Combining High-temperature Spectroscopy and Principal Component Analysis to Understand Mercury Surface Spectra from MESSENGER. Jörn Helbert[1], Mario D'Amore[1], Alessandro Maturilli[1], Noam R. Izenberg[2], Gregory M. Holsclaw[3], James W. Head[4], and Sean C. Solomon[5] [1] Institute for Planetary Research, DLR, Rutherfordstrasse 2, Berlin, Germany, joern.helbert@dlr.de, [2]Johns Hopkins University, Applied Physics Laboratory, Laurel, Maryland 20723, [3]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80303, USA, [4]Department of Geological Sciences, Brown University, Providence, Rhode Island 02912 USA, [5]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA.

Introduction: The MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) spacecraft performed two flybys of Mercury in 2008, a third followed in September 2009, and in 2011 MESSENGER will enter into orbit about the innermost planet. During both the first and second flyby the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) instrument obtained spectra of the surface along ground tracks that each traverse much of the planet [1,2]. Unfortunately, the instrument did not obtain surface data during the third flyby.

We are analyzing the surface spectra using a principal component approach. The main goal of this analysis is to identify and characterize surface units along the MASCS ground tracks.

For the first time we can combine this approach now with new spectral data obtained in the Planetary Emissivity Laboratory (PEL) at the Deutsches Zentrum für Luft- und Raumfahrt (DLR) in Berlin [3,4,5]. These data are obtained at typical Mercury dayside temperature of up to 500°C and under vacuum conditions.

Data analysis: The interpretation of remote sensing data from Mercury to gain insight into surface composition is in general a challenging task. For the specific case of using data from the MASCS instrument on MESSENGER, we have additional challenges due to issues related to the calibration of the instrument. In our analysis approach presented here we have used calibrated data without any further correction or processing and have applied a principal component analysis (PCA). In particular we chose not to perform any phase correction to compensate for the changing illumination and viewing angle, as the phase function for the surface of Mercury is not well known. The results using this untreated dataset are very encouraging and show that this approach holds promise.

To retrieve and characterize the number and spectral shapes of the different components present in the dataset we apply an R-mode factor analysis, a well-established technique in remote sensing [6,7,8]. The factor analysis expresses the data in a new vectorial base, for which the data covariance is minimized. The identification of the different components and their abundance is accomplished by PCA. The eigenvectors and eigenvalues of the covariance matrix are evaluated, and the covariance matrix is decomposed in the space generated by the eigenvectors. The eigenvectors corresponding to larger eigenvalues are associated with most of the information contained in the data. The smaller (secondary) eigenvalues are related to featureless eigenvectors that contribute very little to the data.

Application to the full MASCS dataset shows that in general seven eigenvectors are sufficient to reconstruct the data within the errors. Even if there are small differences between two channels, the eigenvectors do not show strong differences. A comparison of the different channels indicates that the near-infrared (NIR) portion is carrying significantly less information than the visible (VIS) portion. The first eigenvector always displays a strong reddish slope, compared with the others, and all eigenvectors show characteristic spectral signatures .

Each spectral eigenvector can be regarded as a representative of different spectral classes, which change in relative abundance along the track. The concentration coefficients in the C matrix indicate that spectral units show significant geographical variation. Moreover, the spectral unit variations show a strong correlation with surface units mapped by MESSENGER's Mercury Dual Imaging System (MDIS).

High-temperature spectroscopy: In support of the National Aeronautics and Space Agency's MESSENGER mission and especially in preparation for the Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS) instrument on the BepiColombo mission of the European Space Agency and the Japan Aerospace Exploration Agency, we are completely refurbishing the PEL. The upgraded PEL allows measurement of the emissivity of Mercury-analogue materials at grain sizes smaller than 25 µm and at temperatures of more than 400°C, typical for Mercury's low-latitude dayside. The PEL development follows a multi-step approach. We have already obtained emissivity data at mid-infrared wavelengths that show significant changes in spectral behavior with temperature indicative of changes in the crystal structure of the samples [3].

We are currently testing new calibration targets that will allow the acquisition of emissivity data over the full wavelength range from 1 to 50 µm with good signal-to-noise ratio. This allows for the first time the measurement of spectra of relevant minerals under realistic temperature conditions for the NIR part of the MASCS spectral data.

Figure 1: New high-temperature emissivity chamber in the PEL [4,5]

Conclusions and outlook: The PCA shows variations in the spectral characteristics that we attribute predominantly to a geochemical diversity for different surface units rather than geometric effects. We can not exclude some effects due to changing lighting conditions, though such effects appear to be confined to the first eigenvector.

The PCA can identify different units, but it can not identify the materials in the units directly. Such an identification requires a target transformation of the eigenvectors in a set of spectra from analog materials. This step is finally possible with the currently ongoing measurement of spectra in the spectral range 1-50 µm at Mercury dayside temperatures in the PEL at DLR.

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