CHANG'E-1 GAMMA-RAY SPECTROMETER AND ITS PRELIMINARY RADIOACTIVE RESULTS. M. H. Zhu[1], J. Chang[2], T. Ma[2], A. A. Xu[1]. [1]Macau University of Science and Technology, Macau(peter_zu@163.com), [2]Purple Mountain Observatory, Nanjing, China(chang@pmo.ac.cn)

Introduction: Radioactive elements, which are enriched in KREEP materials, are thought to be the last crystallized and sank into the layer between lunar crust and mantle. Their presences at the lunar surface were the end products of a series of processes, such as accumulation, collision, and modification. Therefore, the distribution of radioactivity (U+K+Th) on the lunar surface can not only help us to address lunar formation and evolution, but also give more key information about interior structure, and compositions in the crust and mantle. Gamma Ray Spectrometer (GRS), as a payload of Chang'E-1 (CE-1) mission, aimed to provide maps of the abundances of major elements, O, Si, Mg, Al, Ca, Ti, Na, and Fe, and of the natural radioactive elements, K, Th, and U in the subsurface of the entire Moon[1, 2]. Its radioactive results can not only provide important information about above problems, but also regarding Moon's thermal history and thermal migration.

Gamma Ray Spectrometer: CE-1 GRS mounted inside the spacecraft consists of an 11.8 $\times$ 7.8 cm CsI crystal with added thallium as main detector. The main detector is sensitive to gamma rays in the energy region between 300 keV and 9 MeV with the energy resolution of $\sim$ 9% at 662 keV. Surrounding the main crystal is a 17.8 cm diameter by 10.8 cm long, horseshoe-shaped CsI anti-coincidence shield (ACS), used in anti-coincidence with the main crystal to exclude cosmic-ray events and radiation coming from the materials of the spacecraft body. The ACS is viewed by two 3" photomultiplier tubers (PMTs) as well as the main crystal viewed by a 5" PMT. In order to achieve the best energy resolution, tests are made repeatedly to select the best combination of crystal and PMTs because of the sensitivity of temperature causing signal gain of PMT. The results show that the signal gain of PMT are not particularly sensitive to temperature but is sensitive to voltage variations[2]. Therefore, keeping stable high voltage is very important for effective results in the lifetime of such a detector. Seven levels of high voltage were used and could be controlled easily by command. Two types gamma rays spectra are recorded simultaneously: 512-channel gamma-ray spectrum every 3s and 256-channel from ACS each second. The spatial resolution of CE-1 GRS is 160 km at the nominal CE-1 mapping 200 km altitude.

Observation: Overall the mission, CE-1 spacecraft kept a polar-orbital with a period of 127 minutes. The GRS sampled a spectrum in each 3s interval. In-flight gamma ray spectra were calibrated and the results displayed that GRS had a rather good energy range from 100 keV to 9 MeV with an energy resolution of $\sim$ 9.99% at 511 keV. The measured dataset are stored on the spacecraft and downlinked in packets to the Earth (received by both Miyun and Kunming receivers at the same time)when the spacecraft sees the Earth each time. All the received 0 level data were processed to time series data by several primary processes, including telemetry sync, eliminating noisy data, RS-coding, frame analysis, et al. Gamma ray scientific data were obtained from both receivers and selected the better one for that at the same time. 1701 orbital gamma ray spectral data covering from Nov. 27, 2007 to July 25, 2008, containing a total of 2,467,169 separate 3s spectra are collected in CE-1 one-year's mission. Accumulation time distribution in hours on each binned pixel area with 150 km $\times$ 150 km (see Fig.1), presents that accumulation interval is relatively long in high latitude as well as short at lower latitude because of circular, polar orbit. Least accumulation time in binned pixel, about half a hour, is considered as long enough to distinguish elements in the spectrum and sufficiently good to allow preliminary mapping.

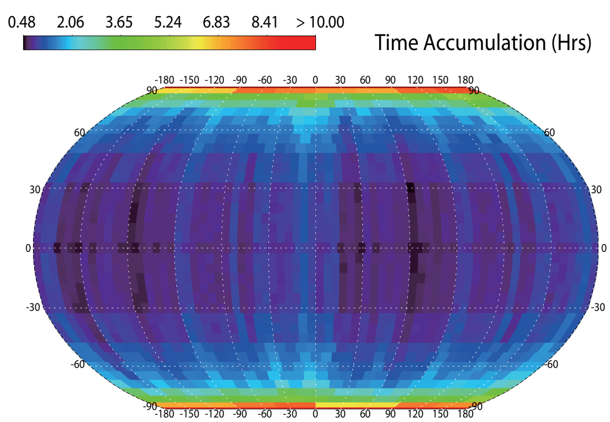

Figure 1: Accumulation time in hours binned in equal area pixels (150 km $\times$ 150 km).

Gamma-Ray Spectrum: A series of corrections were made to the time series data for dead time, gain, galactic cosmic ray, and solid angle variations for scientific analyses. To compare the energy spectrum with that of Lunar Prospector, gamma-ray spectra in the first month were accumulated with an interval of 32s, as shown in Fig.2. From this figure, it can be seen that CE-1 GRS shows an excellent data quality and high energy resolution. Sharper peaks are displayed clearly corresponding to the elements found on the lunar surface.

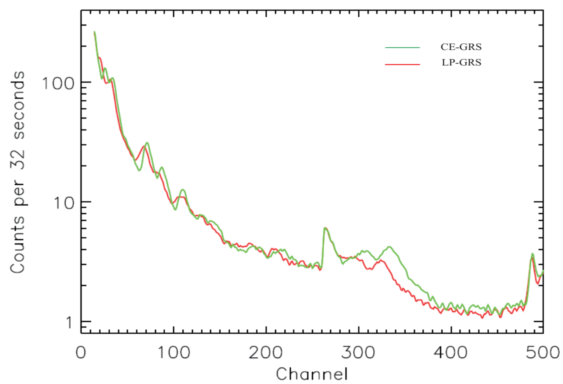

Figure 2: Comparison of gamma ray spectra between CE-1 and Lunar Prospector (LP) for the first month in 32s counts. The peak for LP channels at 260∼280 is under the big CE-1 peak.

Preliminary Results of Radioactive Composition: In the energy region above the positron line at 0.51 MeV (which is attributable to many sources and contains little chemical information), up to and including the highest-energy line due to radioactivity, namely, the 2.64 MeV line due to Th, the regional differences in count rate are overwhelmingly attributable to the varying intensities of the lines of the radioactive elements Th, U, and K. Therefore, any energy band below 2.7 MeV will map natural radioactivity (K+Th+U) on the lunar surface because those gamma rays scatter often in the Moon and make a large continuum that dominates changes below 2.7 MeV. Like Apollo GRS mapped radioactivity with the energy range 0.55 ∼ 2.75 MeV[3, 4], the energy range of 0.60 ∼ 0.70 MeV was selected to describe the radioactive elements on the lunar surface. In this region, the statistical precision of the total count rate is rather excellent and GRS energy resolution is higher than that in other energy range. In addition, any shift of spectrum, if it happened, is rather little compared with that in higher energy range. Except for these, in this region, the flux of Uranium dominates the shape of the spectrum, see Reedy[5]. Therefore, the radioactivity map can describe, indirectly, Uranium distribution on the lunar surface. Radioactive distribution from CE-1 GRS is shown in Fig.3. In this map, 3s-counts are binned into equal-area about 150 km × 150 km firstly. Then counting rates are calculated. The natural radioactivity ranged over more than a factor of 20 and was presented in nine intervals. The enhanced radioactivity is confined to the mare regions with an oval shape on the nearside that corresponding to KREEP Procellarum Terrane (PKT)[6]. Composition in this area has counting rate larger than 155 and no other area has such high concentration. Therefore, this region appears to be a unique feature on the lunar surface. A secondary high radioactivity is concentrated in the South Pole-Aitken basin on the lunar farside, corresponding to the South Pole-Aitken Terrane (SPAT). Most areas in SPA basin have counting rates that lie between 150 and 155, while areas outside SPA region have values less than 150. Highlands, corresponding to the Feldspathic Highlands Terrane, have lower radioactive concentration that is different from both PKT and SPAT. Most part of this region have radioactive counting rate less than 150.

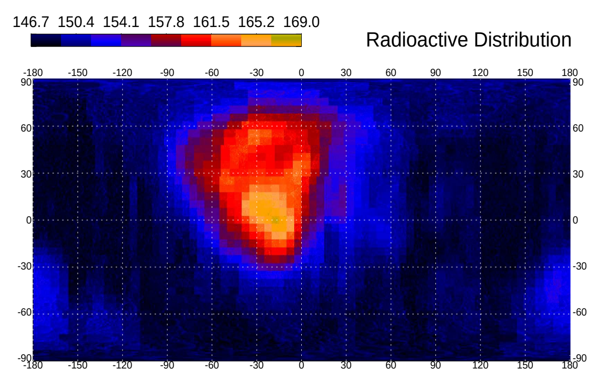

Figure 3: Counting rate of CE-1 GRS dataset with energy range 0.60 ∼ 0.70 MeV.

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References: [1] Zheng, Y.C., et.al, 2008, *Planet Spac. Sci.*, 62:570. [2] Ma, T., et.al, 2008, *Adv. Space Res.*, 42:347. [3] Metzger, A. E et.al, 1977, *PLSC*, 8:949. [4] Metzger, A. E et.al, 1979, *PLSC*, 10:1071. [5] Reedy, R. C., 1978, *PLSC*, 9:2961. [6] Jolliff, B. L., et.al, 2000, *J. Geophys. Res.*, 105:4197.