PHOTOMETRIC AND COMPOSITIONAL SURFACE PROPERTIES OF THE GUSEV CRATER REGION, MARS, AS DERIVED FROM MULTI-ANGLE, MULTI-SPECTRAL INVESTIGATION OF MARS EXPRESS HRSC DATA. P. D. Martin[1], A. Cord[1], B. Foing[1], T. Zegers[1], M. van Kan[1], P. Pinet[2], Y. Daydou[2], H. Hoffmann[3], E. Hauber[3], R. Jaumann[3], G. Neukum[4], and the HRSC Co-I Team, [1]European Space Agency, ESTEC, Research and Scientific Support Department, Postbus 299, NL 2200 AG Noordwijk, The Netherlands; patrick.martin@rssd.esa.int, [2]UMR 5562/CNRS/GRGS, Observatoire Midi-Pyrénées, Toulouse, France, [3]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany, [4]Freie Universitaet, Berlin, Germany.

Introduction: High-resolution stereo and color images of the Gusev crater (176°E, 14°S) and surroundings were acquired by the High Resolution Stereo Camera (HRSC) during several early orbits of the ESA Mars Express mission. The multi-angular aspect of the HRSC data sets can be used to determine the photometric and physical properties (e.g., surface roughness) of the observed Martian surface. From the multi-spectral aspect of the data can be derived an evaluation of the composition and distribution of the surface materials, which in turn provides important information about surface processes and regional or local stratigraphy. The focus of this investigation is to use the potential of the HRSC multi-angular and multi-spectral data sets for identifying photometric, color and compositional units and their heterogeneity, for assessing the relationships with regional geological units, and for providing further insight into the geologic, climatic history of this region of Mars.

Data Sets and Geological Context: Calibrated HRSC frames of the Gusev area for orbits 24 and 72 were produced. Data from subsequent orbits (e.g., 283, 335) will be used for expanding the study area and refining the results, and may be particularly useful for the photometric investigation by bringing additional multi-angular measurements. Figure 1 below sets the regional geological context. Figure 2 gives the geological setting of the Gusev crater and its surroundings, with indication of the HRSC frame boundaries for each of the considered orbits. The geologic map used as background for Figure 2 is the result of a recent geological study of the region, based on Mars Odyssey/THEMIS, MGS/MOC and Mars Express HRSC data sets [1]. For the multi-spectral investigation of HRSC data, the sampled wavelengths are 444 nm (blue), 538 nm (green), 677 nm (nadir), 748 nm (red), and 955 nm (near-IR). Each of these five color bands were co-registered to form the corresponding image cube, and used to derive various sets of data analysis products. Support data sets for this work include multi-angular HRSC measurements, HRSC Digital Terrain Model, MGS/MOC and MOLA data sets, and Mars Odyssey/THEMIS data sets.

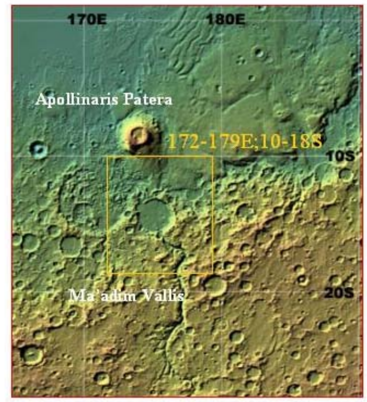

Figure 1: Regional geological context of the study area. The map is a shaded-relief topographic map of the surface, derived from MGS/MOLA measurements. The study region detailed in Figure 2 is indicated by the orange rectangle line.

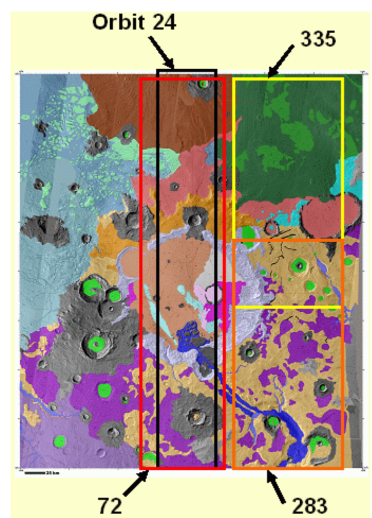

Figure 2: HRSC frames used in the multi-angle and multi-spectral investigations. Geologic map from [1].

Photometric Investigation: The semi-empirical model developed by Hapke [2] is widely used to analyze reflectance data from planetary surfaces (e.g., [3], [4], [5]). The application of this model requires the knowledge of six parameters to calculate the bidirectional reflectance. These parameters correspond to a number of physical quantities characterizing the optical properties of the observed materials: the phase function, the opposition effect, the single scattering albedo and the roughness. This investigation presents a method for the determination of the global set of parameters required by Hapke's model, relying on powerful inversion algorithms [6, 7]. As a demonstration, it is applied to the Martian surface observed by the HRSC instrument in the Gusev crater region. A set of 10 angular conditions provided by the data sets acquired during two overlapping orbits (24, 72; see Figure 2) of Mars Express are used. Following the approach and results presented in [8], the interpretations focus on the link between the photometric parameters and the physical properties of the surface in context with the unique ground truth provided by the *in situ* information from the MER Spirit rover, complementing the first results obtained by a collaborative study of the same region [9]. The resulting photometric description of the surface can be used to improve the calibration of the HRSC color bands, thereby allowing for more accurate color and multispectral analyses and better constrained interpretations of the mineralogical properties of the area.

Multi-Spectral Investigation: This paper focuses on preliminary results obtained with the orbit 24 data set. Multi-spectral band ratios and color composites were produced, as color ratios enhance and isolate the color differences related to surface composition and mineralogy. Fraction- and rms-images derived from a linear spectral unmixing have also been produced, and are displayed along with the 2 five-color spectral end-members E1 and E2 (Fig. 3, 4).

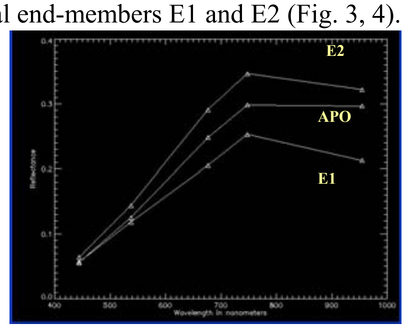

Figure 3: Five-color spectral end-members E1, E2. E1 is representative of the moderate-albedo material within the Gusev crater. E2 is a bright-region spectrum located North of Gusev. APO is a spectrum representative of higher residual rms in the unmixing, located near the summit of Apollinaris Tholus.

Both color-ratio compositing and unmixing modeling support the identification and mapping of two to three main compositional units in and around Gusev, at the scale of the observation.

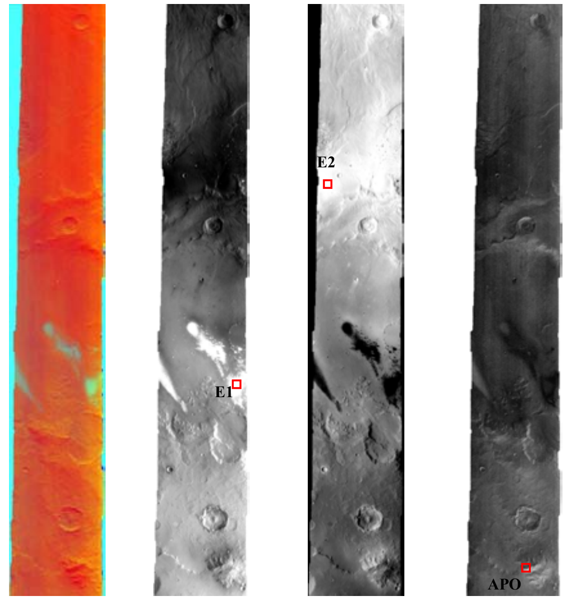

Figure 4, left to right: Color-ratio composite (Red=748/444 nm; Green=748/955; Blue=444/748). E1 fractions. E2 fractions. Rms residual image.

Most of the Gusev region, including E2-type material, can be characterized by the presence of moderate- to high-albedo materials, exhibiting relatively high 748/444-nm ratios and moderate 748/955-nm ratios, which may be consistent with fine-grained, poorly crystalline ferric iron oxides. The color-ratio composite in Fig. 4 highlights the more iron-bearing characteristic of the moderate-albedo materials within the crater walls. These materials are represented by the E1 spectral end-member and were previously interpreted as wind-related features [10]. The HRSC-measured reflectance for E1 (Fig. 3) is consistent with the value of 0.25+/-0.05 given in [11, 12] from MER Pancam *in situ* broadband measurements. The summit of Apollinaris Tholus (APO) exhibits a flat spectral signal in the 748-to-955-nm wavelength interval, indicating a depletion of iron content with respect to the surroundings.

References: [1] Zegers T. et al. (2004) *Ischia Mars Int. Conf.* [2] Hapke B. W. (1993). [3] Johnson P. E (1983) *JGR*, *88*, 3557-3561. [4] Helfenstein P. and Veverka J. (1987) *Icarus*, *72*, 342-357. [5] Cheng A. F. and Domingue D. L. (2000) *JGR*, *105*, E4, 9477-9482. [6] Cord A. et al. (2003) *Icarus*, *165*, 414-427. [7] Nash S. G. (1984) *SIAM J. Numerical Analysis*, *21*, 770-778. [8] Pinet P. et al. (2004) *Ischia Mars Int. Conf.* [9] Pinet P. et al. (2005) this issue. [10] Greeley R. et al. (2003) *JGR, 108*, E12, 8077. [11] Greeley R. et al. (2004) *Science, 305*. [12] Bell J. F. III et al. (2004) *Science, 305*.