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Ionopause-like gradients in the ionospheric dayside of Venus and Mars in light of radio science observations

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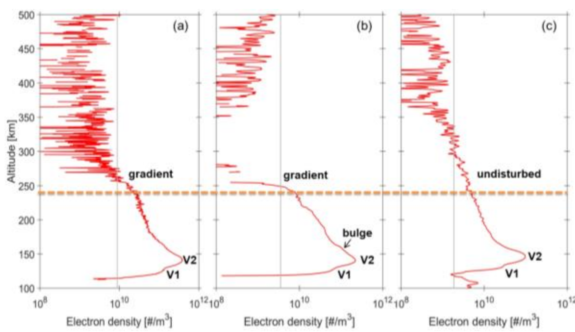

Figure 1: VEX-VeRa open loop observations of the dayside ionosphere of Venus for (a) Day of Year (DoY) 196 (2006) ingress (ING) (b) DoY 210 (2006) ING and (c) DoY 216 (2006) ING. The gray line indicates the noise level of the individual observation.

The term ionopause was first applied to describe the upper boundary of the planetary ionosphere of Venus. Multiple ionopause definitions were derived from Pioneer Venus Orbiter (PVO, 1978-1992) in-situ observations, ranging from the location of pressure balance between the incoming solar wind and the Venusian ionosphere [1] to the location of a substantial decrease in ion density [2] or electron density [3] within short temporal and spatial scales. PVO in-situ observations also indicate an increase in ionopause altitude for increasing solar zenith angle during solar maximum conditions [4]. Two extreme magnetic states of the dayside ionosphere have been identified for PVO solar maximum conditions. Unmagnetized ionospheres (when only small-scale magnetic fields are present) are observed when the solar wind dynamic pressure is significantly lower than the maximum thermal pressure of the ionosphere. In these cases a narrow ionopause is found above 300 km altitude at all solar zenith angles.

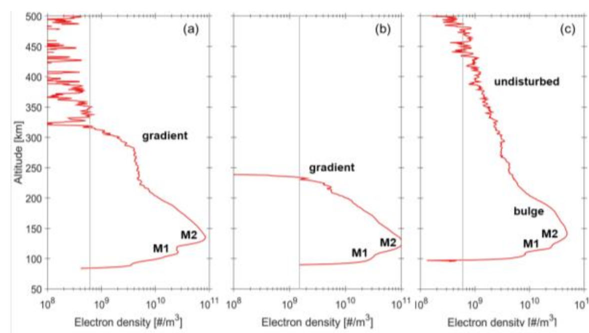

Figure 2: MEX-MaRS closed loop observations of the dayside ionosphere of Mars for (a) DoY 347 (2005), (b) DoY 049 (2006) and (c) DoY 323 (2005).

When the dynamic solar wind pressure reaches or exceeds the maximum subsolar thermal pressure of the ionosphere, the ionosphere can become largely magnetized with a broad ionopause below 300 km altitude [5]. A new opportunity for the remote and in-situ investigation of the solar wind interaction with Venus during solar minimum conditions occurred with the Venus Express spacecraft (VEX, 2006 – 2014). The combination of ASPERA4-ELS and magnetometer (MAG) observations indicated a magnetization of the ionosphere in 58% of the explored observations (2006 – 2009) [6].
The interaction of Mars with the solar wind is that of an unmagnetized planet like Venus, except for the regions with strong crustal magnetic fields. Strong gradients in the Martian dayside ionosphere were identified in few Mars Express Radio Science (MaRS) observations [7, 8, 9] and in Mars Express (MEX) MARSIS observations [10]. A more detailed analysis of MARSIS observations indicates a response of the ionopause altitude to seasonal variations in solar flux and that ionopauses rarely form over strong crustal

magnetic fields [11]. Simultaneous MAVEN observations of Martian plasma and magnetic field properties indicate that ion profiles with gradients in the ionospheric topside are common on the ionospheric dayside. They are accompanied by a higher proton energy flux at high altitudes and also with stronger magnetic field at low altitude than profiles without an ionopause [12].

In this work, VEX-VeRa radio science observations from 2006 - 2014 are correlated with VEX-ASPERA4 solar wind parameters and SIP V2.38 [13] model solar fluxes to determine the origin of the variability of the Venus ionospheric topside seen in radio science observations (Figure 1). More than 15 years of radio science observations are used to study the behavior of the uppermost Martian ionospheric region accessible to MEX-MaRS. MEX-ASPERA3 [14] and MAVEN [15] observations of the pristine solar wind and solar fluxes at the Mars position are applied to identify potential drivers of the ionospheric variability seen by MEX-MaRS (Figure 2). The intercomparison of VEX-VeRa and MEX-MaRS results with PVO and MEX-MARSIS observations, respectively, will improve our understanding of the solar wind interaction at Venus and Mars during changing space weather conditions.

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