Modelling Europa's collisional atmosphere using the DSMC method

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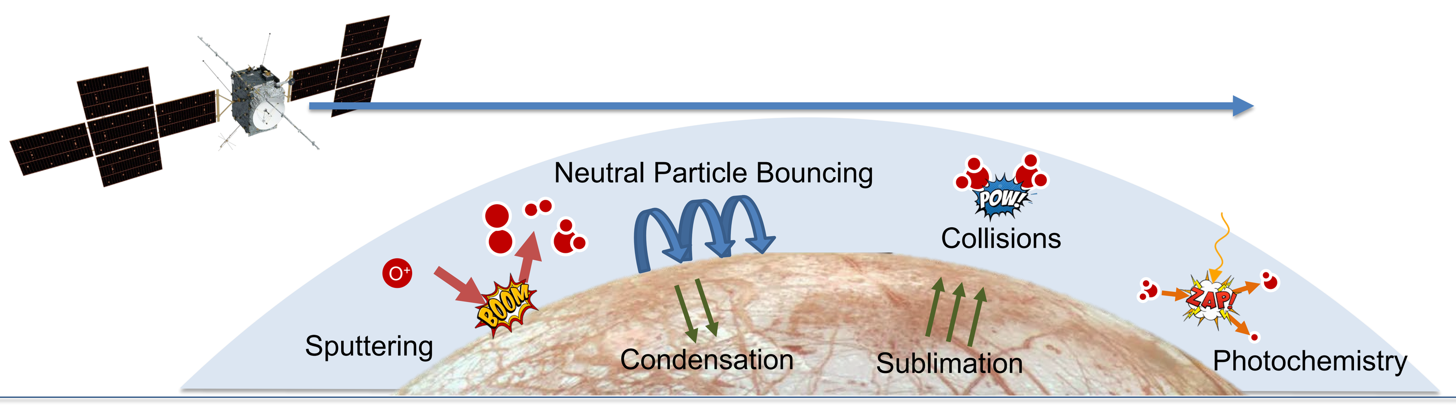
Introduction

In this study, we model the atmosphere of the Jovian satellite Europa using the **Direct Simulation Monte Carlo** (DSMC) method. ESA's JUpiter Icy Moons Explorer (**JUICE**) and NASA's **Europa Clipper** mission will encounter Europa with flybys in the 2030s and sample the moons atmosphere using mass spectroscopy. Here we investigate the impact of molecular interactions, photochemistry and the influence of a non-condensable gas (O_2) on a sublimated water atmosphere.

Europa

The icy moon has a **tenuous atmosphere**, generated by different physical and chemical processes, such as **ion sputtering** due to interaction with Jupiter's magnetosphere, the **sublimation** of ice and **photochemical reactions**. The Neutral gas and Ion Mass spectrometer (**NIM**) onboard JUICE will determine the composition of Europa's exosphere and, potentially, sample the plume material.



Methods

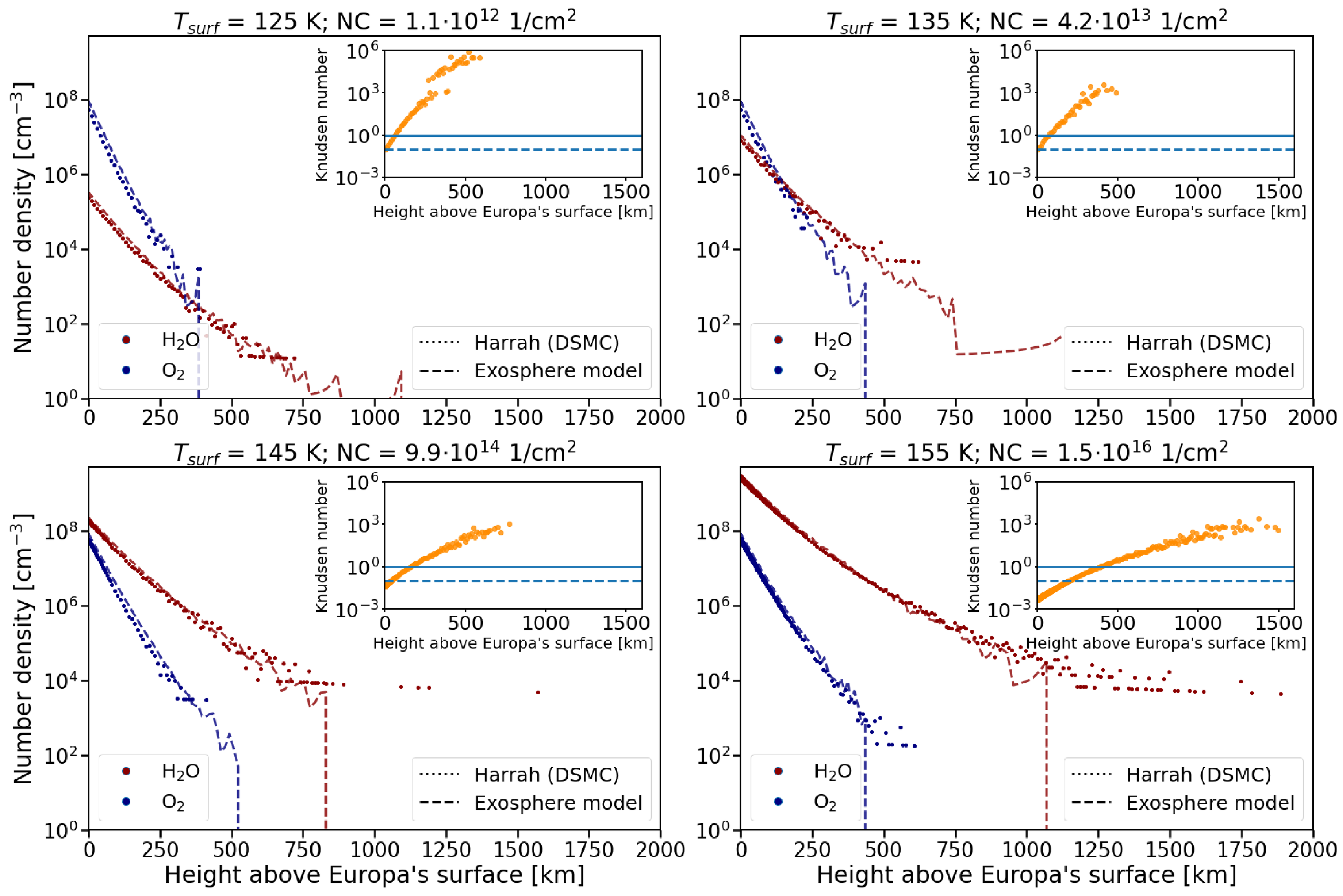
In the **DSMC** method [1] particular gas flows are calculated through the collision mechanics of representative atoms or molecules that are subject to binary collisions to simulate macroscopic gas dynamics. In this study, the DSMC model **Harrah** [2] is used to simulate Europa's atmosphere and compared to the collisionless **exosphere model** of the University of Bern [3].

The **radial column density** (NC) is a measure of the number of particles in a line-of-sight. For NC < 10^{15} 1/cm² atmospheres are expected to effectively be collisionless and the exosphere model is applicable. The **Knudsen number** K_n is the ratio of the mean free path λ to the characteristic length L:

$$K_n = \frac{\lambda}{L} \quad \begin{cases} K_n < 0.1 & \text{effectively collisionless} \\ 0.1 < K_n < 1 & \text{quasi-collisional} \\ 1 < K_n & \text{collisional} \end{cases} \qquad (1)$$

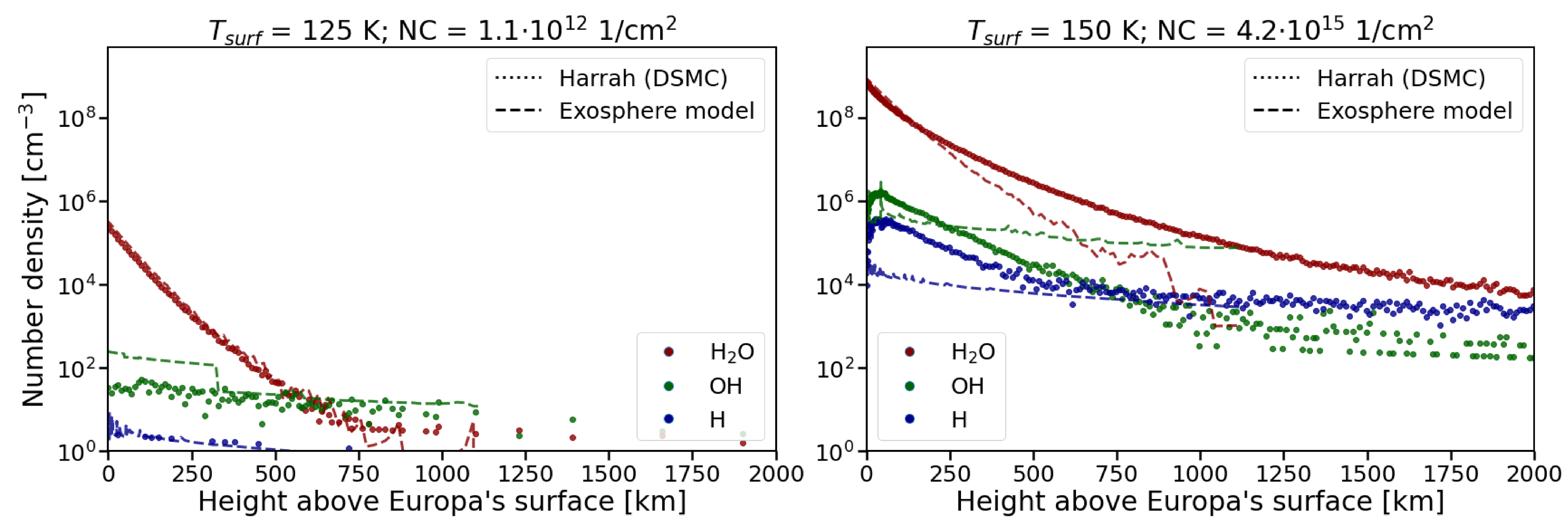
Results

Europa's **sublimated H_2O** & **sputtered O_2** atmosphere is simulated for different surface temperatures T_{surf} with the DSMC and the exosphere model, showing similar number densities.



Photochemistry, such as the photo-dissociation of water to hydroxyl (OH) and atomic hydrogen (H) can influence the composition of the atmosphere, as shown here for surface temperatures T_{surf} of 125 K and 150 K:

$$H_2O \xrightarrow{h\nu} H + OH$$



Conclusion

Europa's tenuous atmosphere is effectively **collisionless**. However, collisions with faster moving photochemical products (e.g., H) can inflate the number density of H_2O at higher altitudes. While the number density of sublimated H_2O is strongly temperature dependent, this is less the case for sputtered O_2. Next step is to model **plumes** with the DSMC model, that transition from being collisional near the surface to ballistic to the near-vacuum of space.

References

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