BACKGROUND PEAKS IN THE KAGUYA GAMMA-RAY SPECTRA. N. Yamashita[1], R. C. Reedy[2], S. Kobayashi[3], M. Hareyama[3], M. Kobayashi[4], N. Hasebe[5], Y. Karouji[5], C. d'Uston[1], O. Gasnault[1], O. Forni[1], K. J. Kim[6], and the Kaguya Gamma Ray Spectrometer team, [1]Institut de Recherche en Astrophysique et Planétologie, Université de Toulouse, CNRS, Toulouse, France, [2]Planetary Science Institute, 152 Monte Rey Dr., Los Alamos NM 87544 USA <reedy@psi.edu>, [3]Japan Aerospace Exploration Agency, Kanagawa, Japan, [4]Planetary Exploration Research Center, Chiba Inst. of Tech., Chiba, Japan, [5]Research Institute for Sci. and Eng., Waseda Univ., Tokyo, Japan, [6]Korea Institute of Geoscience & Mineral Resources (KIGAM), Daejeon, Korea.

Introduction: About 200 peaks have been identified in the spectra from the germanium (Ge) detector of the Kaguya (SELENE) Gamma-Ray Spectrometer (KGRS) [1]. The sources of about 85% of these peaks have been identified. Some of these peaks have been or will be used to map the abundances of several elements over the Moon's surface [e.g., 2,3].

For Mars Odyssey, over 300 peaks have been observed. More than 90% of these peaks have had their sources well determined [4], and many of the other peaks have tentative identifications. That compilation was a big help in determining which peaks not to use for elemental studies, especially for elements without a strong gamma ray. For example, of 20 fairly-weak peaks for Cl, many were rejected because they had backgrounds that could not be quantitatively removed from the peak for the gamma ray of interest [4].

In [1], many background peaks from the Ge detector and the Al structure of the KGRS were discussed. Since the analyses reported in [1], more work has been down on studies of the sources of previously unidentified peaks and of some backgrounds. Analyses were done on the gamma-ray spectra measured while the KGRS was pointed away from the Moon in Dec. 2008, in which most gamma rays from the Moon were attenuated by the mass of the spacecraft and the KGRS [5]. Backgrounds for U, Th, and Ca peaks were studied. Some recently identified peaks from the bismuth germanate (BGO) around the main Ge detector are discussed here. Knowing the sources of as many peaks as possible is necessary to avoid using a peak with major background contributions or without background corrections for elemental mapping.

Background Spectrum: The Kaguya spacecraft was in inertia mode for a day in 11-12 Dec. 2008, such that about 40% of the time most of the spacecraft and the KGRS structure were between the Moon and the KGRS Ge detector. Only 10 hours of background were accumulated, but that background spectrum is very useful for establishing or estimating the intensity of background gamma rays [5]. Fig. 1 shows that spectrum and a lunar spectrum from about the same time. Fig. 2 shows the fits to the peaks for U at 1764 keV, Si at 1779 keV, and ^{26}Mg (from Al) at 1809 keV for the lunar and background spectra.

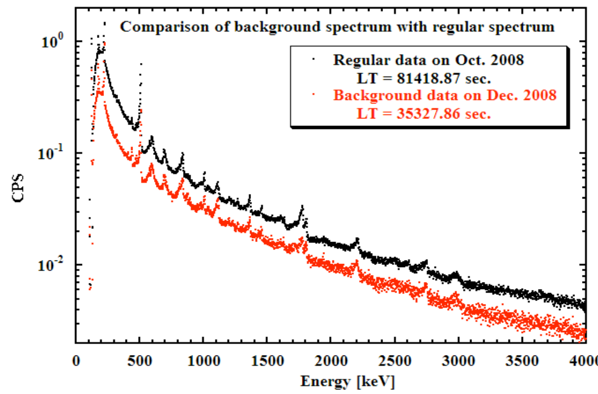

Fig. 1. Kaguya regular (black) and background (looking away from the Moon, red) gamma-ray spectra.

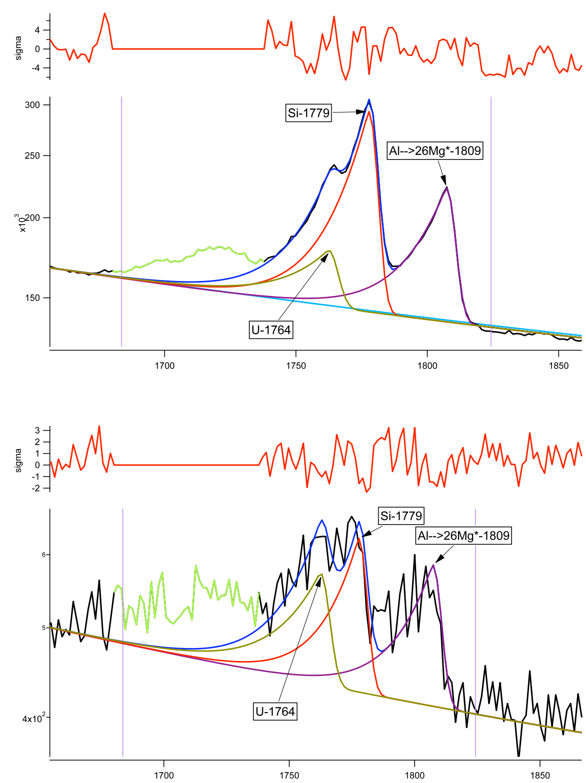

Fig. 2. Fits to peaks from 1740 to 1820 keV for a regular (top) spectrum and the background (bottom) spectrum. Green counts were ignored in the fits. The red curves show the uncertainties of the fits.

The fits to the background spectrum (bottom of Fig. 2) show that there are not many counts and that the errors for the counts are fairly large (about ±5% for Si and Al-^{26}Mg* and ±10% for U). That makes it hard to get good background corrections.

The background count rates for prompt gamma rays made in the Al structure of the KGRS [1] are about half that in the regular spectrum, thus the fluxes of fast neutrons at the KGRS during background were reduced. The background count rate for the gamma ray at 1779 keV from excited ^{28}Si was only ≈30% of the lunar rate. Some of those 1779 keV gamma rays probably are from the decay of ^{28}Al in local structural Al, a source that could also affect analyses of lunar Si using its 1779 keV inelastic-scattering gamma ray.

The ratios of background to regular counting rates for the gamma rays used to map the naturally-radioactive elements are ~35% for both Th-2615 keV and ^{40}K-1461 keV and ~70% for U-1764 keV. Thus these backgrounds for radioactive elements are important for the lunar highland and farside regions with low levels of natural radioactivity. The backgrounds for neutron-capture gamma rays from Fe and Si have large uncertainties but are low. There are probably some capture gamma rays from Ti in the spacecraft.

The U Gamma Rays at 609 and 352 keV: Uranium has its strongest gamma rays at 609 and 352 keV. However, as noted in [3], the 609 keV peak is hard to fit well. The peak is on a big sawtooth (a peak having a long tail at higher energies) peak from ^{74}Ge at 596 keV plus a capture gamma ray from ^{73}Ge at 596 keV. There also appears to be another peak near about 600 keV that could be from the BGO anti-coincidence shield around the Ge detector (possibly excited ^{208}Bi).

The 352 keV U gamma ray is very close in energy to a ^{56}Fe(n,γ) gamma ray. That peak is also part of a complex of lower-energy weak peaks that makes it hard to estimate the continuum under that peak.

Thus, the U gamma ray at 1765 keV was used to map U in [3].

Thorium Gamma Rays: In addition to the 2615 keV from the Th decay chain, other strong Th gamma rays are at 238.6, 583.2, and 911.2 keV. The 239 keV peak is near the 241.0 Th peak that is ~0.1 times as intense and a weak U peak at 242.0 keV. The 583 keV peak is near the 584.5 peak from ^{69}Ge+K [6] and 585.0 peak from ^{25}Mg* (made in Al), so it has major backgrounds. The 911 keV peak does not have interferences, although there are weak peaks (probably from the BGO) near 905 keV. The 239 and 911 keV peaks could be used for Th abundance studies.

Calcium Gamma Rays: The gamma rays from Ca made by both fast and thermal neutrons were studied. The Ca neutron-capture gamma ray at 6420 keV is only 2 keV above a strong gamma ray from Ti, and thus is not a good gamma ray for mapping Ca.

The Ca inelastic-scattering gamma ray at 3737 keV is only 3 keV above a fairly-weak neutron-capture peak from Ti and can't be well resolved in KGRS spectra. There are not enough counts in the background spectrum to fit this energy region. Other Ti capture gamma rays could be used to estimate its intensity, which is ~2-10% of the total counts in this Ca peak.

There is a capture peak from Ge at 1940 keV that could interfere with the use of the Ca capture at 1942 keV. The count rate for the 1942 keV peak in the background is ~0.6 of that for the whole Moon. Much of that background rate could be from the Ge gamma ray. Studies of that Ge gamma ray in other space GRS systems indicate that the Ge gamma ray probably contributes ~10% of the observed signal at 1942 keV in the KGRS lunar gamma-ray spectra.

Peaks from the BGO Anti-Coincidence Detector: Backgrounds from the Bi, Ge, and O in the about 9 kg of bismuth germanate (BGO) around the Ge detector have been [6] or are being [7] studied. The compilation reported in [6] helped to show that 6 peaks in the Ge spectra were from Bi and that another was from the decay of ^{72}Ga made in the BGO. The work in progress [7] is getting better rates for making gamma rays in Bi and could help to identify the sources of more peaks in KGRS spectra. Many peaks from Bi are part of a cascade of several gamma rays, and summing of gamma rays could create peaks that are the sum of 2 or more gamma rays.

Summary: Backgrounds are important for the gamma rays used to map several elements, especially those (like U and Ca) that do not have strong gamma rays. Much work has been and are being done to determine backgrounds in KGRS spectra and to determine any possible sources of backgrounds for peaks used to map elements in the lunar surface.

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