VENUS: THE EXOPLANET LABORATORY NEXT DOOR. G. N. Arney[1,2,3] [1]NASA Goddard Space Flight Center (giada.n.arney@nasa.gov), [2]The Virtual Planetary Laboratory, [3]The Sellers Exoplanets Environments Collaboration

Introduction: Venus is the most Earth-like planet in the solar system in terms of its size, mass, and bulk composition, yet the surface conditions of these two worlds could not be more different. Venus has the hottest terrestrial surface in the solar system. Despite this, Venus may once have hosted clement conditions in its deep past, possibly even with an ocean. Here, we will review what present and past Venus teaches us context of comparative planetology and processes that shape habitability and biosignature "false positives" in exoplanet atmospheres.

Important for future observations of exoplanets, Venus-analogs represent one of the most readily observable types of terrestrial planets for the transit transmission observations [1] that will become possible in the near future with the James Webb Space Telescope. Indeed, many terrestrial exoplanets already discovered, and undoubtedly many that will be uncovered by TESS, are likely to be more Venus-like than Earth-like. However, understanding the processes that affect Venus-like exoplanets will be particularly challenging in the context of characterizing these distant and data-limited worlds. Models used to understand exoVenus analogs must be validated on the Venusian environment. Yet there are still many unknowns about Venus' present and past states, so better understanding exoVenus planets demands a better understanding of Venus in the solar system.

Early Venus may have had oceans [2]. However, its early putative habitability is a provocative question. Recent 3-D modeling efforts have suggested that a slowly-rotating planet like Venus can generate a thick subsolar cloud deck that would substantially cool the planet, producing surface temperatures that could allow for liquid water for potentially billions of years [3]. These same processes have also been applied to tidally-locked, slowly-rotating planets orbiting M dwarfs, including planets interior to the inner edge of their stars' traditional habitable zones [4]. If hot, slowly-rotating exoplanets are observed to be habitable, this may shed light on processes that operated on Venus in the past.

In addition, photochemical and atmospheric loss processes that occur on Venus may also help us to understand the plausibility of mechanisms that could generate abiotic oxygen in exoplanet atmospheres [5], which has important implications for our understanding of oxygen as a robust biosignature for exoplanets.

For instance, massive water loss such as past Venus may have experienced has been invoked as a possible "false positive" mechanism to generate large quantities of abiotic O_2 in exoplanet atmospheres [6]. The strong "electric wind" recently observed at Venus [7] can strip O+ to space. Planets orbiting closely to active M dwarfs may experience even stronger electric winds. Abiotic oxygen is generated even on Venus today through CO_2 photolysis. Recombination of excited O_2 produced by this process generates nightside airglow at 1.27 μm, but ground-state O_2 has not been detected on Venus, suggesting rapid removal from the atmosphere, possibly due to catalytic chlorine chemistry [8]. Better understanding the processes involving Venusian O_2 are vitally important for understanding the viability of multiple proposed oxygen false positive mechanisms for exoplanets.

In summary, we argue that Venus is a key player in shaping our understanding of planetary habitability as a dynamic process that evolves over time. As a world of extremes in temperature and pressure, Venus is particularly useful for model validation across a range of conditions. Venus may even shape our understanding of O_2 as a biosignature. And because exoVenus planets may be ubiquitous, it is particularly important to better understand the world next door so that we may be able to better interpret future observations of analog worlds.

References:

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