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The Role of High Resolution Mass Spectrometry in the Future Exploration of Titan

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Abstract

Cassini and Huygens mass spectrometers have given scientists a high-level inventory of the composition of Titan's atmosphere and hints of what might lie on and beneath the surface. Any follow-on mission must address and definitively answer a wide range of questions that have been raised concerning the origin and evolution of Titan and its atmosphere. This can only be accomplished if the next (and possibly final) mission carries sophisticated mass spectrometers capable of accurately recording the chemistry and cosmochemistry of this complex organic world.

1. Introduction

Measurements of the composition of volatile materials in the atmosphere and on the surface of Titan are critical to understanding its origin and evolution. Recent results from the Cassini and Huygens missions have revealed a cryogenic world that nonetheless has an unexpectedly rich inventory of hydrocarbon and nitrile compounds derived from simple precursors consisting largely of nitrogen and methane. Although Cassini and Huygens have accomplished a great deal, they have raised many more questions than can be answered with existing data. Thus although the primary chemical constituents of the atmosphere are now known, important clues to the origin and evolution of Titan are locked in key isotopic ratios. In particular accurate measurements are needed of D/H and $^{18}O/^{17}O/^{16}O$ in water, $^{36}Ar/^{84}Kr$, and $^{18}O/^{17}O/^{16}O$ and $^{13}C/^{12}C$ in CO and CO_2. Moreover the inventory and makeup of heavy organic compounds, which are of interest as biological precursors, as well as the presence or absence of the heavy noble gas Xe, are of great interest.

2. Next generation instruments

The Cassini and Huygens mass spectrometers represent the best of an earlier generation. However over the past decade new technologies have been developed that make possible miniaturized high-performance mass spectrometers capable of giving definitive answers to questions posed by Cassini/Huygens. In this paper we describe two different approaches to small high-performance mass spectrometers for future Titan missions. The first is a multi-bounce time-of-flight instrument capable of resolutions >20,000 (Figure 1) while the second is a compact magnetic spectrometer employing trochoidal-focusing optics. Both can be used in conjunction with gas chromatography, which is essential for sample separation prior to analysis of complex heavy organics. Prototypes of both instruments have been built and are reported on here.

3. Time-of-flight spectrometer

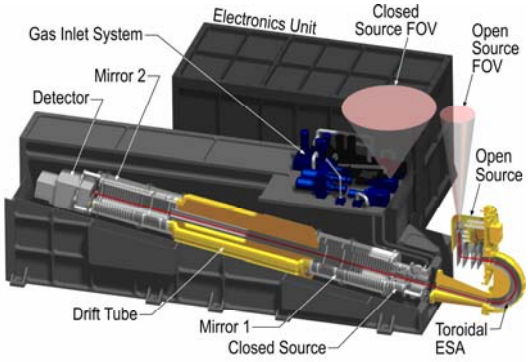

Figure 1: Multi-bounce Time-of-Flight mass spectrometer configured for an orbital mission.

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3. Summary and Conclusions

We have designed, built and tested prototypes of two small high-performance mass spectrometers suitable for future Titan missions.