Current status of X-ray spectrometer onboard Kaguya(SELENE)

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Current status of X-ray spectrometer (XRS) onboard Kaguya (SELENE) will be reported. Kaguya was launched on 14 September 2007 by H2A launch vehicle to investigate lunar science with 15 onboard experiments. XRS is originally planned to map major elements of lunar surface, but the aim is not achieved due to instrumental trouble and historically quiescent solar X-ray flux.

X-ray spectrometer is among the typical remote instruments to determine major elements of atmosphere-free planetary surface. It observes X-rays excited by solar X-ray irradiation to the planetary surface, which is characteristic of elements. During the Apollo 15 and 16 missions, major elemental ratios of Mg/Si and Al/Si in the equatorial region of 10% lunar surface were determined with spatial resolution of several tens of kilometers. In Kaguya, XRS is designed to map these three elements, and some heavier elements (Ca, Ti, Fe) during solar flares, with 20 to 50 km spatial resolution. We adopted charge-coupled devices (CCD) for its detector with 10 times greater energy resolution compared to the conventional proportional counters used in Apollo missions. The XRS consists of lunar X-ray sensor (XRF-A), solar X-ray monitor (SOL-BC), and electronics (XRS-E).

XRF-A has a trouble in its performance. Normally an X-ray event shows a single-pixel event or a split-pixel event where all the charges are included in one or two pixels. But almost all the events have a very long trail along the transfer direction. Without onboard calibration source like Fe55 and with too faint lunar X-rays due to historically quiescent solar X-rays, no direct data is obtained to investigate what is going on in the XRF-A. We changed the transfer clock voltages of CCD, switched the readout frequency, and compared the cases in binned and un-binned data, checked the dependency on CCD temperature, whether any signs of change are shown in the length of trail. We assumed that the degradation of charge transfer efficiency happened in the charge-transfer region, about 2 micrometer from the surface of CCD. This seems caused by defects by radiation of 0.3MeV protons. Although 0.3MeV protons are completely shielded by beryllium filters, 0.8 to 1MeV protons intrude into CCD after decreasing its energy to 0.3MeV. During the 2.5 round phasing orbit before lunar transfer, Kaguya passed through Van Allen radiation belts and must have experienced irradiation by trapped protons. To confirm this assumption, we performed proton radiation test at Tsukuba Space Center and proved that the trail remarkably occurred after irradiation of 3 x 10^8 protons/cm^2, comparable to the fluence during the radiation belts.

We learned from this that in the future X-ray remote experiments particle shields such as open-lid, onboard calibration sources, and use of radiation tolerant detector will be necessary.

However, XRS detected some X-rays from lunar surface at a small-scale flares. Solar X-ray monitor works well and its information can be used for the cross-calibration with other X-ray experiments such as C1XS onboard Indian lunar orbiter Chandrayaan-1. International X-ray spectrometry collaboration is started now.