INTER IIT
TECH MEET 13.0

HIGH PREP

HIGH-RESOLUTION ELEMENTAL MAPPING OF LUNAR SURFACE

About URSC, ISRO

UR Rao Satellite Centre (URSC) , Indian Space Research Organisation (ISRO) under the Department of Space, is the lead centre for design, development and realisation of satellites of ISRO. During the 70's and the 80's URSC was engaged in mastering the basic technologies and skills required for the specialized task of satellite building. Since the early 90's a host of contemporary and advanced communication, meteorological, remote sensing, navigation and space science were built and launched.

The communication, meteorological, remote sensing and navigation satellites launched by URSC have continued to serve the key sectors of the Indian economy like communication, agriculture, water resources, urban planning, Land use, Fisheries, Oceanography, Weather forecasting, Disaster management, Search and Rescue and Navigation. The Space science missions like Chandrayaan-1, 2, 3, Mars Orbiter Mission, Astrosat, Aditya-L1 and XPOSAT have put India in the global map while also inspiring the Gen next.

More than 100 state-of-the-art satellites built over four decades by URSC , the abode of Indian satellites, stand testimony to the technical excellence the centre has scaled. With about 2500 highly trained and skilled manpower, URSC today is home to a host of advanced, cutting edge satellite technologies that feeds into the Indian Space Programme.The centre also houses ultra modern design, development, fabrication and testing facilities for satellites.

Introduction & Motivation

A giant impact on young Earth about 4.5 billion years ago is believed to have formed the Moon. Earth moved on with hardly any memory of this catastrophic event. Moon cooled down and formed a crust, mantle and core and since then has stood as a canvas to mark the events in the early Solar System.
The surface composition of the Moon reflects the crustal composition, excavated materials, impact generated materials and weathering due to solar wind interaction.
The dark regions on the Moon visible to the naked eye are results of several episodes of volcanism that reveals its thermal and magmatic evolution.

Mapping the surface elemental abundances is of importance to understand the composition of the Moon as well as to identify potential sites for sample return and insitu resource utilization. And one of the most direct ways to map the elemental composition is X-ray spectroscopy.

CLASS is an X-ray fluorescence experiment onboard the Chandryaan-2 orbiter which has been operating since September 2019. Over the last five years, CLASS has measured a large number of lunar X-ray spectra. With a detailed spectral modelling, elemental maps of all major rock forming elements at 150 - 15 km spatial resolution have been generated for several regions.

However, there is potential to map the entire lunar surface chemical heterogeneity at finer spatial scales. The proposed problem is to generate a lunar map at unprecedented spatial scales by utilising the X-ray fluorescence line intensity ratios.

Problem Statement

X-ray fluorescence (XRF) lines are detected in CLASS during solar flares. The XRF line energy identifies the element while intensity depends on solar flare strength, solar zenith angle and composition. By taking line ratios, the angular dependence and incident solar flux dependence can be eliminated to some extent.

Mg/Si and Al/Si ratios for example can reflect the compositional heterogeneity fairly well (Figure 1).

Global XRF line ratio maps at a spatial resolution of ~ 12 km can be generated from CLASS data which would be a new independent map useful for geochemical and resource mapping.

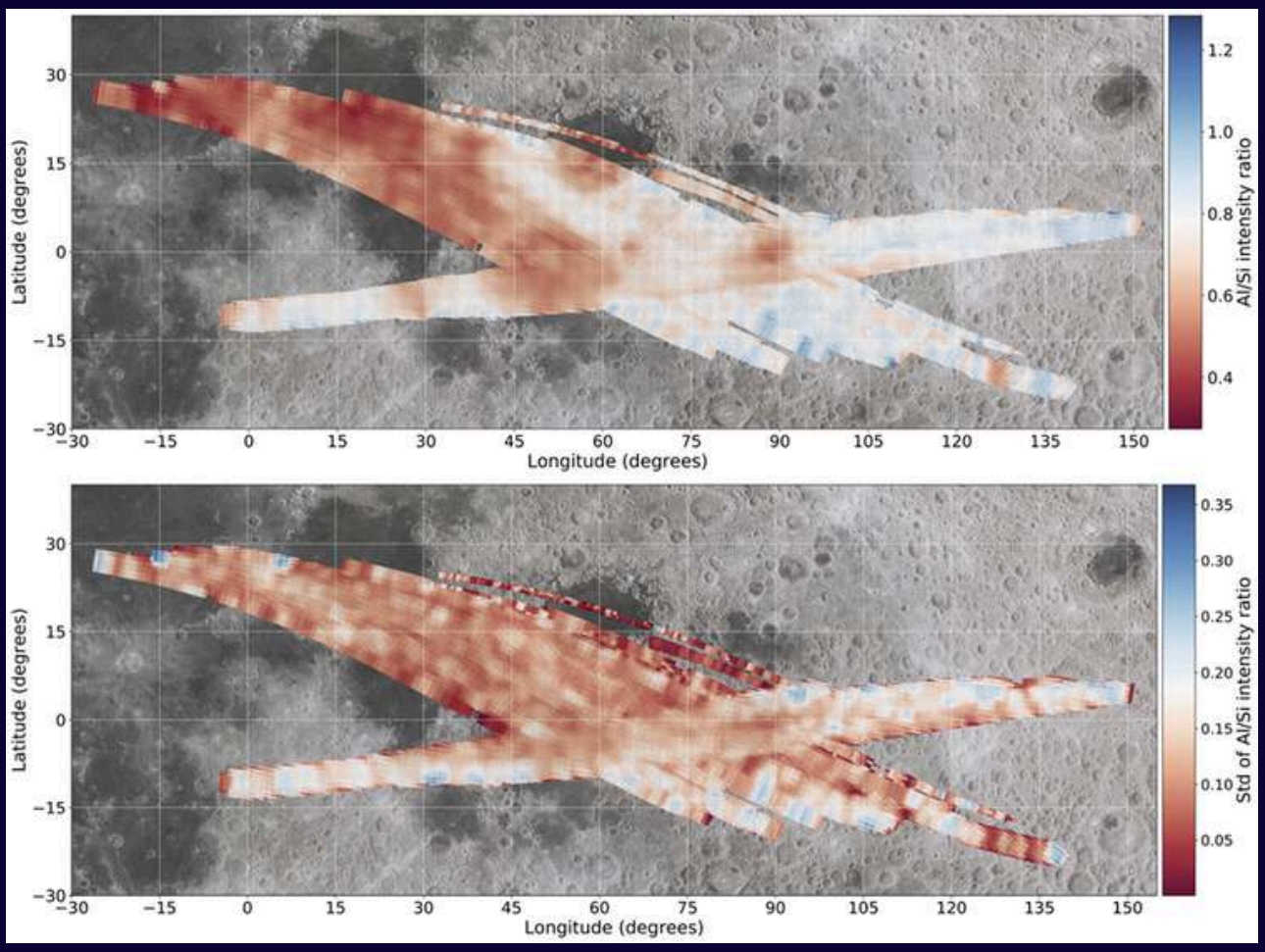

Figure 1: Al/Si X-ray line intensity ratios derived from Apollo 15 and 16 experiments (Gloudemans et al, 2021)

The observed spectrum in CLASS (Figure 2) consists of XRF lines, scattered solar X rays and background arising from particles in the lunar orbit. The routine CLASS data analysis pipeline models the X-ray spectra with good statistics to derive elemental abundances.

Several spectra are added to achieve statistics except for occasions when the incident solar flux is high.

The objective here is to utilise the entire set of XRF spectra measured by CLASS to derive XRF line intensities and create a high-resolution elemental ratio map that would identify compositional differences at km scales.

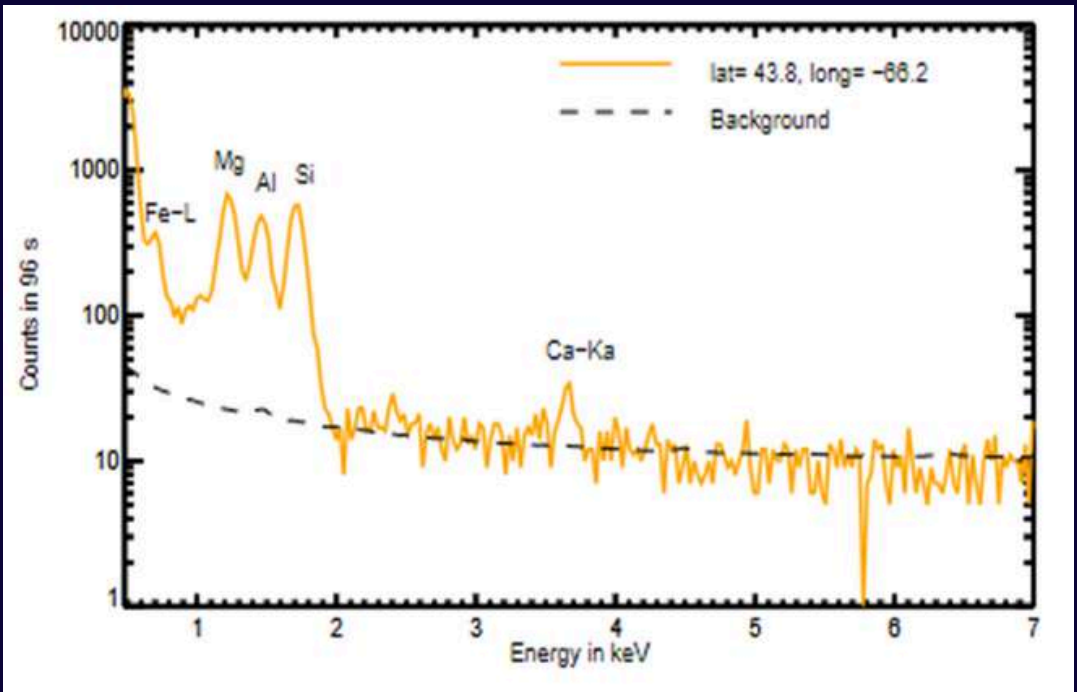

Figure 2: Lunar X-ray spectrum measured by CLASS (Narendranath et al, 2024)

Methodology

- Identify spectra with XRF lines, estimate number of lines detected and the corresponding element and its significance (detection)
- Model the spectra to determine XRF line flux from each of the detected element
- Calculate ratios such as Mg/Si, Al, SI, Ca/Si and map it onto a lunar albedo base map (eg: Lunar Reconnaissance Orbiter Wide Angle Camera global map)
- Derive uncertainties
- Arrive at ratios that best represent the compositional heterogeneity in the terrain
- Explore the use of overlapping tracks to achieve sub pixel resolution

Solution Deliverables

- XRF line intensity maps projected onto a lunar albedo base map in a readable format
- Source codes written in open source (preferably python) software
- Report outlining the steps
- Bonus points for draft of a Journal Paper

Evaluation Parameters

Mid Term Report

1. A catalogue of XRF line detections and the elements along with source codes – 10%
2. Map the coverage of the XRF lines onto a lunar base map – 10 %
3. Compositional groups based on ratios – 10%

Note: These three tasks are to be submitted as a part of the mid-term report. If a task from these three is completed after the mid-term report, then it will receive only half weightage.

End Term Report

1. Map the ratios onto a lunar base map – 40% (dynamic interactive map preferred)
2. Best ratios to use and visualization of data on a lunar map – 20%
3. Subpixel resolution maps – 10%

Note: The final presentation should include a complete solution, and the end-term report must include all the source codes to be handed over to ISRO.

Resources

Data: https://pradan.issdc.gov.in/ch2/

Manual:
https://pradan.issdc.gov.in/ch2/protected/downloadFile/class/ch2_class_pds_release_38_20240927.zip

CLASS instrument:
https://www.currentscience.ac.in/Volumes/118/02/0219.pdf
https://www.sciencedirect.com/science/article/abs/pii/S0019103521001196

CLASS elemental maps:
https://www.sciencedirect.com/science/article/abs/pii/S0019103523004773

Planetary X-ray fluorescence spectroscopy:
https://www.sciencedirect.com/science/article/abs/pii/S0032063312002942