SPECUALAR REFLECTION ON TITAN – LIQUIDS IN KRAKEN MARE. K. Stephan[1], R. Jaumann[1,2], R.H. Brown[3], J. M. Soderblom[3], L. A. Soderblom[4], J. W. Barnes[5], C. Sotin[6], C. A. Griffith[3], R. L. Kirk[4], K. H. Baines[6], B. J. Buratti[6], R. N. Clark[7], D. M. Lytle[3], R. M. Nelson[6] and P. D. Nicholson[8], [1] DLR, Inst. of Plan. Res., 12489 Berlin, Germany; [2] Dept. of Earth Sciences, FU Berlin, Germany; [3] LPL, UoA, Tucson, AZ 85721, USA; [4] Geol. Survey, Flagstaff, AZ 86011, USA; [5] Dept. of Physics, Univ. of Idaho, Moscow, ID 83844-0903, USA; [6] JPL, Pasadena, CA 91109, USA; [7] U.S. Geol. Survey, Denver, CO 80225, USA; [8] Dep. of Astronomy, Cornell Univ., Ithaca, NY 14853, USA; (katrin.stephan@dlr.de).

Introduction: Liquids on Titan have only been conclusively identified in Ontario Lacus [1], one of the few lakes in Titan's south-polar region. As Titan now progresses into northern spring, the much more numerous and larger lakes in the north-polar region suggested by Cassini RADAR data, are becoming directly illuminated for the first time since the arrival of the Cassini spacecraft. This allows the Cassini optical instruments to search for specular glints to provide further confirmation that liquids are present in these evident lakes.

Observations: On July 8th, 2009 the Visual and Infrared Mapping Spectrometer (VIMS) [2] detected an unresolved feature with very high radiance seen only in the 5-µm atmospheric window (Fig. 1). The feature is located near 73°N and 335°W and associated with Kraken Mare, one of Titan's northern large radar-dark units, interpreted as lakes [3-6] (Fig. 2 a). Analysis of the viewing geometry of this feature reveals that the incidence (i) and emission angles (e) are equal (~73°) within the ranges subtended by a pixel (see Fig. 1), indicating specular reflection of sunlight off the surface.

By mapping the footprint of the solar disk onto Titan's surface for the aquired VIMS cubes, the location of the specular reflection can be associated with the western edge of Kraken Mare. The size of the solar image calculated for these observations is sub-pixel; the footprint of the solar disk is ~3.4 and 11.6 km perpendicular and parallel to the Sun-Titan-spacecraft plane, respectively, compared to the size of the VIMS pixel (>100-km across) projected onto the surface.

Correlation of the predicted position of the Sun's footprint reflected from the surface, which moved from east to west during the observation sequence (3h19min), correspond very well to the observed variations in the strength of the 5-µm signal in the individual VIMS spectra (Fig. 3a). Only for VIMS cubes #2 and #3, where the 5-µm reflection is strongest, the image of the Sun is clearly associated with the lake itself, fulfilling the requirement of specular geometry. In contrast to VIMS cube #3, whose solar footprint (I/F = 0.95) lies almost entirely within the lake, the brightest pixels of VIMS cube #2 have a lower intensity (I/F = 0.7) because a fraction of the footprint lies outside the lake. In that case, the observed intensity is lower, arising from a combination of the specular reflection off the lake and from light scattered by the adjacent terrain (Fig. 2a).

In the case of VIMS cube #1, the image footprint is only partially within the lake explaining the weaker (I/F =0.25) but still recognizable 5-µm signal. The predicted position of the solar image for VIMS cube #4 of this observation sequence, whose spectrum shows only a weak signal at 5µm (I/F =0.18), is clearly located outside the lake.

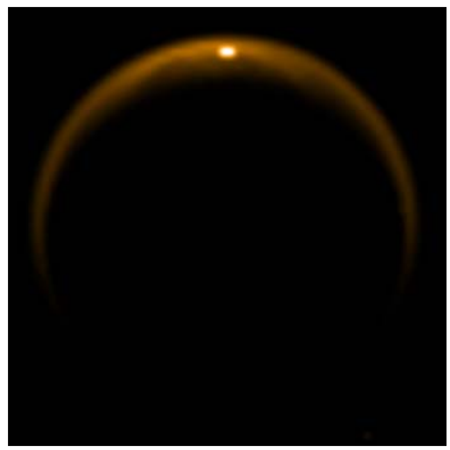

Figure 1: Bright spot in the northern polar region at ~ 72°N/342°W as seen in VIMS cube #3 (1625730355) that is restricted to the VIMS channels at 5 µm.

Interpretation: The observations strongly point to a specular reflection from a smooth surface, close to the southern shoreline of Kraken Mare. Only where the viewing geometry is such that the specular point falls onto one of the RADAR-dark surfaces do the VIMS observations show significant specular reflection. Thus, the most plausible explanation is a liquid surface [7,8] that is smooth on the scale of observed VIMS signal at 5 µm, though a liquid surface with very gentle low-frequency waves is also admissible.

Figure 3b illustrates why the specular reflection could be seen only in the 5-µm window. At wavelengths shorter than 3.3 µm, diffuse illumination dominates the flux that reaches Titan's surface (Fig. 3b) with a relative flux of that varies between ~ 0.1–0.3, depending on absorptive properties of methane between the vibrational bands [9].

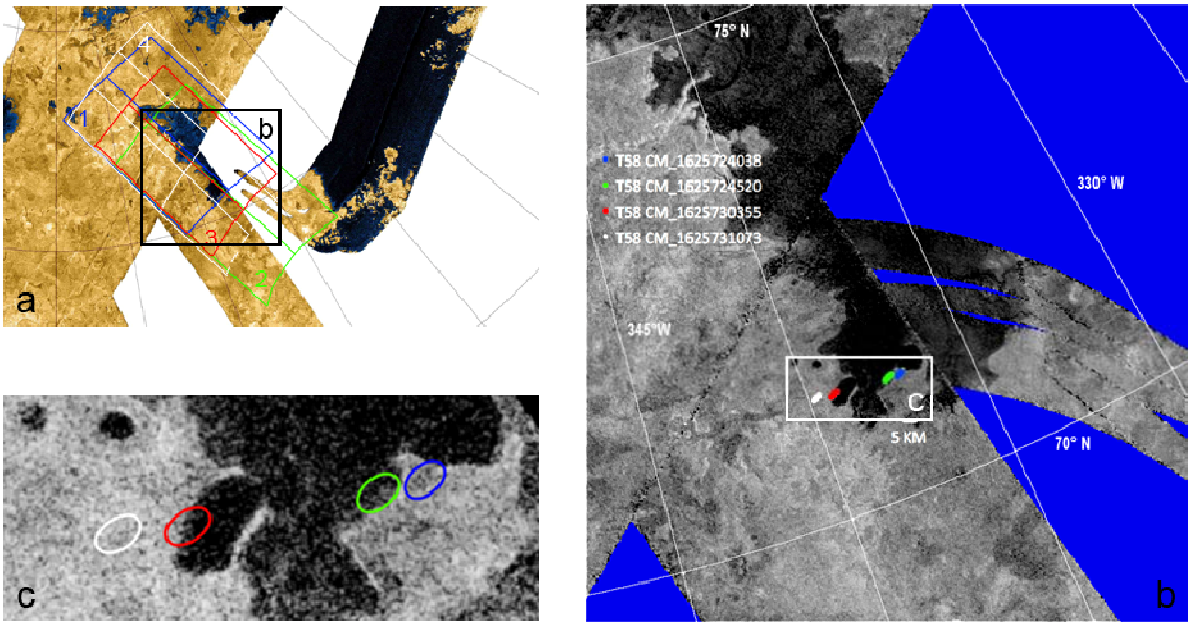

Figure 2: (a) Location and extension of the VIMS pixel that show a high reflectance at 5 μm overlaid onto RADAR images of Kraken Mare; **(b & c)** predicted positions of images of the solar disk derived for the viewing conditions during the four VIMS observations.

Thus at 0.8–3.3 μm, only a tiny fraction of the incident light (1/300 x 1/300) traverses the atmosphere and reflects from the surface fully escaping any scattering event; specular reflection at these wavelengths is suppressed by atmospheric scattering. The direct flux of light that reaches Titan's surface, however, steadily increases with increasing wavelength so that at 5 μm, a significant fraction of the incident light reaching the surface has not been scattered [9]. Roughly 39% of the surface illumination is direct indicating that at 5 μm, light specularly reflected from Titan's surface can be detected. In addition, the opacity due to CO limits the spectral feature of specular reflection to wavelengths long ward of 4.85 μm.

As VIMS observed the specular reflection just at the bright/dark boundary seen in the RADAR SAR image acquired in 2006 it confirms that this section of Kraken Mare's shoreline has been stable and no significant changes of the lake's level of liquid or extent are apparent between 2006 and 2009.

References: [1] Brown et al. (2008) *Nature*, 454, 607-610 (2008). [2] Brown et al. (2004) *SSR*, 115, 111-168. [3] Stofan et al. (2007) *Nature*, 445, 61-64. [4] Turtle et al., (2009) *GRL*, 36, L02204, doi:10.1029/2008GL036186. [5] Jaumann et al. (2009) in *Titan from Cassini-Huygens*, 75 – 140, Springer, NY. [6] Stephan et al. (2009) in *Titan from Cassini-Huygens*, 489 –510, Springer, NY. [7] West et al. (2005) *Nature*, 436, 670 – 672. [8] Campbell et al. (2003) *Science*, 302, 431 – 434. [9] Griffith et al. (2009) *Astrophys. J.*, 702, L105-L109.

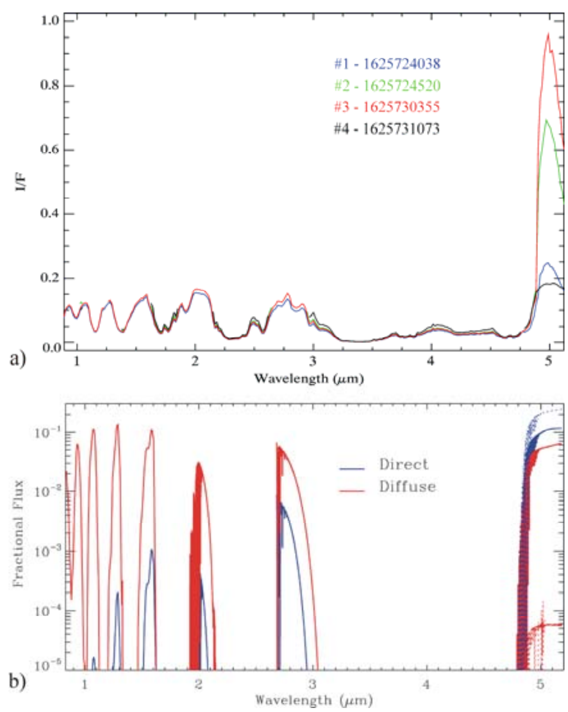

Figure 3: (a) VIMS spectra associated with the strongest reflection at 5 μm selected from the corresponding VIMS observations. **(b)** Calculation of the diffuse (red) and direct (blue) flux that reaches Titan's surface for radiation incident on Titan with an angle of 73.64°.