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Atmosphere and water loss on early Mars: The first Gyr

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The evolution of the Martian atmosphere and the evidence of the existence of an ancient hydrosphere are of great interest in studies regarding the evolution of the planet's water inventory by the ASPERA-3 instrument on board of ESA's Mars Express and NASA's MER rovers. Although the Martian climate is at present too cold and the atmosphere too thin so that liquid water can not be stable on the surface, there are now many indications that the situation was different in the past. Several observations of networks of valleys in crater rich areas of the southern hemisphere suggests that Mars had once a significant hydrologic activity during the first Gyr of the planets lifetime. Recent observations imply that an ancient water ocean equivalent to a global layer with the depth of about 150 m is needed for the explanation of the surface features. The evolution of the Martian atmosphere and its water inventory since the end of the magnetic dynamo at the late Noachian period about 3.5 - 3.7 Gyr ago was dominated by non-thermal atmospheric loss processes like solar wind erosion and sputtering of oxygen ions and thermal escape of hydrogen. Recent studies show that these processes could remove a global Martian ocean with a layer thickness of about 10 – 20 m, indicating that the planet should have lost the majority of its water during the first 500 Myr. Because Mars was exposed before the Noachian period to asteroid impacts, we simulate their effect on atmospheric erosion. Furthermore, the present study uses multi-wavelength observations by the ASCA, ROSAT, EUVE, FUSE and IUE satellites of Sun-like stars at various ages for the investigation of how high X-ray and EUV fluxes of the young Sun have influenced the evolution of the early Martian atmosphere. We apply for the first time a diffusive-photochemical model and investigate the heating of the Martian thermosphere by photo-dissociation and ionization processes and due to exothermic chemical reactions, as well as cooling due to CO_2 IR-radiation loss. Our model yields high exospheric temperatures during the first 100 – 500 Myr, which result in blow off for hydrogen and even high loss rates for atomic oxygen and carbon. By applying a hydrodynamical model for the estimation of the atmospheric loss rates we obtain results, which indicate that the early Martian atmosphere was strongly evaporated by the young Sun and lost most of its water during the first 100 – 500 Myrs after the planets origin. The efficiency of impact erosion and hydrodynamic blow off is also compared.