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Martian Atmospheric and Ionospheric plasma Escape

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Solar forcing is responsible for the heating, ionization, photochemistry, and erosion processes in the upper atmosphere throughout the lifetime of the terrestrial planets. Of the four terrestrial planets, the Earth is the only one with a fully developed biosphere, while our kin Venus and Mars have evolved into arid inhabitable planets. As for Mars, there are ample evidences for an early Noachian, water rich period on Mars. The question is, what made Mars evolve so differently compared to the Earth? Various hydrosphere and atmospheric evolution scenarios for Mars have been forwarded based on surface morphology, chemical composition, simulations, semi-empiric (in-situ data) models, and the long-term evolution of the Sun. Progress has been made, but the case is still open regarding the changes that led to the present arid surface and tenuous atmosphere at Mars.

This presentation addresses the long-term variability of the Sun, the solar forcing impact on the Martian atmosphere, and its interaction with the space environment - an electromagnetic wave and particle interaction with the upper atmosphere that has implications for its photochemistry, composition, and energization that governs thermal and non-thermal escape. Non-thermal escape implies an electromagnetic upward energization of planetary ions and molecules to velocities above escape velocity, a process governed by a combination of solar EUV radiation (ionization), and energy and momentum transfer by the solar wind. The ion escape issue dates back to the early Soviet and US-missions to Mars, but the first more accurate estimates of escape rates came with the Phobos-2 mission in 1989. Better-quality ion composition measurement results of atmospheric/ionospheric ion escape from Mars, obtained from ESA Mars Express (MEX) instruments, have improved our understanding of the ion escape mechanism. With the NASA MAVEN spacecraft orbiting Mars since Sept. 2014, dual in-situ measurement with plasma instruments are now carried out in the Martian planetary realm.

Of particular interest from a planetary atmospheric escape point of view is the long-term implications of solar forcing. From ASPERA-data on MEX it has been possible to cover the transition from cycle 23 up to the cycle 24 maximum, data displaying clear solar cycle dependence. The planetary ion escape rate increased from solar minimum to solar maximum by a factor of 10. From a regression analysis using ion escape fluxes and solar forcing proxies, a "back-casting" tool is developed [1], enabling determination of the planetary ion escape back in time based on long-term solar forcing proxies (F10.7, sunspot number). The tool may be applied to other long-term solar proxies, such as the radiogenic isotopes in the Earth's atmosphere, 10Be and 14C. The cosmic-ray production of these long-lifetime (>10000 year) isotopes is modulated by the solar-heliospheric magnetic flux, i.e. an indirect measure of solar magnetic activity. Beyond that there is so far only one additional rough "back-casting" tool, the "Sun-in-time", a method whereby the age of, EUV/UV radiation, and mass-loss of other sun-like stars are determined [2, 3].

[1] Lundin et al., Geophys. Res. Lett., 40, 23, pp. 6028-6032, 2013.
[2] Wood et al., ApJ, 574:412-425, 2002.
[3] Ribas et al., ApJ., 622:680-694, 2005