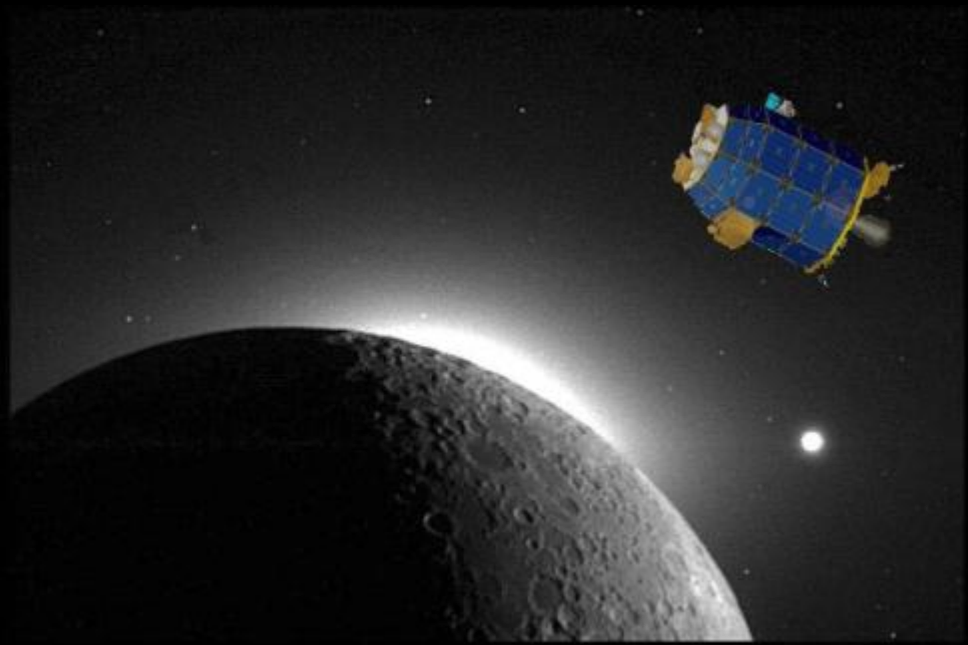
Exploring the Lunar Environment
with the Lunar Atmosphere and Dust Environment Explorer

Ames Amateur Radio Club – January 19, 2012

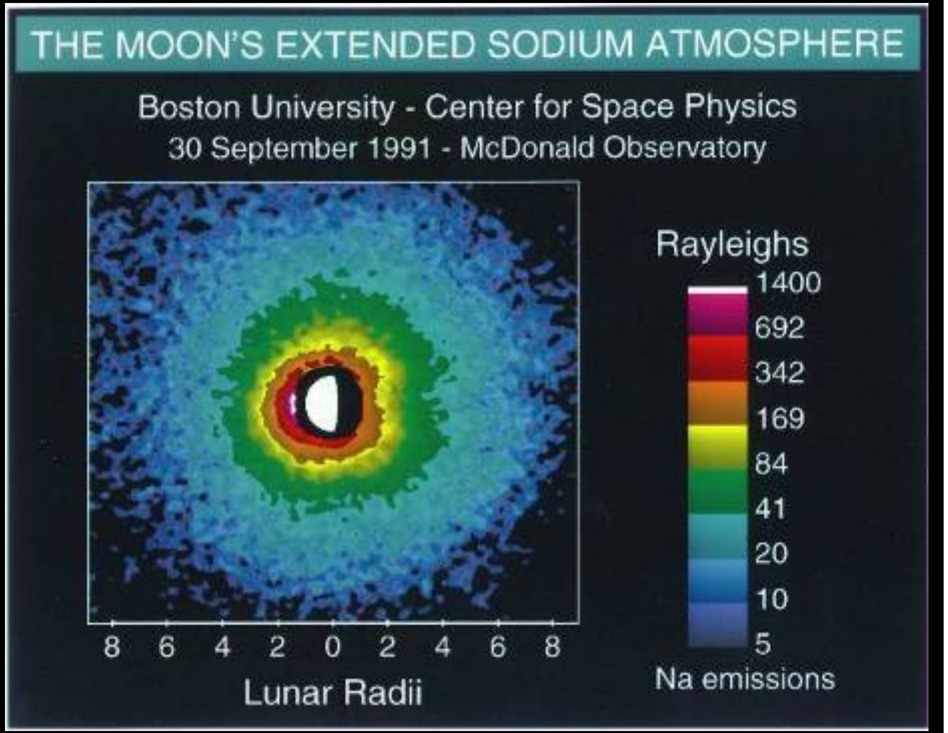
Brian Day
LADEE Mission E/PO Lead
NASA Lunar Science Institute Citizen Science Lead
Brian.H.Day@nasa.gov



Lunar Atmosphere?

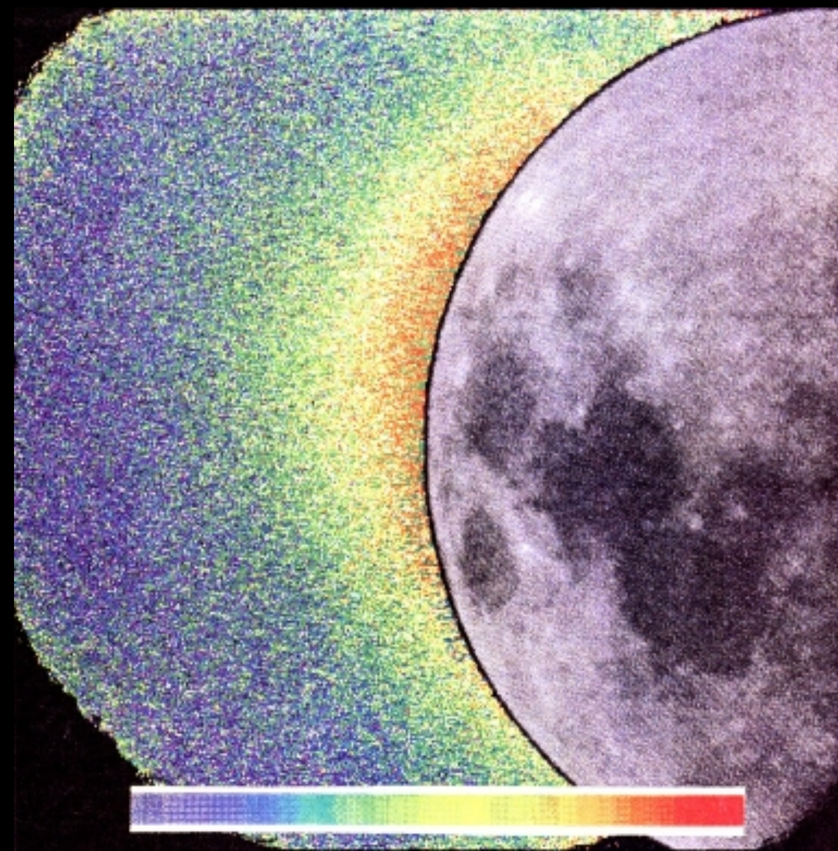
- Yes, but very thin! A cubic centimeter of Earth's atmosphere at sea level contains about 10^{19} molecules. That same volume just above the Moon's surface contains only about 100,000 to a few million molecules.

- It glows most strongly from atoms of sodium. However, that is probably a minor constituent. We still do not know its composition.



Lunar Exosphere

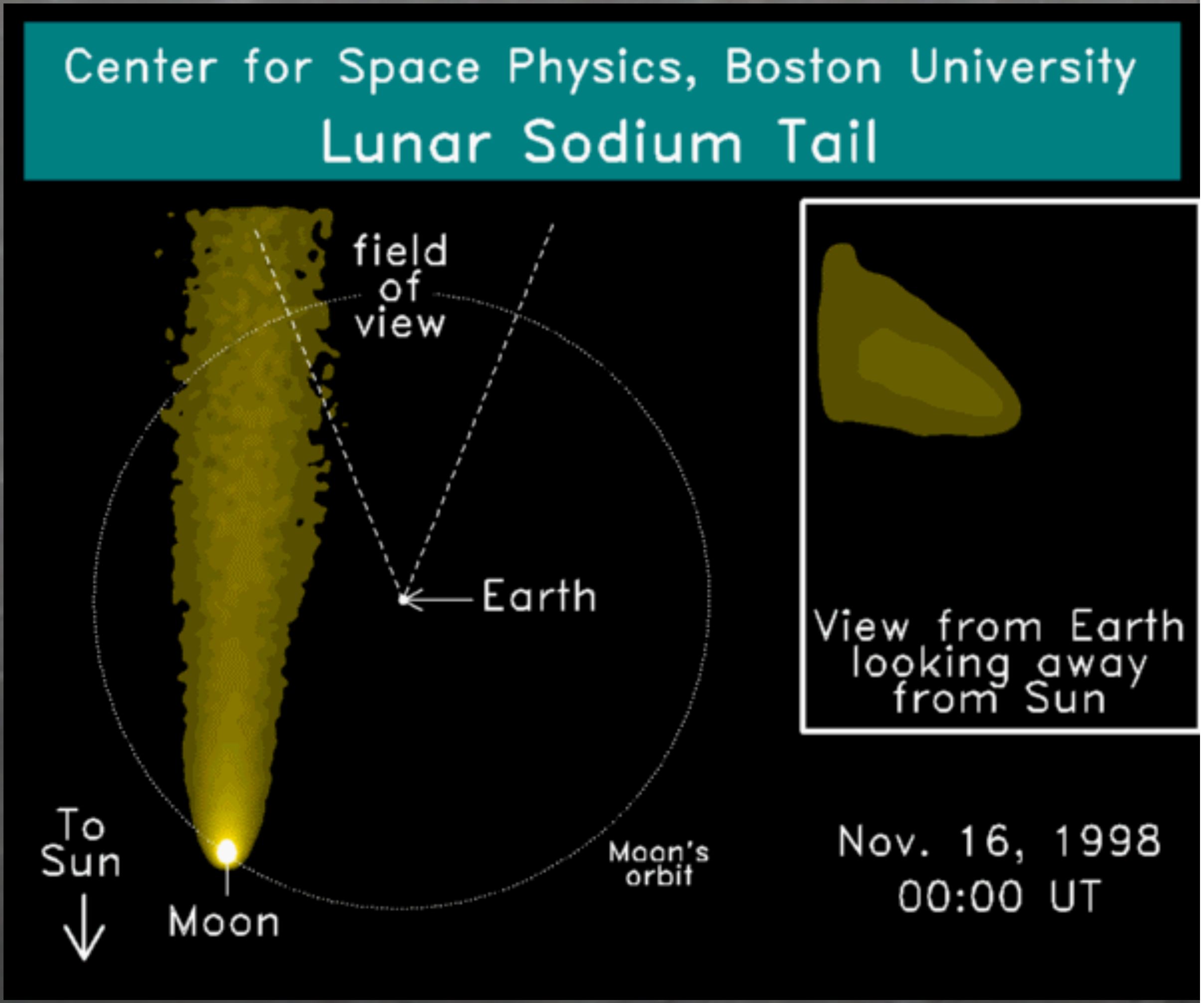
- An exosphere's is a tenuous, collisionless atmosphere.
- The lunar exosphere is bounded by the lunar surface – a *surface boundary exosphere*.
- Consists of a variety of atomic and molecular species – indicative of conditions at the Moon (surface, subsurface).
- Wide variety of processes contribute to sources, variability, losses.



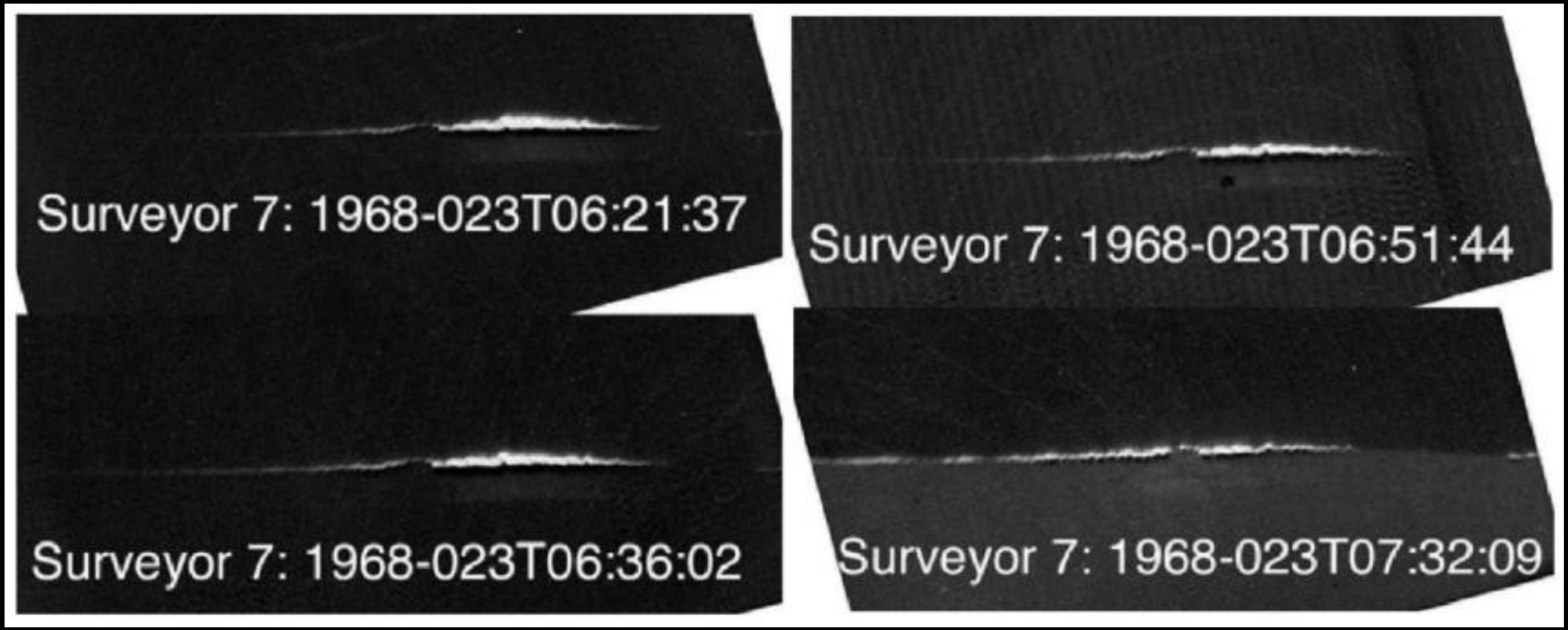
Sodium exosphere of the Moon imaged by the Evans coronagraph, National Solar Observatory, New Mexico (Potter et al., 1998)

A Tale of Two Tails

- The solar wind blows the lunar exosphere into a long comet-like tail.
- The Earth passes through this tail once a month.
- Similarly, the Earth's exospheric tail extends beyond the Moon's orbit.



A Dusty Lunar Sky?

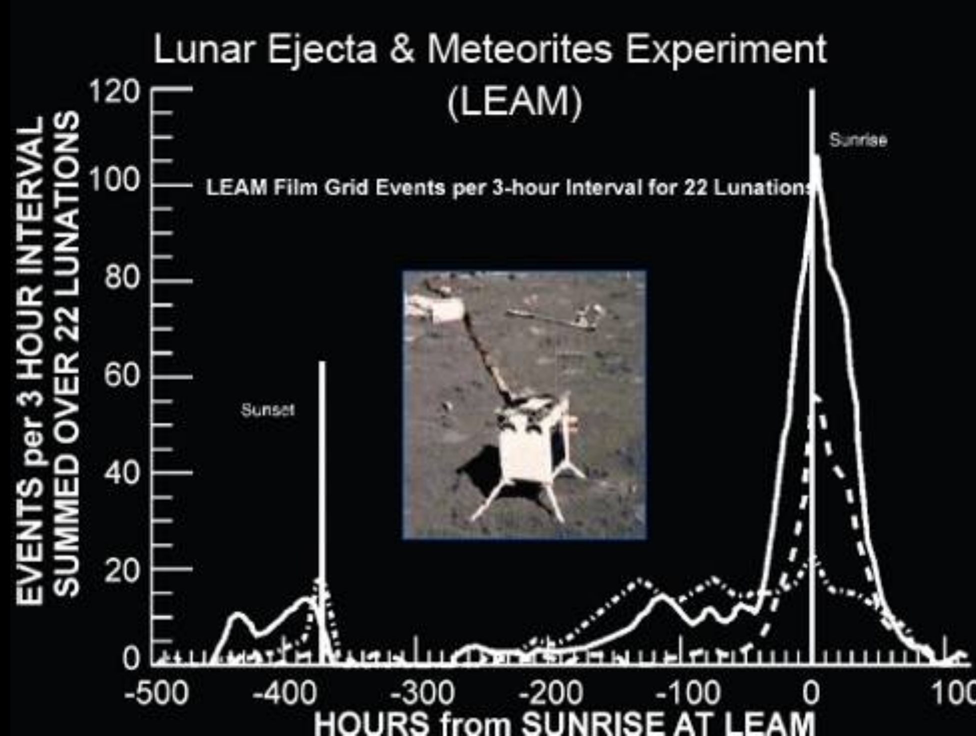


In 1968, NASA's Surveyor 7 moon lander photographed a strange "horizon glow" looking toward the daylight terminator. Observations are consistent with sunlight scattered from electrically-charged moondust floating just above the lunar surface.

A Dusty Lunar Sky?

More possible evidence for dust came from the Apollo missions.

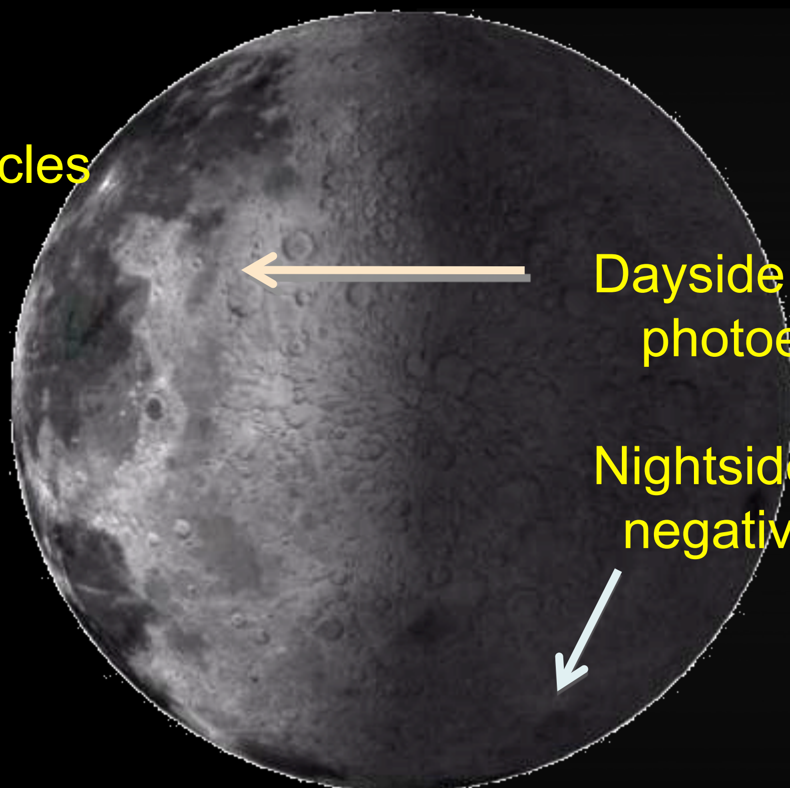
Apollo Astronaut sketch (G. Cernan)



Berg et al., 1976

The Lunar Exosphere and Dust: Sources & Sinks

Inputs:
- Solar photons
- Solar Energetic Particles
- Solar wind
- Meteoric influx
- Large impacts

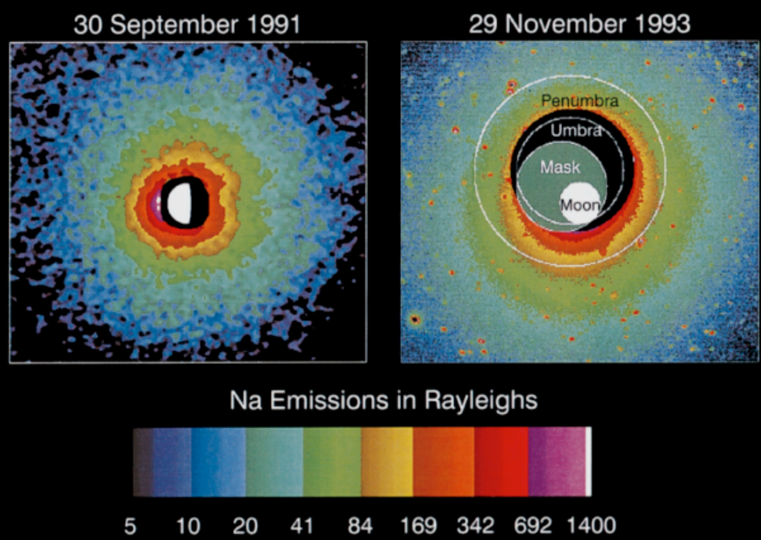


Dayside: UV-driven photoemission, +10s V

Nightside: electron-driven negative charging -1000s V

Processes:
- Impact vaporization
- Interior outgassing
- Chemical/thermal release
- Photon-stimulated desorption
- Sputtering

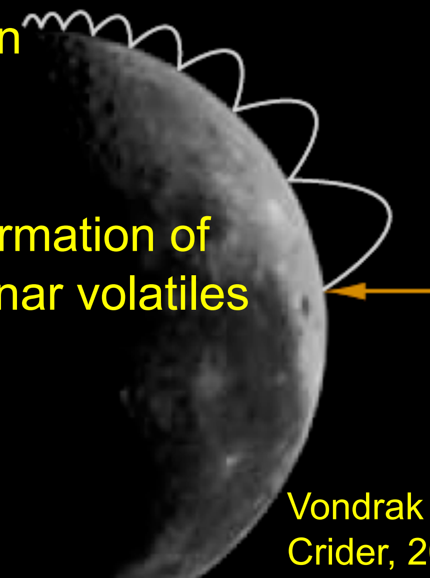
Lunar Exosphere



Mendillo et al, 1997

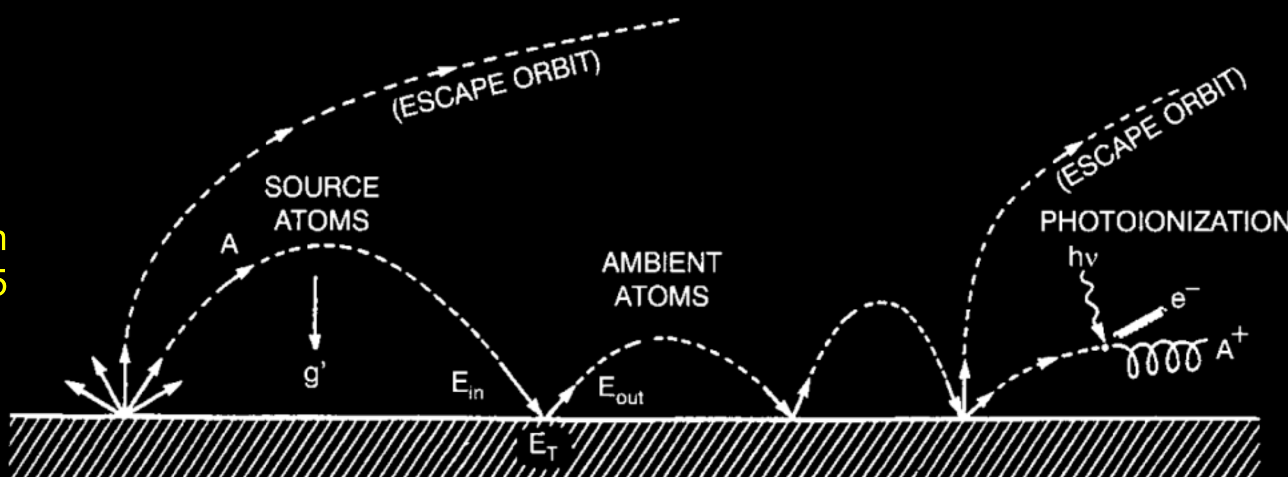
Cold-trapping in Polar regions

Formation of Lunar volatiles



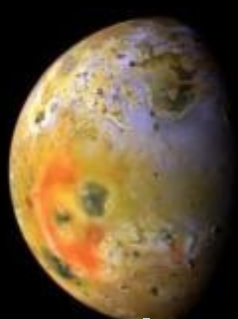
Vondrak and Crider, 2003

Stern, 1999;Smyth and Marconi, 1995



Exosphères and Dust

Surface Boundary Exospheres (SBEs) may be the most common type of atmosphere in the solar system…



Evidence of dust motion on Eros and the Moon....

LADEE

The Lunar Atmosphere and Dust Environment Explorer

•Determine the global density, composition, and time variability of the fragile lunar atmosphere before it is perturbed by further human activity.

•Determine the size, charge, and spatial distribution of electrostatically transported dust grains.

•Test laser communication capabilities.

•Demonstrate a low-cost lunar mission:

- Simple multi-mission modular bus design
- Low-cost launch vehicle

Neutral Mass Spectrometer (NMS)

MSL/SAM Heritage

SMD - directed instrument

In situ measurement of exospheric species

P. Mahaffy
NASA GSFC

150 Dalton range/unit mass resolution

UV Spectrometer (UVS)

LCROSS heritage

SMD - directed instrument

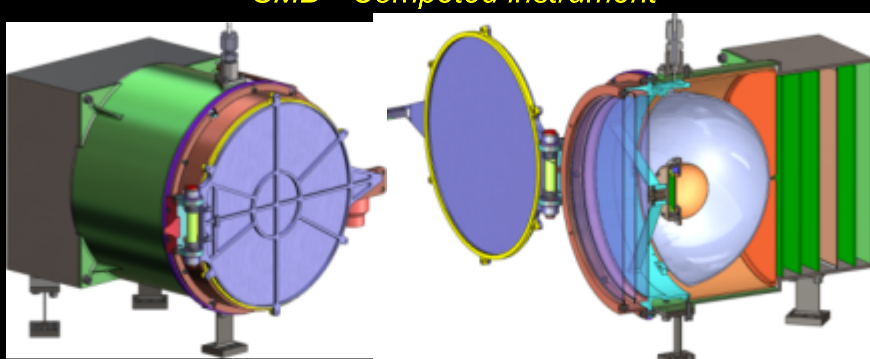
Dust and exosphere measurements

A. Colaprete
NASA ARC

Lunar Dust EXperiment (LDEX)

HEOS 2, Galileo, Ulysses and Cassini Heritage

SMD - Competed instrument



M. Horányi, LASP

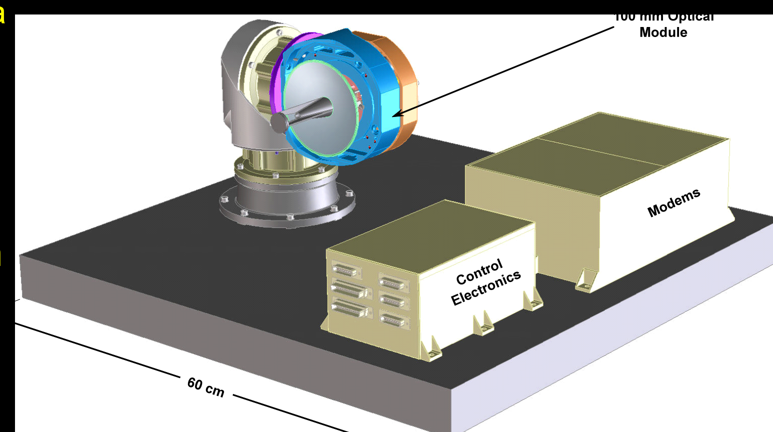
Lunar Laser Com Demo (LLCD)

Technology demonstration

SOMD - directed instrument

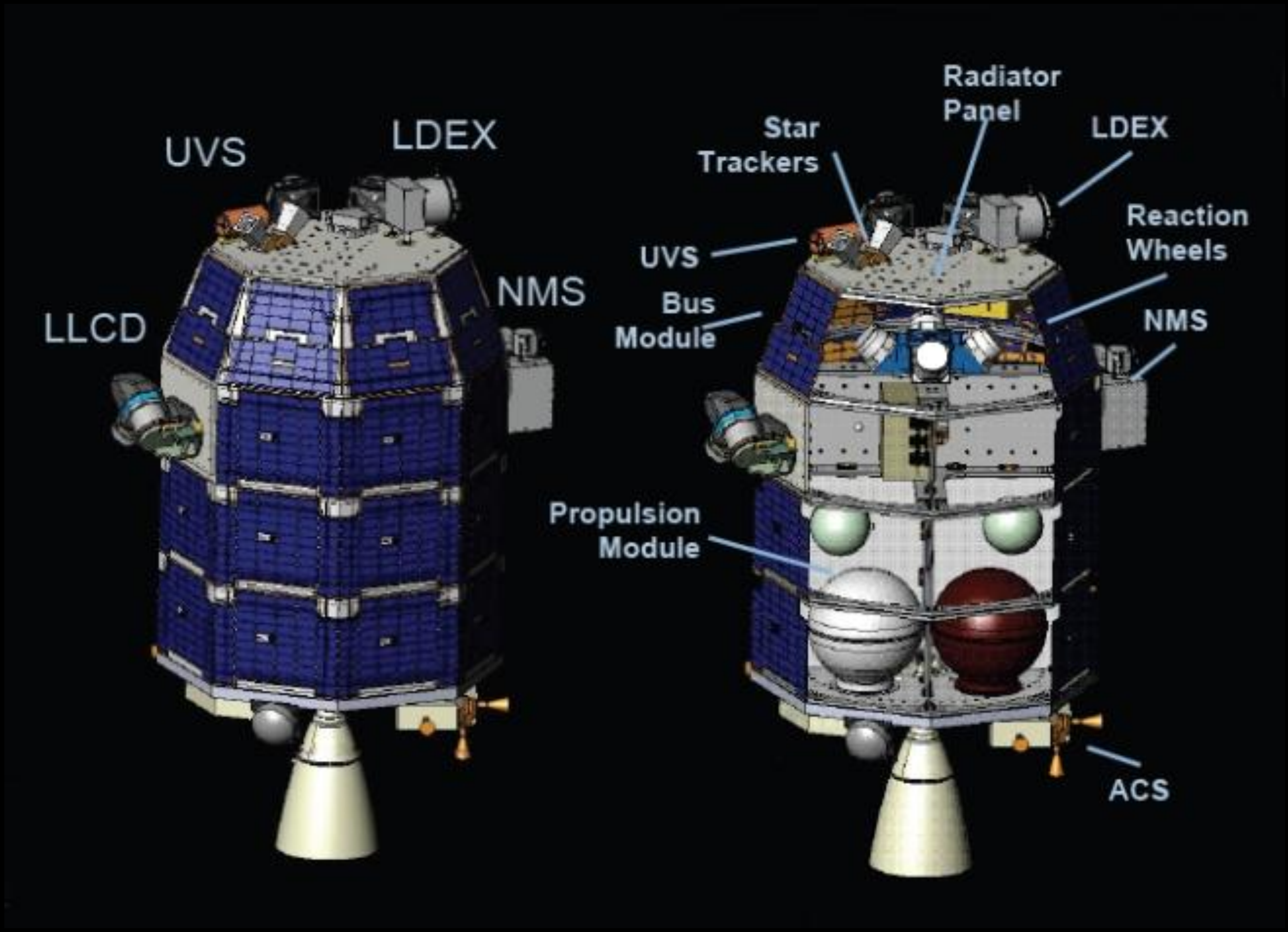
High Data Rate Optical Comm

D. Boroson
MIT-LL



51-622 Mbps

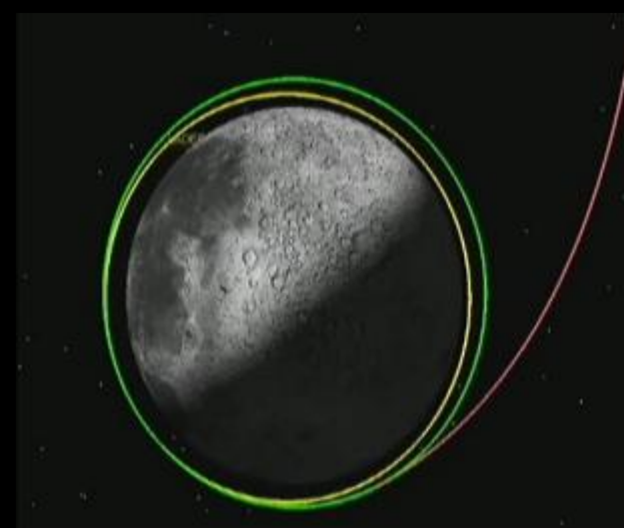
Spacecraft Configuration



- 330 kg spacecraft mass
- 53 kg payload mass

LADEE Mission Profile

- Launch in 2013 from Wallops as the first payload to fly on the new Minotaur V launch vehicle.
- 2-3 phasing orbits to get to Moon.
- Insertion into retrograde orbit around Moon.
- Checkout orbit (initially 250km) for 30 days.
- 100-day science mission at ~20-75km.

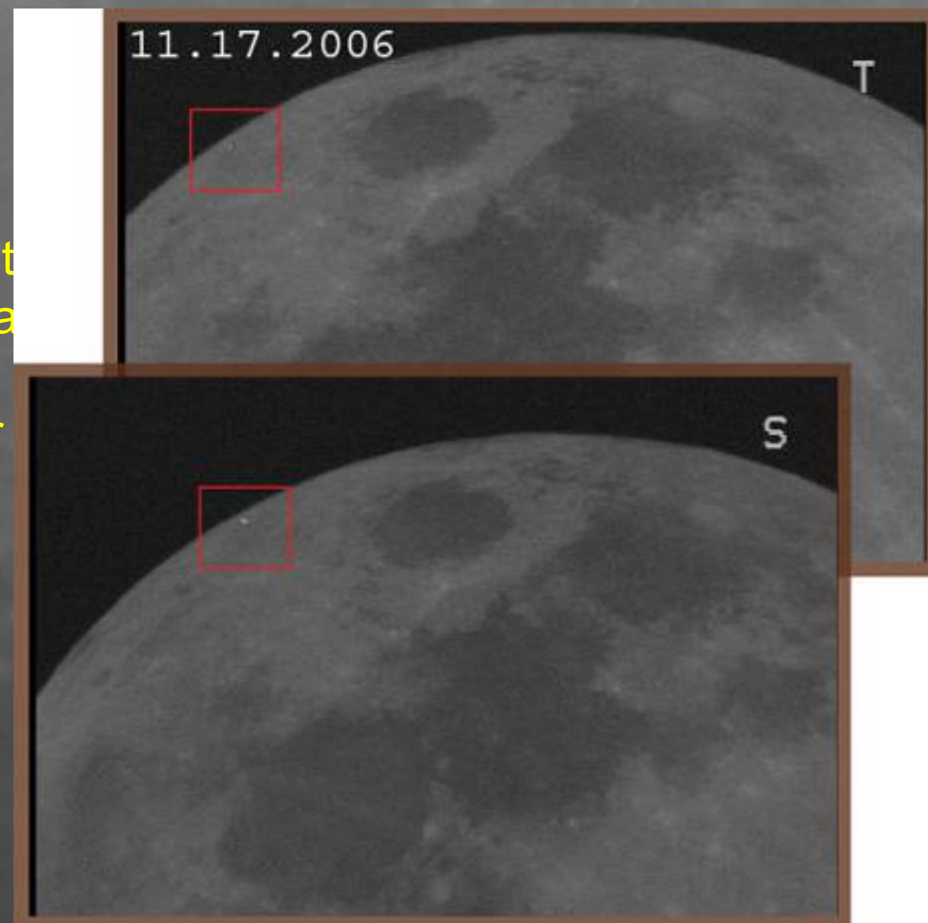


LADEE and Lunar Impacts

NASA Meteoroid Environment Office
Lunar Impact Monitoring Program

- Help lunar scientists determine the rate of meteoroid impacts on the Moon.
- Meteoroid impacts are an important source for the lunar exosphere and dust
- Can be done with a telescope as small a 8 inches of aperture.

Also planning to work with AAVSO Lunar Meteoritic Impact Search Section.



Lunar Meteoroid Impact Monitoring

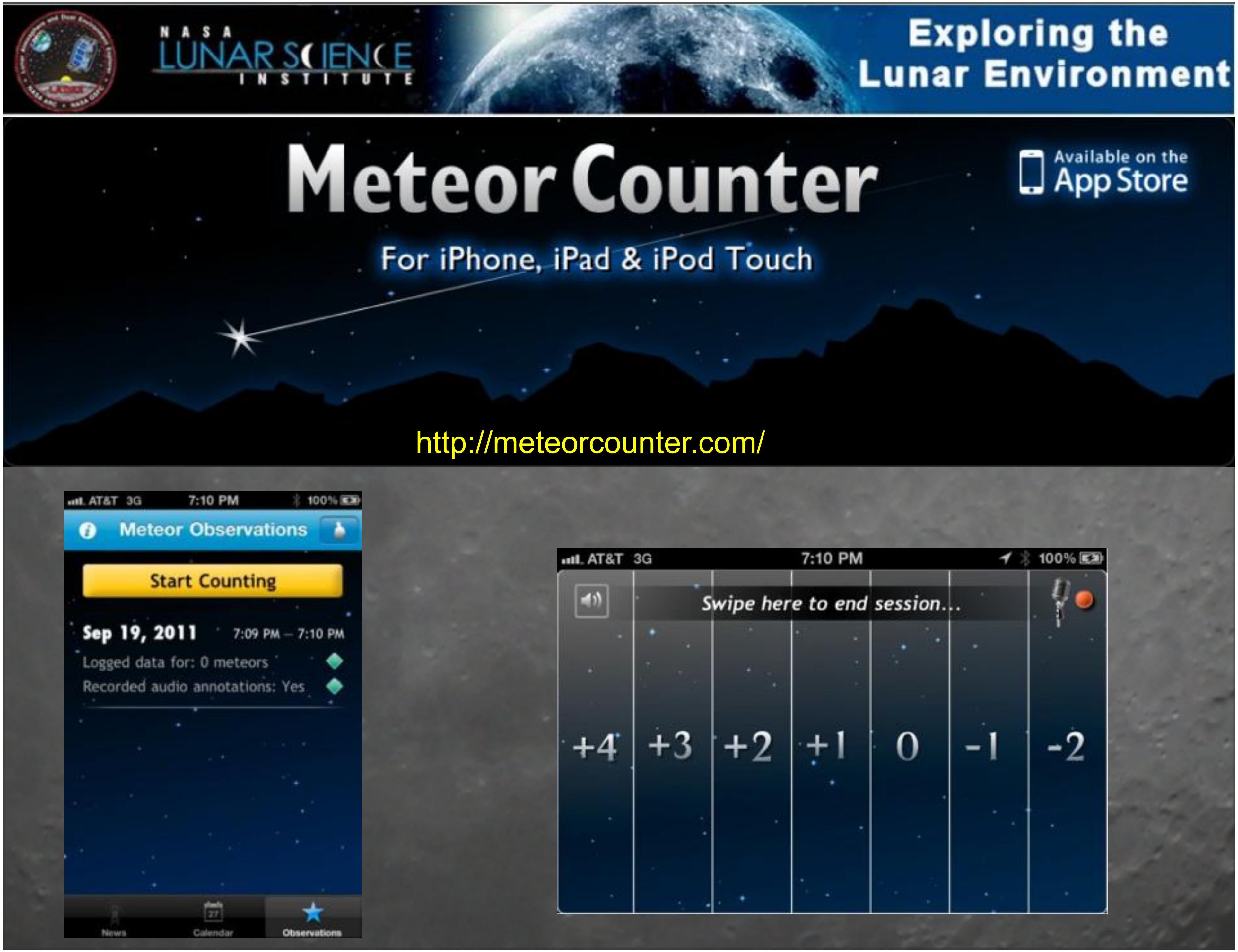
Minimum System Requirements

- 8" telescope
  - ~1m effective focal length
  - Equatorial mount or derotator
  - Tracking at lunar rate
- Astronomical video camera with adapter to fit telescope
  - NTSC or PAL
  - 1/2" detector
- Digitizer - for digitizing video and creating a 720x480 .avi
  - Segment .avi to files less than 1GB (8000 frames)
- Time encoder/signal
  - GPS timestamp or WWV audio
- PC compatible computer
  - ~500GB free disk space
- Software for detecting flashes
  - LunarScan software available as a free download

Meteor Counting

- The vast majority of meteoroids impacting the Moon are too small to be observable from Earth.
- Small meteoroids encountering the Earth's atmosphere can result in readily-observable meteors.
- Conducting counts of meteors during the LADEE mission will allow us to make inferences as to what is happening on the Moon at that time.
- Much more simple requirements: a dark sky, your eyes, and log sheet. (a reclining lawn chair is very nice too!)
- International Meteor Organization (http://imo.net/)
- American Meteor Society (http://www.amsmeteors.org/)

Image credit:NASA/ISAS/Shinsuke Abe and Hajime Yano

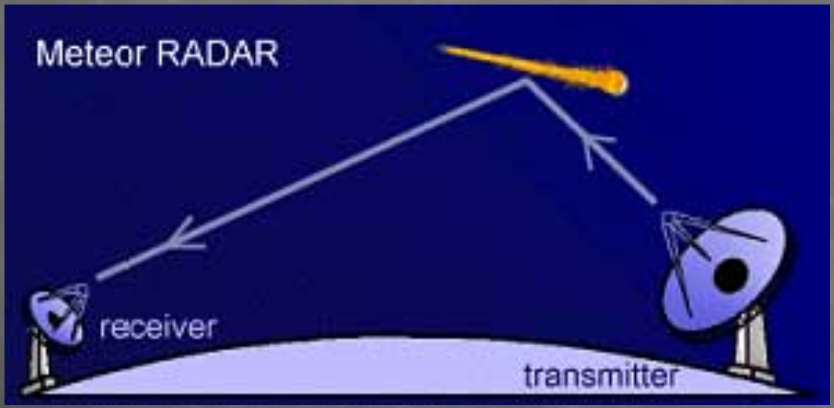

NASA
LUNAR SCIENCE
INSTITUTE
Exploring the
Lunar Environment
Meteor Counter
Available on the
App Store
For iPhone, iPad & iPod Touch
http://meteorcounter.com/
AT&T 3G
7:10 PM
100%
Meteor Observations
Start Counting
Sep 19, 2011
7:09 PM – 7:10 PM
Logged data for: 0 meteors
Recorded audio annotations: Yes
News
Calendar
Observations
AT&T 3G
7:10 PM
100%
Swipe here to end session...
+4
+3
+2
+1
0
-1
-2

Lunar Phases for Major Meteor Showers in 2013

Jan 3	Quadrantids	Last Qtr	61%
Apr 22	Lyrids Waxing	Gibbous	90%
May 5	Eta Aquariids	Waning Crescent	15%
July 27	Delta Aquariids	Waning Gibbous	66%
Aug 12	Perseids	Waxing Crescent	35%
Oct 21	Orionids	Waning Gibbous	90%
Nov 19	Leonids	Waning Gibbous	94%
Dec 14	Geminids	Waxing Gibbous	95%
Dec 22	Ursids	Waning Gibbous	73%

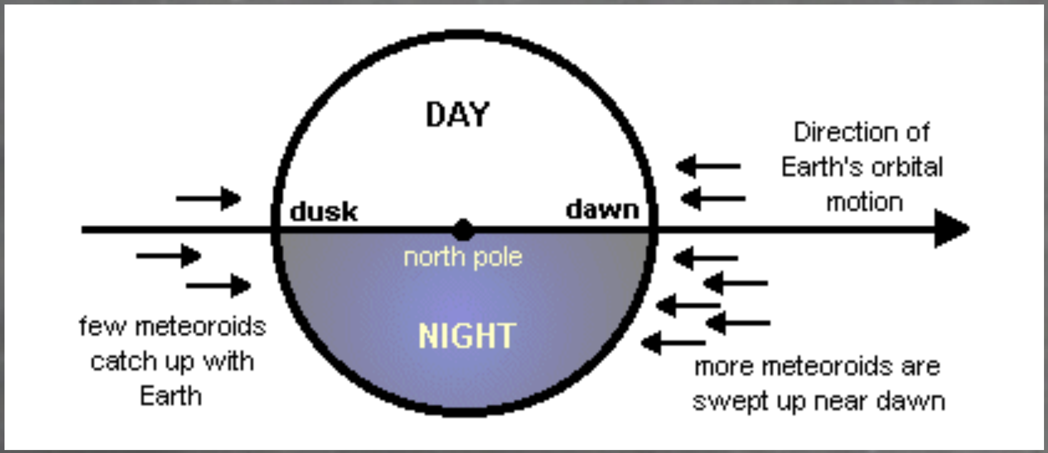
Lunar Phase Aug 12, 2013

Radio Observations of Meteors



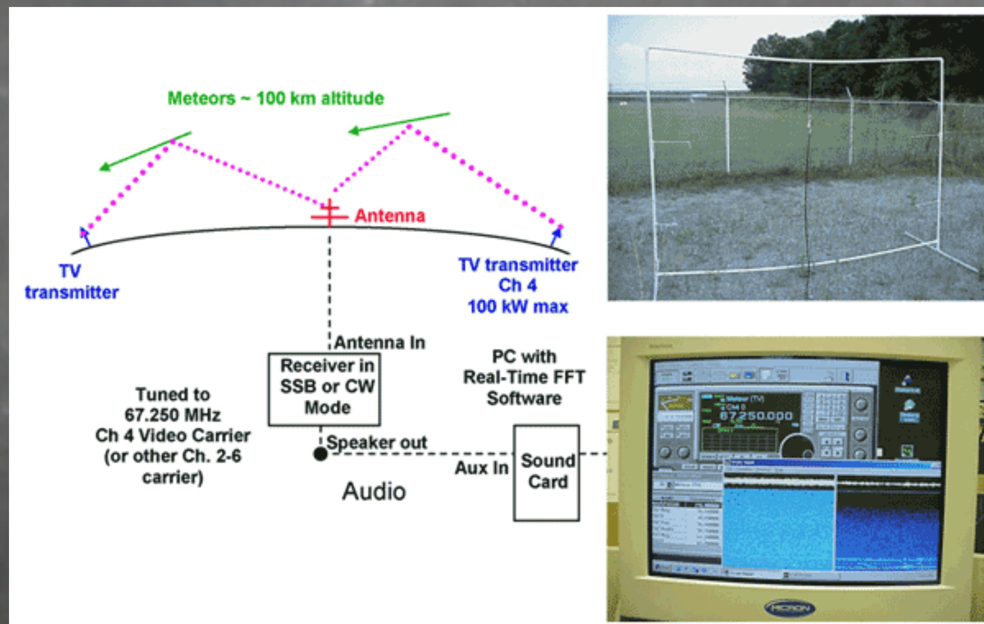
•Meteors produce a column of ionized gas as they pass through the atmosphere.
•This column reflects radio waves from transmitters on Earth's surface.
•The columns of ionized gas created by meteors usually last for only a fraction of a second.
•Brighter meteors can produce columns that last for several seconds.
•Traditionally, VHF frequencies between 40-60 MHz have been used.
•Frequencies at low end of the FM band between 88-104 MHz are also useful.
•Most radio systems used for meteor detection are of the forward scatter type.

Radio Observations of Meteors



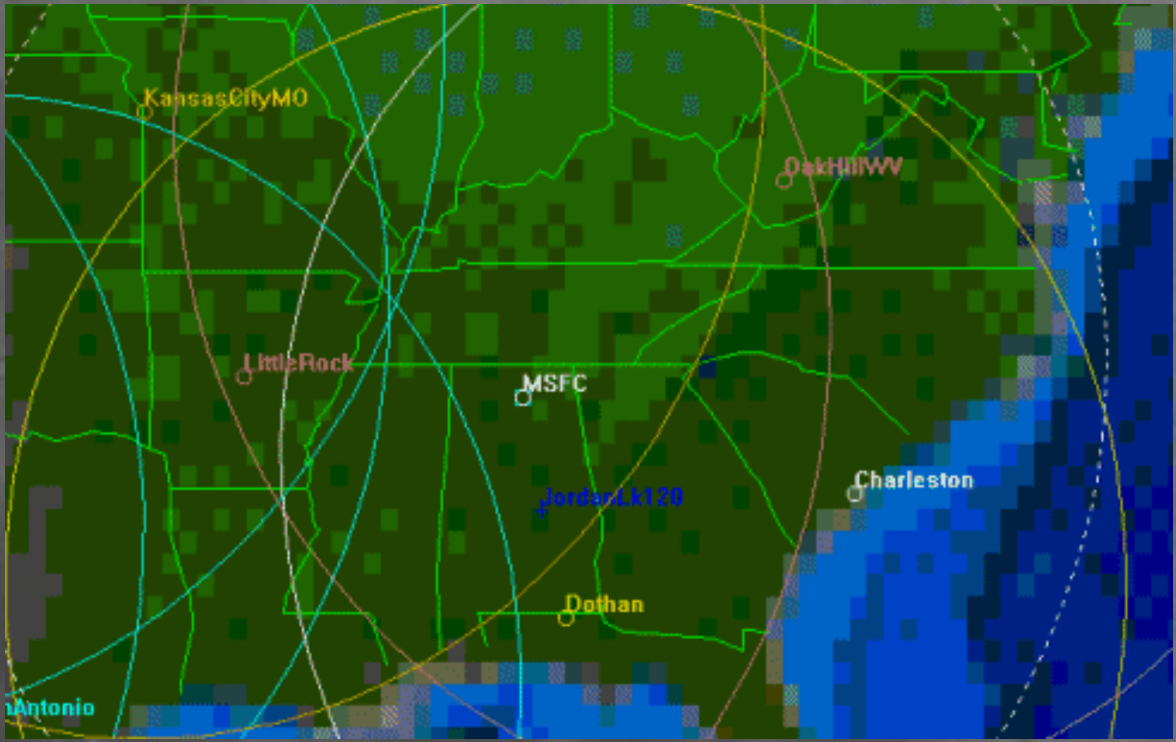
- Radio observations provide the only way to measure activity from daytime meteor showers.
- Radio observations have fewer constraints imposed by clouds and light pollution (both man-made and arising from fuller lunar phases).
- Observations are preferentially made in the hours proceeding from midnight to noon.

Example: MSFC Forward Scatter Meteor Radar



- •Antenna: 6-element Yagi; commercially available cut-to-frequency channel 4 TV antenna
- •Antenna orientation: Sits on the ground, pointed straight up
- •Receiver: ICOM PCR-1000 receiver
- •Receiver Settings: The CW demodulator is used so that 67.250 MHz (channel 4 zero offset) appears at about 700 Hz. This also inverts the passband so that the doppler shift of meteor echoes is reversed (frequency increases rather than decreases to the 'zero' frequency of the trail echo). The filter is set to 3 kHz bandwidth and the AGC is turned off.

Example: MSFC Forward Scatter Meteor Radar



Local Channel 4 zero offset TV transmitters with a circle around each showing the areas they illuminate down to an altitude of 100 km (typical meteor altitude). Although the transmitters are over the horizon for MSFC on the ground, a meteor at 100 km above MSFC has a direct line of sight. System was detecting ~2,000 pings per day.

System Requirements

•General coverage radio receiver capable of tuning TV channels 2-6 (54-88 MHz) with CW or SSB demodulator
• Antenna Commercial TV antenna or build-it-yourself
•PC compatible computer w/sound card
•Required cabling
•Fast Fourier Transform and Meteor Counting Software

Receiver: The only real requirement is that you can tune to 54-88 MHz and demodulate a SSB (single side band) or CW (continuous wave – or Morse code) signal.

Antenna: that a simple 2 element Yagi antenna provides the best gain/field of view combination but have also used a higher gain 6 element cut-to-frequency commercial TV antenna. A good compromise is a VHF or VHF/UHF multi-element TV antenna like those available from Radio Shack.

Daytime Meteor Showers

Shower	Activity Period	Maximum
Capricornids/Sagittariids	1/15-2/4	2-Feb
Chi Capricornids	1/29-2/28	14-Feb
April Piscids	4/8/-4/29	20-Apr
Delta Piscids	4/24-4/24	24-Apr
Epsilon Arietids	4/24-5/27	9-May
May Arietids	5/4-6/6	16-May
Omicron Cetids	5/5-6/2	20-May
Arietids	5/22-7/02	7-Jun
Zeta Persieds	5/20-7/5	9-Jun
Beta Taurids	6/5-7/17	28-Jun
Gamma Leonids	8/14-9/12	25-Aug
Sextantids	9/9-10/9	27-Sep

Challenges

- Fewer appropriate VHF transmitters available with demise on analog TV broadcasting.

- In many areas in the U.S., tuning to an empty frequency can be challenging.

- Ideal VHF window for meteor detection of 25-60 MHz is being impinged upon by increasing solar activity, with ionospheric bounce increasing as exhibited by reflections up to and beyond 30 MHz.

Opportunities

•Gather data that could be useful to the LADEE mission and lunar science.

•Improve understanding of poorly characterized daytime meteor streams.

•Provide enhanced capabilities for U.S. participation in this area of research, building upon experience of Japanese and Dutch networks.

•Coordination with existing groups including Radio Meteor Observers Bulletin and The International Project for Radio Meteor Observation.

•Leverage the interest in NASA space exploration to attract more people to amateur radio.

•Excellent opportunity for student engagement.

•High-profile opportunity to engage students at the California School for the Blind and members of the National Federation for the Blind.

Radio Meteor Observing Resources

NASA Meteoroid Environment Office – Forward Scatter Meteor RADAR
http://www.nasa.gov/offices/meo/outreach/forward_scatter_detail.html

International Meteor Organization - Radio Observations Page
http://www.imo.net/radio

Radio Meteor Observing Bulletin
http://www.rmob.org/index.php?lng=en

The International Project for Radio Meteor Observation
http://www.amro-net.jp/radio.htm

Spaceweather.com Radio Meteor Tutorial
http://www.spaceweather.com/glossary/meteorcounts.html

Meteor Scatter Obs with VHF Radio & Computer
http://www.kolumbus.fi/oh5iy/msobs/msobs.html

How to Use Your FM Radio to Detect Meteors
http://www.skyscan.ca/meteor_radio_detection.htm


Questions