When a planet behaves like a comet: The tail of Venus and the weak solar wind

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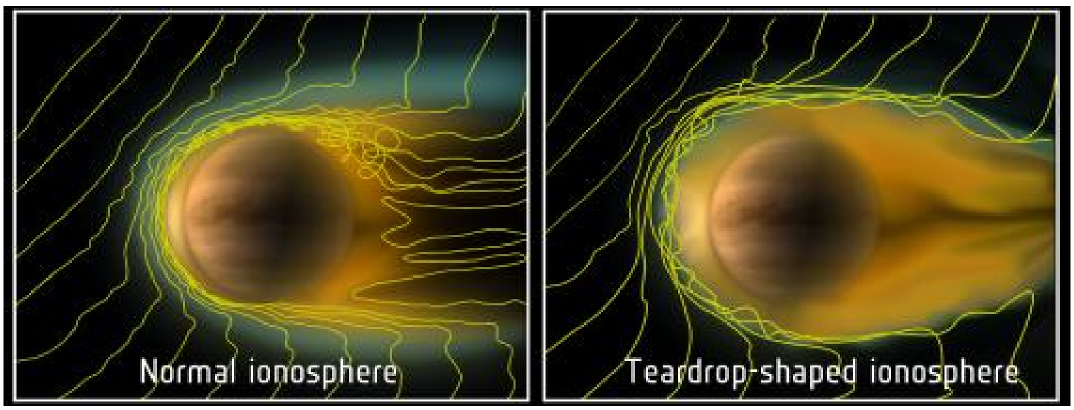

A comparison of the ionosphere of Venus under different solar wind conditions. The yellow lines indicate the solar magnetic field lines as they interact with the ionosphere. When the solar wind's dynamic pressure is normal (left image) the ionosphere is confined to a region 150-300 km above the planet's day side. Positively charged particles (ions) travel quite quickly across the day-night terminator to create a similar ionosphere on the planet's night side. When the solar wind pressure drops to a very low level (right image), the ionosphere expands to a higher altitude above the day side of Venus and weaker magnetic fields are created above the terminator. As a result, the region across which ions are able to travel from the day side to the night side becomes larger. This makes it easier for ions to flow across the terminator. Although the weaker pressure of the solar wind reduces the speed at which the ions travel toward the night side, the first effect outweighs the second, enabling the ionosphere to expand in the planet's wake. Observations from Venus Express show that the night-side ionosphere moved outward to at least 15 000 km from Venus' centre over a period of only a few hours, creating a long, comet-like tail. Credit: ESA/Wei et al

(Phys.org)—Measurements obtained with ESA's Venus Express spacecraft have shed new light on the interaction between the solar wind and the second planet from the Sun. During a rare period of very low density solar outflow, the ionosphere of Venus was observed to become elongated downstream, rather like a long-tailed comet.

Scientists have long known about the existence of the solar wind, a continuous outflow of electrons and protons which flows at high speed across interplanetary space. However, this stream of charged particles is highly variable, both in speed and density.

Under normal conditions, the solar wind has a density of 5 - 10 particles per cubic cm at Earth's orbit, but occasionally the solar wind almost disappears, as happened in May 1999. Although such unusual episodes have been studied near Earth, which is surrounded by a strong magnetic field, there have been very few opportunities to study what happens near planets with negligible magnetic fields, such as Venus.

A rare opportunity to examine what happens when a tenuous solar wind arrives at Venus came 3 - 4 August 2010, following a series of large coronal mass ejections on the Sun. NASA's STEREO-B spacecraft, orbiting downstream from Venus, observed that the solar wind density at Earth's orbit dropped to the remarkably low figure of 0.1 particles per cubic cm and persisted at this value for an entire day.

Meanwhile, Venus Express, which is in an extremely elliptical, near-polar orbit, was able to study the interaction between this sparse solar wind and the planet's ionosphere – the electrically charged region of its upper atmosphere.

The ionosphere is created by incoming extreme ultraviolet light and X-rays from the Sun which splits the atoms in the upper atmosphere of Venus and creates a layer of electrons and ions.

The key data for the ionosphere came from two instruments on board Venus Express: the magnetometer, which continuously measures the local magnetic fields, and the Analyser of Space Plasmas and Energetic Atoms (ASPERA-4), which measures the energy and masses of ions when the spacecraft is closest to Venus. The instruments showed that the solar wind density at Venus decreased to 0.2 particles per cubic cm, while the dynamic pressure dropped to 0.1 nPa – about 50 times lower than normal.

Detailed analysis of the data from Venus Express has been published recently in the journal Planetary and Space Science by an international team of scientists. The measurements showed that the typical features of the ionosphere's tail region, on the night side of Venus, were no longer present during the period of sparse solar wind.

Previous spacecraft measurements have established that most of the ionospheric plasma (ionised gas) on the night side of Venus is supplied by plasma moving across the terminator, from the day side to the night side, driven by plasma pressure gradients. This nightward flow, which mainly involves oxygen ions (O^+), takes place about 150-300 km above the surface of Venus, with a flow speed reaching several kilometres per second.

On 4 August, this flow pattern was clearly disrupted. As Venus Express flew behind the terminator, between 300 km and 15 000 km above the planet, its instruments revealed that the O^+ plasma was moving much more slowly than usual for this location.

"The data indicate that the O^+ flow across the terminator was still taking place, but it was observed to be travelling more slowly, and over a much wider region, than it does under normal solar wind conditions," said Yong Wei, a researcher at the Max Planck Institute for Solar System Research in Katlenburg-Lindau, Germany, who was the lead author of the paper.

"We believe that the low solar wind pressure, which results in weaker magnetic fields, makes it easier for ions to flow from the day side to the night side of the planet."

The data also provide new insights into the processes which shape the ionosphere around Venus and the rate of loss of atoms from the upper atmosphere.

It has been known for a long time that tenuous solar wind has two competing effects on the night-side ionosphere. The ionosphere above the terminator becomes higher, enabling plasma to pass more easily from the day side to the night side, and the lack of magnetic fields tends to enlarge the size of the night-side ionosphere.

On the other hand, the weaker pressure may cause lower flow speeds of this plasma. The new Venus Express data show conclusively that the first effect outweighs the second, enabling the ionosphere to expand in the planet's wake.

"The observations show that the night side ionosphere moved outward to at least 15 000 km from Venus' centre over a period of only a few hours," said Markus Fraenz, also from the Max Planck Institute for Solar System Research, who was the team leader and a co-author of the paper. "It may possibly have extended for millions of kilometres, like an enormous tail."

"Although we cannot determine the full length of the night-side ionosphere, since the orbit of Venus Express provides limited coverage, our results suggest that Venus' ionosphere resembled the teardrop-shaped ionosphere found around comets, rather than the more symmetrical, spherical shape which usually exists."

The results also show that erosion of the planet's upper atmosphere by the solar wind ceases when the wind nearly disappears, but may be enhanced in the aftermath of such a period. A large "bubble" of slow-moving ions is formed behind the planet and when pressure increases again this bubble will partly be lost into space, temporarily accelerating the rate of erosion again.

"This is another example showing that use of similar techniques at Venus, Earth and Mars is a powerful tool for comparative planetology," said Håkan Svedhem, ESA's Venus Express Project Scientist. "We are now able to compare what happens when an extremely weak solar wind regime impacts the inner planets.

"It also shows the importance of having access to data from an international fleet of spacecraft, in which NASA's STEREO can act as a solar wind monitor whilst ESA's Venus Express and Mars Express are inside planetary ionospheres and observing their interaction with the solar wind."

More information: Y. Wei, et al., "A teardrop-shaped ionosphere at Venus in tenuous solar wind", 2012, *Planetary and Space Science*, 73, 1, 254-261, DOI:10.1016/j.pss.2012.08.024

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