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Production and loss of the Martian CO_2 atmosphere

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Abstract

While all studies related to the habitability of Mars focus on present time hostile Martian environmental conditions, the main scientific focus of this study is concerned to model the Martian surface pressure and resulting atmosphere (climate) conditions which, could be expected at the planet's history when life probably originated. One of the most important research problems regarding the martian habitability is focused on the study of those environmental conditions which can possibly lead to liquid water production on the planetary surface at different stages of its evolution [1] (Lammer et al. 2008). Concerning biology, another popular aspect is related to the sterilizing impact of solar UV-radiation. Both aspects depend on atmospheric density, composition and also on the climate. There is geological and mineralogical evidence that stable liquid H_2O existed on the martian surface about 4 Ga ago, indicating a higher surface pressure and consequently less UV radiation, cosmic ray surface exposure and an efficient CO_2 greenhouse effect. As a result, a less hostile environment compared to the present should have taken place. However, such climate conditions require most likely a denser CO_2 atmosphere. Astrophysical observations of young solar like stars indicate that the young Sun was very active in the X-ray and stronger in EUV radiation [e.g., 2] Ribas et al. 2005). In recent model simulations by [3, 4] Tian et al. (2009) it was shown that this environment may have caused a problem for the stability of the early CO_2 atmosphere during the Noachian. The high solar EUV flux would have dissociated CO_2 molecules in the thermosphere so that thermospheric cooling was reduced. The enhanced heating expanded the atmosphere to higher altitudes and most likely even above the early martian magnetosphere. In this work we study various outgassing scenarios of CO_2 from the interior of the planet and combine the outgassing rates with atmospheric evolution scenarios including impacts during the heavy bombardment, thermal escape and non-thermal solar wind induced ion erosion during the first Ga of the planet's origin. We investigate and present scenarios where the CO_2 outgassing rate may have been large enough, at some time period after the planet's origin, so that the loss rates were lower, compared to the outgassing rates and a denser CO_2 atmosphere could have build up around 4 Ga ago (see Figure 1). The evolution modeling of the martian atmospheric partial pressure values since 4 Ga ago and present day will be carried out by atmospheric escape studies related to carbon (ions and neutrals) and oxygen bearing atmospheric species. Modeling the escape of these species during the past 4 Ga – the time when the magnetic dynamo stopped working [5] (Dehant et al. 2007) – will allow

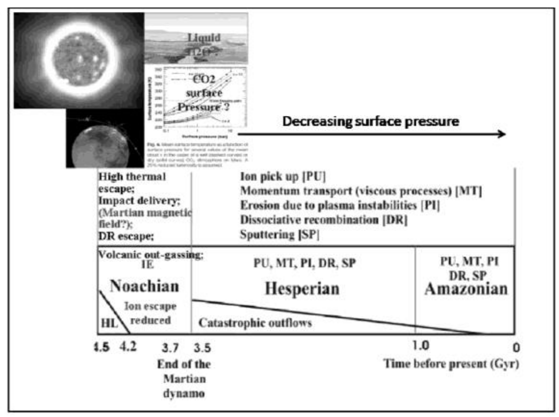

Figure 1: Illustration of the role of the active young Sun to various atmospheric escape processes during the Martian history.

us to have a better understanding of the evolution of the partial surface pressure, atmospheric composition and climate in the martian past. The theoretical results will then be used as input parameters for laboratory habitability experiments.

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