Unique in situ science goals

- Directly determine the chemical composition, abundance and isotopic ratios (i.e. D/H) of volatiles and possible organics cold-trapped in permanently shadowed regions of the lunar poles
- Determine the mechanisms by which volatiles are trapped; e.g. by adsorption, chemical bonding, etc.
- Determine the near-surface vertical profile of the lunar polar deposits
- Monitor the time-sensitive magnitude and variability of current volatile deposition from the exosphere and the environmental conditions that control this process
- Ground truth remote sensing measurements from orbital missions (e.g. LRO, LADEE and Kaguya) to gain a more complete understanding of the history and current state of volatiles in the inner solar system
- Evaluate important physical and geotechical properties of the polar regions

In situ instrumentation

- Many instruments being developed or flown for Mars (see Appendix in Mars 2020 SDT report) – can they be modified for the Moon?
  - Passive techniques for mineralogy, composition (TES, M3)
  - Mass spectrometers, gas chromatographs, Tunable laser Spectrometer (MOMA, TLS+GC+QMS)
  - Induced / active methods (Raman, LIBS, APXS, UV, etc)
  - More advanced lab techniques (ChemMin, in situ dating, etc)
- Simple geotechnical instruments (e.g. cone penetrometer)
- Sample handling, subsurface access

Acronym	Instrument Name	Instrument Category	Measurement Description	References
AOTF Point Spec.	Acousto- optic tunable filter point spectrometer	Fine Scale Mineralogy	Identify minerals associated with aqueous environments at sample scales of ~1 mm; as well as organic molecules and volatiles (notably H2O and CO2 ice)	[illegible] (2012), Miniature Spectrometer for Detection of Organics and Identification of their Mineral Context, in International Workshop on Instrumentation for Planetary Missions, p. Abstract #1142, Lunar and Planetary Institute, Houston. [online] Available from: http://www.lpi.usra.edu/meetings/ipm2012/pdf/1142.pdf
APXS	Alpha Particle X-Ray Spectrometer	Fine scale elemental chemistry	Bulk elemental abundance	Gellert, R., J. L. Campbell, P. L. King, L. A. Leshin, G. W. Lugmair, J. G. Spray, S. W. Squyres, and A. S. Yen (2009), The Alpha-Particle X-Ray Spectrometer APXS for the Mars Science Laboratory MSL Rover Mission, in 40th Lunar and Planetary Science Conference, p. Abstract #2364, Lunar and Planetary Institute, Houston. [online] Available from: http://www.lpi.usra.edu/meetings/lpsc2009/pdf/2364.pdf
ChemCam	Chemistry Camera	Fine scale elemental chemistry; Microscopic Imaging	Remote Fine scale elemental chemistry; panchromatic, focusable, remote microscopic imaging	Maurice, S. et al. (2012), The ChemCam instrument suite on the Mars Science Laboratory MSL rover: science objectives and mast unit description, Space science reviews, 170, 95–166, doi:[illegible]. [online] Available from: [illegible] Wiens, R. C. et al. (2012), The ChemCam instrument suite on the Mars Science Laboratory MSL rover: Body unit and combined system tests, Space science reviews, 170, 167–227, doi:[illegible]
CHEMSENS	Chemical analysis system	Redox Potential; Regolith/Dust Properties	Measure aqueous geochemical soil properties: Ca2+, Mg2+, K+, Na+, NH4+, Cl-, Br-, I-, NO3-, pH, and Ba2; electrical conductivity; oxidation-reduction potential; anodic stripping voltammetry; chronopotentiometry; cyclic voltammetry	Kounaves, S. P., J. M. [illegible], K. M. [illegible], G. D. O'Neil, and M. H. Hecht (2012), CHEMSENS: A Wet Chemical Analysis Laboratory for Mars, in International Workshop on Instrumentation for Planetary Missions, p. Abstract #[illegible], Lunar and Planetary Institute, Houston. [online] Available from: [illegible]
Chirality	Chirality Experiment	Sample Organic Detection	Chirality	[illegible], S., V. K. Valev, and T. Verbiest (2012), Detecting and Analyzing Molecular Chirality on Mars, in Concepts and Approaches for Mars Exploration, p. Abstract #[illegible], Lunar and Planetary Institute, Houston. [online] Available from: [illegible]
CLUPI	Close-Up Imager	Microscopic Imager	Microscopic imager	Josset, J., F. Westall, B. Hofmann, C. Cockell, M. Josset, E. Javaux, and others (2011), CLUPI: the High Performance Close-up Camera System on board the 2018 ExoMars Rover, in EGU General Assembly 2011, vol. 13, pp. [illegible]. [online] Available from: [illegible]

In-situ Studies of Lunar Ice: Solar-System Evolution

Yang Liu, JPL; Barbara Cohen, MSFC; Michael Poston, VT

Science Discoveries: Water, Water, Everywhere

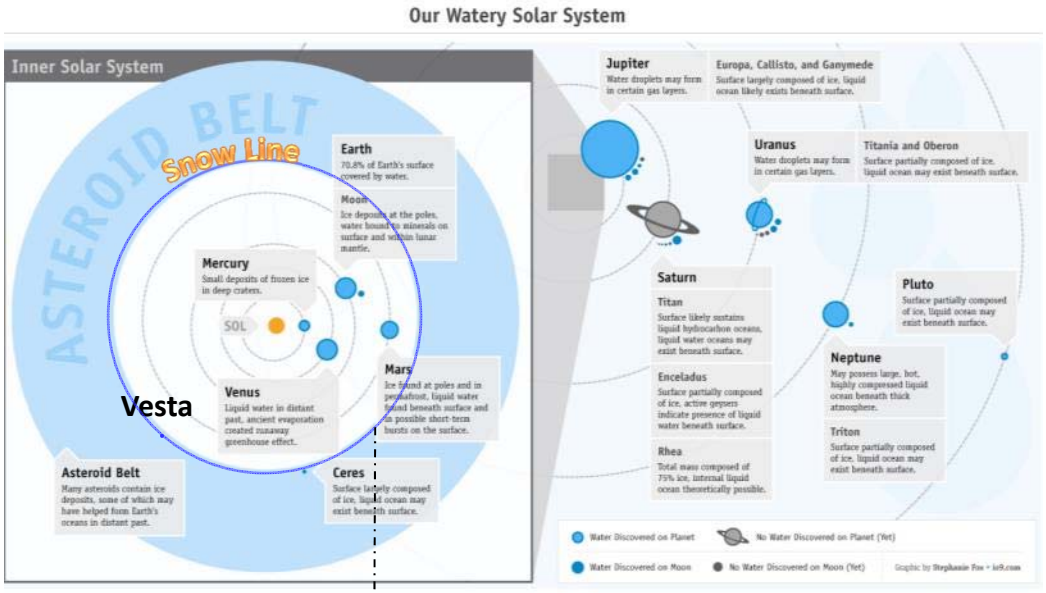
- Previously-thought dry, airless rock bodies: Mercury, the Moon, Vesta and possible some Near-Earth Asteroids
- Origin: Solar-wind, or Comet, or Meteorite, or endogeneous
- Water in Carbonaceous Chondrites ≈ Protosolar Nebular ≠ assumed order of formation distances ≠ ice influx

Unanswered Questions

- Distribution of Water/Solar Nebular Dynamics
- Abundances/Inventory
- Water on Earth

In-situ Measurements

- Avoid alteration during the trip back to Earth
- Avoid contamination in Sample Preparation [alteration of hygroscopic/hydrophilic (like-water) minerals]

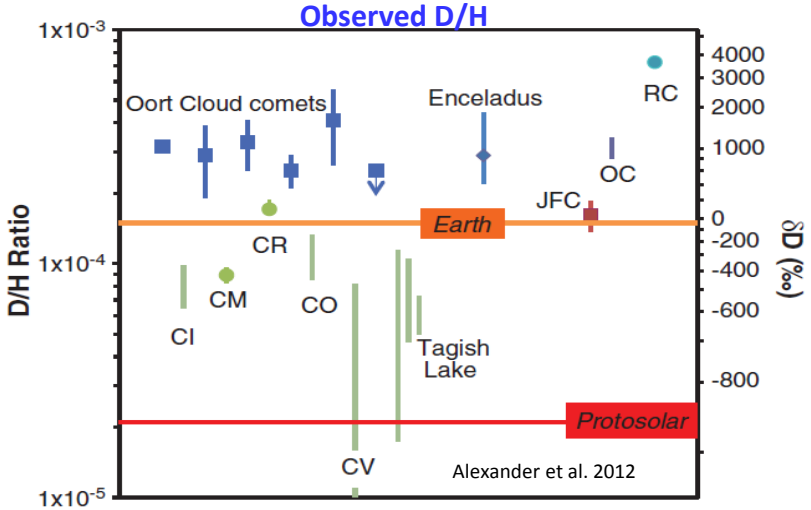


EC, OC | CO, CV, CI, CR, CM

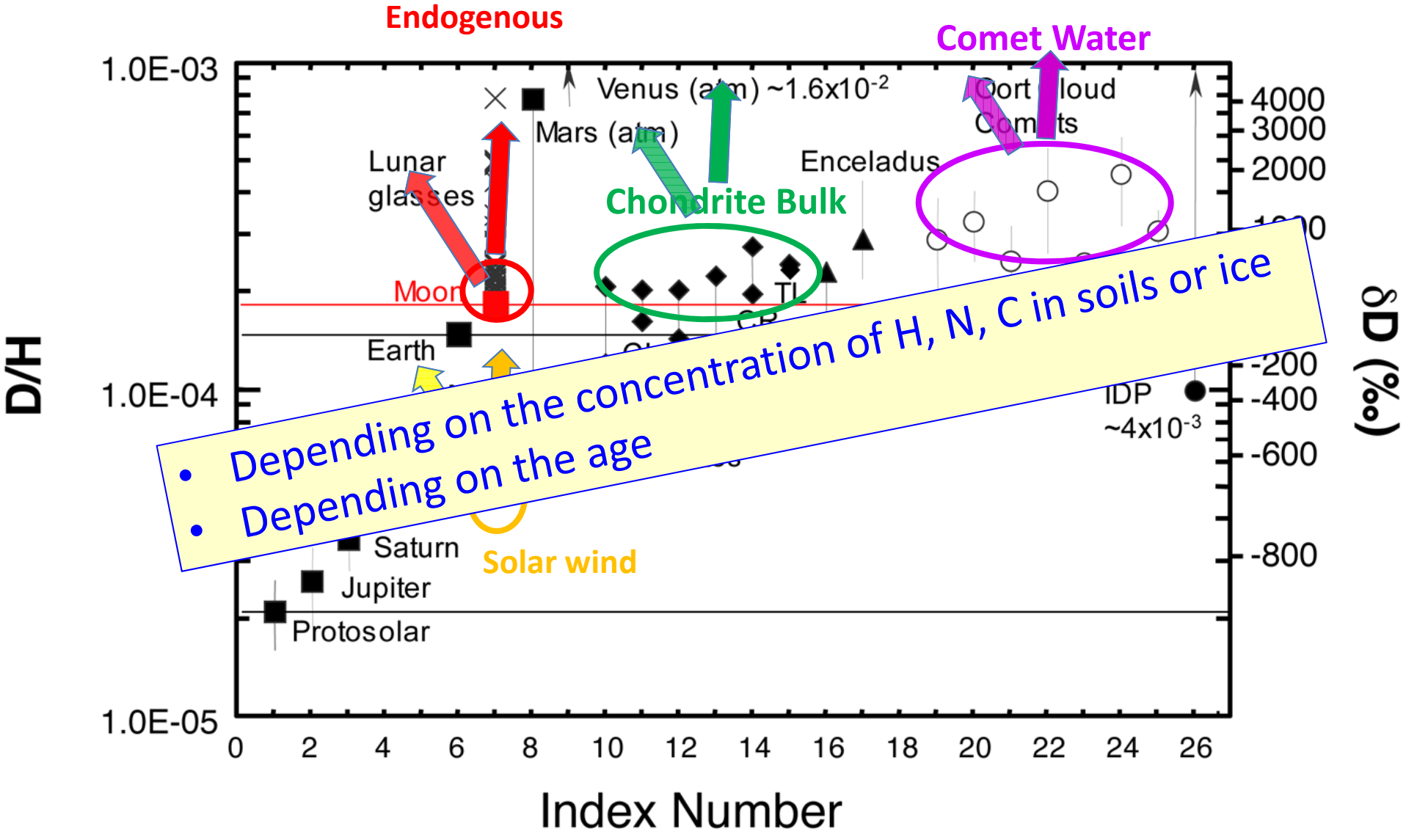
T

Expected D/H from Condensation

Observed D/H



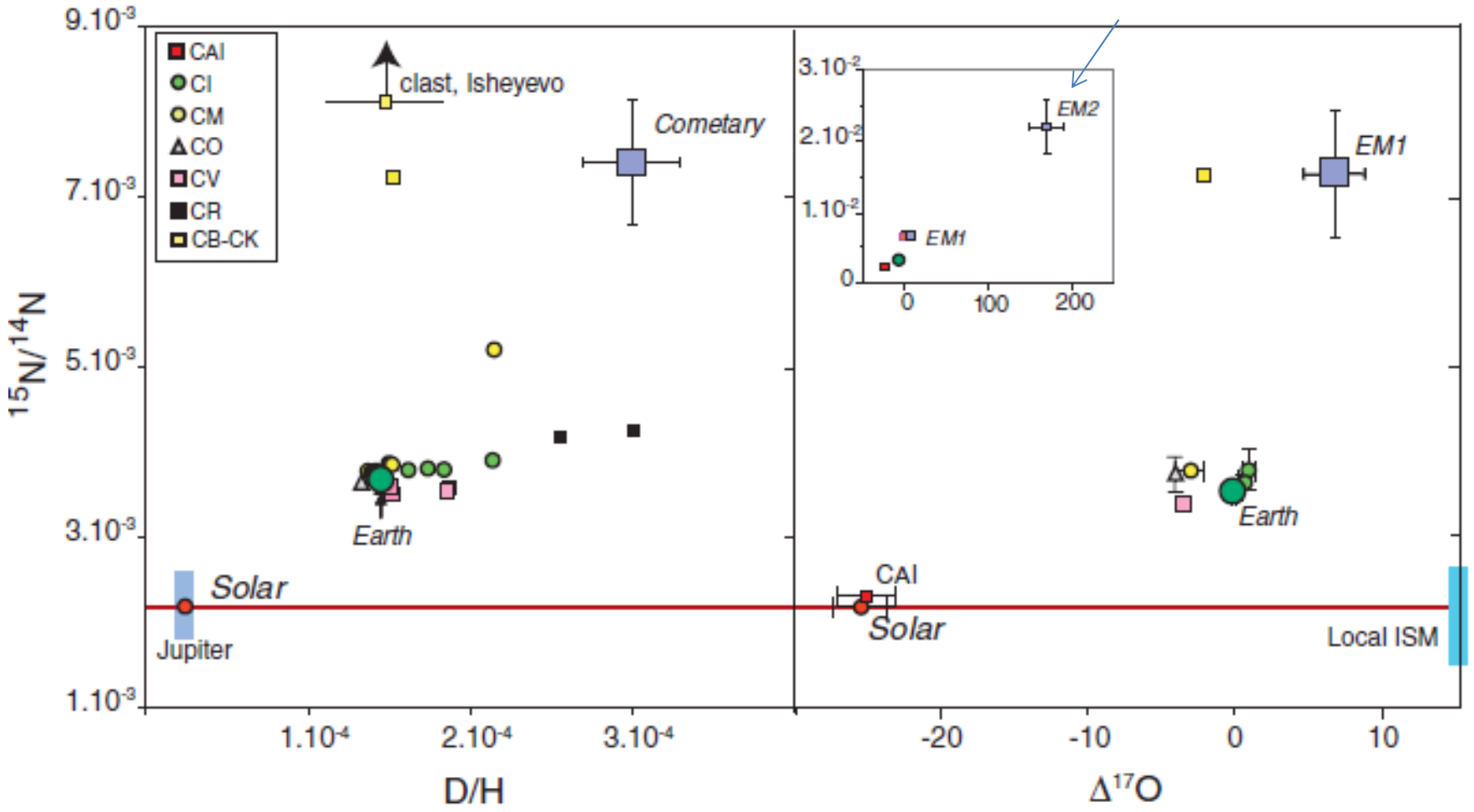
Sample Study



- Depending on the concentration of H, N, C in soils or ice
- Depending on the age

Greenwood et al. (2011); Liu et al. (2012), Saal et al. (2013) Sci.

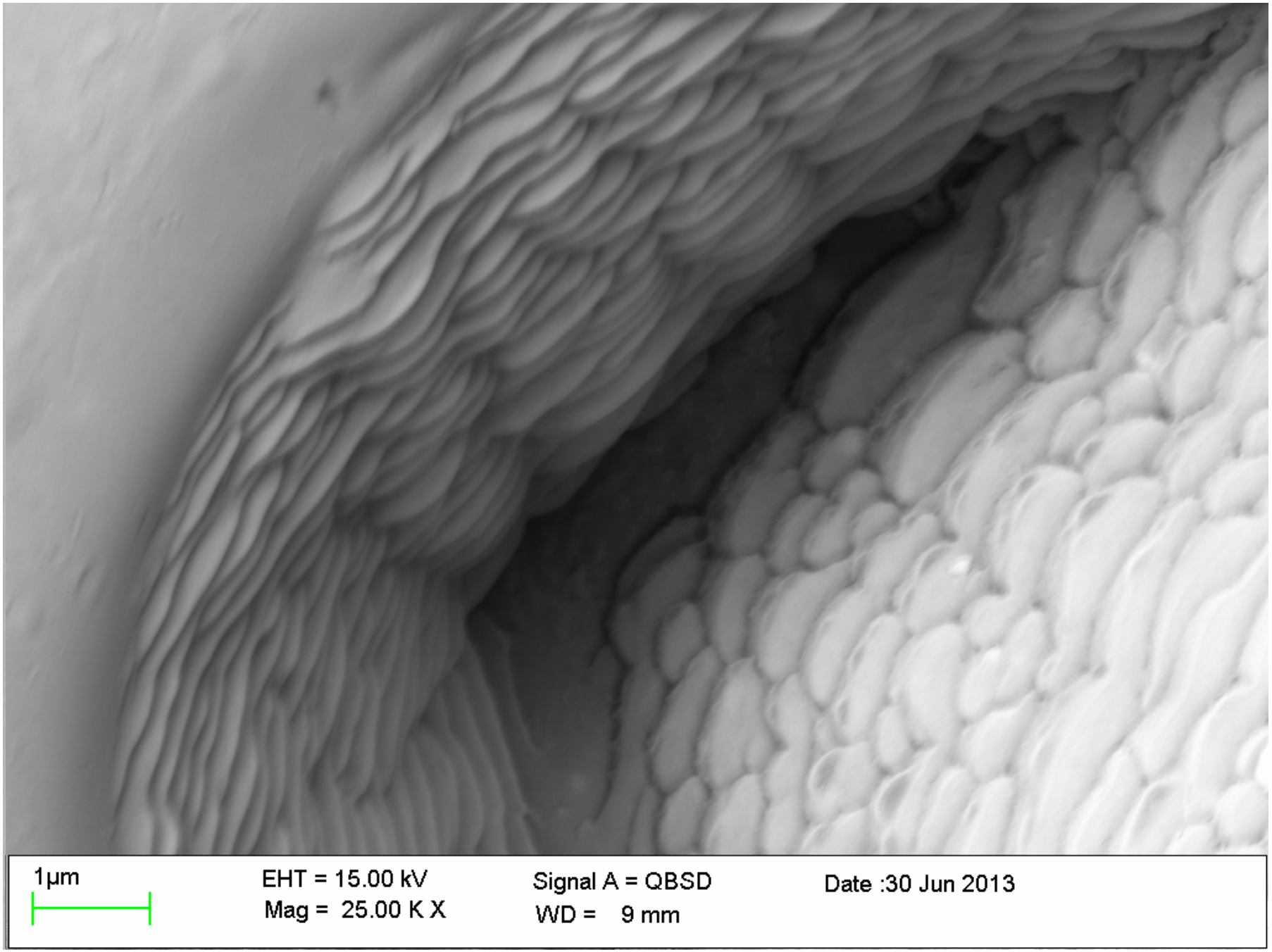
PCP in CC Acfer094



Marty et al. (2011) Sci., 332, 1533

LACE mass spectrometer

- Deployed by Apollo 17 crew
- Mass spectrometer intended to measure the lunar atmosphere
- Sensor oriented up to find migrating species
- Could not be operated during the day due to outgasing
- Apparently outgased for months?
- Discovered lunar Ar cycle, but attempts to confirm from orbit have not yet succeeded


1µm
EHT = 15.00 kV
Mag = 25.00 K X
Signal A = QBSD
WD = 9 mm
Date :30 Jun 2013