High Energy Gamma Rays From the Lunar Surface Observed by GRS onboard SELENE.

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Introduction

The lunar gamma rays are originated from cosmic rays (CRs) interacting with the lunar materials via various processes. γ-ray lines are emitted by the decay of naturally radioactive nuclei and from the de-excitation of nuclei made by neutron reactions. While, γ-ray continua are produced from Compton scattering of photons such as line γ-rays cosmic γ-rays, electron bremsstrahlung initiated from π^0 decay and minor components [1]. In particular, lunar γ-rays beyond the energy of 8 MeV may be almost purely originated from π^0 decay via electron bremsstrahlung with electron piar creation [2, 3]. Since the intensity of π^0 are influenced by CR intensity and lunar material, that of γ-rays with 8 MeV and more will be also influenced by those.

A γ ray spectrometer onboard SELENE (hereafter SELENE/GRS) has been observing γ rays with energy range of 200 keV $\sim$ 13 MeV from the Moon at altitude of about 100 km since December 2007 [4]. This report presents global distribution of high energy γ rays in 8 $\sim$ 13 MeV and discuss about area dependencies.

Observed Results

Fig.1 shows daily profile of observed γ-rays with energy range of 8 $\sim$ 10 MeV and 10 $\sim$ 13 MeV together with that of neutrons obtained by neutron monitor (NM) at Thule station near the magnetic north pole of the earth [5]. Though the intensity variation of CRs as indicated by NM data are rather static during this observation period, variations of the high energy lunar γ-rays seems to be depend on CR intensity. However, since those variations are only a few % through the observation period, we consider as being stable for the intensity of γ-rays.

A distribution map of counting rate of the high energy γ-rays is presented in Fig.2. No corrections such as altitude or detector response were applied to these counting rates. This figure shows that the counting rate in mare is basically higher than that in highlands. Especially, the Mare Insularum and the Mare Imbrium has the highest

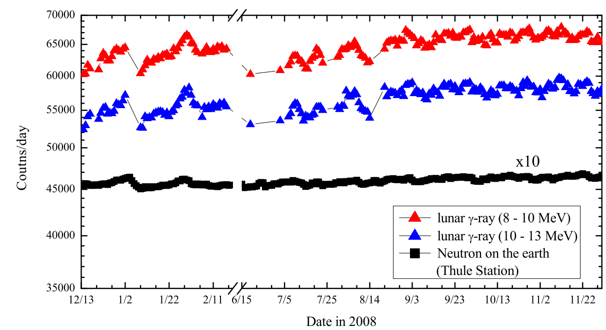

Figure 1: Daily variation of the lunar γ-rays and the earth's neutron produced by galactic cosmic rays. Counts of neutrons were multiplied by 10.

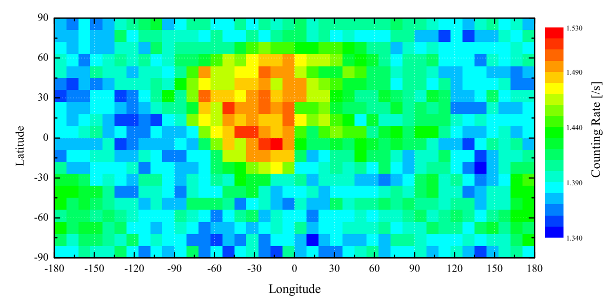

Figure 2: Global map of counting rate of γ-rays in the energy range between 8 and 13 MeV. A pixel size is square of 9 degrees for longitude and latitude.

counting rate.

Discussion

The γ-rays with the energy of 8 MeV and more are considered to be initiated from π^0 decay. However, these γ-rays are not almost γ-rays decayed directly from π^0, since production rate of π^0 decayed γ-rays with 13 MeV or less is very small. As pointed out by the reference [2],

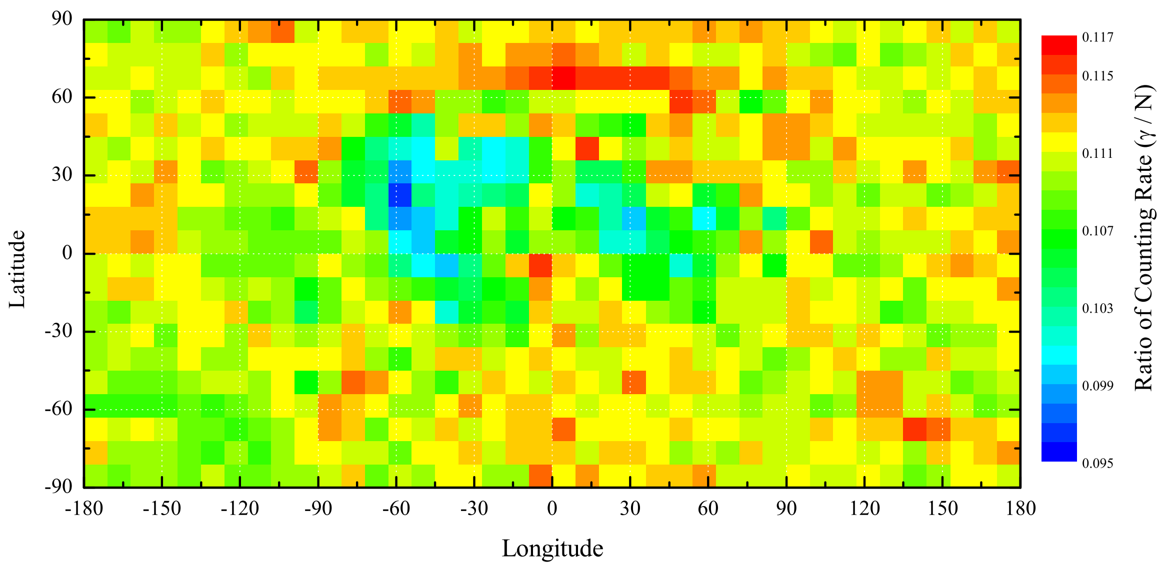

Figure 3: Global ratio map of counting rate of γ-rays in the energy range between 8 and 13 MeV over fast neutrons observed by LP/NS[7]. A pixel size is square of 9 degrees for longitude and latitude.

these γ-rays may be generated via many bremsstrahlung of electrons that are created by pair creation from decayed γ-rays of π^0 so called electromagnetic cascade shower. In general, when an average atomic mass of target is large, a production cross section of π^0 is also large and, moreover, electrons and γ-rays are more produced because of small critical energy of cascade shower development. Therefore, the distribution map of the lunar high energy γ-rays as shown in Fig.2 may indicate average mass distribution on the lunar surface.

As presented by the reference [6], fast neutrons also relate to average atomic mass of target material. A distribution map of ratio of the high energy γ-rays observed by SELENE/GRS over fast neutrons observed by neutron spectrometer onboard Lunar Prospector [7] is shown in Fig.3. The mode of ratio is about $0.111 \sim 0.112$ and the ratio of about 70 % area of all have constantly this value within $\pm$ 5 %. On the other hand, the area having lower ratio concentrate to mare regions, in particular for the Oceanus Procellarum and the Mare Tranquillitatis and the Mare Imbrium, which area corresponds to high iron and titanium concentration area [8]. Although the high energy γ-rays have also higher counting rate in these area, the case of fast neutrons is more enhanced. This difference may be caused the deference of production process between fast neutrons which peak around 1 MeV and high energy γ rays.

Summary

This report present the distribution map of γ-rays in the energy region of 8 $\sim$ 13 MeV observed by SELENE/GRS. This distribution seems to devide regions between mare and highland without any elemetal imfomation. This distribution is almost consistent with the distribution of fast neutrons except for the region of high iron and titanium concentration [8]. These result indicates to derive average atomic mass distribution from high energy γ ray distribution on the Moon, though more detailed discussions are necessary.

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