EPSC Abstracts
Vol. 13, EPSC-DPS2019-1173-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Submillimeter Solar Observation Lunar Volatiles Experiment (SSOLVE)

Timothy A. Livengood (1), C. M. Anderson (2), D. C. Bradley (2), B. T. Bulcha (2), G. Chin (2), T. Hewagama (1), T. L. Jamison-Hooks (2), P. E. Racette (2)
(1) University of Maryland, College Park, Maryland, USA, (2) NASA Goddard Space Flight Center, Greenbelt, Maryland, USA (sciencetimlivengood@gmail.com)

Abstract

The Submillimeter Solar Observation Lunar Volatiles Experiment (SSOLVE) is a pathfinder for lunar exploration, a small and targeted instrument to resolve broad uncertainty in the abundance of lunar water and processes for its supply, removal, and relocation. Water observed in the lunar surface and polar cold traps could be delivered by solar wind or meteoroids or it could be indigenous, with powerful implications for the Moon's formation history and evolutionary processes. The key to distinguishing the source of lunar water and processes controlling it is the present abundance of water in the atmosphere/exosphere and its diurnal variability. SSOLVE is designed to make these measurements with high sensitivity and precision.

1. Introduction

SSOLVE will use the Sun as a light source to illuminate the presence of water in the tenuous lunar atmosphere: its abundance, diurnal variability, chemical state (H_2O vs. OH), and the balance between sources and loss (Fig. 1). Water is critical to understanding lunar formation, the interaction between rocky bodies and space, and the potential for in situ resource utilization (ISRU) in lunar exploration and beyond. The SSOLVE design employs two bore-sighted heterodyne spectrometers: one spectrometer detects the 557 GHz transition of H_2O and the 509 GHz transition of HDO; the other spectrometer detects the 2510 GHz transition of OH. Doppler broadening in the absorption lines will measure the translational temperature of the gas to determine whether it is thermally accommodated to the local surface temperature as usually assumed. A sun-tracking scanner (heliostat) will acquire and track the Sun regardless of lander orientation, as well as enabling measurements on dark sky and on calibration targets. A radome and enclosure will shield the instrument from dust and visible-wavelength sunlight to enable staring at the Sun (Fig. 1).

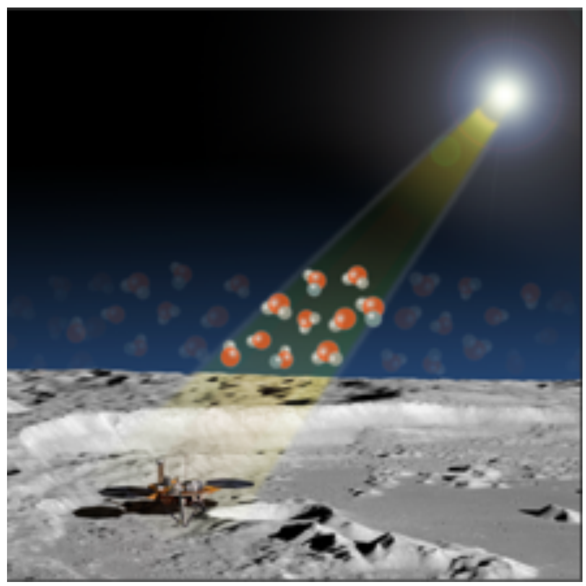

Figure 1: SSOLVE will measure lunar water vapor against the bright Sun. SSOLVE will operate submillimeter spectrometers from a lander, using a heliostat to target the Sun and to measure the column abundance of H_2O, OH, and HDO in the lunar atmosphere.

2. Measurement scenario

In a fourteen-day mission, SSOLVE will quantify the amount of water in the Moon's exosphere, retiring the controversy in the scientific community as to the amount of water and whether there is horizontal transport across the Moon's surface (Fig. 2).

The abundance of water in the tenuous atmosphere immediately above the daytime lunar surface has not been measured, although a wide range of estimates can be derived from measurements on orbit [1], remote sensing [2,3,4] (Fig. 3), and equilibrium between assumed supply and loss rates (Table I). These estimates vary by orders of magnitude. The instruments that were deployed by the Apollo missions were unable to measure the neutral atmosphere in daylight due to instrument problems, so neither the total gas pressure nor the composition of volatiles at the surface are known with any certainty [5,6,7].

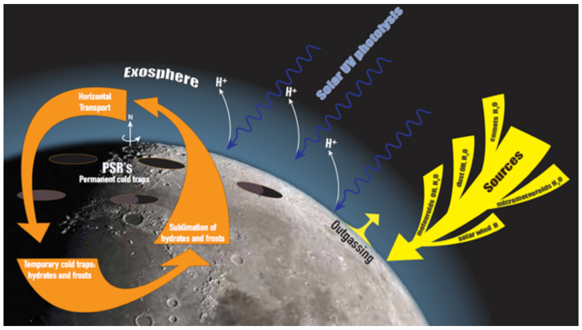

Figure 2: SSOLVE will measure water vapor to learn which source(s) of water dominates the lunar atmosphere. The global inventory of water in the atmosphere/exosphere is in equilibrium between input sources (yellow) and losses to space and (potentially) permanent cold traps at the poles. Molecules migrate from the warm daylight surface across the terminator to be temporarily trapped on the cold night-time surface until the Moon's rotation brings the hydrated/frosted surface into daylight to thermally desorb the volatiles into the atmosphere, completing a hydration cycle (orange).

Water is challenging to investigate in small quantities due to its presence as a contaminant on instrument surfaces, in sample handling environments, and in rocket exhaust. SSOLVE is designed to overcome these problems by measuring the total column of H_2O and OH above the lunar surface, in comparison with calibration measurements that can eliminate local contributions to water vapor in the line of sight. SSOLVE will use high spectral resolution to identify transitions of H_2O, OH, and HDO with certainty, to measure abundance, and to characterize physics in the exosphere using Doppler linewidth from translational motion.

Table I: SSOLVE will determine the abundance of lunar water vapor – or confirm near-zero abundance

basis		column, H_2O or OH	volume density
Maximum above exobase	collisionless atmosphere	3×10^{14} mol/cm^2	3×10^{7} mol/cm^3
LADEE mass spec	4 km above surface	$\leq 10^{10}$ mol/cm^2	$\leq10^{3}$ mol/cm^3
$\geq$ [H_2]	[H_2] ~ 10^{10} mol/cm^2	10^{9}–10^{10} mol/cm^2	10^{2}–10^{3} mol/cm^3
micrometeoroids	<100% H_2O	<10^{12} mol/cm^2	<10^{5} mol/cm^3
solar wind	<100% efficiency	<10^{13} mol/cm^2	<10^{6} mol/cm^3
mineral hydrates	surface reservoir ~10^{19} mol/cm^2	3×10^{16} mol/cm^2	3×10^{9} mol/cm^3

Grey shading indicates abundance less than the H_2O detection threshold of ~3×10^{11} mol/cm^2.

References

[1] Benna et al. (2018). Lunar Soil Hydration Con-strained by Exospheric Water Liberated by Meteoroid Impacts. *Nature Geoscience*, submitted.

[2] Li and Milliken (2017). Water on the surface of the Moon as seen by the Moon Mineralogy Mapper: Distribution, abundance, and origins. *Science Advances* **03**, e1701471, doi: 10.1126/sciadv.1701471.

[3] Livengood et al. (2015). Moonshine: Diurnally varying hydration through natural distillation on the Moon, detected by the Lunar Exploration Neutron Detector (LEND). *Icarus* **255**, 100–115, doi: 10.1016/j.icarus.2015.04.004.

[4] Sunshine et al. (2009). Temporal and Spatial Variability of Lunar Hydration as Observed by the Deep Impact Spacecraft. *Science* **326**, 565–568, doi: 10.1126/science.1179788.

[5] Cook et al. (2013). New upper limits on numerous atmospheric species in the native lunar atmosphere. *Icarus* **225**, 681–687, doi: 10.1016/j.icarus.2013.04.010.

[6] Stern et al. (2013). Lunar atmospheric H2 detections by the LAMP UV spectrograph on the Lunar Reconnaissance Orbiter. *Icarus* **226**, 1210–1213, doi: 10.1016/j.icarus.2013.07.011.

[7] Hoffman and Hodges (1975). Molecular gas species in the lunar atmosphere. *The Moon* **14**, 159–167, doi: 10.1007/BF00562981.