Revisiting rocky planets cooling phase and magma ocean occurence with a consistent atmospheric model

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Abstract

Rocky planets can host two distinct types of magma oceans. First, post-accretion magma oceans, sustained by the residual heat from accretional impacts [1]. The planet's surface can remain molten for extended periods depending on the planet's volatile content and the atmospheric properties. Second, permanent magma oceans, maintained by intense stellar irradiation combined with a strong greenhouse effect. In both cases, the assumption of a fully convective atmosphere, often used in previous studies, may not hold true for hot and dense atmospheres [5] where radiative processes can dominate and significantly lower surface temperatures. These findings challenge former atmospheric models and suggest that magma oceans sustained solely by stellar insolation may be less common than previously thought.

In this study, we present an improved coupling model between magma ocean evolution and a consistent 1D radiative-convective atmospheric model, using the Exo_k framework [3]. This approach enables a more realistic representation of atmospheric structure and radiative transfer compared to prior models [2, 4] and allows us to reassess magma ocean lifetimes under a variety of atmospheric conditions. Our results offer new insights into the early evolution of rocky planets, with potential implications for planets such as Venus.

References

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