Composition Measurements of Uranus' Atmosphere. P. Wurz[1], A. Vorburger[1], O. Mousis[2], and R. Helled[3], [1]Physics Institute, University of Bern, Switzerland (peter.wurz@unibe.ch, audrey.vorburger@space.unibe.ch), [2]Laboratoire d'Astrophysique de Marseille, Aix Marseille Université, Marseille, France (olivier.mousis@lam.fr), [3]Institute for Computational Science, University of Zürich, Switzerland (rhelled@physik.uzh.ch).

Introduction: Knowing the composition of the giant planets is important in understanding their formation and evolution history. The abundances of heavy elements, of noble gases, and isotope ratios reveals the physical and chemical conditions and processes that led to formation of the planetesimals that eventually fed the forming planets [e.g. 1, 2]. The current knowledge of the composition of the giant planets is limited, with Jupiter being best studied thanks to the Galileo probe. Much less is known for Saturn, and almost nothing is known for Uranus and Neptune [3]. Uranus and Neptune contain substantial hydrogen and helium atmospheres, their bulk H_2 and He mass fractions are 5–20%. Their bulk compositions are consistent with the presence of a significant fraction of "ices" and rocks in their interiors, such as H_2O, CH_4, H_2S, and NH_3. Uranus and Neptune are the least-investigated planets in the solar system, but may be representative of similarly sized planets common in the population of exo-planets [4, 5], thus provide some ground-truth.

Abundances of heavy elements and compounds in the atmosphere can be derived through a variety of remote sensing techniques, which is restricted to the upper layers of the atmosphere. Unfortunately, the number of useful observations from Earth is limited as shown by the modest knowledge on the composition of the ice giants. The most significant step forward in our knowledge of giant planet internal composition was achieved with the Galileo probe into Jupiter's atmosphere.

Atmospheric Probe Composition Measurements: The prime instrument to probe the composition of the atmosphere is a mass spectrometer experiment (MSE) [3, 6]. The MSE comprises the actual mass spectrometer for gas analysis, with possible extensions by a gas-chromatographic pre-selection of the gaseous species, a cryogenic trap to strongly enhance the measurement of noble gases and their isotopes, and an aerosol collector and pyrolysis system giving access to the composition of cloud and haze particles. To improve on the isotope measurements of selected species, a Tunable Laser Spectrometer [8] can be added to MSE to measure the isotopic ratios with accuracy of selected molecules, e.g. H_2O, NH_3, CH_4, CO_2, depending on the laser system. Given the great importance to the H/He ratio, an additional measurement of this ratio by a dedicated instrument may be considered, using an optical Helium Abundance Detector, as was done on the Galileo probe [7].

Atmospheric Orbital Measurements: An Uranus orbiter [9], will provide complementary information of the atmosphere via remote sensing. The atmospheric measurements would be mapping the "surface" of Uranus, tracking storms, clouds, and eddies in reflected sunlight, maps of key species, abundances of hydrocarbons in the photolysis layer, and some more. This will put the entry location of the probe in a global perspective, is its entrance at a unique surface feature, is there presence of clouds and hazes, and the temporal evolution during the orbital observations, like convection, upward and downward energy flow, atmospheric wave activity, which shape atmospheric features such as cloud bands and vortices. In addition, microwave sounding might probe deep inside the atmosphere.

Where to enter Uranus' atmosphere: The atmospheric probe will have to enter on a specific location into Uranus' atmosphere. There will be constraints entry location arising from the trajectory of the main spacecraft, the orbiter, delivering the probe, constraints from communication between the descending probe and the main spacecraft, timing, and others. If there is freedom left to choose the entry location based on scientific considerations, what would these be? Entering at lower latitudes, perhaps even near the equator where the zonal flow is retrograde or at higher latitudes with fast prograde zonal flows [10], or even at a pole with very limited horizontal flow, which might be easily accessible because of Uranus' rotation axis being close to the ecliptic plane; at places with clouds running at constant latitudes or at cloud-free areas; at a dark spot (an anticyclonic storm) possibly providing upwelling from material from further inside; or other unique features observed on the surface.

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