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# Observation of Elemental Compositions on the Moon by the Kaguya Gamma-Ray Spectrometer

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## Abstract

The elemental compositions of the lunar surface were obtained by the Gamma-Ray Spectrometer on board Kaguya, a Japanese lunar orbiter launched in 2007. The spectrometer employed a Ge detector for the first time in lunar explorations and provided first global measurement of lunar uranium. The detected elements include radioactive elements K, Th, and U as well as major elements O, Mg, Si, Ca, Ti, and Fe. The absolute abundances of K, Th, and U have been determined with global maps. The results show that the observation was consistent in general with those of previous missions and lunar materials, while some important differences have been found.

## 1. Observation

The SELENE mission is the initial mission in the Japanese lunar exploration program with a main orbiter Kaguya and two daughter satellites, launched in 2007 [1]. Among 14 scientific instruments of the mission, the Gamma-Ray Spectrometer (GRS) aboard Kaguya observed the lunar surface with a high precision, actively cooled Ge detector surrounded by a BGO anti-coincidence detector [2]. Its observation can be divided into several periods coupled with various parameters and operations of the orbiter, as summarized in Table 1.

### 1.1 Regular measurement

With the three-axis attitude control of the spacecraft, the Kaguya GRS was nadir pointing during regular observation. The Kaguya GRS had three regular observation periods characterized by varied high voltages (HV) applied to the Ge crystal and altitude. The observation started in December 2007 with a HV of 3.1 kV at the average altitude of ~100 km (Period 1). After resolving electronic problems, the GRS resumed observation in July 2008 with a HV of 2.5 kV (Period 2). After the successful annealing of the Ge crystal and descent of Kaguya to 30 - 50 km in altitude, the GRS observed the lunar surface with improved energy and spatial resolutions (Period 3). The average energy and spatial resolutions of the potassium line at 1.461 MeV for each period together with effective observation time are shown in Table 1.

### 1.2 Background measurement

In planetary gamma-ray spectroscopy it is important to measure background gamma rays emitted by the detectors and the satellite themselves. Two special operations of the orbiter, separately in July and December 2008, were conducted so that the GRS faced deep space to measure background gamma rays while the satellite body and the BGO detector reduced lunar gamma rays. Such observations were only possible in space due to the presence of galactic

Table 1: Summary of KGRS Observation. See text for detailed definitions.

| Data Set | Date in UT | Effective Duration | HV | Energy Resolution | Nominal Altitude | Spatial Resolution |
|---|---|---|---|---|---|---|
| Period 1 | 14 Dec. 2007 – 17 Feb. 2008 | 32.8 days | 3.1 kV | 0.6% | 100 km | 130 km |
| Period 2 | 07 Jul. 2008 – 11 Dec. 2008 | 78.6 days | 2.5 kV | 1% | 100 km | 130 km |
| Period 3 | 10 Feb. 2009 – 28 May 2009 | 69.5 days | 2.5 kV | 0.5% | 50 km | 67 km |
| Background | 4 Jul. 2008, 11–12 Dec. 2008 | 10.3 hours | 2.5 kV | 1% | 100 km | – |
| Anneal | 16–25 Dec. 2008 | 48 hours | | | | |

cosmic rays (GCR). Intensities of background gamma rays were estimated based on such measurements and were subtracted from regular measurements.

### 1.3 Anneal

The high-energy GCR particles in space damage the lattice structure of the Ge crystal, degrading the energy resolution gradually [3]. To regain the superior resolution and therefore sensitivity, we have annealed the Ge crystal at 80 °C for 48 hours in December 2008, which drastically removed the radiation damage observed in spectra.

## 2. Results

After data selection and correction for deadtime and altitude variation of the craft, energy spectra were accumulated to analyze intensities of line gamma rays corresponding to the abundance of a source element on the Moon. Line gamma rays are emitted by either spontaneous decay of K, Th, and U or through nuclear interaction of major and minor elements on the lunar surface [4].

### 2.1 K, Th, and U

The radioactive elements K, Th, and U have been globally mapped and reported elsewhere using early data (Period 1 and 2) with high altitude (e.g. [5, 6]). The absolute abundances of these elements were derived by calculating gamma-ray emission rates and the detection efficiency. Especially, the distribution of lunar U was revealed for the first time by the Kaguya GRS [6]. Figure 1 shows new distribution map of Th using 2.615 MeV peak in Period 3 (low altitude) data. It is confirmed that their global distribution was generally consistent with previous observation with notable differences in highland and mare regions (e.g. [5-7] in detail though.

### 2.2 Major elements

We have uniquely identified gamma-ray lines from O, Al, Si, Mg, Ca, Ti, and Fe in our spectra, and these elements are being mapped (e.g. [8, 9]). Because of their emission processes, neutrons and/or GCR corrections are necessary to derive absolute abundances.

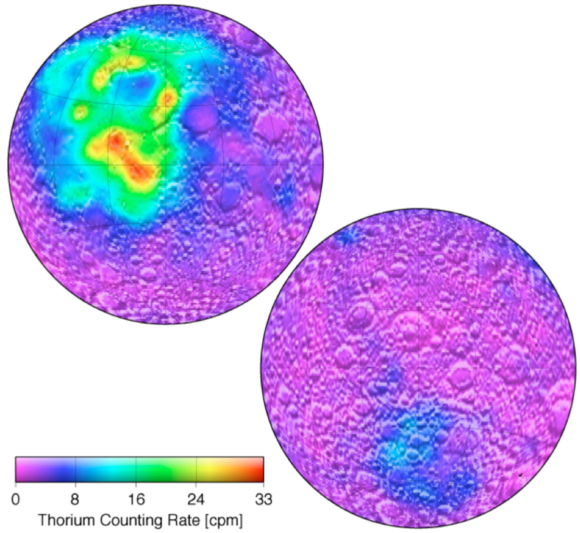


Figure 1: New distribution map of Th on the Moon observed by Kaguya GRS. The higher concentrations of Th are in the Procellarum region (top) and in the South Pole/Aitken (farside) region (bottom).

## References

[1] Kato, M., et al.: The Japanese lunar mission SELENE: Science goals and present status, Adv. Space Res., 42, 294-300, 2008.

[2] Hasebe, N., et al.: Gamma-Ray Spectrometer (GRS) for lunar polar orbiter SELENE, Earth Planets Space, 60, 299-312, 2008.

[3] Brückner, J., et al.: Proton-Induced Radiation Damage in Germanium Detectors, IEEE Trans. Nucl. Sci., 38, 209-217, 1991.

[4] Reedy, R. C.: Planetary gamma-ray spectroscopy, Proc. Lunar Planet. Sci. Conf., 9, 2961-2984, 1978.

[5] Kobayashi, S., et al.: Determining the absolute abundances of natural radioactive elements on the lunar surface by the Kaguya Gamma-Ray Spectrometer, Space Sci. Rev., in press, 2010.

[6] Yamashita, N., et al.: Uranium on the Moon: Global distribution and U/Th ratio, Geophys. Res. Lett., 37, L10201, 2010.

[7] Forni, O., et al.: Large Scale Potassium-Thorium Fractionation Around Imbrium, Lunar Planet. Sci. Conf., 41, 1944, 2010.

[8] Gasnault, O., et al.: Preliminary Analysis of SELENE GRS Data - The Iron Case, Lunar Planet. Sci. Conf., 40, 2253, 2009.

[9] Diez, B.: Determination of planetary surfaces elemental composition by gamma and neutron spectroscopy, Ph.D. thesis, Univ. de Toulouse, Toulouse, France, 2009.