FIRST SPECTROPHOTOMETRIC IMAGING AND PHOTOMETRIC MAPPING OF THE MARTIAN SURFACE PROPERTIES FROM ORBIT (HRSC AND CRISM). P. C. Pinet[1], J. Fernando[2], Y.D. Daydou[1], F. Schmidt[2], X. Ceamanos[3], S. Douté[3], F. Scholten[4], K. Gwinner[4], T. Roatsch[4], H. Hoffmann[4], R. Jaumann[4] , [1]Institut de Recherches en Astrophysique et Planétologie, UMR5277, CNRS, Toulouse University, 31400, France (patrick.pinet@irap.omp.eu), [2]GEOPS, UMR 8148, CNRS, Orsay, 91405, France (jennifer.fernando@u-psud.fr), [3]IPAG, Grenoble, France (sylvain.doute@obs.ujf-grenoble.fr), [4]DLR, Berlin, Germany (ralf.jaumann@dlr.de).

Introduction: Optical observation of the martian surface is complicated by the surface photometric function and atmospheric scattering, which results in wavelength-dependent limb-darkening profiles. Indeed, under a given viewing geometry, the reflectivity of the martian surface depends both on the surface composition and physical properties, such as surface roughness, at all spatial scales (e.g., [1,2,3,4,5]). To progress any further in our understanding and description of the martian surface photometric behavior (e.g., particle size and shape, texture, roughness, porosity, proportion of crystals versus fines) requires multiangular spectrophotometric analyses. This ongoing task has been undertaken both in situ, by appropriate multispectral imaging sensors onboard MER (Mars Exploration Rover) and MSL (Mars Science Laboratory), and from orbit, by spot pointing observations (OMEGA—Observatoire pour la Mineralogie, l'Etude des Glaces et l'Activite)/Mex (Mars-Express)) and systematic emission phase function studies (HRSC (High Resolution Stereo Camera) /Mex (Mars-Express) and CRISM—Compact Reconnaissance Imaging Spectrometer for Mars)/MRO (Mars Reconnaissance Orbiter). Over the last years, new investigations from orbit that can be addressed with the multi-angular HRSC and CRISM datasets aimed at deriving the surface photometric characteristics for mapping the variation of the soil/bedrock physical properties of Mars, and to relate them to the in situ photometric results obtained at the MER landing sites and to the spectroscopic and thermal orbital observations produced by OMEGA, TES and THEMIS instruments.

HRSC observations and results: HRSC is a push-broom imaging system. It contains 9 parallel CCD-line detectors; nominally, their linear fields of view are oriented normal to the orbit track; an image is built up by repeatedly reading out each array as the spacecraft moves over the surface and the field of view scans the surface. Each detector array views the scene at a different angle from forward to aft of nadir so that each detector views a different line in the scene at any instant of time. Nine detectors consecutively scan the same surface area producing nine overlapping images. Five of the nine detectors have the same panchromatic filters. One channel is toward nadir. Two photometric channels (directed 12°.98 in both directions from nadir) and two stereo channels (directed 18°.98 from nadir) provide five overlapping images. Since they have different emission and phase angles, this set of five overlapping images can potentially be used to extract photometric information [6]. However, this possibility presents some limitations due to the narrow range of photometric angles sampled. As a matter of fact, a single orbit HRSC image set does not contain enough information for describing the photometric function. To compensate for the limited number of observational geometries associated with one HRSC acquisition, observations from several overlapping strips acquired at different times along the mission have to be combined [7]. Indeed, a greater phase angle coverage can be achieved by combining carefully chosen observations acquired at different times under varying illumination geometries and low atmospheric opacity conditions.

The region under study is the Gusev Crater and the south flank of Apollinaris Patera for which a number of overlapping strips have been obtained. The HRSC observations have been acquired with a compression ratio varying between 5 and 15 and initial binning modes comprised between 1 and 4. HRSC data are binned at 1.6 km/pixel and orthorectified [8] to correct for mis-registration and minimize compression effects. With very oblique illumination conditions, observational limitations are the shadows caused by the local relief and decreased S/N ratio. These HRSC observations have been pieced together to derive integrated phase functions over a wide range of phase angles (5-95°). Taking advantage of the extended phase domain, associated with a diversity of illumination conditions, the Hapke inversion procedure developed and tested on experimental data [9], employing a double Henyey–Greenstein function, has been used to model the surface photometric properties. Based on the inversion process and a classification (Principle Component Analysis), the photometric diversity at 675 nm, as seen from orbit, across Gusev crater can be depicted with seven units [10]. Three photometric units widespread across the flanks of Apollinaris Patera flank and the floor of Gusev Crater are identified as having high single scattering albedo with rather forward scattering properties, low to intermediate macroscopic roughness and porous or not compacted powdered surface state as indicated by the opposition parameters. Another unit has the highest single scattering albedo, the smoothest surface in terms of macroscopic roughness, associated with an extremely forward scattering behavior. The opposition parameters are consistent with the presence of transparent particles in the surface powder layer. The distribution of this unit is intermittent across the crater and does not seem to indicate any relationship with a given morphological structure. It may correspond to sparse areas where the structure of the surface dust layer is the most preserved. The most pronounced photometric changes are observed in three units associated with the low-albedo features corresponding to dark wind streaks. These units have a low single scattering albedo, are the most backscattering surfaces across Gusev, have a high surface roughness and present variable surface states, consistent with the occurrence of large grains organized in more or less packed layers. Clear differences are seen among these units in terms of opposition effect which thus appears to play a significant role suggesting that the surface state optical properties across Gusev are strongly influenced by the porosity and packing characteristics or grain size distribution of the upper layer of the martian soil.

CRISM observations and results: The CRISM instrument on-board MRO is a visible and infrared hyperspectral imager (i.e., 362 to 3920 nm at 6.55 nm/channel) that operates from a sun-synchronous, near-circular, near-polar orbit. The appropriate mode to estimate surface spectrophotometric properties is the so-called targeted mode providing Full Resolution Targeted (FRT) observations consisting of a sequence of 11 hyperspectral images from a single region acquired at different emission angles. The solar incidence angle is almost constant during the MRO flyby of a targeted observation. A typical targeted sequence is composed of a nadir image (~10x10 km) at high spatial resolution (15–19 m/pixel) and 10 off-nadir images with a spatial binning (resulting in a resolution of 150–200 m/pixel) taken before and after the nadir image. The latter sequence constitutes the so-called Emission Phase Function (EPF) sequence. The pointing of CRISM can rotate (gimbal) +/- 70° [14].

Thanks to the multi-angular observations, the atmospheric mineral aerosol contribution can be properly described. An algorithm, called MARS-ReCO [11] has been developed to estimate the surface reflectance at each geometric configuration at 750 nm. This technique was implemented and tested on MER landing sites [12]. As a result, we estimate surface photometric parameters and build maps (spatial resolution: 200m/pixel) to study the variability of the surface scattering behavior [13]. A direct application of this methodology has been carried out at MER-Spirit and -Opportunity sites presented in [13]. This approach can be applied for any CRISM observations under the following conditions: mineral aerosol content < 1 and broad phase angle range g (i.e. g<40° and g>105°).

The comparison between HRSC and CRISM-based results shows that there is a robust overall first-order consistency, with the possibility for CRISM observations to work more systematically in the case of significant dust opacity conditions. The lack of atmospheric correction in the early HRSC photometric processing also resulted in a slight overestimation of the amount of single scattering albedo and underestimation of the backward scattering fraction value intrinsically associated with the surface properties [12], and these quantities are thus better handled with the current CRISM processing. The HRSC and CRISM-based photometric results obtained for Gusev crater agree with independent investigations based on thermal inertia (e.g., [15,16]), reflectance spectroscopy [17], in situ photometric investigations by means of the Panoramic Camera [18,19] and microscopic imager (e.g., [20]) instruments onboard Spirit and support the idea of a thin layer of fine-grained dust, being stripped off in the low albedo units to reveal a dark basaltic substrate comprising coarse-grained materials.

Conclusions and prospects: Important results have been reached from these works demonstrating that one can document from orbit the photometric diversity of the martian surface properties. Overall, this case study opens an interesting possibility to document surface states by means of orbital spectrophotometric surveys, with the capability of providing from orbit detailed information for the characterization of potential landing sites and/or for the support of in situ roving operations. As recently seen with Curiosity, the characterization of the surface roughness appears to be of the utmost importance for rover trafficability and wheel mechanical degradation issues.

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