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Laser Desorption Mass Spectrometry (LDMS) with an Orbitrap analyzer for in situ planetary science

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Laser desorption mass spectrometry (LDMS) techniques have been applied to the chemical analysis of solid organic and inorganic materials in the laboratory for more than 50 years [1]; however, such methods have yet to be exploited for in situ planetary exploration. Two standoff LDMS instruments were launched onboard the Phobos 2 [2] and Phobos-Grunt missions [3], but neither reached the final destination. Multiple upcoming missions have also baselined LDMS instrumentation in their scientific payloads, including the ExoMars Rosalind Franklin rover [4] and Dragonfly mission targeting Titan [5], but none have yet flown.

Recently, a next-generation LDMS instrument centered around an Orbitrap™ mass analyzer was developed for planetary science objectives [6]. The ultrahigh mass resolving power and ppm-level mass accuracy of the Orbitrap analyzer, coupled with a high-power UV laser source, enables discovery-based detection of nonvolatile organic compounds and characterization of the host matrix. Modulation of the laser output energy provides access to molecular ions as well as diagnostic fragments of complex organics; molecular stoichiometry is derived via exact mass determination. Signal decay rates can be used to corroborate molecular identity and potentially discriminate structural isomers.

An engineering model of an Orbitrap-based LDMS instrument has been qualified for spaceflight via dry heat microbial reduction and random vibration testing with the ultimate goal of detecting biosignatures in ocean world environments, such as those found on Enceladus and Europa [7]. A permutation of the instrument has been adapted to characterize the fundamental chemistry and organic inventory of lunar regolith. Here, we present on the latest demonstrations from these instrument platforms, and outline the deployment strategy for a lunar mission to the Compton Belkovich Volcanic Complex on the farside of the Moon.

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