CHARACTERIZING LUNAR VOLATILES WITH ISOTOPIC PRECISION USING CAVITY RINGDOWN SPECTROSCOPY

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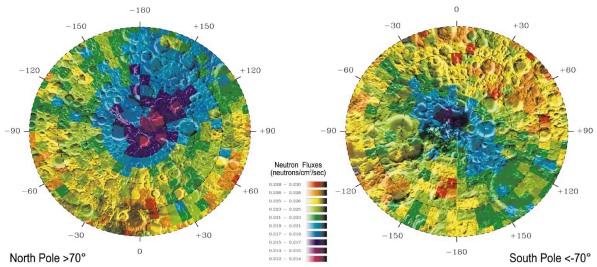
Lunar H_2O/OH

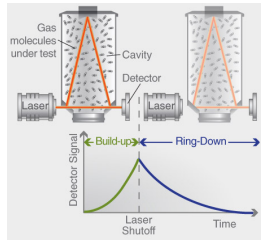


Permanently shadowed regions of the Moon have condensibles like H_2O as suggested by neutron flux observations by LCROSS[1]. Other condensibles may include CO_2 and H_2S.

- **In-situ determinations of the isotopic composition of volatile compounds such as water should help us constrain their origins**
- **Traditional isotope ratio mass-spectrometry (IRMS) instruments, which typically achieves isotopomer separation and quantification using magnetic fields, are too massive for deployment as planetary instruments**
- **Cavity Ring Down spectroscopy (CRD), however, makes use of tunable IR lasers and the existence of distinct IR absorption resonances (ε(λ)) to quantify the abundances of gas-phase molecules**
- **In recent years, CRD has been commercialized to carry out isotope ratio mass-spectrometry in terrestrial applications**

Goal: Develop Flight Ready Prototype to determine the isotopic composition of lunar volatile compounds such as H_2O, CO_2, H_2S, etc. using Cavity Ringdown Spectroscopy

Isotope Ratio Mass Spectrometry with Cavity RingDown (CRD) Spectroscopy



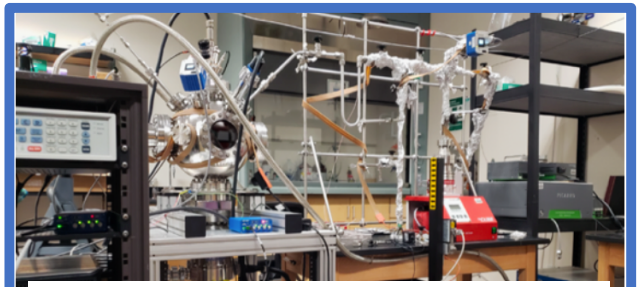
$$I(t,\lambda) = I_0(\lambda)e^{-t/\tau(\lambda)}$$

$$1/\tau(\lambda) = 1/\tau_0(\lambda) + 1/\tau_{sample}(\lambda)$$

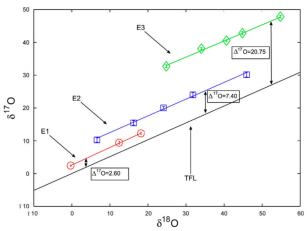
$$1/\tau_{sample}(\lambda) \propto \epsilon(\lambda)C_{isotopomer}$$

$$\delta^j = \left(\frac{{}^jR_{SA}(m_i,m_j)}{{}^jR_{ST}(m_i,m_j)} - 1\right) \times 10^3$$

$$R_x(m_i,m_j) = C_x(m_j)/C_x(m_i)$$



CSUSM Astrophysical Isotopic Characterization Experiment (ICE)

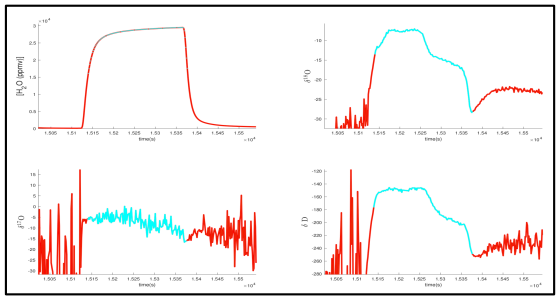


Multi-oxygen isotopic composition of H_2O using CRD as shown in [2]

Previous Work

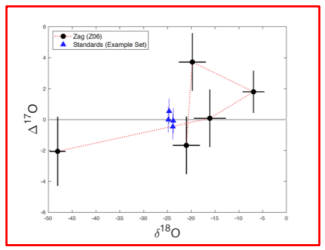
- δD, $\delta^{18}O$, $\delta^{17}O$, $\Delta^{17}O$ of H_2O [2]
- Integration with Vacuum System
- Cryogenic trapping of small samples of H_2O from experiments + Pulse Analysis [3]

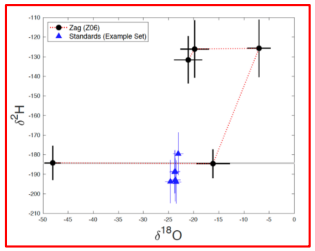
Volatile Pulse Analysis



Pulse analysis of water sample after trapping and release upon thawing can be used to determine isotopic composition of samples as small as 0.25 microLiters [3].

Analysis of Zag Meteorite Water





Isotopic determinations of small natural samples extracted from water-rich halite crystals found within primitive meteorite (Zag) using CRD and CSUSM ICE apparatus (Ogliore et. al, in prep).

Future work will focus on additional volatile compounds with upgraded laser technology and development of extraction techniques from frozen soils as well as prototype instrument development

References & Acknowledgements

[1] Feldman, W.C., et al., Science, 1998. **281,** 1496. [2] Salvo, Gormally, &Dominguez, Anal. Chim. Acta, 2013. 804(1): p. 176-179 [3] Dominguez et al., in prep [4] Ogliore et al., in prep. [5] NASA grant (GD, NNX13AN25G) & NSF AAG grant (GD,1616992)