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Geometry of the intermediate transition in the Venus plasma wake

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ABSTRACT

The ASPERA plasma data and the magnetic field measurements of the Venus Express lead to the observation of the intermediate transition as the spacecraft approached the planet through the Venus wake. An analysis was conducted on data obtained in 4 different observation periods between 2006 and 2009 when that transition occurred by the midnight plane. A data set plotted on the YZ plane transverse to the solar wind direction indicates that the intermediate transition spreads out away from the wake with the downstream distance from the planet and that its displacement is more noticeable on a direction transverse to the ecliptic plane.

VEX DATA

A selection of Venus Express orbits was made in each observation period for the orbit that is traced closest to the midnight plane and thus that can provide a better identification of the intermediate transition which arises from momentum transport processes by the polar regions. An example of the energy spectra of the solar wind and the planetary O+ ions, together with their density and speed profiles derived from those spectra in the 27-08-2008 orbit is shown in Figure 1. Among the various features seen in the energy spectra in that figure it is noticeable the strong change that occurs in the energy spectrum of the H+ ions (top panel) at 03:23 UT with a gradual energy decrease before that time and a severe absence of ion fluxes right afterwards. At that time there is a sudden drop in the density and speed of those ions similar to what has been reported across a plasma transition in previous studies (1). Equally notable is an increase of the solar wind ion density and magnetic field intensity measured by 02:00UT as the spacecraft moved along the wake and that is comparable to a bow shock crossing far downstream from Venus (at X ~3.69 R_V). Figure 1 also shows that throughout its transit through the Venus wake the Venus Express moved near the midnight plane since there are only very small values of the Y coordinate. Independent of those measurements in the wake an outbound bow shock crossing upfront at ~04:15 UT was also detected.

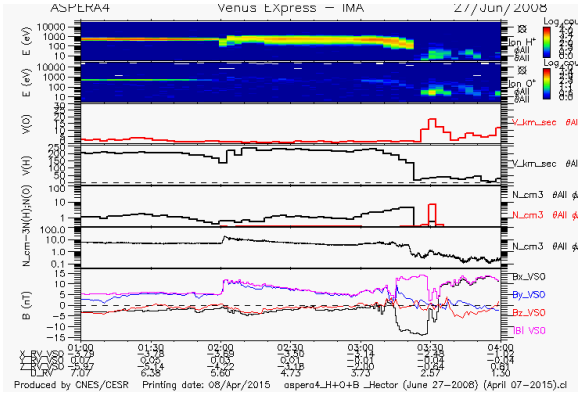

Figure 1. Energy spectra of the solar wind and planetary O+ ions measured with the Venus Express spacecraft in the Venus wake on August 27, 2008.

Together with the example shown in Figure 1 we selected 4 orbits between 2006 and 2009 that are traced in the vicinity of the midnight plane. Those cases are listed in Table I with the time and the coordinate values where the intermediate transition and the inbound bow shock were detected. The X and the Z coordinate values of both transitions in the 4 observation periods are plotted separately in Figure 2 in different data sets. Both of them show a similar trend with the X and Z values reaching a smaller (negative) magnitude in the later orbits (27-06-2008 and 19-09-2009). However, while there is a nearly linear variation in the position of the bow shock between 2006 and 2009 a similar dependence seems to be applicable to the data points of the early orbits (23-08-2006 and 17-11-2007) for the intermediate transition. In fact, in the 2 latter orbits (27-06-2008 and 19-09-2009), the position of the data points of the intermediate transition taper off along the X-direction suggesting that its shape may be modified in the near Venus wake (at smaller X values).

A further analysis of the position of the intermediate transition in the September-2009 observation period was conducted by selecting 12 orbits of the Venus Express where the spacecraft probed throughout the inner wake Different from the small values of the Y coordinate indicated in Table 1 the Y values in the 12 orbits now extend between ± 0.50 R_V for the 12 orbits.

The position of the intermediate transition derived from these orbits is plotted in Figure 3 to show a near linear dependence between their X and Z coordinate values. That variation indicates that with larger X distances downstream from Venus the intermediate transition becomes located further away from the wake as it is also indicated in Figure 2,

	INTERMEDIATE TRANSITION		BOW SHOCK		
	23-08-06	17-11-07		23-08-06	17-11-07
UT	01:36	00:48	UT	00:00	23:28
X	-3.23	- 3.00	X	-4.26	-3.88
Y	0.02	0.10	Y	0.02	0.19
Z	-1.44	-1.35	Z	-4.48	-4.35

	INTERMEDIATE TRANSITION		BOW SHOCK		
	27-06-08	19-09-09		27-06-08	19-09-09
UT	03:22	01:47	UT	02:00	00:38
X	-2.68	-2.56	X	-3.69	-3.30
Y	-0.03	0.04	Y	0.03	0.02
Z	-1.00	-1.18	Z	-4.22	-4.00

TABLE I. Date and time (in UT) together with coordinate values (in Venus radii) for the position of Venus Express at the intermediate transition and at the inbound Venus bow shock that were detected in 4 orbits traced by the midnight plane at different observation periods.

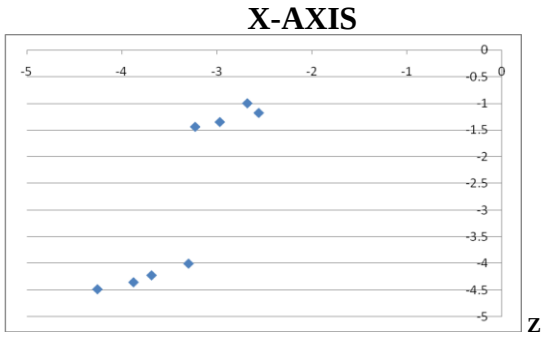

Figure 2. Data points for the intermediate transition (upper set) and for the bow shock (lower set) of the 4 orbits of Table I traced on the XZ plane .

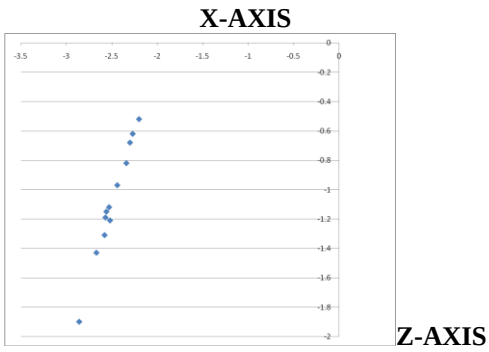

Figure 3. Data points for the intermediate transition derived from 12 orbits of the Venus Express that probed around the midnight plane between 12-09-09 and 26-09-09 in the September 2009 observation period.

DISCUSSION

The overall tendency for the intermediate transition and the bow shock to be located at smaller X and Z coordinate values in the later observation periods between 2006 and 2009 as shown in Figure 2 is consistent with the onset of solar minimum conditions by 2009 when the ionospheric plasma becomes less eroded by the solar wind. Even though the response in the position of both transitions is consistent with that variation the same issue was also addressed by comparing the position of the intermediate transition in 12 selected orbits between 12-09-09 and 26-09-09 that probed throughout the inner wake in the September-2009 observation period. The results in Figure 3 show a near linear dependence between the Z and the X-coordinate values in the position of the intermediate transition, thus indicating that even in the same observation period the displacement of that transition away from the wake along the Z-coordinate increases downstream from the planet. In fact, the interaction between the solar wind and the upper polar ionosphere is different from that at other latitudes as plasma channels are produced by the polar regions (2) thus expanding the eroded upper ionosphere into the wake. Such conditions are different further downstream where the expansion process mostly proceeds away from the wake (1).

[1] Pérez-de-Tejada, H. et al., JGR, 116, doi:JA015216, 2011.
[2] Pérez-de-Tejada, H. et al., JGR, 109, doi:JA009811, 2004.