USMI – ULTRAVIOLET SPECTRAL MAPPING INSTRUMENT FOR THE GERMAN LUNAR EXPLORATION ORBITER (LEO). K. Werner[1], J. Barnstedt[1], N. Kappelmann[1], W. Kley[1], H. Tomczyk[1], H. Wende[1], H. U. Keller[2], U. Mall[2], H. Becker-Roß[3], S. Florek[3], H. Hoffmann[4], S. Mottola[4], D. Kampf[5], G. Staton[5]

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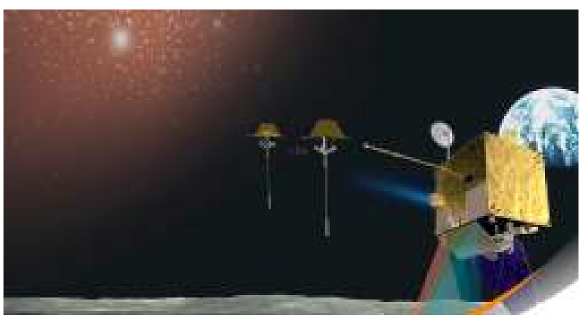
Introduction: The German initiative for the Lunar Exploration Orbiter is aimed at providing a globally covered, highly resolved, integrated, geological, geochemical, and geophysical database of the Moon [1]. LEO is planned to be launched in 2012 and shall orbit the Moon for about four years at low altitude (<50 km) in order to map the Moon geomorphologically, geochemically, and geophysically with resolutions down to less than 1 m globally. Among the future planned missions to the Moon, LEO will be unique, because it will globally explore the Moon in unprecedented spatial and spectral resolution: <1 m in stereo, <10m spectrally (0.2-14µm), 2 m subsurface resolution, 0.2 mGal for lunar gravity at 50 km resolution.



LEO is currently in phase A. The mission scenario foresees a launch in 2012, a five-day lunar transfer, a two-month commissioning phase, and a four-year mapping phase.

Scientific approach: Why UV mapping of the Moon? The reflection characteristics of solid surfaces in the UV spectral range can be used to constrain the mineralogical, petrologic, and chemical composition of geologic material or, in combination with observations in the visual and IR, to determine it in greater detail. Laboratory research of lunar material and other minerals shows that in this wavelength range characteristic features exist for many minerals relevant for planetary geological science.

The spectral dependence of the reflectivity of solid surfaces is determined by many factors (weathering, grain size, crystallisation sequence, material composition) whose de-convolution can often be achieved only by observation over the entire spectral range from the UV to the IR with adequate spectral resolution.

Lunar material was analysed in the laboratory in the nineteen-seventies and -eighties. Lunar rock like KREEP (mainly pyroxene and plagioclase) or basalt with low or high titanium content as well as others often show a steep characteristic absorption edge in the range 250 to 400 nm (Figure 1). For lunar soil these absorption edges are less pronounced (Figure 2). Just by combination with observations at longer wavelengths (VIS and IR) the potential for identification can be significantly enhanced.

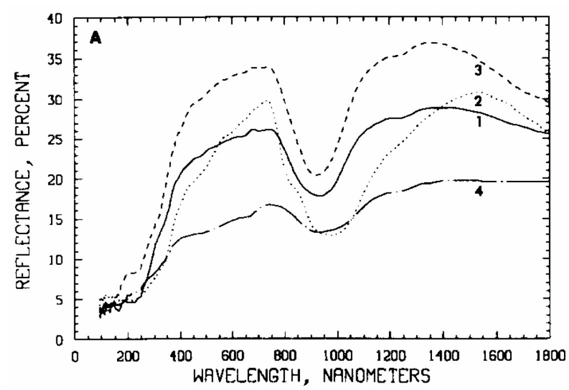


Figure 1. Spectra of powdered samples of lunar rocks. 1,2,3,4: Apollo samples 14310, 15555, 65015, 70017, respectively. From [2].

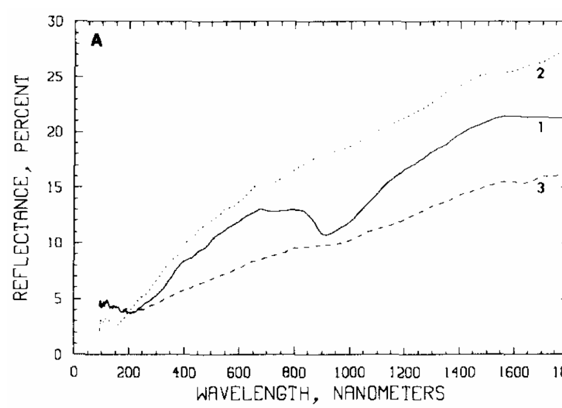


Figure 2. Spectra of lunar soils. 1,2,3: Apollo samples 15601, 68501, 70011, respectively. From [2].

Recent laboratory research in the UV range reveals relations of the spectral shape with the minerals. One example is feldspar (Figure 3). Another example is ilmenite that, in contrast to other minerals, shows a characteristic absorption minimum between 400 and 500 nm and, hence, can be distinguished from other lunar minerals in the UV. In titanium-rich basalts titanium is mainly stored in ilmenite, so that in this case the UV-to-VIS ratio is hardly affected by other minerals. On the other hand, in titanium-poor soil one has to consider that the effect of some titanium-poor or even titanium-free minerals (chromite or ulvöspinel) on the reflection spectrum is very similar to that of ilmenite and, thus, can severely corrupt estimates of the ilmenite content if the spectral resolution is too low.

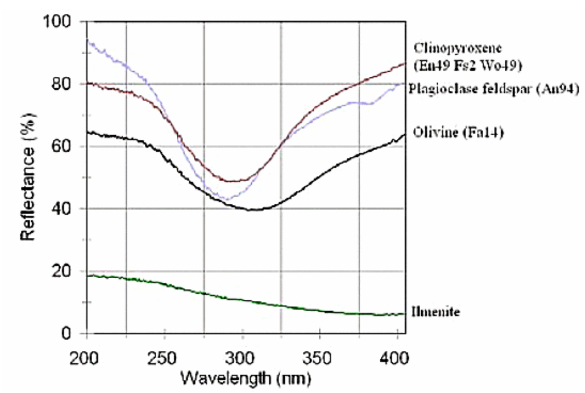


Figure 3. Representative 200-400 nm sample spectra (clinopyroxene, plagioclase feldspar, olivine, ilmenite). From [3].

Space weathering on the lunar surface by influences of the Sun (solar wind and UV radiation) and by cosmic particle radiation acts to make the spectra redder in the IR as well as to make them bluer in the UV. It is possible to distinguish surface material from crushed lunar rock. The increased blue colouring is strongest in the range 300 to 400 nm, because here the above mentioned absorption edge is being degraded. Therefore, quantitative observations in the UV can also be used for a relative age determination of the material on the lunar surface.

A UV spectrometer to characterise the mineral composition and to determine the degree of weathering in the wavelength range 200 to 400 nm does not need to have a high spectral resolution because all phenomena cover broad bands over several 10 nm. A resolution of $\lambda/10$ is sufficient.

The Ultraviolet Spectral Mapping Instrument (USMI): USMI has been selected as one of the instruments to be flown aboard LEO. It will globally map the Moon in the wavelength range from 200 to 400 nm in 10 bands with a resolution of 10 m per pixel.

USMI will provide UV data which will be complementary to those of other LEO instruments that shall perform observations from the visual to the thermal infrared. Combined with the geological and morphological mapping by the high-resolution camera HRSC-L in the visual, and the mineralogical measurements of the VIS-NIR instrument in the near infrared, and the SERTIS instrument in the medium infrared, USMI will enable to determine, spatially highly resolved, the distribution of the principal minerals on the lunar surface by a broad, up to now never achieved coverage of the electromagnetic spectrum. The strived resolution of about 10 m on the lunar surface represents a quantum leap in the multi-spectral mapping of the lunar surface (up to now about 100 to 400 m) and will yield significant progress in detection of the surface mineralogy, because the spatial smearing of spectral signatures will be strongly reduced.

A particular technical challenge for the USMI design is the low surface brightness of the Moon in the 200-250 nm range caused by both the low lunar surface albedo and the strongly reduced solar flux in this spectral range. This is clearly demonstrated by Figure 4 which shows a ultraviolet spectrum of the Moon in the range from 180 to 320 nm, that was observed by the astronomical International Ultraviolet Explorer (IUE) observatory.

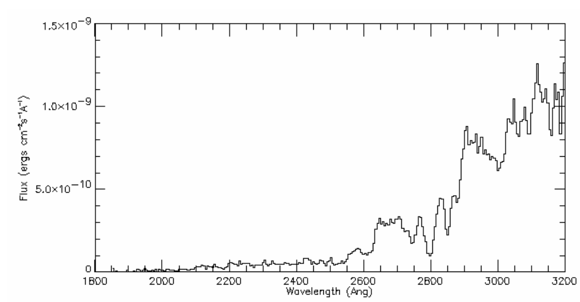


Figure 4. Ultraviolet spectrum of the Moon, recorded in 1979 by the IUE satellite observatory (image number lwr05719 Large Aperture). Retrieved from the NASA Multimission Archive (MAST) at the Space Telescope Science Institute.

References: [1] Jaumann R., et al. (2008) *LPS XXXIX,* Abstract #1391. [2] Wagner J. K., Hapke B. W., Wells E. N. (1987) Icarus, 69, 14. [3] McCormack K., et al. (2006) *LPS XXXVIII,* Abstract #2158.