June 9, 2006

Organics and water in STARDUST
Mapping of keystones with infrared microscope at the ALS

Saša Bajt
Lawrence Livermore National Laboratory

First results on a keystone (C009, 27Mar06) provided by Andrew Westphal and Christopher Snead (Space Science Laboratory, UC Berkeley).

In my previous report from May 31, 2006 I determined that there is a noticeable difference in the strength of –OH and C=O bands and in the amount of $–CH_2$ vs. $–CH_3$ bands between archival and flight aerogels. I was speculating that the flight aerogel is rich in water and organics. Since then 6 keystones (all from tile 9) with different tracks (ginseng, bulbous, straight, etc.) were mapped using the infrared microscope at the ALS.

Summary: Large enrichments of –OH (characteristic for water), C=O (characteristic for ketones, kerogens, etc.) and of C-H (in particular $C-H_3$) are related to the tracks.

Based on these results I am pretty convinced that there results are indicative of comet material and not due to contamination. Below are results just from C009, 27Mar06 keystone, as an example. All measurements were taken in transmission mode, normalized to the air spectrum and background corrected. Bright colors (high transmittance) are associated with small absorption and low intensity while cold colors (low transmittance) are associated with high absorption and high intensity of the peaks. Each map has a color bar showing the range in transmission values for each particular wavenumber.

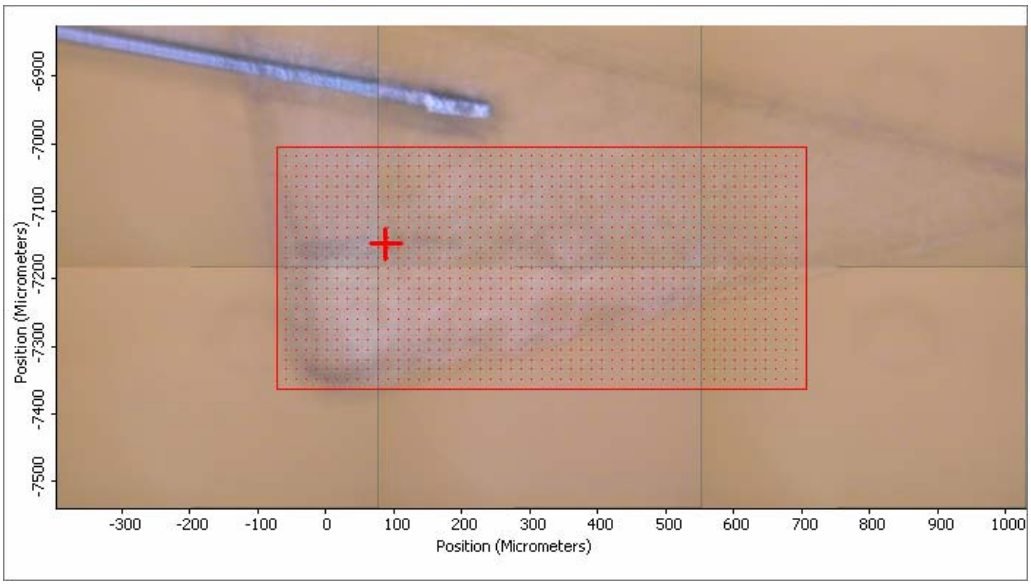

Figure 1: Optical image of keystone C009, 27Mar06 clearly showing the mapped area.

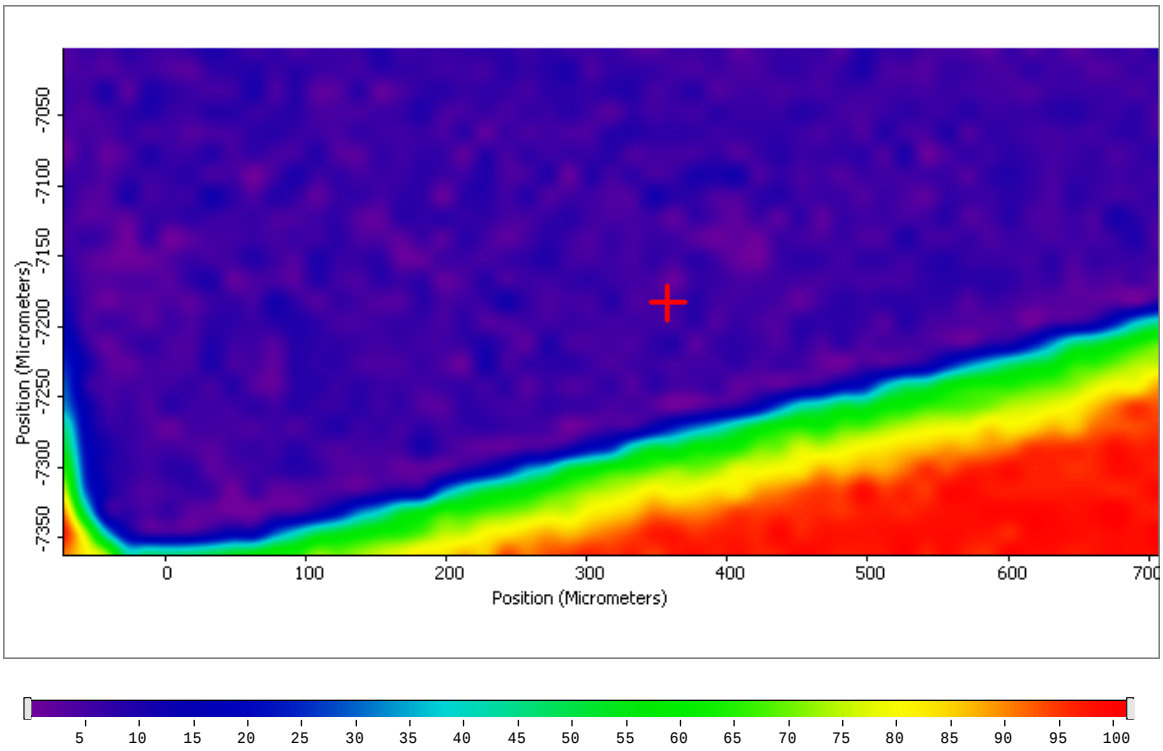

Figure 2: Map of ~1100 cm^{-1} peak characteristic for aerogel.

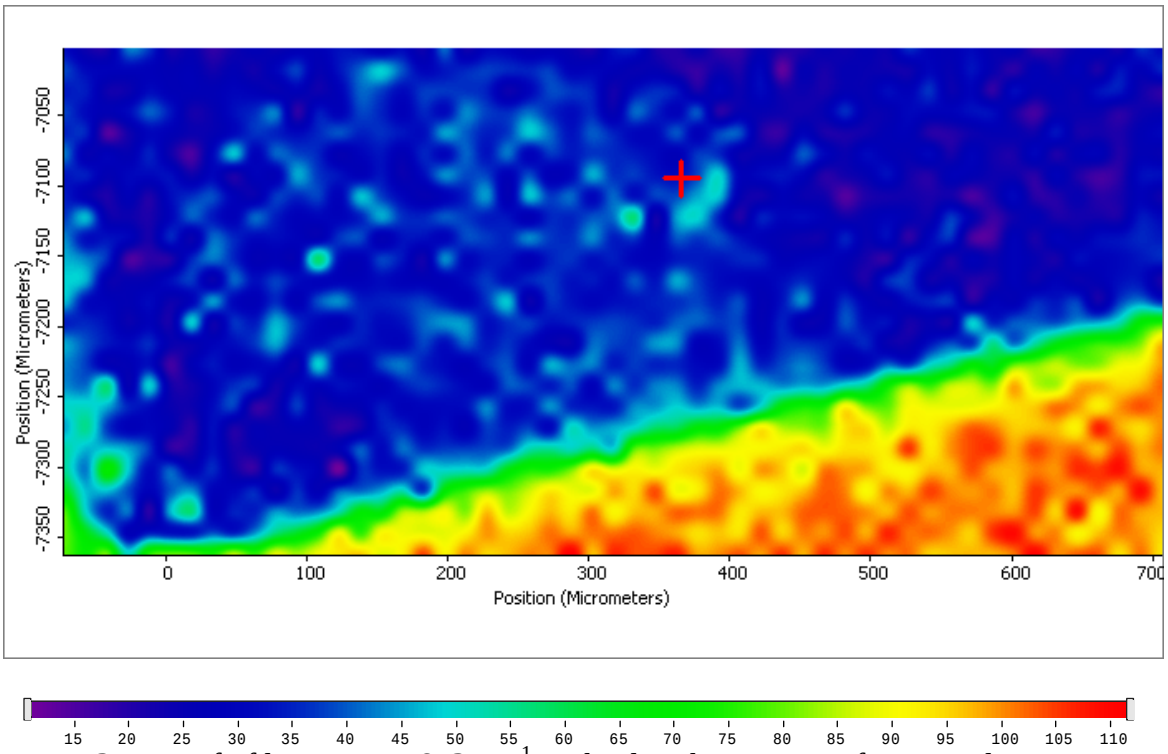

Figure 3: Map of of less intense 813 cm^{-1} peak, also characteristic for aerogel.

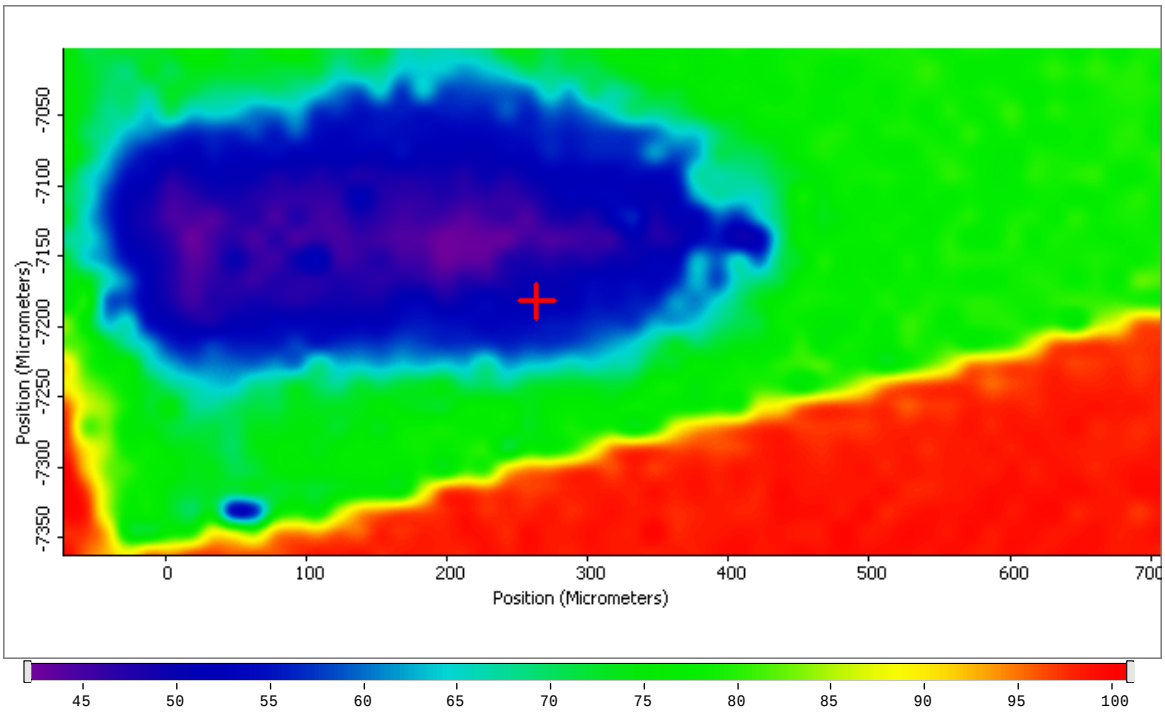

Figure 4: Map of 2966 cm-1 (-CH_3) peak.

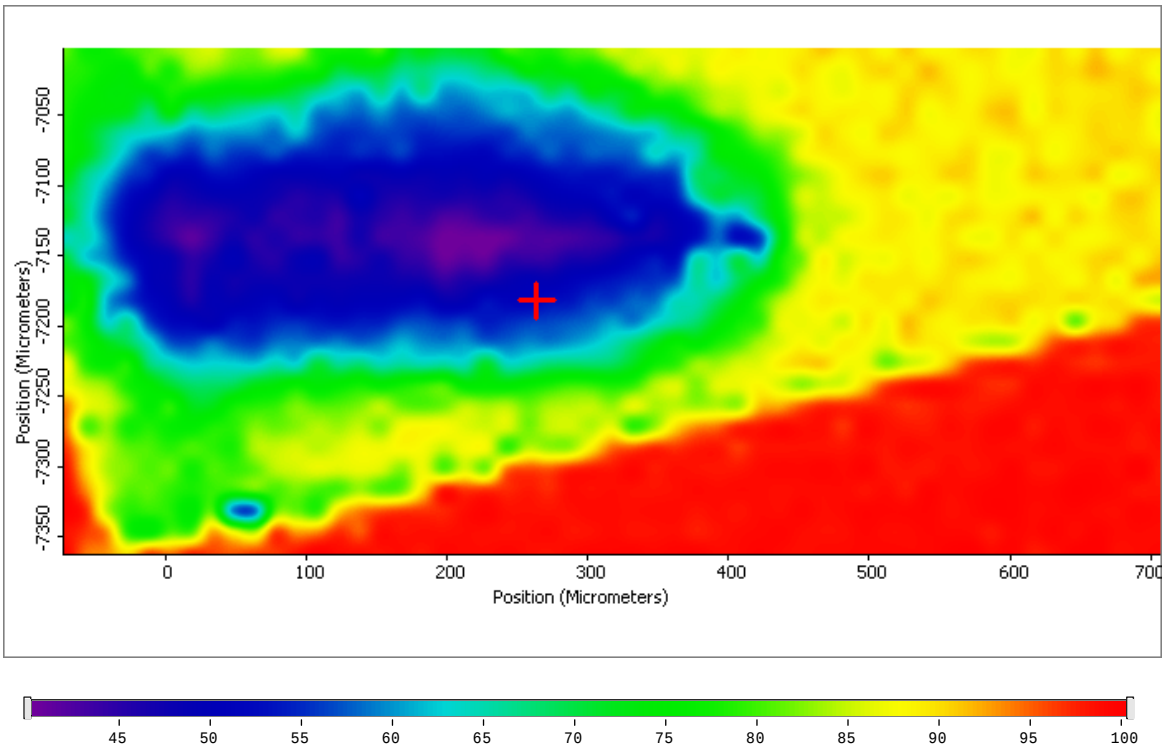

Figure 5: Map of 2929 cm-1 (-CH_2) peak. Notice difference in distribution (layering) as compared to Figure 4.

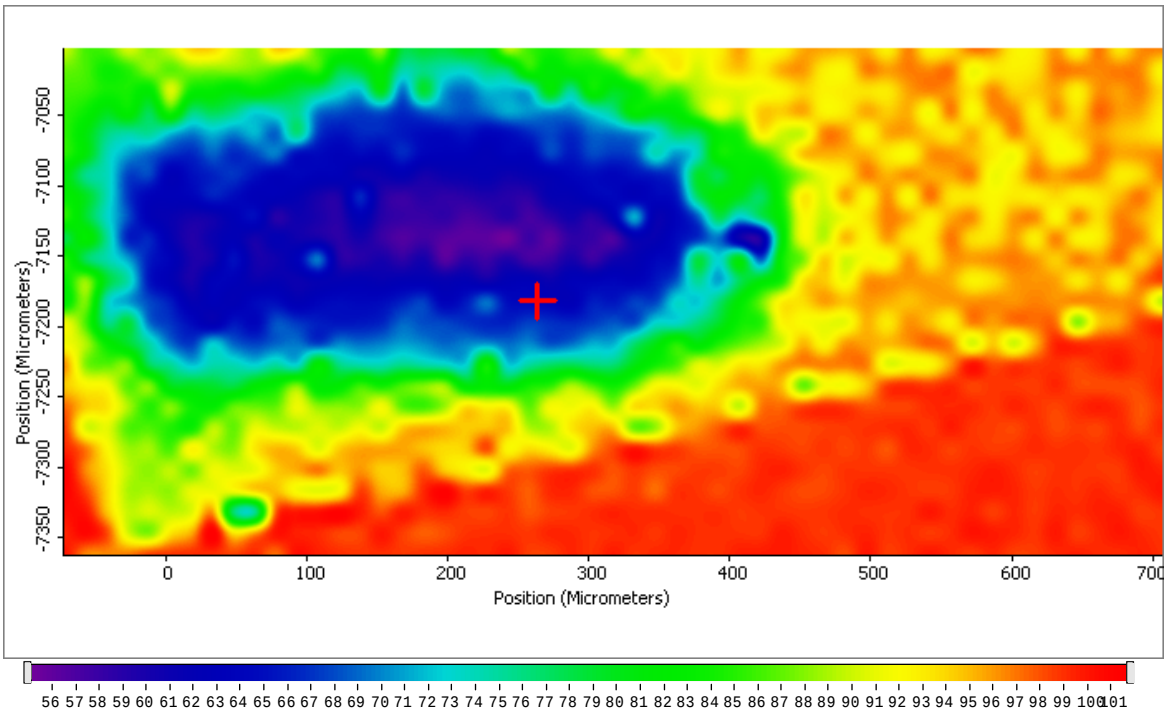

Figure 6: Map of ~3410 cm^{-1}, a broad peak characteristic for –OH (water)

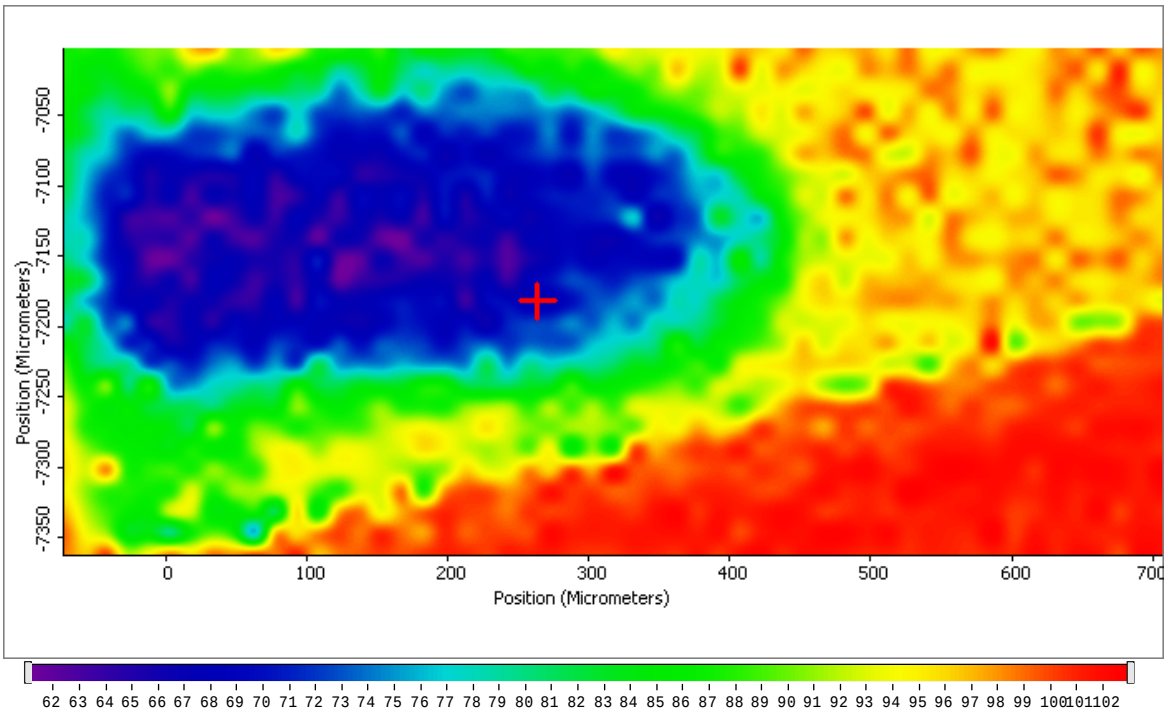

Figure 7: Map of ~1713 cm^{-1} peak (associated with C=O, possibly due to ketone, kerogene,…).

First image is an optical image taken on the infrared microscope to show the map area with over 1300 individual spots. In each spot I collected a complete spectrum from 650-4000 cm^{-1} with a resolution of 4 cm^{-1}. Figure 2 shows the map at ~1100 cm^{-1} (the position of the strong Si-O peak due to aerogel) and Figure 3 shows a map at 813 cm^{-1} (peak also associated with aerogel). The first peak (at 1100 cm^{-1}) is saturated and this is why it is important to see that the distribution of unsaturated peak due to aerogel correlates with the aerogel. Both maps correlate nicely with the aerogel position on the optical image. There is small random variation within the aerogel, possibly related to density fluctuation (Figure 3) but nothing as seen below in other images. Therefore the images of other peaks are not due to changes in aerogel thickness or density variation.

Figure 4 shows a map of $–CH_3$ peak (2966 cm^{-1}). This peak is present in archival aerogel and in aerogel far away (~400 μm) from the track but is much stronger within ~100 μm distance from the track. Notice few hot spots (purple) within the track. In the hot spots, the absorption is about twice as strong as in the aerogel away from the track. Figure 5 shows distribution of$–CH_2$ bond (~2929 cm^{-1}). This peak is very weak (less than 1% absorption) in archival aerogel or in aerogel away from the track but has up to 60% absorption (40% transmission) in the hot spots. The hots spots are along the track. Interestingly, the intensity of this peak falls of gradually with the distance from the track (layering around the track).

Figure 6 shows a map of –OH (~3410 cm^{-1}). This broad peak is most likely associated with water or some hydroxyl bond. This map shows very similar distribution as the map due to $–CH_3$ bond (Figure 5). It is important to notice that this peak does not increase on the edges of the keystone so the water or hydroxyl could not be associated with water from the environment. Figure 7 is a map of C=O bond (possibly ketone, kerogene or something similar). The hot spots of this material are not in the same positions as hot spots of $–CH_3$ and –OH material. In particular this bond is not very strong in the terminal particle (present at the end of the track but invisible in the optical image because it is out of focus).

This is just one of the many maps that I collected yesterday and on June 7. I didn't have time to analyze other data yet but overall the other maps seem to show similar results (enrichments of –OH, C=O and $–CH_3$ in the proximity of the tracks). There are some variations in enrichments of $–CH_3$ that seem to be correlated with the type of track and more work in this direction would be very interesting. This could possibly correlate different type of impact particles with different type of tracks (ginseng, carrot, turnip, etc.)