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A Study of a Tycho Crater Ray Using Data From Past and Recent Lunar Missions

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Abstract

A lunar ray emanating from Tycho crater was selected and studied using various sources of data. The difference in composition to the surrounding terrain was examined and modelled to determine the response of C1XS (Chandrayaan-1 X-ray Spectrometer) to the ray, and to establish the effect of rays on C1XS data analysis.

1. Introduction

Lunar rays rank amongst the brightest and most impressive features of the Moon. A ray will typically consist of a long, bright feature stretching out from a source crater [1]. It is generally accepted today that rays are formed at the same time as, and as a result of, the formation of the central crater. Rays are thought to consist of several types – immaturity rays, where the brightness is due to the relative youth of the overlying ray material; compositional rays, where the mineralogical content of the ray is different to the underlying surface; and combination rays, which are formed by a mixture of the two effects.

This distinction between ray types is important in the context of interpreting data from recent lunar missions. The instrument C1XS on Chandrayaan-1 was an x-ray spectrometer capable of detecting the mineralogical content of the lunar surface due to x-ray fluorescence from solar irradiation [2]. A large portion of the C1XS final coverage consists of the near-side highlands, which is crossed in several places by rays of Tycho (Figure 1), so it is important to determine whether a compositional difference exists between ray and underlying terrain, and whether this is high enough to be detectable by C1XS.

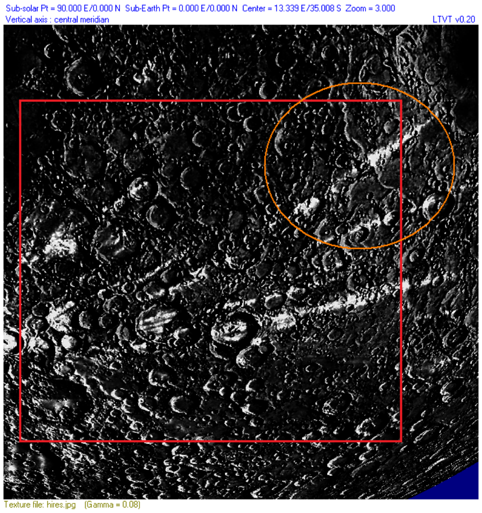

Figure 1: A low gamma visible light photograph of the region in question. White streaks are mostly rays of Tycho, and the red box shows the area where C1XS footprints are largely concentrated. The ray studied here is circled orange.

2. Using Clementine and Kaguya Data

Mineralogical maps derived from Clementine data are publicly available. Algorithms have been applied to the pure UV-VIS data to separate out maturity effects from mineralogical effects by Lucey et al [3], and they have been improved upon by Gillis et al [4].

Iron and titanium maps for the region stretching between Tycho and Mare Nectaris were studied. While other rays emanating from Tycho showed marked iron differences to their surroundings, the ray being studied did not. In the titanium map there is a very slight difference between the ray and the surroundings, and so this map was used to look at the ray. Figure 2 shows a gamma(brightness)-adjusted version of the titanium map showing the region in question.

Figure 2: A Ti map of the nearside southern highlands. This map has been gamma-adjusted to make the dark rays more visible.

The colour values of the map images correspond directly to the mineralogy of the terrain. In the titanium map, in the file format used (.png), the %wt of TiO_2 is found by dividing the colour value of a given pixel by 10. As C1XS measures elemental abundances rather than minerals, this was then converted to the wt% of titanium alone.

Using the Photoshop application, a section of the ray was selected and the average colour values for the pixels recorded. The selection box was then moved to the non-ray areas to the North and South, and more measurements made. This process was repeated several times and the average Ti in the ray, North of the ray, and South of the ray was found. The difference between the ray values and the surrounding terrain were then calculated, with a value of 0.0596 wt% to the North and 0.0214 wt% to the South.

3. C1XS Modelling

To find out whether the small difference between the ray and its surroundings is resolvable by C1XS, code written to model the response of C1XS to lunar surface fluorescence was used.

An average lunar surface (from Lunar Prospector) data was taken, and the titanium value replaced with that of the ray average. The instrument response of C1XS to this concentration was modelled, assuming a flare strength of B5 and a 12 second integration time. This was then compared with models of the titanium concentrations north and south of the ray.

There is a small but noticeable difference between the ray plot and the surroundings' plots – Figure 3 shows the comparison between the ray and the area to the North.

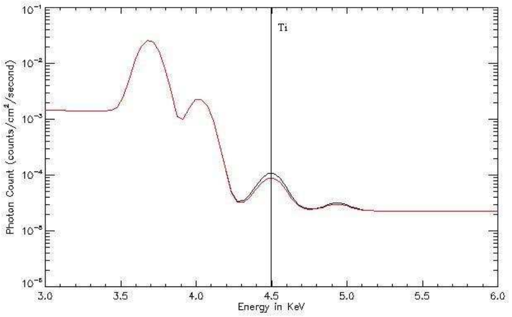

Figure 3: A comparison using the modelling software showing the difference in C1XS output between the ray (red line) and the area to the North (black line).

4. Summary and Conclusions

In reality such a low amount of counts gained from titanium from a B5 flare would almost certainly not be resolvable using C1XS. Higher flare values, of C or M class, would be needed for accurate results. Due to the shortened length of the Chandrayaan-1 mission, and the low solar activity during its operational life, these results were not obtained.

Even though the titanium difference may not be seen, it may point to other elemental differences which might be resolvable – for example, magnesium aluminium or silicon. These differences will be looked for in the C1XS data.

Acknowledgements

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References

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