Preparation of Mercury analogue materials to calibrate instruments onboard the BepiColombo spacecraft

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Understanding the formation and evolution of planet Mercury is crucial to comprehend the processes that have shaped the solar system and other exoplanetary systems. The observational work initiated by NASA's MESSENGER mission will be built upon by the BepiColombo mission (Benkhoff et al., 2021), a joint endeavor of ESA and JAXA. Onboard of the BepiColombo spacecraft, which will enter Mercury's orbit in late 2025, the Mercury Imaging X-ray spectrometer (MIXS, Bunce et al., 2020) will measure the atomic composition of the top 10 to 20 µm of the surface by fluorescence spectroscopy. MIXS will use X-rays emitted from the solar corona as its source. Its primary goal is to generate a global map of Mercury's regolith atomic composition but specific locations will undergo higher-resolution measurements by rotating the device to increase the dwell time.

MIXS's signal calibration relies on numerical modeling of X-ray radiative transfer and laboratory experiments. However, due to the unique composition of Mercury' surface (high sulfur and low iron content), usual reference geochemical standards provide incomplete calibration of the MIXS data. Moreover, the signal will be influenced by factors such as observation geometry and grain size. To address these challenges, a ground facility has been established to simulate space observations on Earth. Various samples will be analyzed to mimic possible regolith compositions (with differing compositions and textures), in order to fine tune data processing protocols and instrument parameters.

We are producing pressed pellets of known chemical compositions for this purpose, chosen to address critical scientific questions regarding Mercury's composition and evolution. The MESSENGER mission has revealed peculiar characteristics of Mercury's surface, showing abundant potassium and sulfur, indicative of high volatile content. Understanding the spatial distribution of these elements is crucial as they are linked to pyroclastic volcanism and the formation of hollows (i.e. depressions believed to form by sublimation). Therefore, we prepared pellets with a range of K2O and S concentrations relevant to the surface of Mercury (0 – 2 and 0.5 – 10 wt.%, respectively). Calcium is added to the samples containing potassium as the peaks of these elements overlap, complicating potassium detection. Besides these global characteristics, different geochemical provinces, probably formed by partial melting of a heterogeneous mantle, have been identified. Sodium is more abundant in the northern smooth plains, hinting at a mantle source richer in clinopyroxene. Sodium detection is however challenging due to the overlap with the magnesium K emission line. Hence, we also prepared samples with varying Na2O content (ranging from 0.1 to 8 wt.%) and a fixed MgO concentration. These samples, along with other additional materials produced by other teams, will enable accurate and precise measurement of the surface atomic composition of Mercury.

Benkhoff J, Murakami G, Baumjohann W, Besse S, Bunce E, Casale M, Cremosese G et al. (2021) BepiColombo - Mission Overview and Science Goals. Space Science Reviews 217(8): 90. Bunce E, Martindale A, Lindsay S, Muinonen K, Rothery DA, Pearson J, McDonnell I, et al. (2020) The BepiColombo Mercury Imaging X-Ray Spectrometer: Science Goals, Instrument Performance and Operations. Space Science Reviews 216(8): 126.