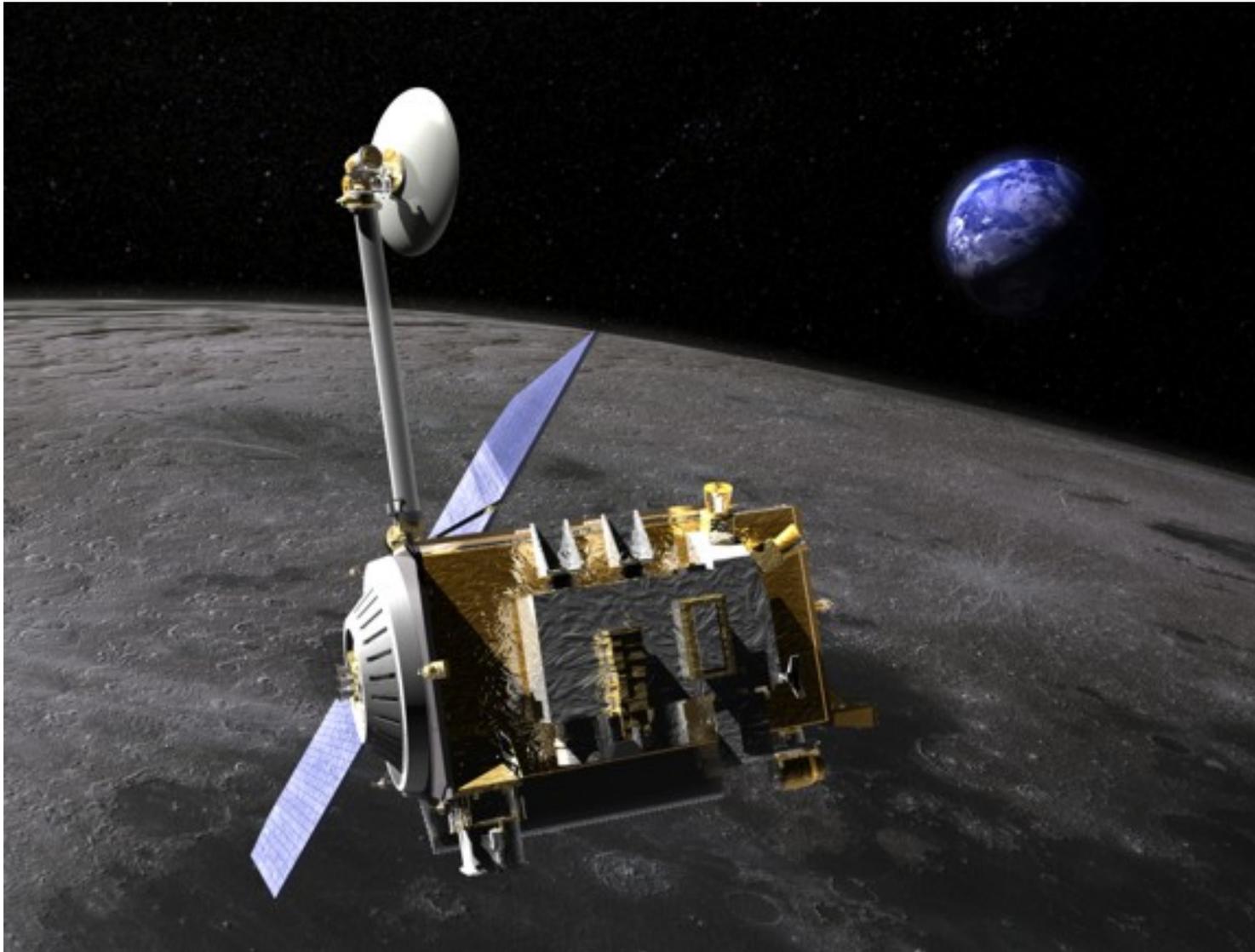


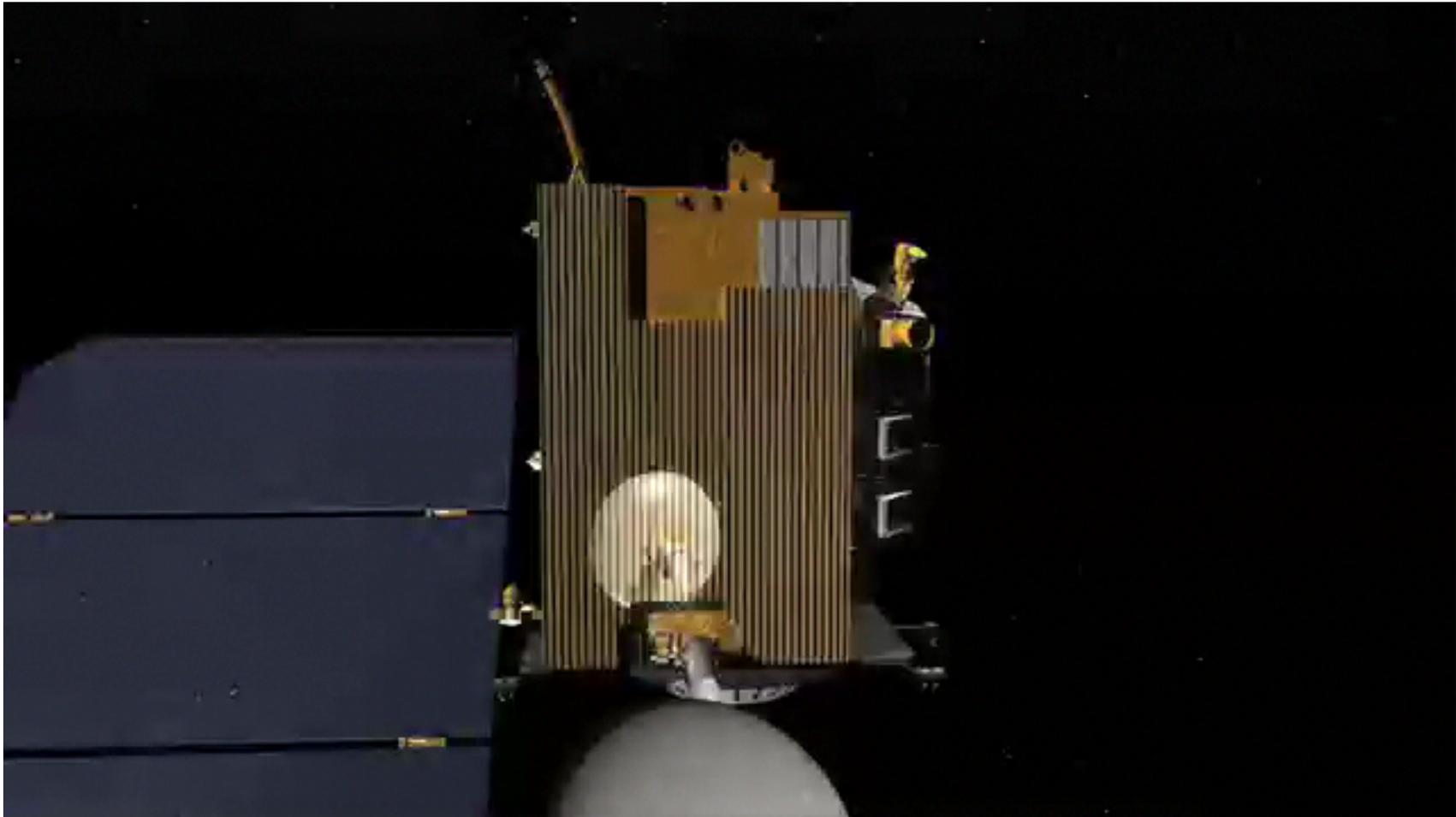


# The Lunar Reconnaissance Orbiter:- Highlights and Looking Forward





# LRO has 7 Instruments





## LRO Key Dates – Five Years of Successful Operations

First NLSI Forum	20-Jul-08
Launch	18-Jun-09
Commissioning Orbit (30 x 216 km) established	27-Jun-09
Insert into Mapping Orbit (50 ±15 km)	16-Sep-09
LCROSS Impact	9-Oct-09
First Public Release of LRO Data From Planetary Data System (total at least 500 Tbytes through May)	3/15/2010 and every 3 months
Begin Science Phase	17-Sep-10
Begin First Extended Mission	17-Sep-12
Complete First Extended Science Mission	16-Sep-14
Complete proposed Second Extended Science Mission	16-Sep-16



# Rim of Shackleton Crater





# LRO's Second Extended Mission – Five Themes



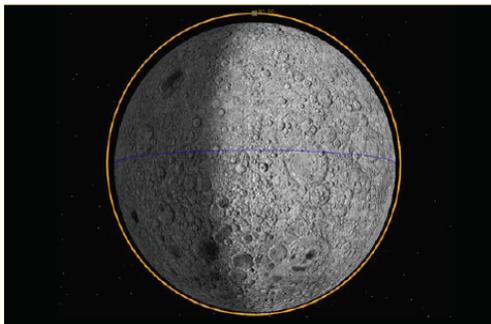
- **Transport of Volatiles**
  - How are volatile elements and compounds distributed, transported, and sequestered in near-surface environments on the surfaces of the Moon and Mercury?
- **Contemporary Surface Change**
  - What causes changes in the flux and intensities of meteoroid impacts onto terrestrial planets
- **Regolith Evolution**
  - Characterize planetary surfaces to understand how they are modified by geologic processes.
- **Probing the Interior from Observations of the Surface**
  - Characterize planetary interiors to understand how they differentiate and evolve from their initial state
- **Interactions with the Space Environment**
  - How is surface material modified exogenically?
  - How do exospheres form, evolve, and interact with the space environment?



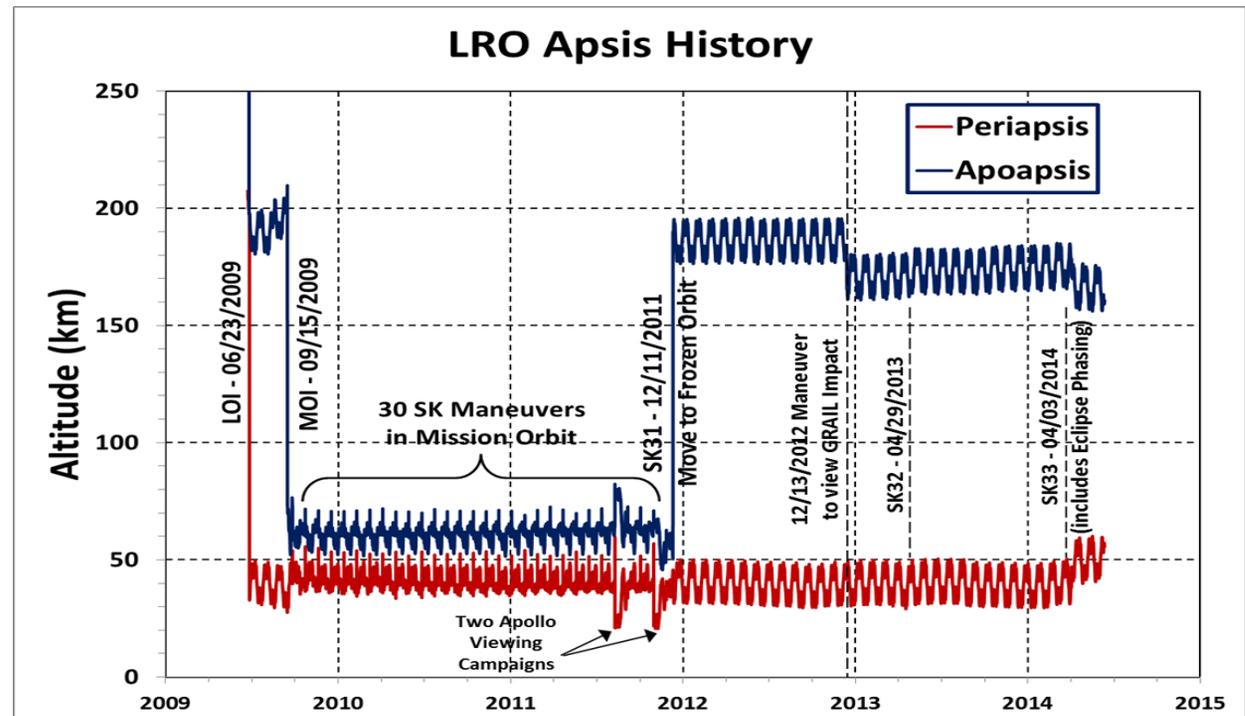
## LRO Orbits – Maximizing Science and S/C Resources



- LRO initially placed in a 30 x 216 km quasi-frozen polar orbit for commissioning
- Moved to  $50 \pm 15$  km orbit on 9/15/09 for science mission
- Low-periapsis (21 km) orbits in August & November of 2011
- LRO returned to a quasi-frozen orbit on 12/11/11 with decreasing inclination for Extended Science Missions
- Anticipated orbital lifetime at least eight years of fuel remaining



30 x 216 km Altitude  
Quasi-Frozen Orbit





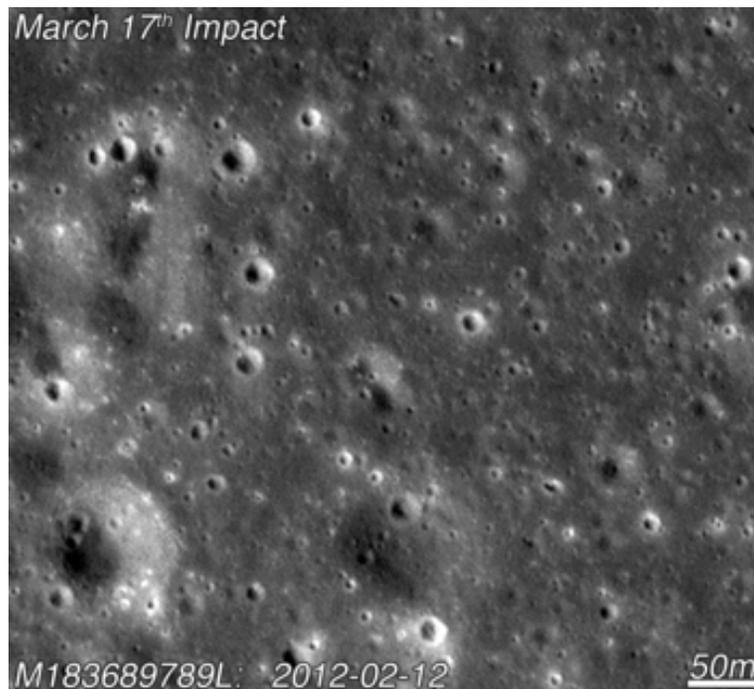
## The LRO Second Extended Mission Science Themes:

**Change at the Moon - on the surface, beneath the surface, and in the exosphere.**

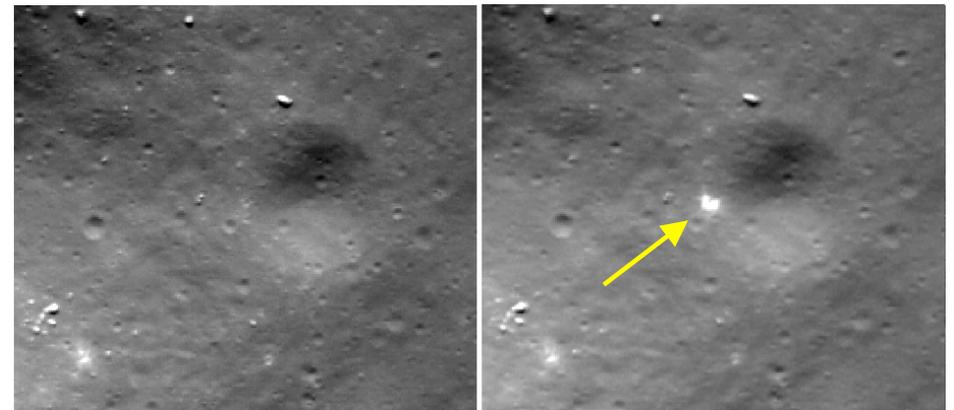


### ESM2 Theme: Contemporary Surface Change

- LRO will survey fresh (LRO era) impacts to determine their global abundance and the current flux of small meteorites while elucidating new information on impact dynamics.



LROC image of 18 m diameter impact crater formed March 17, 2013. Impact flash was observed by MSFC Automated Lunar and Meteor Observatory



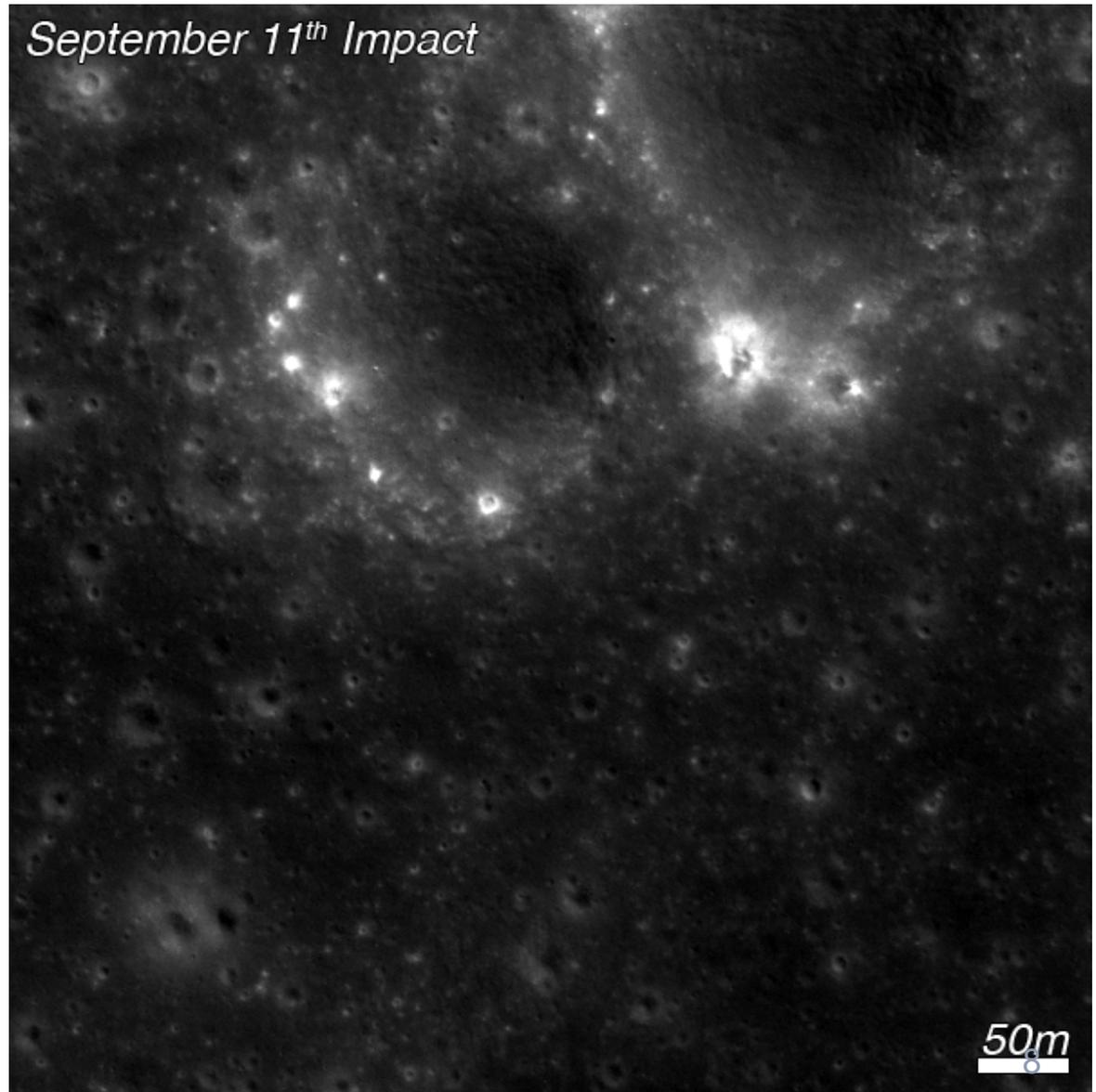
Before and after LROC NAC images showing one of many distinctive white splotches that the LROC team is finding in temporal comparisons. Such features are found as far as 30 km from the March 17 impact site.



# 11 Sept 2013 Impact Event



- Reported as bright flash by Moon Impacts Detection and Analysis System (MIDAS) team, Seville Spain
- Estimated crater diameter 46 -56 m
- Actual crater diameter 36 m
- Calibrate ground based observations



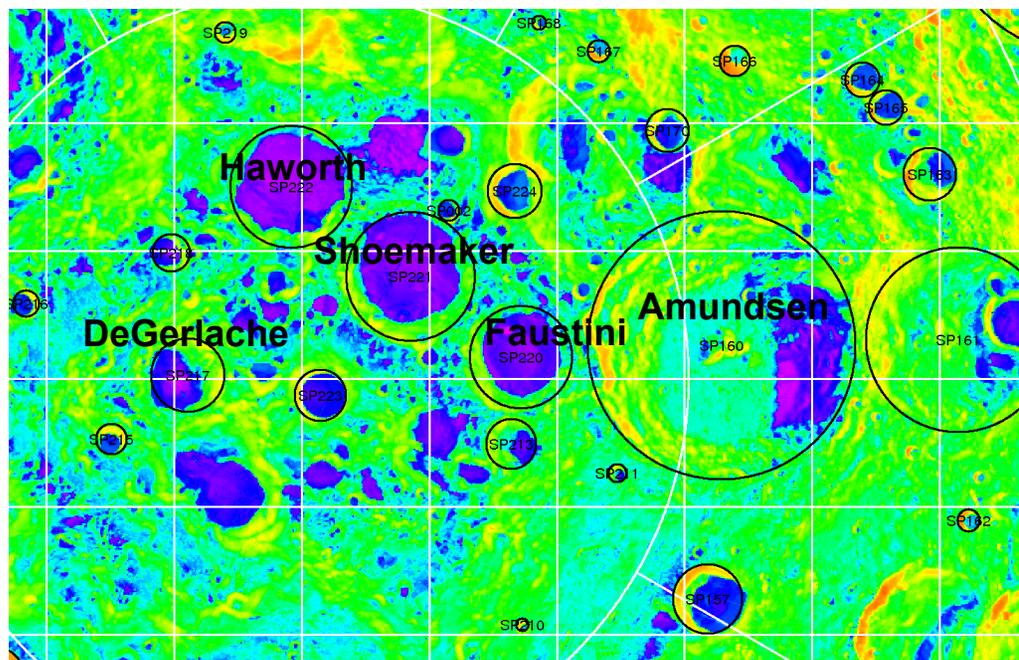
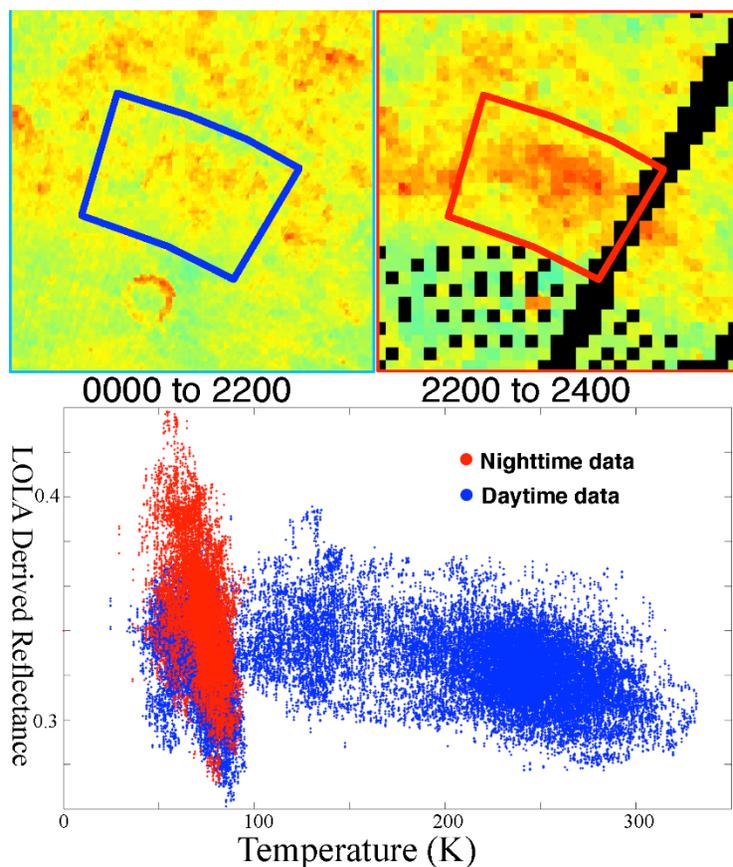


# The LRO Second Extended Mission Science Themes: Change at the Moon - on the surface, beneath the surface, and in the exosphere.



## ESM2 Theme - Transport of Volatiles

### LRO Observation of Temperature Dependent Reflectivity changes



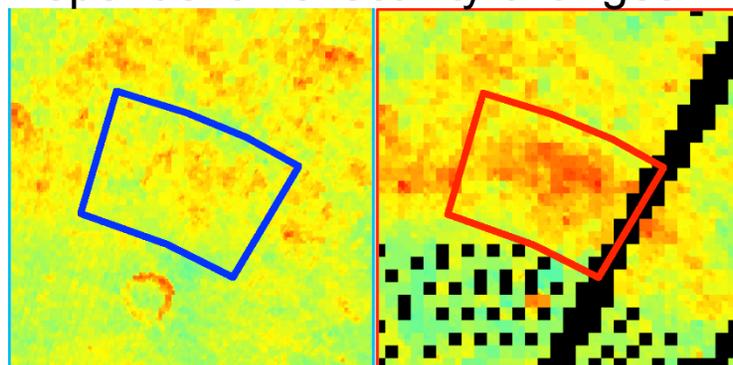


# The LRO Second Extended Mission Science Themes: Change at the Moon - on the surface, beneath the surface, and in the exosphere.



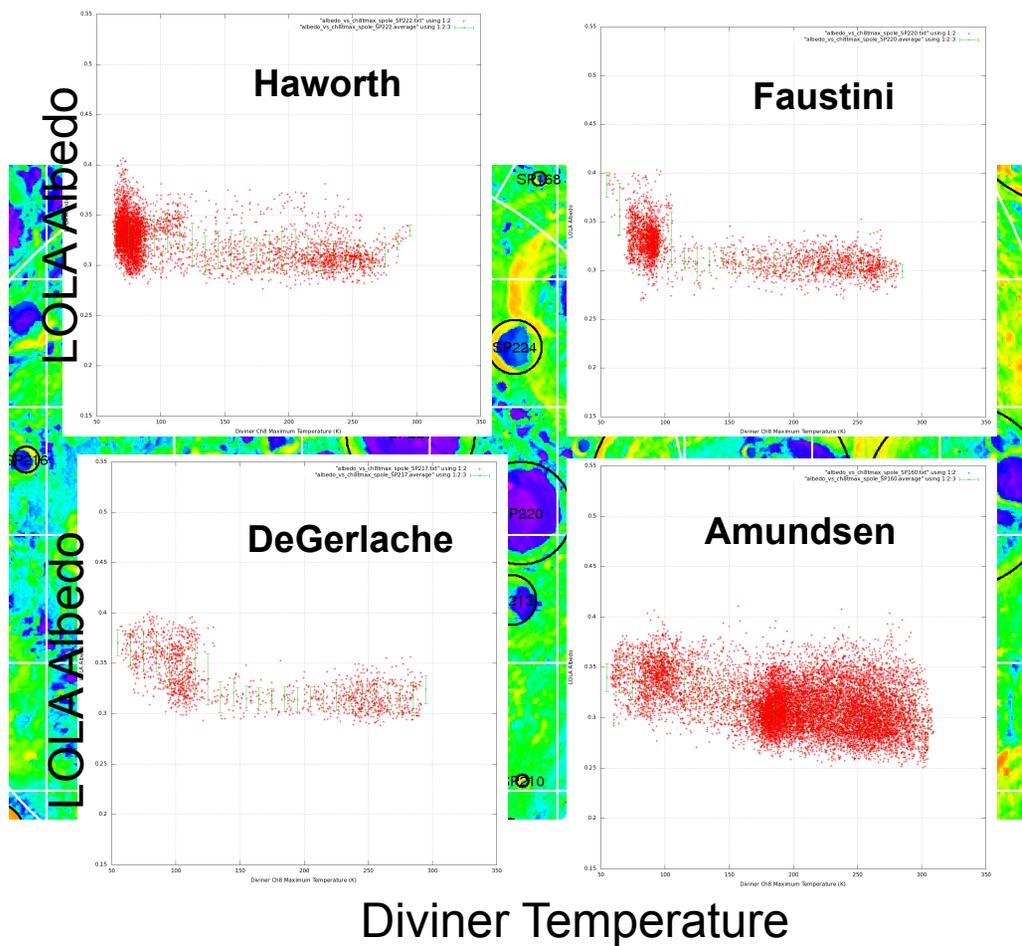
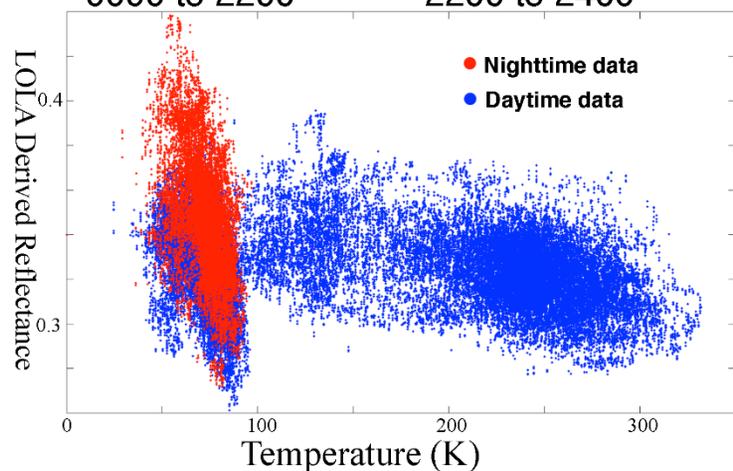
## ESM2 Theme - Transport of Volatiles

### LRO Observation of Temperature Dependent Reflectivity changes



0000 to 2200

2200 to 2400

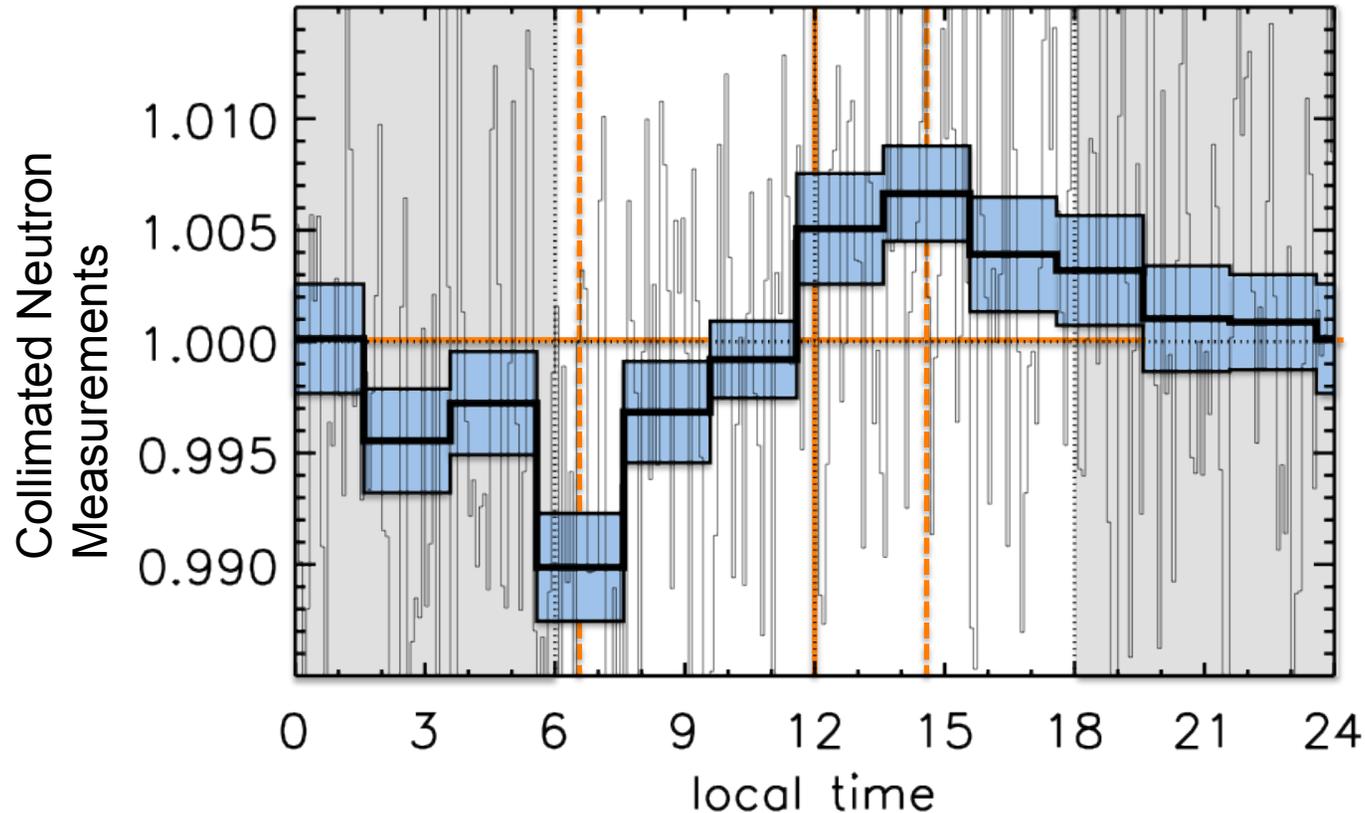




# The LRO Second Extended Mission Science Themes: Change at the Moon - on the surface, beneath the surface, and in the exosphere.



## ESM2 Theme - Transport of Volatiles



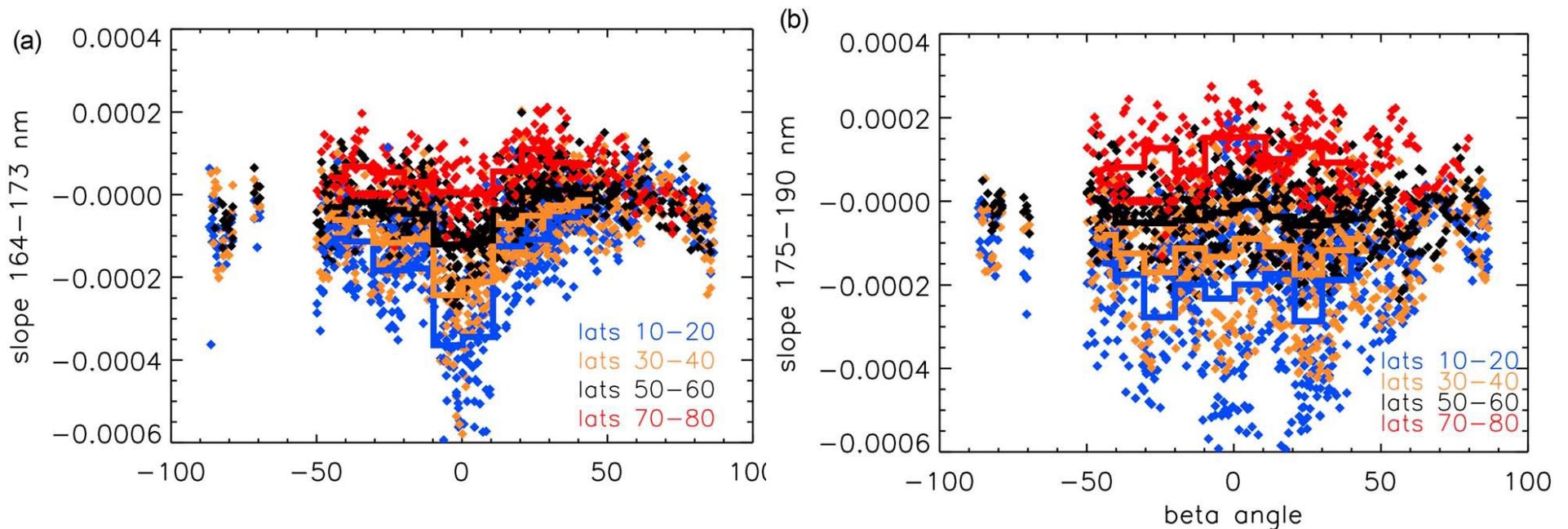
A time-of-day dependence of Epithermal Neutron measurements is beginning to emerge from the data. A drop in epithermal count rate is indicative of water mixed in with the regolith.



# The LRO Second Extended Mission Science Themes: Change at the Moon - on the surface, beneath the surface, and in the exosphere.



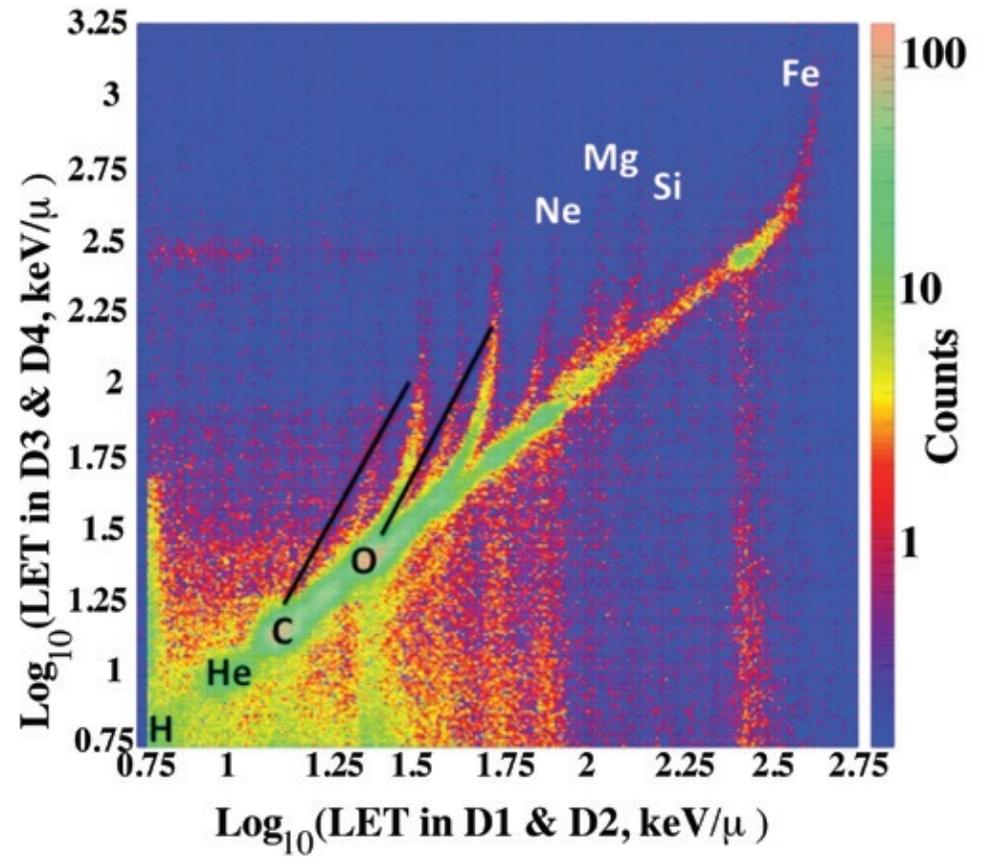
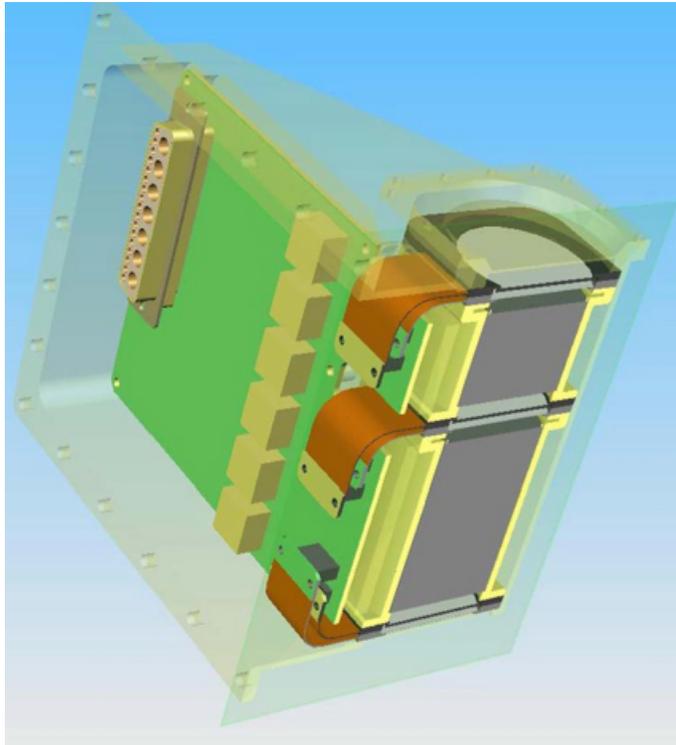
## ESM2 Theme - Transport of Volatiles



164-173 nm far UV band is sensitive to water the 175 – 190 nm band is not. These data show a clear time-of-day dependence of the spectral slopes for the former vs. the latter

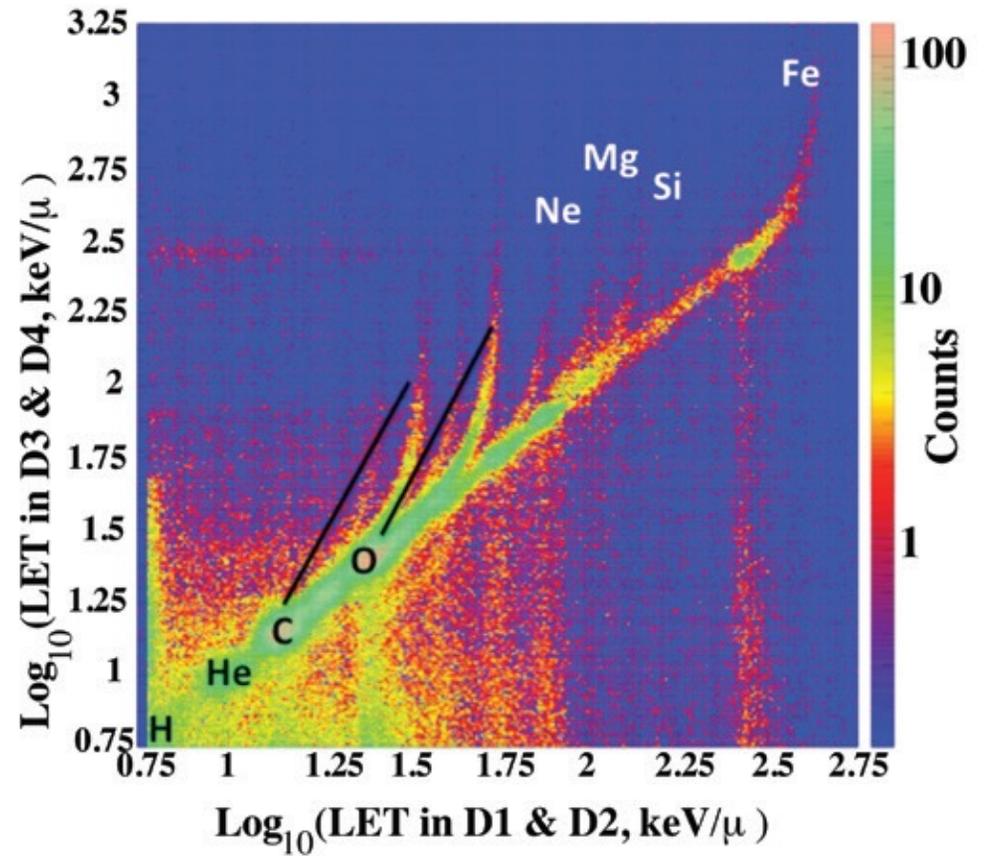
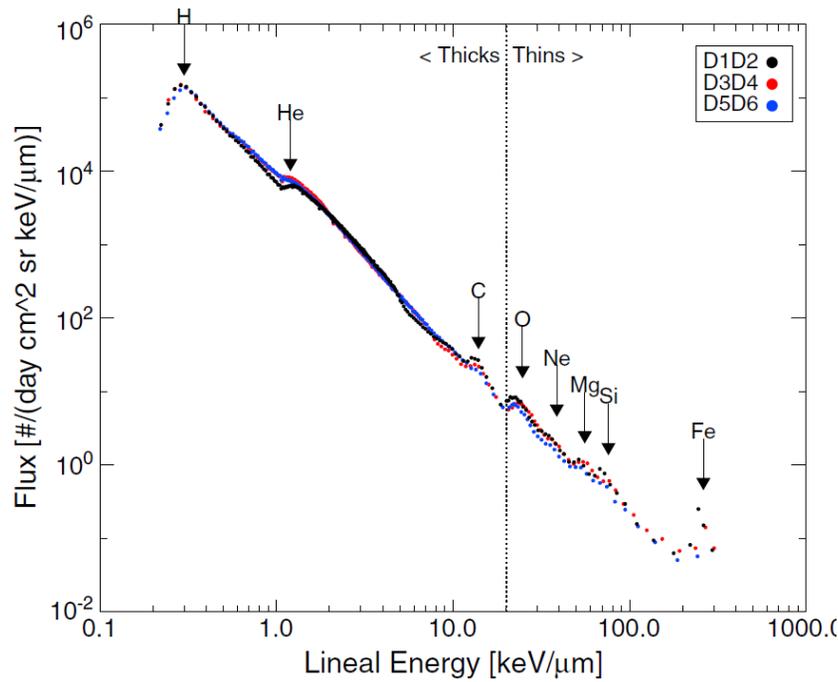


# CRaTER: Heavy Atom Cosmic Rays



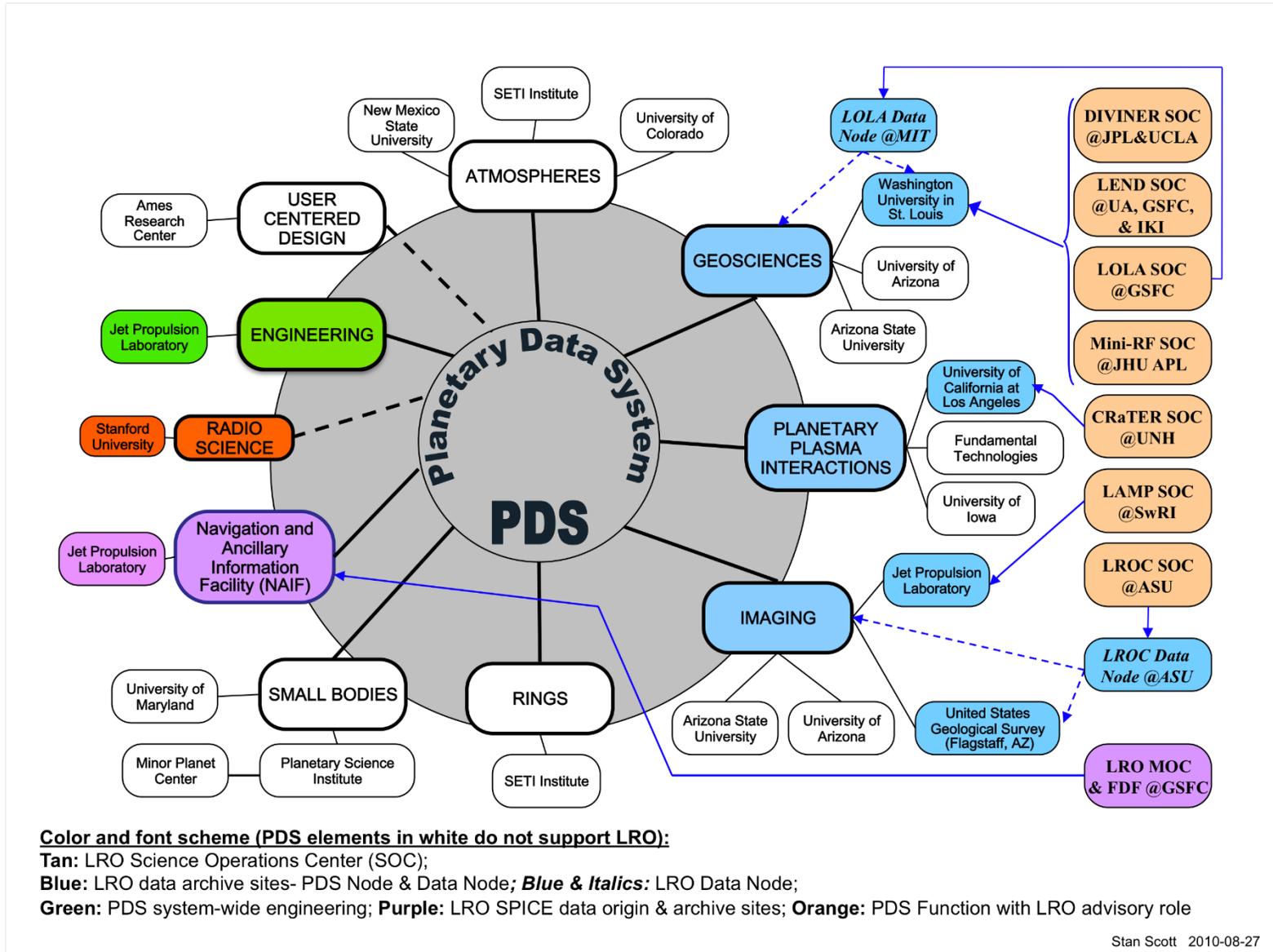


# CRaTER: Heavy Atom Cosmic Rays



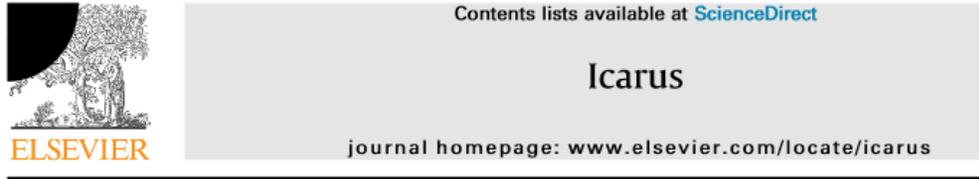


# LRO SOC's & PDS Support





# LRO Data is Widely Used.



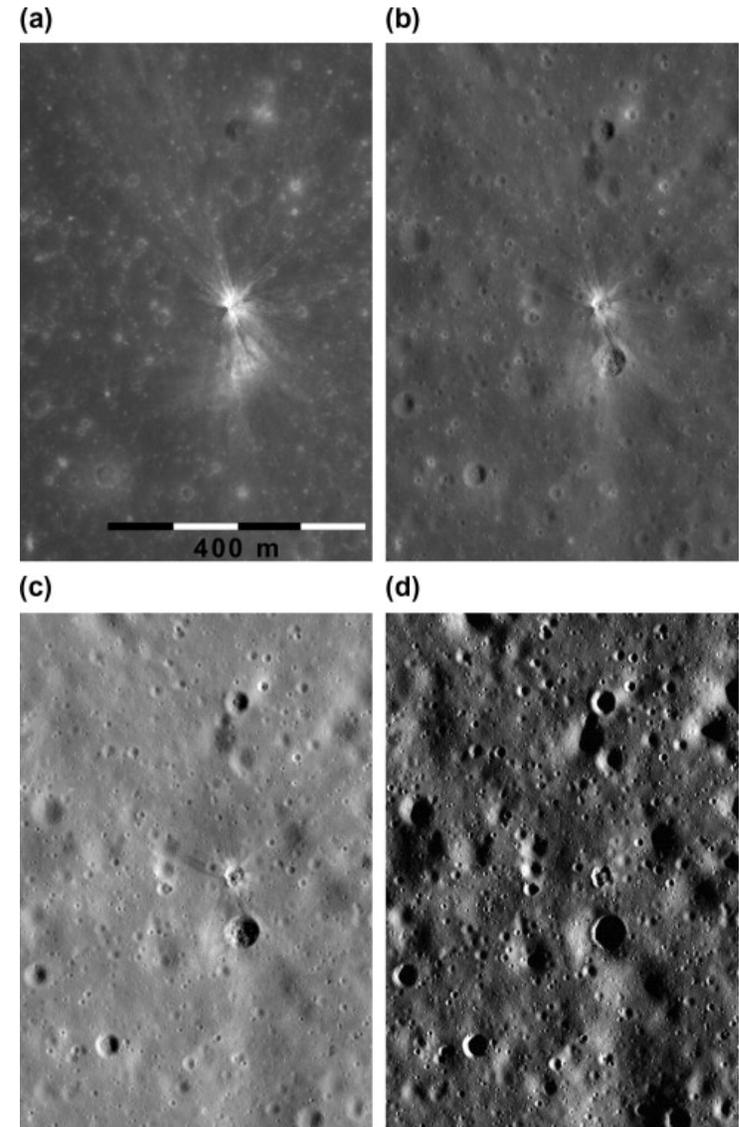
Dark halos and rays of young lunar craters: A new insight into interpretation

Vadym Kaydash<sup>a</sup>, Yuriy Shkuratov<sup>a</sup>, Gorden Videen<sup>b,\*</sup>

<sup>a</sup>Astronomical Institute of Kharkov V.N. Karazin National University, Sumskaya 35, Kharkov 61022, Ukraine

<sup>b</sup>Space Science Institute, 4750 Walnut St. Suite 205, Boulder, CO 80301, USA

- Extensive LROC data set enables phase angle analysis to draw conclusions on the properties of the regolith
- In ESM2 the full photometric function (variable incident and emission angle) will be extended to higher latitudes. Variable emission angle measurements will be made in the IR (Diviner).





# LRO Data also serving the SSERVI Teams



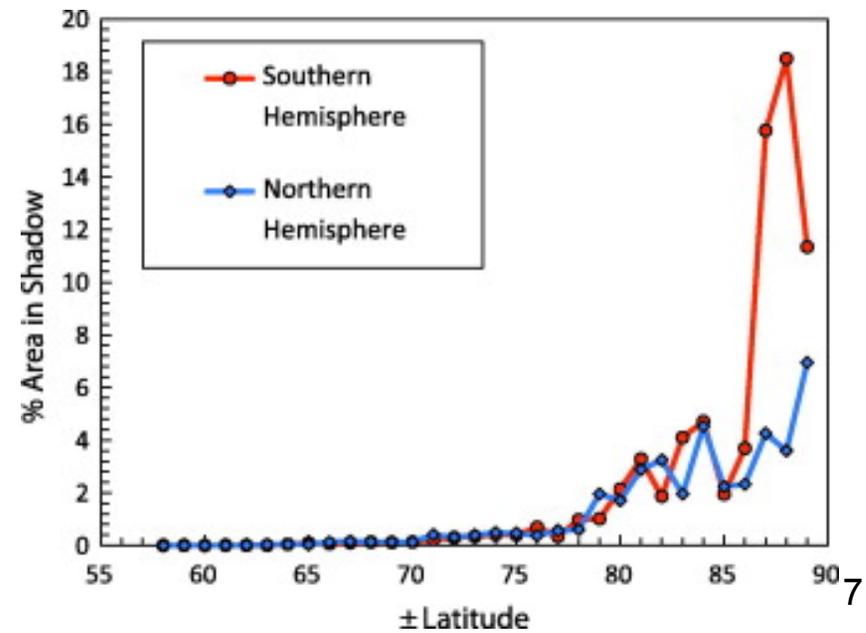
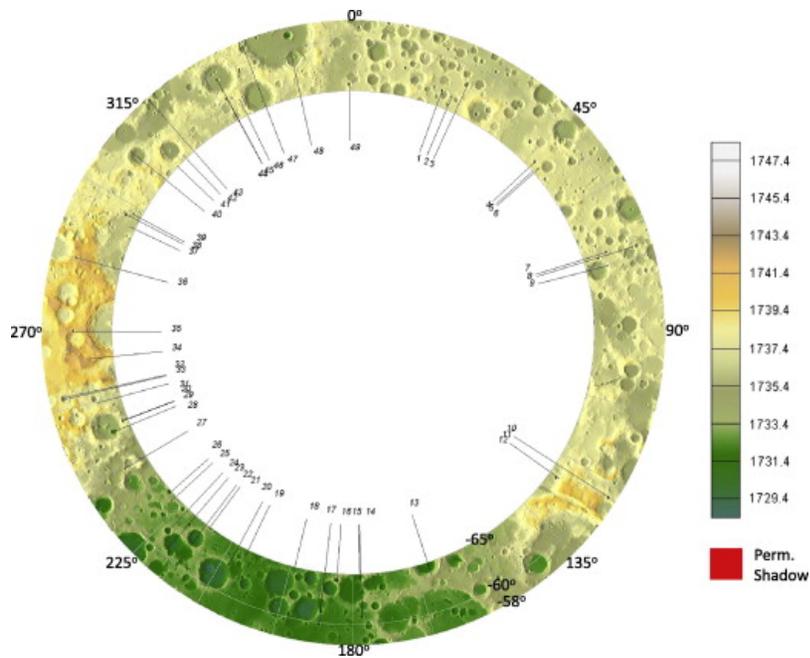
Icarus

Volume 223, Issue 1, March 2013, Pages 566–581



## Mapping and characterization of non-polar permanent shadows on the lunar surface

J. Andrew McGovern<sup>a</sup>, D. Benjamin Bussey<sup>a</sup>, Benjamin T. Greenhagen<sup>b</sup>, David A. Paige<sup>c</sup>, Joshua T.S. Cahill<sup>a</sup>, Paul D. Spudis<sup>d</sup>





# LRO Data also serving the SSERVI Teams



Contents lists available at [SciVerse ScienceDirect](http://SciVerse.ScienceDirect.com)

Earth and Planetary Science Letters

journal homepage: [www.elsevier.com/locate/epsl](http://www.elsevier.com/locate/epsl)



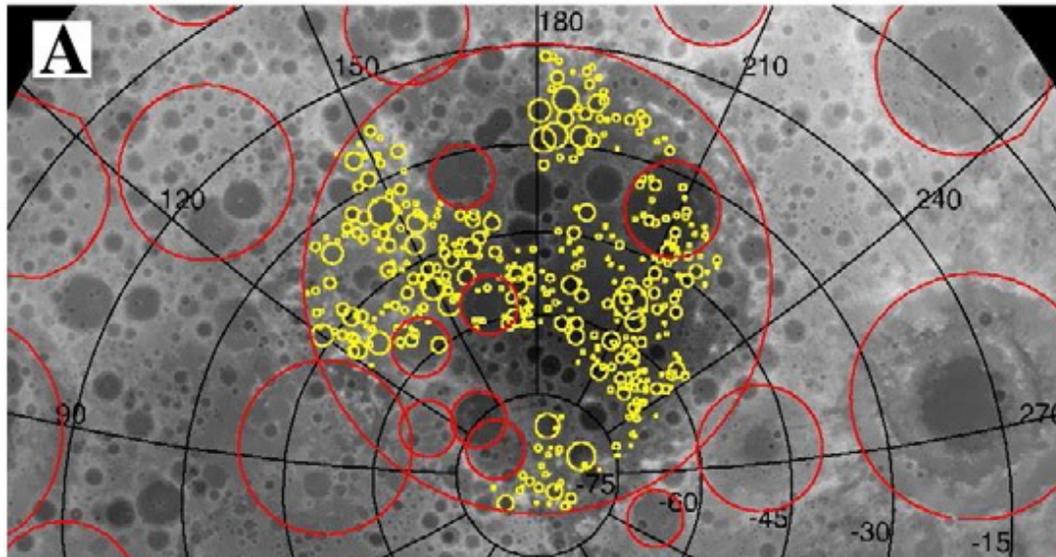
## The onset of the lunar cataclysm as recorded in its ancient crater populations

Simone Marchi <sup>a,b,c,\*</sup>, William F. Bottke <sup>b</sup>, David A. Kring <sup>c</sup>, Alessandro Morbidelli <sup>a</sup>

<sup>a</sup> Laboratoire Lagrange, Université de Nice Sophia-Antipolis, CNRS, Observatoire de la Côte d'Azur, France

<sup>b</sup> Center for Lunar Origin & Evolution, SwRI, Boulder, CO, USA

<sup>c</sup> Center for Lunar Science & Exploration, USRA – Lunar and Planetary Institute, Houston, TX, USA



Analysis of LRO (and other) data led to these conclusions

- The existence of distinct low and high impact velocity (impact crater) populations supports the existence of a lunar cataclysm.
- ...interpretation that the cataclysm started near the formation time of Nectaris basin also implies that the ancient SPA basin did not form during the LC but instead was derived from an earlier phase of lunar history.



# Lunar Data Analysis Program

Step 1 due 08/29/14

Step 2 due 10/24/14



LDAP supports scientific investigations of the Moon using publicly available (released) data. These include the following missions:

Lunar Crater Observation and Sensing Satellite (LCROSS),

Moon Mineralogy Mapper (M3),

Lunar Reconnaissance Orbiter (LRO)

Gravity Recovery and Interior Laboratory (GRAIL),

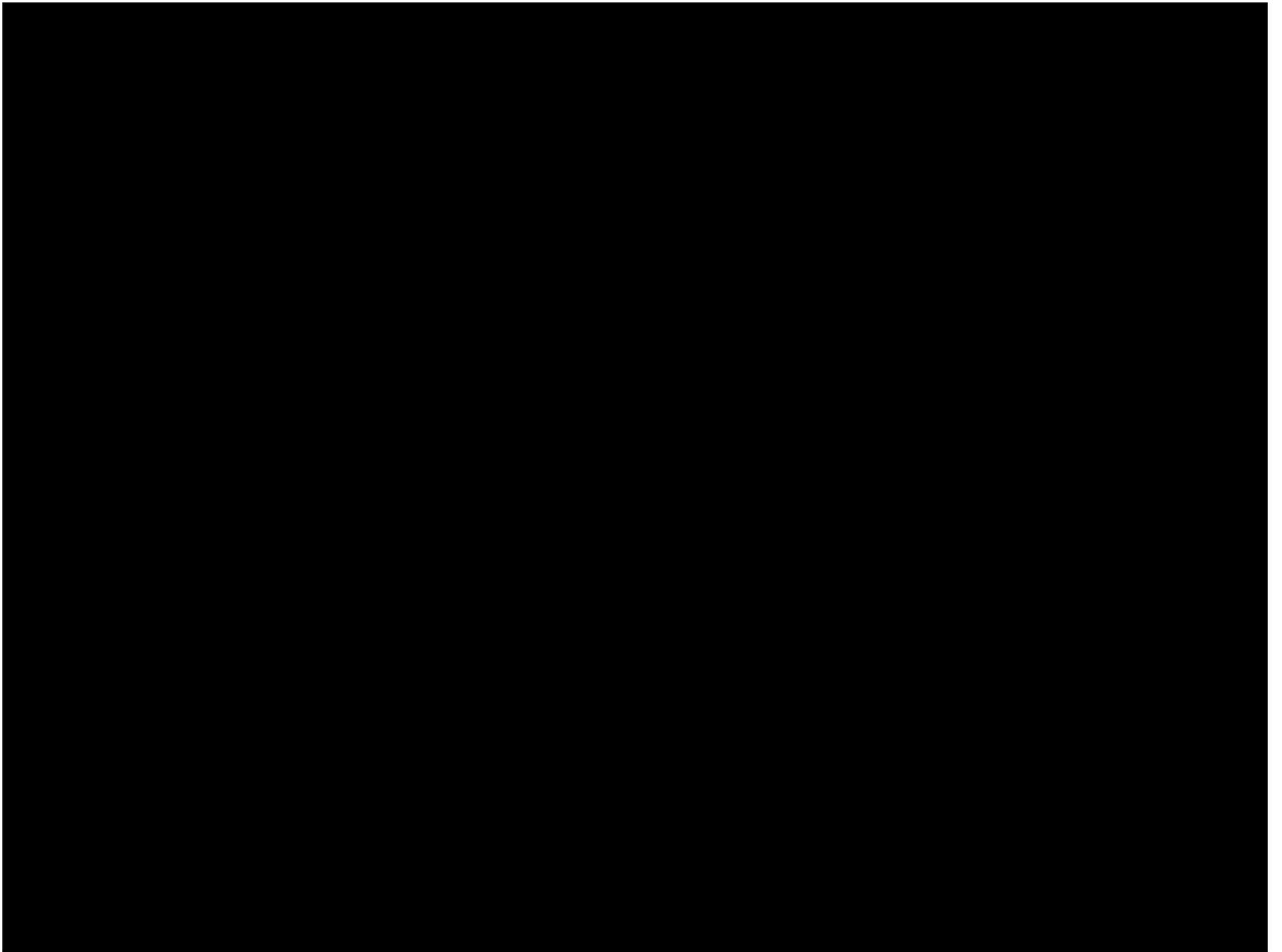
Acceleration, Reconnection, Turbulence, and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS),

Lunar Atmosphere and Dust Environment Explorer (LADEE),

Non-U.S. missions: Kaguya, Chang'e 1, Chang'e 2, Chandrayaan-1, Chang'e 3.

Any proposal may incorporate the investigation of data from more than one mission.

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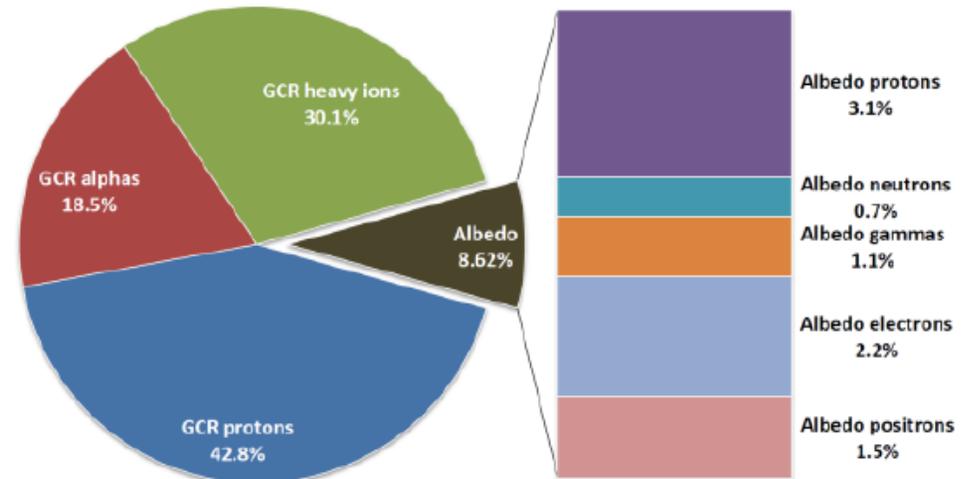
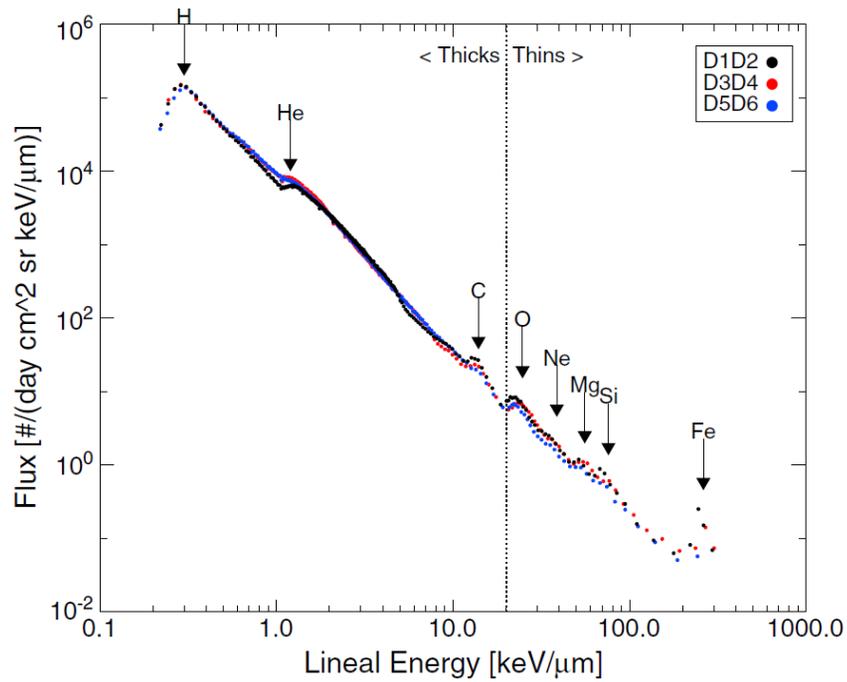


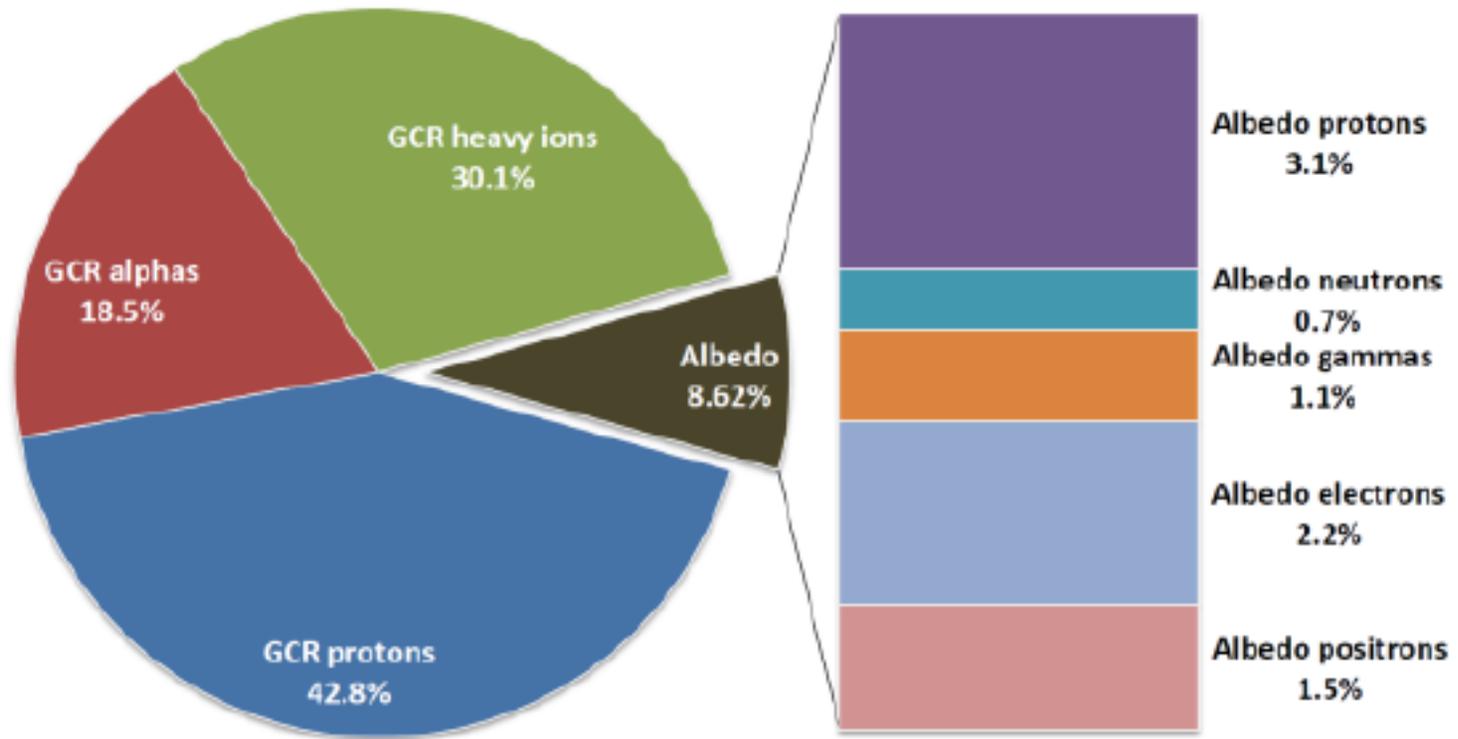
# Backups





# CRaTER: Heavy Atom Cosmic Rays





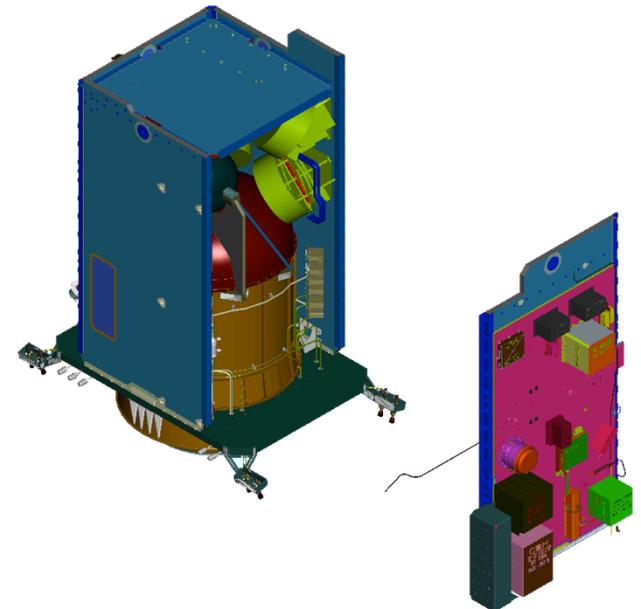


# Half of LRO Mass is Propellant LRO's Data Volume is Enormous



## LRO Orbiter Characteristics

<b>Launch Mass</b>	<b>1916 kg</b>	Dry: 1018 kg, Fuel: 898 kg (1313 m/sec)
<b>Orbit Average Power</b>	<b>681 W (2 kW array)</b>	
<b>Data Volume, Max Downlink rate</b>	<b>459 Gigabits/day, 100 Megabits/sec</b>	
<b>Pointing Accuracy, Knowledge</b>	<b>60 arc-sec, 30 arc-sec</b>	





# Lunar Reconnaissance Orbiter (LRO)



## Seven instrument payload

- Cosmic Ray Telescope for the Effects of Radiation (CRaTER)
- Lunar Orbiter Laser Altimeter (LOLA)
- LRO Camera (LROC)
- Lyman-alpha Mapping Project (LAMP)
- Diviner Lunar Radiometer Experiment (DLRE)
- Lunar Exploration Neutron Detector (LEND)
- Miniature Radio Frequency System (Mini-RF)

## LRO is returning

- Global day/night temperature maps (Diviner)
- Global high accuracy geodetic grid (LOLA)
- High resolution monochrome imaging (LROC)
- High resolution local topography (LOLA, LROC)
- Global far ultraviolet albedo map (LAMP)
- Polar observations both in shadowed and illuminated areas (LEND, LROC, LOLA, DLRE, Mini-RF, LAMP)
- Ionizing radiation measurements in the form of energetic charged particles and neutrons (CRaTER, LEND)



*LRO was launched June 18, 2009 and entered mapping orbit September 15, 2009*