

**Important SKGs for
Lunar Water Resources:
Time/Space Variations of Surficial OH/H₂O**

**Carle M. Pieters
Ralph E. Milliken
Brown University**

Lunar Volatile Resources...

Polar Volatiles

- PSR; buried
- Localized
- ISRU **TBD**
- Potential **TBD**
- Non-renewable

Surficial OH/H₂O

- Surficial
- Global
- ISRU **TBD**
- Potential **TBD**
- Renewable ??

Internal Water

- Early interior
- Samples
- NA
- NA
- NA

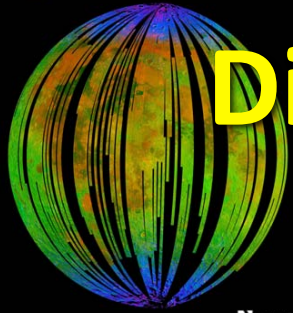
Early SS science

Topics

- **Review Surficial 'Water' (OH/H₂O)**
 - Discovery
 - Character
- **Summary of Issues**
- **Recommendations**

Science

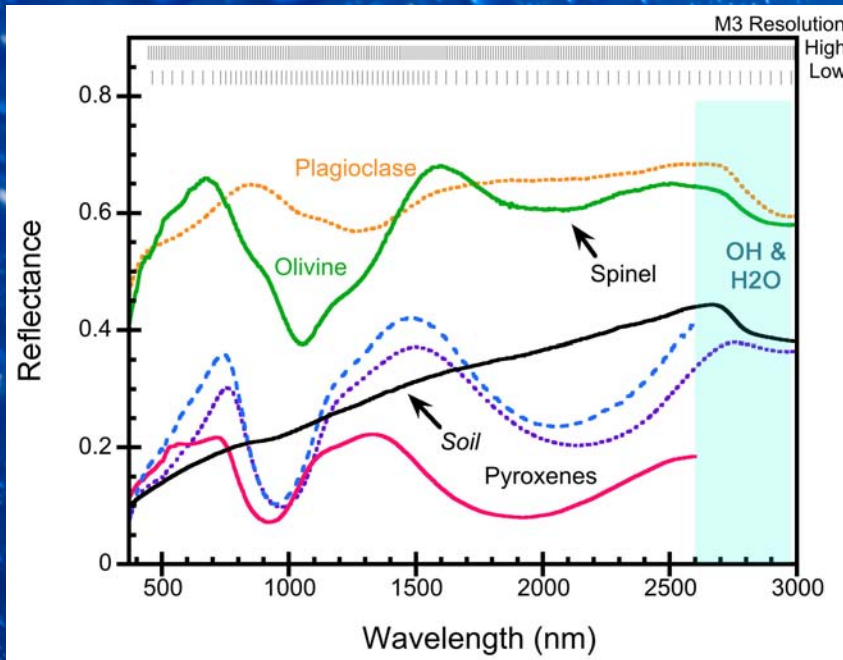
23 October 2009/99



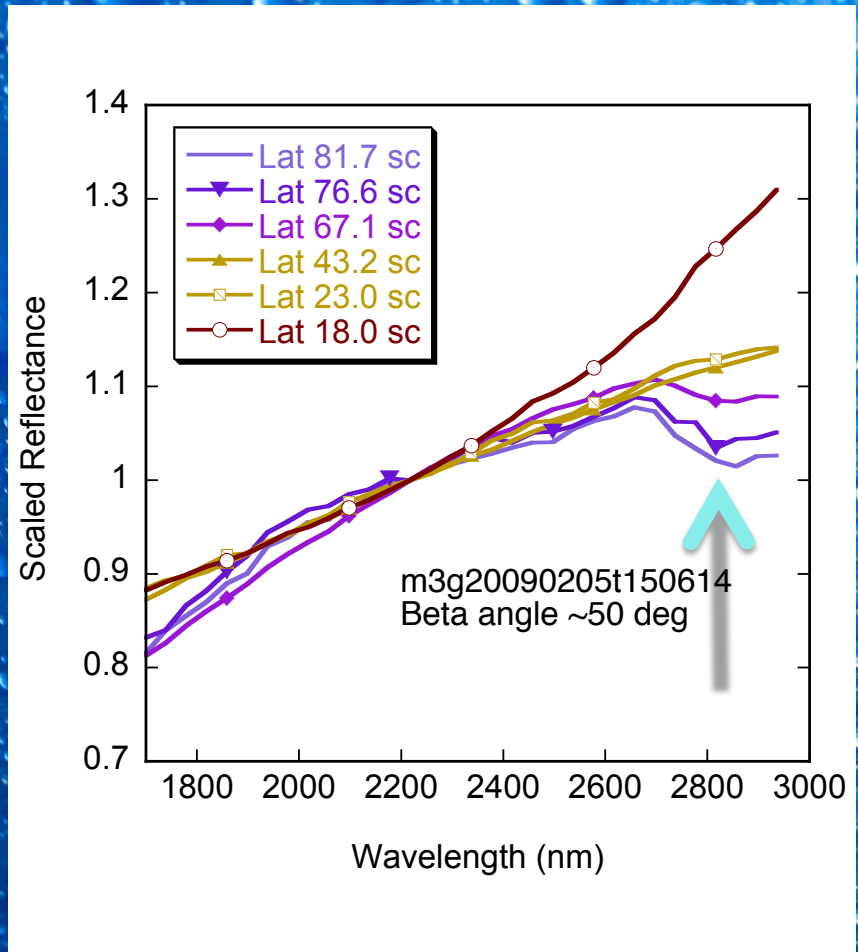
Discovery of Surficial OH/H₂O

5 years ago

AAAS



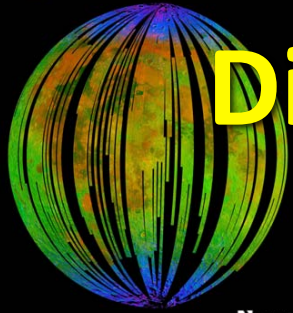
Lunar Samples



M³ Cassini Epoxi

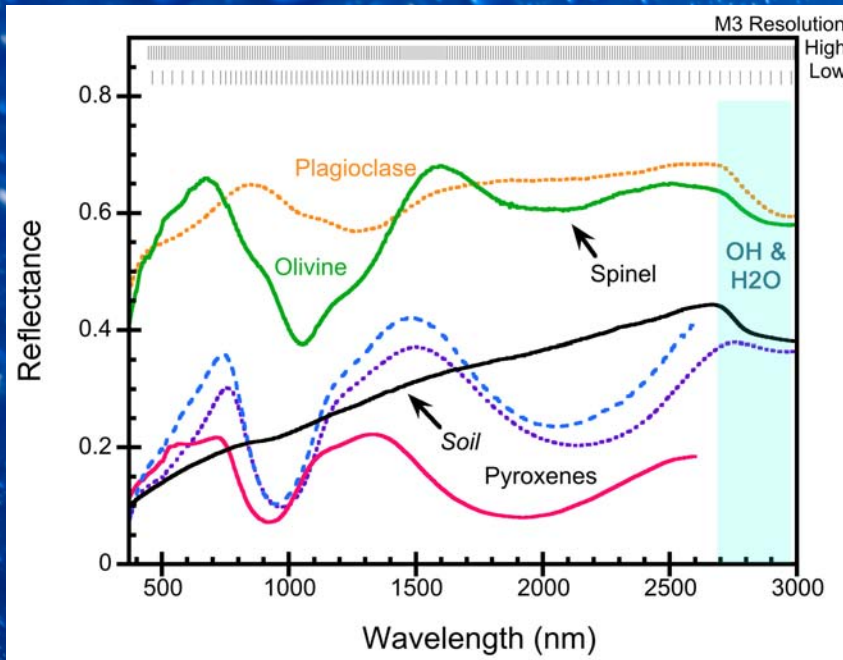
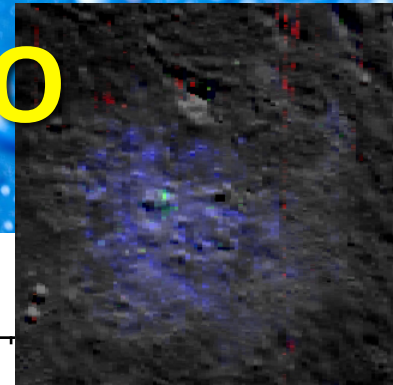
Science

23 October 2009/90

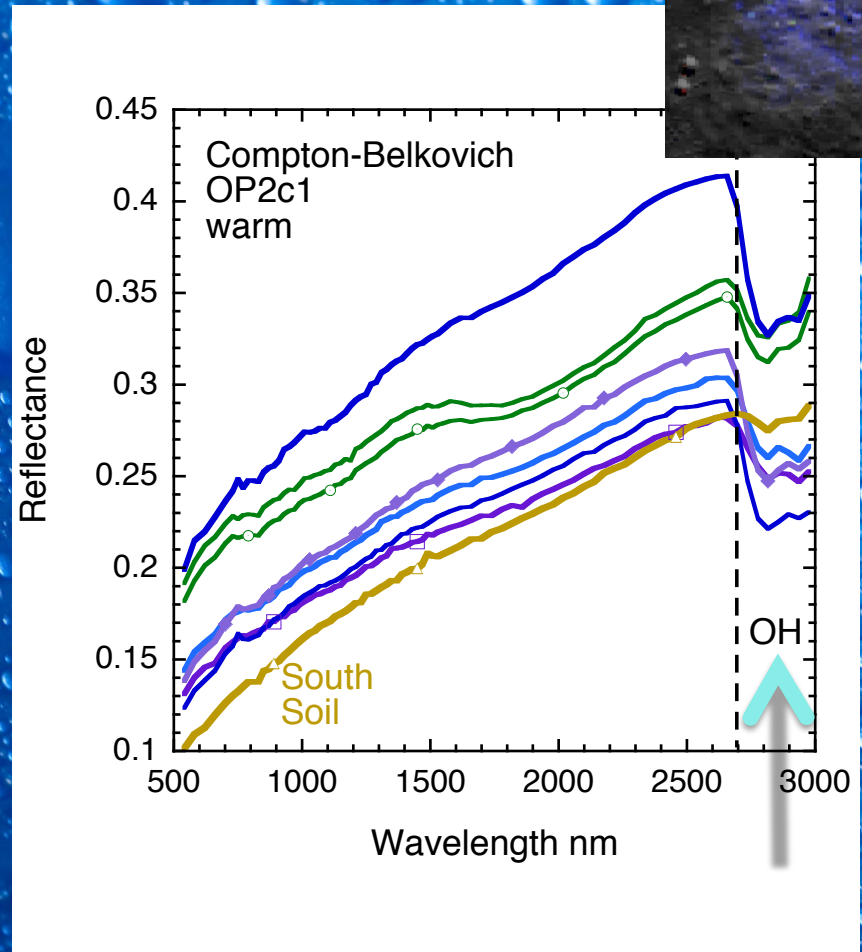


Discovery of Surficial OH/H₂O

5 years ago



Lunar Samples

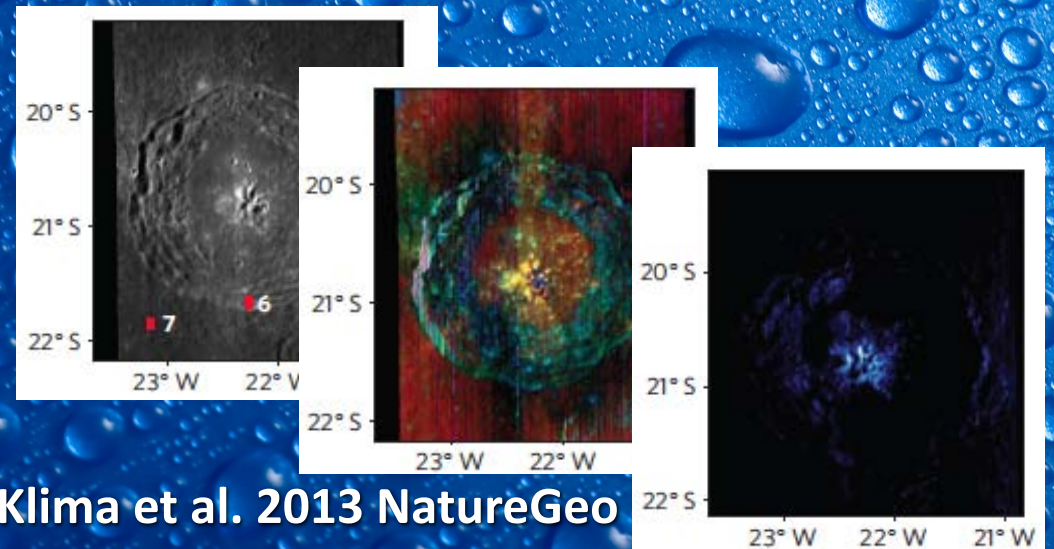
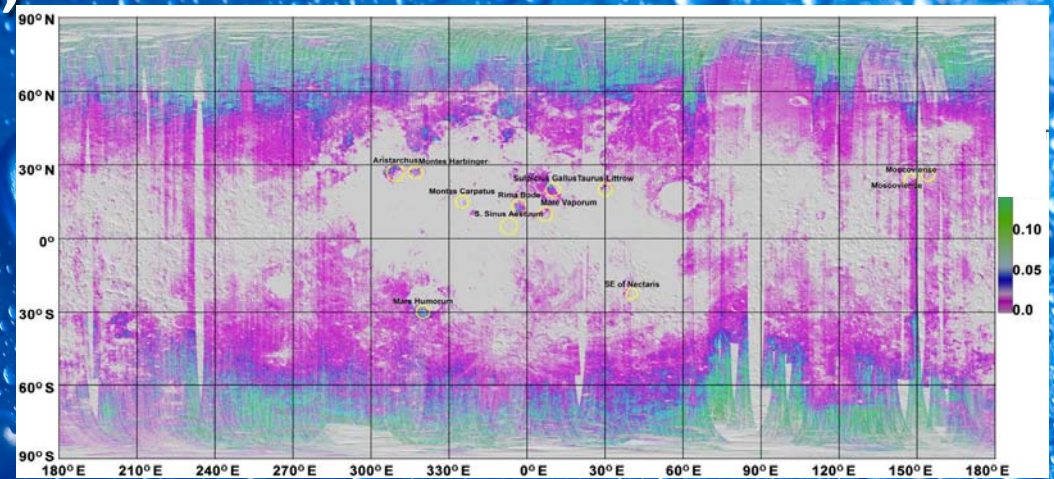


M³

Character of Surficial OH/H₂O

- Readily detected at cool, high latitudes
- Pervasive across the surface
- Local concentrations identified
- Suggestion of regular variability
 - Local composition
 - Time of day

Li and Milliken, 2013, 2014 LPSC

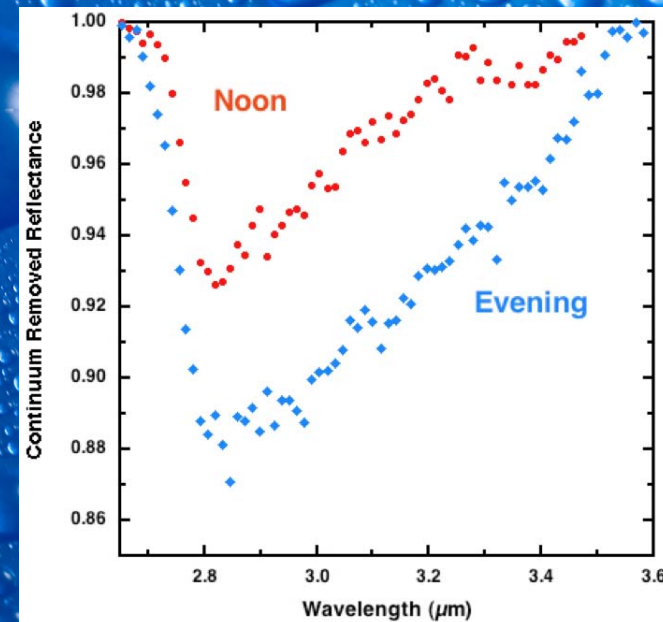


Klima et al. 2013 NatureGeo

Character of Surficial OH/H₂O

- Readily detected at cool, high latitudes
- Pervasive across the surface
- Local concentrations identified
- *Suggestion* of regular variability
 - Local composition
 - Time of day

EPOXI data (Sunshine et al., 2009, Science)



See discussion in McCord et al., 2011, JGR

Strategic Knowledge Gaps

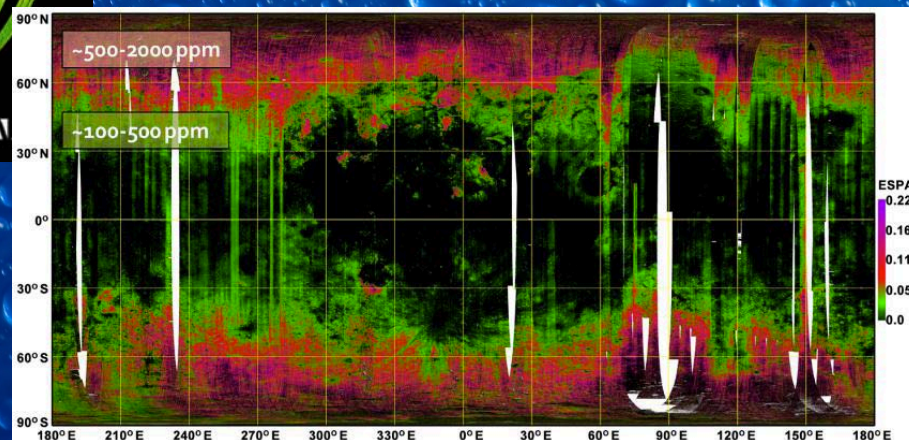
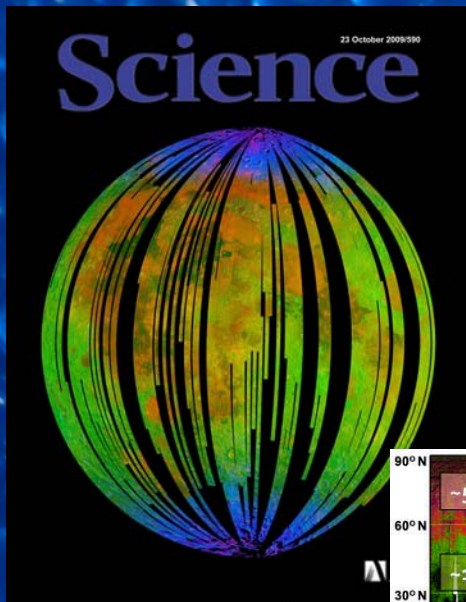
1. What is **the distribution and abundance** of OH/H₂O across the lunar surface?
2. What are **the processes responsible for formation** of surficial OH/H₂O on the Moon?
3. At **what rate** does surficial OH/H₂O form and what role, if any, does composition play in this rate?
4. **How mobile** is surficial OH/H₂O?
5. What is the **resource potential** of the surficial OH/H₂O and is it **renewable**?

Strategic Knowledge Gaps

1. What is **the distribution and abundance** of OH/
H₂O across the lunar surface?

Needs:

- Uniform, reliable data
- Global coverage
- High spectral resolution
- Accurate thermal information

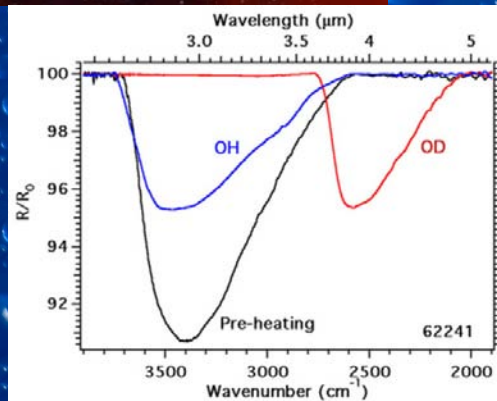


Strategic Knowledge Gaps

2. What are the processes responsible for formation of surficial OH/H₂O on the Moon?

Needs:

- Laboratory experiments, tests
- Physical modeling
- Uniform, reliable data
- High spectral resolution [OH vs H₂O]
- Accurate thermal information

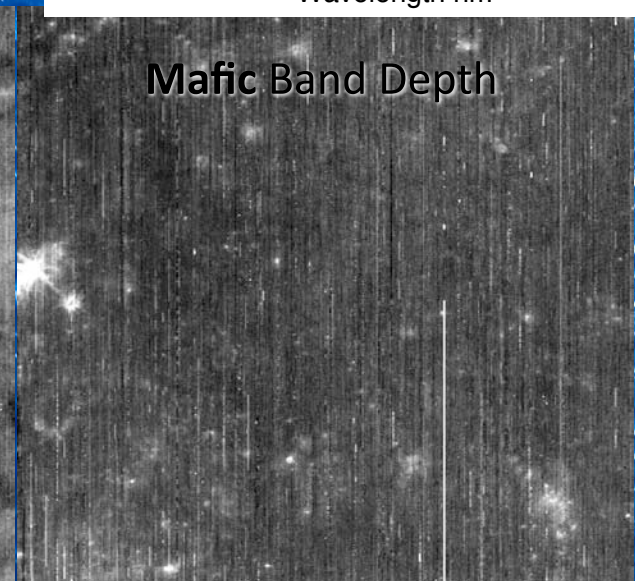
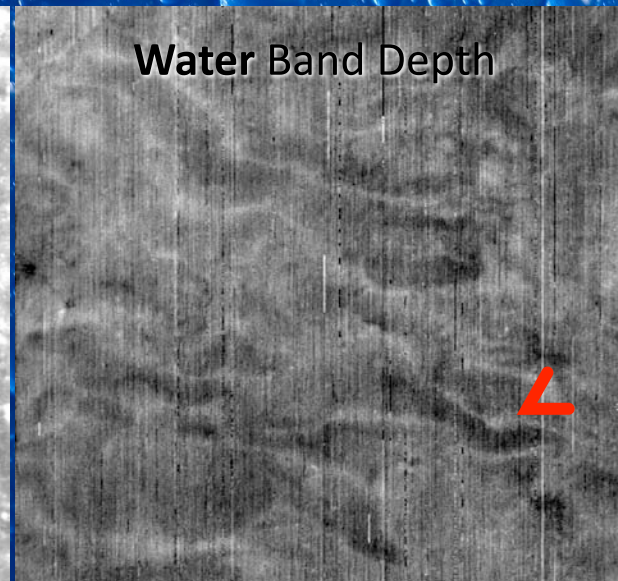
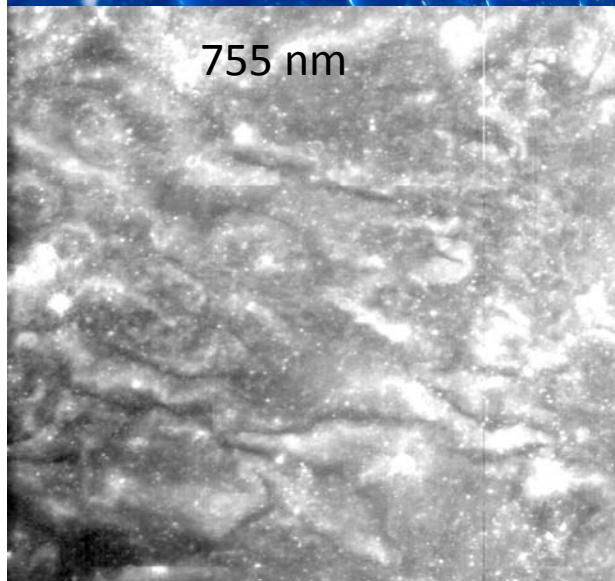
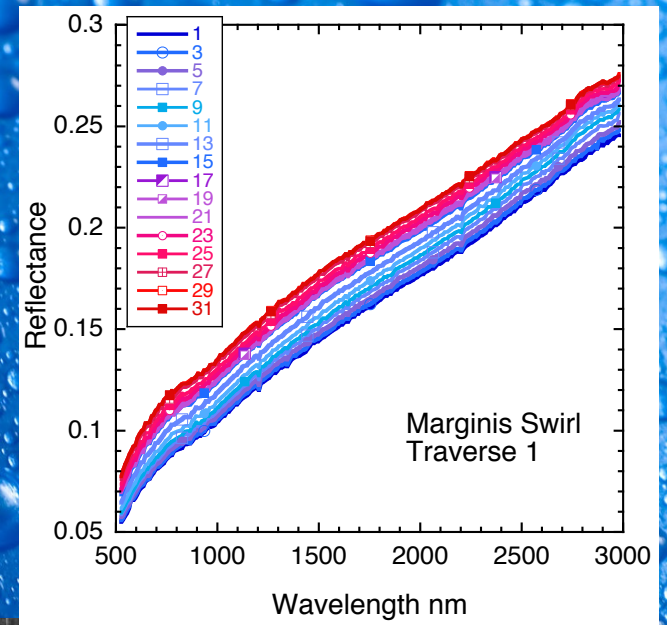


Ichimura et al. 2012

3 μm Feature Linked to Solar Wind

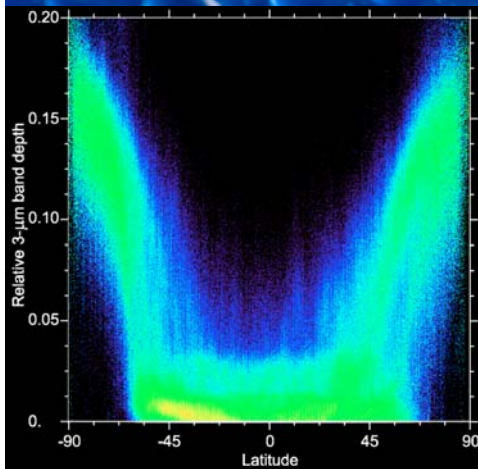
M3 calibrated high resolution Target data for Marginis confirms:

- Bright swirl – weaker water band
 - Dark lanes – stronger band
- => Magnetic field shields surface from H



Strategic Knowledge Gaps

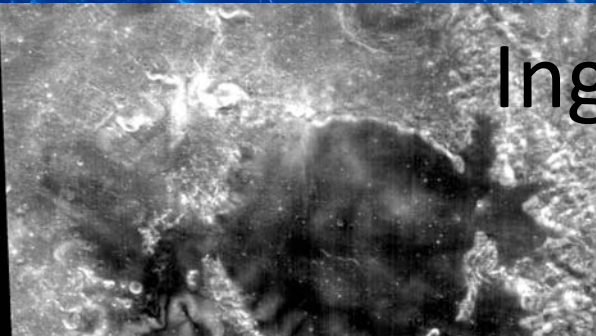
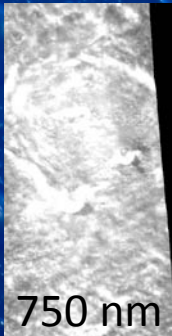
3. At **what rate** does surficial OH/H₂O form and what role, if any, does *composition* play in this rate?



McCord et al., 2011 JGR

Needs:

- Multiple diurnal measurements
- Global coverage
- Uniform, reliable data
- High spectral resolution
- Accurate thermal information



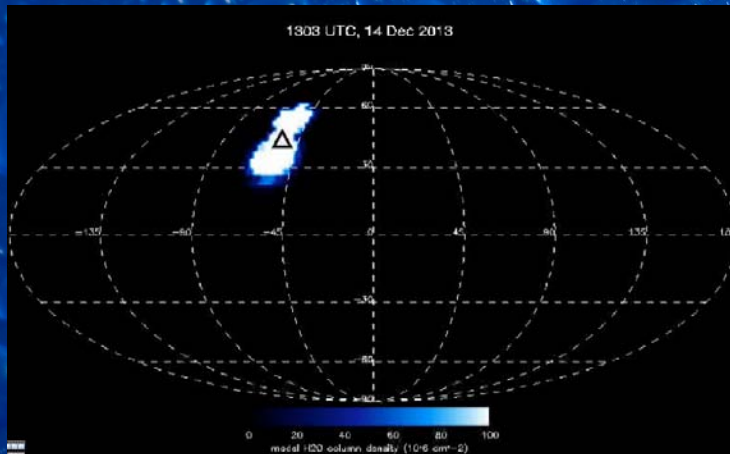
Strategic Knowledge Gaps

4. **How mobile** is surficial OH/H₂O?

OH may be stable, but
H₂O is likely mobile.....

Needs:

- Time-varying coverage*
- Uniform, reliable data*
- High spectral resolution*
- High spatial resolution*



See D. Hurley 2014 LEAG discussion
on H₂O mobility

See also Neutron Spectrometer(s) discussion

Strategic Knowledge Gaps

5. What is the **resource potential** of the surficial OH/H₂O and is it **renewable**?

Needs:

- Global coverage*
- Time-varying assessment*
- Uniform, reliable data*
- High spectral resolution*
- Accurate thermal information*

ISRU

???

Strategic Knowledge Gaps

1. What is **the distribution and abundance** of OH/H₂O across the lunar surface?
2. What are **the processes responsible for formation** of surficial OH/H₂O on the Moon?
3. At **what rate** does surficial OH/H₂O form and what role, if any, does composition play in this rate?
4. **How mobile** is surficial OH/H₂O?
5. What is the **resource potential** of the surficial OH/H₂O and is it **renewable**?

Summary

To address these 5 SKGs requires:

- *Uniform, reliable NIR data to 3.6 μm*
- *Accurate thermal information*
- *Global coverage*
- *Time-varying assessment*
- *High spectral resolution*
- *High spatial resolution*

Recommendations

1. Add these 5 SKGs to the important to-do list.
2. Explore the closure of these SKGs with
 - Orbital experiments
 - Global NIR coverage with repeat cycles
 - High spatial resolution
 - High spectral resolution to 3.6 μm spectral range
 - Lander experiments
 - Time variation NIR spectra through several lunar days
 - Multiple local geologic (and compositional) context
 - High spectral resolution to 3.6 μm spectral range
 - Lunar sample analyses
 - Laboratory experiments and modeling