LARGE SCALE POTASSIUM-THORIUM FRACTIONATION AROUND IMBRIUM.

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Introduction: The lunar surface offers a variety of rock and regolith compositions that result from the complex evolution of the Moon during the first third of its existence [1]. Today's crust is a mixing of feldspathic suites, various basalts (a small part in volume), and some materials enriched in incompatible and rare earth elements (KREEP). The global compositional maps, such as those returned by gamma-ray and X-ray spectrometers or derived from imagery cameras, are useful to study these geologic processes in more details. The SELENE mission is the first to employ a germanium (Ge) detector to observe lunar gamma rays [2]. In particular, the Potassium line at 1461 KeV and the Thorium line at 2650 Kev are well observed. This two elements, though well correlated [3], show some discrepancies. Since Potassium and Thorium are not beared by the same phases, the variation of their ratio puts important constrain on the lunar history. One of the goals for measuring accurately K abundances, is to find where they deviate from Th abundances, which for nonmare regions would indicate the occurrence of materials with non-KREEP-like K/Th.

Observation: The SELENE satellites were launched on Sep. 14, 2007. The main orbiter Kaguya was on a circular polar orbit around the Moon, at 100 km altitude, for more than one year. The GRS data used in this work were obtained from Dec. 14, 2007 to Feb. 17, 2008 (Period 1) and from Jul. 7, 2008 to Oct. 31, 2008 (Period 2) with an effective measurement time of approximately 2100 hours [4]. These two periods differ by the high-voltage applied on the detector, respectively of 3.1 kV and only 2.5 kV for the first and second periods, resulting in a poorer energy resolution for the latter. Finally, from Feb, 11, 2009 to May, 2009, the Moon was observed from an altitude of ~50 km. Two 8192-channel gamma-ray spectra are accumulated every 17 seconds (or 1° over the surface) with resolutions of about 0.4 and 1.5 keV per channel [2]. All individual spectra are adjusted to be on the same energy scale. Preliminary results for several elements from these data have been reported [e.g., 4, 5, 6].

Methodoly: We use the Healpix representation to project the data on the sphere. Healpix [7] is a Hierarchical, Equal Area, and iso-Latitude Pixelisation of the sphere and the final dataset is therefore a "spherical cube" of 3072 spatial elements times 8192 spectral channels. In this analysis we have only used the spectra of the first period because of their better quality.

We first pre-process the data in order to remove the noise as much as possible. This denoising stage is applied in three steps. The first one is to apply an Ambscombe transform to the data since they are dominated by Poisson noise. The second one consists in performing an isotropic undecimated wavelet transform on the sphere for each energy channel. This has been done using the MRS package [8]. We estimate the noise at each wavelet scale and retain all significant wavelet to reconstruct the denoised energy channel. The third step consists in denoising in the spectral direction, with the same algorithm.

Then we have applied an Indepenent Component Analysis (ICA) method on the filtered data. ICA, like PCA, tries to transform the original representative space by searching for directions in a new space, so that the resulting vectors are independent, and not only uncorrelated like with PCA [9]. As in [10] we have used the JADE algorithm [11], which is an orthogonal ICA method and, like most mainstream ICA techniques, it exploits higher order statistics related to the fourth order cross cumulants to maximise the non-gaussianity of the sources.

Results: Using this procedure, an Iron component has been already identified as well as a radioactive element component [4, 12]. But with this refined signal processing treatment, it appears that the former radioactive element component is splitted into two new components, the first one bears the lines of Uranium and Thorium, and the second one bears only the line of Potassium. This means that Potassium on one side and Thorium and Uranium on the other side are spectrally independent, statistically speaking (Fig 1). The maps of Potassium (Fig. 2) and Thorium (Fig. 3) are obtained by fitting the Potassium line at 1461 KeV and the Thorium line at 2615 KeV in the smoothed dataset. The value of the integral may not exactly reflect the concentration of the elements since we know that a background is present especially for the Potassiun [13]. A preliminary estimation of this background has been estimated and substracted to the fit values.

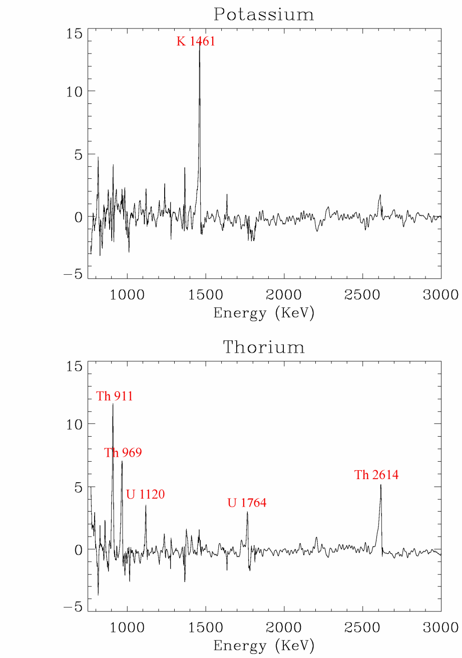

Figure 1. Plot of the spectrum of the ICA Potassium component showing the charistic line of Potassium at 1461 KeV (Upper panel); Plot of the ICA Thorium component showing the lines of Thorium and Uranium, note the absence of the Potassium line (Lower Panel)

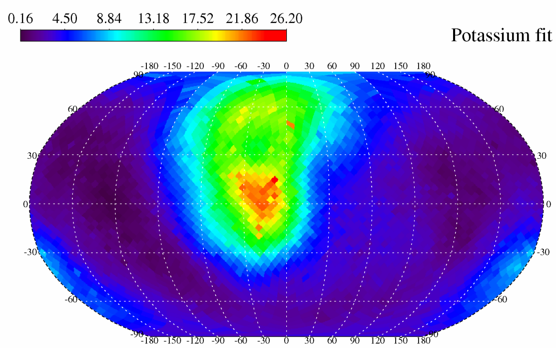

Figure 2: Fit of the 1461 KeV Potassium line. A preliminary background has been removed.

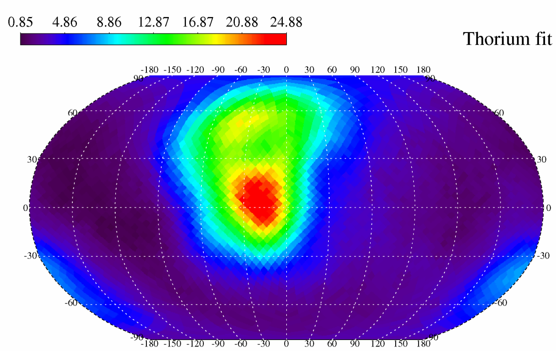

Figure 3. Fit of the 2615 KeV Thorium line

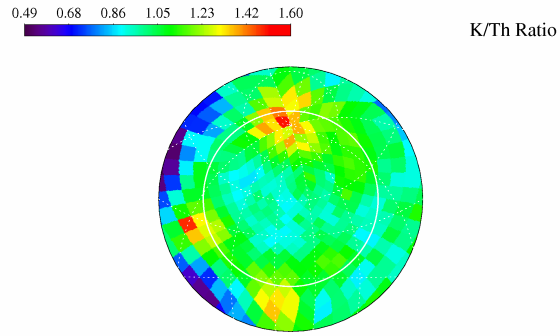

Figure 4: Map of the Potassium-Thorium ratio. Stereographic projection centered at the center of the Imbrium basin. The white circle as an aperture of 65°

Figure 4 shows the map of the Potassium/Thorium ratio, centered on Imbrium basin. We observed an enhancement of the K/Th ratio especially at the north Pole, in the south of Nubium, and in Humorum. Moreover, this enhancement seems to follow a circle around Imbrium at the PKT limit with a moderate Thorium content. Possible explanations to that behaviour could be (i) the excavation by the Imbrium impact [14] of rocks resulting form liquids preferentially enriched in K or depleted In Th, (ii) the trace of pre-existing high K/Th ratio materials that were not totally obscured by Imbrium ejectas [15], (iii) ejectas that have undergo a partitioning during the impact.

Conclusion: Although K and Th are highly correlated, globally at the surface of the Moon and in the lunar samples, we found large scale areas where K and Th behave differently. High K/Th ratio seem to be distributed concentrically with respect to the Imbrium impact. More detailed analysis are underway and especially correlation with other elements like Ti or Fe.

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