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Southbound Displacement of Vortex Structures in the Venus wake

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SOUTHBOUND DISPLACEMENT OF VORTEX STRUCTURES IN THE VENUS WAKE

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1 – VEX Data

From measurements conducted with the Venus Express spacecraft (VEX) it has been possible to identify vortex structures within the Venus plasma wake (Pérez-de-Tejada et al., INTECH (ISBN 978-953-51-0880), 2012; Lundin et al., GRL 40(7), 273, 2013). Such features derive from the energy spectra of the solar wind H+ and planetary O+ ions measured with the ASPERA instrument and are reproduced in **Figure 1.** The energy spectra of the O+ ion component (second panel) indicate the presence of appreciable planetary O+ ion fluxes between 02:05 UT and 02:30 UT and that lead to their enhanced density and speed values.

Figure 1. Energy spectra of the H+ and O+ ions (upper panels) measured during the Sept 26-2009 VEX orbit in the Venus wake by the midnight plane (small Y-values at the bottom of the figure). Between 02:05 UT and 02:30 UT there are enhanced O+ density and speed

values (third and fifth panels).

2 - Vortex Structures in the Venus wake

A comparative view of the distribution of the vortex structures on the XZ plane obtained in different VEX orbits is presented in **Figure 2** to show the position of the VEX entry and exit crossings in orbits that probed near the midnight plane. Most notable is a general tendency for the vortex structure to be displaced toward the southern hemisphere with decreasing distance downstream from Venus. At larger (negative) X-values the vortex is located at larger (negative) Z-values. Two sets with 4 orbits corresponding to measurements made in 2006 and in 2009 indicate a different displacement of the vortex structures in that plane. There is a general preference of those features to occur closer to Venus in the 2009 measurements since their passage across the Z = 0 axis is by X = -1.7 R_V in that set while it reaches X = -2.2 R_V in the 2006 measurements. This difference implies that the vortex structures are located closer to Venus during solar cycle minimum conditions by 2009 and that their position along the wake varies during that cycle.

- **Figure 2. Position of the VEX spacecraft projected on the XZ plane during its entry (inbound) and exit (outbound) through a vortex structure in orbits traced by the midnight plane. The two traces correspond to 4 orbits in 2006 and 2009 (Pérez-de-Tejada and Lundin, ICARUS, submitted 2021).**

3 – Origin of the southbound displacement

A dominant feature in the motion of the solar wind particles that stream around the Venus ionosphere is that they experience local heating when they move over its polar regions. That heating derives from dissipation processes produced by the transport of solar wind momentum to the Venus polar ionosphere where there is a reduced local pile up of the solar wind magnetic field fluxes. As a result the solar wind plasma expands by thermal pressure forces and thus moves into the Venus wake from both polar regions. An implication of that displacement is that there are two different flows of plasma particles reaching the central wake from two opposite directions along the Z-axis. Both flows move from a region where the planetary O+ ions first experience a week polar rotation around Venus and then are displaced to lower latitudes where the rotation speed of the local planetary ions around the planet is larger. Since both plasma flows also move along the X-axis following the solar wind direction there should be a Coriolis force that deflects them along the Y-axis. For both flows the deflection should be in opposite direction to each other since in the north hemisphere it will move in the –Z sense and in the south hemisphere in the +Z-sense. In addition to this motion they will also be influenced by the effects of a general Magnus force that drives all planetary ions to move around the planet with a velocity component directed in the +Y sense (Pérez-de-Tejada, JGR, 111(A11), 2006).

Since the latter force is contrary to the direction of motion along the -Y sense imposed by the Coriolis force for the O+ ions in the south hemisphere their resulting total velocity will be smaller than that for the O+ ions in the upper hemisphere where the velocity components implied by the Coriolis and by the Magnus force are directed in the same sense along the +Y axis. An implication of that velocity difference between both hemispheres is that **the momentum of the planetary O+ ions along the Y-axis in the south hemisphere is smaller than that for the O+ ions that move in the north hemisphere.** Also, from such momentum difference in the XY plane there will be a tendency for the velocity component of the planetary ions moving along the +Z-axis in the south hemisphere to contribute with a fraction of their own momentum to balance the momentum difference in the XY plane. Consequently, a fraction of the momentum of the O+ ion fluxes that move north along the Z-axis will be transferred to that in the Y-sense to compensate for the smaller values of their momentum with respect to the larger +Y-directed momentum values of the O+ ions in the north hemisphere. Thus, there will be smaller values in the momentum of the O+ ions that drive north along the Z-axis in the south hemisphere. **Under such conditions the momentum of the O+ ions that are directed south in the north hemisphere will be dominant over that directed north in the south hemisphere.** As a result the motion of the O+ ions in the north hemisphere will force the entire vortex structure to be displaced south in the –Z direction. Such an effect is in agreement with the profiles on the XZ plane of the VEX position where the vortex structures measured during the 2006 and 2009 orbits become displaced to lower –Z values with increasing distance downstream from Venus as indicated in **Figure 2.**