Structure and evolution of the envelopes of hot water worlds

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Sub-Neptunes represent compelling targets for being water worlds, exhibiting masses and radii that have been shown to match those of hypothetical water rich bodies. Recent work for irradiated water worlds predict that water in their envelope would be in the supercritical state, with steam atmospheres on top, which significantly alters the mass-radius relation. However, proper knowledge of the thermal state of the interior, which affects the predicted planetary radius, is elusive. This challenge is due to both lack of knowledge of laboratory data of material (equation of state and opacity), and difficulty to self-consistently model such interiors.
Sub-Neptunes form with a huge energy reservoir, and cool down and contract over time, which has been incorporated into grids of H2-rich sub-Neptune models, but never for water worlds. Here, we present a new model that accounts for the thermal contraction of water rich envelopes. This model combines an interior structure model with a radiative-convective steam atmosphere model, that are coupled through the heat lost from the planet's interior. The interior structure model uses the most up-to-date thermodynamic data for pure water substance, and the steam atmosphere model uses a new treatment for the opacity of water. This model provides new mass-radius relationships for water-rich hot sub-Neptunes through time, which reassesses the water content in sub-Neptunes. This allows us to quantify the range of radii accessible to such hypothetical planets.