Laboratory Reflectance Measurements of Ice and Dust Mixtures. Application to Permanently Shaded Regions on the Moon and Mercury.

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Permanently shadowed regions (PSRs) at the poles of the Moon and Mercury have been pointed out as candidates to host water ice at their surface. Many efforts are being made to detect and quantify that ice:

These are the **techniques employed**

Earth- and Bistatic Radar

Neutron Spectrometry

In-situ Volatile Measurement

UV & NIR Reflectance Measurements

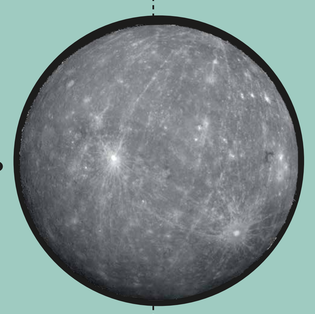
Topography Measurements

Imaging

Illumination Modeling

Temperature Modeling

These are some of the **accepted ideas**



On **Mercury**, water ice is exposed at latitudes higher than 80ºN.

On **the Moon**, the presence of ice is lower than on Mercury (if present at all), an it is probably mixed within the regolith.

Find out more in Lawrence, 2016 [1]

At a Glance:

In PSRs of the Moon and Mercury, ice could be detected through its reflectance. ▶ How does the reflectance of icy, intimate mixtures behave? ▶ We conduct an experimental study to support the inversion of reflectance data. ▶ We find that large quantities of ice can be masked in intimate mixtures. ▶ We give optimal observational conditions to detect water ice within planetary soils.

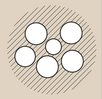
At the Icelab (University of Bern) [2], we have protocols to prepare and characterize associations of ice w/ mineral as analogs of icy planetary surfaces.

We produced two size distributions of particulated ice by nebulizing and freezing droplets of deionized water [3].

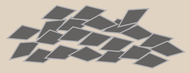
Water Ice

SPIPA A
4,5 ± 2.5 µm

SPIPA B
70 ± 30 µm



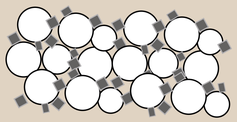
JSC-1 AF



Mean diameter: 24 µm

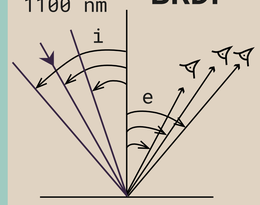
As dry-member, we used JSC-1 AF, the fine fraction of the lunar mare regolith simulant distributed by NASA [4].

In some PSRs, ice is thought to be mixed with the regolith at the grain level [5]. Hence, we reproduce these mixtures.



Intimate Mixtures

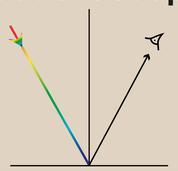
BRDF



We measure the Bidirectional Reflectance Distribution Function with PHIRE-2 [2], a goniometer that allows low-phase-angle measurements.

We acquire reflectance spectra with SCITEAS [6], a hyperspectral imager for icy samples.

Reflectance Spectroscopy



One way to detect ice in PSRs is through the study of their reflectance, since the addition of ice into soil or regolith is likely to change its reflectivity. Now, how well do we understand the reflectance of icy intimate mixtures?

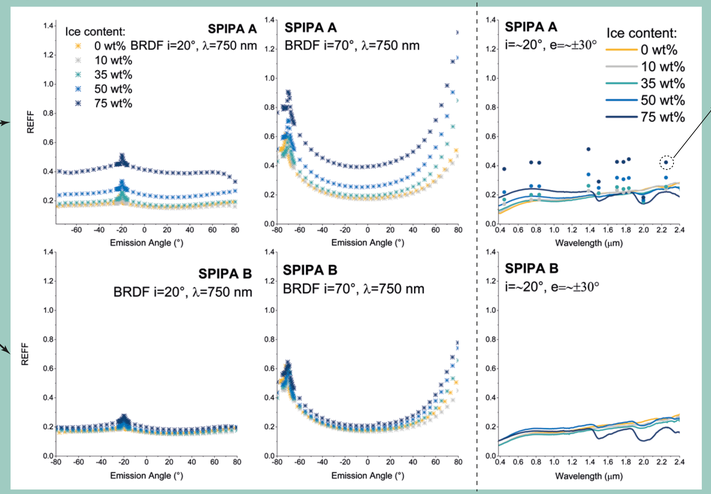
We show the reflectance measurements on mixtures of JSC-1 AF with variable concentrations of water ice:

These are **BRDFs**

Measured at 750 nm at low and high incidence angles.

These are **Reflectance Spectra**

From 0.38 to 2.4 µm.



Because sublimation of fine ice is faster than the acquisition of the whole spectrum, we first scan the absolute reflectance (±10%) at key wavelengths.

You can observe the shape of the spectra with the solid lines and assess the absolute brightness with the dots.

At concentrations of 35wt%, there is no significant spectro-photometric signature of ice in the continuum. At low incidence angles and with big ice particles, this threshold can be raised to 75wt%. In [7], we studied how reflectance models cope with this behavior.

75 wt%

Of coarse-grained ice can be masked by dust at low phase angles.

High-phase angles

Can be used to detect low concentrations of water ice.

Fine-grained ice

Is easier to detect because of its greater surface-to-volume ratio.

Absorption bands

Are more sensitive to the presence of water ice than the continuum.

Next journey to Mercury: BepiColombo

Onboard BepiColombo goes BELA [8], a laser altimeter that will measure the reflectance of the southern PSRs.

Next journey to the Moon: Lunar Flashlight

This CubeSat [9] will measure the reflectance of PSRs at strategic wavelengths, such as 1.5 and 2.0 µm.

[1] Lawrence, D. J (2016) JGR: Planets, 122
[2] Pommerol et al., (2011) PSS, 59
[3] Poch et al. (2016) Icarus 267, 154-173.
[4] Schrader et al. (2009) Aerosp. Sciences Meet.
[5] Lucey et al. (2014) JGR: Planets, 119
[6] Pommerol et al. (2015a) PSS, 109-110
[7] Yoldi et al. (2015) GRL, 42
[8] Thomas et al. (2007) PSS, 55
[9] Cohen et al. (2014) AMLEAG

* Credits:
BepiColombo pic: ESA
Flashlight pic: NASA

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