IMAGING SPECTROMETER FOR LUNAR SILICATE COMPOSITIONAL DETERMINATION AND DIRECT DETECTION OF H_2O IN THE 4-8 MICRON INTERMEDIATE INFRARED (IMIR) SPECTRAL RANGE.

C. H. Kremer[1,2], John F. Mustard[2], Carle M. Pieters[2], Robert O. Green[3], Stephen W. Parman[2], and Michael S. Bramble[3], [1]Department of Geosciences, Stony Brook University, Stony Brook, NY, [2]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA (christopher_kremer@brown.edu).

Introduction: The 4-8 µm Intermediate Infrared (IMIR) spectral range exhibits well-defined spectral bands of both silicate minerals and H_2O. IMIR spectral bands of mafic minerals, which result from combinations and overtones of fundamental vibrations at longer wavelengths, shift systematically with Mg#, enabling quantitative determination of olivine [1] and pyroxene [2] Mg# using band position alone. Laboratory data indicate that Mg# determination using IMIR bands is robust in mafic and ultramafic lunar-like rock materials [3,4] and that effects of npFe0, a major component of space weathering, are modest [5].

The IMIR wavelength region likewise exhibits a strong fundamental absorption of H_2O at ~6 µm, enabling recent direct detections of H_2O on the lunar surface using SOFIA [6]. The spectral bands of silicate minerals and H_2O make IMIR spectroscopy an attractive tool for high-priority lunar science goals such as mapping and identifying different species of hydration and mineralogical investigation of the Moon's crustal evolution. LEAG has therefore recently identified IMIR spectroscopy as a powerful technique for potential next generation continuous lunar orbital investigations [7].

Recent technological developments enable the design of small high fidelity instruments capable of measuring in this under-utilized wavelength range. We describe a design for an IMIR spectrometer capable of being implemented on orbital and landed missions for the Moon, Mercury, as well as other planetary bodies.

Science Background: Olivine exhibits two well defined spectral bands at ~5.6 and ~6.0 µm, which shift systematically to shorter wavelengths and increase in strength with increasing Mg# [1]. High-Ca pyroxene has well-defined spectral bands at ~5.1 µm and ~5.3 µm, and low-Ca pyroxene has a well-defined spectral band at strong band at ~5.2 µm [2].

The positions of these pyroxene spectral bands shift to shorter wavelengths and increase in strength with increasing Mg#, irrespective of Ca content. Using IMIR band position alone, quantitative determination of Mg# of olivine and low-Ca pyroxene is accurate within +/–10 mol% and +/–23 mol% for high-Ca pyroxene. As band position is related directly to Mg#, qualitative discrimination is also in principle possible between populations of olivine and pyroxene with smaller differences in Mg#.

Ongoing work is investigating the spectral bands of other silicate materials in the 4-8 µm range.

Instrument Design: Our new small IMIR imaging spectrometer measures the spectral range from 4 to 8 µm. The instrument has <250 spectral channels and a spectral sampling of 20 nm through a 35 degree field of view with a 2 milliradian spatial sampling. The instrument would measure emitted thermal radiation from the surface of the Moon. IMIR spectroscopy

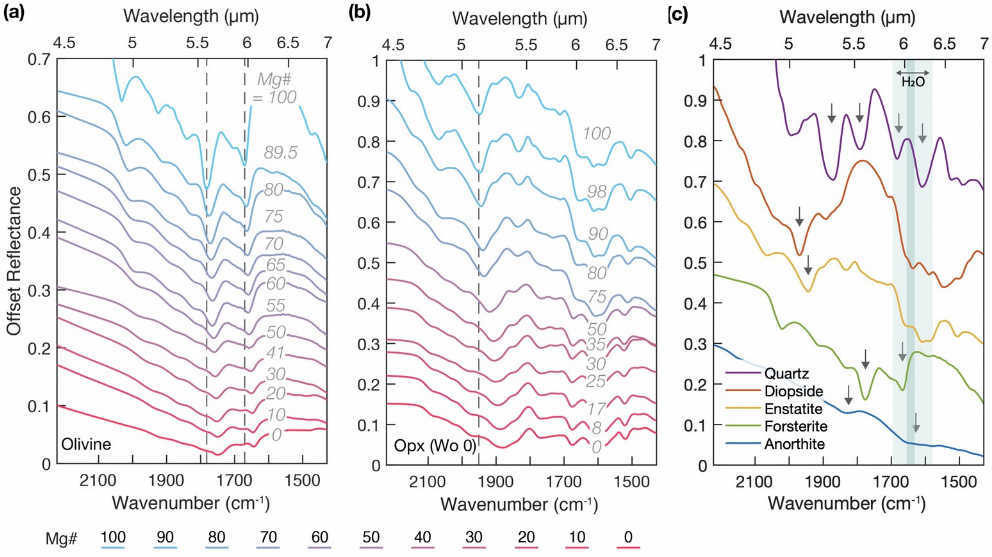

Fig. 1. IMIR (4-8 µm) spectra of (a) synthetic olivine, (b) synthetic low-ca pyroxene, and (c) other minerals of interest. Color of spectra is keyed to Mg#, also given in italics. Dashed lines indicate the positions of the 5.6 and 6.0 µm bands in forsterite and of the 5.2 µm band in enstatite. See [1,2] for detailed spectral analysis. Range of positions of the 6.0 µm H_2O band [c.f. 6]

utilizes the new advances in imaging spectrometer components in conjunction with a HOT-BIRD detector array developed by JPL [8]. The High-resolution Volatiles and Minerals Moon Mapper (HVM3) aboard Lunar Trailblazer may serve as a potential heritage analog for the optical system [9]. The spectrometer will use an electron-beam lithography fabricated grating, slit, and light trap developed by JPL that are of high-heritage from EMIT [10] and M3 [11]**.** Further instrument and detector specifications are given in Tables 1 and 2, respectively.

Team members are currently investigating the effects of instrument signal-to-noise ratio [12] and lunar-like surface temperatures [13] on the ability to detect and quantify spectral bands in the IMIR range.

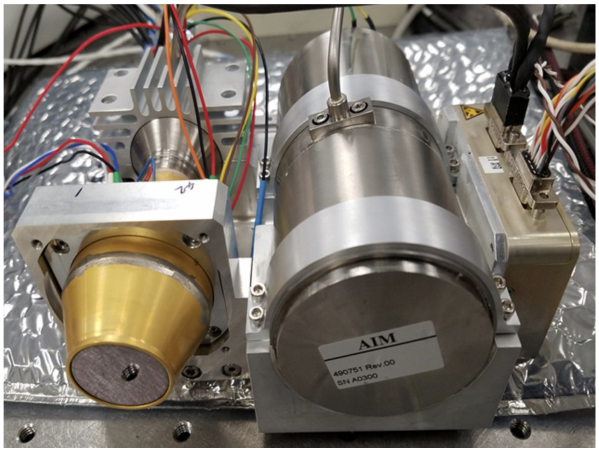

Fig. 2. Available packaged HOT-BIRD detector with cryocooler.

Implications for Mercury: Strong, unique spectral bands of high-Mg olivine and pyroxene also make IMIR spectroscopy a highly attractive tool for the direct detection of silicate minerals on the surface of Mercury. Applications to Mercury are discussed further by [14].

Acknowledgments: Spectra from RELAB are archived on the PDS Geosciences Node Spectral Library and are available at https://pds-speclib.rsl.wustl.edu/.

References: [1] Kremer, C. H. et al. (2020) *Geophysical Research Letters*, *47*. [2] Kremer, C. H. et al. (In Review) Earth and Space Science. [3] Kremer, C. H. (2023), LPS LIV, Abstract #2202. [4] Kremer, C. H. et al. (2022), LPS LIII, Abstract #2196. [5] Kremer, C. H. et al. *LPSC*, (2022), LPS LIII, Abstract #2239. [6] Honniball, C. I. et al. (2020) *Nature Astronomy*. [7] Greenhagen, B. T. et al. *Final Report of the Continuous Lunar Orbital Capabilities Specific Action Team (CLOC-SAT)*, (2023). [8] Cañas, C. et al. (2020) *Proceedings of SPIE*, *11505*. [9] Bender, H. et al. (2022) *Proceedings of SPIE*, *1223503*. [10] Green R. et al. (2020) IEEE Aerospace. [11] Pieters, C. et al. (2008) Current Science, *96*. [12] Perez-Lopez, S. et al. (2023) LPS LIV, Abstract #2388. [13] Wilk, K. et al. (2023) LPS LIV, Abstract #2316. [14] Parman, S. et al. (2023) LPS LIV, Abstract #1607.

Table 1: *Instrument Specifications*

Spectral Range	4-8 µm
Spectral Channels	<250
Spectral Sampling	20 nm
F/#	3
Detector	48 µm (24*2 of 640x480, 24)
Slit Width	48 µm
Spatial Samples	<300
Spatial FOV	35 deg (adjustable)
IFOV	2 milliradians (adjustable)

Table 2: *Detector Specifications*

Detector Type	T2SL HOT-BIRD
Format	640x512 pixels
Treat as	320x256
Pixel pitch	24 µm
Wavelength cutoff	7 µm
Operating temp.	90 K
QE	>40%
Pixel operability	>99%