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# *In situ* Probe Science at Saturn

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## Abstract

## 1. Introduction

A fundamental goal of solar system exploration is to understand the origin of the solar system, the initial stages, conditions, and processes by which the solar system formed, how the formation process was initiated, and the nature of the interstellar seed material from which the solar system was born. Key to understanding solar system formation and subsequent dynamical and chemical evolution is the origin and evolution of the giant planets and their atmospheres.

Several theories have been put forward to explain the process of solar system formation, and the origin and evolution of the giant planets and their atmospheres. Each theory offers quantifiable predictions of the abundances of noble gases He, Ne, Ar, Kr, and Xe, and abundances of key isotopic ratios $^{4}He/^{3}He$, D/H, $^{15}N/^{14}N$, $^{18}O/^{16}O$, and $^{13}C/^{12}C$. Detection of certain disequilibrium species, diagnostic of deeper internal processes and dynamics of the atmosphere, would also help discriminate between competing theories.

Measurements of the critical abundance profiles of these key constituents into the deeper well-mixed atmosphere must be complemented by measurements of the profiles of atmospheric structure and dynamics at high vertical resolution and also require *in situ* exploration.

The atmospheres of the giant planets can also serve as laboratories to better understand the atmospheric chemistries, dynamics, processes, and climates on all planets including Earth, and offer a context and provide a ground truth for exoplanets and exoplanetary systems. Additionally, Giant planets have long been thought to play a critical role in the development of potentially habitable planetary systems.

In the context of giant planet science provided by the Galileo, Juno, and Cassini missions to Jupiter and Saturn, a small, relatively shallow Saturn probe capable of measuring abundances and isotopic ratios of key atmospheric constituents, and atmospheric structure including pressures, temperatures, dynamics, and cloud locations and properties not accessible by remote sensing can serve to test competing theories of solar system and giant planet origin, chemical, and dynamical evolution.

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