Atmospheric Escape from Mars: Lessons for Studies of Exoplanets. D. Brain¹, M. Chaffin¹, S. Curry², H. Egan¹, R. Ramstad¹, B. Jakosky¹, J. Luhmann², C. Dong³, and R. Yelle⁴, ¹LASP / University of Colorado (david.brain@colorado.edu), ²SSL / University of California Berkeley, ³PPPL / Princeton University, ⁴LPL / University of Arizona, ²SSL / University of California Berkeley.

Introduction: The planet Mars provides an intriguing laboratory for investigations of habitability on exoplanets. Though conditions at the Martian surface today are not well-suited for life, the Martian surface and atmosphere hold many clues that suggest that the necessary conditions for life were present billions of years ago. Habitable surface conditions long ago are thought to require a substantially different atmosphere, implying that much of the Martian atmosphere escaped to space over time. Mars may have been particularly susceptible to escape (compared to Earth) because of its small size and/or its lack of global magnetic field to shield the atmosphere. Each of these differences has implications for the loss rates of both neutral and charged particles over time.

The Mars Atmosphere and Volatile (MAVEN) mission to Mars has provided a wealth of data over the past three years that teach us about atmospheric escape processes and rates both today and over Martian history. These data can be applied (with caution) to situations at other planets both in our solar system and beyond; in a sense Mars is a nearby laboratory for examining issues of atmospheric retention and habitability terrestrial exoplanets.

Atmospheric Escape from Mars: We will begin by reviewing the escape processes active on Mars today, and place them in context with processes thought to be occurring on exoplanets. Further, we will review the amount of atmosphere that could have been removed from Mars over solar system history.

Mars as an Exoplanet: If Mars is a laboratory for exoplanets, one could consider what might happen if a ‘Mars’ were discovered orbiting a nearby star. Since M Dwarf stars are both particularly numerous and host exoplanets, we choose to consider how Mars might fare if it orbited an M Dwarf.

First, we examine whether the atmosphere of “ExoMars” would hydrodynamically escape and find that, for a Mars in its star’s habitable zone, that the exospheric temperature would need to exceed the effective temperature by a factor of 50. Thus, it seems plausible that at least some Mars-like planets orbiting M Dwarves would not lose their atmosphere via hydrodynamic processes.

MAVEN’s measurements have enabled estimates of the thermal loss of hydrogen from the Mars extended exosphere, the photochemical loss of oxygen from the thermosphere, and the loss of oxygen ions accelerated by electric fields near Mars. In addition, MAVEN’s data have been used to validate models for the loss of atmosphere from the planet. We consider how each of these ‘pathways’ for atmospheric loss would be changed if: the stellar photon and particle flux were consistent with a typical (such as it is) M Dwarf star, stellar disturbed (i.e. storm) periods were more frequent and more intense, and the planet orbited at a closer distance from the star. We examine the influence of these changes on thermal escape of hydrogen, photochemical escape of oxygen, ion loss, and sputtering. We find that in all cases we expect atmospheric escape to either increase or remain roughly constant. Thus, the timescale for atmospheric retention would be reduced on “ExoMars”. This timescale may be as short as 10’s of thousands of years (compared to 100’s of millions for present-day Mars), depending upon the activity of the host star.