

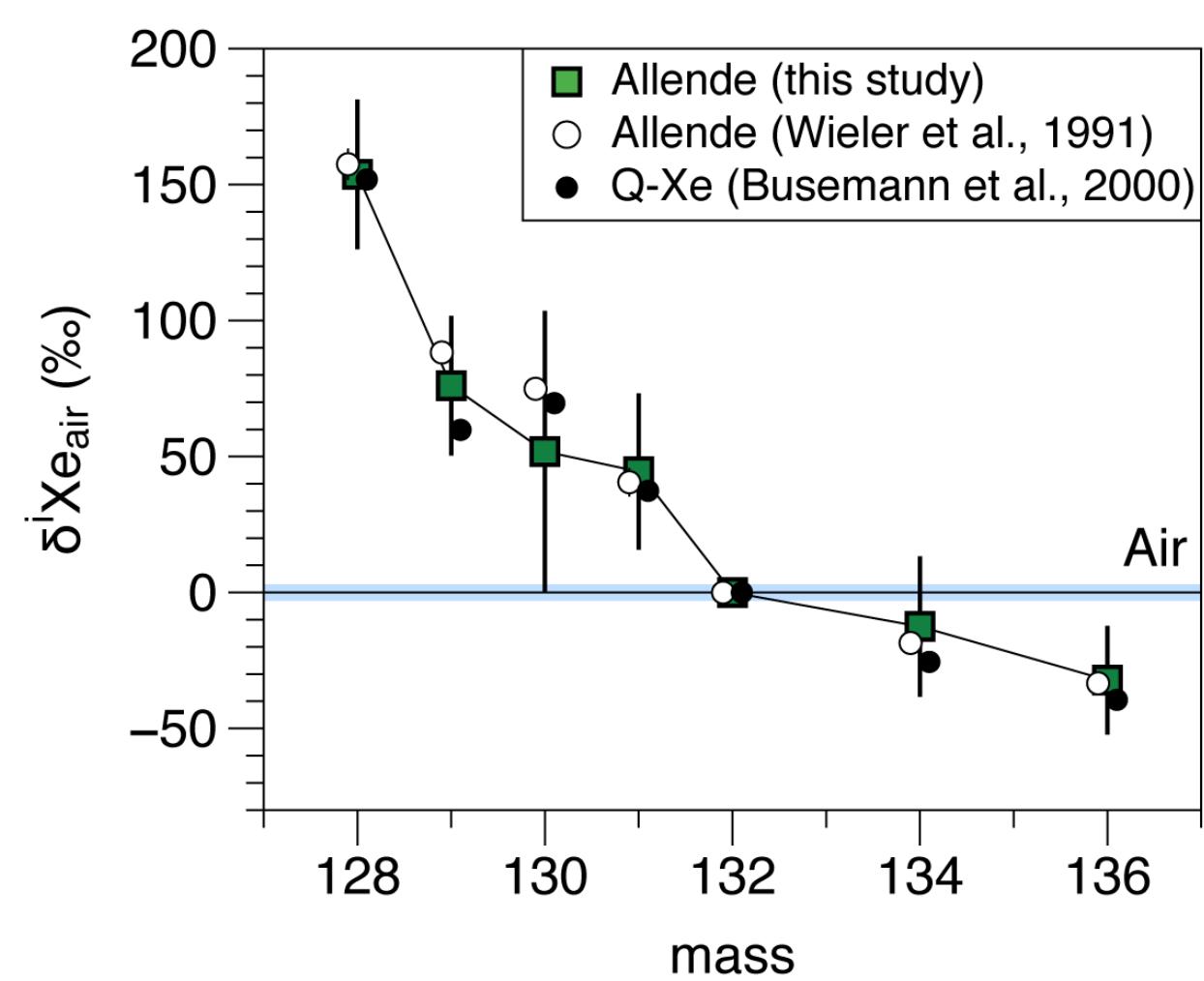
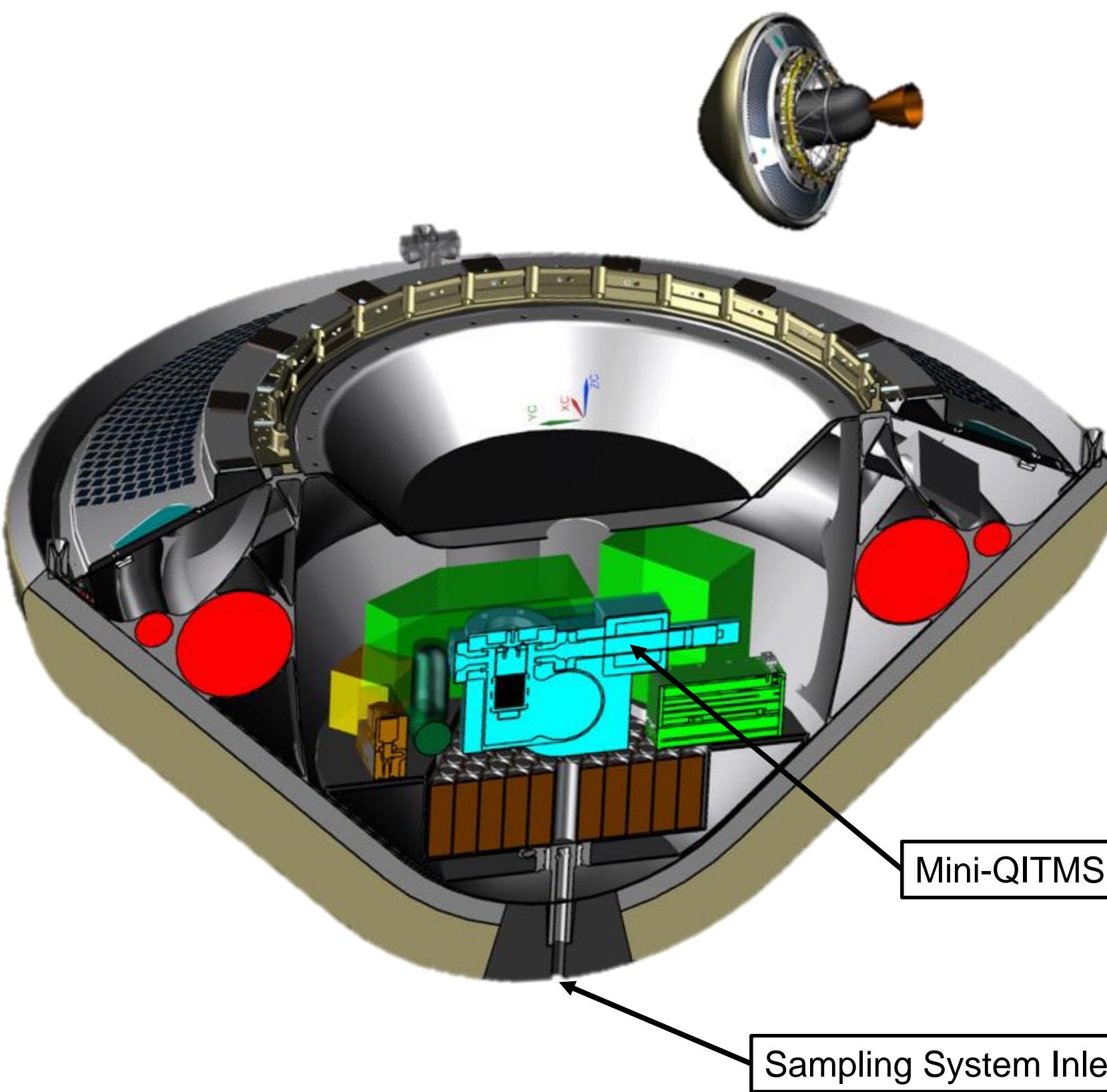


Feasibility Of Hypervelocity Sampling Of Noble Gases In The Upper Atmosphere Of Venus

J. Rabinovitch¹, C. Sotin¹, A. Borner², M. A. Gallis³, G. Avice⁴, M. Darrach¹, S. Madzunkov¹, B. Marty⁵, J. Baker¹, and N. N. Mansour⁶, ¹Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States (jason.rabinovitch@jpl.nasa.gov), ²STC at NASA Ames Research Center, Moffett Field, CA, United States, ³SANDIA National Laboratories, Albuquerque, NM, United States, ⁴IPGP Institut de Physique du Globe de Paris, Paris, France, ⁵CRPG Centre de Recherches Pétrographiques et Géochimiques, Vandoeuvre-Les-Nancy, France, ⁶NASA Ames Research Center, Moffett Field, CA, United States

Cupid's Arrow Mission Concept Overview

- Small satellite (< 1 m diameter) 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
 - Measuring noble gas concentrations would provide required information to understand why Earth and Venus have diverged in their geological evolution
- Atmospheric skimmer designed to sample the Venus atmosphere below the homopause
- Gas samples acquired at ~110 km while traveling at ~10.5 km/s
- QITMS [1,2] measures noble gas concentrations



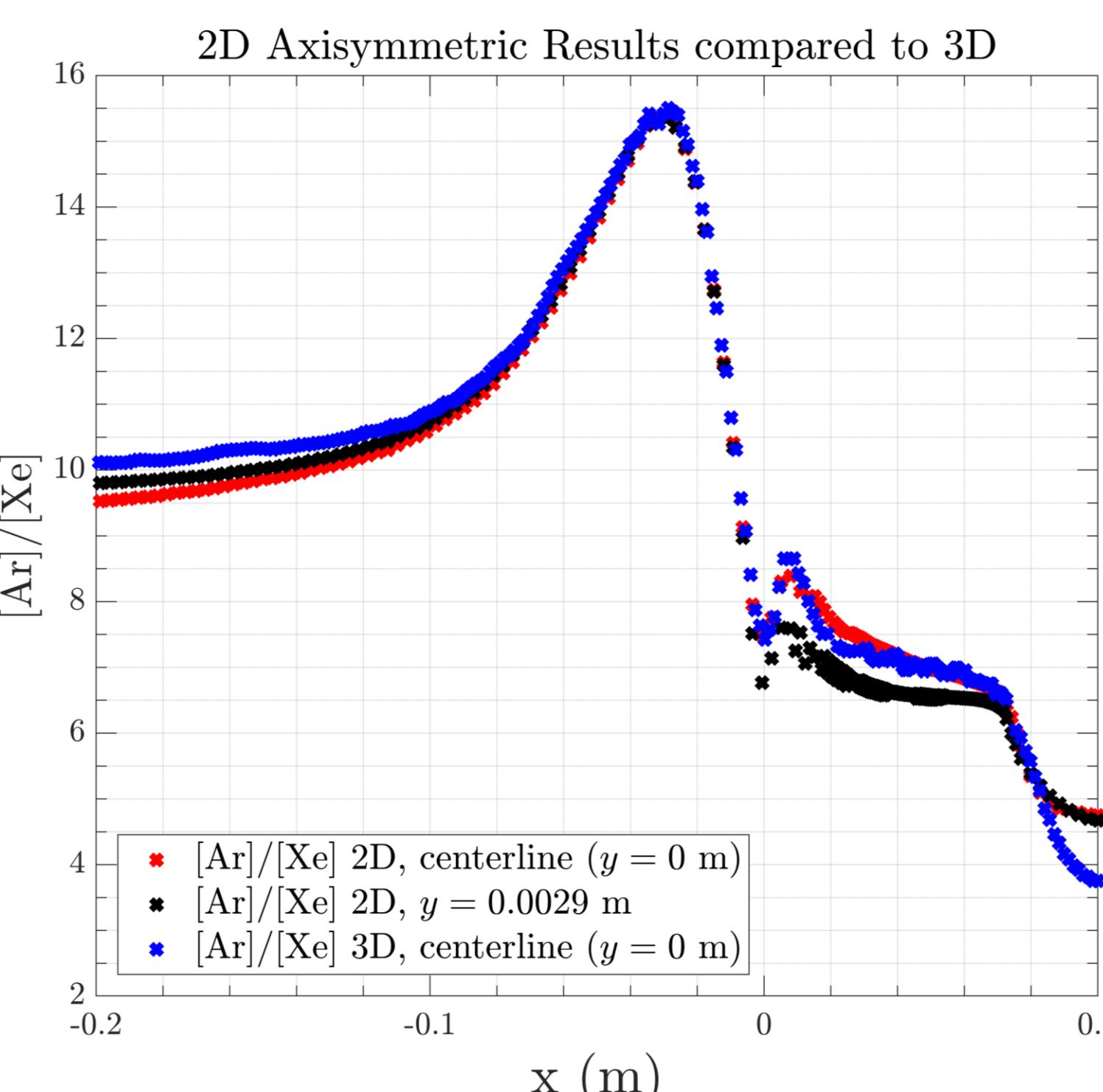
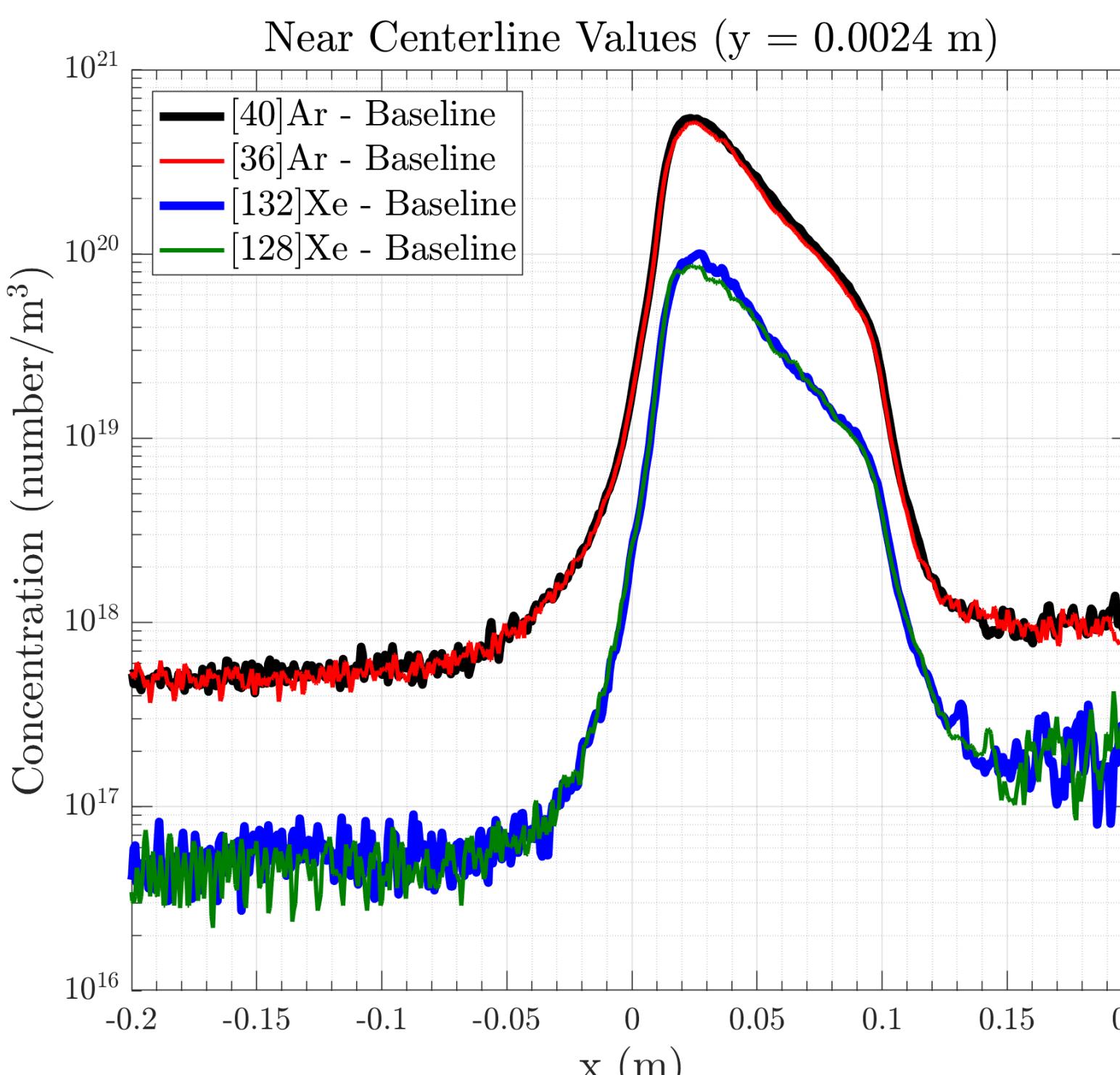
JPL developed miniaturized Quadrupole Ion Trap Mass Spectrometer (QITMS) will be used to measure noble gas concentrations in the Venus atmosphere. QITMS capabilities demonstrated in [1].

Hypervelocity Sampling Challenges

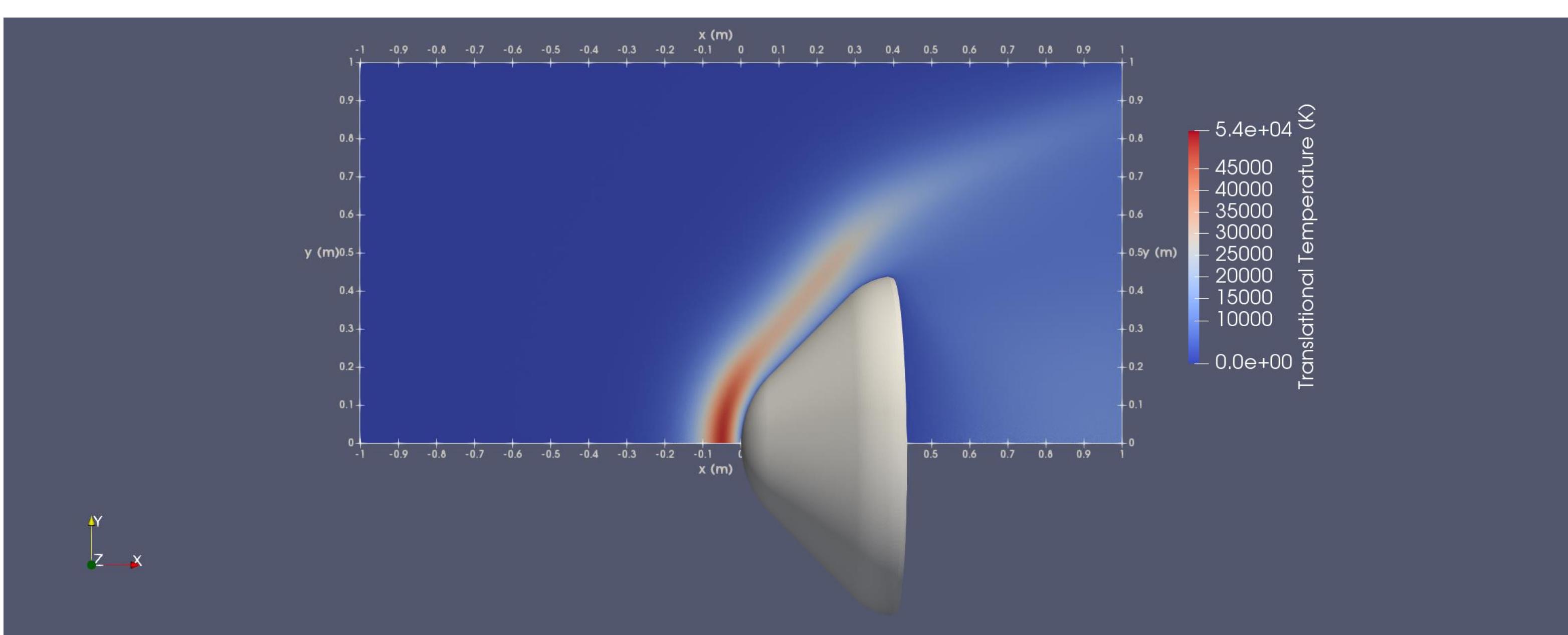
- Driving question: what would the differences in noble gas concentrations be between the Venus atmosphere and the gas sampled in the Cupid's Arrow Mission Concept?
 - Does elemental and/or isotopic fractionation occur?
- Rarefied flow in thermal and chemical non-equilibrium motivates the use of the Direct Simulation Monte Carlo (DSMC) code SPARTA [3]
 - Based on Bird's DSMC method [4], SPARTA is a molecular-level gas kinetic technique
 - Noble gases are *trace* species in the Venus atmosphere – preliminary simulations include 2% Ar and 0.2% Xe by volume
- Entire sampling system should be modeled in order to account for real geometries (including bends, orifices, valves, etc.)
- Validation of computational models
 - Ongoing effort including code-to-code verification and design of validation experiments to take place in the Arcjet facilities at ARC
- Large parameter space will be investigated numerically which will influence the sampling system design
- Future goal to demonstrate a Cupid's Arrow-like sampling system experimentally with Arcjet experiments



Figures show SPARTA simulation results: free stream velocity of 10.5 km/s, with thermal and chemical non-equilibrium. Left: simplified geometry with sampling tank closed.



Upper figures show preliminary computational results looking at possible isotopic fractionation (left) and possible elemental fractionation (right). Preliminary simulations have been completed with 2D-axisymmetric and 3D numerical domains. Bottom figure shows preliminary translational temperature results for a 2D-axisymmetric simulation.



References

- [1] Avice et al., JAAS, 2018
- [2] Madzunkov et al., JASMS, 2014
- [3] Plimpton and Gallis, <http://sparta.sandia.gov>
- [4] Bird, 1994