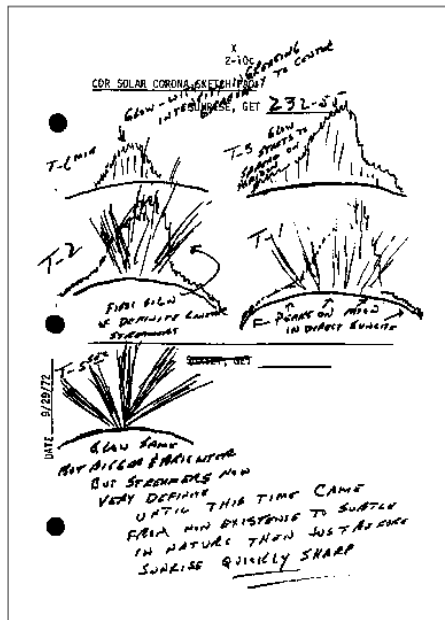


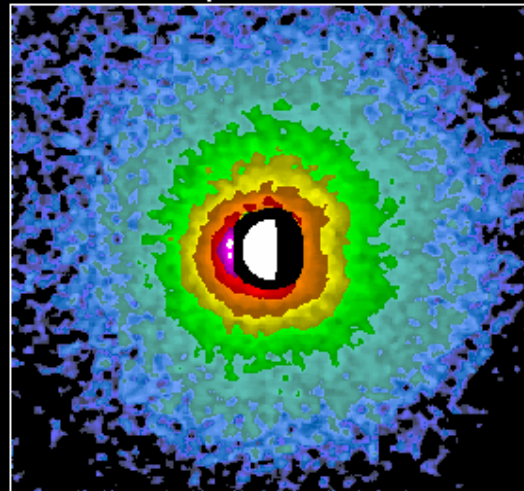
# The Lunar Atmosphere

Alan Stern

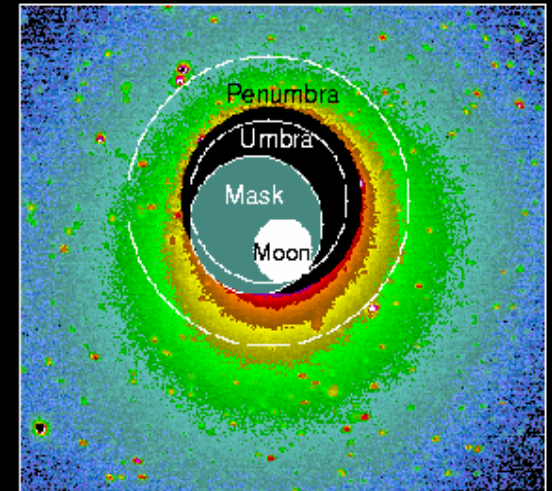
Southwest Research Institute



30 September 1991



29 November 1993



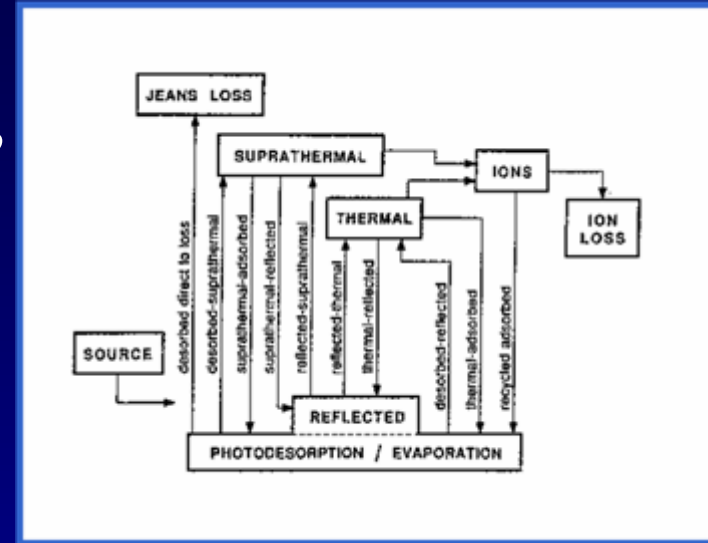
Na Emissions in Rayleighs



5 10 20 41 84 169 342 692 1400

# The Lunar Atmosphere: Quick Overview

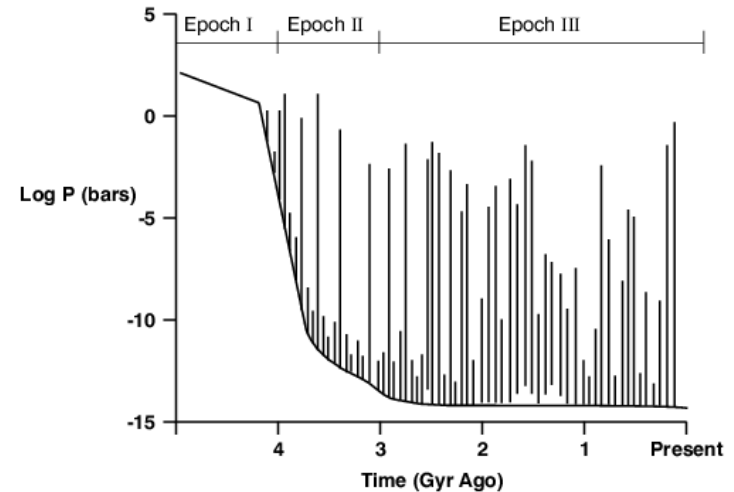
- ❑ Surface Boundary Exosphere (SBE).
- ❑ Sources: Surface sputtering, solar wind, micrometeoroid vaporization, interior outgassing, and volatile deposition.
  - All are highly time variable.
- ❑ Mass ~100 tons ( $10^8$  gm,  $10^{30.5}$  atoms).
- ❑ Continuously replenished
  - ❑ Timescale: weeks.



- ❑ Composition mostly unknown: Gas and Dust.
- ❑ Na, K, Ar detected.  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_4$ ?
  - ❑ But these are only a fraction of the total measured by Apollo
  - ❑ Numerous metal atoms, molecular frags, volatiles expected.
- ❑ Al, Si, O, Mg ions detected escaping the atmosphere.
- ❑ Winds and other dynamics seen.

# The Lunar Atmosphere: Importance

- ❑ SBE atmospheres are the most common type of atmosphere in the solar system.
- ❑ E.g., on Mercury, Galilean satellites, Enceladus, etc.
- ❑ Suspected on all icy satellites, large asteroids, some KBOs.
  
- ❑ The lunar atmosphere:
  - ✓ Is the most accessible SBE in the solar system.
  - ✓ Has particularly important ties to Mercury's SBE (asteroids too?)
  - ✓ Offers interesting analogies to Io.
  - ✓ Will be corrupted by heavy rocket traffic and a lunar outpost.



**The ancient lunar atmosphere was massive. The current lunar atmosphere is only occasionally so.**

# Some Open Questions for Lunar Science

- What is the complete composition of the lunar atmosphere?
- Which source and loss processes dominate?
- How do the various source and loss processes vary in time?
- How efficiently does water migrate to the poles?
- How do rocket exhaust and other pollutants:
  - Change the character of the atmosphere?
  - How long do these effects last?
  - How will this affect lunar-based astronomy?
  - Will surface contamination become a problem for science?
- ...
-

# How The Lunar Atmosphere Ties to Lunar Exploration

- ❑ **The lunar atmosphere is both a fragile and scientifically important aspect of the Moon, with implications for similar atmospheres around the solar system (e.g., see LEXSWG and recent NRC studies).**
- ❑ **The native environment will be corrupted by exploration.**
- ❑ **The lunar atmosphere should be documented before it is lost to that cause.**
- ❑ **Exploration will “perform” an experiment in SBE modification that itself is of intrinsic interest in several regards.**
- ❑ **The native and “constructed” lunar atmospheres both have important implications for lunar astronomy, lunar-based studies of Earth, and also possibly lunar surface sampling.**

# The Impact of Lunar Exploration

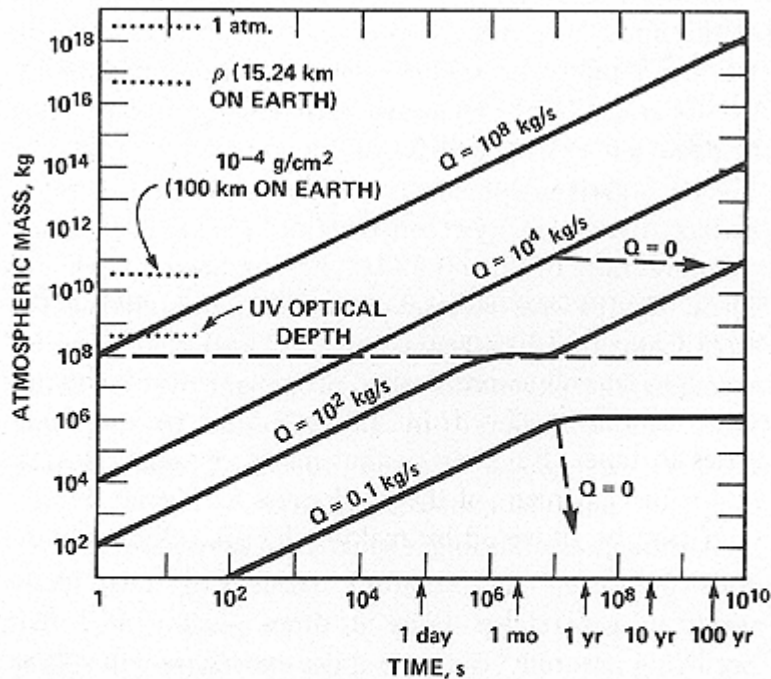


Figure 5-35.— Growth of the lunar atmosphere for various constant gas addition rates. Comparable densities in the terrestrial atmosphere are indicated. Dashed lines indicate decay in the total mass if the gas source is shut off (after Vondrak, 1974).

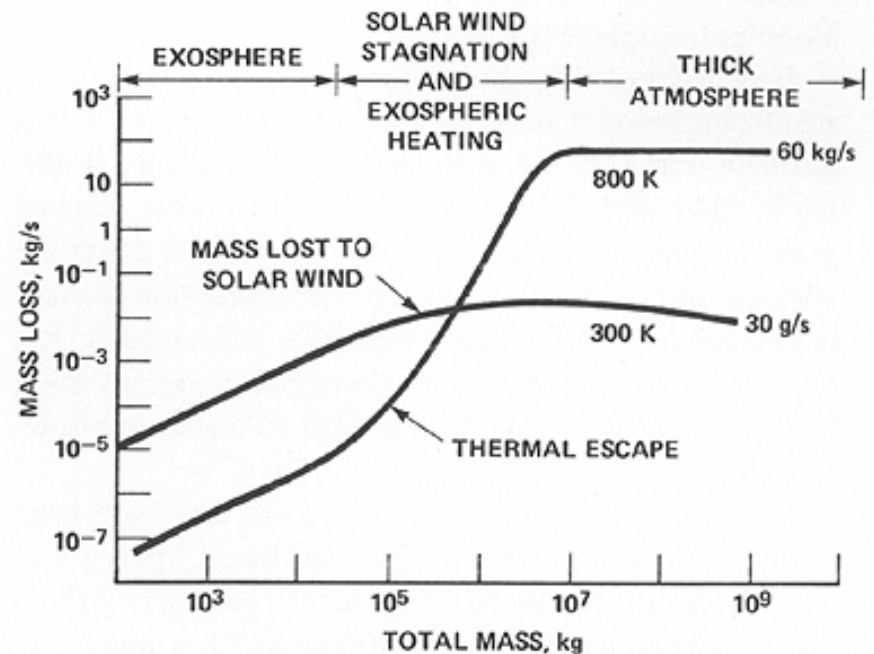


Figure 5-34.— Loss rates for an oxygen atmosphere (mass = 16 amu). At a total mass of  $10^8$  kg, the lunar atmosphere approaches a constant rate of mass loss (after Vondrak, 1974).

# Early Observational Study Objectives

- ❑ Determine the composition of the native lunar atmosphere.
- ❑ Determine the current rate of volatile transport to the poles.
- ❑ Determine the variability of indigenous (e.g., outgassing, sputtering) and exogenous (e.g., meteorite and solar wind) sources.
- ❑ Determine the loss rates, by process.
  
- ❑ Spectral and sky brightness survey for astronomy suitability.
- ❑ Active experiments that inject tracer species to study their transport (e.g., H<sub>2</sub>O to the poles, hydrazine propellant migration/breakdown/loss).

➤ **ALL OF THIS CAN BE ACCOMPLISHED BY LANDERS, NETWORKS, OR EVEN ORBITERS.**

➤ **THE FIRST FOUR OBJECTIVES ABOVE SHOULD PRECEDE ANY OUTPOST.**