MERTIS – A thermal infrared imaging spectrometer for the Bepi-Colombo Mission J. Helbert[1], E. Jessberger[2], J. Benkhoff[3], G. Arnold[4], M.Banaszkiewicz[5], A. Bischoff[2], M. Blecka[5], S. Calcutt[6], L. Colangeli[7], A. Coradini[8], S. Erard[9], S. Fonti[10], R. Killen[11], J. Knollenberg[1], E. Kührt[1], I. Mann[2], U. Mall[12], L. Moroz[2], G. Peter[4]. M. Rataj[5], M. Robinson[13], T. Spohn[1], A. Sprague[14], D. Stöffler[15], F. Taylor[6], J Warrell[16]
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Introduction: Among the terrestrial planets, Mercury plays a special role. It is the smallest planet, the densest, the one with the probably oldest surface heavily gardened by space weathering, and shows large daily surface temperature variations. Understanding Mercury is crucial to develop a better understanding of the early processes in the inner solar system, of how our Earth formed, how it evolved, and how it interacts with the Sun.

The ESA mission Bepi-Colombo consists of two probes - a planetary and a magnetospheric orbiter. The mission will be launched in 2012 and will reach Mercury in 2016. MERTIS is part of the payload of the planetary orbiter, focused on understanding the surface and interior of Mercury.

The instrument: MERTIS is an imaging spectrometer for the thermal infrared wavelengths range. It covers the range from 7-14 µm at a high spectral resolution of up to 90nm which can be adapted depending on the actual surface properties to optimize the S/N ratio. MERTIS will globally map the planet with a spatial resolution of 500m and a S/N of at least 100. For a typical dayside observation the S/N ratio can exceed 1000 even for a fine grained and partly glassy surface. MERTIS will map 5-10% of the surface with a spatial resolution higher than 500m. The flexibility of the instrumental setup will allow to study the composition of the radar bright polar deposits with a S/N ratio of >50 for an assumed surface temperature of 200K.

MERTIS will produce classification maps for the global distribution of surface types on Mercury. The deconvolution algorithms will be developed based on existing methods and drawing from the experience gained in laboratory measurements

Science goals: The scientific goal of MERTIS is to provide detailed information about the mineralogical composition of Mercury's surface layer by measuring the spectral emittance of different locations in the spectral range from 7-14µm. Knowledge of mineralogical composition is crucial for choosing the best of several competing theories, and thus for selecting the valid model for origin and evolution of the planet. MERTIS has four main scientific objectives, building on the general science objectives of the Bepi-Colombo mission.

- Study of Mercury's surface composition
- Identification of rock-forming minerals
- Global mapping of the surface mineralogy
- Study of surface temperature and thermal inertia

Formation of Mercury: Mercury might teach some important lesson on the formation of our solar system. There are numerous models addressing the unusual features of the planet, like its high density, indica-tive of a large metallic core and the apparent low FeO surface abundance. These models fall in different classes. The first class focuses on the enrichment of metal, either by differential accumulation of metal and silicate or by blasting away the silicate rich crust by a giant impact [1,2,3] Evaporation models are the second class of models. Based on models by [4], during the early T-Tauri phase, the formation region of Mercury might have experienced temperatures up to 2500-3500K. [5] modelled several cases assuming different silicate magmas as starting conditions. One of their models with a FeO abundance of ~3.4%, close to present day estimates, would predict very low SiO_2, high MgO and no K. The next class are refractory condensation models, based on the temperature gradient in the solar nebula indicated by theoretical models. If these gradients were steep enough the com-position of the solar nebula would vary as a function of temperature and distance [6]. Mercury would have been formed from high-temperature condensates, like metallic iron and FeO-free silicates. The final class are the chondritic models, based on the long discussed notion that chondrites were the building blocks for the planets. Enstatite chondrites have been proposed as possible analogues for Mercury [7], based on the idea that these chondrites formed also close to the Sun. [8] found some similarities between the spectral properties of enstatite chondrites and Mercury.

MERTIS capabilities to study the mineralogy of the surface in details will set further con-straints on the formation models for Mercury and will thereby further our knowledge on plane-tary formation in the inner solar system.

Surface properties: Our knowledge of the Mercury' surface is based mostly on the Mariner 10 data, which covers only about 50% of the surface and ground-based observations. [9] suggested based on the analysis of albedo and color relationships on Mariner 10 images that the surface of Mercury has very low contents of FeO and TiO_2. This was later confirmed by ground-based spectral observations. [10] and [11] have found close spectral similarities between mature (heavily space weathered) lunar anorthosites [12] and the spectra of Mercury. Lunar anorthosites have less than 3 wt.% FeO and consist largely of plagioclase feldspar. Recently, [13] concluded that the best match to VIS-NIR spectra of Mercury was provided by a member of plagioclase series labradorite and enstatite (Mg-pyroxene with low Ca content) intimately mixed in proportion of 3:1. Such composition yields 1.2 wt.% FeO and 0 wt.% TiO_2.

VIS-NIR spectra of minerals and rocks show diagnostic absorption features only unless FeO content in the minerals is too low. Ground-based telescopic NIR spectra of Mercury show no absorption features [14]. However The TIR-range offers unique diagnostic capabilities for the surface composition of Mercury. In particular, feldspars can easily be spectrally detected and characterized, since in this range they show several diagnostic spectral signatures: Christiansen frequency, Rest-strahlen bands, and transparency feature. In the TIR range at wavelengths longer than 7 µm spectral signatures in silicates result from characteristic fundamental Si-O vibra-tions, therefore FeO- and TiO2-free silicates (e.g., feldspars, Fe-free pyroxenes and Fe-free olivines) undetectable in the vis-NIR region, can be detected in the TIR.

Scientific performance: In order to assess the instrument performance under realistic conditions we used telescopic data obtained by [15]. We used the apparent emissivity they derived as input for our simulation. While using pure minerals is a best case assumption, using the telescopic data is a worst case assumption. The telescopic data is already noisy and is at least partly still contaminated by telluric absorption features.

We treated the telescopic data like the laboratory data, assuming again a surface tempera-ture of 590K typical for higher latitudes on the dayside. We added noise, both instrumental and background and calculated the simulated brightness temperatures as they will be ob-served by MERTIS.

The figure shows the resulting brightness temperature measurements. A visual inspection con-firms that the features are reproduced accordingly. Using the highest spectral resolution of 90nm and full spatial resolution we obtain an S/N ration of over 300 at 8µm. Using moderate 3*3 macro-pixel, as would be done in the mapping phase for medium to high latitudes, we obtain a S/N ratio of more than 1000 at 8µm.

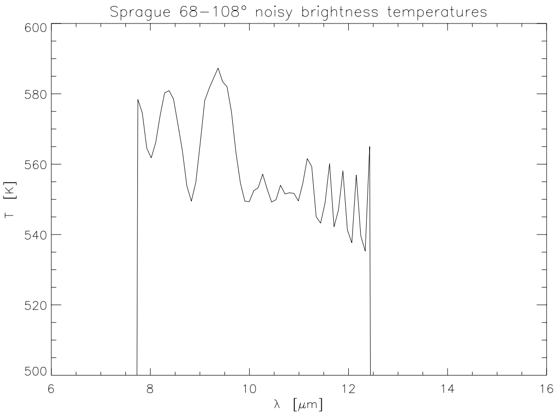

Figure 1 Simulated brightness temperatures as measured by MERTIS with full spectral and spatial

Conclusions: MERTIS will provide detailed insight into the surface composition of Mercury and will allow to study the mineralogy on spatial scales of 500m and less. The will give important constraints to models for the formation of the planet.

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Additional Information: See the MERTIS webpage at http://solarsystem.dlr.de/TP/MERTIS_en.shtml