The VATMOS-SR Mission Concept: DSMC Studies of the Gas Sampling

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VATMOS-SR (Venus ATMOSpheric - Sample Return) is a small spacecraft mission concept that would return a gas sample from the upper atmosphere of Venus to Earth for scientific analysis. This could be the first sample return mission for an extra-terrestrial atmosphere and potentially the first sample return from an Earth-sized planet. The VATMOS-SR mission concept consists of a SmallSat atmospheric sampling probe (45 deg. sphere/cone geometry, <1 m diameter) that is designed to skim through the Venus upper atmosphere and acquire gas samples below the homopause altitude (around ~110 km altitude), where the different atmospheric gases are mixed. The velocity of the spacecraft where sampling would occur is expected to be between ~10.5 km/s and ~13.1 km/s, depending on the trajectory chosen. **This presentation will discuss hypervelocity sampling in the upper atmosphere of Venus with respect to the VATMOS-SR mission concept.**

VATMOS-SR would enable critical atmospheric measurements to form a complete picture of how, why, and when Venus evolved to be so different from Earth and Mars. The abundances and isotopic compositions of volatile elements (such as N, C, S, O, and the noble gases) in planetary atmospheres record volatile delivery during accretion, outgassing from planetary interiors, and atmospheric loss to space. Precise and accurate determinations of volatile atmospheric signatures are the key to understanding the origins and geodynamical evolution of Venus compared to the other terrestrial planets.

Hypersonic sampling poses unique technical and scientific challenges. To ensure it is possible to relate the composition of the sampled gases to the free stream atmospheric composition, large-scale numerical simulations are employed to model the flow through the VATMOS-SR sampling system. In particular, an emphasis is placed on quantifying noble gas isotopic fractionation that occurs during the sample acquisition and transfer process to determine how measured isotopic ratios of noble gases in the sample compared to actual isotopic ratios in the Venusian atmosphere.

The Direct Simulation Monte Carlo (DSMC) [2] code SPARTA, an open-source software package developed by Sandia National Laboratories, is used in this work. SPARTA, based on Bird's DSMC method [3], is a molecular-level gas-kinetic technique. As SPARTA is able to model hypervelocity reacting flows in strong chemical and thermal non-equilibrium, this software package is well suited to determine relevant flow properties for the VATMOS-SR mission concept and to numerically quantify the expected level of elemental and/or isotopic fractionation in the sample acquired by VATMOS-SR. This presentation will show results from 3D simulations correlating the noble gas isotopic fractionation in the gas acquired at hypervelocity speeds to its ambient atmosphere value. In particular, emphasis will be placed on Xenon isotopes of masses 128 and 130, as precise measurements of that ratio would yield comparison to Earth's atmosphere. Additionally, sensitivity studies that quantify the uncertainties due to the freestream parameters, as well as the modeling parameters, will be performed.

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