NEW INSIGHTS FROM CHANDRAYAAN-2 LARGE AREA SOFT X-RAY SPECTROMETER. S.

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Introduction: Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS) [1] is one of the payloads on Chandrayaan-2 mission which is in a circular, polar orbit around the Moon at an altitude of ~100 km. CLASS has been acquiring scientific data since September 2019 and has been able to map near global distribution of multiple elements including oxygen, magnesium, aluminum and silicon despite low solar activity. Solar flares of C class and above are needed to generate XRF lines of Ca, Ti and Fe. CLASS has also made detection of these elements on local scale.

The field of view (FOV) of the instrument is 7X7° which corresponds to a spatial resolution of 12.5X12.5 km from 100 km spacecraft altitude. Class provides the best spatial resolution among the X-ray spectrometers ever flown to the Moon [2,3,4]. In this work, we derive elemental abundances obtained from CLASS corresponding to a strong solar flare.

Data: CLASS operates on the sunlit side of the Moon. XRF line from oxygen is always observed while a solar activity level of ~A5 (GOES class) and above is required to measure other elements. The first set of data consisting of the calibrated X-ray spectra are available to the scientific community from the Indian Science Data Center (in PDS4 standard) along with analysis tools(https://pradan.issdc.gov.in/).

The spatial coverage of detectable signals from CLASS instrument is shown in Figure 1. This map covers the data collected between 12 Sep 2019 to 30 Nov 2020. The color coding shows the coverage binned by data quality as the incoming solar flare intensity keeps changing. As a result, the best available spatial resolution and number of detected elements is different for each data strip. Accordingly, regions coded in red offer the best spatial resolution and maximum number of elements would be mapped in these regions due to high solar x-ray input. In contrast, the blue regions offer the coarsest spatial resolution. We expect increasingly higher spatial resolution for various regions and eventually at global scale as the mission progresses and with the solar cycle 25 picking up.

Lunar XRF spectral analysis: The lunar XRF spectrum is back ground subtracted and modeled in XSPEC which is a standard tool in X-ray astronomy. The XRF lines are modeled as Gaussian functions. We calculate scattered solar component from lunar surface and use it to model the continuum. The best fit model is derived using least square minimization. The fraction of
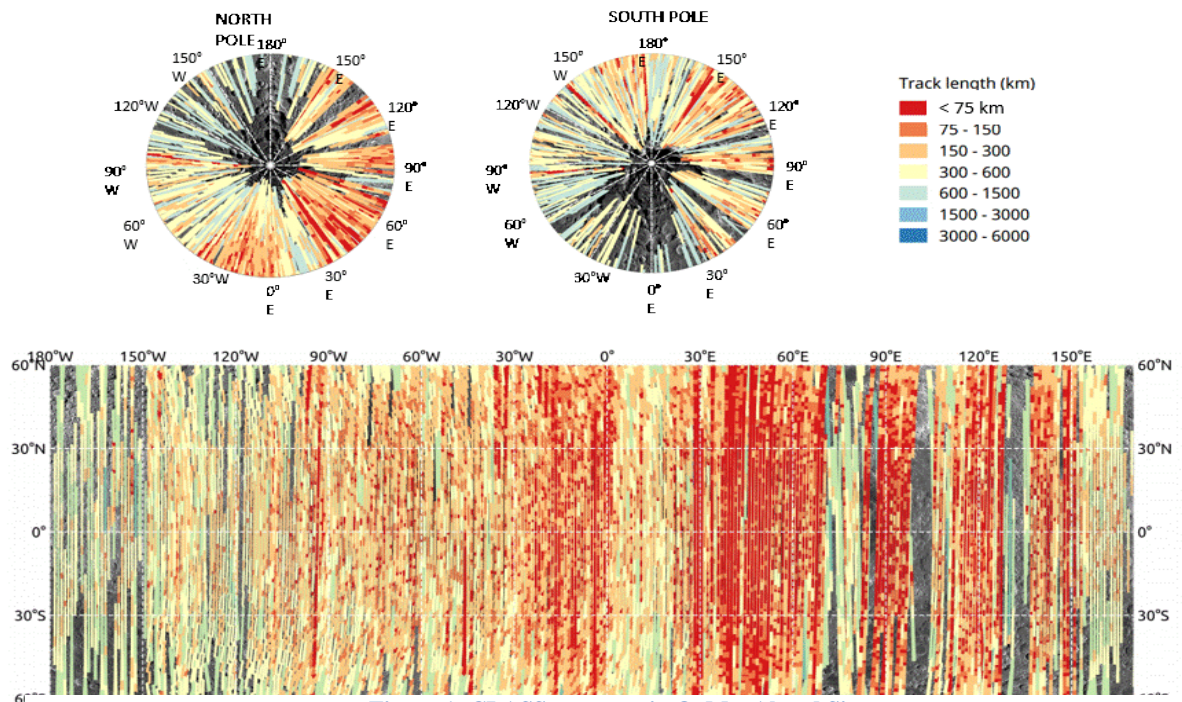

Figure 1: CLASS coverage in O, Mg, Al and Si

scattered component in the spectrum including solar lines can be well modeled using the energy intervals where there are no lunar XRF lines. The abundances are derived by comparing the measured XRF line flux to that calculated using an algorithm called *x2abundance* as described in [5,6].

CLASS observations of elemental abundances and their spatial variability: An M4.4 solar flare on 29 Nov 2020 enabled measurement of XRF spectra with high signal levels for all the major elements. We have taken a portion of the track during the peak of the solar flare that passes through Mare Tranquilatis and Mare Nectaris to demonstrate the compositional differences discernable at 12.5 km spatial resolution (Figure 3). The distinctively high titanium content of Mare Tranquillitatis region is captured in its X-ray spectrum (magenta spectrum). In contrast, the spectrum for outside this does not show any prominent signature of Titanium for the region mapped by CLASS. The Fe measured in both spectra is of similar strength that shows that the solar spectrum is strong enough to excite Ti and Fe in both cases. As the mission progresses, we hope to capture such differences in titanium abundances for all major mare regions. It would provide an independent measure of titanium which has so far either been derived at extremely coarse spatial resolution of several tens of kilometers or derived indirectly from spectral reflectance measurements.

Since titanium abundance is a key discriminator in the case of lunar basalts, XRF derived titanium map of mare regions would provide stronger constraints on the basaltic mineralogy on the Moon.
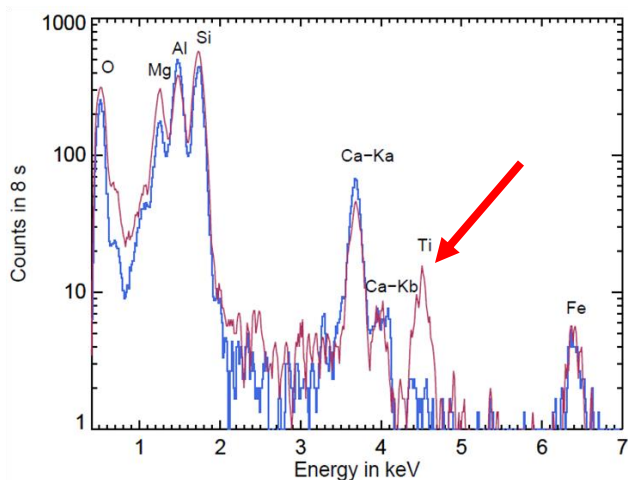
Figure 2: Lunar XRF spectrum from two pixels of 12.5 km x 12.5 km each showing the distinct difference in composition especially in Titanium (red arrow).

Potential Detection of chromium: Chromium is a minor element in lunar soils. However, CLASS has been able to detect Cr-XRF line for the first time (Figure 4) from a region in Mare Tranquillitatis. Further analysis of the signature and its source region is underway to better understand its signature and quantify its occurrence.
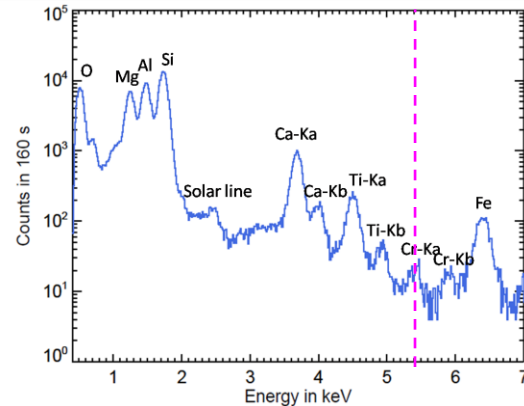
Figure 4 X-ray spectrum showing the detection of Chromium Kα line for the first time.

Summary: CLASS instrument onboard Chandrayaan-2 orbiter is producing high quality abundance maps of various elements which would provide new insights into the character of crustal evolution. The direct detection of elemental abundance at high spatial resolution would provide tighter constraints on the elemental inventory of the lunar surface. We anticipate generating global, high resolution elemental maps from CLASS in the near future.

References:
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