CALIBRATION METHOD USING A SOLAR X-RAY MONITOR WITH A STANDARD SAMPLE FOR PLANETARY REMOTE X-RAY SPECTROSCOPY. T. Okada[1], [1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-Ku, Sagamihara, Kanagawa 252-5210 Japan (email: okada@planeta.sci.isas.jaxa.jp).

Planetary remote X-ray fluorescence spectroscopy should provide major elemental composition as precisely as possible, especially adopting an X-ray detector with high energy resolution. But there are some problems happened in the previous missions. Uncertainty of solar X-ray monitoring is a crucial topic on this, and a possible solution is described here by using a standard sample.

Introduction: Remote experiment to map planetary surface composition is a powerful tool to understand the global characteristic of the planet and investigate its origin and evolution. Quantitative major elemental composition (especially Mg, Al, and Si) of lunar and planetary surface is most crucial for surface rock type identification and the key information on investigating evolution process of those bodies. Here an advantage of X-ray spectrometry is described with some lessons learned from the previous missions. Solar X-ray monitoring is among the most essential points for accurate elemental analysis.

X-Ray Spectrometry: X-ray fluorescence spectrometry is the most powerful tool for quantitative elemental mapping around the planetary orbit, especially for the three elements when the solar activity is sufficiently high. The principle of XRF spectrometry is basically the same as that of well established technique in the laboratory but for using the solar X-rays as the excitation source. Solar X-rays excite by photo-absorption the constituent atoms of upper most tens of micron of surface material on the atmosphere-less planets, followed by the transition of electrons from outer shell to the vacant inner shell with emitting the energy. The emission has energy in KeV order and characteristic of element so that it is called characteristic X-rays or fluorescent X-rays. If the input solar X-rays is known and all the response functions are well calibrated, quantitative elemental analysis can be done.

Gamma-ray spectrometry is often used in planetary missions but considered difficult to determine those three elements quantitatively enough as proven in the past missions, due to a low effectiveness of gamma-ray excitation as well as a severe contamination from the backgrounds excited by cosmic-rays irradiating to the spacecraft itself.

XRF Spectrometry in Past Missions: Planetary XRF spectroscopy was proven as a qualitative and maybe quantitative elemental mapping method from orbit during the Apollo 15 and 16 missions. At that time the Apollo instrumentation allowed only qualitative elemental ratios of Mg/Si and Al/Si. The solar X-ray intensity was measured in time series, and some correlations were found with each XRF.

In NEAR-Shoemaker mission to asteroid 433 Eros, the instrument has better energy resolution and well calibrated before launch and not only qualitative but quantitative elemental analysis was targeted. Its solar monitor was well designed and covered wide range of energy from 1 to 10 KeV. Unfortunately the solar X-ray monitor was not well calibrated for oblique input of solar X-rays and caused difficulty to identify rock type or meteoritic type [1]. And this kind of solar X-ray monitor (useful only for normal incidence) is only used for NEAR-Shoemaker type orbiter that orbit the terminator of the asteroid, and unfavorable for lunar orbiter in equatorial orbit.

X-ray fluorescence spectrometry in the SMART-1, Kaguya, Chang'E-1, and Chandrayaan-1 lunar orbiter missions could have completed the global maps of Mg/Si and Al/Si composition ratio of the Moon, but all of them failed due to instrumental troubles and historically deemed solar activity in a century. This is the lost information among the key points to investigate the origin and evolution of the Moon and should be revenged soon.

In SMART-1, Kaguya, and Chang'E-1, quality of data was severely degraded by some kinds of instrumental troubles such as radiation damaged by trapped protons and single events. In Chandrayaan-1 which was in trouble of spacecraft, the C1XS (=Chandrayaan-1 X-ray Spectrometer) observed X-ray spectra off the lunar surface with high quality at limited areas (very small coverage). But the team is suffering from obtaining elemental composition by different results derived from individual methods of analysis.

One of the problems is insufficient concurrent monitoring of solar X-rays. Direct solar X-ray monitor data exists which is observed by the XSM instrument also onboard Chandrayaan-1, but the fundamental problem is that energy detection range is not appropriate for elemental analysis since XSM does not cover the energy range of 1.0-2.0 KeV, so that the most important energy range is not observed.

Solar X-ray numerical model is another point of problem. Use of fundamental parameter method for elemental analysis also causes expansion of uncertainty. In this method, the accuracy of total efficiency of X-ray detection device is needed: thickness of X-ray window, efficiency of detector, and dependency of onboard analysis.

XRF Spectrometry in the Future Missions: One solution is compared elemental analysis by the solar X-ray calibrator with a standard sample method used in Hayabusa [2] and Kaguya/XRS/SOL-C [3]. Hayabusa is a Japanese asteroid explorer for demonstrating technology of sample return from near-earth asteroid. Compared analysis is the most useful and established technique in the laboratory. This method applied in space use is also considered the best way to compensate those problems mentioned above, although the individual detectors must be used for X-ray observation and solar X-ray calibrator at the same time. Both of intensity and spectral profile changes time to time. Especially in the solar flare time, the intensity enhances several orders of magnitude and the spectrum becomes harder. This makes it difficult for direct solar X-ray direct monitor to work in its full performance.

In Kaguya, CCD (charge-coupled device) was used as X-ray detector because of its energy resolution sufficiently good to discriminate each XRF of major elements and of its large detection area. SOL-C of XRS is also a CCD-based solar X-ray monitor with a standard sample plate. It has shown good performance to detect X-ray spectral change in time series as the response of XRF lines off the rocky material excited by solar X-rays that was normal to almost ±80° incident angles. This instrument could have shown the future standard instrumentation for XRF spectrometry: CCD-like detector with a large area and good energy resolution for X-ray observation off the planetary surface and off the standard sample.

Concluding Remarks: As was shown above, Hayabusa type or Kaguya SOL-C type solar X-ray monitor with a standard sample plate is considered favorable in future planetary remote XRF spectrometry. In this method, solar X-ray monitor is based on the same detector, electronics, and analytical method is applicable. In addition the solar X-ray monitor has a wide field of view so that a single detector can observe the Sun all the time. It is useful to constitute a compact system for a planetary mission.

References:

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[3] Shirai, K., et al. Earth Planet Space **60**, 277-281, 2008.

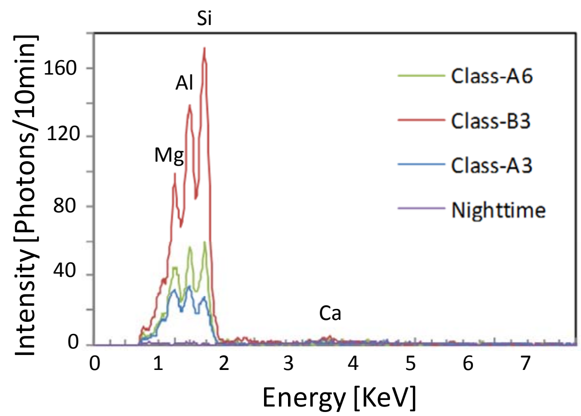

Figure 1. X-ray spectra by Kaguya SOL-C off the standard sample during three different levels of flare times and also a night time spectrum as backgrounds are shown.

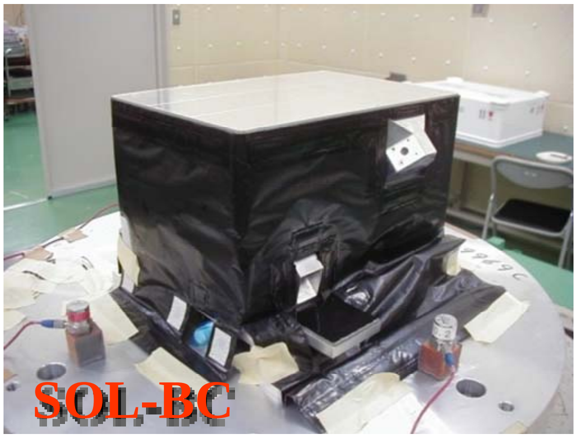

Figure 2. Kaguya SOL-BC component on the mechanical test. SOL-C is part of this component with a standard sample and the entrance of XRF off the standard sample by CCD, which are shown at the center of this photograph.