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SIMULATION OF SPACE-WEATHERED TIR SPECTRA ON MERCURY

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1. Introduction

The BepiColombo spacecraft will carry the spectrometer MERTIS which is designed to perform hyperspectral measurements of the Mercurian surface in the thermal infrared (TIR) domain (7 µm – 14 µm) [1]. TIR spectra have been used to quantify modal abundances on Mars from Thermal Emission Imaging System (TEMIS) and Thermal Emission Spectrometer (TES) data [2,3]. Spectral measurements in the TIR range of Mercury's surface are subject to the superposition of solar reflection and variable thermal emission [4]. Additionally, the regolith is affected by space weathering, which is known to have an impact on the spectral shape. In order to address combined reflectance and emittance as well as space weathering in view of the evaluation of MERTIS measurements, this work contributes in two ways: At first, we apply our space weathering simulation framework [5] to generate artificially space weathered spectra of silicates in the TIR region and compare them to laboratory weathering experiments [6]. Secondly, we employ our previous approach [7] to simulate combined reflectance and emittance spectra of space weathered silicates under conditions which are comparable to Mercury's environment. This will not only improve the accuracy of previous simulations but it is also a step towards a comprehensive model of Mercury's radiance characteristic relevant for soil characterization, spectral unmixing and modal abundance estimation.

2. Method

Space weathering simulation: In our previous work [5], the effects of space weathering are simulated by directly modeling the scattering behavior of submicroscopic iron spherules employing Mie theory. The technique falls into two steps: At first, the scattering behavior of iron is computed. Secondly, the single scattering albedo of the simulated iron is mixed with the single scattering albedo of a silicate. Subsequently, the mixed albedos are fed into Hapke's model [8] in order to generate reflectance spectra under arbitrary illumination conditions.

Combined reflectance and emittance: The wavelength-dependent radiance I which is measured at the sensor is a superposition of solar reflection and thermal emission. Solar irradiance J [W/m^2] illuminates the surface and is reflected according to the reflectance function $r(i, e, g)$. It depends on the incidence angle i, the emission angle e and the phase angle g. Additionally, thermal radiation U emerges from the surface according to Planck's law which is multiplied with the directional emissivity ϵ_{d}:

$$I(i, e, g, \lambda) = Jr(i, e, g, \lambda) + \epsilon_{\mathrm{d}}(e, \lambda)U(T, \lambda)$$

The combined model was presented in [7]. It relies on the anisotropic reflectance model proposed in [8] and the hemispherical directional emissivity which is obtained by integrating r [7,8]. We make use of our artificially weathered spectra in order to simulate realistic radiance emerging from Mercury.

3. Results

Space weathering simulation: We carried out a space weathering simulation of an olivine sample in the TIR region for iron particle sizes of 100 nm in diameter. The results for different weight percentages are plotted in Figure 1. In the work of [6], olivine samples were irradiated by laser pulses, where two effects are observed (Figure 2): A larger number of pulses and more powerful irradiation yield a more prominent darkening effect, where the darkening effect becomes less strong with increasing wavelength. The strongest irradiation with 5 pulses of 50 mJ produces a severe darkening effect for the whole spectrum, but the authors of [6] state that this scenario is likely to be unrealistic. The comparison of our simulation with the results from [6] indicates an overall consistency: An increasing iron content accounts for a stronger darkening effect, and the effect becomes weaker with increasing wavelength. An unrealistically high amount of 10 wt% of iron causes the very dark spectrum. Note that we studied bidirectional reflectance r_{d}, whereas in [6] a scaled reflectance is studied. Moreover, different olivine samples were used. This explains the different scaling of the reflectance and the slightly different spectral shapes.

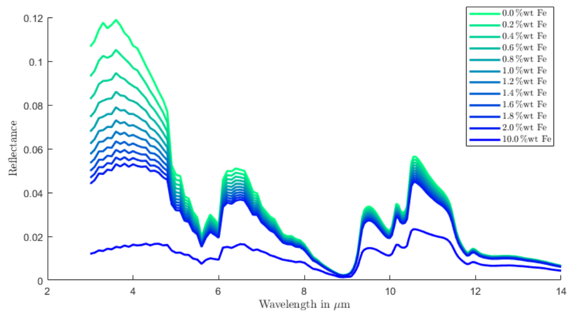

Figure 1. Simulated space weathering of olivine.

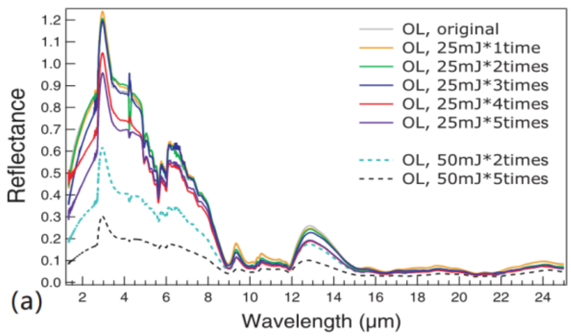

Figure 2. Space weathering experiment (from [6]).

Combined reflectance and emittance: We used a reflectance spectrum which was computationally space weathered with 2 wt% of iron and fed it into our combined reflectance and emittance framework. The spectrum was acquired at room temperature. Thus, temperature dependent changes of the spectral bands will not be observed in our simulation. In the work of [9] the latitude-dependent temperatures at perihelion and aphelion are given. We examine several keypoints ranging from (0°W|15°N) to (0°W|88°N) for perihelion and from (90°W|15°N) to (90°W|86°N) on aphelion. A higher latitude also implies that the incoming solar irradiance decreases with the cosine of the latitude. The resulting spectra are divided by the blackbody radiation and we call this quantity apparent emissivity. As depicted in Figures 3 and 4, the spectra of the apparent emissivity only show a variation with temperature for wavelengths roughly below 5 µm. This indicates that thermal emission is the dominant source of radiance emerging from Mercury in the spectral range of MERTIS.

Local Topography: In our simulations, Mercury was assumed to be a perfect sphere. In reality, the Mercurian surface exhibits a rich topography. Some surface elements in this area may face the sun, have low solar incidence angles and thus become hotter than an even surface. Surface elements which are only tangentially lit are colder. Thus, a small area with many different slopes may exhibit a mixture of different temperatures and incidence angles.

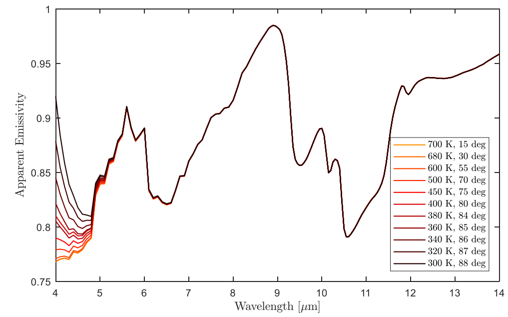

Figure 3. Simulated apparent emissivity at perihelion.

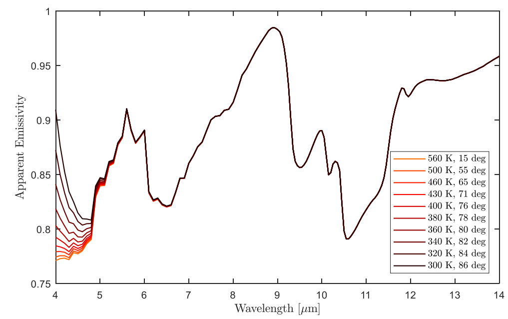

Figure 4. Simulated apparent emissivity at aphelion.

4. Conclusion

We simulated combined reflectance and emittance spectra under the influence of space weathering for realistic scenarios on the Mercurian surface. Our model enables the simulation of various conditions on the planet. The results indicate that emission is the predominant source of radiance emerging from Mercury at wavelengths beyond 5 µm. Further investigations shall combine the model with information on topographic information and local temperature, which is crucial for a physically meaningful interpretation of radiance spectra of Mercury's surface.

References

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