SODIUM IN THE LCROSS PLUME FROM TWO VIEWS.

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Introduction: As the Lunar CRater Observation and Sensing Satellite (LCROSS) mission crashed a 2300 kg Centaur stage in the lunar permanently Shadowed Region (PSR) inside of Cabeus crater, it released material from the PSR into sunlight where it could be observed. We have reported on the time evolution of H_2, Ca, Hg, CO, and Mg by comparing data from the passing Lunar Reconnaissance Orbiter (LRO) spacecraft with a model of the evolution of the vapor plume [1-2]. Here, we apply the same model to the evolution of sodium. The best fit model from the LRO observations is different than previous application to sodium observations from ground [3]. In addition we now compare to observations from the LCROSS shepherding spacecraft (SSC) [4-5].

Vapor Plume Model: The Monte Carlo Exosphere model was developed for the lunar exosphere [6] and adapted for the application to the LCROSS impact [7]. The model follows the equation of motion for a set of test particles under the influence of gravity. Particles are followed until they reach the Hill sphere at 37 R_{moon} or until they are photoionized by sunlight, using probabilities given in [8]. The model launches particles from the point of impact using a drifting Maxwellian distribution of velocities. This is a two component velocity, a bulk velocity and a thermal velocity. The bulk velocity represents the expanding vapor plume and has a constant magnitude and an isotropic distribution in direction. The thermal velocity is taken from a Maxwell-Boltzmann distribution with an isotropic direction.

Surface interactions are accounted for by assigning parameters to approximate sticking to the surface and thermalization. Owing to the energetics of the vapor plume and the short duration of the observations, very few particles reencounter the lunar surface. Those that reencounter the surface are assumed to stick.

McMath-Pierce Data: The McMath Pierce telescope was used to observe the LCROSS impact. The slit was initially aligned with Cabeus crater, where the impact occurred. From ground we observed sodium immediately at the impact site in the first minute after impact. The second integration period detected a decrease in sodium. Then the slit was raised to detect at higher altitude. These data were compared to an earlier version of the vapor plume model that implemented a thermal distribution. Because the observations from LRO were better fit with the drifting Maxwellian and the same distribution fit the LRO observation of the GRAIL impacts, we reexamine the sodium data with the present best fit parameters.

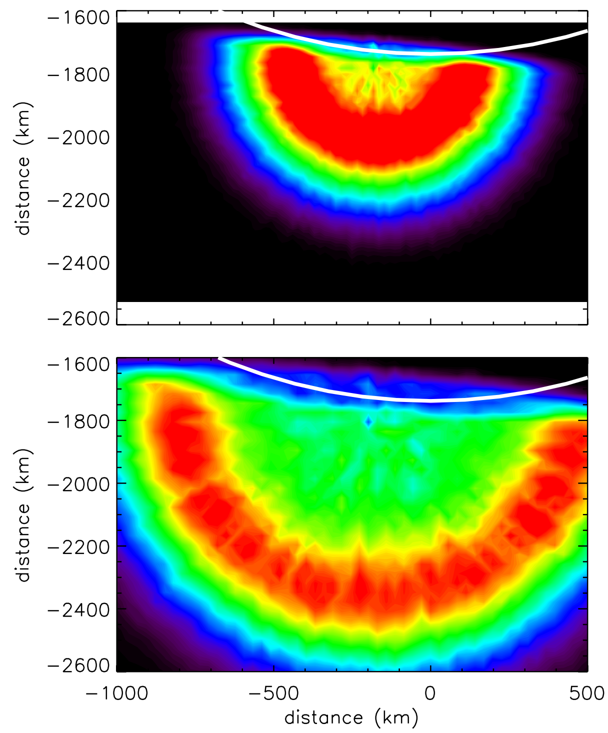

Fig. 1. Modeled column density of sodium from the Earth-based viewing geometry. The modeled plume is shown for two different times after impact corresponding to integrations 40 and 41 in [3].

LCROSS SSC Data: The SSC was 600 km above the Centaur when impact occurred. The SSC followed and crashed nearby 4 minutes later, as planned. During the final minutes, the instruments onboard the SSC followed the evolution of the plume and the impact site. The visible spectrometer (VSP) onboard the SSC had a 1° field of view, which was centered on the impact site. At the time of impact spectra showed a sharp rise in sodium that then decreased to background levels over the following minute.

Conclusions: The SSC data have a complementary perspective to the ground-based measurements. We compare the time series of the sodium line in the VSP data to the McMath-Pierce observations and the model. Having two different perspectives on the plume will better characterize the 3-D nature of the plume. This is a good test of whether the drifting Maxwellian velocity fits the evolution of sodium, thus the mechanism of release of the sodium. Further, we quantify the total sodium released by LCROSS by scaling the total amount of sodium released in the model to reach agreement with the amount of sodium in the fields of view. This constrains the abundance of sodium in the PSR in comparison with the abundance of water. We place the results in context with relative abundance on the rest of the Moon, as well.

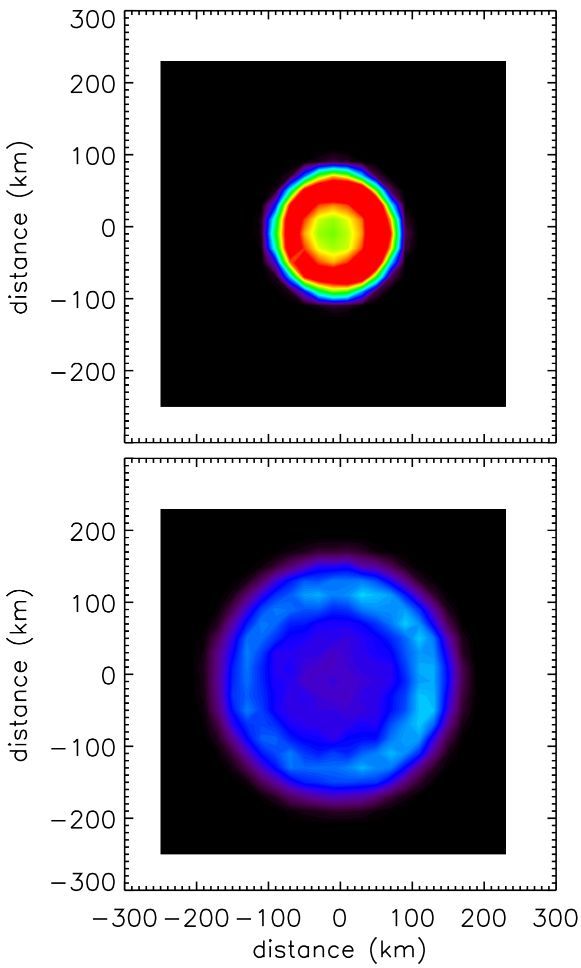

Fig. 2. Modeled column density of sodium from the SSC viewing geometry. The modeled plume is shown at 30 s and 60 s after impact.

References: [1] Gladstone G. R. et al. (2010) *Science 330*, 472-476. [2] Hurley, D. M. et al. (2012) *JGR 117*, E00H07. [3] Killen R. M. et al. (2010) *GRL 37*, L23021. [4] Colaprete A. et al. (2010) *Science 330,* 463-468. [5] Schultz P. et al. (2010) *Science 330,* 468-472. [6] Crider, D. H. and Vondrak, R. R. (2000) *JGR 105*, 26773-26782. [7] Hurley, D. M. (2011) *JGR 116*, E10007. [8] Huebner W. F. et al. (1992) *Astrophys. Sp. Sci. 195*, 1-294.