Lunar Advanced Vacuum Apparatus (LAVA)

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INTRODUCTION

In Situ Resource Utilization (ISRU)

ISRU is a rapidly growing area of pure and applied space research devoted to the prospecting and processing of planetary resources to produce commodities that permit long-term robotic and crewed missions. For example, H_2O at the lunar poles can be used for drinking or for hydrolysis into H_2 and O_2 for rocket propulsion. Regolith from the Moon, Mars, and asteroids can be used to fabricate engineered materials suitable for construction and radiation shielding.

Lunar Surface

The atmosphere of the Moon is considered to be a "surface-bounded exosphere" (SBE) [1]. We know this binding surface to be permeable from both above and below, as solar wind-implanted ions (H^+, He^+) are released from regolith grains in our lunar sample 10084, and composition of the lunar atmosphere, measured from both the lunar surface [2] and from lunar orbit [3] include radiogenic argon (^{40}Ar), a gas derived from the long-lived ($\tau_{½}$ =1.25x10^9 yr) potassium isotope (^{40}K) present in lunar rock.

Extreme High Vacuum (XHV)

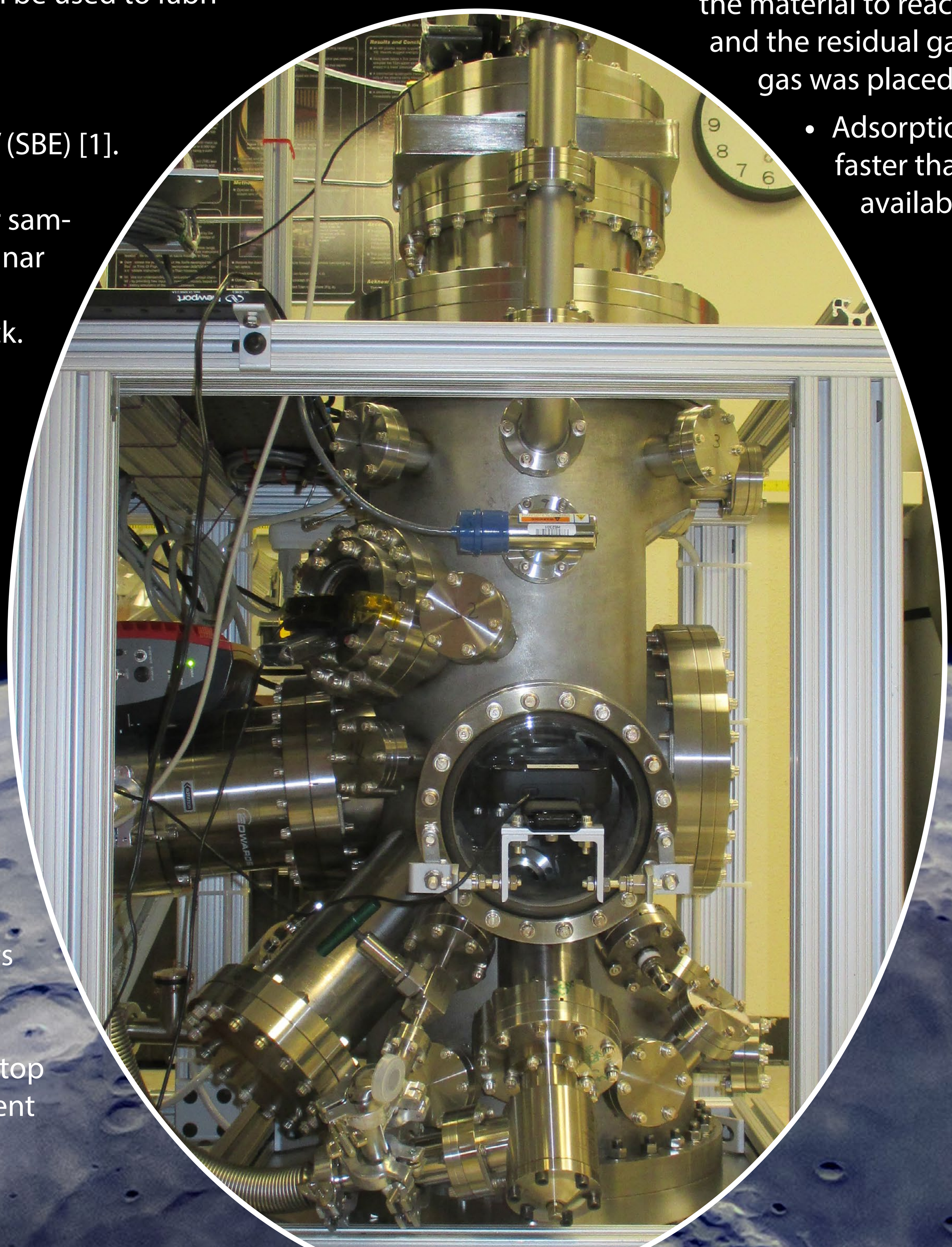
The pressure of the lunar exosphere at night is 2x10^{-12} Torr. So far we have achieved 6x10^{-8} Torr, but expect a lower base pressure after bakeout.

Volatiles

Volatiles are atoms and molecules with low melting points that are gaseous under typical conditions of terrestrial-like worlds, but can easily become sequestered in cold traps such as at the lunar poles, or adsorbed or otherwise chemically trapped just beneath the lunar surface where solar wind and UV cannot penetrate. The LCROSS impact [4] produced evidence of volatiles that included H_2, H_2O, NH_3, CO_2 and CH_4. LAVA was specifically constructed to study gas-grain interactions at the lunar surface and subsurface using such gases.

THE SYSTEM

To simulate the lunar surface and near subsurface in the laboratory, LAVA consists of a 60-liter vacuum chamber housing a 50 cm column of JSC-1A lunar soil simulant. A gas line permits gas injection at the base of the simulant column. The column is monitored by three USB 1080p video cameras (Fig. 1). A gate valve at the top of the system permits isolation of the sample volume for the switch-out of different tools, optical probes, or drills as shown in the cross section graphic (Fig. 2).



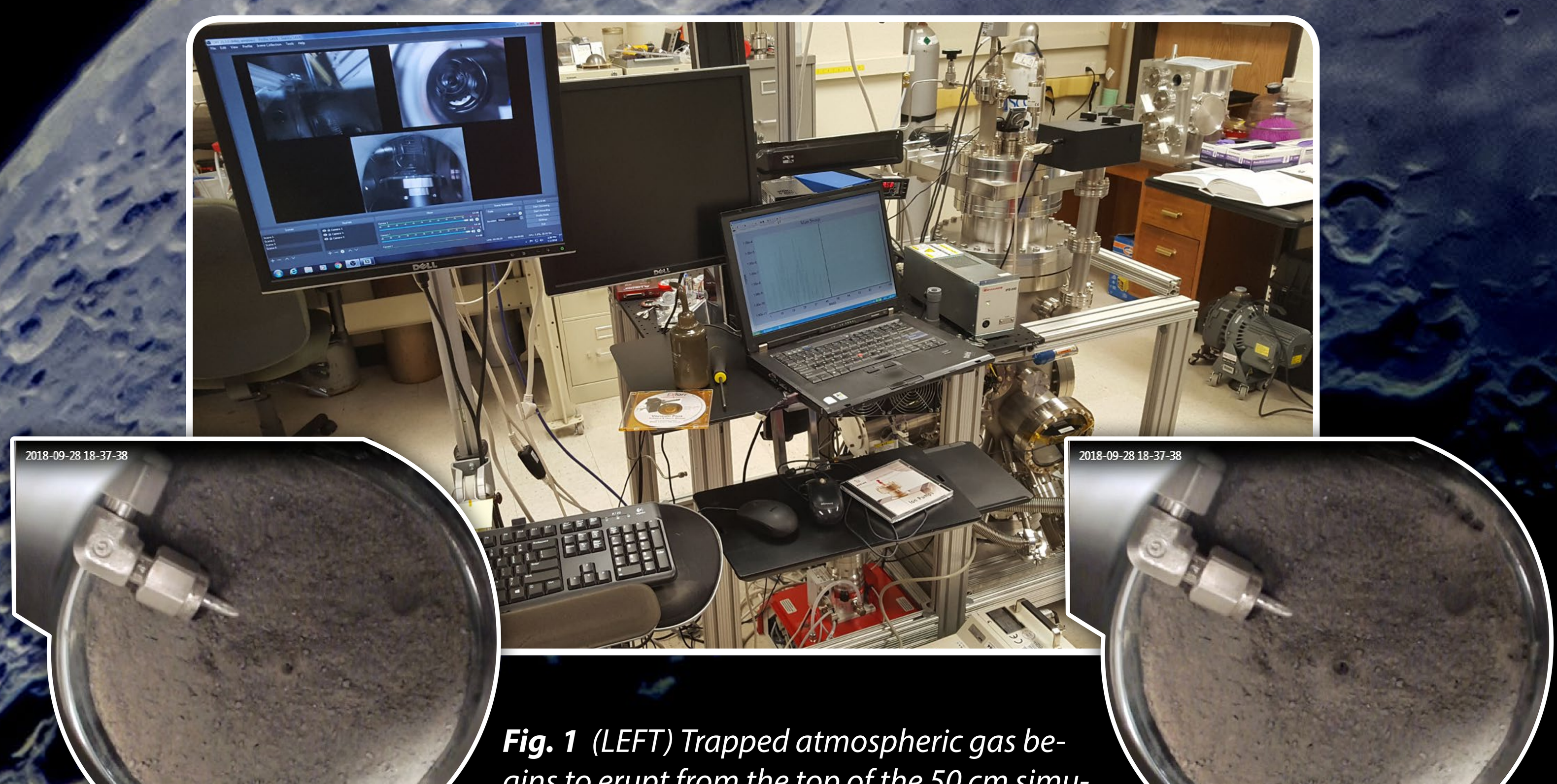


Fig. 1 *(LEFT) Trapped atmospheric gas begins to erupt from the top of the 50 cm simulant column inside LAVA. (RIGHT) Gas plumes erupt at the center of the column and along the cylinder walls as the finest of the grains are ejected onto surfaces. (CENTER) LAVA includes several 1080p USB cameras for monitoring gas eruption from the column, as well as a quadrupole mass spectrometer (QMS) residual gas analyzer (RGA).*

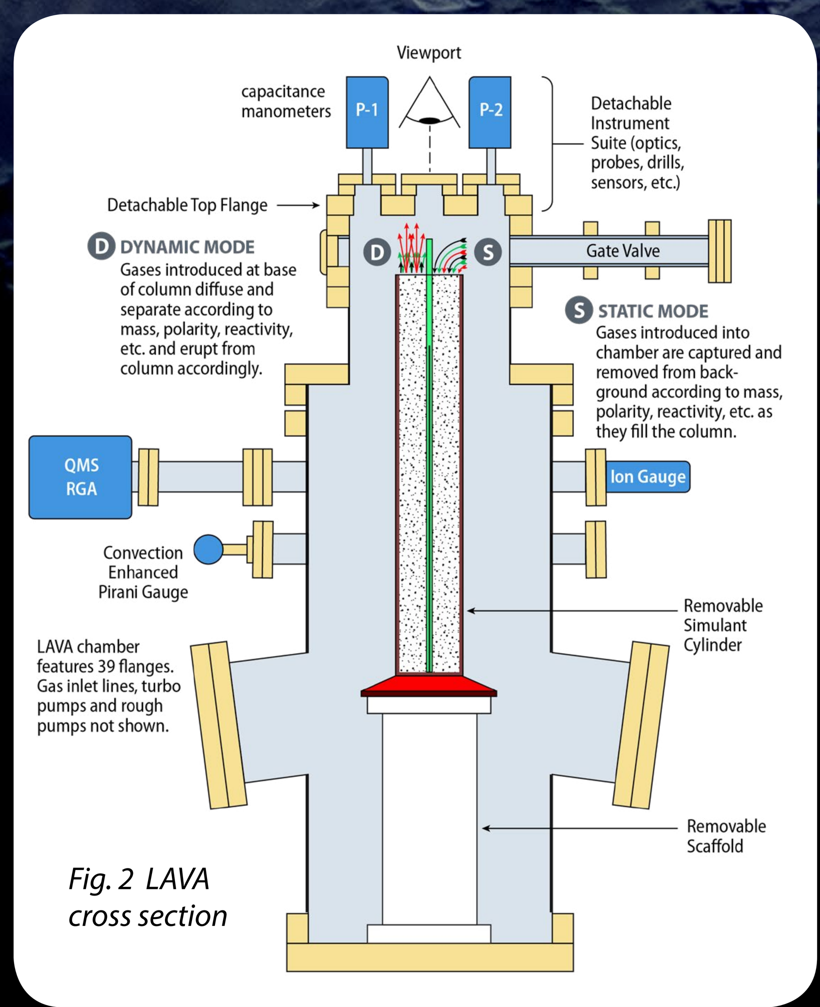


Fig. 2 *A cross section of the LAVA chamber and two primary experiment concepts. In the dynamic mode, gas is introduced while the magnetically-levitated turbomolecular pump is evacuating the system under continuous gas exposure to the column base, or from individual gas boluses released to the column base. In the static mode, the vacuum system is isolated from the chamber volume and gases released into the chamber interior are exposed to the simulant to undergo adsorption (if possible) over time through the surface layer at the top of the column.*

RESULTS

- Visual and IR spectra from 350 to 2500 nm were taken in air of JSC-1A lunar soil simulant, Knippa basalt fines, and Apollo sample 10084 with the intention to measure the reflectance again once these samples are baked under vacuum (Fig. 3).
- Even with a 50-cm column of JSC-1A simulant, in preliminary tests, gas pulses rapidly penetrated the bulk of the material to reach the surface of the column, and in quantities that easily overwhelmed the ion gauge and the residual gas analyzer (RGA) quadrupole mass spectrometer (QMS). For these reasons, only 1 Torr of gas was placed into the gas sample ballast volume for introduction to the simulant column.
- Adsorption? A sample of lab air was used in the earliest experiments. Decay of the O_2 signal was faster than that of the N_2 signal, suggesting a possible trapping mechanism such as oxidation unavailable to the N_2 molecule (Fig. 4).

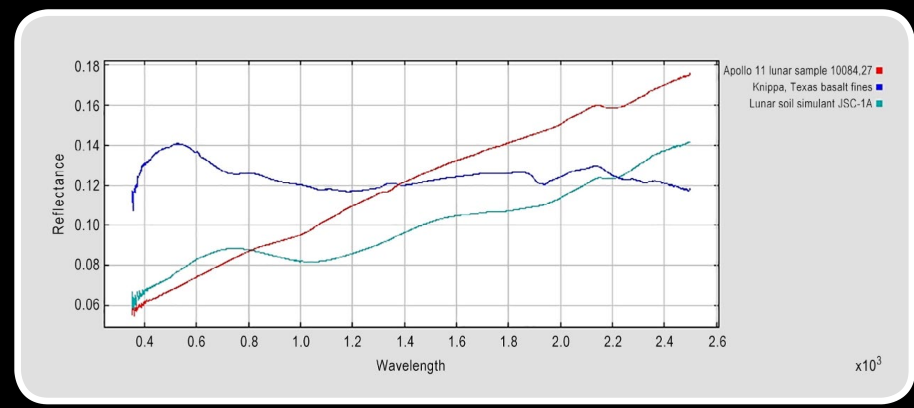


Fig. 3 The visual and IR reflectance spectra of Apollo 11 sample 10084, Knippa basalt fines, and lunar soil simulant JSC-1A were measured in the wavelength range from 350 to 2500 nm. As part of the LAVA investigation, we intend to monitor changes in reflectivity when samples are under vacuum and after bakeout to drive adventitious water from their grain surfaces.

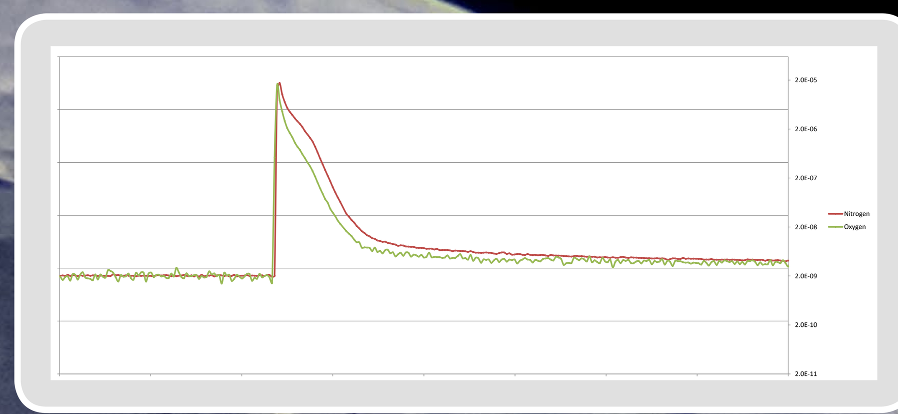


Fig. 4 Results from initial tests of atmospheric air produced N2 and O2 mass signatures that are superposed here. The complex shape of the decay results from multiple factors, including gas streaming up the walls of the glass cylinder. However, the faster decline of the O2 signature suggests an additional trapping mechanism we believe to be due to oxidation on grain surfaces of the JSC-1A lunar soil simulant produced from crushed basaltic ash.

CONCLUSIONS

Our previous laboratory results showing retention of CO_2 in JSC-1A [5] and recent results with 10084 suggest that lunar surface and subsurface trapping is more complex than we currently understand.

RECOMMENDATIONS

- A return to the lunar surface to retrieve samples is an absolute necessity.
- Regolith samples should be hermetically sealed along with their disturbed and released native gases.
- Sentinel spacecraft could monitor the long-term production and destruction of native and artificial gases.

ACKNOWLEDGEMENT

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