

MASS SPECTROMETER CALIBRATION OF THE CASSINI COSMIC DUST ANALYZER FOR H₂O AND D₂O ICES VIA LASER ABLATION. M. J. Willis¹, T. J. Ahrens¹, M. Heinrich¹ and J. L. Beauchamp², ¹Seismological Laboratory (252-21), California Institute of Technology, Pasadena, CA 91125. mjwillis@gps.caltech.edu ²Noyes Laboratory of Chemical Physics (127-72), California Institute of Technology, CA 91125

Introduction: The Cosmic Dust Analyzer (CDA) instrument aboard the Cassini spacecraft contains a time-of-flight mass spectrometer (TOF-MS) which is studying the composition of dust particles in the vicinity of Saturn [1]. Dust particles impacting on the CDA instrument's Chemical Analyzer Target generate ionized material which is accelerated via an electric field to a multiplier, with the arrival time of ion species at the multiplier being determined by their mass. The response of CDA to impacts of iron and carbon particles has been determined by experiment [2, 3]. However, no calibration data exists for particles consisting of planetary ices (e.g. H₂O, CH₄, NH₃), which are expected to be encountered in the Saturnian system. Previous experiments have performed TOF-MS analysis of water ice through vaporization and ionization from particle impact on ice targets [4, 5], where it has been found that significant quantities of vapor are produced at impact velocities as low as 100 m s⁻¹. We present results of experimental work in which laser ablation of a H₂O and D₂O coated copper target is used to simulate the impact of ice particles onto the CDA instrument. Laser ablation was previously used to calibrate CDA for minerals [6, 7].

Experimental Method: The experimental setup is shown in Figure 1. A mock-up of the CDA mass spectrometer was assembled in a vacuum chamber. The target consists of a Cu plate mounted on the end of a loop of stainless steel tubing. Cu was used to provide efficient target cooling. LN₂ was pumped through the tubing to cool the target to 77K. A leak valve was then opened to allow vapor from a vial of liquid H₂O or D₂O into the chamber via an inlet tube 10 mm from the target. The valve was kept open for 5 min to allow a ~50 nm layer of ice to be deposited on the cooled Cu target. With the valve closed, a 3 mJ, 20 ns pulse from an Nd:YAG laser operating at 532 nm was fired at the target. The laser pulse was focused via lenses to produce a power density of ~10⁹ W cm⁻² over a 7×10⁸ m² area of the target. At this wavelength H₂O and D₂O ices have very low absorptivity; however, the laser energy is instead absorbed by the Cu substrate, briefly raising its temperature to ~10⁴K [8]. This causes vaporization and ionization of the Cu substrate, which in turn heats and ionizes the ice layer. This two-stage technique for ionization of water ice using a visible laser has previously been used by [9, 10]. Positive ions from H₂O and D₂O, as well as Cu and surface con-

taminants, are accelerated away from the target by a -1kV potential between the target and a grid mounted 5 mm away. After passing through the grid the ions pass through a 23 cm field-free drift tube before arriving at a multi-channel plate (MCP) detector where the resultant signal is recorded by an oscilloscope. The arrival time t of a singly-charged ion is proportional to its mass m by $t \propto \sqrt{m}$.

Results: Spectra collected from this work are shown in Figures 2-4. Figure 2 displays a spectrum which was collected with laser pulses incident on the Cu target only, at room temperature, to provide timing calibration. This spectrum displays peaks at 63 and 65 amu, corresponding to Cu⁺ isotopes, with the relative peak heights (6.3:2.5) being comparable with the relative abundances (68:32) of the isotopes. Figure 2 also shows peaks at 39 and 41 amu. These are consistent with isotopes of K⁺, a common surface contaminant, and the relative peak heights (4.2:0.5) are also similar to the relative isotopic abundances (93:7) of ³⁹K and ⁴¹K. Figure 3 shows spectra from laser pulses on the Cu target cooled to 77K with H₂O deposited. In 3 (a) a peak is visible at 19 amu, corresponding to the H₃O⁺ ion, as well as a slight 23 amu peak corresponding to Na⁺. The H₃O⁺/Na⁺ peak height ratio is 5:1. In 3 (b) a strong peak at 17 amu corresponds to OH⁺, while peaks at 39 and 40 are consistent with K⁺ and Ca⁺. The OH⁺/K⁺ and OH⁺/Ca⁺ ratios are both 3:1. Figure 4 shows spectra from laser pulses on the Cu target cooled to 77K with D₂O deposited. In 4 (a) a single peak is visible at 22 amu, corresponding to the D₃O⁺ ion. In 4 (b) D₃O⁺ is also observed, while a trace peak at 23 amu corresponds to Na⁺. The peak ratio D₃O⁺/Na⁺ is 9:2, similar to the ratio for H₃O⁺/Na⁺. By comparison, in [4] spectra were obtained for impacts on H₂O ice which displayed H₃O⁺ and Na⁺ peaks at a relative abundance of ~2:1, with a similar ratio for H₃O⁺/K⁺ peaks. The observed intensities of peaks from ice species are ~2-5 times greater than those for mineral species in [7].

Conclusions: We performed laser ablation on H₂O and D₂O ice to calibrate the Cassini CDA instrument, obtaining peaks consistent with OH⁺, H₃O⁺ and D₃O⁺ species. It is hoped that this work can be extended to other ices, such as NH₃. The technique used here is however limited to ices whose vapor pressure at the temperature of the coolant, is less than the pressure in

the vacuum chamber. CH_4 , for example, has a vapor pressure of 10 mb at 77 K, for TOF-MS, & cooling to below 30 K (requiring LH_2 or LHe) would be necessary to achieve $\sim 10^{-6}$ mb needed to perform TOF-MS.

References: [1] Srama R. et al. (2004) *Space Sci. Rev. (in press)*. [2] Goldsworthy B. J. et al. (2002) *Adv. Sp. Res.* 29, 1139-1144. [3] Goldsworthy B. J. et al. (2003) *A&A*, 409, 1151-1167. [4] Timmermann R. & Grün E. (1991) in: *Orig. & Evol. Interplan. Dust (eds. Lvasseur-Regourd & Hasegawa)*, 375-378. [5] Sugi N. et al. (1998) *GRL*, 25, 6, 837-840. [6] Jyoti G. et al. (1999) *IJIE*, 23, 401-408. [7] Ahrens T. J. et al. (2003) *JGR*, 108, E2, 5007-5016. [8] Vertes A. et al. (1989) in: *Microbeam Anal. (ed. Russell)*, 273-276. [9] Nelson R. W. et al. (1989) *Sci.*, 246, 1585-1587. [10] Williams P. (1994) *Int. J. Mass Sp. & Ion Proc.*, 131, 335-344.

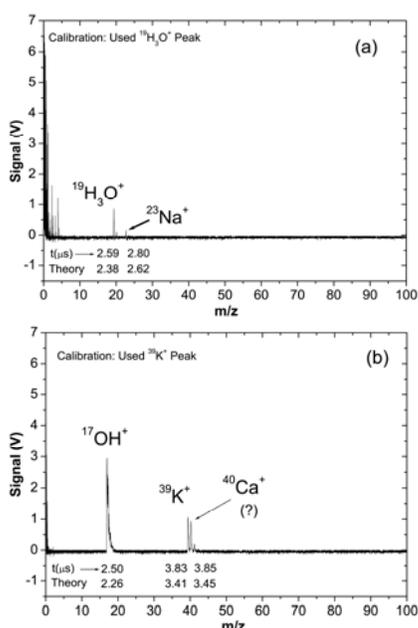


Figure 3: Mass spectra from laser ablation of H_2O ice coated Cu target

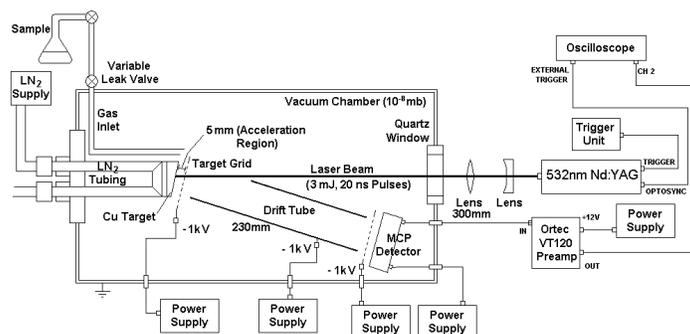


Figure 1: Schematic of experimental setup for laser ablation mass spectrometry of ices. H_2O and D_2O vapor is admitted through inlet and freezes on LN_2 -cooled Cu target.

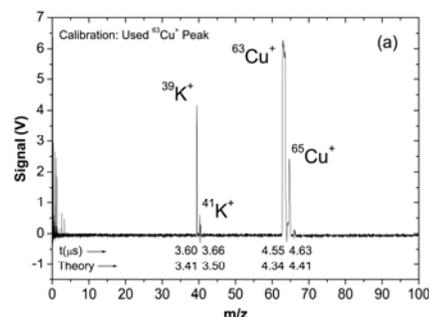


Figure 2: Mass spectra from laser ablation of D_2O ice coated Cu target

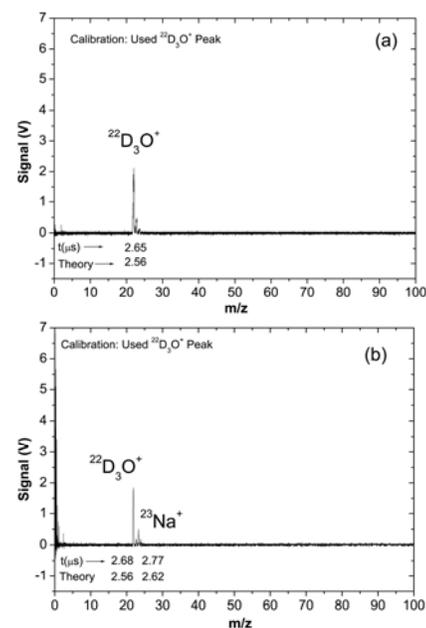


Figure 4: Mass spectra from laser ablation of D_2O ice coated Cu target