Investigating the Origin of the Radius Cliff and Water Formation on Sub-Neptune Exoplanets

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NASA's Kepler Mission has discovered over 5,800 exoplanets in our galaxy, revealing a puzzling phenomenon known as the "radius cliff." The "radius cliff" is a sharp decline in the number of planets with radii larger than approximately 3 Earth radii, a feature that has left planetary scientists perplexed for over fifteen years. Additionally, water has been detected on many sub-Neptunes (planets smaller than Neptune but larger than Earth), but the origin of water on these exoplanets remains unresolved, making it a key subject of ongoing research. The goal of my project is to explore the mechanisms behind both the "radius cliff" and the origin of water on sub-Neptune exoplanets. I hypothesize that high-pressure chemical processes occurring at the interface between silicate ($MgSiO_3$) magma oceans and hydrogen (H_2) atmospheres may limit the growth of sub-Neptunes, while simultaneously facilitating water formation on these planets. To test this hypothesis, I will conduct quantum molecular dynamics (QMD) simulations, which model atomic-level interactions, to investigate how hydrogen reacts with silicate magma under high-pressure and high-temperature (P-T) conditions typical of primordial sub-Neptunes. The research will involve developing computational tools to analyze QMD simulation data, focusing on two primary aspects: the diffusion coefficient of hydrogen (H_2) within the magma ocean and the molecular fraction of H_2O formed at different high P-T conditions. These results will provide new insights into the processes shaping exoplanet evolution, they will shed light on the mechanisms behind the "radius cliff" and the formation of water on sub-Neptune exoplanets.

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