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Submillimeter Solar Observation Lunar Volatiles Experiment (SSOLVE)

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The Submillimeter Solar Observation Lunar Volatiles Experiment (SSOLVE) is a pathfinder for lunar exploration, a small and simple 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 present processes controlling it is the abundance of water in the atmosphere/exosphere and its diurnal variability. SSOLVE is designed to make these measurements, with high sensitivity and precision.

Mission concept: The SSOLVE instrument design and measurement goals assume a solar-powered lander outside the polar regions, within approximately ±60° latitude. The diurnal variability that SSOLVE will measure is diminished closer to the poles. Solar power restricts the basic mission to one lunar day, as surviving the lunar night cannot be assumed without power for survival heaters. We assume sufficient power for instrument operation in 12 days out of ~14 days of sunlight. The longest integration time that we consider assumes a duty cycle of 1/6 to conserve average power, resulting in 48 hours' total integration time. Longer total survival or higher duty cycle would reduce the minimum measurable column proportional to the square root of integration time.

Progress: SSOLVE development is supported by NASA as part of the Development and Advancement of Lunar Instrumentation (DALI) program, beginning in April 2019.

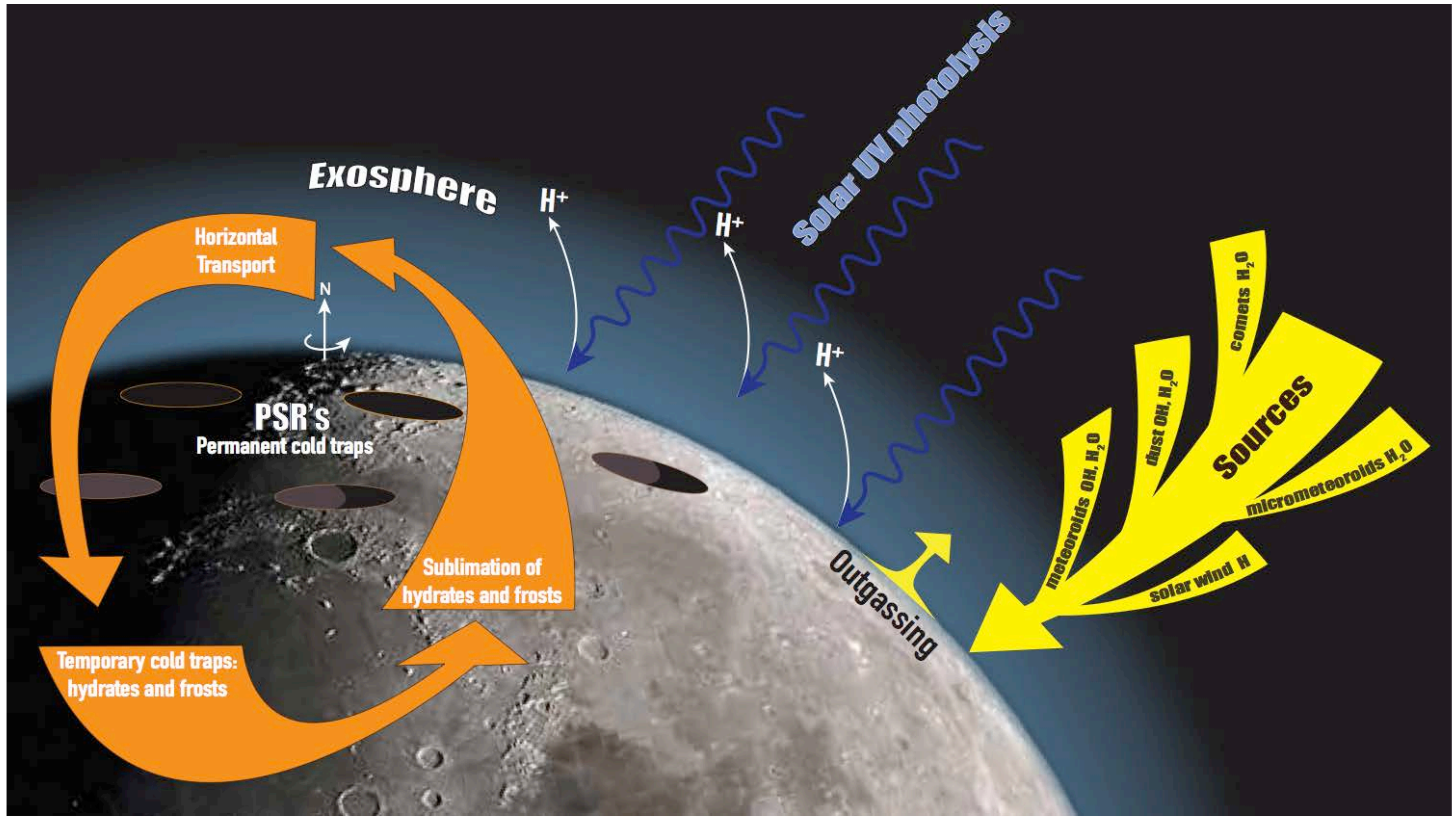

Fig. 1: SSOLVE will measure water vapor to learn which source(s) of water dominates the lunar atmosphere. The global inventory of water in the atmosphere/exosphere is in equilibrium between input sources (yellow) and losses to space and (potentially) permanent cold traps at the poles. Molecules migrate 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).

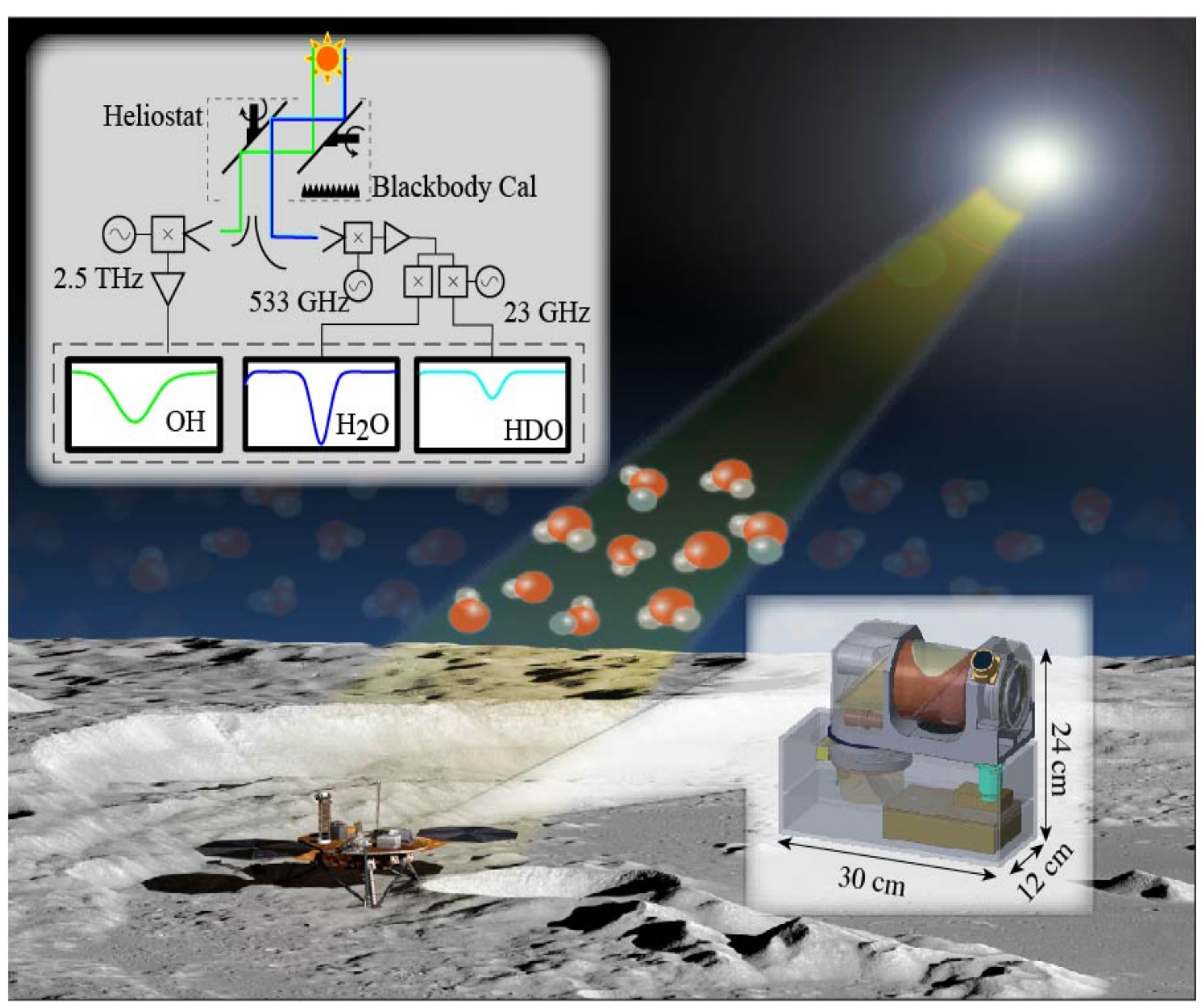

Fig. 2: SSOLVE will measure lunar water vapor against the bright Sun. SSOLVE will operate two submillimeter spectrometers from a lander, using a heliostat to target the Sun to measure the column abundance of H_2O, OH, and HDO in the lunar atmosphere. H_2O and OH establish the chemical state of water and constrain current photolysis and loss rates, while HDO/H_2O constrains the history of hydrogen loss. Spectral absorption features can measure very small quantities of atmospheric water, $<10^{12}$ mol/cm^2 (~10^5 mol/cm^3 at surface). Vapor quantities inferred from diurnal variability of surface hydration, $>10^{14}$ mol/cm^2 (~10^7 mol/cm^3), could be detected in <10 min.

SSOLVE will determine the abundance or absence of lunar water vapor

Basis of estimate	Description	Column density of H_2O or OH	Volume density of H_2O or OH	Ratio to exobase column	SNR in 10 min	Reference
Maximum above exobase	Collisionless atmosphere, surface-bounded exosphere	3×10^{14} mol/cm^2	3×10^{7} mol/cm^3	1	190	Chamberlain & Hunten (1987), p. 331
LADEE mass spectrometer	*4 km above surface*	*≤10^{10} mol/cm^2*	*≤10^{3} mol/cm^3*	*~10^{-5}*	—	*Benna et al. 2018*
comparable to or greater than [H_2]	*[H_2] ~10^9–10^{10} mol/cm^2*	*<10^{10} mol/cm^2*	*<10^{3} mol/cm^3*	*~10^{-5}*	—	*Stern et al. 2013*
micrometeoroid dominated	<100% H_2O	<10^{12} mol/cm^2	<10^{5} mol/cm^3	~3×10^{-3}	~1	derived from Cintala (1992)
solar wind dominated	<100% efficiency	<10^{13} mol/cm^2	<10^{6} mol/cm^3	3×10^{-2}	~7	derived from Crider & Vondrak (2000)
mineral hydrate concentrations	total surface reservoir ~10^{19} H_2O/cm^2	3×10^{16} mol/cm^2	3×10^{9} mol/cm^3	10^2	~1000	derived from Li and Milliken (2017)
diurnal modulation of neutron flux	volatile surface reservoir ~10^{20} H_2O/cm^2	~10^{18} mol/cm^2	~10^{11} mol/cm^3	~3×10^{3}	~1000	derived from Livengood *et al.* (2015)