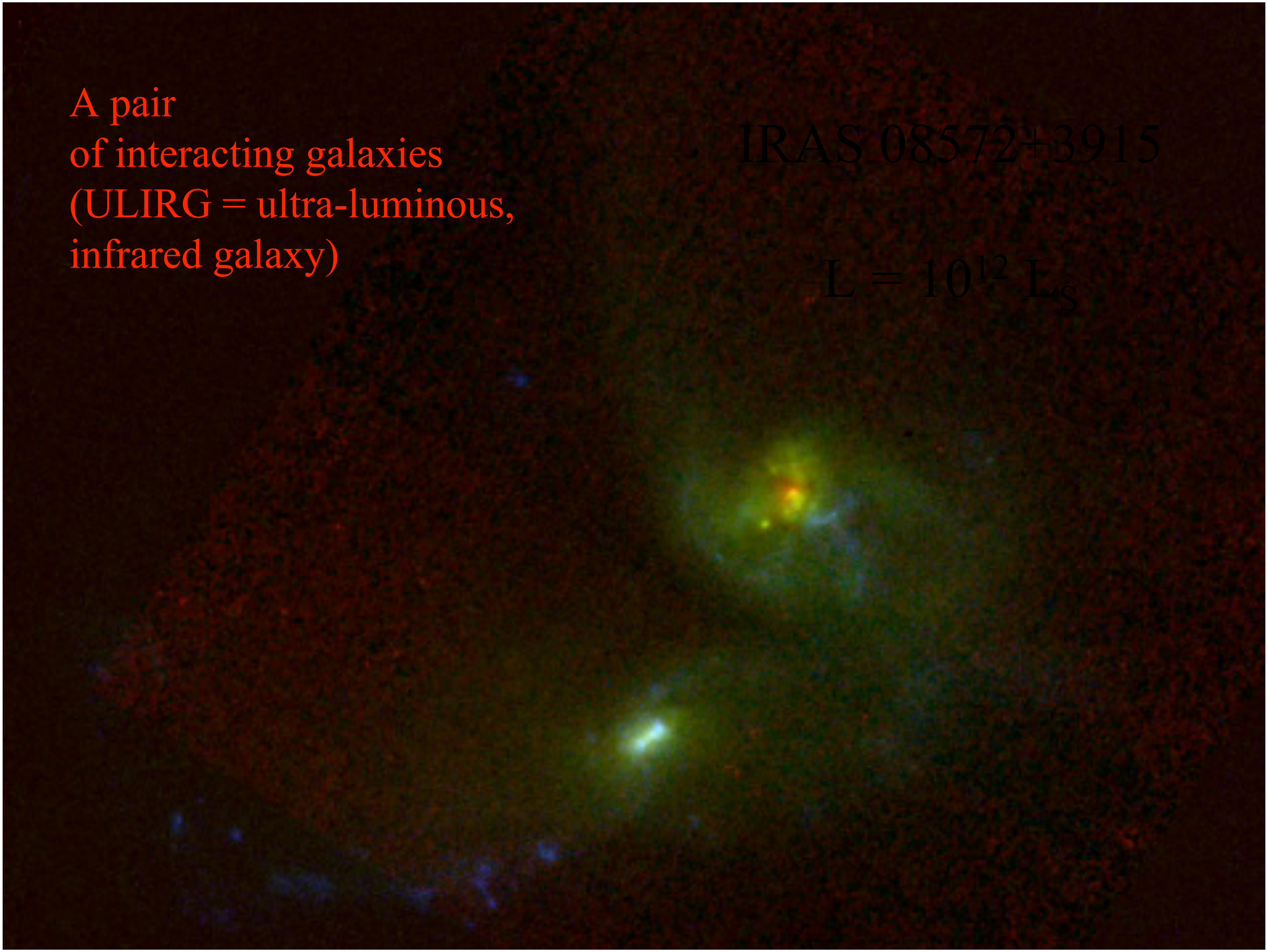
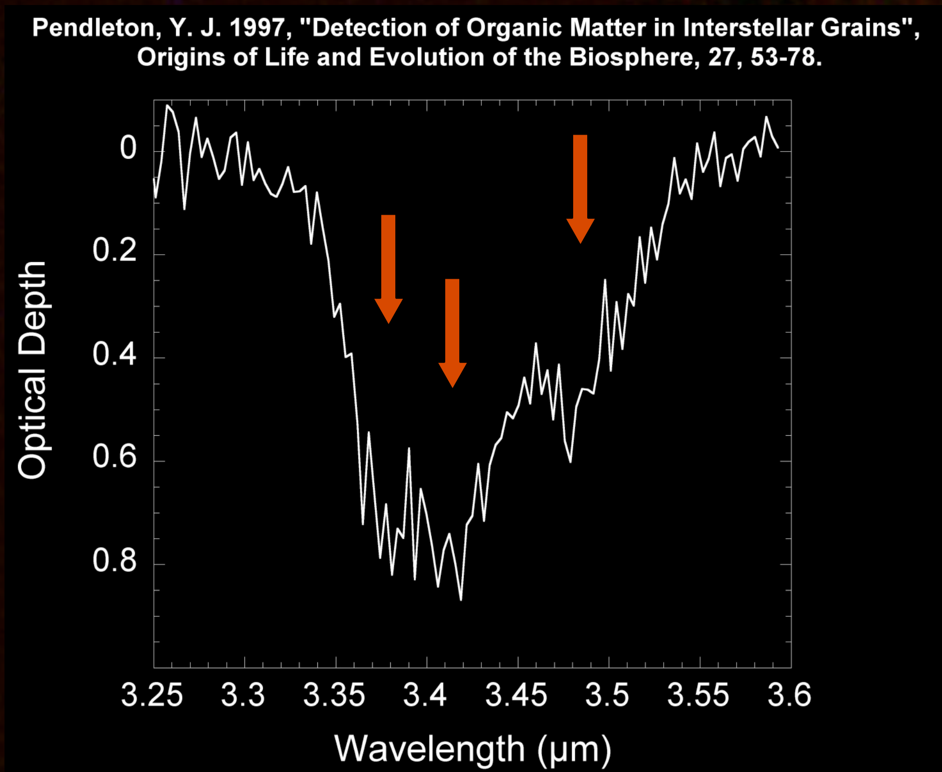
Dust Analysis at the Moon

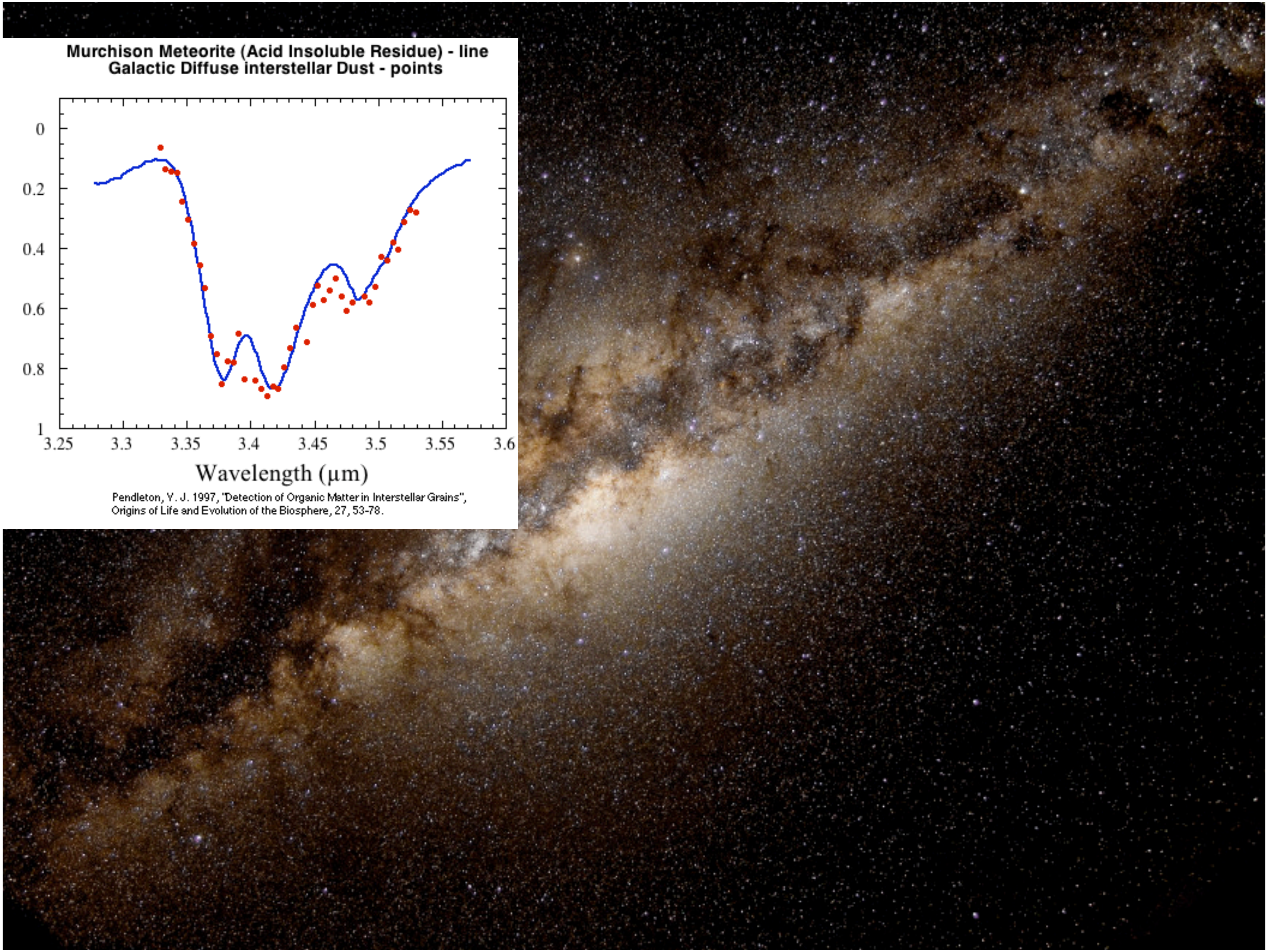
Yvonne Pendleton, NASA Ames Space Science Division Chief
S. Pete Worden, NASA Ames Center Director
Michael Bicay, NASA Ames Director of Science
Jennifer L. Heldmann, NASA Ames Space Sciences Division


A pair
of interacting galaxies
(ULIRG = ultra-luminous,
infrared galaxy)
IRAS 08572+3915
$L = 10^{12} L_S$

Organics in External Galaxies



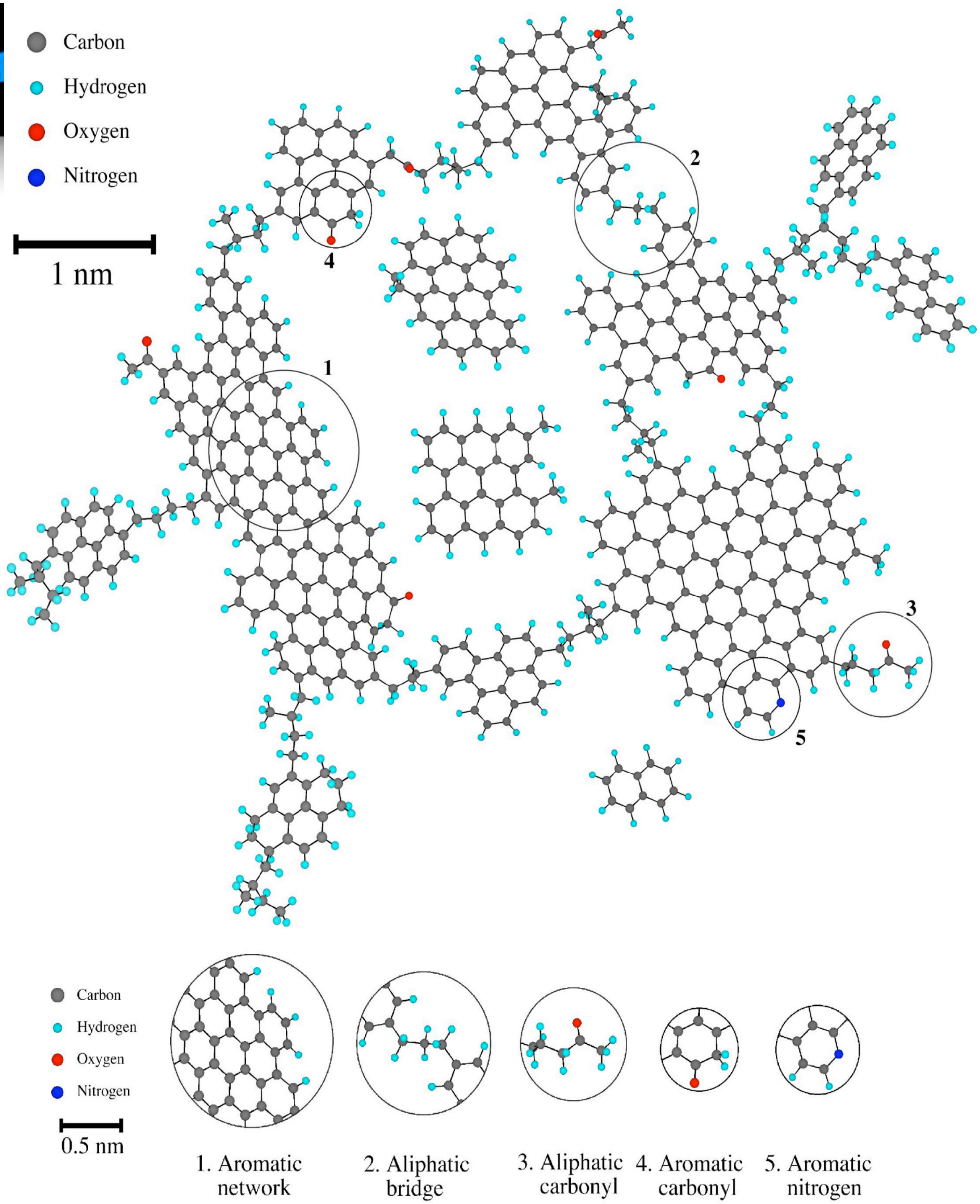
Aliphatic hydrocarbons in
the dust in
IRAS 08572+3915


Murchison Meteorite (Acid Insoluble Residue) - line
Galactic Diffuse interstellar Dust - points
0
0.2
0.4
0.6
0.8
1
3.25
3.3
3.35
3.4
3.45
3.5
3.55
3.6
Wavelength (μm)
Pendleton, Y. J. 1997, "Detection of Organic Matter in Interstellar Grains",
Origins of Life and Evolution of the Biosphere, 27, 53-78.

Organic structures in meteorites and IDPs are similar to those found in interstellar dust grains.

From Y. J. Pendleton & L. J. Allamandola, Astrophys. J. Supp. 138, 75, 2002

Figure created by Jason Dworkin

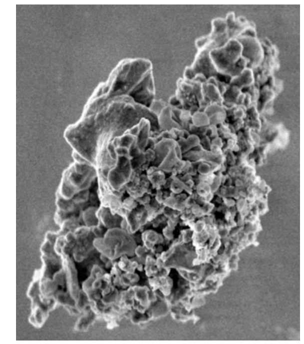


Ames Research Center
in Silicon Valley

Organic Matter in Meteorites and Interplanetary Dust Particles (IDPs)

Carbonaceous Meteorites

- Up to ~2 weight % organic matter



IDPs

- Up to ~35 weight % organic matter

- Mostly macromolecular
- H and N isotopes indicate pre-solar origin
- Some may be from outer protoplanetary disk
- Isotopic signatures have survived heating events

Reasons to Study Dust From The Moon

SCIENCE

Composition and other properties from infalling particles, electrostatic lofting & transport properties of in-situ dust, studies of zodiacal dust using the Moon as a Coronograph.

EXPLORATION

Evaluation of potential hazards of regolith dust: 1) the small, angular particulates are especially harmful to humans, 2) fine particles are harmful to hardware components, joints, etc. and 3) incoming high velocity particle, though infrequent, could prove fatal if impacting a critical component (such as an astronaut face shield), 4) lofted dust could scatter sunlight and ruin very low sky background light opportunities.

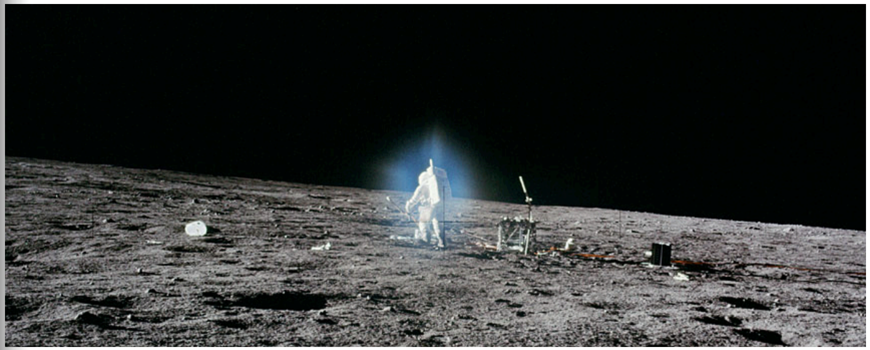
Apollo Experience with Lunar Dust

Dust coating and contamination

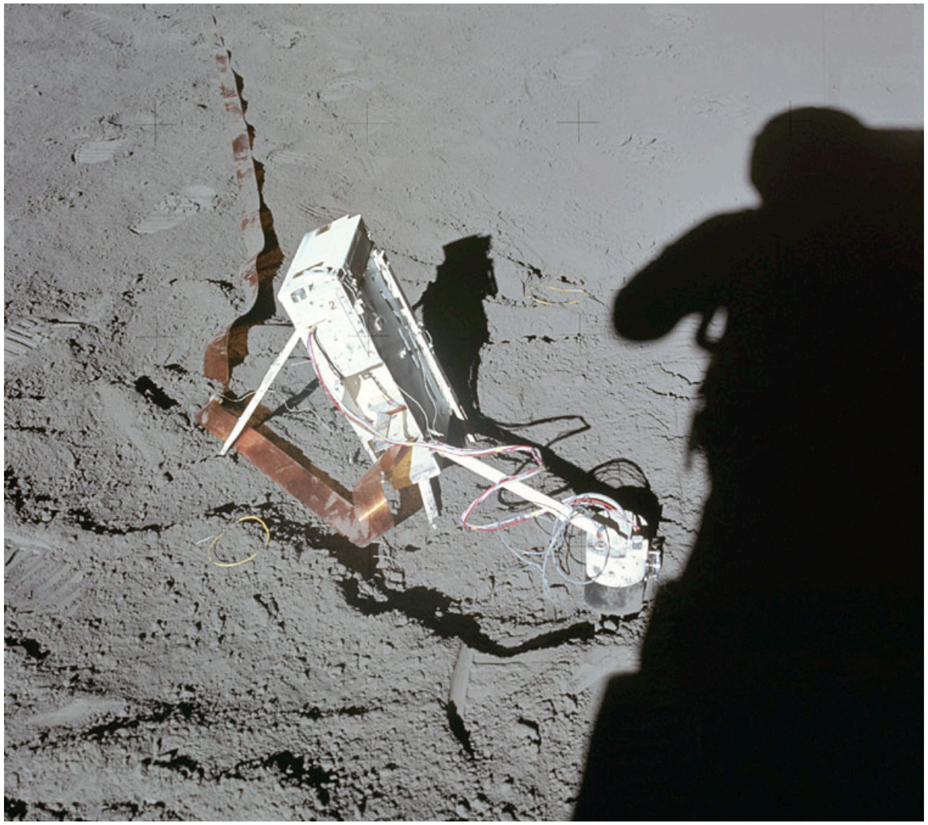
- Dust quickly coated boots, suits, gloves, tools

- Dust on Apollo 11 TV cord hid it and created tripping hazard

- Dropped Apollo 12 contrast chart became unusable



Apollo 12: Multiple images show a blue glow due to a dust smudge on the camera lens.



Apollo 15: Note the dust covering the ribbon cable connecting the instrument to the Central Station.

Ref. Gaier 2005

Apollo Experience with Lunar Dust

Vision obscuration during landing

- Larger rockets on CEV could cause more obscuration
- Concerns that could land on unseen boulder, crater, etc.

False instrument readings

- Apollo 12 velocity trackers locked onto moving dust during descent
- Apollo 15 radar outputs affected at altitudes less than 30 feet

View from LM (Armstrong's window) during descent of craters Messier & Messier A

Ref. Gaier 2005

Apollo Experience with Lunar Dust

Seal Failures

- Apollo 12 higher than normal suit pressure losses

- Some Apollo sample container seals compromised

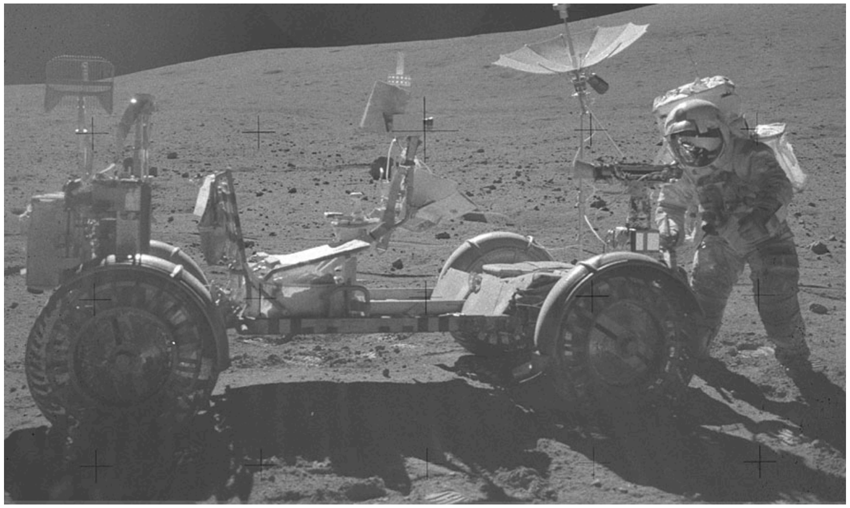
Clogging of Mechanisms

- Multiple systems compromised (including equipment conveyor to LM, lock buttons, camera equipment, velcro fastners, zippers, wrist and hose locks, faceplates, sunshades, vacuum cleaner)

Abrasion

-Brushing dust off scratched indicator dial covers, making some LRV indicators unreadable on Apollo 16

- Apollo 17 (Schmitt) sun visor shade scratched, obscuring vision in certain directions



Apollo 16, John Young dusting off the LRV

Ref. Gaier 2005

Apollo Experience with Lunar Dust

Thermal Control Issues

- Apollo 12: Magnetometer was 68°F higher than expected due to dust on thermal control surfaces.

-Apollo 16 LRV batteries exceeded temperature limits.
(Lost fender extensions increased radiator exposure to dust; increased dust cover led to thermal anomalies).

Apollo 17: Makeshift fender (LM maps) for LRV to limit dust kicked up by wheels.

Ref. Gaier 2005

Apollo Experience with Lunar Dust

Human Health Concerns

-Apollo 11: Reported dust gave off pungent odor

-Apollo 12: Reported eye and lung irritation on return trip

-Apollo 17: Reported hay fever-like symptoms from dust

Small dust particles suspended in spacecraft (< 10 micron), may have reactive volatiles on surface - toxicity unknown.

Apollo 17: Gene Cernan in the LM covered in lunar dust.

Ref. Gaier 2005

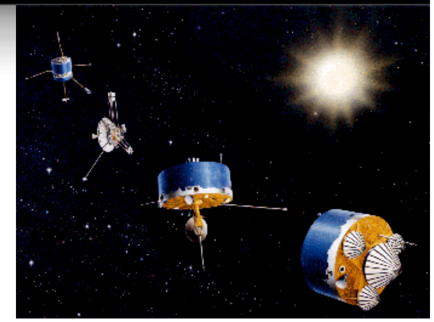
Lunar Dust

- We do not know whether or not the dust is a serious problem or simply a problem requiring mitigation techniques. Possible mitigation techniques can only move beyond speculation once the data are available.

Therefore robotic precursor missions are necessary to adequately characterize the lunar dust.

- Early knowledge will ensure that systems are adequately designed (not over or under designed) which will result in **cost savings, risk reduction, and decreased development times.**

Small Satellite Missions

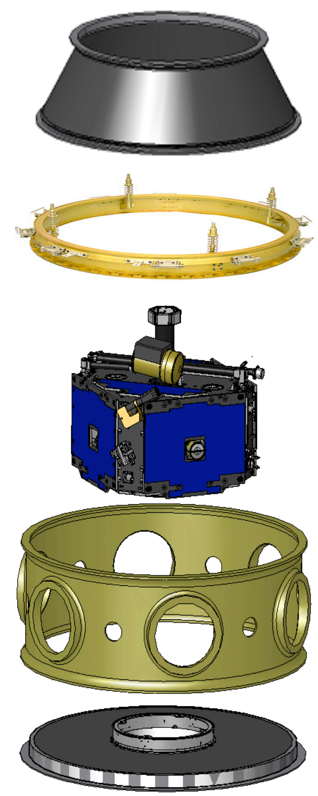


- NASA Ames Research Center, Goddard Space Flight Center and collaborators are formulating a coordinated series of low-cost lunar orbiters and landers

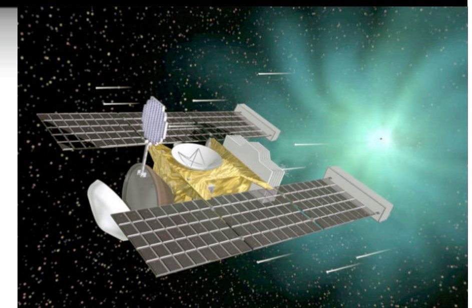
- Small satellite science requires a mission philosophy of rapid development timescales and the use of commercial-off-the-shelf components.

- Schedule compression and use of heritage should make it possible to implement a series of low-cost small satellite launches every six months.

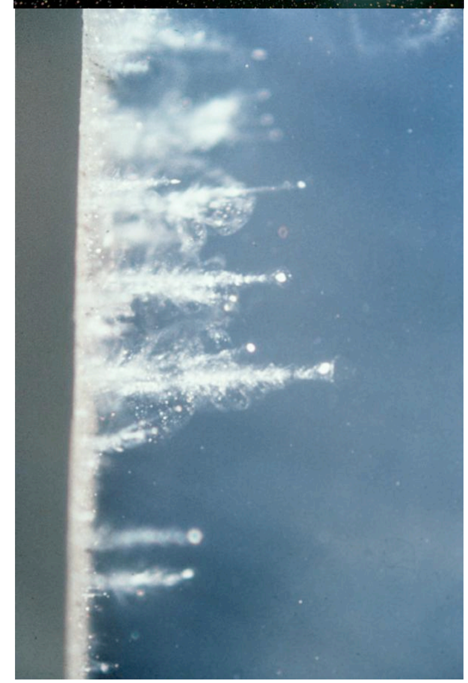
- Small 0.5- 1.0 m telescopes and other components could be delivered via small landers carrying a few tens of kgs. Transit search science and general site survey information easily gathered this way.



Dust Measurements: Lunar Raker



- A small orbiter mission concept: collector plates capture particles entering at both high and low velocities, with the ability to capture the stickiest of particles lofted up from the lunar surface.
- Would combine a highly elliptical lunar orbit (skim down to 15-20 km altitude) and a *Stardust* aerogel-based collector to capture and return lofted dust to Earth.
- Samples would be analyzed for composition, isotopic anomalies and evidence of extra-lunar matter, such as meteoritic materials and embedded solar wind particles.



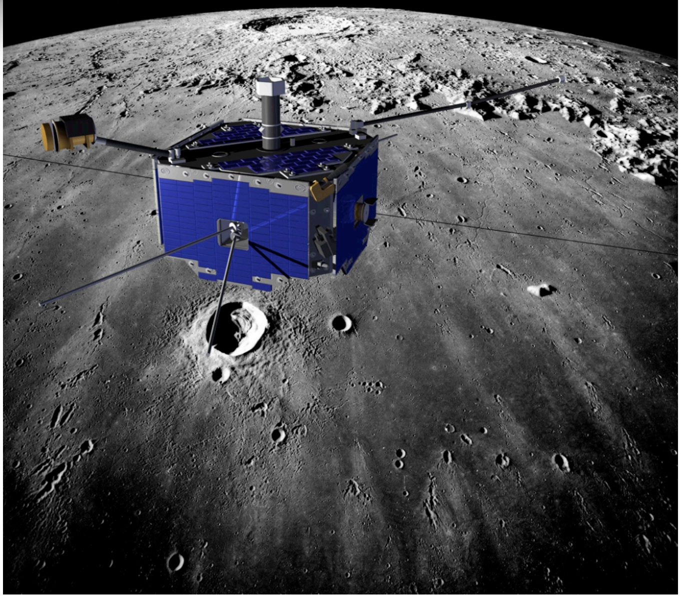
Lunar Science Orbiter

One mature concept for a low-cost orbiter under study is the Lunar Science Orbiter.

LSO is designed to systematically explore the lunar surface composition using a unique ion mass spectrometer technique capable of detecting the presence of water in all areas, including permanently shadowed regions.

It will characterize dynamic processes that cause lifting and transport of lunar dust, and the dependence of this activity on solar illumination and the local space environment.

LSO will characterize radiation through total integrated dose and solar energetic particle measurements. It can also carry a novel biology experiment that will examine the impact of both radiation and microgravity on living systems.



Astronaut Deployable Experiments

NO PEST STRIPS

- Deploy vertical strips of materials to which dust will adhere to gather vertical profiles.

AEROGEL CANISTER

- Used to record high velocity particles

- This would allow researchers to obtain vertical profiles of dust lofting and to assess the relative "stickiness" of the lunar dust. Due in part to the changing mass to surface area ratios of different sized particles, it is expected that the adhesion efficiency of lunar particles depend on the particle size. It is also anticipated that different components of lunar fines may preferentially adhere to different types of materials.
- Apart from the scientific knowledge gained, these data could be integrated into NASA's design for next-generation equipment to be used by crews on the lunar surface.

X-ray analysis of lunar minerals

Regolith samples could be analyzed by CheMin, (a combined XRD and XRF instrument) to characterize chemical and mineralogical compositions

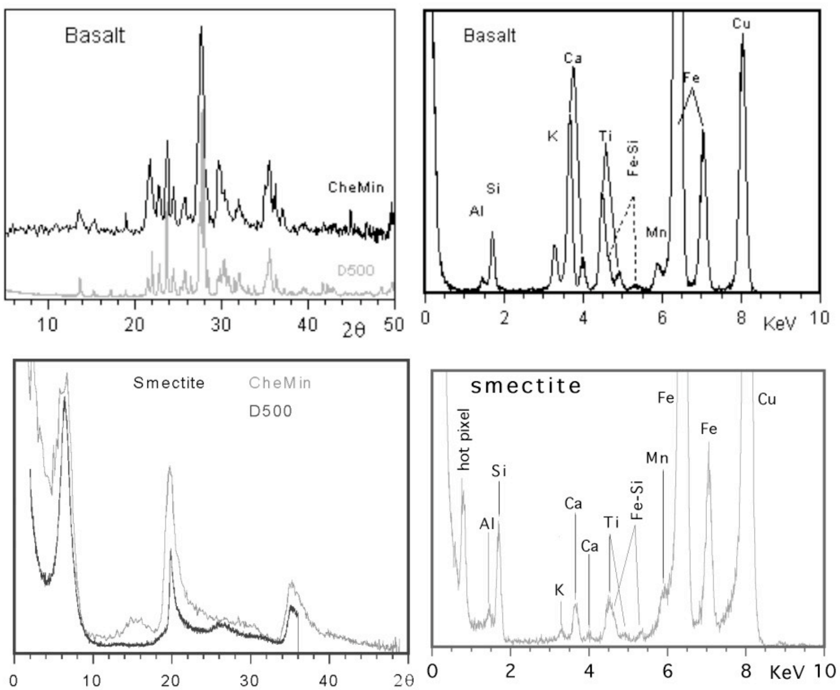
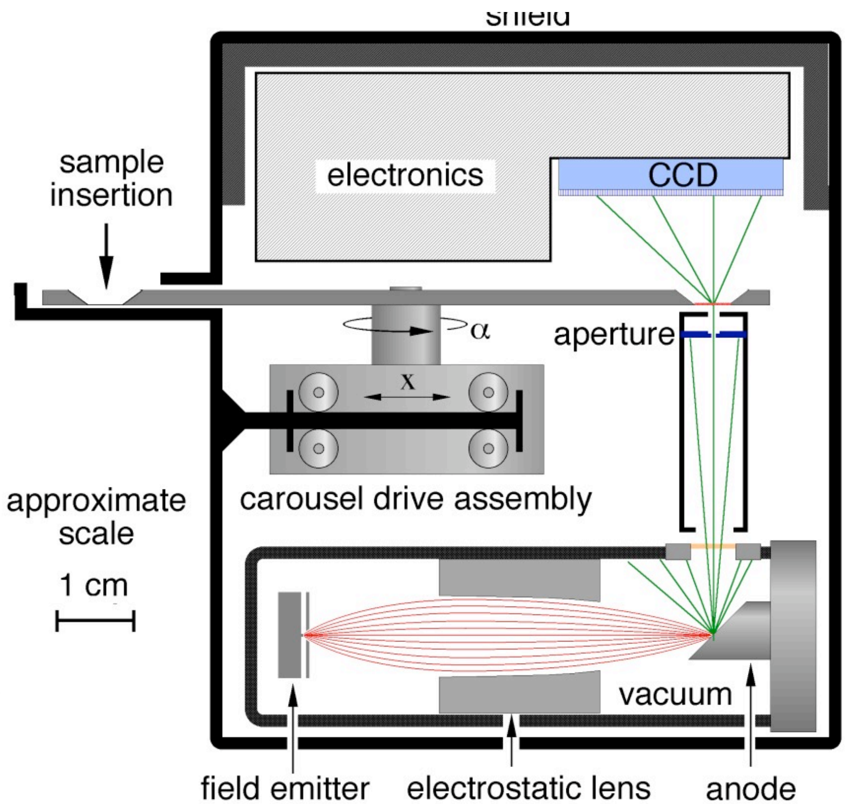


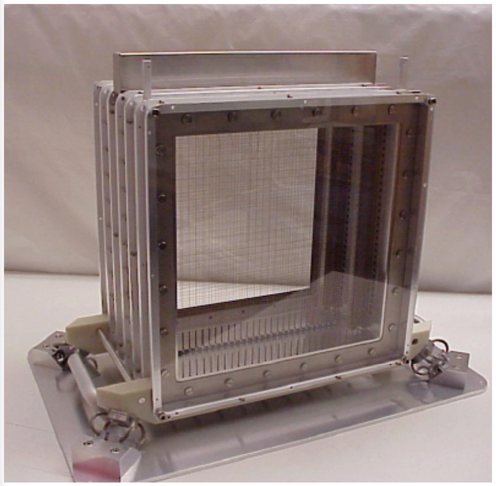
Figure 1: Example of data provided by CheMin, left:



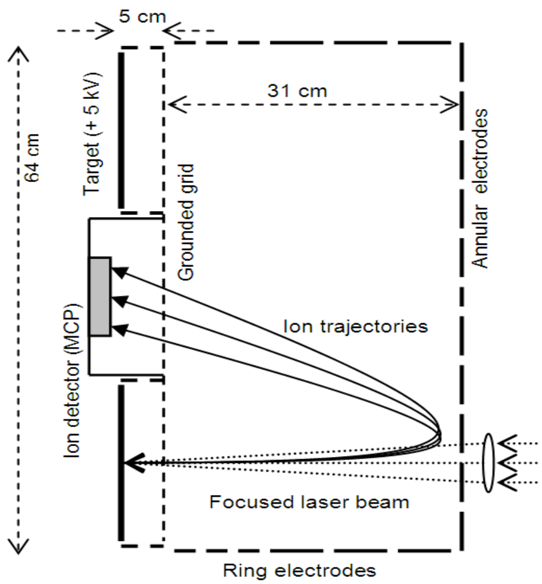
LAMA and DTS

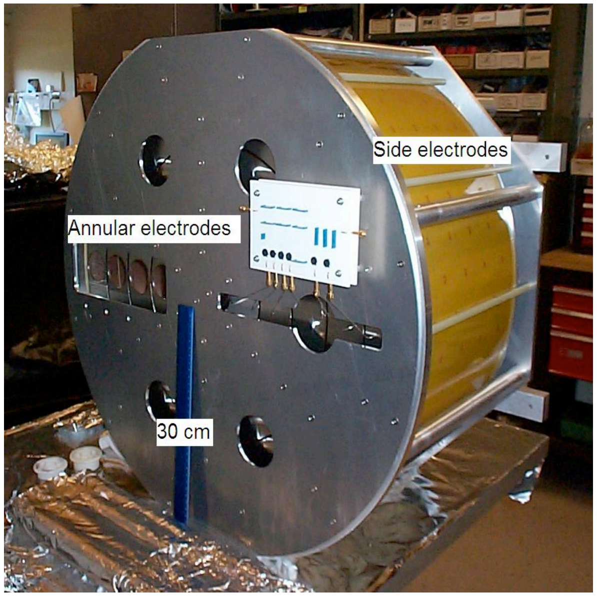
Dust Analysis (trajectory and composition)

Accurately assess dust in-situ which is important both for assessing hazards and for understanding the distribution and sources of dust in the Earth-Moon environment.



The laboratory version of the Dust Trajectory Sensor (DTS)

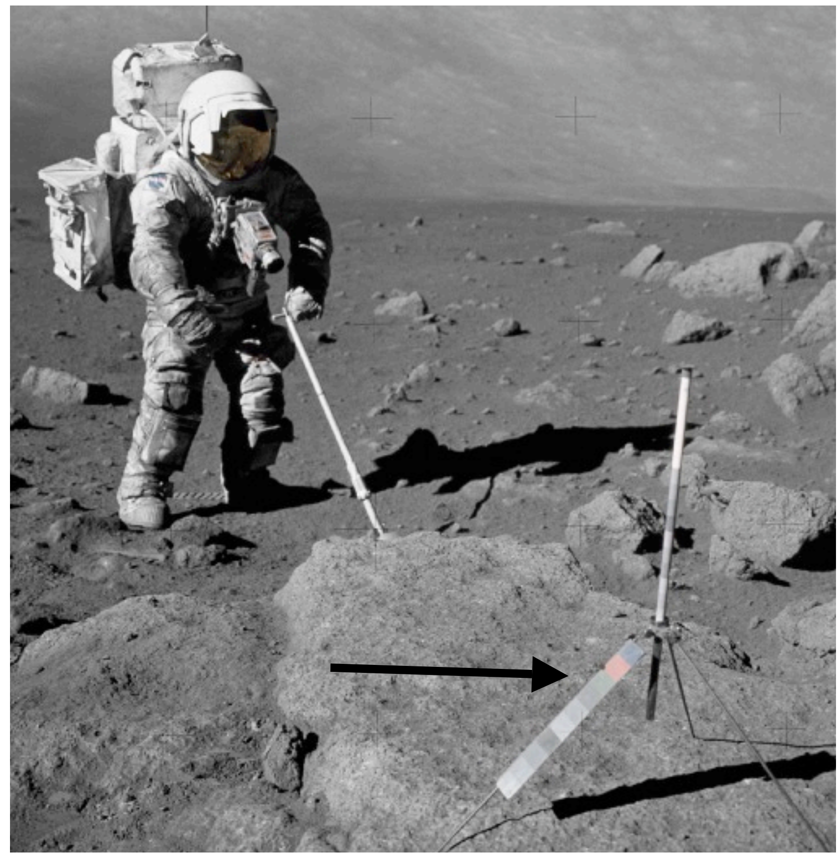




The schematic diagram of the LAMA instrument with illustrating ion trajectories. Right: The laboratory prototype instrument. The annular electrodes are covered by an aluminum disk

Summary

- NASA plans to return humans to the Moon by 2020.
- Previous lunar missions have provided some information regarding lunar dust.
- Additional information is required via robotic precursor missions to properly engineer dust mitigation strategies and provide cost savings, risk reduction, and decreased development times.
- Several mission concepts have been presented to obtain early information regarding lunar dust.



Color photograph of Jack Schmitt on lunar surface. Arrow points to color chart.