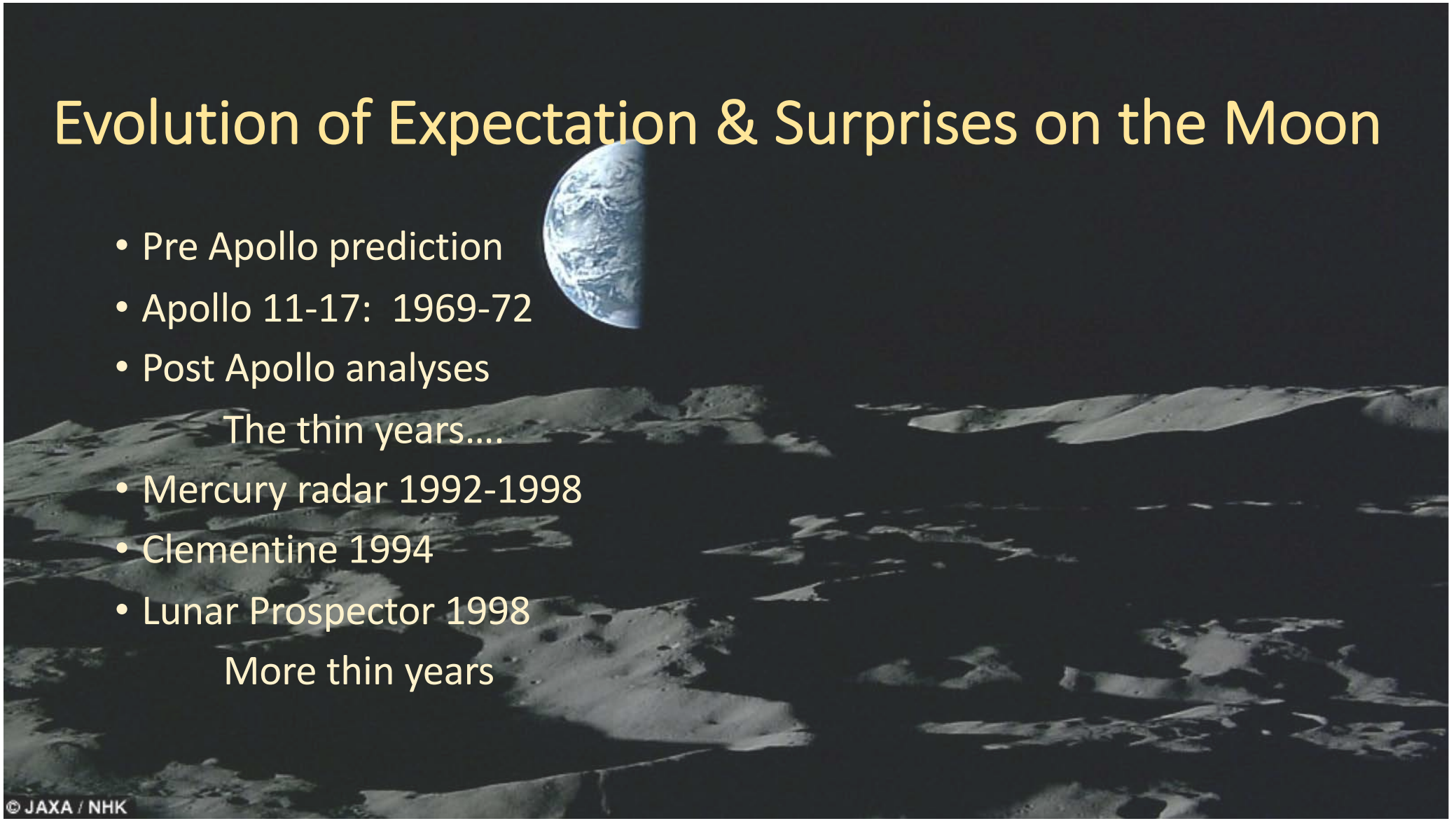

# Planetary Protection Categorization of Lunar Missions: Historical Context

Dr. Carlé M. Pieters

Brown University

CoPP September 18, 2020

# Evolution of Expectation & Surprises on the Moon




- Pre Apollo prediction
- Apollo 11-17:  1969-72
- Post Apollo analyses

  The thin years….
- Mercury radar 1992-1998
- Clementine 1994
- Lunar Prospector 1998

  More thin years

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1961 JGR

**The Behavior of Volatiles on the Lunar Surface**[1]

KENNETH WATSON, BRUCE C. MURRAY, AND HARRISON BROWN

*Division of Geological Sciences, California Institute of Technology*
*Pasadena, California*

*Abstract.* Volatiles, and water in particular, have been thought to be unstable on the lunar surface because of the rapid removal of constituents of the lunar atmosphere by solar radiation, solar wind, and gravitational escape. The limiting factor in removal of a volatile from the moon, however, is actually the evaporation rate of the solid phase, which will be collected at the coldest points on the lunar surface. We present a detailed theory of the behavior of volatiles on the lunar surface based on solid-vapor kinetic relationships, and show that water is far more stable there than the noble gases or other possible constituents of the lunar atmosphere. Numerical calculations indicate the amount of water lost from the moon since the present surface conditions were initiated is only a few grams per square centimeter of the lunar surface. The amount of ice eventually detected in lunar 'cold traps' thus will provide a sensitive indication of the degree of chemical differentiation of the moon.

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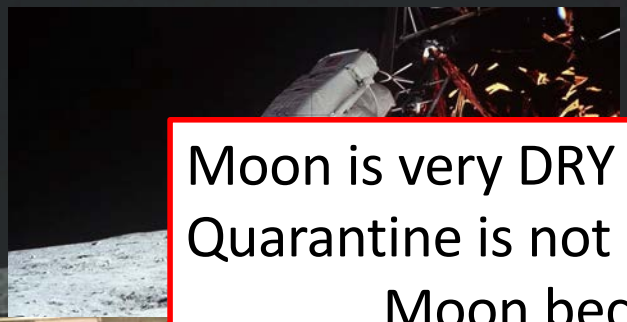

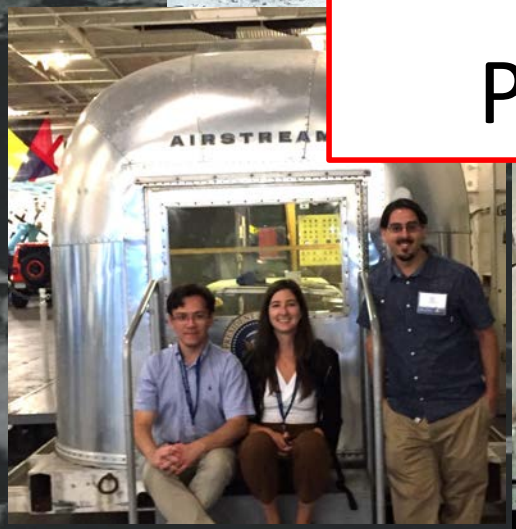

Moon is very DRY and very OLD
Quarantine is not necessary…..
Moon becomes

**PP Category I**

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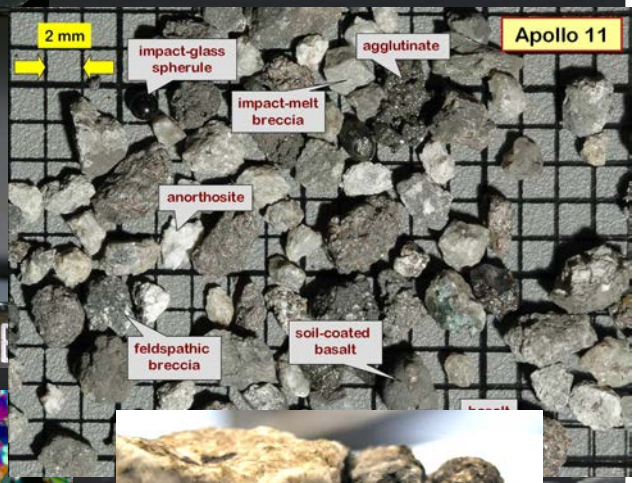


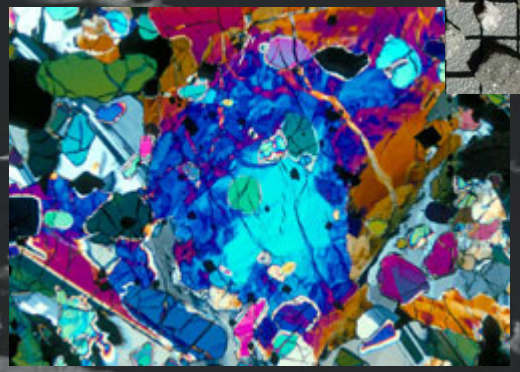


Lunar Samples!!

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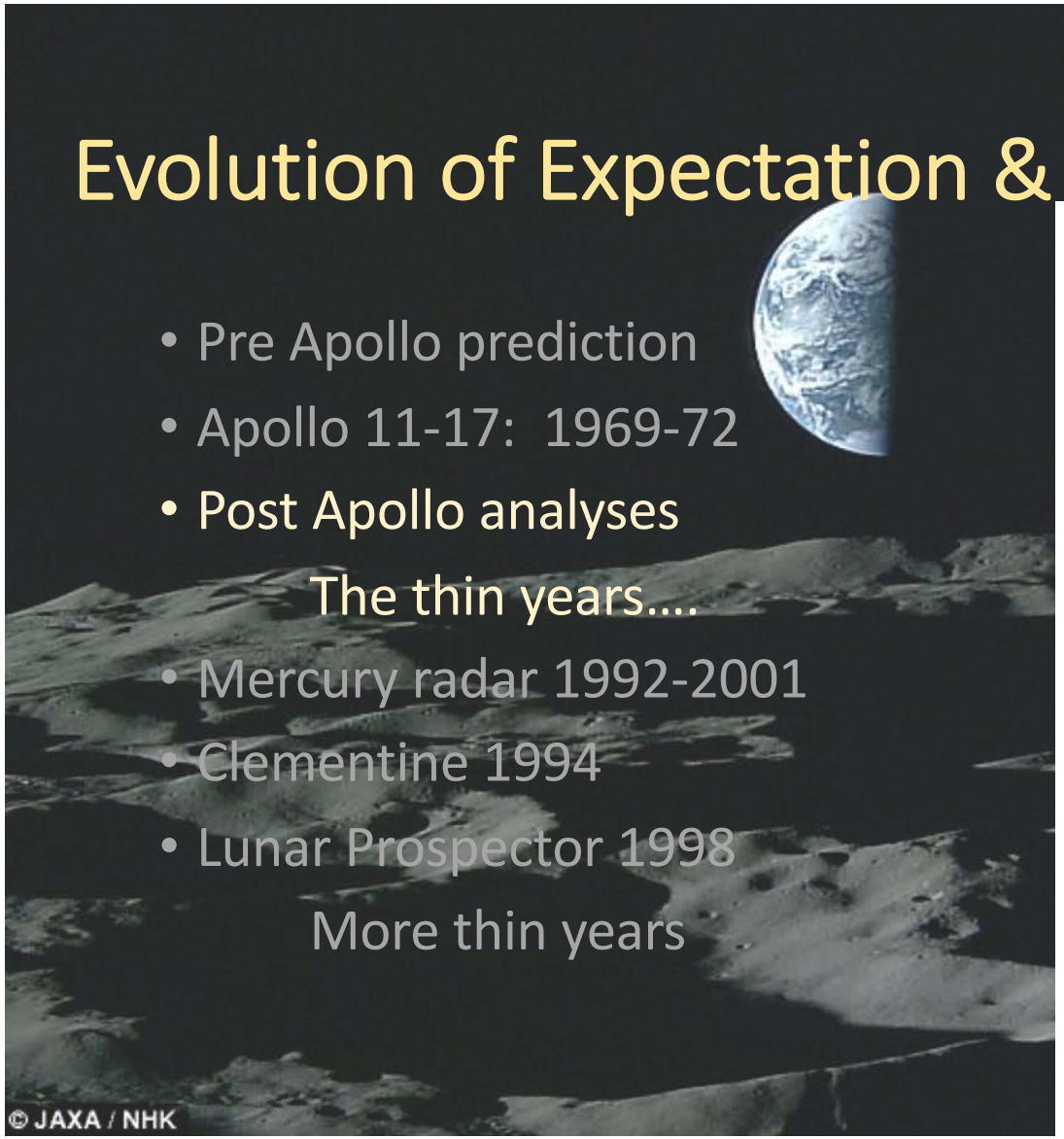


## ICE IN THE LUNAR POLAR REGIONS

JGR 1979

**James R. Arnold**

Abstract. The idea that ice and other trapped volatiles exist in permanently shadowed regions near the lunar poles was proposed by Watson, Murray, and Brown [1961]. It is reexamined in the present paper, in the light of the vast increase of our lunar knowledge. The stability of the traps and the trapping mechanism are verified. Four potential sources of lunar $H_2O$, (1) solar wind reduction of Fe in the regolith, (2) $H_2O$-containing meteoroids, (3) cometary impact, and (4) (the least certain) degassing of the interior, can supply amounts of trapped $H_2O$ estimated in the range of $10^{16}$–$10^{17}$ g. Two important destructive mechanisms have been identified: photodissociation of $H_2O$ molecules adsorbed on the sunlit surface and sputtering or decomposition of trapped $H_2O$ by solar wind particles. The effect of impact gardening is mainly protective. The question of the presence of $H_2O$ in the traps remains open; it can be settled by experiment.

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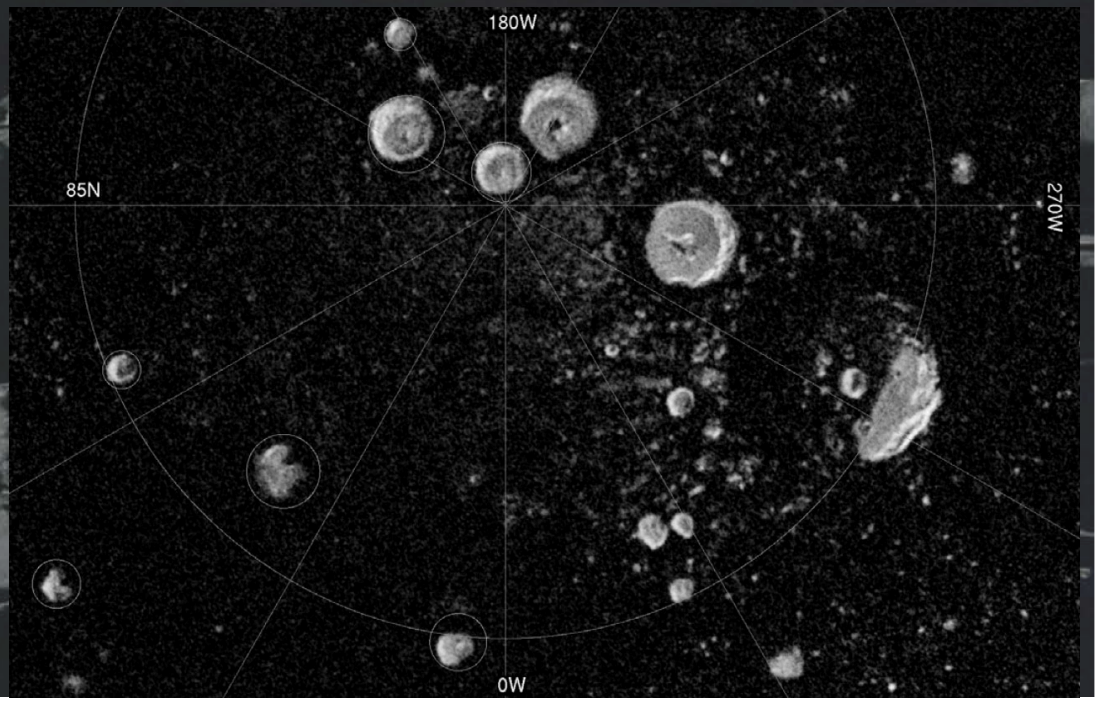
## Mercury PSRs: Radar **Bright** Deposits!

- *Science* (1992): Slade et al.; Harmon and Slade
- *Icarus* (2001): Harmon et al.



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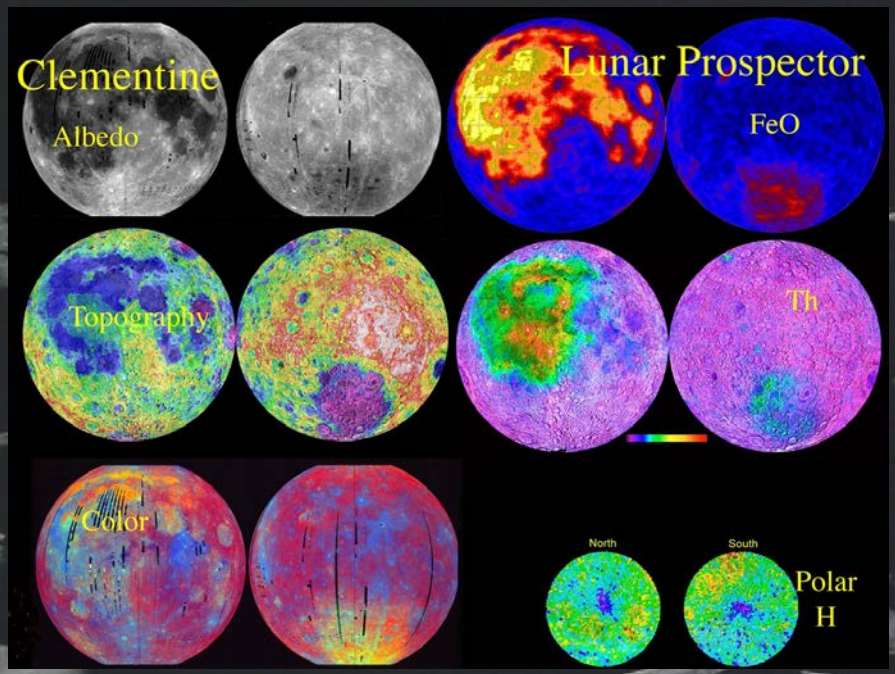

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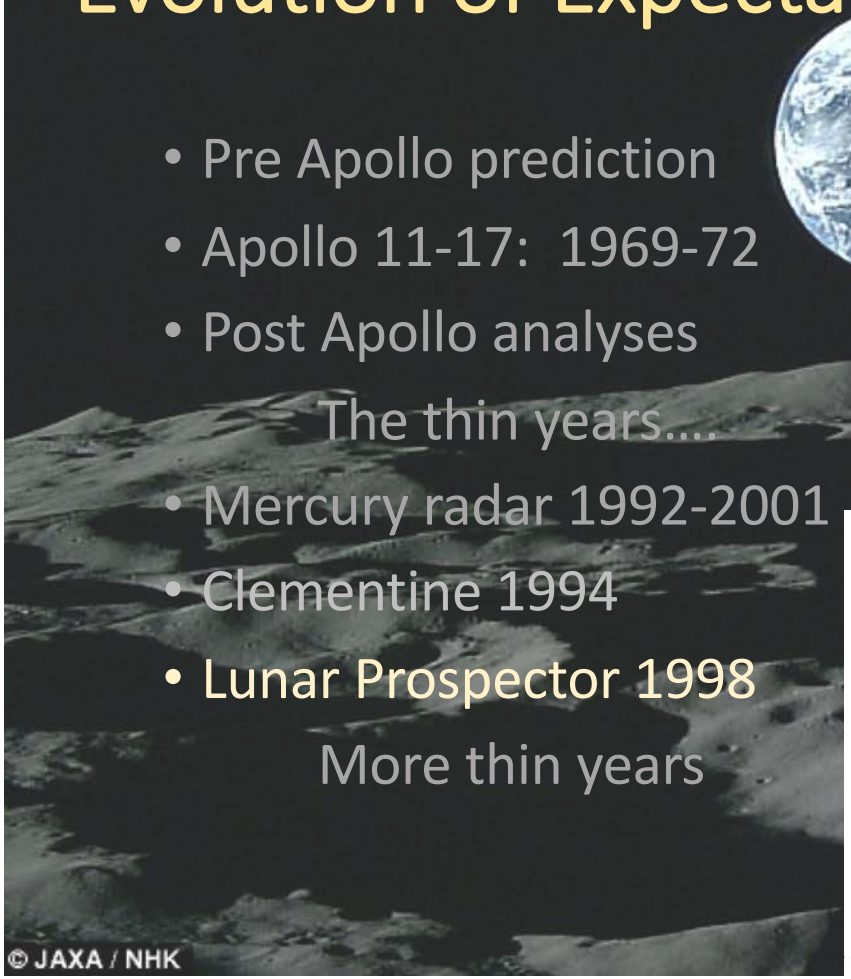
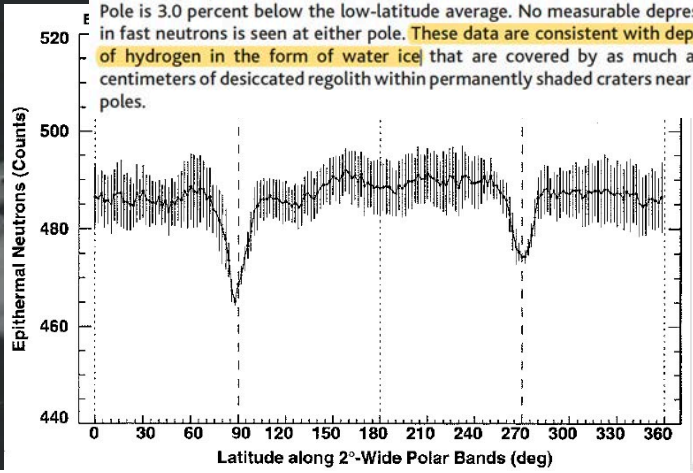
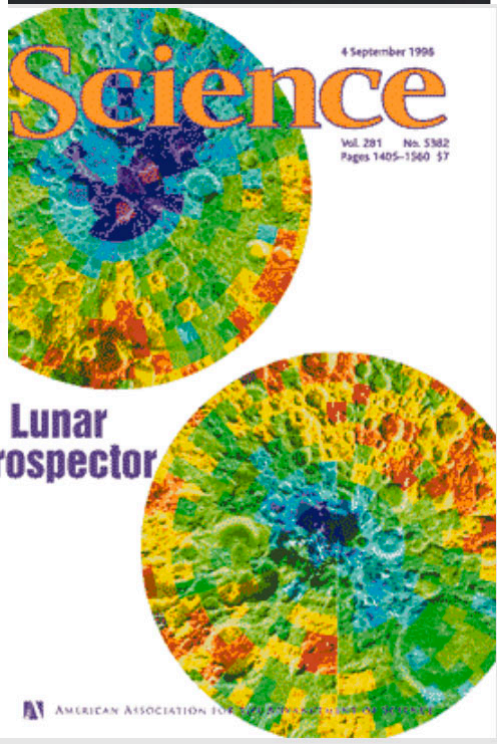



## Fluxes of Fast and Epithermal Neutrons from Lunar Prospector: Evidence for Water Ice at the Lunar Poles

W. C. Feldman,* S. Maurice, A. B. Binder, B. L. Barraclough, R. C. Elphic, D. J. Lawrence

Maps of epithermal- and fast-neutron fluxes measured by Lunar Prospector were used to search for deposits enriched in hydrogen at both lunar poles. Depressions in epithermal fluxes were observed close to permanently shaded areas at both poles. The peak depression at the North Pole is 4.6 percent below the average epithermal flux intensity at lower latitudes, and that at the South Pole is 3.0 percent below the low-latitude average. No measurable depression in fast neutrons is seen at either pole. These data are consistent with deposits of hydrogen in the form of water ice that are covered by as much as 40 centimeters of desiccated regolith within permanently shaded craters near both poles.



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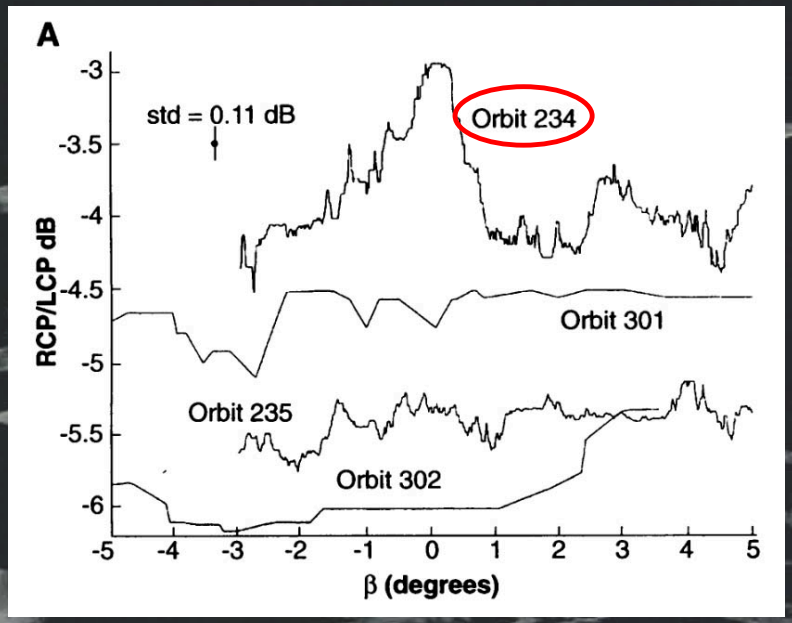
- Nozette et al., (1996) Science; -- Science (1997); --- (2001) *JGR*




One orbit of bi-static radar measurements suggest enhancement over lunar south pole permanently shadowed area => ICE ?

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More thin years

COSPAR PP Policy October 2002:

Moon is assigned

**Category II** (with organic inventory)

And

**Category V** (unrestricted Earth return)

# Evolution of Expectation & Surprises on the Moon

*International* interest **expands** seriously:

- SMART-1 2003 [ESA] ➢Solar electric; Technology demonstration
- Selene 2007 [JAXA] ➢Advanced instruments; global coverage
- Chang'e 1 2007 [CNSA] ➢First of 5 lunar orbiter and lander missions
- Chandrayaan-1 2008 [ISRO] ➢First ISRO launch beyond LEO
- LRO 2009 [USA/NASA] ➢Advanced ***LONG-LIVED*** instruments; global
  [+LCROSS 'ride share'] ➢Instrumented impact into lunar PSR

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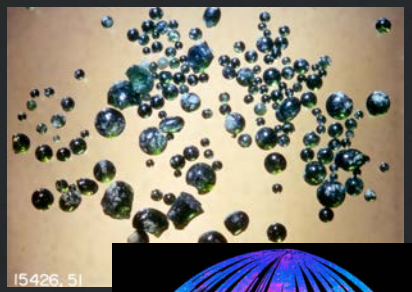
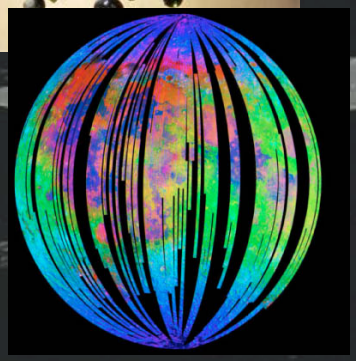
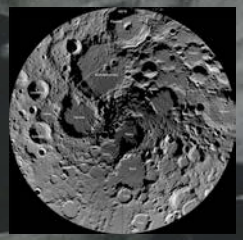
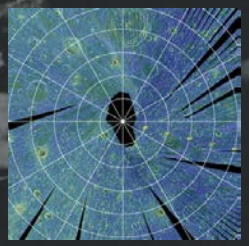
# In 2008-2010 we learned there are at least *three* types of water on the Moon

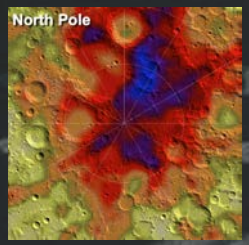
- Interior (primordial, ancient)
- Surficial (ongoing; recent)
- Buried (accumulated at the poles)











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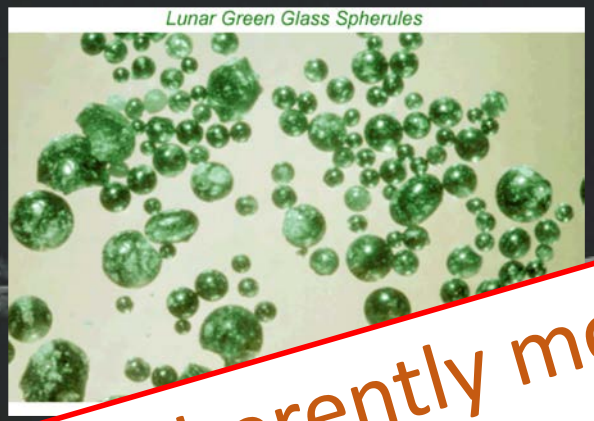
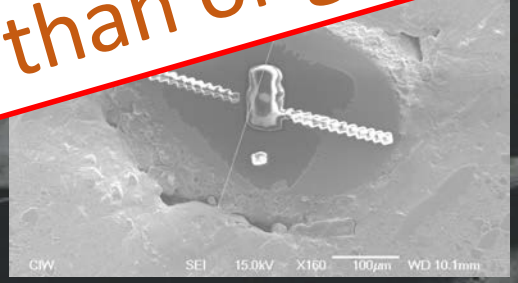
Lunar Samples: the 'gift that keeps on giving….'

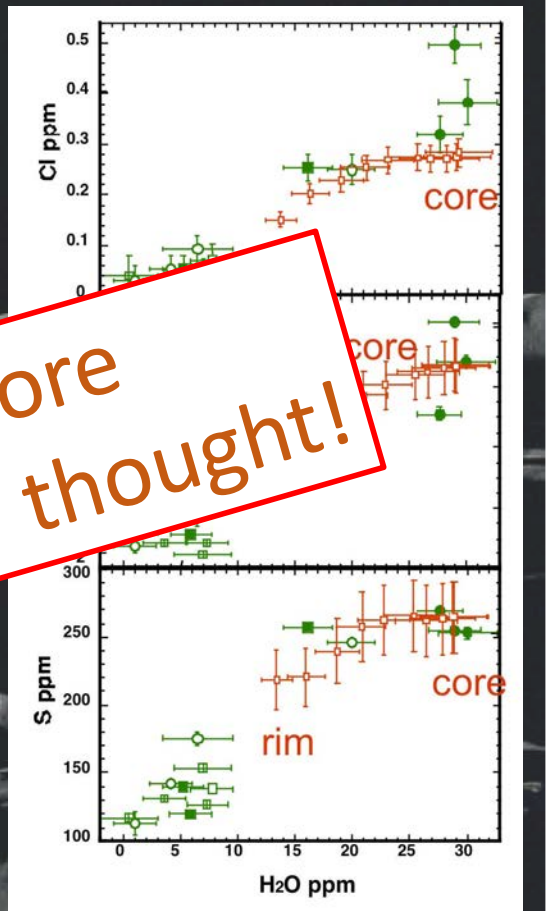
- Advanced instruments
- Address new issues….

Saal et al. *Nature* 454, 192-195 (2008); Hauri et al., (2011) measured the water content across individual Apollo 15 green glass beads: Degassing suggested an initial water conc 750 ppm….. Melt inclusi volatile contents of lunar equivalent to those found



**The Moon Is inherently more water-rich than originally thought!**




© JAXA / NHK

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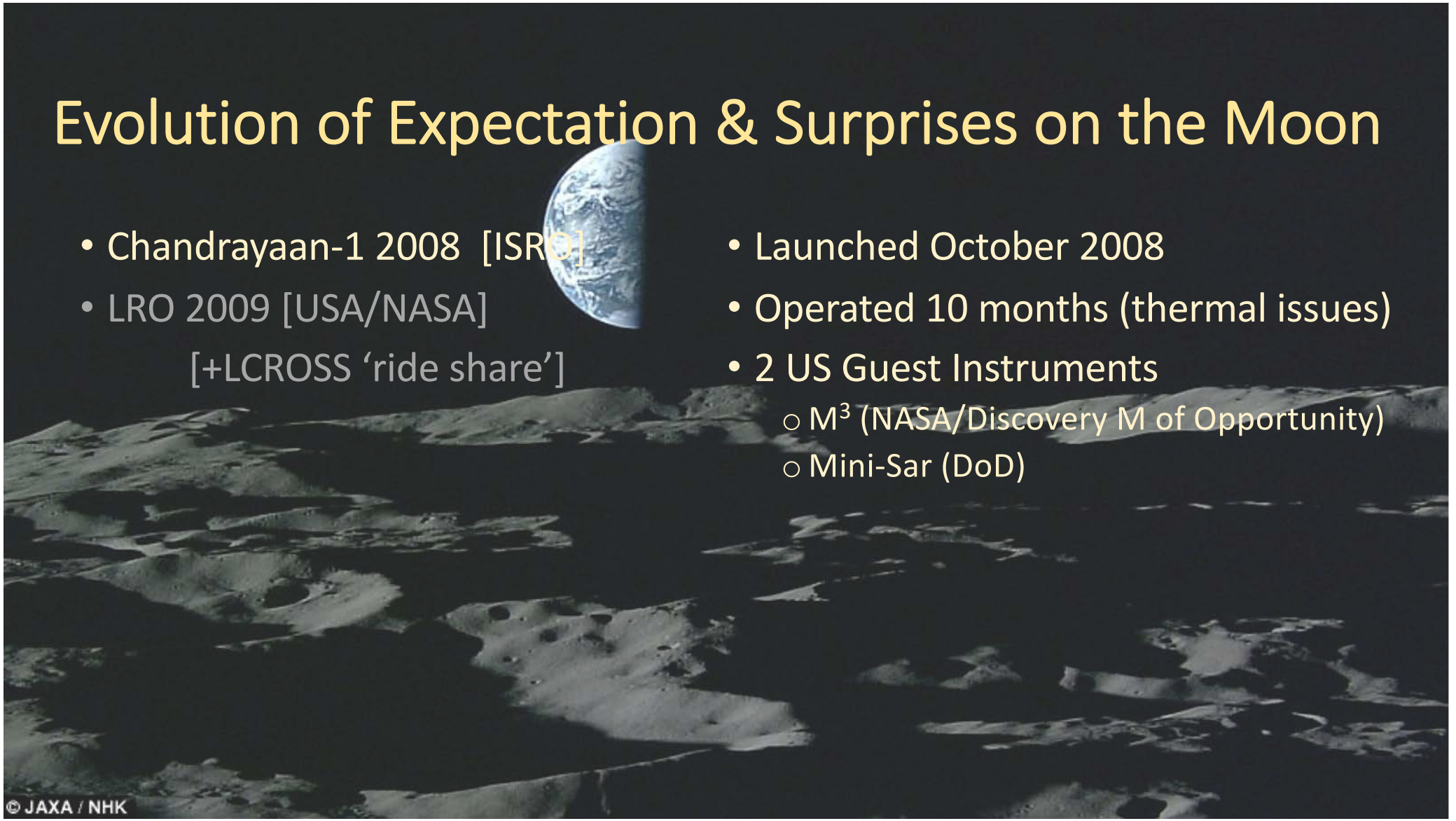


- Chandrayaan-1 2008 [ISRO]
- LRO 2009 [USA/NASA]
  [+LCROSS 'ride share']

- Launched October 2008
- Operated 10 months (thermal issues)
- 2 US Guest Instruments
  - $M^3$ (NASA/Discovery M of Opportunity)
  - Mini-Sar (DoD)

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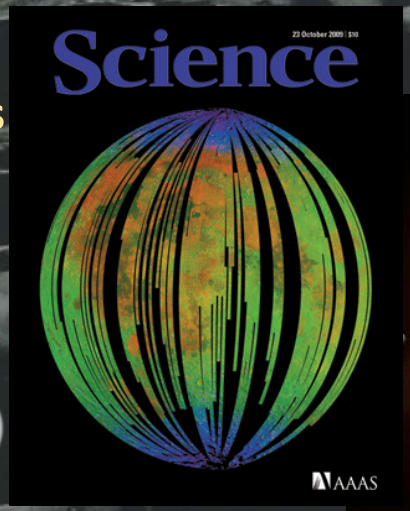
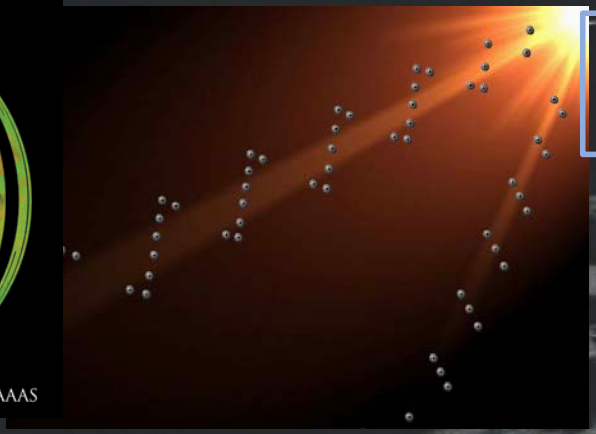
**NearIR spectroscopy discovers Widespread surficial $OH/H_2O$!**
*Science*, 326, 2009
- C Pieters (the $M^3$ Team)
- R Clark (VIMS)
- J Sunshine (the DI Team)



$H^+ + O^= = OH^-$
$H^+ + OH^- = HOH$

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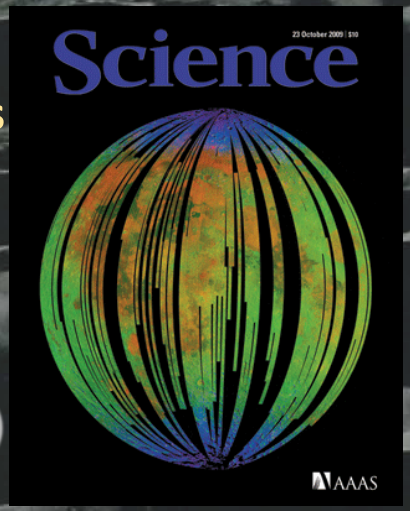
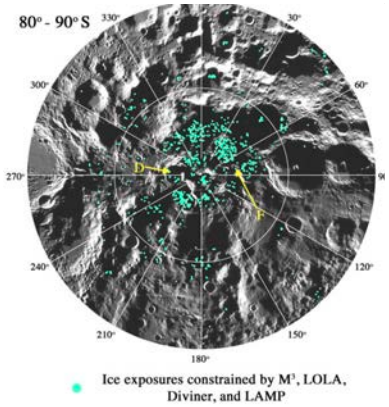



Later, ***S. Li et al. (2018) PNAS*** identified ice-bearing pixels at the poles using M3 data.



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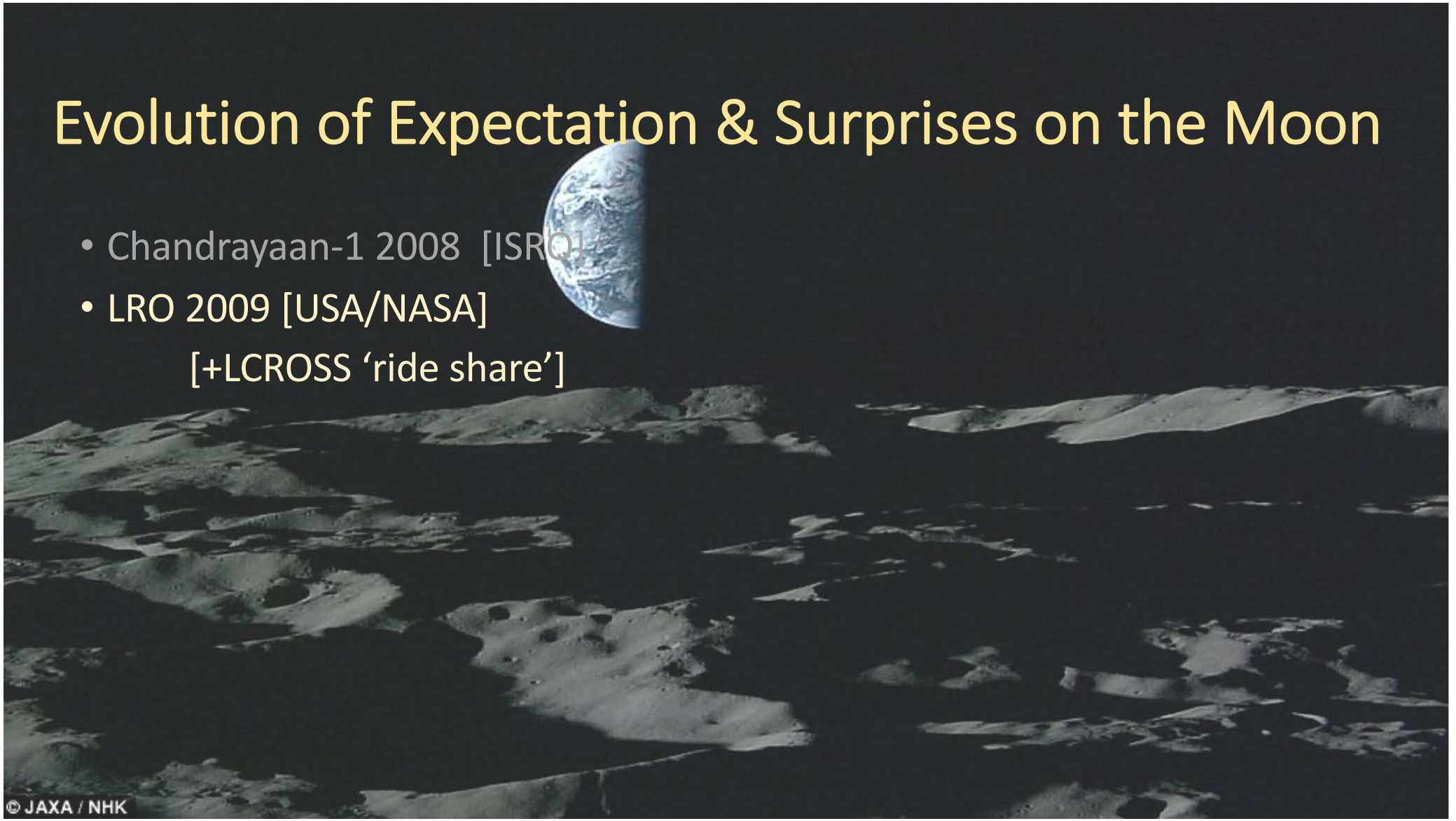


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  [+LCROSS ‘ride share’]

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**Still providing fundamental data!!**

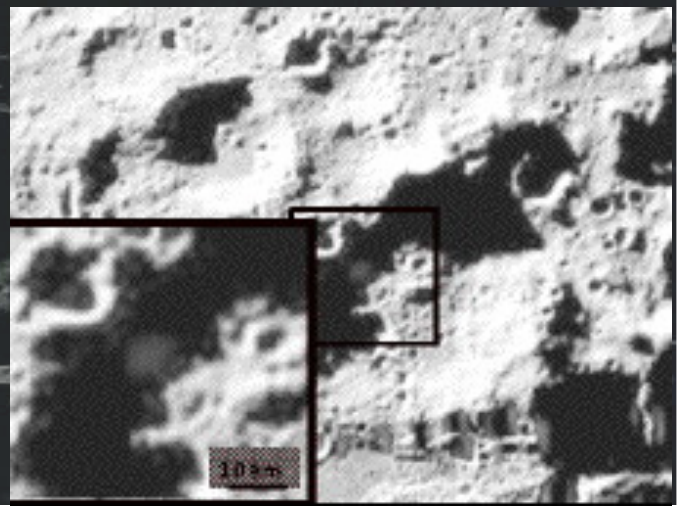
- LROC WAC & NAC Global images
- DIVINER Global thermal assessment
- LOLA Global topography
- LAMP UV spectrometer
- LEND Neutron Spectrometer (Russia)
- Mini-RF radar

# Evolution of Expectation & Surprises on the Moon

- Chandrayaan-1 2008 [ISRO]
- LRO 2009 [USA/NASA]

  [+LCROSS 'ride share']

- LCROSS targeted an impactor onto a key PSR at the South Pole: Water and many other volatile components were excavated and identified in this permanently shadowed "cold trap" by a trailing S/C.



# Lunar Water Origin and Solar System History

Today we recognize 3 forms of lunar water:

- Interior (primordial)
- Surficial (SW interaction)
- Polar (PSR or buried)

We expect the poles to have accumulated volatiles from multiple sources over eons and is likely to be a unique SS record. **TBD!**

NASA recommended new PP classes for the Moon, July 2020 NID:

- I-L: All lunar areas except A & B
- II-L: Exceptions [with redefined documentation - *only* biological]
  - A. PSRs
  - B. Apollo landing and historic sites

"Because there is incomplete knowledge of transport mechanisms on the lunar surface, this NID is subject to change if new information about lunar environments indicate a different planetary protection categorization should be used for such missions."

# Concerns

- The [as yet to be characterized] lunar polar volatile deposits are likely to have accumulated over billions of years of Solar System history.
- As such, they would be a *UNIQUE* record of Solar System volatiles, some of which may contain important clues for the evolution of life.
- Given the incomplete knowledge of transport across the lunar surface, it would be wise to prevent further contamination of these special deposits before their value can be assessed.