# Elemental Ratios as derived from Chandrayaan-2: High Resolution XRF Mapping of the Lunar Surface

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**We created the first complete X-ray fluorescence line ratios map of the lunar surface!**

## Introduction

### Lunar Surface

- Compositional analysis of lunar surface provides critical insights into the effects of differential cooling of the lunar primordial magma and the characteristics of it's crust.
- Systematic mapping of these elemental abundances is essential for advancing our understanding of the Moon's composition.

### X-ray Fluorescence (XRF)

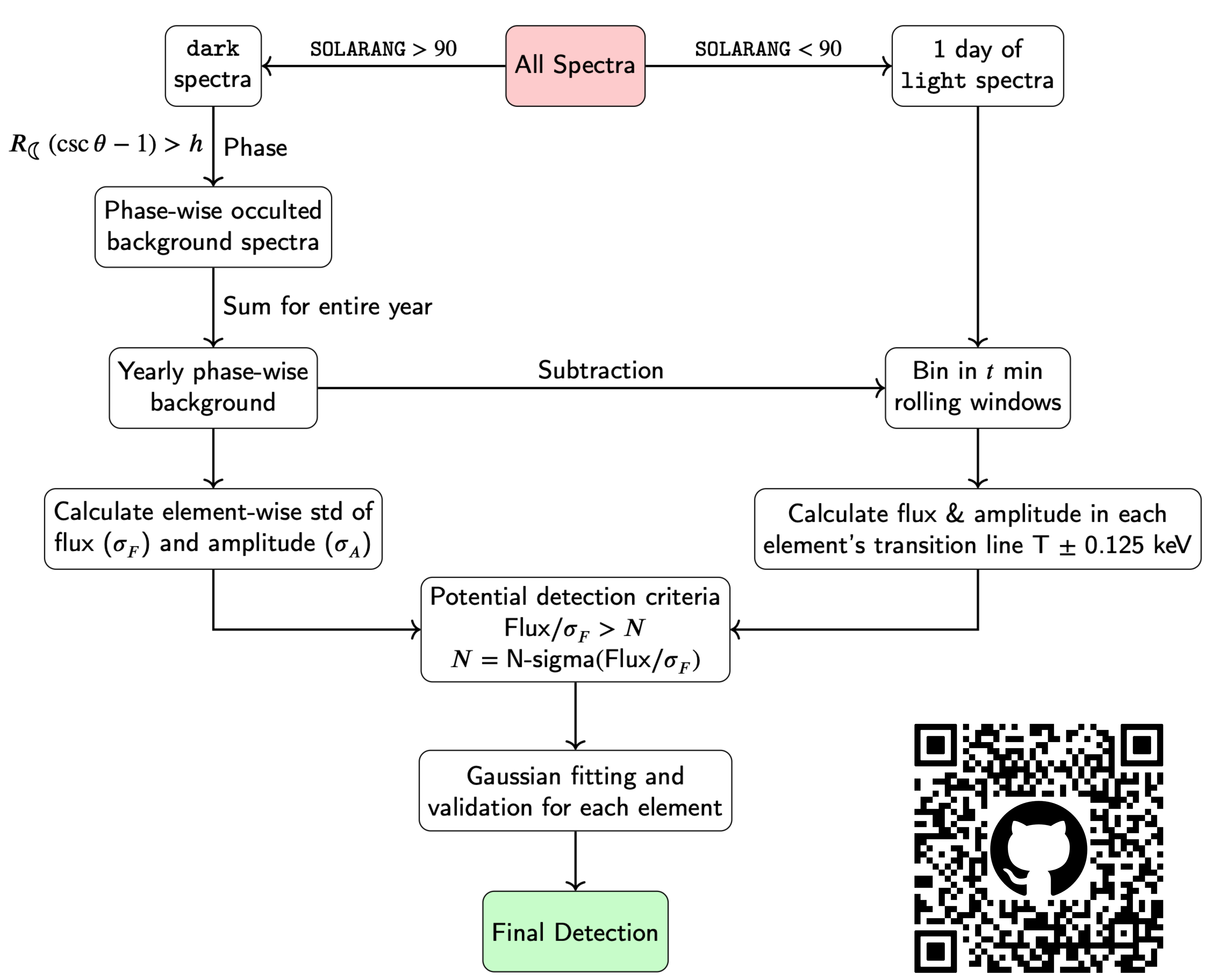
- Non-destructive analytical technique employed to determine elemental composition by detecting unique X-ray emissions of specific elements.
- Triggered when high-energy photons ionize inner-shell electrons. Their intensity is proportional to the element's abundance, solar flare strength, and solar zenith angle

### Line Ratios

- Ratios eliminate angular and incident solar flux dependence to some extent and allow for mapping of the surface independent of corresponding solar spectra.

We develop a novel algorithm to detect XRF lines using the Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS) and take their intensity ratios to create the first complete XRF line ratios map of the lunar surface

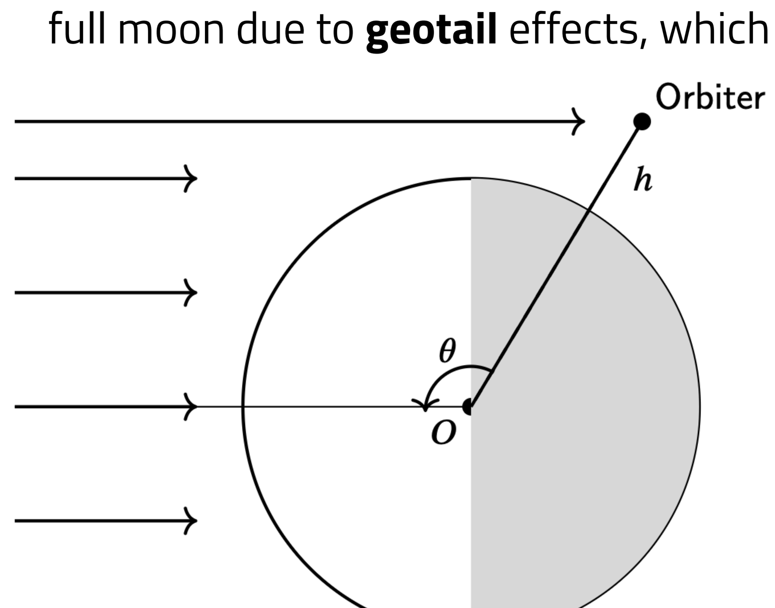
## XRF Detection Algorithm

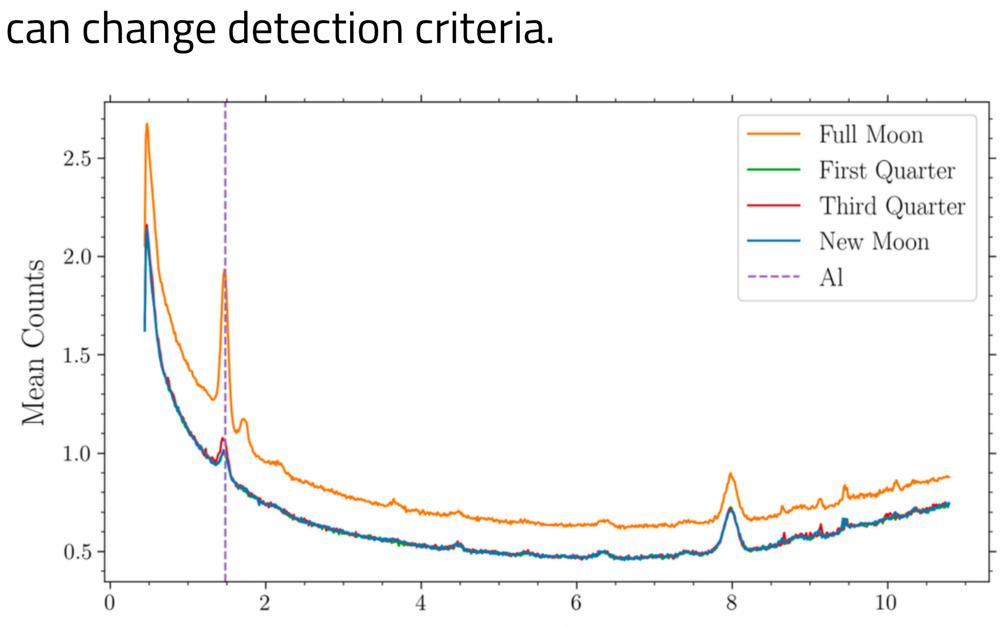



**Check out our code & results!**

### Dynamic Background Estimation

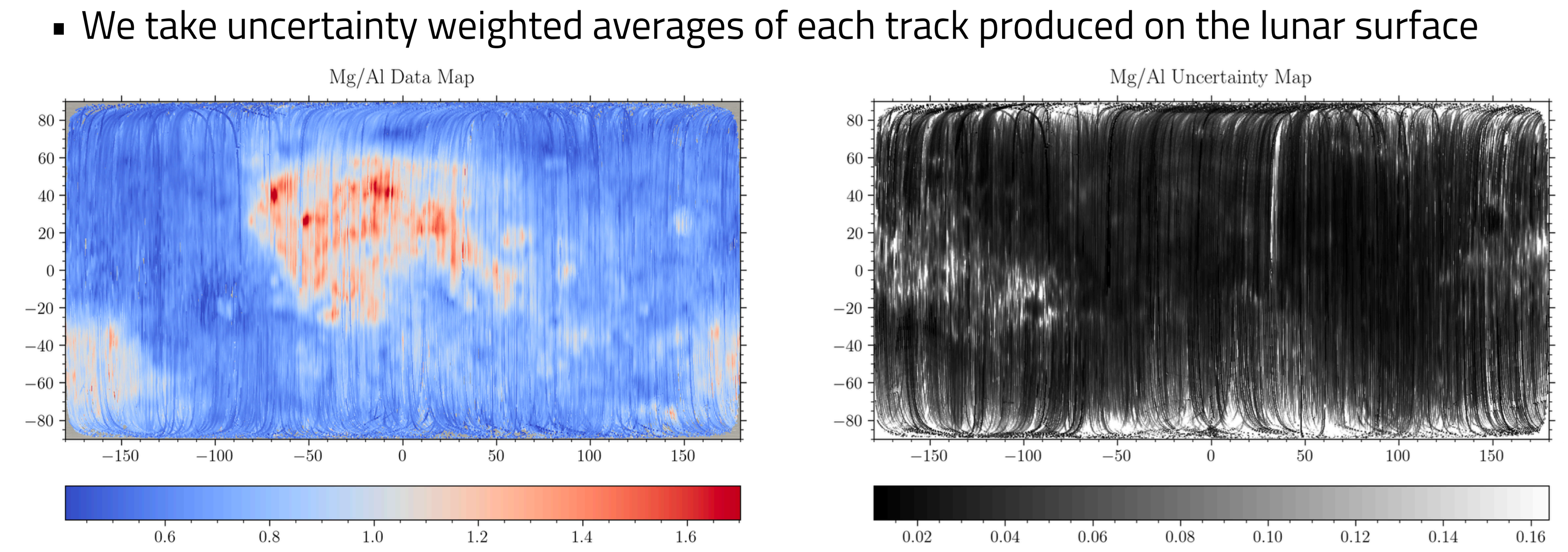
- *Need for occulted spectra:* Aluminum present on the detectors gets excited by the solar flares even when the orbiter is on the **dark** side.
- *Need for phase-wise background:* The orbiter experiences increased levels of radiation during the full moon due to **geotail** effects, which can change detection criteria.



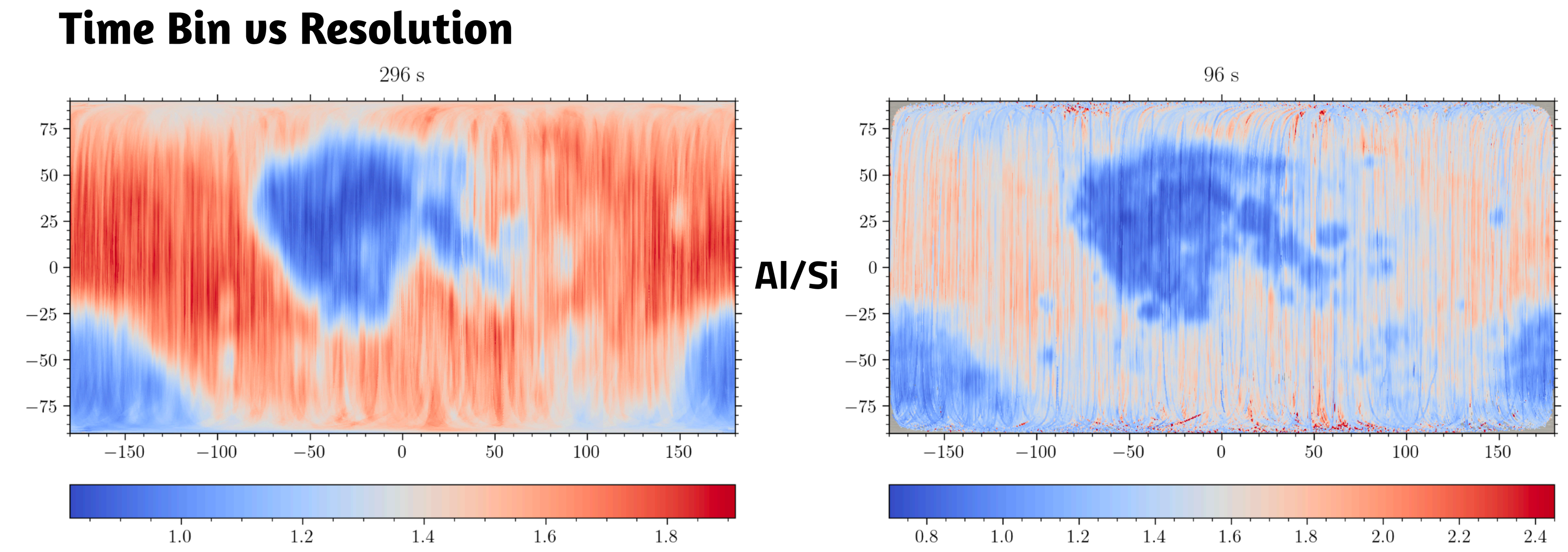

## Mapping

- We take uncertainty weighted averages of each track produced on the lunar surface

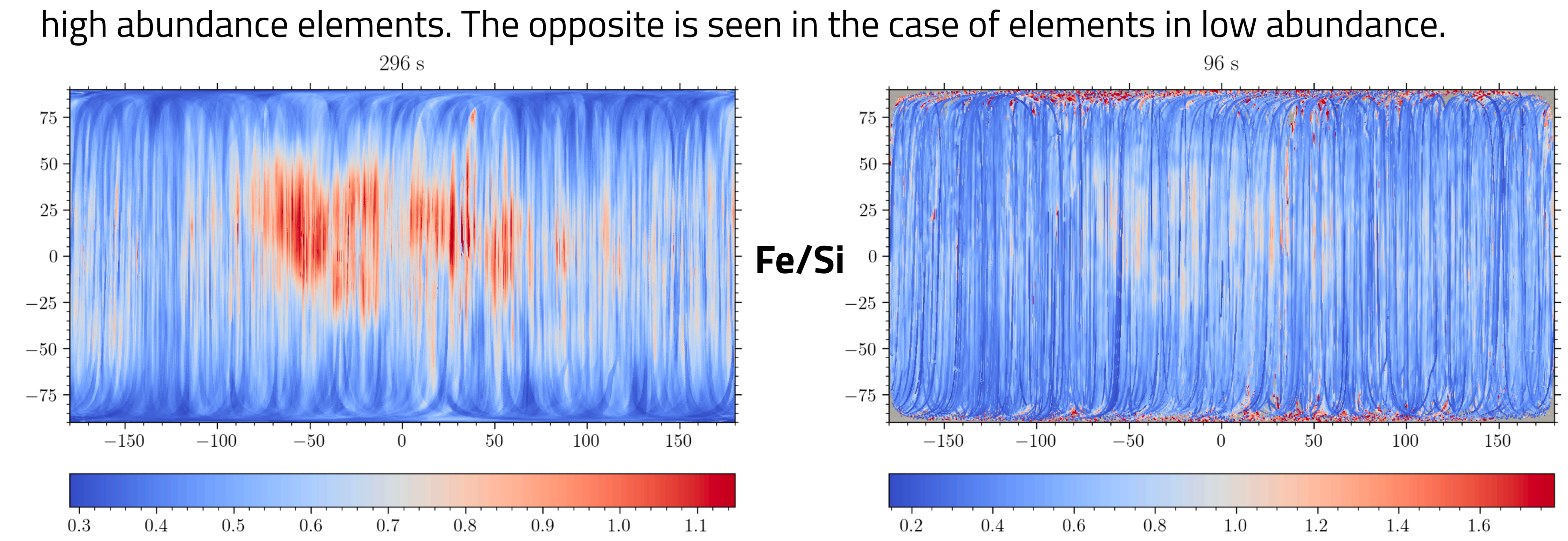



Note the higher uncertainty near the poles, caused due to low solar flux, thus low XRF intensity

### Time Bin vs Resolution

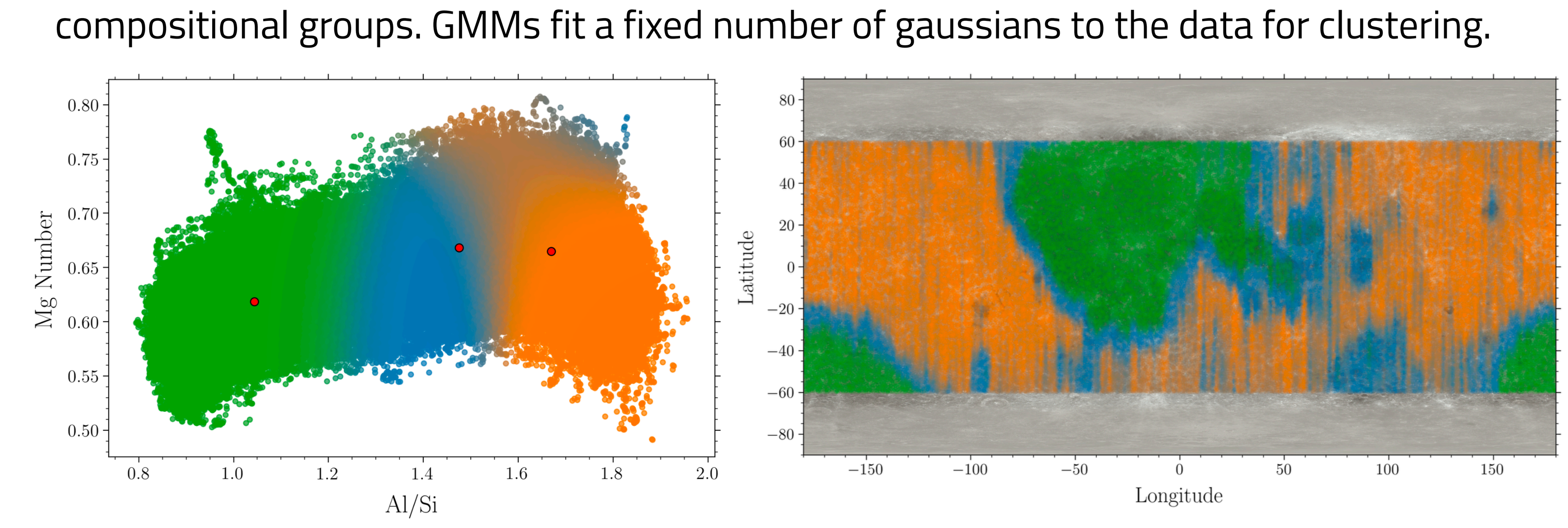



Lower time bins result in shorter tracks being covered on the moon, increasing resolution for high abundance elements. The opposite is seen in the case of elements in low abundance.



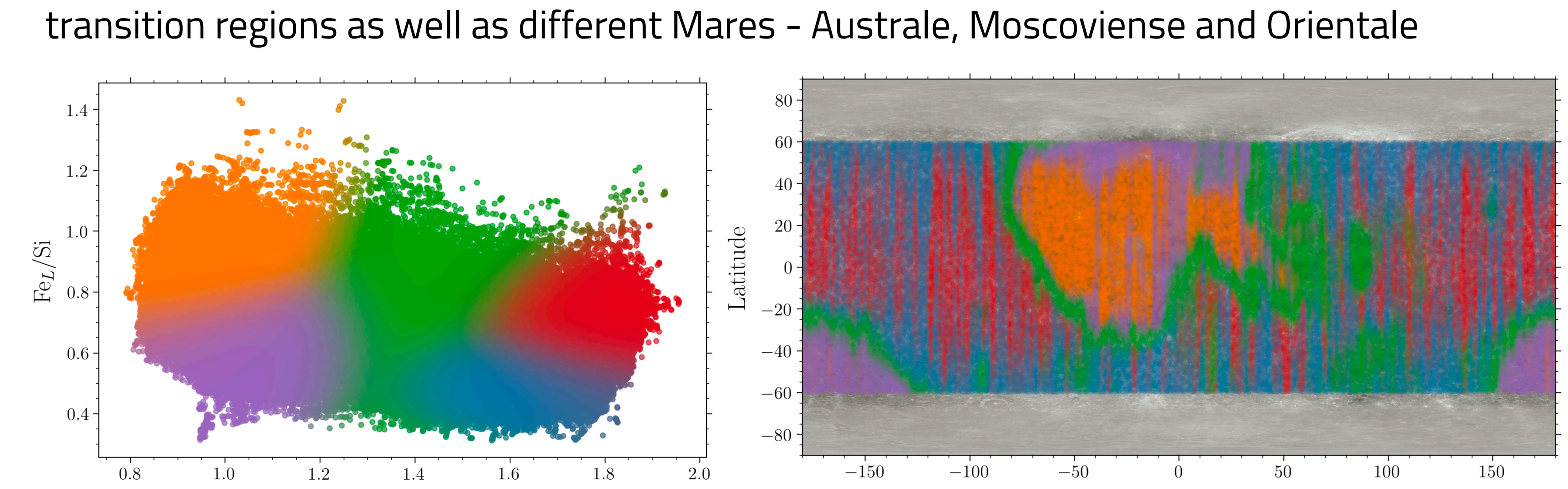

## Results

- We utilize Gaussian Mixture Models (GMM) for 2D clustering of the maps to identify compositional groups. GMMs fit a fixed number of gaussians to the data for clustering.




*3 GMM fit to Mg Number vs Al/Si map data*

- Mg number is defined as ratio of magnesium oxide in magnesium oxide and ferrous oxide.
- It differentiates the surface into Maria (green), highland (orange) and SPA basin (green) and transition regions as well as different Mares - Australe, Moscoviense and Orientale




*5 GMM fit to Fe/Si vs Al/Si map data*

- We are able to make the same distinctions as before, along with separation of the highland (orange) into low and high Fe regions. This matches closely with the Kaguya mission

## Acknowledgements

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References

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