Modelling the Lunar Water Cycle Through Coupled Monte-Carlo Simulation of the Moon's Surface and Exosphere

Alexander Smolka[1] (a.smolka@tum.de), **Philipp Reiss**[1], [1]Technical University of Munich, Lunar and Planetary Exploration Technologies

This work aims to capture the lunar water cycle by providing a thorough overview of physical and chemical processes featuring **water** (H_2O), **hydroxyl** (OH), as well as **atomic and molecular hydrogen** (H and H_2). While the exosphere can be fueled by several processes, this overview features only the solar wind protons, p^+_{SW}, as a source process of new particles. Losses include **Jean's Escape**, **EMF Escape**, which applies only to charged particles influenced by electromagnetic forces, **Adsorbate Sputtering**, and **Cold-Trapping**.

The paths show the conversion reactions between the different species and subspecies. A distinction was made between **exospheric** particles ($\bullet_{exo}$) and **(sub-) surface** particles ($\bullet_{reg}$). For the former, the respective exospheric ion was included, while for the latter another distinction between **gaseous** and **adsorbed** particles has been made.

Only in a **coupled Monte-Carlo simulation** (Smolka et al., 2023) of the lunar water exosphere, a particle can be tracked from its origin to its eventual loss, while it is undergoing multiple conversions to other (sub-) species in its lifetime. **Figure 1** shows an exemplary exospheric surface number density originating solely from solar wind input. Through the **conversions**, the incoming protons can turn into more complex molecules like water, before breaking back down into its components or escaping entirely. This **Lunar Water Cycle Map** will be used to model inter-species connections of exospheric densities and adsorbate concentrations.

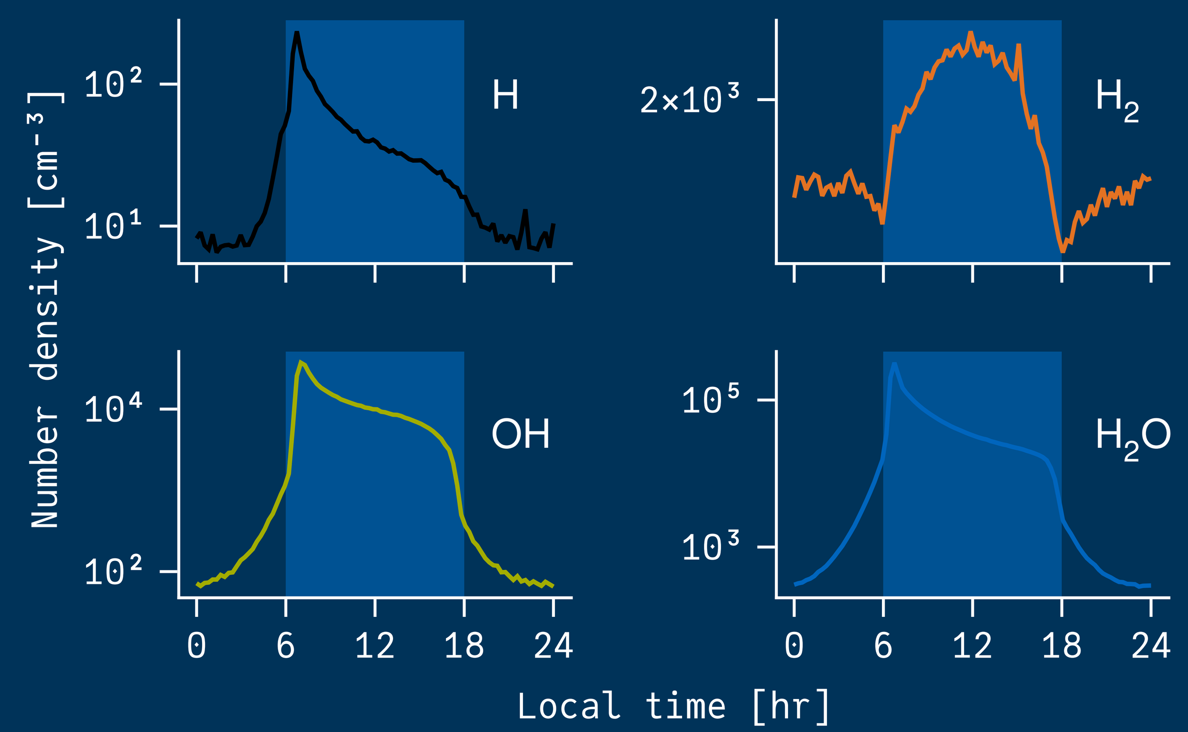

Figure 1: Exemplary exospheric surface number densities vs. local time at the lunar equator, resulting from a coupled Monte-Carlo simulation. The highlighted area indicates lunar daytime.

Conversion Paths:

- Surface Impact & Release: process exchanging particles between exosphere and regolith regime (Monte-Carlo method).
- Surface Neutralization: recycling process of charged particles through a surface interaction.
- Photoionization/-dissociation: interaction with solar wind photon.
- 1st Order Ad-/Desorption: thermal process to adsorb to a free and active site or desorb from it.
- 2nd Order Ad-/Desorption: recombinative and dissociative process leading to ad- and desorption of reaction products.
- Photon Stimulated Desorption: non-thermal process providing energy for adsorbate desorption.
- Adsorbate Photoionization/-dissociation: non-thermal process providing energy for adsorbate dissociation.

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