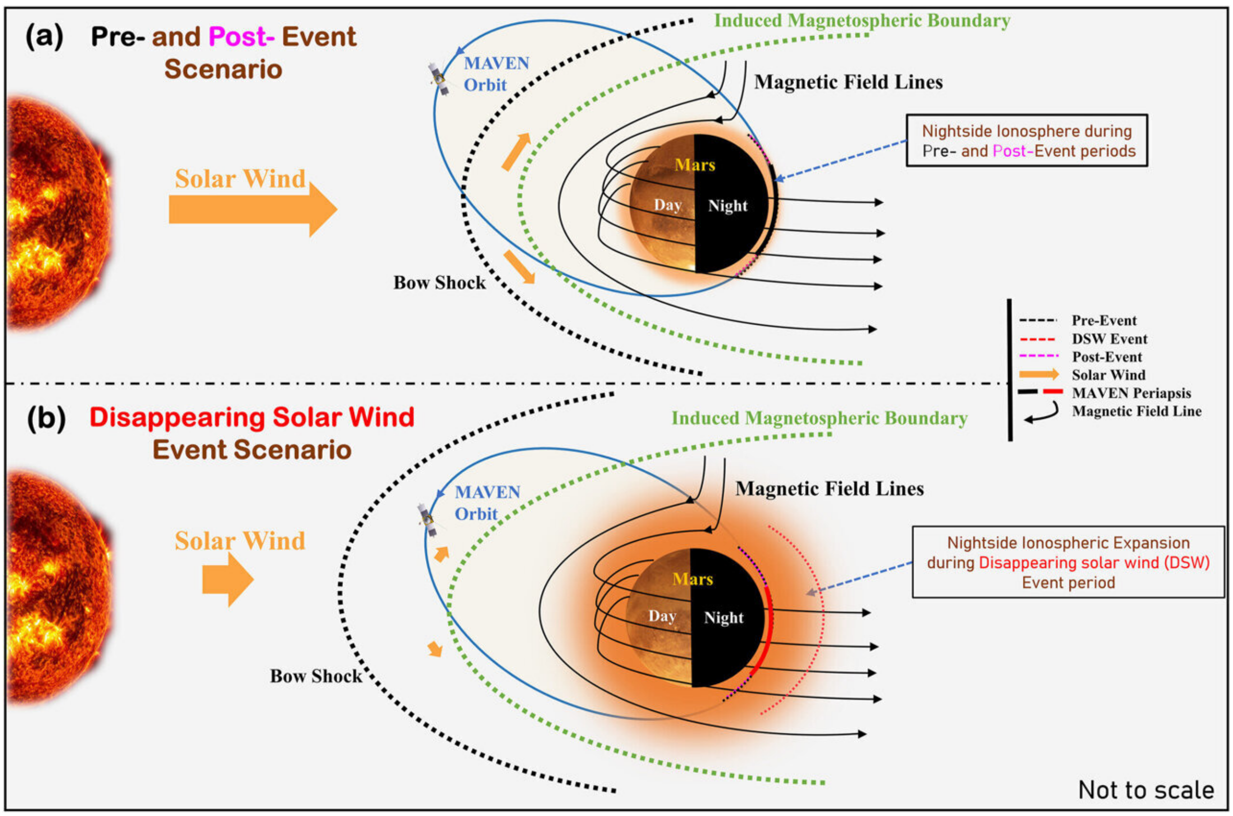

Illustration of Martian ionosphere and magnetosphere pre-, during and post-disappearing solar wind event. Credit: Ram et al., 2024.

Mars's atmosphere and climate are impacted by interactions with solar wind, a stream of plasma comprised of protons and electrons that flows from the sun's outermost atmosphere (corona), traveling at speeds of

400–1,000 kilometers per second.

As these charged particles interact with the planet's magnetic field and atmosphere, we may see spectacular auroras over polar regions on Earth. Given Mars's lack of a global magnetic field, auroras here are instead diffused across the planet.

However, sometimes this solar wind can "disappear" in rare events when there is a gap in the solar wind path as the sun increases its solar activity. This occurs when a faster portion of solar wind overtakes a slower one in a corotating interaction region and incorporates it, leaving a lower-density void in the solar wind path.

This phenomenon was observed over three days in December 2022 during NASA's MAVEN (Mars Atmosphere and Volatile EvolutioN) mission. As a result of the lack of solar wind, the pressure decrease caused Mars's atmosphere and magnetosphere to expand by thousands of kilometers, tripling in size. It also sent a supersonic shockwave around the planet, known as a bow shock.

New research, published in *Geophysical Research Letters*, has investigated the effects of this reduced solar wind activity. Professor Sumanta Sarkhel and Ph.D. researcher Lot Ram (of the Indian Institute of Technology Roorkee), alongside Dr. Diptiranjan Rout (of India's National Atmospheric Research Laboratory) used data from the Solar Wind Ion Analyzer, Magnetometer, Langmuir Probe and Ion Mass Spectrometer onboard the MAVEN spacecraft to explore Mars's electrons and ion densities, solar wind ion densities, velocities, pressure and magnetic field during the event.

The researchers identified that the side of the planet that faces away from the sun, its nightside, had increased plasma density in the ionosphere at altitudes of 200–280 kilometers, the maximum being 2.5

times higher than that occurring during normal conditions. This results from an up to two orders of magnitude increase in ionospheric pressure compared to solar wind magnetic and dynamic pressure.

During this event, the number of electrons and ions in the ionosphere increased by 2.5 and 10 times respectively. However, individual ions had varying increases in their maximum density from 10 times for N^+ to 67 times for O^+.

The scientists suggest possible causes for this higher plasma density may be expansion from the lower to topside ionosphere due to pressure differences (high in ionosphere and low in solar wind) and/or increased transport of plasma from Mars's dayside to nightside.

Beyond this, further work is required to understand the role of magnetic field topologies, referencing the structure and connectivity of magnetic field lines and their strength on the interaction of plasma with Mars's surface.

"In a closed magnetic field loop, plasma is trapped inside, meaning no atmospheric plasma is lost to space," Professor Sarkhel says. "In an open loop, Martian plasma can escape through the magnetic field or solar wind plasma can enter into the Martian atmosphere and change the atmospheric dynamics.

"Lastly, in the draped loop scenario, the solar wind magnetic field can engulf the planet and magnetize the ionosphere, which means ions and electrons board the solar wind field and plasma escapes from the planet. In stronger magnetic field regions, plasma binds more to the magnetic loops, and vice versa in weaker regions."

Understanding the effect of disappearing solar wind events is vital not only for expanding our knowledge of its interactions with Mars's space environment and surface, but also for human exploration as it may require adjustments to spacecraft orbit to account for increased drag by dense plasma in order to continue a successful mission.

"Our interest in studying disappearing solar wind arose from the profound impact it has on an unmagnetized planet like Mars, which eventually helps us to understand its climatic evolution and atmospheric escape over time," Professor Sarkhel explains.

"The expansion of the magnetosphere-ionosphere system can lead to atmospheric loss and enhanced interaction with solar radiation or cosmic rays. Also, the expansion results in more drag to the orbiting satellites at both low and high planetary orbits. For example, in 2022, Space X lost 40 low Earth orbiting satellites a day after launch due to enhanced density at ionospheric heights during a geomagnetic storm.

"Therefore, understanding planetary space weather during solar quiescence (or disappearing solar wind events) and storm periods is crucial for the future of planetary satellites and exploration, both for the safety of robotics and astronauts. Eventually, the knowledge may even be useful to assess Mars's habitability."

More information: L. Ram et al, Mars Nightside Ionospheric Response During the Disappearing Solar Wind Event: First Results, *Geophysical Research Letters* (2024). DOI: 10.1029/2024GL113377