Miniature Spectrometer for Detection of Organics and Identification of their Mineral Context

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Project Background & Motivation

- Surface reconnaissance and sample selection will be “built into” future astrobiology investigations (e.g. on Mars, Europa, small bodies)
- A “quick-look” near-IR / mid-IR spectral survey tool can be incorporated into an instrument suite. Identify (or eliminate):
  - Aqueous minerals
  - Volatiles (ices)
  - Functional group absorption features of organic materials
- **Objective**: Develop a simple NIR/MIR “point” reflectance spectrometer (PS) at NMSU. Integrate with a laser desorption time-of-flight (LDTOF) mass spectrometer at GSFC/699. Shared focal plane.
- Received NASA ASTID & EPSCoR funding in FY09
- **Institutional roles**:
  - **NMSU**: Develop & package the NIR spectrometer
  - **GSFC**: Concurrently miniaturize the LDTOF. Accommodate the NMSU PS
  - **NM Tech**: Sample control and curation for both instruments.
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IR Point Spectrometer - Features

- Tuning technology: Acousto-optic tunable filter (AOTF) RF-tuned
- Spectral coverage: 1.6 - 3.6 μm
- Spectral resolution: 10 - 15 cm\(^{-1}\) \((\lambda/\Delta \lambda \sim 180-400)\)
- Sample field-of-view: ~ 1 mm
- Etendue \((A\Omega)\): ~ 0.01 cm\(^2\) sterad
- SNR > 100
- Co-aligns with GSFC LDTOF, or operates stand-alone
- Mass: ≤ 1 kg
- Power: ~ 10 W
Optical Design

1. Broadband source light is directed through an acousto-optic tunable filter (AOTF).

2. Monochromatic light illuminates a ~ 1 mm sample area, coincident with LDTOF target.

3. Wavelength selection via applied RF frequency (30-70 MHz @ 2-3 W).

4. Reflected (scattered) light is reimaged onto an IR detector.

5. Data acquisition: Multiple RF-sweep coaddition ("sweep averaging").
Spectrometer Evolution at NMSU and GSFC

I. NMSU breadboard
- Radiometric modeling
- Optical design
- Component testing
- Breadboard assembly
- Survey measurements

II. Packaging (NMSU)
- Optomechanical design
- Fixture fabrication
- Alignment & calibration
- “Field-case” electronics
- Performance assessment

III. GSFC Integration
- Vacuum harnessing
- LDTOF coalignment
- Pump down
- IR checkout

New Mexico State University
Vacuum Desorption of H$_2$O from Gypsum

Initial measurement of gypsum made with the AOTF PS in the LDTOF MS vacuum chamber:

- In vacuum, gypsum loses adsorbed as well as structurally bound H$_2$O in the top monolayer(s).

- Similar results observed by Cloutis et al., GRL, ‘07

- Analysis of these data is ongoing
Carboxylic and Amino Acids

Diagram showing reflectance vs. wavelength for different samples:
- A. Gypsum
- B. Gypsum + Phthalic Acid
- C. Gypsum + Phthalic Acid + Valine

Graph showing absorbance ratio $\frac{C}{B}$ for Valine absorbance (NIST).
Status and Near-Term Plans

- The AOTF point spectrometer has been mated with the GSFC LDTOF (discussed in more detail in the next talk)
- Initial diagnostic measurements using gypsum
- In progress: Measurements of reference samples, e.g. PAH’s and amino acids on basalts
- Have begun looking at “unknowns”, i.e. irradiated ice residues supplied by the Cosmic Ice Laboratory (Code 691), with several starting materials.
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  - A steep learning curve!!