A NEW SCHEME FOR ESTIMATING THE DEGREE OF SPACE WEATHERING THROUGH VISIBLE MULTIBAND SPECTROSCOPY USING AN ECAS-TYPE FILTER SYSTEM SUCH AS HAYABUSA AMICA. Takahiro Hiroi[1], Yuji Ueda[2], Tokuhiro Nimura[2,3], Masanao Abe[3], Masateru Ishiguro[4], and Sho Sasaki[5], [1]Dept. of Geolog. Sci., Brown Univ., Providence, RI 02912, USA (takahiro_hiroi@brown.edu), [2]Dept. of Earth and Planet. Sci., Univ. of Tokyo, Hongo, Bunkyo-ku, Tokyo 113, Japan, [3]JAXA Inst. of Space and Astronaut. Sci., 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan, [4]School of Earth Environment. Sci., Coll. of Natural Sci., Seoul Natl. Univ., Seoul 151-742, Korea, [5]RISE Group, Mizusawa Astrogeodynamics Obs., Natl Astronom. of Obs. Japan, 2-12 Hoshigaoka-cho, Mizusawa City, Iwate 023-0861, Japan.

Introduction: Visible multiband spectroscopy using ground-based telescopes or sensors onboard spacecraft has been commonly used for mapping planetary surfaces for detecting the compositional, physical, and space weathering information. However, detecting the degree of space weathering from simple color plots using band ratios, etc. can easily suffer from the effects of variation in grain size and viewing geometry. In this paper, we have attempted to develop a new scheme for estimating the degree of space weathering which is more free from such effects.

Experimental: Samples of Harleton (L6) and Cherokee Springs (LL6) ordinary chondrites were each prepared into a chip, and power size fractions of 125-500 and <125 μm. An Alta'ameem (LL5) sample was prepared into a <125 μm size fraction. Powder samples (<250 μm) of NWA1799 (LL5) were pressed into pellets and were irradiated with pulse laser at 5 and 15 mJ in energy as a space-weathering simulation [1] at Mizusawa Astrogeodynamics Observatory in Japan.

Bidirectional reflectance spectra of the above samples were taken at either NASA Reflectance Experiment Laboratory (RELAB) at Brown University, University of Tokyo, or JAXA Institute of Space and Astronautical Sciences at various incidence and emergence angles. Reflectance spectra of laser-irradiated olivine samples (<75 μm) were taken from [1], and spectra of bulk samples of Apollo lunar soils 12030, 12037, 12024, 12070, 67461, and 61241 were taken from the RELAB database (http://lf314-rlds.geo.brown.edu/). Maturity indices (Is/FeO) of the above lunar soils were taken from [2]. Spectral transmittance data of Hayabusa/AMICA filters were taken from [3].

Space-Weathering Indices: It has been well known from observational, experimental, and modeling studies (e.g., [4], [5]) that space weathering most-strongly alters the visible reflectance spectra of airless planetary surface materials, namely darkening and reddening. Less known are changes in inflections around 0.42 and 0.55 μm in wavelength as shown in Fig. 1. As the degree of space weathering progresses (increasing laser energy), negative amounts of inflections at those wavelength points change toward 0 (smoother).

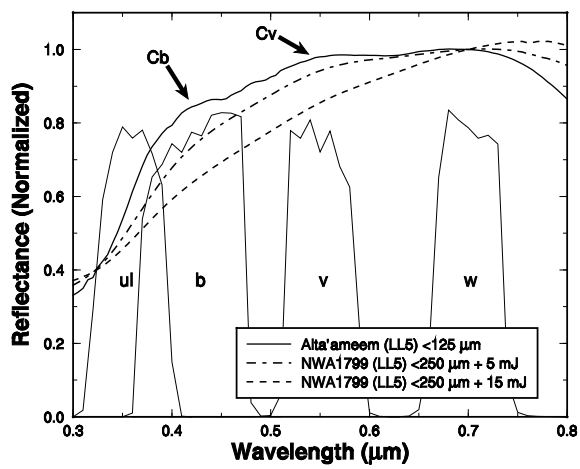

Fig. 1. Extended-visible reflectance spectra of fresh and laser-irradiated LL5 chondrite samples plotted with Hayabusa/AMICA filter transmittance spectra [3].

Multiband spectroscopy using an ECAS-type filters [6] such as Hayabusa/AMICA can adequately measure these amounts of inflections:

$$Cv = \frac{(1 - R_v / R_w)}{\lambda_w - \lambda_v} - \frac{(R_v / R_w - R_b / R_w)}{\lambda_v - \lambda_b} \quad (1)$$

$$Cb = \frac{(1 - R_b / R_v)}{\lambda_v - \lambda_b} - \frac{(R_b / R_v - R_{ul} / R_v)}{\lambda_b - \lambda_{ul}} \quad (2)$$

where R_x and λ_x indicate reflectance and center wavelength for a band x, respectively. Band center wavelengths for the ul, b, v, and w bands are assumed to be 0.36, 0.42, 0.55, and 0.70 μm in this study.

Test Results: Validities of the above quantities as the speace-weathering indices were tested. Shown in Fig. 2 is the correlation between the degree of space weathering and these indices. As shown in Fig. 2a, both Cv and Cb show a good correlation with the amount of irradiated pulse-laser energy for both olivine and NWA1799 LL5 chondrite samples. This is consistent with the fact that LL5 chondrites are rich in olivine. In the case of lunar soils shown in Fig. 2b, a positive correlation between Is/FeO value and Cb index is seen only within each group of samples having similar composition, most likely the Fe content.

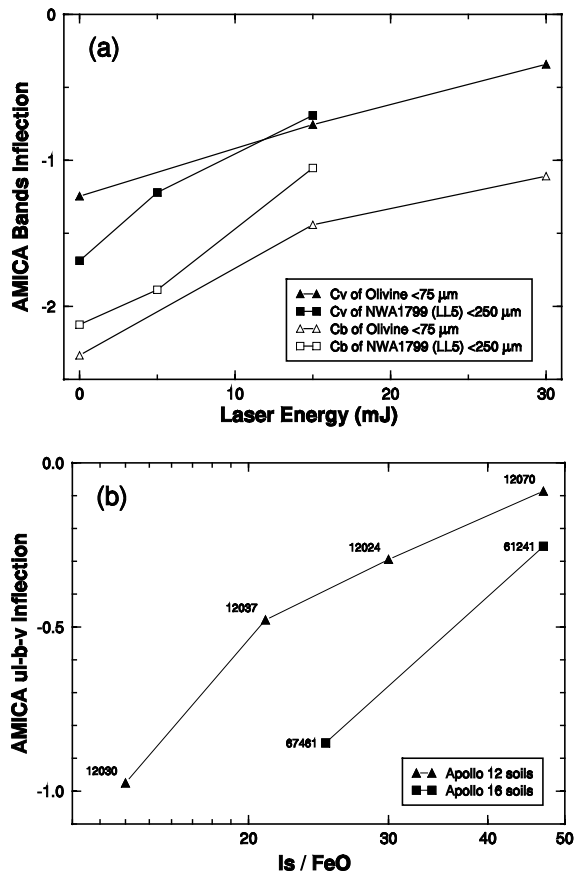

Fig. 2. Correlation between the amounts of ul-b-v-w inflections and the degree of space weathering. (a) Laser energy vs. Cv and Cb for olivine and LL5 chondrite samples, (b) Is/FeO vs. Cb for lunar soils.

Shown in Fig. 3 are the effects of viewing geometry and grain size on Cb and Cv. As shown in Fig. 3a, for this particular LL5 chondrite sample up to 50 degrees of phase angle, Cv and Cb are around –1.0 and –3.4, and the variation is about ±0.2. The effect of incidence angle change shown in Fig. 3b is similar, except that the change in Cb value becomes significant at around 60 degrees of incidence angle. As shown in Fig. 3c, the effect of grain size is as small as ±0.1 for both Cv and Cb, except Cb for the Cherokee Springs sample which shows a variation of ±0.2.

Conclusion: The Cb and/or Cv indices introduced in this study are useful for estimating the degree of space weathering of LL5-6 chondrites and limited sets of lunar soils if incidence angle is less than about 60 degrees and particles are not extremely small.

References: [1] Yamada M. et al. (1999) EPS 51, 1255-1265. [2] Morris R. V. (1980) Proc. LPSC 11th, 1697-1712. [3] Nakamura T. et al. (2001) EPS 53, 1047-1063. [4] Cassidy W. and Hapke B. (1975) Icarus 25, 371-383. [5] Hapke B. (2001) JGR 106, 10037-10073. [6] Zellner B. et al. (1985) Icarus 61, 355-416.

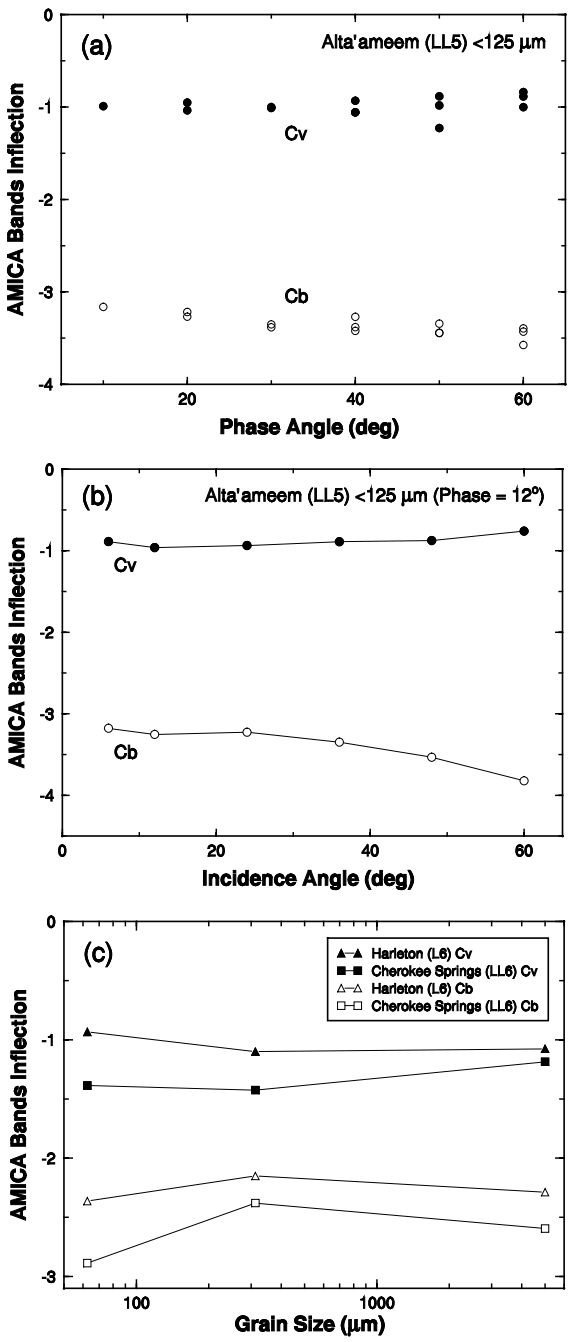

Fig. 3. Effects of viewing geometry and grain size on the amounts of ul-b-v-w inflections Cb and Cv. Effects of (a) phase angle and (b) incidence angle using an LL5 chondrite, and (c) the effect of grain size using L6 and LL6 chondrite chip and power samples.

Acknowledgment: Parts of this research were supported by NASA Discovery Data Analysis Program to T. H. and JAXA Hayabusa Mission. Some meteorite samples were loaned from National Museum of Natural History. We appreciate Dr. Tim McCoy for the assistance. RELAB is a multiuser facility operated under NASA grant NAG5-13609.