

Inversion of Elemental Abundances from the Data of the First Detection by Active Particle-induced X-ray Spectrometer on Chang'E-3 YuTu Rover

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Introduction: Chang'E-3, Chinese third lunar mission landed on the Moon on December 14th, 2013 (UTC). The landing site was located at the north of Mare Imbrium (N44.12°, W19.51°) (Figure 1). Eight hours after the landing, Chinese first lunar rover YuTu was released from Chang'E-3. An Active Particle-induced X-ray Spectrometer (APXS) onboard the rover was designed to detect the elemental abundances on lunar surface. Few days after landing, APXS began to work and transmit the data to the Earth.

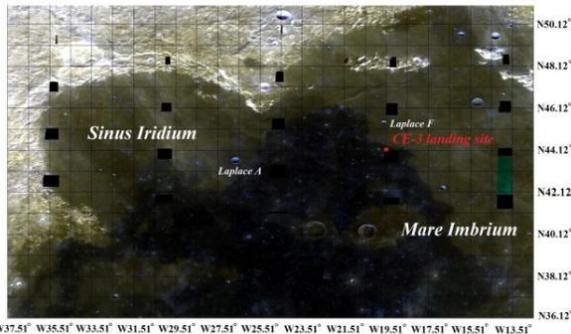


Figure 1 CHANG'E-3 landing site: Clementine UV/VIS Multispectral Mosaic image[1][2]

APXS: APXS was composed of a sensor head, a radioactive heat unit (RHU) and an in-flight calibration target (Figure 2).



Figure 2 APXS components: sensor head, RHU and in-flight calibration target (from left to right)[2]

The sensor head (~752g, 1.2Watts) was comprised of an Silicon Drift Detector (SDD, 7mm² effective area) and eight excitation sources. The RHU (~390g) was em-

ployed to provide heat source (~4 watts) to help the sensor head pass the cold lunar nighttime. The in-flight calibration target, actually a basalt rock sheet (Φ20mm×5mm) fixed in a aluminum frame with copper coating was used to check the inflight performances of APXS before each detection. The eight excitation sources consisted of ⁵⁵Fe (×4, ~70mCi per each) and ¹⁰⁹Cd (×4, ~2.5mCi per each) [2].

Before the launching, all the essential environmental tests and ground calibration experiments for APXS have been accomplished. The calibrated energy range of APXS is 0.4~22keV, and the energy resolution is about 135~142eV@5.9 keV (at 20°C) [2].

Data: On December 22th, 2013 (UTC), APXS accomplished the first calibration of the inflight basalt target in 416 seconds. The spectrum (in Figure 3) shows the stable and excellent performance of APXS on the lunar surface.

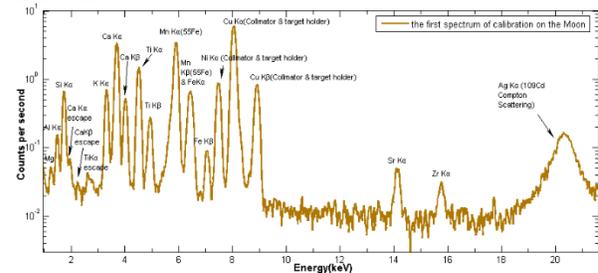


Figure 3 The first spectrum of calibration on the Moon

The first spectrum of sampling point on lunar surface was obtained after 2656 seconds detection on December 24th, 2013 (UTC) when APXS was deployed to about 5cm above the lunar surface and initiated detection mode around the landing site (Figure 4).

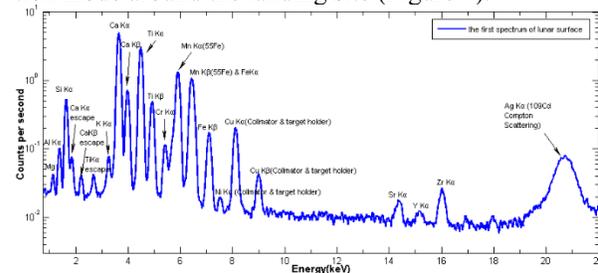


Figure 4 The first spectrum of lunar surface

In the spectrum, eight rock-forming elements (Mg, Al, Si, K, Ca, Ti, Cr and Fe) and three trace elements

(Sr, Y and Zr) of lunar surface could be identified. X-ray fluorescence intensities of the elements could be obtained by fitting the spectra (Table 1).

Table 1 X-ray fluorescence intensities of elements with 2σ errors

Mg K α	Al K α	Si K α	K K α	Ca K α	Ti K α	Fe K β
0.177	0.819	5.12	0.578	60.304	39.172	2.447
± 0.032	± 0.033	± 0.034	± 0.105	± 0.139	± 0.177	± 0.050

Method: For a given incident spectrum of X-ray, the intensities of X-ray fluorescence generated from any known sample can be calculated by formulas [3, 4]. However, calculating elemental abundances with given intensities of elemental X-ray fluorescence is very difficult because of complexity of the formulas. As the fundamental physical parameters and the geometry are known, the fundamental parameter algorithm is employed to gain the elemental abundances from X-ray fluorescence intensities. The approach is widely implemented in laboratory experiments and yields accurate results.

A set of calculated elemental X-ray fluorescence intensities fractions (ratio of X-ray fluorescence intensity for an element to total intensities of X-ray fluorescence, R^c) are obtained by calculating a set of elemental abundances. Then R^c are compared with observed elemental X-ray fluorescence intensities fractions (R^m). If the difference of any elemental R^c and its R^m is more than 1ppm, that set of elemental abundances will be modified according to $\frac{R^m}{R^c}$ and the R^c will be calculated again. By iterative computation, the best set of elemental abundances are derived, the one of which every elemental R^c almost equal every elemental R^m (the difference is smaller than 1ppm).

Result and Discussion: The elemental abundances (%) derived from the first spectrum of lunar surface with 2σ errors are listed in Table 2.

Table 2 The elemental abundances (%) derived from the first spectrum of lunar surface with 2σ errors

Mg	Al	Si	K	Ca	Ti	Fe
4.304	9.024	20.457	0.0720	5.613	1.772	16.442
± 0.017	± 0.018	± 0.020	± 0.022	± 0.017	± 0.018	± 0.033

APXS accomplished other two detections 328 seconds after the first. The spectra of the later two detections were accumulated for 2768 and 2032 seconds respectively. The horizontal distances between the first and second sampling point and between the second and third sampling point are about 10cm. The heights of later detections are about 2~3cm above the lunar surface and much lower than that of the first detection. In that case,

the elemental abundances inversed from the two spectra of later detections may be more accurate. The work of processing the later two detections is underway and the results will be obtained soon.

Laboratory experiment used Apollo 16 Clam Shell Sampling Devices (CSSDs) to analyze soil from the top 100 μ m and 500 μ m of the soil. It suggested that ultrafine (<2 μ m) particles dominate the uppermost lunar surface [5]. There is a layer of lunar dust above the soil. In that case, the X-ray spectra of lunar surface gained by APXS were generated by the ultrafine particles, so the particle size has almost no effect on the result.

References: [1] Eliason, E., C. Isbell, E. Lee, T. Beck-er, L. Gaddis, A. McEwen, M. Robinson, Mission to the Moon: The Clementine UVVIS Global Lunar Mosaic, PDS Volumes USA NASA PDS CL 4001 through 4078, produced by the U.S. Geological Survey and distributed on CD media by the Planetary Data System, 1999. [2] W. X. Peng. et al. (2014) *LPSC XXXV*, Abstract # 1699. [3] Sherman J. (1955) *Spectrochim. Acta.* **7**, 283–306. [4] Shirawai T. and Fujino N. (1966) *Appl. Phys.* **5**, 886–899. [5] Noble S.K. (2010) *LPSC XXXI*, Abstract # 1505.