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An automated spectrogoniometer system with planetary science applications

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AN AUTOMATED GONIOMETER SYSTEM FOR REFLECTANCE SPECTROSCOPY

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BACKGROUND

Reflectance spectroscopy is a major technique for characterizing the composition of planetary surfaces, and has led to many key findings in planetary geology (e.g. [1,2]).

When a reflectance spectrometer collects data, it does so at some viewing geometry (Figure 1). In the lab, this is usually at a standard viewing geometry (e.g. i=0, e=30). In situ measurements taken by spacecraft, however, may be taken at a wide range of viewing geometries. Western Washington University's new automated goniometer enables the collection of reflectance spectra across a range of viewing geometries similar to those of spacecraft observations. By acquiring spectrogoniometric measurements for planetary analog samples in the lab, we will facilitate more comprehensive interpretations of spectral data from spacecraft than are currently possible.

Viewing Geometry

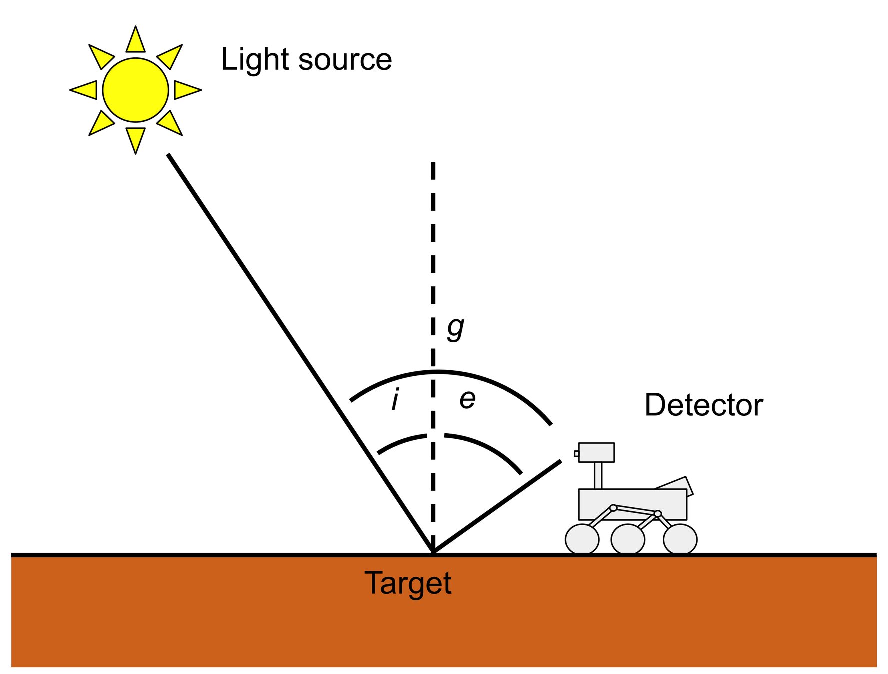


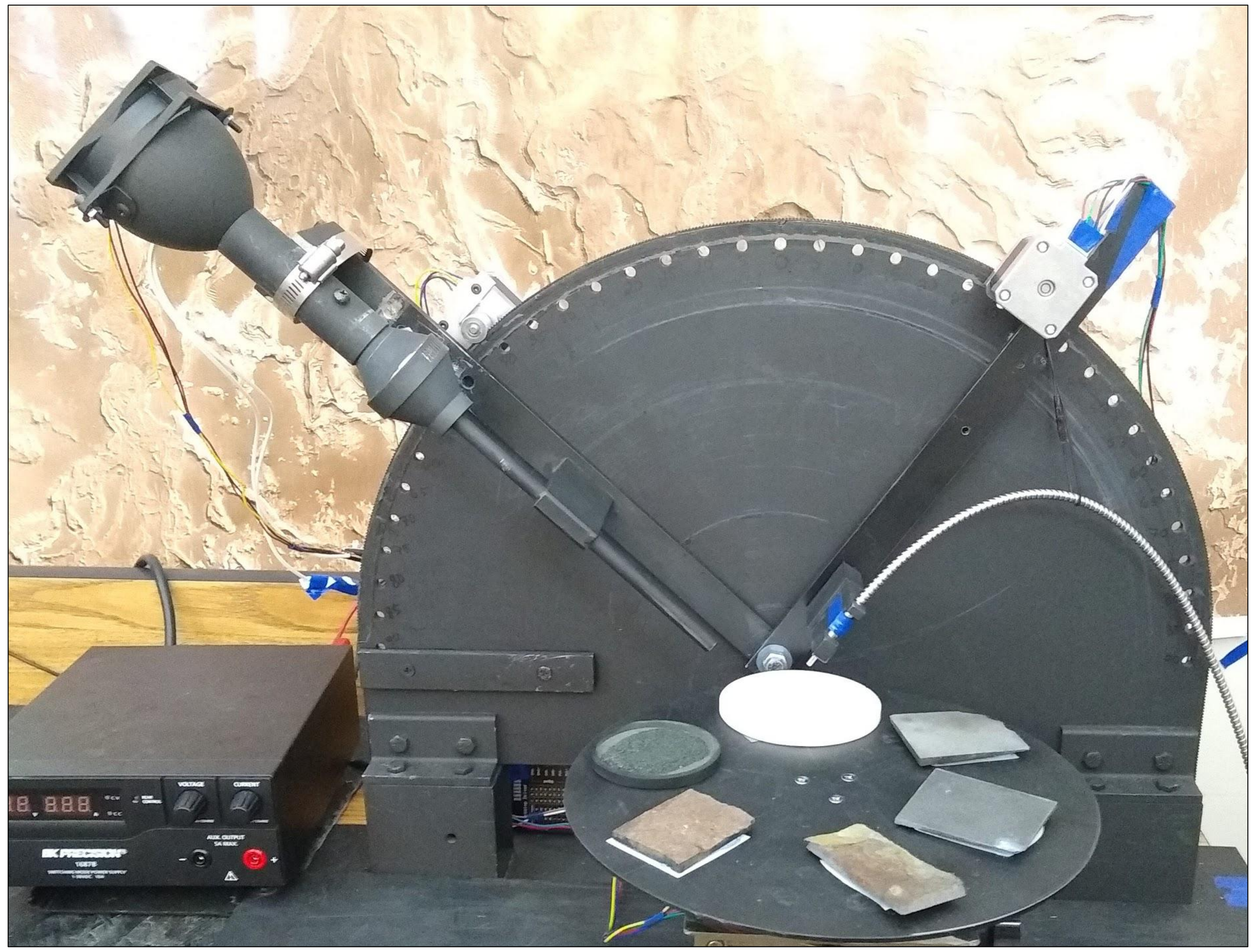
Figure 1: A 2-dimensional viewing geometry is defined by an emission angle *e* and incidence angle *i*. Phase angle *g* is the angle between *e* and *i*.

REFERENCES

[1] Ehlmann et al. (2012) *JGR*, 117, E00J16. [2] Grotzinger et al. (2013) *Science*, 342. [3] Jackson et al. (1992) *Remote Sensing of Environment*, 40, 3, 231-239. [4] Cloutis et al. (2006a) *LPS XXXVII*, Abstract #2121. [5] Bhandari et al. (2011) *Applied Optics*, 50(16), 2431.

THE INSTRUMENT

A custom-built spectrogoniometer system automatically iterates through a range of viewing geometries while collecting reflectance spectra.



Goniometer

The goniometer consists of an aluminum backboard with two rotating arms, one holding a light source and the other holding a detector. Stepper motors attached to the incidence and emission arms enable automatic iterations through geometries with 1 degree of angular resolution. This system allows for highly efficient collection of photometric data. For example, spectra for a suite of 5 samples at 10 different viewing geometries each can be acquired in under 1 hour.

Samples may be positioned using either 1) an automated rotating tray holding up to 5 small samples (shown above) or 2) a manually adjusted sliding tray for larger samples. To correct for changing light flux on the target, detector field of view, and drift within the spectrometer, the goniometer system takes a white reference spectrum at each viewing geometry using a Labsphere Spectralon panel, which is a near-Lambertian reflector [3].

Control Software

Custom software provides a graphical user interface that enables the user to simultaneously control both the ASD spectrometer and the goniometer. The software comes in two open source packages available at https://github.com/kathleenhoza/autasd and https://github.com/kathleenhoza/autospec. These packages can also be installed using pip install autoasd and pip install autospec.

Detector

Signal is collected by a fiber optic cable that channels input signal to an Analytical Spectral Devices, Inc. (ASD) FieldSpec 4 Hi-Res visible/near infrared spectrometer.

Light Source

This instrument incorporates a light source based on the design used by the HOSERLab at the University of Winnipeg [4].

SCIENCE APPLICATIONS

Work in this lab so far has focused on characterizing the photometry of naturally-weathered basalt surfaces (Figure 2) and polished basalt slabs with SiO2 coatings precipitated in the lab (Figure 3), which are both Mars-relevant materials.

Weathered Basalt

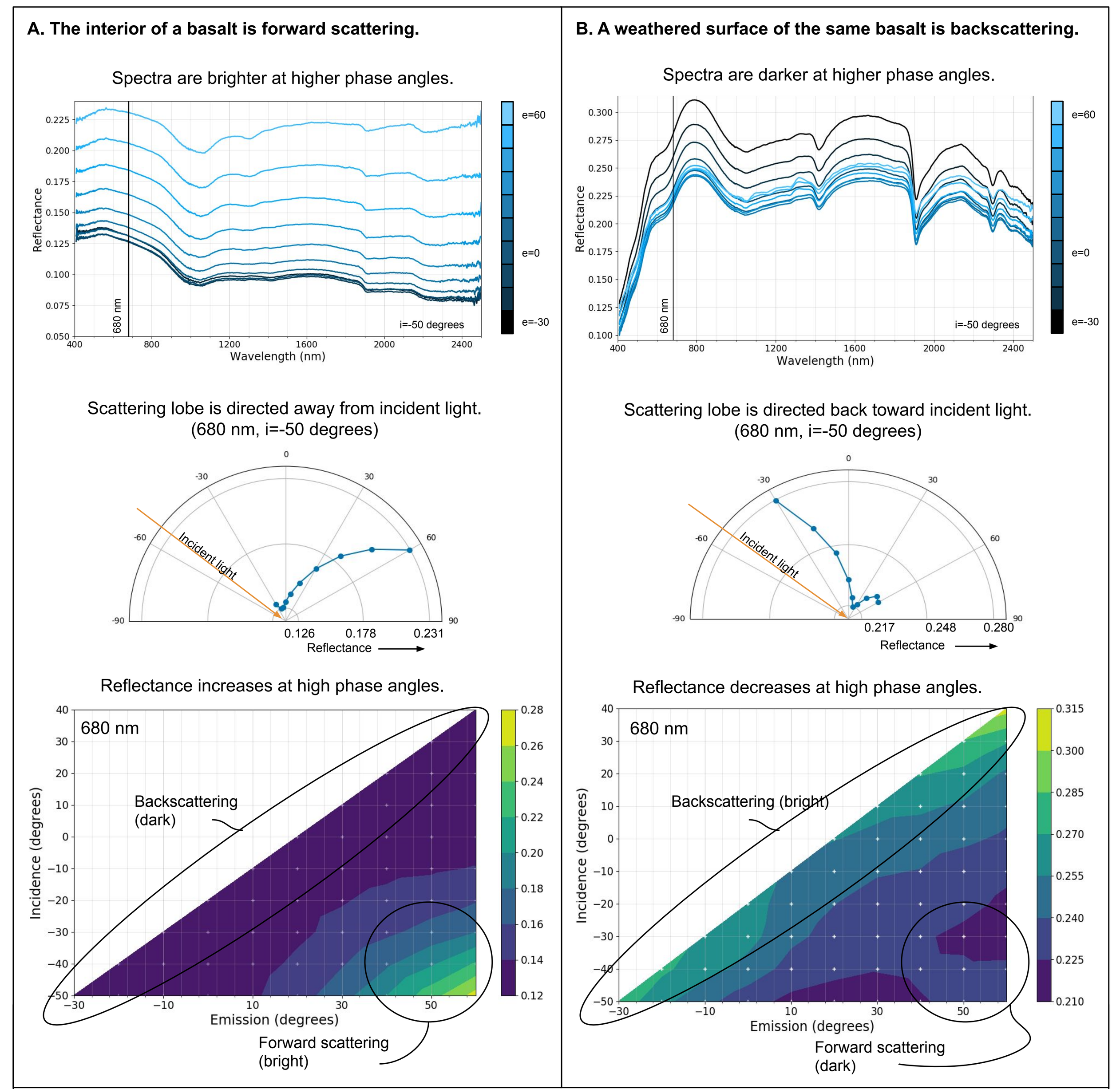


Figure 2: Weathering has been found to have the potential to strongly influence photometry, with some weathered surfaces changing the behavior of the scattering lobe from forward scattering (A) to backscattering (B). Other weathered surfaces have different effects including making the samples darker, redder, and/or more specular. The particular type of photometric effects caused by weathering may be the result of paleoclimate conditions.

Synthetic SiO2-coated Basalt

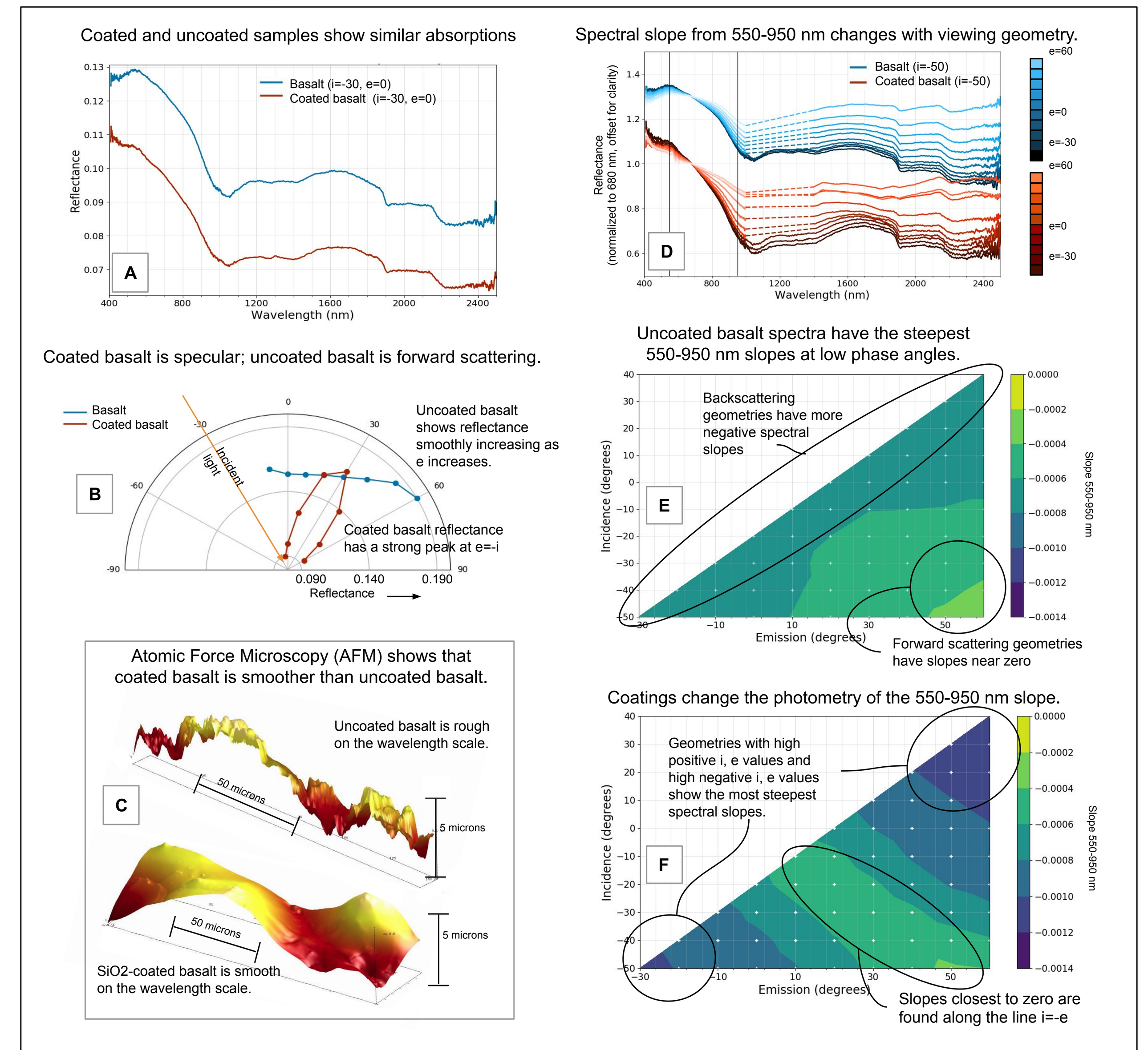


Figure 3: SiO2 coatings a few microns thick are found to be largely transparent to visible/near-infrared radiation, and standard viewing geometry spectra have absorptions very similar to the substrate material (A). However, coated samples are more specular than uncoated samples (B) which may be related to increased smoothness (C) and they show distinctive photometric behavior from 550-950 nm (D-F). These characteristics could help spacecraft identify SiO2 coatings, which are linked to aqueous conditions, where they might otherwise be overlooked.

INSTRUMENT VALIDATION

Non-Lambertian White Reference Correction

The ideal white reference material would have perfectly diffuse reflectance at all viewing geometries. In practice, such a material does not exist, and Spectralon has been shown to have geometry-dependent reflectance (Figure 4).

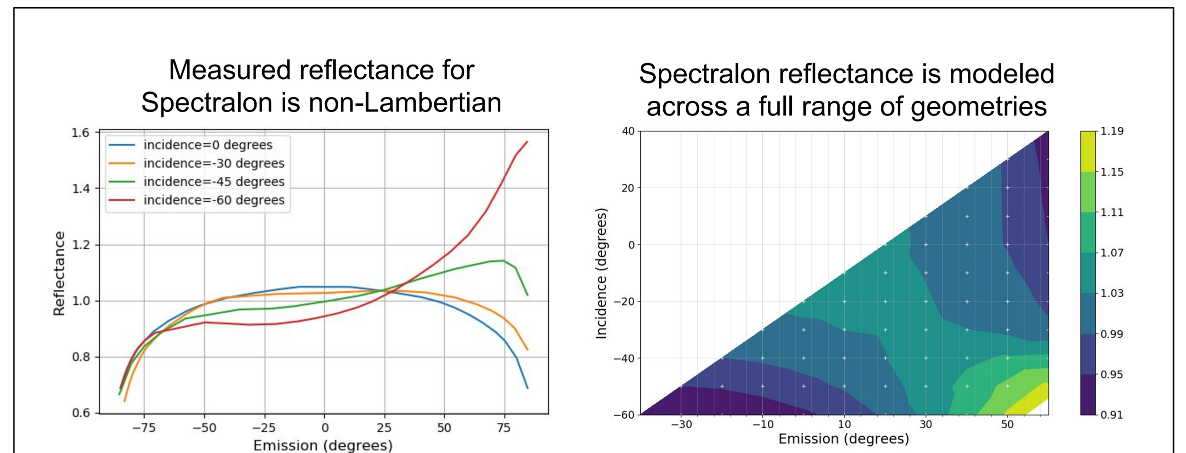


Figure 4: Reflectance data for Spectralon was extracted from [5] and a linear interpolation is used to model reflectance at all relevant viewing geometries.

To correct for this non-Lambertian behavior, measurements are scaled to published Spectralon reflectance values using a linear interpolation when needed.

ASD Polarization Artifacts

At high phase angles, ASD spectrometer measurements are prone to artifacts that have been linked to polarization sensitivity of the instrument (Figure 5).

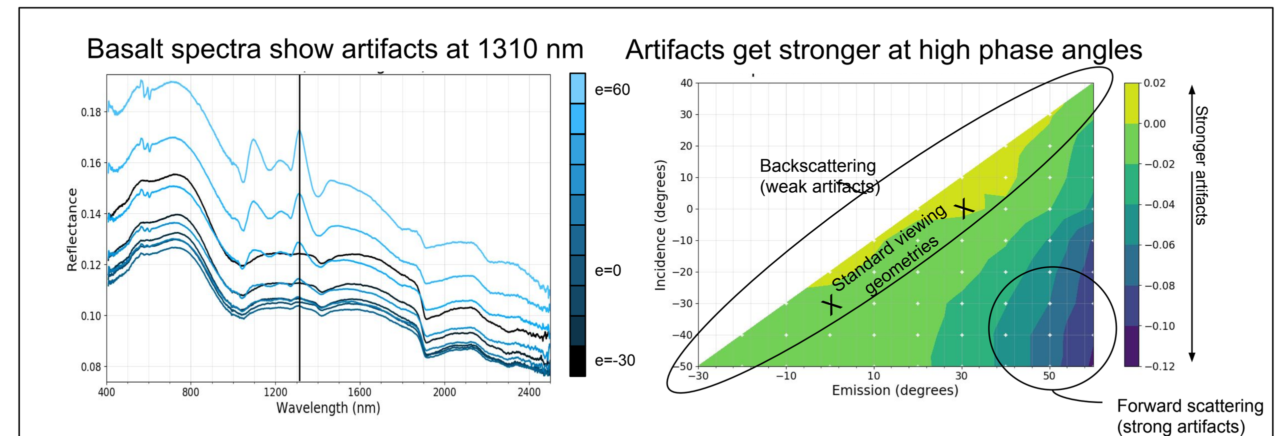


Figure 5: Depth of the 1310 nm artifact was measured with shoulders at 1270 and 1360 nm. Artifacts are small for backscattering geometries but this sample shows large (~10% of signal) negative-depth artifacts beginning at moderate phase angles. The 1100 nm artifact is similar.

To minimize the impact of these artifacts, photometric effects are examined either at wavelengths far from known artifact regions or only at geometries from *g*=-20 to *g*=40 degrees, where polarization effects are known to be small.