REVISITING THE THERMAL INFRARED SPECTRAL OBSERVATIONS OF PHOBOS.

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Introduction: The Martian moon Phobos is still considered an enigmatic object although it has been investigated both by Earth-based observations and by close spacecraft approaches. Its origin and its mineral composition are debated issues since several years. Its very low density/visual albedo, initially favored the hypotesis of a C-type porous object with internally trapped ice [1]. Lately, Vis-Nir spectroscopic investigations showed a nearly featurless spectrum without traces of hydration but with a very steep red slope [2]. These signs were not consistent with a C-type asteroid. Two major unit were found onto the Phobos surface differing only for the spectral slope (Red and Blue units). Recent investigations [3] suggested a D and T-type composition for the Red and Blue units, respectively, with a dehydrated Carbonaceous Chondrite as the best analogue for the Blue Unit.

Data analysis: The Thermal Emission Spectrometer (TES), onboard the Mars Global Surveyor spacecraft [4], observed Phobos during the end of 1998 summer. TES consists of a 3x3 array of IR thermal detectors that allow to obtain spectra with resolution of 10 cm^{-1} (6 cm^{-1} at best) in the interval 200-2000 cm^{-1}. Since the Phobos shape is very irregular, the shadow and the full sunlight can characterize in very dramatic way adjacent regions. In the thermal infrared the overall effect is a superposition of emitted radiances generated at different temperatures. Therefore, to correctly retrieve the surface emissivity we developed an algorithm to fit the TES observed radiance with the suitable number of planckian curves (Fig. 1). The algorithm simultaneously search for the optimal number of planckian curves, their temperatures and areal fraction in the field of view. We also constrain the fit to eliminate some mathematically correct configuration that are physically not meaningful. Considering the low radiance coming from Phobos, in order to optimise the TES spectra SNR, we choose to analyze the spectral range between 250 cm^{-1} and 1300 cm^{-1}. To retrieve and characterize the number and spectral shapeses of the different components present in the dataset we apply an R-mode factor analysis, a well-established technique in remote sensing [5][6]. The identification of the different components and their abundance is accomplished by principal component analysis (PCA) [7]. After the PCA processing we estimated the different spectral units by using an unsupervised hierarchical cluster algorithm based on the pairwise distance between each couple of data. Those distances was used to compute the hierarchical clustering of the data points by a weighted centroid approach, where distance between clusters is defined as the distance between the centroids of each cluster, a centroid being the average position in the cluster.

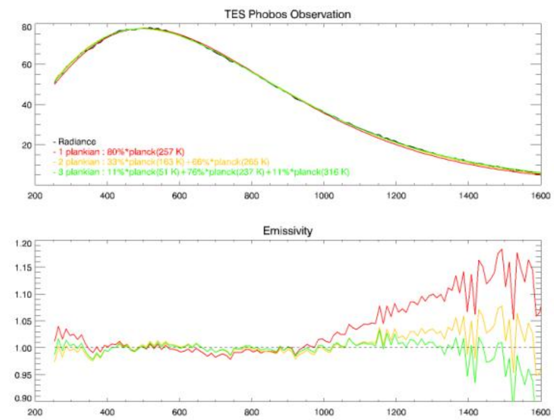

Fig.1: An image describing the algorithm used to infer the emissivity of Phobos from radiances

Results: **T**he retrieved Phobos spectral emissivities are similar enough to be grouped into two main families showing only subtle differencies. Apparently, these families are not correlated to geomorphological features. However, a refining of the observation geometries is currently ongoing. Tipically the spectral contrast is very low with the largest emissivity variation of 3%, only. However, the spectral emissivity is quite well developed with clear spectral characteristics and features. The emissivity maxima (Christensen Frequency-CF) are located between 1148 (8.71μm) and 1170 cm^{-1} (8.55μm). The transparency features (TF) are placed between 810 cm^{-1} (12.35 μm) and 852 cm^{-1} (11.74 μm).

Laboratory spectral comparison: A first step to understand the compositional information given by the retrieved emissivitities is a direct comparison with laboratory data. To this aim we used the new emissivity spectral data available at the Institute for Planetary Research (PF) of the German Aerospace Center (DLR) (the Berlin Emissivity Dataset-BED) [8]. The use of real emissivities is certainly more suitable instead of the Kirchoff retrieved emissivities (i.e. 1-reflectance), since the Kirchoff law can be applied only in condition of thermal equilibrium [9], a condition not always valid in Space. In Fig. 2 we show the two retrieved typologies of spectral emissivities, compared with the emissivities of the Biotite phyllosilicate in three different grain size intervals (0-25, 26-63, 63-125 μm). As expected, the spectral contrast and the Reststrahlen feature decrease with the grain size, while the TF increases. Normally, this behaviour is valid for all the analysed minerals, even if in some cases (e.g. diopside) the spectrum of the finest fraction has still a strong contrast showing many spectral features. This suggests a very fine grained regolith for the surface of Phobos, probably even as small as few microns in size. In order to infer compositional information we retrieved the CF and the TF for the spectral emissivities of several minerals available in the BED. From this analysis the feldspar mineral class cannot be considered as characteristic of the Phobos spectra. The olivines and the pyroxenes seems to be ruled out, too. However, considering the CF, only, many pyroxenes match quite well the Phobos emissivity maxima. The materials that seems to fit well the Phobos CF-TF positions are few phyllosilicates and feldspathoids, only.

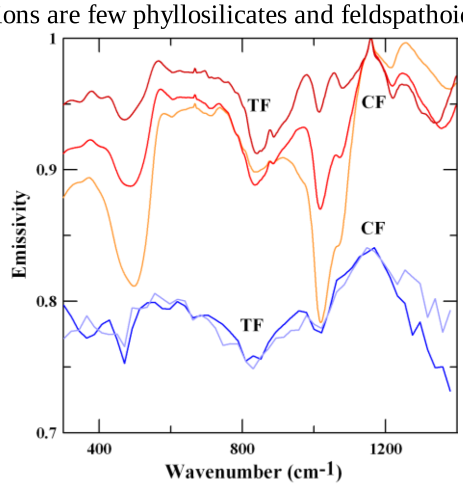

Fig. 2: Comparison between spectra of two Phobos emissivities (blue lines), and the biotite emissivity spectra (from top to bottom: 0-25 μm, 25-63 μm and 63-125 μm)

Asteroid spectral comparison. The actual suite of the asteroid thermal IR (TIR) spectra is relatively scarce. However, thanks to IR space telescopes, such as ISO or Spitzer, some TIR investigations have been recently added to the dataset. Among the published data, we selected asteroids that are classified as D-type, of C-type, invoked as the family type for Phobos. In Fig. 3 we show three Trojan asteroids (D-type), 624 Hektor, 911 Agamemnon, 1172 Aneas [10] and the asteroid 21 Lutetia [11], next target of the Rosetta mission, in comparison with the Phobos spectra. Lutetia is a peculiar object, since spectrally is a C-type but due to its high IRAS albedo values is classified as M [11]. Phobos spectral shape is quite different both from the D-type and from the C-type asteroids. The position of the CF is located at lower wavelength while the TF

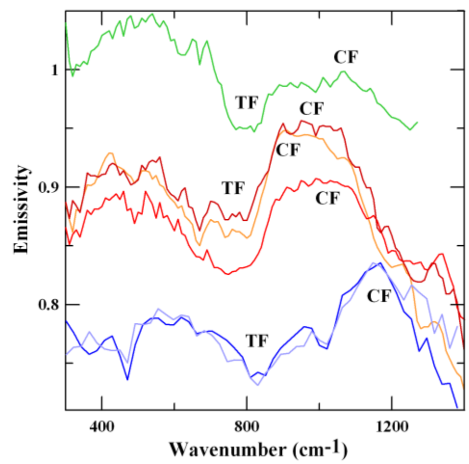

Fig. 3: Comparison between spectra of Phobos (blue lines) and some asteroid (green: 21 Lutetia, dark red: 911 Agamennon, red: 1172 Aneas, orange 624 Hektor

Conclusions. Phobos retrieved spectral emissivity, suggests a phyllosilicate/feldspathoid rich regolith material. While the presence of feldspathoid is questionable, phyllosilicates are not, being a common mineral family among the Carbonaceous Chondrite materials. Since Vis-Nir observations did not show traces of hydration a plausible hypothesis is that phyllosilicate could be de-hydrated by some kind of process related to the space weathering (micrometeorite impacts, solar wind). A comparison with the TIR spectra of other asteroids seems to exclude a link of Phobos with T-type asteroids. Although, the Lutetia CF is located longward, the shape and position of the transparency feature seems to be similar to the Phobos ones.

References

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