OBSERVATIONS OF THE LCROSS LUNAR IMPACT FROM HUBBLE SPACE TELESCOPE.

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Introduction: We report the results of observations of the impact plume from the Lunar Crater Observing System (LCROSS). The Hubble Space Telescope (HST) attempted to image the initial plume with the new Wide Field Camera 3 (WFC3) and make spectra of a temporary lunar atmosphere with the Space Telescope Imaging Spectrograph (STIS). A preliminary analysis of the data shows scattered lunar light but no signals from OH or other radicals at the 10 sigma level.

Observation Design: The main thrust of this project was spectral observation of radicals in a temporary lunar atmosphere, caused by the LCROSS impact. HST's unique contribution to the effort was aimed at observations in the vacuum ultraviolet, so most of the time was spend obtaining spectra with the Space Telescope Imaging Spectrograph (STIS) at wavelengths between 210 and 310 nm. At the actual time of impact, images with the newly-installed Wide Field Camera 3 (WFC3) were made just off the limb of the Moon, in a filter centered on 300 nm.

Tracking the Moon with HST is possible but difficult. The fine guidance sensors don't work close to the Moon, so observations have to be made under gyro guiding (which accumulates pointing error at a rate of about 1 milliarcsec per second). The Moon is too close for the onboard pointing software to accommodate the change in apparent target position caused by HST's orbital motion, so a linear track must be uplinked that can partially correct for this. These and other technical details are discussed in [1]. In practical terms, we can point HST at precise points on the Moon only three times in an HST "visibility period": when HST is moving more or less straight toward or away from the Moon, and when HST is moving perpendicular to the lunar direction.

Data: Immediately before the time of impact, we obtained STIS spectra for comparison. The intended pointing is illustrated in figure 1. This is the same pointing for all STIS observations, but remember that these observations are made under gyro guiding and so drift. During the 45 minute "visibility period" the expected pointing error would be 0.001 arcsec/sec times 45 minutes times 60 sec/min or 2.7 arcsec, but the actual drift was probably more as one of the replacement gyros wasn't well calibrated at the time of our observations.

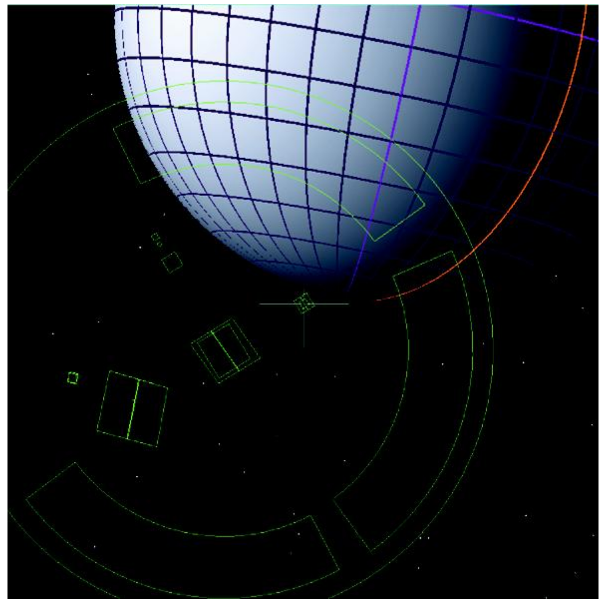

Figure 1: The intended pointing for STIS spectra.

The long STIS exposures were broken into many shorter exposures, to minimize the effects of scattered light should the telescope point at the bright surface of the Moon, instead of the desired pointing (just off the limb).

Spectral Results: A preliminary look at the data does not show any emission, although some hint of scattered solar continuum is visible. The data "pipeline" processing does not account for the vagaries in pointing in this kind of observation, however, and efforts continue to try to quantify any trace emissions of radicals in this wavelength region.

Imaging results: The WFC3 images were made in three groups of two, during the periods of HST's orbit when the linear track follows the apparent lunar motion to a high degree of precision. The images of the first pair executed just before the impact, the second image immediately afterward. No obvious ejecta were detected (figure 2), and no low level glow from a developing temporary atmosphere was observed in the second pair of images. The third pair of images drifted on to the lunar disk, resulting in an amazing display of scattered light in the instrument but no useful data.

An upper limit to the column density can be derived by extrapolation from the comet model described in [2]. For a signal to noise ratio (SNR) less than 2 in a 45 second exposure, the column density of OH per pixel is less than $4x10^5$ cm^{-2}.

Future work: All of the data needs to be reduced taking into account the pointing uncertainty, to the extent this can be quantified. The standard data "pipeline" assumes the telescope pointed where you told it to, but the changes in the amount of scattered light during the exposure sequences show that this was not the case. A frame-by-frame comparison between the spectra before the impact to that of each succeeding orbit is necessary to determine an upper limit to radicals that emit in this region of the vacuum ultraviolet.

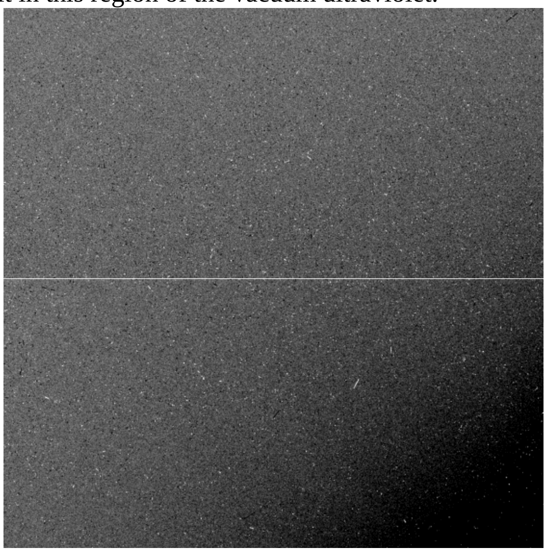

Figure 2: Difference between WFC3 images immediately before and after LCROSS impact. Moon is towards the lower right. Slight gradient in this direction is probably due to drift towards the limb between the exposures.

References: [1] Roman T. and Skillman D. (2007) UIR-2007-001, STScI. [2] Lupu R. E. et. al (2007) *ApJ, 670*, 1473-1484.

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