Remote-Sensing of Planetary Surface Using Infrared Spectroscopy.

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Infrared remote sensing provides essential knowledge about the current state of solid planetary surfaces. This allows addressing fundamental questions in comparative planetology. A large part of our knowledge about surface composition and structure of solid planetary surfaces is based on infrared remote sensing techniques. These techniques allow performing mineralogical composition analyses, measurement of surface temperature, thermal inertia, and photometric observation of surface regolith texture. The combination of geological mapping based on (visibile light) imaging with infrared spectral data forms the basis for comparative studies in planetology. This paper will provide an overview of what we have learned about the surfaces of planetary bodies using infrared techniques from orbit and provide an outlook on future plans. Typically examples of the main types of instruments are described, and the interplay of disciplines like planetology, IR measuring techniques, and space flight engineering is demonstrated.

The nature of planetary surfaces provides key information about the geologic, physical, and chemical structure as well as the evolution of a planetary body. Key goals of comparative planetology are to unveil common origin processes and divergent evolutionary paths. For most bodies in the solar systems the remote-sensing view onto the surface is still the main if not the only available data source for comparative planetology analyses. Spacecraft studies have made it possible to make meaningful observations of a large number of different planetary objects including small bodies like asteroids and comets, the terrestrial and outer planets and their moons.. Over the last decades, these spacecraft studies have strongly changed our view on the origin, the current similarities, differences, and the evolutionary paths of the single bodies. Missions have succeeded in recording different evolutionary stages of our solar system studying the whole spectrum of planetary objects. These objects ranging from poorly differentiated bodies like asteroid 2867 Šteins [1] (ESA Rosetta mission) over protoplanet type bodies like asteroid (4) Vesta [2] (NASA DAWN mission) to differentiated objects like planets. This enables reconstructing the planetary system's formation starting from early processes up to the current stage of the highly differentiated objects. Apart from this time line, new geoscientific results like the geologic activity of the icy outer moons driven by tidal forces [3] have led to a fundamental review of habitability in our solar system.

Among various remote sensing methods, the IR spectroscopy is a key technology to study planetary atmospheres and surfaces. Such analyses enable information about their composition, texture, structure and dynamics. During the last twenty years, high-resolution (spatial) multispectral imaging systems for photogeologic surface mapping and multi/hyperspectral sensors for thematic mapping have been developed to operate together for planetological applications on deep space missions. Planetary spectrometers, which were successfully developed, applied, and operated on different planetary projects can be loosely divided into three groups: imaging spectrometers for the 0.25 to 5 µm range, imaging spectrometers in the 7-14 µm region, and interferometers from 1.25 up to 45 µm. The instrument designs are driven by the specific conditions of the target bodies. Surface science requires high spatial, high radiometric, and moderate spectral resolution. If the signal is influenced by planetary atmospheres additional observations are required at high spectral resolution. Hyperspectral technologies for planetary application require an interdisciplinary approach combining scientific and observing strategies, advanced engineering conecpts, as well as extensive laboratory work.

The techniques for interpretation of infrared remote sensing data have been continuously improved over the last decades. The computing resources available today allows to apply more sophisticated methods as for example neural network approaches to disentangle the various factors that contribute to the infrared signal recorded from orbit. The advances in the development of data analysis approaches have influenced the design of new generations of infrared instruments as can be seen for example in the design of the GRISM instrument on the NASA Mars Reconnaissance Orbiter (MRO) [4] or the MERTIS instrument on the ESA BepiColombo mission [5].

All interpretation of remote sensing data relies on a solid groundwork of laboratory analog studies ideally performed under realistic surface conditions. The latter becomes increasingly important when studying planetary surface with extreme conditions, as for example Mercury, Venus or the Pluto. The extreme conditions encountered on the surfaces of theses bodies can alter spectral signatures significantly and might lead to misinterpretation if compared to measurements obtained under standard conditions (e.g. [6]).

Unfortunately so far we only have a very limited set of bodies from which samples have been returned to Earth [e.g 7,8]. In the absence of samples we can study in details in laboratories on Earth, in-situ studies on lander elements can provide us with ground truth for orbital observations. Both, sample return and in-situ exploration, can only provide us information about a very small area on a planetary surface. The synergy of in-situ analysis with remote sensing studies can greatly enhance the science return as shown currently by the NASA Curiosity rover working closely together with MRO [9], as well as by the ESA Rosetta orbiter and the Philae lander element [10]. In the foreseeable this synergies between in-situ exploration, sample return and global mapping using remote sensing techniques will allow to extend our understanding of the solar system.

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