Space Weathering on the Surface of Mercury viewed from Spectroscopic Data obtained by the MESSENGER Mercury Dual Imaging System. Makoto Hareyama[1], Yoshiaki Ishihara[2], Chikatoshi Honda[3] and Makiko Ohtake[4], [1]St. Marianna University School of Medicine (m-hareyama@marianna-u.ac.jp), [2]National Institute for Environmental Studies, [3]University of Aizu, [4]Japan Aerospace Exploration Agency.

Introduction: The Mercury is the most inner planet in the solar system. As this planet has characteristics similar to the earth's Moon such as airless body, much craters and size, the planet has been studied a lot compared to the Moon since the past. However, the US Mercury Explorer MESSENGER has revealed the various differences between the Mercury and the Moon (e.g. [1], [2]). We have classified the lunar spectral data by unsupervised classification methods such as K-means and ISODATA and discussed the lunar crustal evolution [3]. A similar method applied to the Mercury's spectral data of the MESSENGER Mercury Dual Imaging System (MDIS) [4] (Fig.1) revealed that the spectra was first bisected by spectral slope and then classified by reflectance (Fig.2, 3 and 4) [5]. The average spectra in Fig.4 have been divided largely into two classes. One is hard spectral slope group of Class 1 and 2 (red and green respectively in Fig. 3 and 4), the other is soft slope group of Class 3, 4, 5, and 6 (blue, yellow, cyan, and purple). The former corresponds to the red class of K =2 in Fig.2 and the latter corresponds to the green class in Fig.2.

In the context of airless bodies such as the Moon and asteroids, the slope of spectrum is known as one of indicators for space weathering effect on their surface materials. The Mercury has different environment for space weathering from the Moon, which are a magnetosphere existing, low iron content, and high solar wind intensity and low galactic cosmic ray flux due to close to the Sun. Therefore, the Mercury's multiband spectral may provide constrain space weathering process.

This work analyzed 8 bands cubed global mosaic data called 8 color (MDR) of MESSENGER/ MDIS [4] and discussed space weathering on the surface of Mercury.

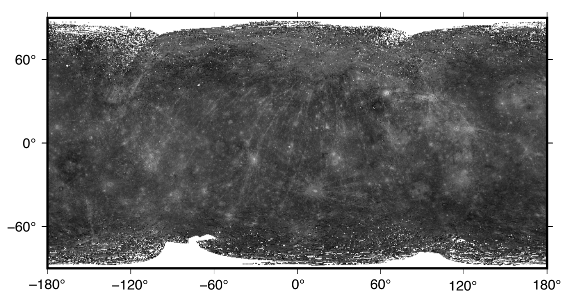

Fig.1 MDIS 630 nm reflectance map of the Mercury.

Continuum Determination and Spectral Slope Map: In Figure 4, each spectrum has similar spectral shape to each other, and a weak absorption is found around 750 nm wavelength of every spectrum. Though this absorption is found on lunar black glass beads of Apollo samples[6], any average spectra of lunar global classification [3] does not show such 750 nm absorption. Also, both reflectance at 430 nm and 1000 nm in a class

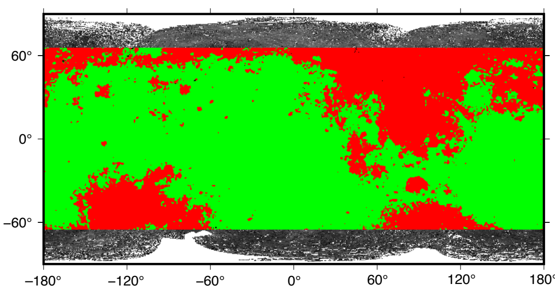

Fig. 2 Classification map by K = 2 of K-means.

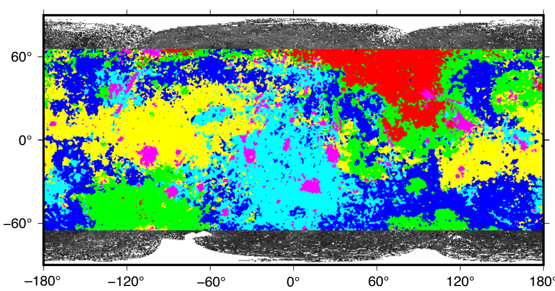

Fig. 3 Classification map by K = 6 of K-means.

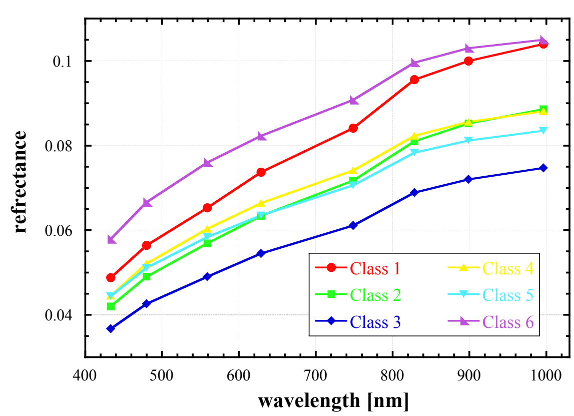

Fig.4 Average spectra of each class by K = 6 of K-means classification.

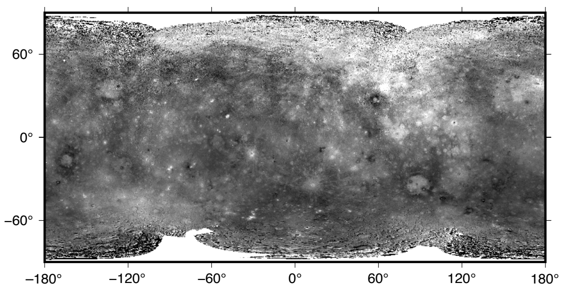

Fig. 5 The spectral slope map (s-map). tie points of continuum : 630 nm and 830 nm.

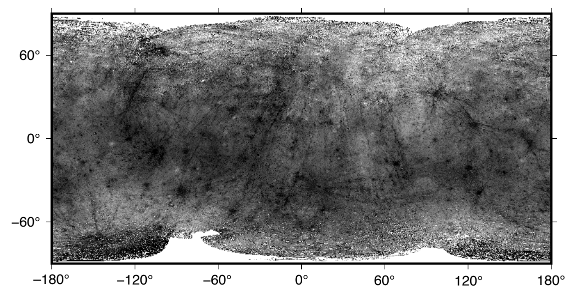

Fig. 6 The reflectance ratio, R(830nm)/ R (630nm), map (r-map).

looks to show different absorption rate to the other classes. Therefore, each linear continuum of spectrum was determined as a line with two tie points of 630 nm and 830 nm reflectance. The spectral slope, s,

$$s = \frac{R(830\text{nm}) - R(630\text{nm})}{830\text{nm} - 630\text{nm}},$$

was defined as a slope of this linear continuum, where $R(\lambda)$ is reflectance at wavelength of λ. On the other hand, a reflectance ratio, r,

$$r = R(830\text{nm})/R(630\text{nm}),$$

is also one of indicators for the spectral slope. This ratio corresponds to the index of exponential for exponential type continuum.

The spectral slope map (s-map) and the ratio map (r-map) show in Fig.5 and Fig.6, respectively. The both maps had large values in the smooth plain at northern hemisphere and regions around south pole as similar to the distribution of red class in Fig.2. However, some differences are appeared between two maps. The s-map shows clear land features such as basins and craters, but non-clear crater rays. While the r-map shows clear crater rays, but non-clear basin and/or crater structure.

Space Weathering on the Mercury: Generally, in context of space weathering, albedo of fresh material is brighter than that of old one. In case of the Moon, the spectra changed to become darken and redden by space weathering. Peters and Noble [2] summarized on Mercurian spectra that fresh material exhibits a higher albedo and less steep continuum slope. However, the result of this work indicates that high albedo area has steep slope. The reason of this difference may be that this work defined the spectral slope quantitatively from narrow range between 630 nm and 830 nm in the entire Mercury, while they conclude the gradient visually in wide range from 300 nm to 1400 nm from some spectra.

Basins, craters and their ejecta as crater rays, which are considered relatively fresh surface materials, show high albedo as seen in Fig.1. In the s-map of Fig.5, though basins and craters are clear as steeper spectral slope, crater rays are not clear. Oppositely, in the r-map of Fig.6, crater rays are clear but basins and craters are not. In other words, this result means that the reflectance in basins and craters changes at a constant rate for that in their peripheral region regardless of the wavelength, while that in the crater rays changes at a constant absolute value for that of their peripheral region regardless of the wavelength. No such results were reported for the Moon. Further analysis is needed to elucidate the cause, but this difference in the spectral changes may indicate that space weathering on Mercury's surface is related to its weathering process with Mercury's chemical composition.

Conclusion: In this study, the global map of spectral slopes of the entire Mercury was derived based on the results of an automatic classification that the spectrum of Mercury was largely divided into two classes by the spectral slope. The map revealed that even the same fresh materials had different spectral slope changes between materials inside crater and basin, and their ejecta. This result may show that the process of space weathering is different between those, or that is depends on unique Mercurian chemical composition.

Acknowledgments: This study is supported by JSPS KAKENHI (Grant-in-Aid for Scientific Research(C)) Grant Number 17K05641 (P.I.: Makoto Hareyama).

References: [1] Domingue, D.L. et al. (2014), *Space Sci. Rev.*, ***181***, 121-214. [2] Pieters, C.M. and Noble, S.K. (2016) *JGR Planets* ***121***, 1865-1884. [3] Hareyama, M. et al. (2019) *Icarus* **321**,407-425. [4] http://messenger.jhu-apl.edu/Explore/Images.html#global-mosaics. [5] Hareyama, M. et al. (2019) *LPS XXXXX,* Abstract #1714. [6] Tompkins, S. and Pieters, C.M. (2010) *Meteo. Planet. Sci.* ***45***, 1152-1169.