CH_4-RICH ICES DISTRIBUTION AT THE SURFACE OF PLUTO EVIDENCED BY NEW HORIZONS.

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Introduction: The New Horizons mission flew by Pluto the 14th of July 2015 and revealed the surface of the icy planet. CH_4 was known to be one of the major component of the surface, which was confirmed with LEISA data [2]. Previous earth-based observations showed that a 'pure' form of CH_4 ice is present at the surface. Pure CH_4 refers to the CH_4-dominant phase of the binary phase molecular mixture N_2-CH_4. CH_4 and N_2 ices coexists on Pluto and form a molecular mixture because they are partly soluble in each other at Pluto's surface temperature (-40 K). Two phases can co-exist due to the partial miscibility: a N_2-rich phase and a CH_4-rich phase. Pure CH_4 has been detected from Earth observations [2]. It can be detected by two ways: 1) the presence of the 1.69 µm band, which is active only for pure or almost pure CH_4 ice and is absent for CH_4 diluted in N_2 ice [3], 2) the position of the CH_4 bands that are strongly shifted towards lower wavelength (higher frequency) when CH_4 is diluted in N_2, compared to their positions in pure and CH_4-rich ices [3, 4].

We used LEISA spectro-images data [5] to investigate the presence of CH_4-rich ices at the surface of Pluto by quantifiying the minimum positions for several CH_4 bands that could reveal areas where CH_4 ice is in its relatively pure state. This work is complementary to the one on the mixing lines of the Pluto components [6] and to the modeling effort aimed at quantifying the N_2/CH_4 mixing ratio [7].

Band minimum addition: To assess the possible shift of CH_4 bands on LEISA data, an index was created. The minimum position of seven CH_4 bands is automatically calculated and the addition of these minimum positions indicates the overall CH_4 bands shift for a given pixel. The highest the index, the purest the CH_4. Bands used to calculate this criterion and the spectral ranges used for each band are indicated in Fig. 1. The result of this calculation is presented in Fig. 2. This map displays the CH_4 rich zones in red-green-blue colors. It can be compared to the N_2 map calculated earlier: N_2 rich zones correspond to black area on the map, which validate the method.

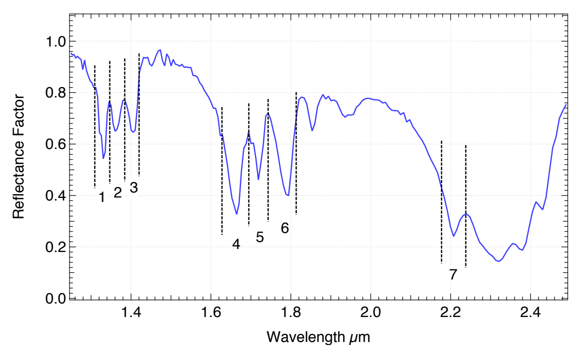

Figure 1: Position of the different CH_4 band used for the calculation of the purity index for methane ice

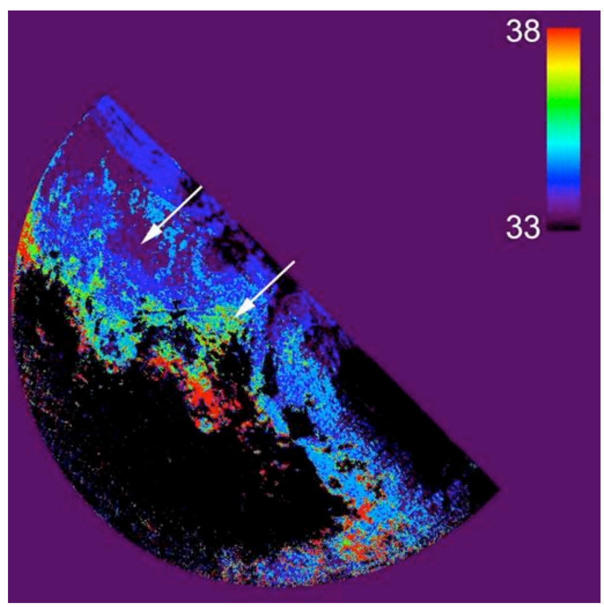

Figure 2: Map of CH_4-rich ice as determined by the CH_4 bands positions. The red-green-blue colors indicates that CH_4 bands are shifted toward high wavelength (CH_4-rich molecular mixture) while black indicates that CH_4 bands are shifted toward lower wavelength (no CH_4 or N_2-rich molecular mixture). This figure has to be compared with the N_2 ice band depth map in Fig 4.

CH_4–rich zones are located mostly around the area dominated by the reddish materials, as well as in the northeast and in the southwest vicinity of Sputnik Planum.

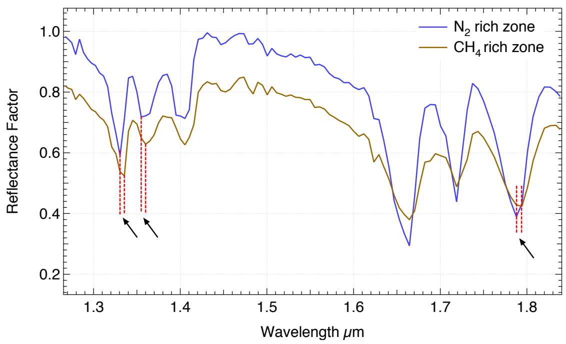

Figure 3: Difference in terms of band positions between a CH_4-rich zone and a N_2-rich zone (indicated by the two arrows in figure 2)

Part of this global shift of the bands could be related to the smile effect that affects LEISA data. The smile effect is a global wavelength shift of the spectrum as we move from the center to the edges of the original image (before geographic projection). Typically, on the map, the smile effect is along a NE-SW axis and is low in the center of the map and high near the edges.

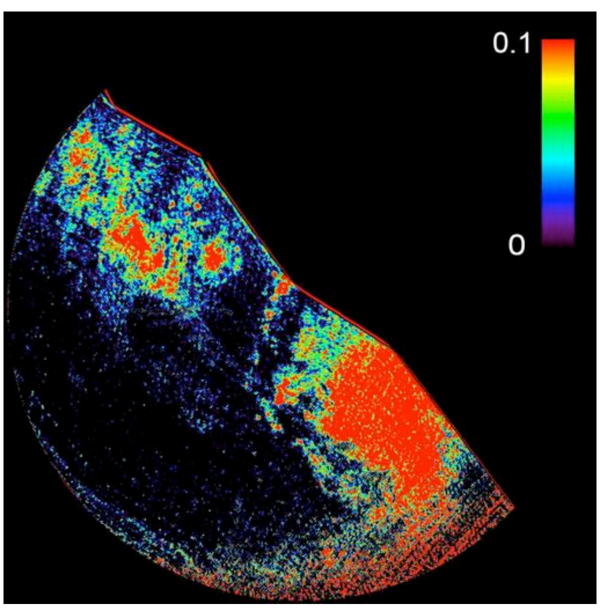

Figure 4: Map of the equivalent width of the N_2 ice band at 2.15 µm.

However, strong regional and local variations indicate that our criterion is valid and that the smile effect, even if present and superimposed, plays a small role in the measured band shift. As an example, on Fig. 3, we extracted 2 spectra from two different areas that both exhibit CH_4 absorptions but different CH_4 band positions. We selected their location to be at the same distance from the center column of the original image to avoid a possible smile effect. The difference of the band positions is visible.

Anti correlation CH_4–rich and N_2–rich areas : CH_4-rich areas can be compared to N_2-rich areas, previously determined, with a correlation plot. In Fig. 5 the N_2 ice band depth at 2.15 µm is plotted vs. the criterion of CH_4 band minima positions. Zones that are characterized by a strong N_2 ice band depth have a low value of the CH_4 band minima positions criterion. In the other way, zones with a low value of N_2 band depth (0±0.05) have a high value of CH_4 band position criterion.

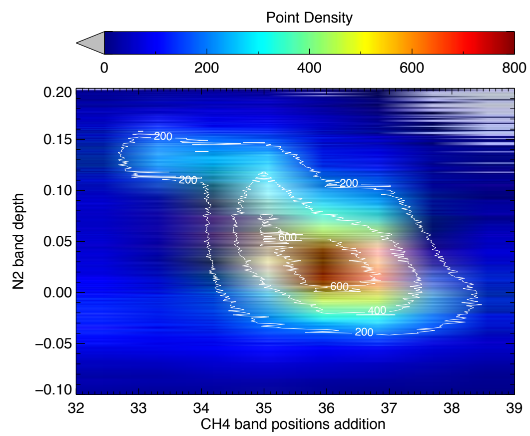

Figure 5: Correlation plot of the N_2 ice band depth at 2.15 µm versus the CH_4 band positions criterion.

This indicates that where N_2 ice is detected at the surface, it is the main component of the molecular mixture N_2-CH_4-CO, even if the spectral shape is almost entirely determined by methane ice. Inversely, when N2 is not present at the surface, CH_4 is in its pure or almost pure state. The result of this statistical analysis will be confirmed with radiative transfer modeling [7].

Acknowledgments: This work was supported by NASA's New Horizons Project. B. Schmitt, S. Philippe and E. Quirico acknowledge the Centre National d'Etudes Spatiales (CNES) for its financial support.

References: [1] Grundy W. M. et al. (2016) *Science*, submitted. [2] Douté S. et al. (1999), *Icarus, 142*, 421.- [3]Quirico, E. and B. Schmitt 1997. *Icarus* 127, 354-378. [4] Protopapa S. P. et al. (2015) *Icarus, 253*, 179-188. [5] Reuter D. C. et al. (2008) *Space Science Reviews, 140,* 129-154. [6] Schmitt B. et al. (2016) *LPSC 47.* [7] Protopapa S. et al. (2016) *LPSC 47.*