Mass Spectrometer System for Giant Planet Atmospheric Probes. A. Vorburger[1] and P. Wurz[1], [1]Space Research and Planetary Sciences, Physics Institute, University of Bern, Bern, Switzerland (audrey.vorburger@unibe.ch).

Introduction: The giant planets are key witnesses to the formation of our Solar System. Having formed from the same material that constitutes the proto-Sun and the surrounding proto-planetary disk, their chemical composition offers valuable information into the formation and evolution history of our Solar System (e.g., [1] and references therein). Determining the bulk chemical composition of giant planets is difficult, though.

Since no direct access to their bulk compositions is available, these have to be determined from the planet's mean density, gravity fields, abundance of atmospheric constituents, and modeling efforts. Remote sensing allows determination of the atmospheric constituents. However, the efficiency of this technique has limitations when used to study the bulk atmospheric composition that is crucial to the understanding of planetary origin, namely due to degeneracies between the effects of temperatures, clouds, and abundances on the emergent spectra, but also due to the limited vertical resolution. An alternative is provided by mass spectrometric measurement, where the atmospheric gas is sampled and analyzed in situ during the descent of an atmospheric probe.

Mass Spectrometer: In this presentation we present a time-of-flight (TOF) mass spectrometer system that is well-suited to the task of measuring atmospheric composition on an atmospheric probe up to atmospheric pressures of >20 bar. The TOF mass spectrometer system offers extremely high sensitivity because each mass spectrum contains the full mass spectral information (non-scanning instrument) at high mass resolution ($M/\Delta M \sim 1000$), with a high dynamic range, and with high cadence of collecting mas spectra to optimize vertical resolution during the descent. This allows for the measurement of major volatiles such as H_2, CH_4, CO_2, CO, NH_3, N_2, H_2S, hydrocarbons, AsH_3, GeH_4, and others. Because of the high sensitivity and mass resolution also isotopic ratios such as D/H, $^{3}He/^{4}He$, $^{13}C/^{12}C$, $^{15}N/^{14}N$, and others can be measured. Also the noble gases such as He, Ne, Ar, Kr, and Xe will be measured, either via direct atmosphere sampling or with the help of a cryotrap. The cryotrap selectively collects noble gases, which allows even for the accurate measurement of their isotopes $^{20}Ne/^{22}Ne$, $^{38}Ar/^{36}Ar$, $^{36}Ar/^{40}Ar$, as well as those of Kr and Xe. These mentioned species hold key information on the formation and evolution process of our Solar System (e.g., [1-4]).

Implementation on an Atmospheric Probe: Measuring a giant planet's atmospheric composition gives valuable insight into the gas and dust reservoir available and the processes at work when our Solar System formed. We propose a measurement system that measures both the gas and the condensed phase of the atmosphere using two inlets. This allows determination of both the gas composition and the composition of clouds, giving us a picture of the full chemical reservoir present, irrespective of matter state.

The mass spectrometer will be calibrated shortly before atmosphere entry using three reference gases. In addition, the system contains a gas separation and enrichment system that contains two cryotraps ([5]). The cryotraps will collect and purify noble gases to be analyzed in a later stage during the descent.

Also part of the proposed system is a tunable laser spectrometer that can sample the gas directly to investigate selected isotopic ratios, e.g., D/H, $^{13}C/^{12}C$, $^{18}O/^{16}O$, and $^{17}O/^{16}O$, depending on the selected laser system. If feasible, a Helium Abundance Detector will be added, to provide redundancy to the H_2/He measurement.

Besides the technical details of the proposed mass spectrometer system, we will also present a proposed sample operation sequence that consists of 6 phases, depending on the atmospheric pressure range the descent probe finds itself in. In the highest resolution phase measurements will be taken at a high cadence (~10 sec), allowing the recording of a full mass spectrum every ~ 120 m.

The proposed sampling procedure was worked out for Saturn, but is also applicable to other giant planets. In light of the recently published Decadal Survey, in which the committee prioritizes the Uranus Orbiter and Probe, we will also discuss applicability of the mass spectrometer system for an atmospheric probe to Uranus.

References: [1] Mousis, O. et al. (2014) PSS, 104, 29-47 [2] Atreya, S. K. et al. (2018) The Origin and Evolution of Saturn, with Exoplanet Perspective, 5-43 [3] Atreya, S. K. (2020) SSR, 216, 18 [4] Cavalié, T. et al. (2020), SSR, 216, 58 [5] Brockwell, T. G. (2016) IEEE Aerospace Conference, 1-17.