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Initial results from the C1XS x-ray spectrometer on Chandrayaan-1

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Introduction: The Chandrayaan-1 lunar mission which was cuccessfully launched by the Indian Space Research Organisation (ISRO) on 22 October carried as part of its payload the C1XS Chandrayaan-1 X-ray Spectrometer (Grande et al 2009 [1]). It exploits heritage from the D-CIXS instrument (Grande et all, 2007[2]]) on ESA's SMART-1 mission. However, by comparison with SMART-1, Chandrayaan-1 is a science oriented rather than a technology mission, leading to far more favourable conditions for science measurements. C1XS is designed to measure absolute and relative abundances of major rock-forming elements (principally Mg, Al, Si, Ca, Ti and Fe) in the lunar crust with resolution ~25 km.

The C1XS hardware was designed and built by an international team led from the Rutherford Appleton Laboratory (RAL), STFC. The Principal Investigator is Prof. M. Grande at Aberystwyth University. There is also a major science and design contribution from ISRO Satellite Centre, Bangalore, India; CESR, Toulouse, France provides 3-D Plus video processor integrated circuits, and there is an important contribution to the detector characterisation from Brunel University. The Science team is chaired by Dr. I. A. Crawford of Birkbeck College London. In order to record the incident solar X-ray flux at the Moon, C1XS carries an X-ray Solar Monitor (XSM) provided by the University of Helsinki Observatory, Finland. C1XS is primarily funded by ESA with partial support to RAL from ISRO.

Instrument

The baseline instrument design consists of 24 nadir pointing Swept Charge Device (SCD) detectors (Howe et al., forthcoming). A traditional box collimator defines the field of view of each SCD, resulting in a triangular angular sensitivity with 50% of the X-ray signal deriving from 14° of the collimator aperture, corresponding to 25 km on the lunar surface from Chandrayaan-1's circular 100 km orbit. A deployable door protects the instrument during launch and cruise, and also provides a 55Fe calibration X-ray source for each of the detectors, allowing in flight calibration to be performed. The source strength is sufficient throughout the two year mission for gain calibration to be obtained within 10 minutes.

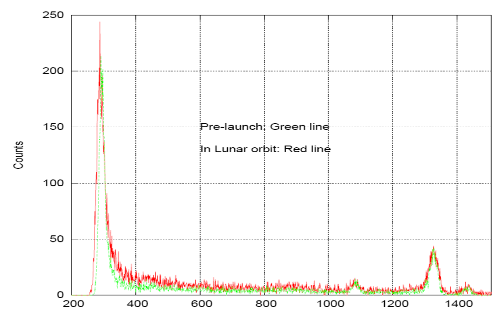

Figure 1: Comparison of in-flight and laboratory performance, using the onboard Mn^{55} sources. Note similarity between the two spectra.

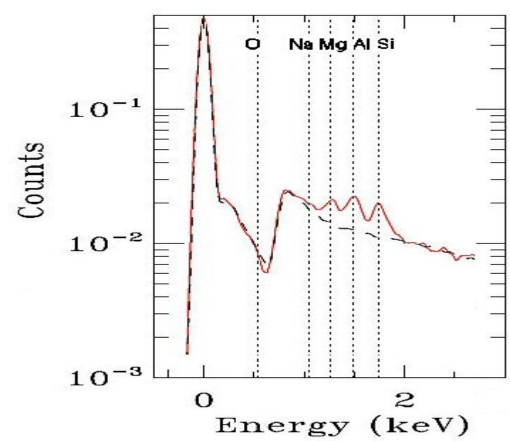

Figure 2: Lunar Spectrum obtained on 12 Dec 2008, in low illumination conditions. Note the excellent resolution achieved in the Magnesium, Aluminium and Silicon Lines

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The Swept Charge Device (SCD) detectors (Gow et al 2007) provide high detection efficiency in the 0.8 to 7 keV range, which contains the X-ray fluorescence lines of interest. The principal requirement is a spectral resolution sufficient to clearly resolve the three common light rock forming elements (Mg, Al, Si).

The X-ray solar monitor (XSM) is based on the SMART-1 XSM (Huovelin et al 2002 [3]) and consists of a separate silicon detector unit on the spacecraft. The non-imaging HPSi PIN sensor has a wide field-of-view (FOV) to enable Sun visibility during a significant fraction of the mission lifetime, which is essential for obtaining calibration spectra for the X-ray fluorescence measurements by the C1XS spectrometer. The energy range (1–20 keV), spectral resolution (about 200 eV at 6 keV), and sensitivity (about 7000 cps at flux level of 10^{-4} W m^{-2} in the range 1–8 keV) are tuned to provide optimal knowledge about the solar X-ray flux, matching well with the activating energy range for the fluorescence measured by C1XS.

In Flight Performance

The instrument has recently been turned on, and is operating nominally. In flight calibration has been carried out using the onboard Mn^{55} radiation sources, and the results are shown in Figure 1, as a comparison with the equivalent lab based calibration spectrum.

It is seen that the flight spectrum matches very closely the lab spectrum, indicating that the instrument is performing well, and has undergone very little degradation as a result of the cruise to the Moon, and the consequent radiation belt passages. Detailed analysis suggests a broadening of the FWHM by 30ev, far less than predicted.

The Sun continues to show X-ray emission characteristic of the Solar minimum, and the onset of this solar maximum is significantly delayed. However, C1XS has been able to observe the Moon even in these very low illumination conditions. Figure 2 shows the result of an integration during an A class flare on Dec 12, 2008. The expected lines at Mg, Al and Si are clearly seen and resolved. This performance shows that the instrument is easily meeting its design requirements, and in the higher illumination conditions expected during the rest of the mission will be capable of meeting its science goals.

Science Goals:

C1XS will determine the major element geochemistry (and especially Mg/Si and/or Mg/Fe elemental ratios) in the main lunar terrain types (i.e. Procellarum KREEP Terrane, South Pole-Aitken Basin, and the Farside Highlands; Jolliff et al., 2000) and establish the geographical distribution of the magnesian suite of rocks. A key ambition is to determine the large-scale stratigraphy of lower crust (and possibly crust/mantle boundary region) by measuring the elemental abundances of the floor material of large basins not obscured by mare basalts (e.g. SPA and other farside basins), and the central rings and ejecta of large basins which expose material derived from depths of many tens of km. In addition, determination of the crustal aluminium abundance and distribution is important for the assessment of lunar refractory element enrichment, and C1XS-derived aluminium abundance maps will thus constrain models of lunar origins.

Conclusions

The C1XS instrument is optimised to perform X-ray spectroscopy in the framework provided by the ISRO Chandrayaan-1 mission to the Moon. Initial results suggest that its performance as a science instrument will be outstanding.

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