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Solar wind interaction with Venus upper atmosphere: A review of VEX/ASPERA-4 findings and future prospect

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Abstract

Venus has intrigued planetary scientists since the start of the space-era in 1960s. While Venus is nicknamed "Earth's twin", Venus has huge differences from the Earth. The space environment is significantly different, mainly because of the absence of an intrinsic magnetic field. The Venusian magnetosphere is formed by electric current in the ionosphere induced by the interaction with the solar wind (therefore, we call it an induced magneto-sphere). Various signatures have been measured by Venera and Mariner series in the 60s and 70s, and basic signatures of the space environment near Venus were revealed. Pioneer Venus Orbiter was launched in 1978 providing a huge dataset of the Venus envi-ronment, and our knowledges about the ionosphere and the far-tail were enhanced. In 2006, ESA's first Venus probe, Venus Express (VEX), was inserted into orbit. VEX made unique measurements in the near-Venus tail for >8 years until VEX consumed all its fuels. VEX was equipped with plasma instrument package, Analyser of Space Plasma and EneRgetic Atoms (ASPERA-4). ASPERA-4 has provided a huge amount of discoveries about the near-Venus space environment. In this presentation, we will review the findings of ASPERA-4.

1. VEX/ASPERA-4 instrument

In early 2006, Venus Express (VEX) was inserted into a highly-elliptical Venusian orbit. VEX conducted science operation for 8.5 years until its fuel was fully consumed. Throughout the mission, the plasma instrument package, ASPERA-4, was operated, and these instruments provided a large amount of datasets.

The ASPERA-4 instrument comprises five sensors: three energetic neutral atom (ENA) sensors, an electron spectrometer (ELS) and an ion mass spectrometer (IMA) [1]. IMA provides ion measurements in the energy range 0.01-30 keV/q for the main ion components H^+, H_2^+, He^+, O^+, and heavier ions. ELS provides electron measurements in the energy range10 eV–15 keV. The FoV is narrow in elevation but with 360˚ coverage in the azimuth direction, so that the coverage is quite limited.

2. VEX/ASPERA-4 findings

Together with the magnetometer (MAG [2]), onboard, ASPERA-4 has provided a huge amount of findings about the near-Venus space environment. Figure 1 depicts an overview illustration of VEX findings [3].

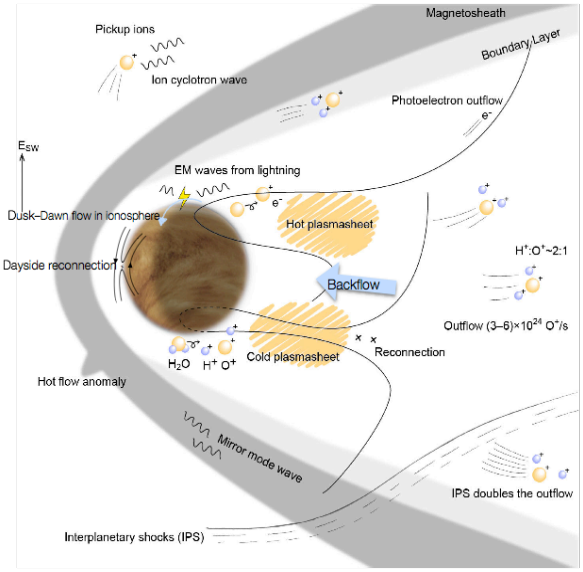

Figure 1: New finding in the near-Venus space environment by VEX/ASPERA-4 together with MAG. The figure is adopted from [3], where a comprehensive review of VEX findings is found. Additional findings after the publication have been added.

The key findings include

- The loss of ionospheric ions to space with their composition rate of H^+ and O^+ as 2 to 1 was identified [4], while the ratio is highly controlled by the solar activity [5].

- The outflowing O^+ flux is enhanced during the interplanetary shock passage [6]

- Significant fractions of outflowing H^+ and O^+ are returned back to Venus inside the plasmasheet, particularly when the solar activity is high [5,7,8]

- The structure and dynamics of the Venusian induced magnetosphere respond to the prevailing solar wind conditions with various time scales.

- Magnetic reconnections are in operation inside the Venusian plasmasheet [9]

- The plasma flow pattern of the polar ionosphere is different from that of the equatorial ionosphere [10]

We review what has been found by VEX in a context of the plasma environment. We further will formulate the key questions to increase our understandings about the Venus–solar wind interaction for future missions; and more in general, to understanding other Solar System bodies and exoplanets.

3. Future prospect

Venus flybys by ongoing and future missions are planned. BepiColombo (ESA and JAXA) launched in 2018 will flyby Venus in 2020 and 21, and scientific operations during the flyby are planned. Solar Orbiter, launch planned in 2020, also considers flybys with science operations. It is yet unclear for science operations during Venus flybys by JUICE (ESA), but it would be discussed. Parker Solar Probe (NASA) has conducted first Venus flyby in October 2018, and six further flybys are planned. The ASPERA-4 data will be excellent reference data for interpreting the obtained flyby data.

Acknowledgements

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