IAPETUS, PHOEBE AND HYPERION: ARE THEY RELATED? F Tosi[1], A. Coradini[1,2], F. Capaccioni[2], P. Cerroni[2], G. Filacchione[2], G. Bellucci[1], A. Adriani[1], M. Moriconi[14], E. D'Aversa[1], R.H. Brown[3], K.H. Baines[4], J.-P. Bibring[5], B.J. Buratti[4], R.N. Clark[6], M. Combes[7], D.P. Cruikshank[8], P. Drossart[7], V. Formisano[1], R. Jaumann[9], Y. Langevin[5], D.L. Matson[4], T.B. McCord[10], V. Mennella[11], R.M. Nelson[4], P.D. Nicholson[12], B. Sicardy[7], C. Sotin[13] [1]INAF-IFSI, Istituto di Fisica dello Spazio Interplanetario, Via Fosso del Cavaliere 100, 00133 Rome, Italy, federico.tosi@rm.iasf.cnr.it. [2]INAF-IASF, Istituto di Astrofisica Spaziale e Fisica Cosmica, Via Fosso del Cavaliere 100, 00133 Rome, Italy [3]Lunar and Planetary Lab, University of Arizona, Tucson, AZ, USA [4]Jet Propulsion Laboratory, Pasadena, CA, USA [5]Institut d'Astrophisique Spatiale, Orsay, France [6]US Geological Survey, Denver, CO, USA [7]Observatoire de Paris, Meudon, France [8]NASA Ames Research Center, Moffet Field, CA, USA [9]Insttute for Planetary Exploration, DLR, Berlin, Germany [10]HIGP/SOEST, University of Hawaii, Winthrop, WA, USA [11]INAF-OAC, Napoli, Italy [12]Cornell University, Astronomy Department, Ithaca, NY, USA [13]Laboratoire de Planétologie et Géodynamique, Université de Nantes, Nantes, France [14]CNR-ISAC, Via Fosso del Cavaliere 100, 00133 Rome, Italy.

Introduction: Saturn's satellite Iapetus shows one of the most striking dichotomies in the Solar System, with the leading side significantly darker than the trailing side. Understanding the origin of the dark material coating the leading hemisphere of Iapetus is a focus of the Cassini mission. Proposed sources of the accreted particles are Phoebe and Hyperion, or even other small dark bodies. Phoebe was first invoked to be the source of the dark material coating the leading hemisphere of Iapetus: according to the first version of the exogenous model [1], particles from Phoebe were spiralled towards Saturn due to the Poynting-Robertson effect, and, since moving inward on retrograde orbits, were collided with Iapetus' leading side. Afterwards, Hyperion's parent body was suggested as a potential source of particles impacting the leading hemisphere of Iapetus, because of an advantaged mass transfer [2, 3].

The VIMS experiment onboard the Cassini Orbiter combines the ability of acquiring spectra in the 0.35 – 5.1 µm range with imaging capabilities [4]. With the data now available, characterized by a wider spatial and spectral coverage, and a better spatial resolution than those achieved by the Voyager probes, a more exhaustive comparison can be attempted. In this case, we applied the G-mode clustering method to the 1 – 5 µm infrared portion of the VIMS spectra relative to Iapetus, Phoebe and Hyperion, in order to automatically search for spectral affinities among the three bodies in this range.

The G-mode method: The *G-mode* method allows to classify a statistical *universe* described by *N* samples each depending on *M* variables into homogeneous taxonomic units, considering the instrumental errors. Details of the method are given in [5, 6].

Procedure: In this application, a global set of 857 infrared spectra was considered, sampled in 256 wavelengths from ~0.9 to 5.1 µm. The overall universe of samples is made up by 158 spectra from a cube of Phoebe acquired during the close flyby occurred on 11 June 2004; 411 spectra from a cube of Iapetus acquired during a distant flyby occurred on 31 December 2004; and 288 spectra from a cube of Hyperion acquired during a close flyby on 26 September 2005. All of the spectra were calibrated in radiance by means of the responsivity function provided by the VIMS team [7], keeping into account the exposure time; divided by the solar radiance scaled for the heliocentric distance of the target in order to obtain a I/F spectrum; and finally despiked.

The I/F spectra were organized into a text file (857 rows and 256 columns), used by the G-mode algorithm as an input, with a header containing information on the file and the error applied to each variable. This error corresponds to the average value of the inverse of the SNR typical of the infrared channel of VIMS. It is worth noticing that, since all the major satellites of Saturn are characterized by a spectrum in which the ice and bound water features are very prominent, the weight of the statistical variables is computed accordingly by the G-mode program. In this sense, the classification is automatically performed on the basis of the variables (bands) which are more significant. Another key parameter for the classification, that can be either defined by the user or automatically computed by the program in an optimized way, is the confidence level of the statistical test. By changing this level it is possible to obtain different levels of classification and correspondingly different degrees of class homogeneity [6]. The confidence level usually applied ranges from 94.3% up to 99.9%.

Results: With high confidence level (99.86%), three average spectral types are found by the procedure (Fig. 1). From a spectral point of view, the most interesting range appears to be the one beyond 3 µm, where, besides the water ice and hydrated minerals features typical of these icy satellites, other compounds were first identified [8, 9]. By plotting the samples in a three-dimensional space in which the variables are the I/Fs corresponding to the characteristic features of H_2O ice (1.50 μm), trapped CO_2 (4.26 μm) and the C≡N bond (4.55 μm) or the aromatic C−H stretch (3.3 μm), the three average types are arranged as in Fig. 2. The position of the barycentres of the homogeneous classes gives information about their statistical distances. Two large groups are evident, while the third is made up by just a few samples.

By plotting the same samples with colours related to the corresponding satellites, it can be seen that the first type is made up by samples from Iapetus and Phoebe, while the second type includes most of the samples from Hyperion (Fig. 3).

Moreover, within the first type, two branches can be recognized: these samples belong to the leading (dark) and trailing (bright) hemisphere of Iapetus, respectively. Samples belonging to Phoebe appear to be closer to those of the dark side of Iapetus, so the spectral affinity is stronger in this sense and in the explored spectral range.

Although abundances were not computed in this work, by analyzing the 2-D projection of this plot, another result can be inferred. The reflectance of the CO_2, CN (and CH) features, somewhat related to the abundances of these compounds, seems to be poorly dependent on the amount of water on the dark side of Iapetus, while on the bright side this correlation is more strict.

Conclusions: The use of a clustering method such as the G-mode can help in finding spectral correlations between different bodies or different areas of a given body, on the basis of many weighted variables. In the case of Iapetus, this work can give some indications about the discrimination of the possible sources of the dark material coating its leading hemisphere. In this employment, a stronger spectral correlation between Iapetus and Phoebe, with respect to Hyperion, is pointed out on the basis of 256 infrared wavelengths measured by VIMS. Moreover, some other interesting spectral trends, related to the abundances of some volatile compounds, can be pointed out as well.

References:

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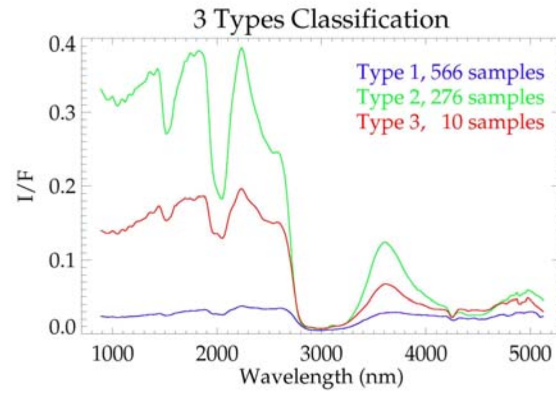

Fig. 1 Average spectral types found by the G-mode procedure on a set of 857 spectra of Phoebe, Iapetus and Hyperion.

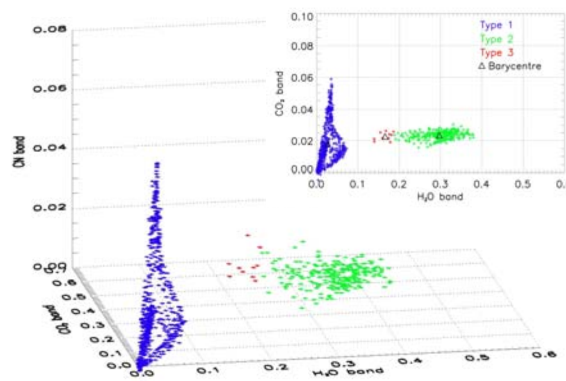

Fig. 2 The distribution of samples is shown in the space of 3 variables, corresponding to the reflectances measured in the wavelengths characteristics of water ice H_2O (1.50 μm), CO_2 (4.26 μm),and the C≡N bond (4.55 μm). In the upper box, a projection on the CO_2 – H_2O plane is provided, with information about the positions of the barycentres of the classes.

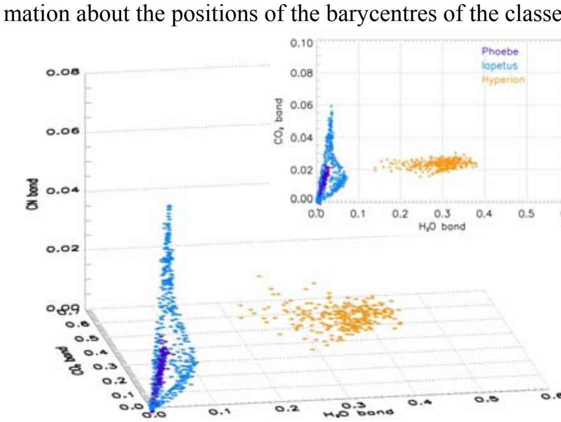

Fig. 3 Here the same distribution is shown in terms of the real objects belonging to the identified types. The main type (Type 1 in the previous graph) is made up by spectra of Phoebe and the dark hemisphere of Iapetus, while another branch presents a stronger correlation with Hyperion (Type 2 in the previous graph).