***LCROSS* Observes Ocean Glint from Earth: Implications for Detecting Habitability.** T. D. Robinson[1,5], V. S. Meadows[2,5], W. Sparks[3,5], K. Ennico[4], and E. W. Schwieterman[2,5], [1]NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035; tyler.d.robinson@nasa.gov, [2]Astronomy Department, University of Washington, Seattle, WA, 98195, [3]Space Telescope Science Institute, Baltimore, MD 21218, [4]NASA Ames Research Center, MS 245-6, Moffett Field, CA 94035, [5]NASA Astrobiology Institute Virtual Planetary Laboratory.

**Introduction:** By definition, a habitable exoplanet must be able to maintain liquid water on its surface. Thus, detecting habitability requires either the direct detection of surface liquid water or measurements of the planetary surface pressure and temperature. Both of these approaches were demonstrated on spatially-resolved observations of Earth from *Galileo* flyby data [1]. However, next-generation exoplanet characterization missions will not spatially resolve their targets, instead seeing planets in the disk-integrated sense (i.e., as point sources). In such cases, the primary approach to detecting habitability from reflected-light observations will be to attempt to detect the mirror-like, specular reflection of sunlight off a planetary ocean, which is the so-called "glint" effect [2,3]. This effect is most prominent at crescent phases, and, until recently [4], glint detection in disk-integrated observations was unproven.

**Observations and Models:** On three occasions in 2009, the *Lunar CRater Observation and Sensing Satellite* (*LCROSS*) observed the distant Earth, including a rare crescent phase observation (Figure 1). For each epoch, the satellite acquired near-infrared (0.9–1.7 μm) and mid-infrared (6.0–10.0 μm) full-disk images, and visible (0.26–0.65 μm) and near-infrared (1.17–2.48 μm) partial-disk spectra [4]. The spectra contain significant absorption features due to water vapor and ozone, a biosignature gas, and the crescent-phase, reflected-light images show a distinct ocean glint feature. Observations were modeled using the high spectral resolution, time-dependent, fully-scattering Virtual Planetary Laboratory (VPL) 3-D Earth model [3,5].

**Results:** We find good agreement between models and observations for all three epochs of *LCROSS* observation—the VPL 3-D spectral Earth model reproduces the absolute brightness and dynamic range of all spectral data, thereby validating the model to within the 10% data calibration uncertainty. Most critically, glint is detected via comparisons between the validated model and disk-integrated crescent phase observations, and is shown to contribute roughly 80% of the reflected-light signal in the near-infrared at 1.5–1.8 μm. This work provides the first observational test of the glint technique, and is a promising indication that glint could be used to detect exoplanet habitability.

**References:** [1] Sagan C. et al. (1993) *Nature*, *365*, 715–721. [2] Williams D. M. and Gaidos E. (2008) *Icarus*, *195*, 927–937. [3] Robinson T. D., Meadows V. S. and Crisp D. (2010) *Astrophys. J. Lett.*, *721*, L67–L71. [4] Robinson T. D. et al. (2014) *Astrophys. J.*, *787*, 171. [5] Robinson T. D. et al. (2011) *Astrobiology*, *11*, 393–408.

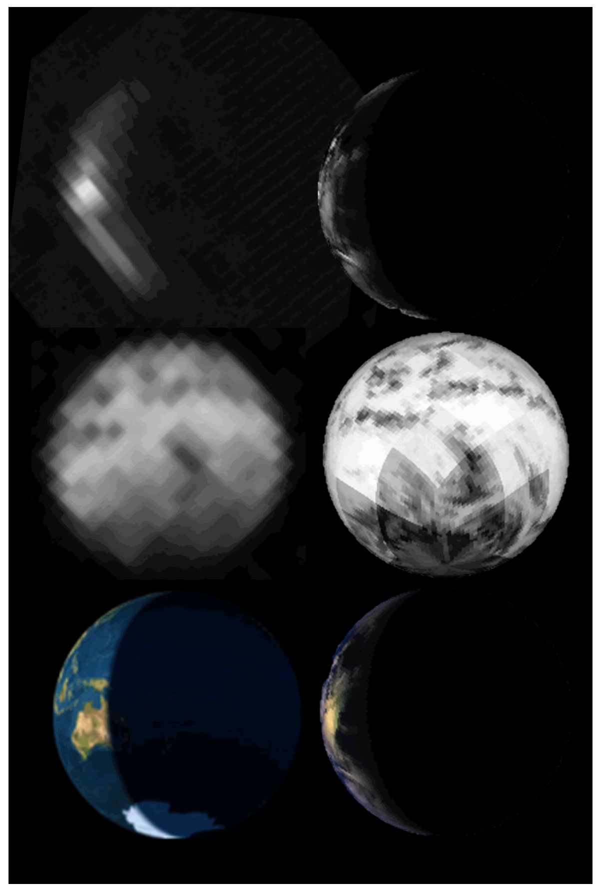

**Figure 1:** *LCROSS* observations and VPL models of crescent phase Earth. Reflected-light image (top-left) is from the *LCROSS* NIR2 camera (0.9–1.7 μm), while the thermal image (middle-left) is from the MIR1 camera (6.0–10.0 μm). Corresponding model images, from the VPL 3-D spectral Earth model, are shown at top-right and middle-right. Diagram in lower-left shows the viewing geometry, and is from the Earth and Moon Viewer (credit J. Walker). Model image in lower-right is a true-color composite, and shows a prominent glint feature.