DIRECT EVIDENCE OF ENHANCED SODIUM CONTENT ON THE MOON AROUND TYCHO REGION: C1XS OBSERVATIONS. P. S. Athiray[1, 2], K. N. Kusuma[3], S. Narendranath[1] and P. Sreekumar[4], [1]Space Astronomy Group, ISRO Satellite Centre, Bangalore, India. (athray@gmail.com). [2]Department of Physics, University of Calicut, Kerala. [3]Department of Earth Sciences, Pondicherry University. [4]Indian Institute of Astrophysics, Bangalore.

Introduction The objective of Chandrayaan-1 X-ray Spectrometer (C1XS) was to map the abundances of major rock-forming elements (viz., Mg, Al, Si, Ti, Ca and Fe) on the lunar surface using the X-ray Fluorescence (XRF) technique [1]. Low solar flare occurrences during C1XS observation period (Nov.'2008 – Aug.'2009) hampered the objective of global elemental mapping. However, C1XS with its high spectral resolution measured the x-ray signals of rock-forming elements simultaneously under different solar flare conditions. Also, some of the observed C1XS spectra clearly show the direct evidence of x-ray signature of Sodium from the Moon. We derived the elemental abundances from C1XS data using an XRF inversion algorithm called *x2abundance* [2] that we developed. Here we report the observation of enhanced sodium near the young crater Tycho on the lunar surface.

C1XS Observations: Majority of C1XS flare observations were made during July 2009, when the Sun was relatively active in x-rays. Simultaneous measure of incident solar x-ray spectrum was obtained from X-ray Solar Monitor (XSM) onboard Chandrayaan-1. Measurements made on the 6th July'09, when there was a ~ C1 class flare occurred, covered regions in and around the Copernican aged impact crater Tycho and its rays. To improve statistics and perform useful spectral analysis, data from multiple ground-pixels were added resulting in a coarser spatial resolution. The entire observation was divided into four subsets for spectral analysis as depicted in Fig.(1) which is the ground-track of C1XS observed regions overlaid on LRO Diviner map [3] showing the subsets.

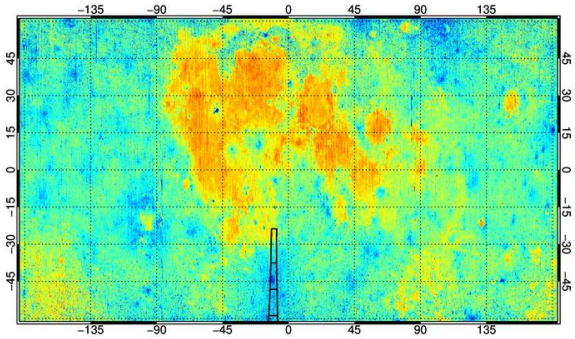

Figure 1: Ground-track of C1XS observed regions overplotted on Diviner map

Spectral analysis: The following are the major steps involved in spectral analysis of an observation (a) Build appropriate background spectrum (b) Derive scattered solar spectrum, reflected from the Moon's surface (c) Perform spectral fitting and extract XRF line fluxes (d) Convert line fluxes to elemental abundances. Spectral analysis was performed using X-ray Spectral Analysis (XSPEC) package. Apart from the lines of major rock-forming elements, C1XS clearly observed the XRF signature of Na at 1.04 keV in many spectra. Best fit to one of the background subtracted C1XS spectrum with all components marked is shown in Fig. (2). Elemental abundances were determined from the observed XRF emission lines using *x2abundance*.

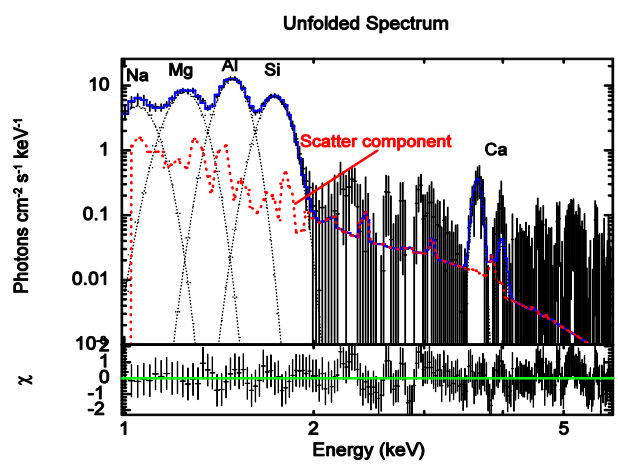

Figure 2 : Best fitted C1XS spectrum with all components. XRF lines of observed major elements are labelled. Bottom panel shows the fit residuals in terms of sigma.

Results: Elemental abundances determined from C1XS observations are listed in Table (1) along with compositions of the average lunar soil [4] and lunar meteorites [5] for comparison. The results clearly show that the derived abundance of Na is significantly larger than what has been known so far from earlier studies (<1 wt %). Further the derived abundances with 1σ uncertainty for C1XS observed regions matches well with the distribution of abundances derived from the Lunar Prospector (LP) gamma ray observations [6]. Also, C1XS results suggest an inverse relation between Ca and Na abundances.

Table 1 : Elemental abundances from C1XS observations on 6th July 2009 with 1σ uncertainties

Lat, Lon	Na	Mg	Al	Si	Ca
-63.2, -10.5	- -	**6** +1 -1	**18** +1 -1	**13** +1 -1	**14** +1 -1
-53.2, -10.5	**2** +1 -1	**6** +1 -1	**17** +1 -1	**16** +1 -1	**10** +1 -1
-43.0, -10.5	**3** +1 -1	**5** +1 -1	**17** +1 -1	**18** +1 -1	**8** +1 -1
-30.7, -10.3	- -	**4** +2 -1	**16** +2 -1	**23** +3 -2	**8** +2 -3
Apollo16 Soil average	**0.35**	**3.62**	**14.4**	**20.9**	**10.4**
Lunar Meteorites average	**0.26**	**3.26**	**14.9**	**20.9**	**11.7**

Discussion: Region in and around the nearside young impact crater Tycho is likely to be dominated by the ejecta and disturbed regolith. Diviner results using Christiansen Frequency (CF) value located unusual compositions around this region. The measured CF for these regions has values < 7.8 which correspond to sodium rich lithologies. C1XS observed the XRF line from Na and shows that Na abundance in this region is indeed higher. A more detailed report on this work including larger data sets is to be published elsewhere [7].

References:

[1] Crawford et al. (2009) *Planet., & Sp. Sci., 57*, 725-734 [2] Athiray P. S. et al. (2013) *Planet., & Sp. Sci., 89*, 183-187. [3] Greenhagen B. T. et al. (2010) *Science, 329*, 1507-1509. [4] Haskin L. and Warren P. (1991) *Lunar source book*, 357-474. [5] Korotev L. R. et al. (2003) *Geochim. Cosmo. Acta, 667*, 4895-4923. [6] Lawrence D. J. et al. (1998) *Science, 281*, 1484-1489. [7] Athiray P. S. et al. *submitted to Earth & Planet. Sci. Letters.*