**Science Across Disciplines**

**Chemistry of the Solar System**: Uranus is an ice giant located in the outer region of our Solar System. By analyzing its atmospheric composition, we can gain insights into the primordial conditions and processes leading to the formation of Uranus, the giant planets, and the Solar System as a whole. Uranus’ chemical composition provides clues about the distribution and abundance of various atoms and molecules during the early stages of the Solar System’s evolution.

**Atmospheric Dynamics**: Uranus has a unique atmosphere compared to gas giants like Jupiter and Saturn. It consists mainly of hydrogen and helium, but also contains significant amounts of methane, which gives the planet its characteristic blue-green color. Studying the composition can help us understand the complex atmospheric dynamics, including the formation and behavior of cloud layers, atmospheric circulation patterns, and the occurrence of storms and atmospheric disturbances.

**Atmospheric Probes**: Studying the chemical composition of Uranus’ atmosphere can provide valuable insights into the planet’s interior by helping us constrain internal structure models of Uranus. Specifically, studying Uranus’ atmospheric chemical composition can provide information on core composition, volatile abundances, heat distribution, and convection processes, and core-atmosphere interaction.

**Mass Spectrometer Experiment**

- **To learn more about the science themes listed to the left**, a mass spectrometer on board an Uranus probe needs to determine (i) the fractional abundance of He relative to H, (ii) the atmospheric abundance and isotope ratios of C, H, O, N, and noble gases, (iii) the vertical abundance profiles of CH$_4$, CO, PH$_3$, H$_2$S, NH$_3$, and other species, and (iv) the abundances of condensable species below the cloud bases.

- **To reach the science goals set, several challenges must be addressed.** The mass spectrometer experiment must provide (i) high sensitivity to quantify species with very low abundances, (ii) high mass resolution to determine the abundances of isotopes, and (iii) short acquisition times to allow rapid sampling and analysis.

- **To address these challenges we propose the following mass spectrometer experiment:**
  - A tunable laser spectrometer for fast gas analysis,
  - a reference gas system to assist instrument characterization,
  - an electrical conductivity system for noble gases,
  - an ultra stable oscillator to help quantify certain isotopes.

**References**