THE CHARACTERISTICS AND ITS IMPLICATIONS OF IN SITU DETECTION DATA FROM ALPHA PARTICLE X-RAY SPECTROMETER IN CE-3 MISSION. G. L. Zhang[1,2], C. L. Li[1,2], Q. Zhou[1,2], M. J. Yao[1,2],X.H. Fu[1,2], [1]National Astronomical Observatory, Chinese Academy of Sciences, 20A Datun Road, Chaoyang District, Beijing , China, 100012, zhanggl@nao.cas.cn. [2]Key Laboratory of Lunar and Deep Space Exploration, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China.

Introduction: For the lunar and planetary mission, Alpha Particle X-ray spectrometer (APXS) is the important instrument on the rover and lander to analyze the chemical composition of soils and rocks [1]. These kinds of instruments are widely used in Surveyor lunar missions, three generations of Mars rovers (Mars pathfinder, Spirit and Opportunity, Curiosity), and British Beagle-2 lander with the features of small size, low power, and easy sample preparation [2]. APXS sensor head is mounted on the turret of the rover's robotic arm, which makes it easier to detect the interested soils and rocks in the rover path [3]. The Surveyor V mission is the first in-situ chemical analysis of the lunar surface with an alpha-scattering instrument based on Rutherford's alpha-particle scattering theory [2]. The successful experiences of the lunar mission have been applied to explore Mars. Each Viking Lander carried an X-Ray Fluorescence Spectrometer (XRFS) to perform elemental analysis of the Martian regolith. Three generations of Mars rovers carried aboard the science payload APXS using the radioactive source ^{244}Cm [4].

Mission description: The third Chinese lunar mission, CE-3, successfully landed on the Moon on the December 14, 2013. The landing site of CE-3 is located at the northern part of Mare Imbrium(44.1260° N，19.5014° W), which is quite close to the boundary of two disparate geological units. It is the first time to detect chemical composition in the lunar surface. The Yutu rover carried two payloads, including Visible and Near-infrared Imaging Spectrometers (VNIS) and Alpha Particle X-ray spectrometer.

VNIS mainly detect minerals from the lunar soil. The VNIS detected the mineral type and composition of lunar surface in the patrol area. The work time of VNIS accumulated 8.8 hours and it analyzed three lunar spots. Currently, this payload got the 3360 frames with the visible near-infrared (spectral range of 450nm - 950nm) and short-wave infrared spectral image data (spectral range of 900nm - 2400nm). From the results, the visible and near-infrared (VNIR) spectral imageand Short Wave Infrared (SWIR) spectral data can be qualitatively identify the lunar regolith in olivine and pyroxene absorption peaks, but it does not completely determine the minerals composition of the lunar soil and the main the scope of source rock composition.

APXS's scientific objective is to in-situ analyze the chemical compositions of lunar soils and rocks during Yutu rover's exploration. The APXS spectra are generated via both X-ray fluorescence (XRF) and particle-induced X-ray emission (PIXE), which is the same as APXS on the Mars Science Laboratory (MSL). Instead of ^{244}Cm, a combination solution with ^{55}Fe (4X, 70mCi per each) and ^{109}Cd (4X, 2.5mCi per each) were chosen to be the radioactive sources of APXS on Yutu [5]. The detection methods are consistent with Mars rover [6, 7]. WhenX-raysand alpha particles interact with atoms in the surface material, they knock electrons out of their orbits,producingan energy release that can be measured bysilicon drift detector (SDD). The element and its' concentrations could be achieved by analyzing peak energy and intensity [8, 9, 10].

Fig 1 The geomorphologic map was acquired by panoramic camera at the spot of N0205.N0108 is at the far from the corner. It is approximately 24 m between two locations.

Results and Analysis: From the figure of the Panoramic Camera, The terrain is relatively flat and the landing area on the lunar surface is covered primarily by fine lunar soil with common sizes of gravel. Due to the probe position and limited detection range, only fine lunar soil could be detected by APXS. There are 7 major elements could be detected, including Mg, Al, Si, K, Ca, Ti, and Fe, under the work condition of distance less than 30 mm and integration time of 30 min according to the scientific verification test. The analytical accuracy is better than 15%. These results can prove the instrument detection ability for major elements in the sample. The increase of integration time could reduce the measurement error of peak area, which is useful to detect the elements of Mg, Al, and Si. In contrast, the increase of work distance could result in larger errors in measurement, which significantly influences the detection of element Mg.

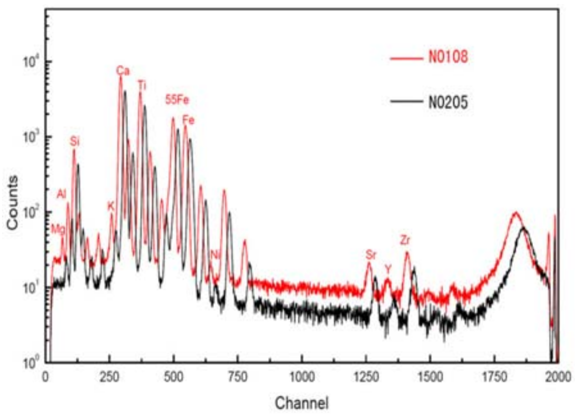

Fig2 The energy spectrum of lunar soil at the locations of N0108 and N0205. The peaks positions of two energy spectrums were without making correction.

During the inspection probe, the APXS's working time accumulated about four hours and gained a total of 2095 spectra data. During the lunar surface exploration, the APXS detected the lunar soil chemical composition in two spots and the location numbers are N0108 and N0205. The straight-line distance between these two locations is about 24 meters in accordance with the telemetry data. In quantitative analysis, the measured X-ray intensities are converted into the concentration of the elements. This issue is rather complicated because the measured intensities depend not only on the element concentration but also on matrix effects, sample type (solid, liquid or powder sample), shape and the thickness of the analyzed sample, and measurement conditions such as geometrical setup of the spectrometer.Through dead time correction, energy calibration and other treatment, the energy spectrums of lunar soil in two points were gained. From the entire spectrum of characteristics, the overlapping peaks are relatively less and the impact of back-end data is small. Therefore, it can be clearly identified the eight kinds of major elements (Mg, Al, Si, K, Ca, Ti, Cr and Fe) and three kinds of trace elements (Sr, Y and Zr) from the energy spectrum [[5].

The element distribution of these two locations are basically identical, which probably shows that the long-duration space weathering could result in the characteristics homogeneity, similar to the Martian surface evolution of fine mars clay [11]. The difference is that lunar surface was absent of water and the atmosphere during the process of homogenization. From identified elements of the lunar soil, the fine material probably was derived from the weathered basalt in the landing site at the bottom of the Mare Imbrium. The weathering and accumulation processes in Lunar surface may be produced after violent volcanic or intense meteorite impact.. However, there is still a regional homogenization process of the lunar surface composition and its scope and distance are only related to the rocks that outcropped in situ.

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