

COMMENT ON "IONOSPHERIC EVIDENCE OF HOT OXYGEN IN THE UPPER ATMOSPHERE OF VENUS"

Andrew F. Nagy

Department of Atmospheric, Oceanic and Space Science, Space Physics Research Laboratory, University of Michigan, Ann Arbor

Thomas E. Cravens

Department of Physics and Astronomy, University of Kansas, Lawrence

Mahajan et al. [1992] searched through the Pioneer Venus database and found data from a number of dayside orbits for which the ionopause was at unusually high altitudes. Dayside orbits with ionopause altitudes in excess of 500-1000 km are very rare and provide unique glimpses at the Venus ionosphere under conditions of very low solar wind pressure. Mahajan et al. [1992] selected orbits 421 and 422 for further examination and showed that O⁺ was the dominant ion in the upper ionosphere and that H⁺ remained a minor ion at all altitudes. They used this result to conclude that "the existence of O⁺ as a dominant ion at these high altitudes can only be explained if atomic oxygen is the major neutral constituent". This conclusion is incorrect.

Comprehensive model calculations have shown that even if the presence of the hot oxygen population is totally neglected O⁺ ions remain the major upper ionospheric species [e.g., Nagy et al., 1980]. The reason for this result is that ionization and chemical processes which control the ion composition below about 200 km, become negligible at higher altitudes, where transport processes dominate. The ion composition is established in the transition region where chemical processes give way to transport. The high altitude ion composition is determined by the transition region composition and is modified only by diffusion and other transport processes, which are largely composition independent. At this transition region [~ 200 km] thermal

atomic oxygen is the dominant neutral gas, and hot oxygen is a minor species, thus the O⁺ to H⁺ ratio at high altitudes is not an indicator of the presence of hot oxygen at these altitudes.

In order to further demonstrate this point we constructed a one dimensional model [coupled continuity and momentum equations] for H⁺ and O⁺ appropriate for the dayside ionosphere of Venus. We also looked at a number of Pioneer Venus orbits with high ionopause altitudes. We restricted our attention to orbits with solar zenith angles less than 30°, in order to limit the likely transport processes to vertical diffusion. We averaged the measured electron and ion temperatures over seven of these orbits and used this information as input parameters to our model. We selected a neutral hydrogen density value for 150 km, the lower boundary of our model, such that there was a reasonable overall match between the observed and model H⁺ density values. The thermal oxygen density and neutral gas temperature values were taken from Table 4-9 of the VIRA model [Keating et al., 1985], corresponding to a solar zenith angle of 34°. The calculated H⁺ and O⁺ densities, along with the mean measured H⁺ and O⁺ values are shown in Figure 1. We ran our calculations with hot atomic oxygen density values which varied from 10³ to 10⁶ cm⁻³ at 150 km [we used a scale height of 400 km, which has been used before as being consistent with observations]. We found that within

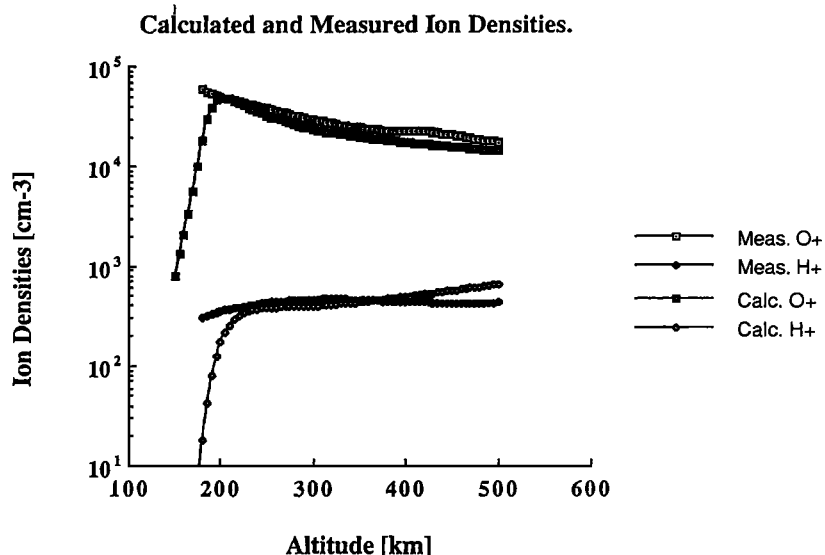


Fig. 1. Calculated and measured H⁺ and O⁺ densities. The calculations presented in this figure were carried out for an assumed hot oxygen density of 10⁵ cm⁻³ at 150 km.

Copyright 1993 by the American Geophysical Union.

Paper number 93GL00491
0094-8534/93/93GL-00491\$03.00

this range of values the calculated H^+ and O^+ densities did not change in any meaningful way [the changes were of the order of ten percent], because the hot oxygen population remained a minor neutral constituent below 200 km, which is the approximate height of the transition between chemical and diffusive equilibrium conditions for the ions. A hot oxygen density value of 10^6 cm^{-3} at 150 km is already more than a factor of ten higher than is consistent with that indicated by the UVS [Stewart, 1980] 1304 Å measurements [Nagy and Cravens, 1988].

Therefore, in conclusion, Mahajan et al. [1992] provided our community a useful service in drawing our attention to the existence of PVO orbits with very high ionopause altitudes, but they, unfortunately, were wrong in stating that the dominance of O^+ ions at high altitudes can be used as an indicator of the presence of the hot oxygen population. Our calculations have demonstrated that the H^+ and O^+ density profiles are just not sensitive to the presence of hot oxygen, within the range of plausible concentrations.

Acknowledgments. We wish to thank Ms. Linnea Nooden who worked on the PVO data base and catalogued the data from the high ionopause orbits used in this work. Support for this study was provided by NASA Grant NAG2-491.

References

- Keating, G. M., J. L. Bertaux, S. W. Bougher, T. E. Cravens, R. E. Dickinson, A. E. Hedin, V. A. Krasnapolsky, A. F. Nagy, J. Y. Nicholson, L. J. Paxton, U. v. Zahn, Models of Venus neutral upper atmosphere: Structure and composition, *Adv. Space Res.*, *5*, 117, 1985.
- Mahajan, K. K., S. Ghosh, N. K. Sethi and R. Kohli, Ionospheric evidence of hot oxygen in the upper atmosphere of Venus, *Geophys. Res. Lett.*, *19*, 1627, 1992.
- Nagy, A. F., T. E. Cravens, S. G. Smith, H. A. Taylor and H. C. Brinton, Model calculations of the dayside ionosphere of Venus: Ionic composition, *J. Geophys. Res.*, *85*, 7795, 1980.
- Nagy, A. F. and T. E. Cravens, Hot oxygen atoms in the upper atmospheres of Venus and Mars, *Geophys. Res. Lett.*, *15*, 433, 1988.
- Stewart, A. I. F., Design and operation of the Pioneer Venus Orbiter ultraviolet spectrometer, *IEEE Trans. Geosci. Remote Sens.*, *GE-18*, 32, 1980.

(Received: November 16, 1992;
accepted: January 25, 1993.)