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ScienceDirect
Planetary and Space Science 54 (2006) 1336–1343
Planetary and Space Science
www.elsevier.com/locate/pss

Magnetic field investigation of the Venus plasma environment: Expected new results from Venus Express

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Accepted 10 April 2006

Abstract

The Venus Express mission is scheduled for launch in 2005. Among many other instruments, it carries a magnetometer to investigate the Venus plasma environment. Although Venus has no intrinsic magnetic moment, magnetic field measurements are essential in studying the solar wind interaction with Venus. Our current understanding of the solar wind interaction with Venus is mainly from the long lasting Pioneer Venus Orbiter (PVO) observations. In this paper, we briefly describe the magnetic field experiment of the Venus Express mission. We compare Venus Express mission with PVO mission with respect to the solar wind interaction with Venus. Then we discuss what we will achieve with the upcoming Venus Express mission.

Keywords: Venus; Solar wind interaction

1. Introduction

Venus, like other planets in the solar system, is under the influence of a continuous flow of charged particles from the Sun, the solar wind (cf. Russell and Vaisberg, 1983; Luhmann, 1986; Phillips and McComas, 1991; Luhmann et al., 2004). However, its lack of an intrinsic magnetic field makes Venus a unique object to study the interaction between the solar wind and a planetary body. Venus has a dense atmosphere, but no significant instrinsic magnetic field, and thus the solar wind interacts directly with the upper atmosphere. Present knowledge of the solar wind interaction with Venus comes almost entirely from the Pioneer Venus Orbiter (PVO) mission. PVO was inserted into Venus orbit in December 1978 and it remained in orbit for 14 years investigating the solar wind interaction with Venus over a complete solar cycle. PVO observations as well as other spacecraft observations revealed that the solar wind interaction with Venus leads to a highly structured plasma.

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0032-0633/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pss.2006.04.018

The solar wind is a supersonic plasma flow in which the solar magnetic field can be considered to be frozen. The highly electrically conducting ionosphere deflects the oncoming supersonic solar wind around the planet so that a bow shock is formed (Russell et al., 1988; Kallio et al., 1998). In the solar wind frame, this bow shock and its associated upstream waves provides the earliest evidence of the approaching obstacle. Because the bow shock location and shape are determined by the size and shape of the effective obstacle, a bow shock study gives insight regarding the interaction of the solar wind with the planetary obstacle (Zhang et al., 1990).

The interaction of post-shock solar wind flow with the ionosphere results in a distinct boundary, the so-called ionopause. This ionopause separates the thermal plasma of the ionosphere from the hot magnetized plasma of the magnetosheath, which is defined as the region between the ionopause and bow shock. The ionopause is located where the solar wind dynamic pressure is approximately balanced by the thermal pressure of the ionospheric pressure. At solar maximum, the location of the ionopause varies from 300 km altitude from Venus surface at the subsolar point to 900 km altitude near the terminator (cf. Phillips and McComas, 1991). At solar minimum, there are no direct measurements of the ionopause due to the increasing PVO orbital altitude. However, electron density profiles measured by the radio occultation experiment showed significant decrease in the electron density from solar maximum to solar minimum. It is found that the ionopause was much depressed during the solar minimum with an equal altitude of ~250 km everywhere in the dayside (Zhang et al., 1990a).

Downstream from the bow shock, a magnetic barrier is formed in the inner region of the dayside magnetosheath to transfer solar wind momentum to the ionosphere (Zhang et al., 1991). The magnetic barrier at Venus is a region within which the magnetic pressure dominates all other pressure contributions. It is strongest at the subsolar point and weakens with increasing solar zenith angle. At solar maximum, this barrier deflects the solar wind and serves as an effective obstacle instead of the ionopause. In a series of recent papers, the solar wind flow around Venus is investigated within the frame of magnetohydrodynamics (e.g., Biernat et al., 2005). In particular, the plasma and magnetic field behavior within the magnetosheath including the magnetic barrier is examined. In addition, effects of mass loading, instabilities, the bow shock compressibility and results of energetic neutral atom imaging are reported.

Venus has the most explored and best understood ionosphere in our solar system, other than that of Earth. While the Venus ionosphere can deflect the solar wind to form a bow shock, it is not a perfect conductor, so some magnetic flux can diffuse into the ionosphere. The ionosphere exists in two different states: magnetized or unmagnetized (cf. Luhmann and Cravens, 1991). The magnetic character of the ionosphere depends critically on the dynamic pressure of the solar wind that in turn determines the altitude of the ionopause. When the maximum ionospheric thermal pressure is significantly larger than the solar wind dynamic pressure, the ionopause forms at an altitude in which the ionosphere is collisionless and the ionosphere is unmagnetized except for small-scale magnetic features known as flux ropes. However, even at solar maximum, for about 15% of the time the solar wind dynamic pressure approaches the peak ionospheric pressure, the ionopause forms in a collisional environment and the dayside ionosphere becomes largely or fully magnetized (Phillips et al., 1984). At solar minimum, it is expected that the ionosphere exhibits a magnetized character due to the weaker ionosphere and higher solar wind dynamic pressure.

All planets visited by spacecraft to date have had magnetotails whether or not they have intrinsic magnetic fields. In the case of the magnetized planets, the magnetotail is formed due to the tangential stresses of the interaction of the solar wind on an intrinsic magnetic field. Planetary bodies without intrinsic magnetic fields, but with substantial atmospheres, are known to possess such comet-like induced magnetotails. The induced magnetotail forms as a result of the atmospheric mass loading and subsequent draping of passing magnetosheath flux tubes that sink into the wake. Luhmann (1992) showed that the induced magnetic field around Venus is toroidal with near-complete wrapping of interplanetary magnetic field (IMF) around the planet obstacle, rather than simply deflected around the obstacle.

The absence of a planetary magnetic field leads to important differences between Venus' and Earth's atmospheric escape and energy deposition processes. The upper atmosphere of Venus is not protected by the magnetic field from the direct interaction with the solar wind. As a result, a large portion of the exosphere resides in the shocked solar wind flow; photo ionization, charge exchange and electron impact ionization lead to the removal of ionized exospheric components by the action of plasma flow. Another type of atmospheric loss is due to tailward convection of the plasma mantle, situated between the shocked solar wind flow and the ionosphere. Ions gyrating around the magnetic field lines embedded in the plasma may re-enter the atmosphere, causing extensive sputtering. Finally, erosion of the Venusian ionosphere under varying solar wind conditions provides an additional mechanism for loss of atmospheric constituents. The solar wind interacts with the top of the ionosphere to form a complex array of plasma clouds, tail rays, filaments and ionospheric holes on the night side through which a substantial amount of material leaves the planet.

Venus Express is the first European mission to planet Venus (Titov et al., 2006; Svedhem et al., 2006). Although a wealth of knowledge about the interaction of Venus and the solar wind has been obtained from the earlier missions, notably the long lasting PVO mission, Venus Express will greatly improve our view of the Venus plasma environment due to many unique characteristics of the mission such as the improved capability of the instrumentation onboard, the unique orbital trajectory and the solar minimum observation with a low altitude compared with PVO. In many aspects of the solar wind interaction with Venus, Venus Express will provide us the measurement information for the first time. It is the purpose of this paper to illustrate some of the new sciences to be obtained by the Venus Express.

The paper is organized as follows. The Venus Express magnetometer is first described briefly. This will be followed by the discussion and comparison of the Venus Express mission with PVO mission, emphasizing on the study of the solar wind interaction with Venus and possible new results that will emerge from the Venus mission.

2. Venus express magnetometer

The Venus Express magnetometer MAG measures the magnetic field vector with a cadence of 128 Hz (Zhang et al., 2006). It consists of two triaxial fluxgate sensors. The electronics box comprises two sensor electronics boards, the DPU board and the DC/DC converter. In addition to sensors and electronics, a 1 m boom is provided by the MAG team as part of the magnetometer hardware. The outboard sensor is mounted to the tip of this 1 m deployable boom, whereas the inboard sensor is directly attached to the spacecraft with a separation of 10 cm from the top panel of the spacecraft. The hardware benefits from the heritage of the Rosetta Lander magnetometer ROMAP which has successfully been commissioned in spring 2004 (Auster et al., 2006). The MAG has a large dynamic range between ±32.8 and ±8388.6 nT with a corresponding digital resolution between 1 and 128 pT. The default range for the outboard sensor is set to ±262 nT with a resolution of 8 pT. The default range for the inboard sensor is ±524 nT. During the operational phase, an artificial magnetic field of ±10,000 nT can independently be applied to each sensor for compensation of any disturbing spacecraft stray field.

The MAG instrument operates throughout each orbit of the spacecraft around Venus and is intended to operate mostly in an autonomous mode, requiring little or no commanding. After switching on, the MAG instrument automatically operates in a standard mode with both sensors at 1 Hz data rate. During a typical science orbit, MAG is switched to fast mode at 32 Hz 1 h before reaching pericenter and switched to standard mode 1 h after the pericenter. In addition, the instrument is set to a high resolution burst mode of 128 Hz 1 min before pericenter for 2 min in order to detect Venus lightning (cf. Russell, 1991).

Since the Venus Express mission takes its heritage from Mars Express mission, which has no magnetometer onboard, no real efforts were made to investigate the magnetic cleanliness of the spacecraft and its payload due to the tight schedule and budget. Thus the MAG instrument is designed using dual magnetometer method, i.e., both sensors take measurements simultaneously at the same sampling rate, to enable separation of spacecraft originated stray field effects from the ambient space field (Ness et al., 1971).

3. Venus express vs. PVO

One of the main scientific objectives of Venus Express is to study the solar wind interaction with Venus. Current knowledge of the solar wind interaction with Venus comes almost entirely from the PVO mission. Thus it is instructive and necessary to compare these two missions first before we address the possible outcome of the Venus Express mission.

Venus Express mission was conceived almost three decades after the PVO mission. At first glance there appear many similarities in the solar wind interaction investigations of these two missions. For example, both carry a magnetometer and plasma analyzer, both have a highly elliptical polar orbit with the same apoapsis of 12 Rv, and both have a orbital period of 24 h. Despite these similarities Venus Express is indeed designed to complement Pioneer Venus and many breakthrough measurements are expected. Below we discuss the major differences between the Venus Express and PVO missions.

3.1. Instrumentation

The PVO mission was planned about three decades ago and the instrument design reflected the technology of that time. Most importantly the telemetry rate was much lower for the PVO payload than for the Venus Express payload. Thus the PVO magnetometer and plasma analyzer had much lower temporal resolutions, digital resolutions and in the case of the plasma analyzer lower energy and angular resolutions.

The PVO magnetometer (OMAG) is a fluxgate type with three sensors mounted on a 4.7 m rigid boom (Russell et al., 1980). The nominal range of the PVO magnetometer sensor is ±128 nT. The resolution of the measurement varies with field component magnitude. It ranges from ±1/2 nT for fields of 64 nT or greater to ±1/16 for fields less than 16 nT. Up to twelve vectors can be measured each second. As we described in the last section, MAG measures over a large dynamic range with a resolution up to 8 pT. MAG is capable of sampling the magnetic field at a rate up to 128 Hz. The improved resolution and sampling rate will enable us to study phenomena such as waves or turbulences. Nevertheless, we note that the short boom length might limit some of the applications of the magnetic field data due to the difficulty of removing the disturbance fields originated from the spacecraft.

The PVO plasma analyzer (OPA) is an electrostatic analyzer capable of determining plasma distribution parameters for ions and electrons. However, it was primarily designed for solar wind monitoring with a low time resolution of about 10 min. In addition, lack of ion composition information and limited energy range restricted the use of OPA data, e.g., detailed study of the ion pickup process and plasma boundary identification. Now the Venus Express mission is well equipped with an advanced plasma analyzer, ASPERA-4 (Barabash et al., 2006). The ion mass spectrometer, i.e., ASPERA-4 IMA, has an energy range of 10–40 keV and the ability to separate ion masses. Its highest temporal resolution for providing a 3D ion distribution is 32 s. In addition, ASPERA-4 measures composition and the spectrum of fast neutrals. The ASPERA-4 experiment will extend our knowledge of plasma boundary and pickup process beyond what was possible with PVO instrument.

3.2. Orbit

On December 1978, the PVO spacecraft was inserted into a highly elliptical orbit about Venus, with apoapsis near 12 Rv and a periapsis altitude changing with time (Russell, 1992). The orbit was nearly polar with an inclination of 105° and a periapsis latitude of 15°N initially (Fig. 1). The orbital period was 24 h. For the first 600 days of the mission, the periapsis was maintained in a low altitude about 150 km. Later, the periapsis was allowed to rise to an altitude of more than 2000 km (Fig. 2).

The orbit of Venus Express is similar to that of PVO with an elliptical polar orbit of 24 h period and a 12 Rv apoapsis. However, the periapsis of Venus Express will be maintained in 250–350 km range with periapsis latitude at 78°N, compared to PVO's 15°N initial periapsis latitude and nominal ~150 km periapsis altitude. Thus Venus Express has a sampling geometry much different from that of PVO. It will cover two important regions which were not covered by the PVO measurement: the low altitude terminator region and mid-magnetotail about 4 Rv. As we will discuss later, studying of the terminator region is of essential importance in understanding the plasma transport from dayside to nightside, i.e., the formation of the nightside ionosphere and wake.

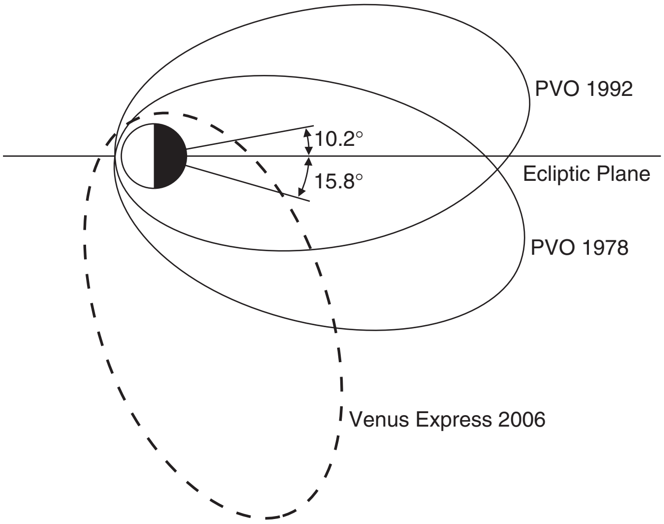

Fig. 1. Comparison of the PVO orbit and Venus Express orbit. Solid lines show the PVO orbit and its evolution with time. The dash line indicates the Venus Express orbit whose periapsis will be maintained in 250–350 km range with periapsis latitude at 78°N.

3.3. Solar activity

Since Venus has no intrinsic magnetic field, the solar wind interacts directly with the upper atmosphere, which is partially ionized by solar ultraviolet radiation (EUV) and energetic particles that enter from the surrounding space. Thus strictly, it is the ionosphere, which interacts with the solar wind. Since the ionosphere is mainly maintained by the solar EUV flux, the solar cycle variation of the EUV flux plays an important role in the solar wind interaction with Venus. In fact, solar activity controls almost every aspect of the Venus plasma environment. Although PVO gave us a wealth data for a whole solar cycle, during solar minimum the PVO periapsis was too high (more than 2000 km) to sample the near Venus plasma environment. Now Venus Express will be inserted into the Venus orbit and spend its nominal mission near solar minimum with a periapsis altitude maintained at 250–350 km (Fig. 2). This will fill the gap left by the PVO observations due to its orbital sampling bias. In the following section, we explore some of the new sciences to be obtained on solar wind interaction provided by the low periapsis altitude of Venus Express at solar minimum with improved instrumentations.

4. New science

4.1. Foreshock and upstream waves

Usptream of the bow shock, the foreshock is formed behind the first intersecting IMF line with the bow shock. Upstream phenomena consisting of charged particles and waves can be seen in the foreshock region, providing the earliest evidence of the approaching obstacle to the flow. In the foreshock region, some solar wind charged particles are reflected by the bow shock and move upstream against the solar wind flow. The waves can either be locally generated by these backstreaming particles or generated at the bow shock and move upstream. From PVO observations, it is found that the wave and particle phenomena in front of the Venus bow shock are in general the same as those generated in front of the Earth bow shock. This implies that the Venus upstream phenomena do not provide a diagnostic of the nature of the obstacle. However, this conclusion might require checking again by Venus Express mission based on two upstream phenomena found by the Phobos-2 observation at Mars.

One unique observation upstream of the Martian bow shock is the solar wind deceleration. The deceleration of the solar wind is often observed in the Earth's foreshock region (cf. Zhang et al., 1995 and references therein). The deceleration is of an average of 7–10 km/s and it is correlated with the so-called "diffuse" ions backstreaming

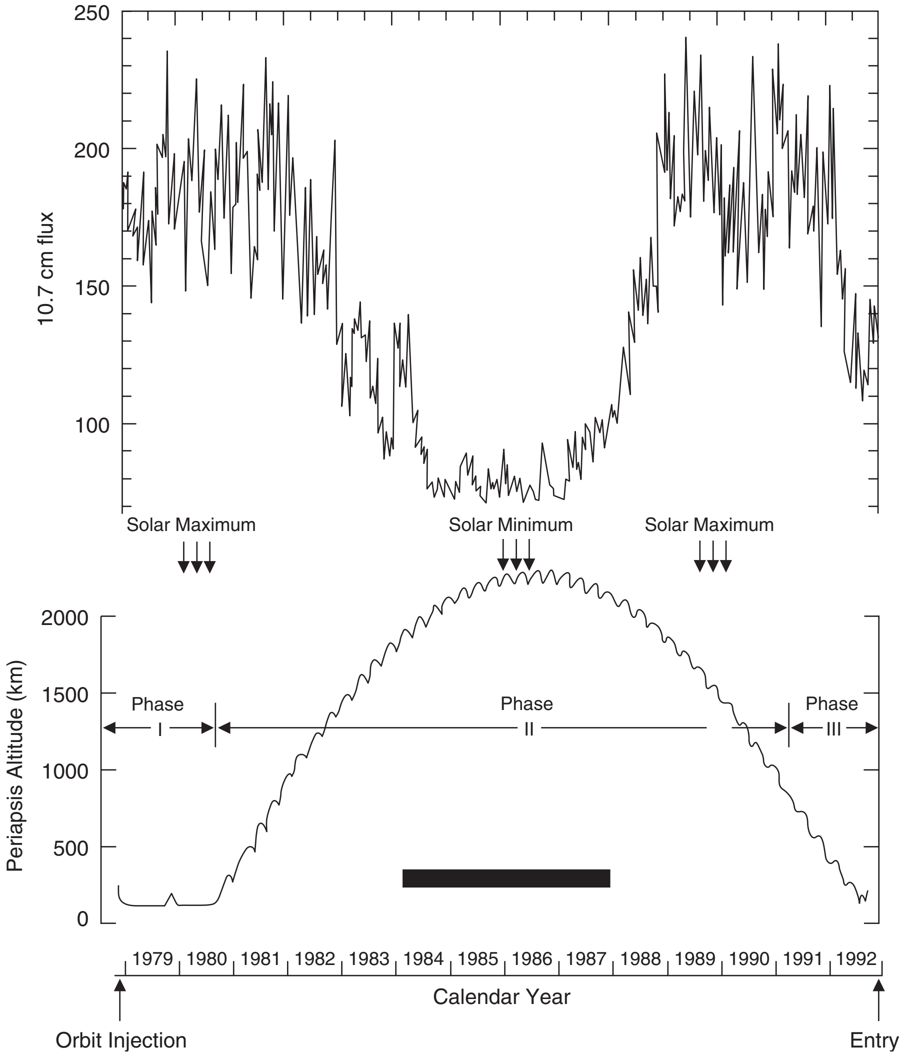

Fig. 2. PVO orbital evolution with solar activity. During solar minimum, the periapsis was well above 2000 km. The thick line in the lower panel shows the Venus Express periapsis altitude in the relative solar activity.

from the bow shock. However, at Mars, the solar wind deceleration is a common feature upstream of the Martian bow shock, for either quasi-parallel or quasi-perpendicular shocks (Kotova et al., 1997; Zhang et al., 1997). The deceleration could be as much as 100 km/s. It was suggested that this Mars solar wind deceleration is due to the mass loading by the ions originating from the hot oxygen/hydrogen corona of the Mars. Thus this upstream phenomenon at Mars is related to the nature of the obstacle. Solar wind deceleration, either Earth-like or Mars-like, has not been reported at Venus, possibly due to poor time resolution of the plasma instrument. It is found that at both Mars and Earth, the solar wind deceleration has a maximum near the bow shock and decreases with the distance from the bow shock (Zhang et al., 1997). The OPA with 10 min time resolution might have missed this observation. In this regard, we expect ASPERA-4 IMA will observe the solar wind deceleration upstream of the bow shock, although we cannot speculate if it is Mars-like or Earth-like at this moment.

Another apparent difference between the Venus and Mars interactions is the pickup of protons in advance of the bow shock. These were first noted through the observation of proton cyclotron waves in the solar wind at Mars by Phobos (Russell et al., 1990). Delva and Dubinin (1998) have pointed out that these ion cyclotron waves occur well in front of the foreshock boundary. These ion cyclotron waves do not occur at Earth or at Venus. A recent survey of proton cyclotron waves at Venus has been carried out by Russell et al. (2006a, b) that confirms the absence of such waves in the solar wind although it did find these waves in the magnetosheath.

With Venus Express, we will find out if the Venus upstream phenomena provide a diagnostic of the nature of the obstacle.

4.2. Bow shock

Although Venus has no detectable intrinsic magnetic field, the solar wind is still deflected about the ionopause with the formation of a detached bow shock because the diffusion time of the magnetized solar wind plasma into the ionosphere, under typical conditions at solar maximum, is very long. By classifying the PVO shock crossings in terms of the solar wind plasma parameters, the effects of solar wind dynamic pressure, Mach numbers, IMF orientation, and solar cycle on the bow shock have been deduced (cf. Slavin et al., 1980; Russell et al., 1988; Zhang et al., 1990).

The size of bow shock is largely determined by the planetary obstacle size. Prior to the PVO era, Russell (1977) raised the question if the Venus bow shock is detached or attached. Based on a single shock crossing by Mariner 10, he postulated that the Venus bow shock might be attached to the planet when the absorption of the solar wind by Venus is great enough. We note that the Mariner 10 Venus flyby was near solar minimum. Later, the solar cycle variation of the Venus bow shock location has been thoroughly studied (Russell et al., 1988; Zhang et al., 1990). At intermediate solar activity, the subsolar bow shock is at an altitude of 2200 km. At solar minimum the subsolar shock altitude decreased to 1700 km, a large decrease but still well above the Venus' ionopause. In other words, the shock is still detached although not all the plasma is deflected. Thus Russell's conjecture has not been advocated since the PVO observation.

However, with the upcoming Venus Express mission, which will observe the bow shock at solar minimum, it is worthwhile to reopen this issue again. We note that due to the orbital bias of PVO, the subsolar bow shock locations given by Zhang et al. (1990) are statistical in nature. No case study has been performed on the subsolar bow shock location. Furthermore, it was found that the effective altitude of the obstacle, derived from the Spreiter and Stahara (1980) gasdynamic model, is close to 0 km altitude even if the shock is still detached, which implies that the obstacle is weak and significant absorption of the solar wind is taking place. While the average effective altitude of the obstacle is on the Venusian surface, it is reasonable to postulate that sometimes an attached bow shock might be formed.

The orbit of the Venus Express is more suitable to study the subsolar bow shock at solar minimum than that of PVO. In addition, the bow shock models which will be used to fit the bow shock have been largely improved in the last decade (Khurana and Kivelson, 1994; Verigin et al., 2004). We expect that Venus Express will enable us to find out if a detached bow shock ever exists or not.

4.3. Ionopause and magnetic barrier

As mentioned in the Introduction, it is expected that the ionosphere exhibits a magnetized character due to the weaker ionosphere and relatively higher solar wind dynamic pressure at solar minimum. Associated with this weaker ionosphere, the ionopause tends to thicken and be less well defined. At solar minimum, there are no direct measurements of the ionopause due to the increasing PVO orbital altitude. From radio occultation observation, it is found that the ionopause was much depressed during the solar minimum with an equal altitude of ~250 km everywhere in the dayside (Zhang et al., 1990a). Venus Express, with a periapsis of ~250 km altitude, might provide some valuable observation of the Venus ionosphere and ionopause during solar minimum although most of the time it is expected to be in the magnetic barrier when periapsis is on the dayside, or above the ionosphere at night.

The magnetic barrier at Venus is a region within which the magnetic pressure dominates all other pressure contributions (cf. Zhang et al., 1991). It is strongest at the subsolar point and weakens with increasing solar zenith angle. The lower boundary of the magnetic barrier is defined by the ionopause and the upper boundary is defined as the altitude where the magnetosheath magnetic pressure is equal half of the upstream solar wind dynamic pressure. The upper boundary of the magnetic barrier is not well defined because of the insufficient temporal resolution of the PVO plasma instrument. Together with the high time resolution measurement of ASPERA-4 IMA, we expect to identify the magnetic barrier upper boundary for the first time. We note that at solar maximum, this barrier deflects the solar wind and serves as an effective obstacle. However, the role and configuration of the magnetic barrier during solar minimum is unknown and we will investigate this issue with Venus Express. In addition, recently Bertucci et al. (2003) has shown that the magnetic barrier upper boundary has a wave activity transition nature. With the MAG high-resolution measurement, we will investigate the wave and turbulence phenomena in the inner magnetosheath. Further, the ASPERA4-IMA ion composition measurements will be able to determine if any plasma present in the solar minimum magnetic barrier is of ionospheric or solar wind origin.

4.4. Terminator region

The nightside ionosphere is mainly maintained by ion transport from the dayside through the terminator because the solar photonization does not contribute directly to the ionization (cf. Brace and Kliore, 1991, and the references therein). In addition, the electron impact ionization may also play an important role in maintaining the nightside ionosphere. The nightward ion flow is driven primarily by the large pressure gradient at the terminator. It is known that the height of the terminator ionopause controls the transport of the ionospheric plasma from dayside to nightside (Knudsen et al., 1987). When the altitude of the terminator ionopause is low as during solar minimum, the nightside ionosphere is expected to be highly depleted (Luhmann et al., 1987; Zhang et al., 1990b). The in situ measurement around the ionopause by Venus Express will enable us to study plasma transport in detail.

Above the ionopause in the inner magnetosheath, the so-called plasma clouds, which may develop due to the

Kelvin–Helmholtz plasma instability at the ionopause boundary were observed by PVO (cf. Brace et al., 1982; Russell et al., 1982). These clouds can detach and carry planetary plasma away. The plasma clouds are accelerated near the terminator region. Lammer et al. (2006) found in agreement with Terada et al. (2002) that these plasma clouds might cause substantial ionospheric erosion and loss of hydrogen and oxygen from the upper atmosphere. In this regard, the orbit of the Venus Express is most ideal to observe plasma clouds and compare their efficiency in appearance between high (PVO) and low solar activity (Venus Express) periods. These observations will allow us, to get a better understanding of contribution of the loss due to ion clouds compared to ion pick up over the whole solar activity cycle, which is important for models, which are applied to the study of evolutionary aspects of Venus' atmosphere (see Kulikov et al., 2006).

4.5. Wake

Venus has a well-defined magnetotail (cf. Phillips and McComas, 1991). The magnetic field lines passing close by the planet will pick up mass from the atmosphere/ionosphere and slow down, thereby draping around the obstacles. The magnetotail is the result of the slowing of magnetic flux tubes convected past the planetary obstacle. Luhmann (1992) showed that the induced magnetic field around Venus is toroidal with near-complete wrapping of IMF around the planetary obstacle, rather than simply deflected around the obstacle. A possibility of reconnection was suggested; however, no clear observational evidences have been obtained. Nevertheless, if there were reconnection, then Venus Express is well equipped and well located for finding reliable evidence of this process.

4.6. Lightning

Venus lightning remains an interesting topic and MAG could provide some further support on this investigation. Near the pericenter, MAG will sample magnetic wave at 128 Hz. The reader is referred to another paper in this volume on this topic (Russell et al., 2006b).

4.7. Ion pickup

The OPA was primarily designed for solar wind monitoring with a low time resolution of about 10 min, a lack of ion composition capability and limited energy range. Thus ion pickup process has not been studied properly (cf. Phillips and McComas, 1991). In comparison, ASPERA-4 IMA has an energy range of 10–40 keV and an ability to separate ion masses. Its highest temporal resolution for providing a 3D ion distribution is every 32 s, which should allow us to study the acceleration of planetary ions from ionopause altitudes to large planetary distances. Furthermore, these observations will give us a better understanding of ion fluxes, which are backscattered to the upper atmosphere where they can act as sputter agents of heavy neutrals. Indeed, the pickup process is one of the major subjects for the Venus Express plasma and magnetic measurements. The reader is referred to Luhmann et al. (2006) and Lammer et al. (2006) for extensive discussions on this topic.

4.8. Contribution to space weather study

Venus Express will have a highly elliptical orbit about Venus. Since the induced magnetosphere is very small at Venus, during most of a Venus year, the spacecraft spends the majority of its orbital time in the solar wind. Thus Venus Express can be used as a solar wind monitor at 0.72 AU. More interestingly, the nominal life time of the Venus Express mission is concurrent with STEREO which is dedicated to study the coronal mass ejections from vantage points at 1 AU, but behind and in front of Earth on its orbit around the Sun. Venus Express will provide part of an inner heliospheric constellation for plasma and field measurements of solar wind structure and space weather disturbances—some of which will also impact the Venus environment.

5. Summary

Renewed interest in the topic of the solar wind interaction with the planet Venus will be generated with the Venus Express mission. We describe in this paper the magnetic field investigation onboard Venus Express. We have compared the Venus Express mission with PVO mission to illustrate the major differences between these two missions, namely the new instrumentation, the different orbit and the different solar activity. We found that Venus Express will fill many observational gaps left by PVO. It is clear that Venus Express will provide a deeper understanding of the solar wind interaction with Venus than we have gathered to date.

Acknowledgments

The preparation of this paper at Graz is partially supported by the Austrian "Fonds zur Förderung der wissenschaftlichen Forschung" under project P17100-N08. The hardware provided by TU-Braunschweig is supported by Astrium-EADS. The work in Imperial College is supported by the Particle Physics and Astronomy Research Council (PPARC). The preparation of this paper at UCLA was supported by the National Aeronautics and Space Administration. The preparation of this paper in Slovakia was supported by Slovak VEGA grant agency project 4064. The preparation of this paper in China is supported by the International Collaboration Research Team Program of the Chinese Academy of Sciences.

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