**Atmospheric evolution and past habitability of Venus: understanding the roles of ion escape processes.**

C.M. Fowler[1] and R.A. Frahm[2] and S. Xu[3] and M. Chaffin[4] [1]West Virginia University, West Virginia, USA (christopher.fowler@mail.wvu.edu), [2]Southwest Research Institute, San Antonio, USA, [3]Space Sciences Laboratory, University of California, California, USA, [4]Laboratory for Atmospheric and Space Physics, University of Colorado, Colorado, USA.

Current day Venus is incredibly dry, with an atmospheric water content of only a few 10s ppm [1, 2]. The observed high abundance ratio of Hydrogen to Deuterium (~120 times that of Earth [3]) suggests that Venus was once much wetter than it is today. Interpretations put forth by [4] attempt to explain current observations via two main scenarios: (1) continuous outgassing from a highly fractionated mantle source, or (2) massive hydrogen escape following a recent (~0.5-1 Gyr) catastrophic resurfacing event. Both of these scenarios depend upon, among other parameters, the absolute and relative loss rates of hydrogen (H) and deuterium (D) to space over the history of Venus.

Remote sensing observations by Pioneer Venus Orbiter (PVO) have provided wide constraints on Hydrogen loss rates [e.g. 5, 6, 7], where charge exchange between gravitationally bound H and solar wind protons is the primary driver of planetary H loss [8, 9, 10]. In this case, "hot" planetary H from the energetic tail of the distribution function can reach high altitudes and is exposed to solar wind protons where planetary H is subject to charge exchange reactions. The contribution of ions to the atmospheric loss process must also be considered [eg 11], and in contrast, planetary ions are thought to be lost via their interaction with electric and magnetic fields in the upper atmosphere [e.g. 12, 13, 14]. These fields can energize the cold planetary ions that are produced via photochemistry, allowing them to overcome Venus' gravitational potential and escape to space. While the Venus EXpress (VEX) spacecraft has provided constraints on heavy ($O^+$ and $O_2^+$ in particular) ion loss rates [e.g. 15, 16] much is still unknown about the underlying ion energization mechanisms and how they respond to various solar drivers.

The importance of atmospheric loss to space is highlighted when we observe Venus in the context of other solar system bodies, in particular those that also do not possess a significant planetary magnetic field. These bodies include comets, Pluto, Titan and Mars. Recent observations at these bodies have demonstrated that atmospheric loss to space, including ion loss, can play an important role in the evolution of their climates and atmospheres [17, 18, 19, 20, 21]. This presentation will discuss ion loss at Venus, driven by one particular type of electromagnetic wave interaction process. This process, known as "magnetic pumping", has recently been observed at Mars, and case studies of PVO and VEX data show that conditions are likely ripe for this process to be active at Venus as well. Understanding how individual processes influence atmospheric evolution will allow us to fully understand the evolution of Venus as a whole.

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**References:**

[1] Pollack, J.B. et al. (1993), *Icarus*, *103*(1), 1-42. [2] Bézard, B. et al. (1990), *Nature*, 345(6275), 508-511. [3] De Bergh, C. et al. (1991), *Science*, 251(4993), 547-549. [4] Grinspoon, D.H. (1993), *Nature*, 363(6428), 428-431. [5] Rodriguez, J.M. et al. (1984), *Planetary and space science*, 32(10), 1235-1255. [6] Donahue, T.M. et al. (1992), *Geophysical research letters*, 19(24), 2449-2452. [7] Brace, L.H. et al. (1987), *Journal of Geophysical Research: Space Physics*, 92(A1), 15-26. [8] Hodges Jr, R.R. et al. (1986), *Journal of Geophysical Research: Space Physics*, *91*(A12), 13649-13658. [9] Hodges Jr, R.R. e al. (1981), *Journal of Geophysical Research: Space Physics*, *86*(A9), 7649-7656. [10] Chassefière, E. (1996), *Journal of Geophysical Research: Planets*, *101*(E11), 26039-26056. [11] Donahue, T.M., & Hartle, R. E. (1992), *Geophysical research letters*, *19*(24), 2449-2452. [12] Barabash et al. (2007), *Nature*, *450*(7170), 650-653. [13] Luhmann, J.G. et al. (2008), *Journal of Geophysical Research: Planets*, *113*(E9). [14] Fränz, M. et al. (2017), *Planetary and Space Science*, *146*, 55-65. [15] Fedorov, A. et al. (2011), *Journal of Geophysical Research: Space Physics*, *116*(A7). [16] Persson, M. et al. (2018), *Geophysical Research Letters*, *45*(20), 10-805. [17] Brain, D.A. et al. (2016), *Journal of Geophysical Research: Planets*, *121*(12), 2364-2385. [18] Jakosky, B.M. et al. (2015), *Geophysical Research Letters*, *42*(21), 8791-8802. [19] Heritier, K.L. et al. (2018), *Astronomy & Astrophysics*, *618*, A77. [20] Persson, M. et al. (2020), *Journal of Geophysical Research: Planets*, *125*(3), e2019JE006336. [21] Ramstad, R. et al. (2018), *Journal of Geophysical Research: Planets*, *123*(11), 3051-306