Active Particle-induced X-ray Spectrometer for CHANG'E-3 YuTu Rover Mission and its first results

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Introduction: CHANG'E-3, Chinese third lunar mission made a successful soft landing on the Moon in 13:11 December 14th, 2013 (UTC). The landing site of CE-3 is in N44.12 °, W19.51 °located at the northern of Mare Imbrium (Figure 1), which is quite close to the boundary of two disparate geological units (dark part and light grey part in Figure 1) making this mission more attractive.

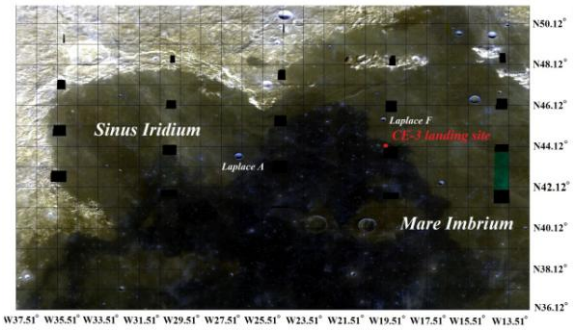

Figure 1 CHANG'E-3 landing site : Clementine UV/VIS Multispectral Mosaic image[1][2]

Eight hours after the landing, a six-wheeled rover named by YuTu was released from the lander. The rover was planned to operate for at least three months, exploring an area of more than three square kilometres on the Moon. Four scientific payloads were carried by the rover, including Panorama Camera (PC), Ground Penetrating Radar (GPR), Infrared Spectrometer (IS) and Active Particle-induced X-ray Spectrometer (APXS) (Figure 2).

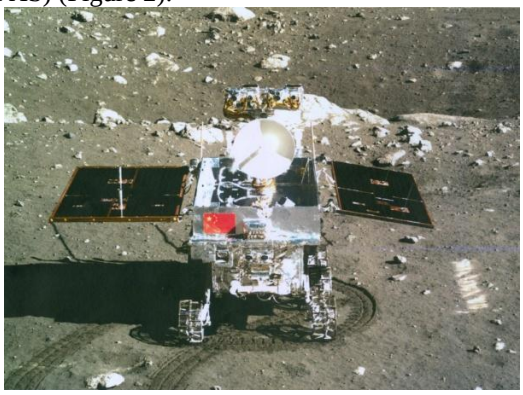

Figure 2 Photograph of YuTu rover on the landing site

APXS design and performance: APXS is the only payload on the robotic arm. Its main objectives is to investigate the elemental compositions along the route of the lunar rover on the Moon. Combing with other payloads of YuTu,the crucial in-situ data for the lunar geochemistry and geology evolution studies will be provided.

APXS consists of a sensor head mounted on the arm, an in-flight calibration target and a radioactive heat unit (RHU) (Figure 3). The sensor head (~752g, 1.2Watts) comprises an Silicon Drift Detector (SDD, 7mm^2 effective area) and eight excitation sources. The RHU (~390g) is employed 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, the elemental concentrations are listed in Table 1) fixed in a aluminum framce with copper coating is used to check the in-flight performances of APXS before each detection.

The working principle of APXS is similar to other similar instruments flied on the Mars missions. Instead of using ^{244}Cm, a combination solution with ^{55}Fe (×4, ~70mCi per each) plus ^{109}Cd (×4, ~2.5mCi per each) ever used in Viking and Beagle-2 mission to Mars were chosen to be the flight sources of APXS.

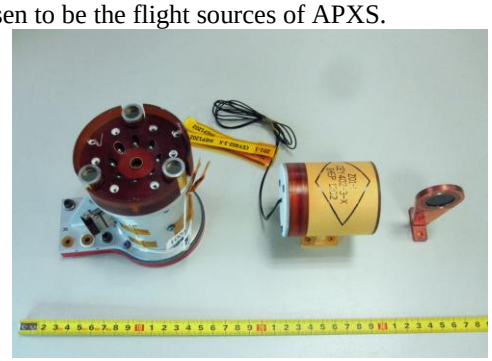

Figure 3 APXS componenets: sensor head, RHU and inflight calibration target (from left to right)

Table 1 Major elemental concentration of calibration target

Elements	**Mg**	**Al**	**Si**	**K**
% (weight)	6.07	7.13	21.56	1.42
Elements	**Ca**	**Ti**	**Fe**	
%(weight)	5.11	1.23	7.77	

The sensor head can be deployed by the robotic arm to get close to the interesting targets like soils or rocks on the Moon. The robotic arm has two sections (upper arm and lower arm) with three joints, i.e. the shoulder pitch joint, shoulder yaw joint and wrist pitch joint. During the arm deployment, APXS also acts as a distance sensor by making use of the X-ray count rates varied with distance. A certain threshold of count rates will be set to control the arm to stop at an appropriate distance related to the target.

Before the launching, all the essential environmental tests (vibration, shock, thermal cycling, thermal vaccum, EMC and lunar dust contaminination tests) and ground calibration experiments (energy response, temperature drift, and geochemistry certificated reference materials tests) 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℃) .

First results: On the lunar surface, APXS started commissioning on December 22th (UTC) and an initial calibration of the in-flight basalt target was done in 400 seconds. This spectrum in Figure 4 showed its stable and excellent performance on the Moon.

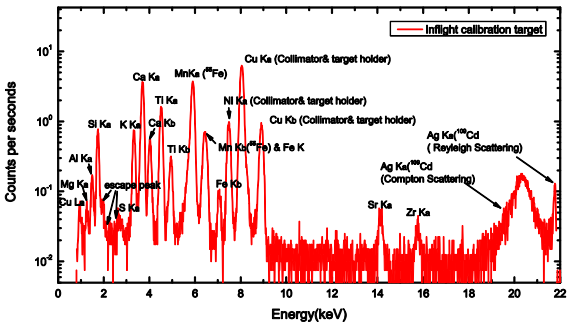

Figure 4 Spectrum of calibration target

On December 24th (UTC), APXS was successfully deployed to about 2~3cm above the lunar regolith surface by the robotic arm of Yutu around the landing site and started the detection mode. The spectra of two sampling points (named by Sol_001 and Sol_002, and the horizontal distance between them is ~10cm) were accumulated for 46 and 33 minutes respectively (Figure 5).

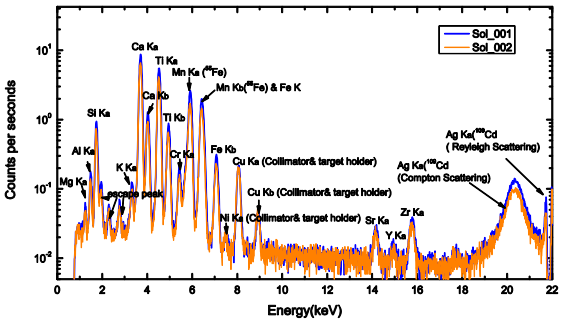

Figure 5 Spectrum of lunar regolith

Obviously, eight major and minor rock-forming elements (Mg, Al, Si, K, Ca, Ti, Cr and Fe) and at least three trace lements (Sr, Y and Zr) of the Moon can be directly identified in the spectra. The energy resolution of APXS is estimated to be 138eV@5.9keV, which is good enough to resolve the K-lines of elements (Z=12~41).

Furthermore, in Table 2, we present the Ka peak area ratio (The Ka peak area of each element was ratioed to Si Ka area) calculated for Mg, Al, K, Ca, Ti and Fe. It's clear that Sol_001 and Sol_002 was expected to be more rich in Ti and Fe than the calibration target, but the concentration of K was much lower. Of cource, this is the initial semi-quantitative analysis, and the detailed quantitative analysis will be finished in the near future.

Table 2 Elemental Ka peak Area ratio to Si

Ka _ratio	Calibration	Sol_001	Sol_002
Mg/Si	5.26E-02	2.83E-02	3.23E-02
Al/Si	2.07E-01	1.55E-01	1.67E-01
K/Si	1.19E+00	1.48E-01	1.50E-01
Ca/Si	5.91E+00	1.15E+01	1.15E+01
Ti/Si	2.76E+00	7.73E+00	7.76E+00
Fe/Si	9.85E-01	2.61E+00	2.56E+00

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References: [1] Eliason, E., C. Isbell, E. Lee, T. Becker, 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.