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Loss of nebula-captured hydrogen envelopes from 'sub'- to 'super-Earths' in the habitable zone of Sun-like stars

Helmut Lammer (1), Nikolai V. Erkaev (2,3), Petra Odert (4), Yuri N. Kulikov (5), Kristina G. Kislyakova (1), Alexander Stoekl (6), Ernst A. Dorfi (6), Manuel Guedel (6), and Martin Leitzinger (4)

(1) Austrian Academy of Sciences, Space Research Institute, Graz, Austria, (2) Institute for Computational Modelling, Russian Academy of Sciences, Krasnoyarsk, Russian Federation, (3) Siberian Federal University, Krasnoyarsk, Russian Federation, (4) Institute of Physics, University of Graz, Graz, Austria, (5) Polar Geophysical Institute, Russian Academy of Sciences, Murmansk, Russian Federation, (6) Institute for Astronomy, University of Vienna, Vienna, Austria

We investigate the escape of captured hydrogen envelopes from protoplanets having masses in a range between 'sub-Earth'-like bodies of 0.1 Earth-mass and 'super-Earths' with a mass of 5 Earth-masses in the habitable zone at 1 AU of a Sun like G star, assuming that their rocky cores had formed before the nebula gas dissipated. For studying the escape of these accumulated hydrogen-dominated protoatmospheres, we apply a hydrodynamic upper atmosphere model and calculate the loss rates due to the heating by the high soft-X-ray and extreme ultraviolet (XUV) flux of the young Sun/star. The results of our study indicate that under most nebula conditions 'sub-Earth' and Earth-mass planets can lose their captured hydrogen envelopes by thermal escape during the first 100 Myr after the disk dissipated. Depending on nebula properties and protoplanetary luminosities, it is possible that even protoplanets with Earth-mass cores may keep their hydrogen envelopes during their whole lifetime. In contrast to lower mass protoplanets, more massive 'super-Earths' that can accumulate a huge amount of nebula gas, lose only tiny fractions of their primordial hydrogen envelopes. Our results agree with the fact that Venus, Earth, and Mars are not surrounded by dense hydrogen envelopes, as well as with the recent discoveries of low density 'super-Earths' that most likely could not get rid of their dense protoatmospheres.