NEW VIEWS OF SOUTHERN NEARSIDE LUNAR HIGHLAND COMPOSITION FROM THE CHANDRAYAAN-1 X-RAY SPECTROMETER (C1XS). C1XS team, athray@gmail.com, Manipal Centre for Natural Sciences, Manipal University, Manipal – 576 104. India.

Introduction: Lunar missions over the last decade have revealed the complexity of the compositional, mineralogical, geomorphological and geophysical structure of the lunar crust and the near surface environment of the Moon. These new insights are helping to test models of lunar evolution from understanding the formation of the lunar ancient anorthositic highlands, to the chemical diversity and temporal history of volcanic and magmatic rocks.

The C1XS instrument: Chandrayaan-1, India's first lunar mission was launched on 22nd Oct. 2008 and was in operation until Aug. 2009. The primary scientific objective of the Chandrayaan-1 X-ray Spectrometer (C1XS) was to produce elemental maps using the X-ray Fluorescence (XRF) technique [1], with a spatial resolution of ~25 km on the lunar surface.

The instrument was the first well calibrated remote-sensing experiment to measure the characteristic XRF emission lines from all major rock-forming elements including Mg, Al, Si, Ca, Ti, Fe and Na with a good on-board spectral resolution (~ 153 eV peak width at 6 keV ref. *Fig 2*). C1XS was accompanied by X-ray Solar Monitor (XSM) which simultaneously measured the incident solar X-ray spectra, essential to derive the surface elemental chemistry. Systematic data reduction and spectral analysis was made adopted using detailed instrument calibration [2]. Elemental abundances with uncertainties are determined using well-established inversion algorithm [3].

Observations and Analysis: The majority of observations made during solar flare events coincided with ground tracks in the lunar near-side southern highland regions, including the relatively young impact crater Tycho and its ejecta crater rays (Fig. 1).

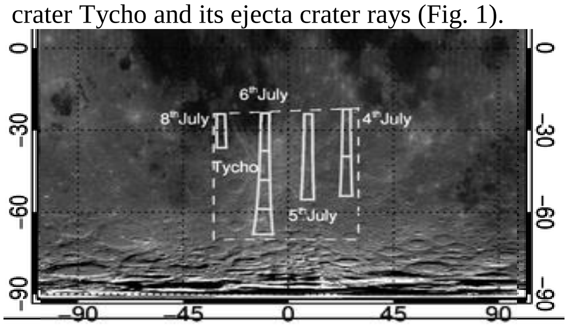

Fig. 1: Distinct elemental measurements were made for these C1XS observed ground-tracks over southern lunar highlands [4,5].

Results: The lunar southern highlands results (Fig. 2) from the 6th July 2009 flare are consistent with regoliths dominated by the mineral plagioclase (i.e., anorthositic-rich rocks), with a slight mafic mineral content. Interestingly, these results suggest that the mapped regoliths have Ca/Al ratios significantly lower than measured in lunar returned samples[4]. One of the major findings of C1XS is the demonstration of first direct detection and quantification of the moderately volatile element Na from these nearside highland areas [5].

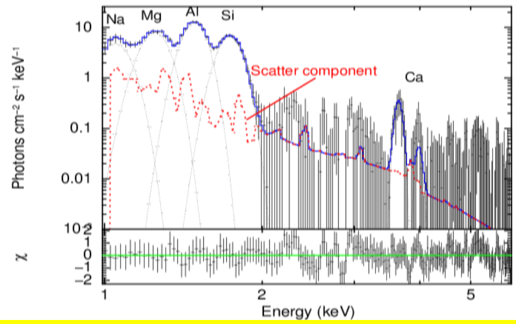

Fig. 2: The best fit to one of the C1XS spectrum observed during a C1 flare (6th July 2009) showing the unambiguous spectral evidence of Na.

Discussion: The lunar crustal highlands on the central nearside of the Moon are interpreted to be produced from primary crust ferroan anorthositic bedrock, mainly composed of plagioclase feldspar with anorthite content > An_{95}, as observed in lunar samples and remote sensing IR observations [6]. The C1XS XRF results imply that some of these areas may also have enhanced levels of sodium, which may equate to the presence of more sodic (albitic) plagioclase. Albitic plagioclase (~An_{70}) are typically found in rocks form the magmatic high alkali suite, although are rare in the Apollo and lunar meteorite sample collections.

One of the plausible explanations for this sodic rock-type being located in lunar highlands [7] could be the signature of evolved magmatism. Global elemental mapping of Na distribution and concentration is essential for further detailed scientific interpretation of these observations, and to identify outcrops of alkali-rich lithologies across the lunar surface.

Future perspectives: The upcoming Chandrayaan-2 Large Area Soft x-ray Spectrometer (CLASS) [8] to be flown on the second Indian lunar mission Chandrayaan-2 will continue global elemental mapping with greater sensitivity and better spatial resolution.

References: [1] Crawford et al. (2009) *Planet., & Sp. Sci.*, 57, 725-734. [2] Narendranath et al. (2010) *Nucl. Inst. & Meth. Res.* A 621,344-353 [3] Athiray et al., (2013) *Planet., & Sp. Sci.*, 89, 183-187. [4] Narendranath et al. (2011) *Icarus* 214, 53-66. [5] Athiray et al. (2014) *Planet., & Sp. Sci.*, 104, 279-287. [6] Ohtake (2009) *Nature*, 461, 236-240. [7] Athiray (2015) Ph.d Thesis. [8] Narendranath et al. (2014) *Adv. Sp. Res.* 54, 1993-1999.