# A COMPACT TWO-STEP LASER TIME-OF-FLIGHT MASS SPECTROMETER FOR IN SITU ANALYSIS OF PLANETARY SURFACES



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# SOLAR SYSTEM DESTINATIONS... THAT ARE JUST BEGGING TO BE ANALYZED!

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# Enceladus & Titan





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# CERES

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# WHAT DO THESE BODIES HAVE IN COMMON? VOLATILES, INCLUDING WATER!



# WHY MASS SPECTROMETRY FOR PLANETARY MISSIONS?

• 'Universal' Detector

• Comprehensive Sample Analysis: compatible with various front-end analytical techniques

• Flexible to mission architecture: flybys, orbiters, landers, rovers

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# LASER DESORPTION/IONIZATION FOR DIRECT ANALYSIS OF PLANETARY SURFACE MATERIALS



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Commercial LD-TOF-MS (or MALDI) is a gold-standard technique for the analysis over a wide range of molecular weight, including large biomolecules





#### LD-TOF-MS as a compact instrument is capable of analyzing broadband composition directly from a solid sample

- Minerals
- Small organics: amino acids, carboxylic acids, polycyclic aromatics, etc.
- Intermediate organics: molecular fossil precursors, conjugated polymers, etc.
- Large organics: peptides, biopolymers, informational polymers, etc.
- Can resolve isotopes elemental & <sup>12</sup>C/<sup>13</sup>C patterns



### DUAL POLARITY ION MODE: INORGANIC COMPOSITION SEDIMENTARY AND AQUEOUSLY ALTERED MINERALS



### COMPLEMENTARY POSITIVE AND NEGATIVE ION DETECTION: DETECTING ORGANICS ACROSS CLASSES



### BUT IN REALITY WE COULD GET A SPECTRUM LIKE...



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#### L2MS PROTOTYPE:

### FEATURES AND OPERATING PRINCIPLES

Ionization

Pulse

# Two-Step Laser MS







**Precision Ion Gating** 

# **Fragment Analysis**

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#### 2-10 mJ/pulse(0.2-1 mJ/mm<sup>2</sup>)



Resonance Enhanced Multiphoton Ionization Selective ionization:

- A. molecules ionization energy is lower than the two-photon energy
- B. intermediate state can be pumped by onephoton absorption

Absorption of IR photons (0.12 eV): Molecules may be at a higher state

Annu. Rev. Phys. Chem. 2007. 58:585–612

10/19/2015



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### MOTIVATION FOR L2MS: MOLECULAR SPECIFICITY

- L2MS has been an informative technique used in the analysis of extraterrestrial materials, such as meteorites and Stardust samples
- The ionization laser can be chosen to be selective to a subset of organic species, such as polycyclic aromatic hydrocarbons
- Comparison between the single-laser baseline and L2MS spectra can allow separation of aromatic contributions





### L2MS PROTOTYPE: LABORATORY EXPERIMENT

IR Laser:

- 1064 nm Nd:YAG
- 2.7 to 3.1 um tunable OPO
- 10 um CO2

UV Laser:

266 nm harmonic Nd:YAG 4-7 ns pulse width focused to 50-100 um spot



### L2MS prototype: SELECTIVITY TO AROMATICS



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# L2MS prototype: SELECTIVITY TO AROMATICS



Getty et al. IEEE AeroConf 2014

# L2MS – SELECTIVITY IN IONIZATION STEP



# L2MS – SELECTIVITY IN DESORPTION STEP





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Transmittance

# FEATURES AND OPERATING PRINCIPLES

Two-Step Laser MS Pulse

L2MS PROTOTYPE:







# **Precision Ion Gating**

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### L2MS PROTOTYPE: PRECISION ION GATING AND TANDEM MS

Structural determination using MS/MS techniques



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MCP Signal (V)

# L2MS PROTOTYPE: FEATURES AND OPERATING PRINCIPLES Ionization Pulse



**Precision Ion Gating** 



# Fragment Analysis

Neutral Plume

lons

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Laser Pulse

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### L2MS PROTOTYPE: LASER-ASSISTED COLLISION-INDUCED DISSOCIATION FOR PSEUDO-TANDEM MASS SPECTROMETRY



#### L2MS INSTRUMENT DESIGN:

### 5 KG-CLASS IN SITU ANALYZER



#### POTENTIAL MISSIONS: 2020S-2030S





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# Our Team

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