FEASIBILITY OF HYPERVELOCITY SAMPLING OF NOBLE GASES IN THE UPPER ATMOSPHERE OF VENUS. J. Rabinovitch[1], C. Sotin[1], A. Borner[2], M. A. Gallis[3], G. Avice[4], M. Darrach[1], S. Madzunkov[1], B. Marty[5], J. Baker[1], and N. N. Mansour[6], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States (jason.rabinovitch@jpl.nasa.gov), [2]STC at NASA Ames Research Center, Moffett Field, CA, United States, [3]SANDIA National Laboratories, Albuquerque, NM, United States, [4]IPGP Institut de Physique du Globe de Paris, Paris, France, [5]CRPG Centre de Recherches Pétrographiques et Géochimiques, Vandoeuvre-Les-Nancy, France, [6]NASA Ames Research Center, Moffett Field, CA, United States.

Introduction: Cupid's Arrow is a small satellite mission concept that would determine the amount of noble gases and associated isotope ratios in the Venus atmosphere. Noble gases act as tracers of the evolutionary process of planets, as their concentration ratios are correlated to processes such as the original supply of volatiles from the solar nebula, delivery of volatiles by asteroids and comets, escape rate of planetary atmospheres, and degassing of the interior and its timing in a planet's history. Performing high-fidelity noble gas measurements in the Venus atmosphere would provide the required information to understand why Earth and Venus have diverged in their geological evolution; a critical piece of information required to assess whether a terrestrial exoplanet is Earth-like or Venus-like.

Mission Concept: The Cupid's Arrow mission concept is a small spacecraft skimmer that would sample the Venus atmosphere below the homopause where the different atmospheric compounds are well mixed [1]. Four samples of Venus atmosphere would be acquired at periapsis, and then noble gas concentrations for each sample would be determined with a miniaturized Quadrupole Ion Trap Mass Spectrometer (QITMS) [2,3]. Velocity at periapsis, where sampling is to occur, is expected to be ~10.5 km/s, and the altitude is expected to be ~110 km. One potential issue with this mission architecture relates to whether or not a sample that is collected by the spacecraft is representative (compositionally) of Venus' atmosphere. Due to the high velocity of the spacecraft and associated high enthalpy of the flow, complicated thermodynamic and fluid mechanical processes occur around the spacecraft and associated sampling system. Therefore, it should be demonstrated that elemental and/or isotopic fractionation processes do not significantly alter the relative concentrations of the gas to be measured by QITMS. In order to address this topic, both experimental and modeling work is being performed, though this work will focus on numerical modeling progress.

Numerical Simulations: The Direct Simulation Monte Carlo (DSMC) code SPARTA, an open source software package developed by SANDIA National Laboratories [4], is used in this work. SPARTA, based on Bird's DSMC method [5], 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 Cupid's Arrow mission concept, and to numerically investigate the possibility of elemental and/or isotopic fractionation in the sampled gases.

Preliminary Results: Preliminary simulations have been run for simplified spacecraft and sampling system geometries in both 2D axisymmetric and full 3D configurations. Preliminary results show that while there is no significant isotopic fraction for Xe or Ar isotopes, the total ratio of Ar to Xe does change throughout the domain. Additional simulations are being performed in order to investigate the sensitivity of the numerical results to a wide range of parameters that include, but are not limited to: 1) thermo/chemical models, 2) surface models, 3) sampling geometry (valves, orifices, tanks, etc.), 4) initial gas compositions, 5) vehicle velocity and attitude, 6) 2D vs 3D simulation frameworks, and 7) freestream flow properties. Numerical simulation results will help inform the overall spacecraft and sampling system design.

Conclusion: Through a combination of numerical and experimental work, it is believed that a better understanding of the physical processes occurring during hypervelocity sampling in the upper atmosphere of Venus will be acquired. This knowledge will allow an optimized Cupid's Arrow spacecraft to be designed, and also demonstrate whether or not elemental and/or isotopic fractionation is expected to contaminate scientific measurements performed by QITMS on gas samples acquired in the upper atmosphere of Venus.

References: [1] Sotin et al., *LPSC*, 2018, 1763, [2] Avice et al., *JAAS*, submitted 2018, [3] Madzunkov et al., *JASMS*, 2014, [4] Plimpton and Gallis, http://sparta.sandia.gov, [5] Bird, 1994.

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