JOURNÉES SF2A 2023
Atelier S12
Origine de l'eau et de la vie : Quels défis astrophysiques et instrumentaux pour demain ?

Steam atmospheres

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A planet with a significant water content can give rise to a steam atmosphere (dominated by water vapor) when the incoming stellar flux exceeds the so-called runaway limit or after large impacts or accretion. All steam-atmosphere current models predict that the greenhouse effect of an ocean worth of water vapor is sufficient to generate a surface magma ocean. This has far reaching consequences for the early evolution of warm rocky planets and the coupling of their interior with the atmosphere. In this paradigm, the solidification of the mantle of Venus is believed to have happened only after the escape of its steam atmosphere to space, leaving the mantle desiccated.
However, these conclusions rely on the assumption that atmospheres are fully convective below their photosphere. This hypothesis was introduced in the 80s and is used in a large part of the literature on the subject. Its validity had however not been assessed thoroughly. We will present the results of a climate model that has been specifically designed to model the radiative-convective equilibrium of steam atmospheres without any a priori hypothesis on their convective nature. These results show that steam atmospheres are generally not fully convective, which yields much cooler surfaces than previous models. A runaway greenhouse does not systematically melt the surface. This changes completely our view of the early evolution of Venus', with even more drastic changes for planets around stars redder than the Sun.
The equilibrium thermal structure of a steam atmosphere, which affects observable signatures and mass-radius relationships of warm Earth-like to water-rich planets, becomes strongly dependent on the stellar spectrum and internal heat flow. Our current constraints on the water content of the internal Trappist-1 planets should for example be revisited. For ultracool dwarfs, these results even question the nature of the inner edge of the sometimes called *habitable zone*.