OBSERVATIONS OF THE GEOTAIL WHILE IN LUNAR ORBIT BY THE CHANDRYAAN-1 X-RAY SPECTROMETER (C1XS)

S. Narendranath[1], , Srikar Paavan Tadeppalli[1], P.S. Athiray[1,3] Ankesh Misra[1], P.Sreekumar[2], [1]Space Astronomy Group, ISRO Satellite Centre, Bangalore,India ,[2] Indian Institute of Astrophysics, Bangalore, [3]University of Calicut, Kerala, India email:kcshyama@isac.gov.in

Introduction: Earth's magnetic field lines are stretched by the solar wind and extends to several tens of R_E towards the anti-Sun side. Interactions with the interplanetary magnetic field and solar wind in this region called the geotail results in a very dynamic environment (Figure 1). There are very few measurements of charged particles in the geotail especially at lunar distances. The Chandrayaan-1 X-ray Spectrometer (C1XS) [1] measured low energy charged particles as background during the nine month mission in a 100-200 km lunar orbit. Here we present preliminary results from this data that clearly shows signatures of enhanced particle flux during geotail passes .

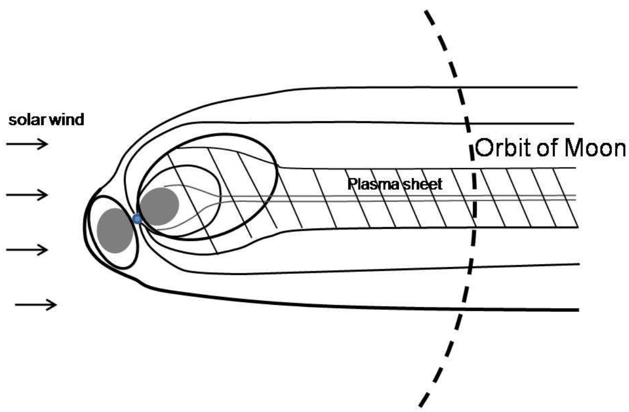

Figure 1: Structure of the geotail

C1XS: The C1XS experiment on Chandrayaan-1was designed to map the abundance of major rock-forming elements on the lunar surface. A complementary experiment alongside C1XS, the X-ray solar monitor [2], provided simultaneous observation of the solar X-rays. C1XS consisted of 24 Swept Charge Devices (SCDs) below a passive collimator with suitable visible light filters, yielding an x-ray spectrometer that operates in the 1-20 keV.

Charged particles also deposit energy in the SCDs and are read out just like X-ray events. We have simulated this scenario in GEANT4 (a Monte Carlo simulation toolkit) [3] and derived the energy range of particles that can thus mimic X-ray events in the SCD. This helps in modeling the background in C1XS detectors as well as in understanding changes in the incident particle spectra.

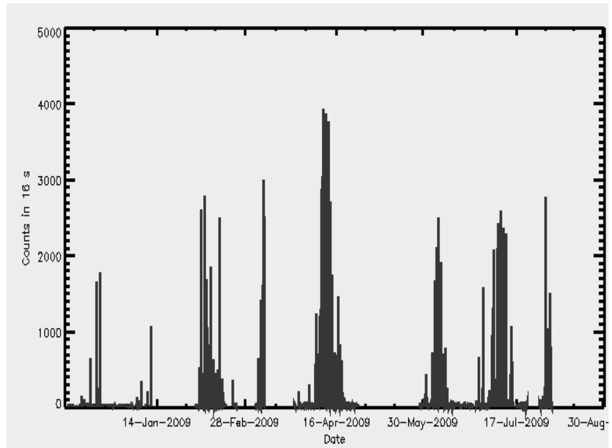

Figure 2: Enhanced particle flux observed during geotail passes (one pass was not recorded).

C1XS observations: Chandrayaan-1 operated from 28 Nov 2008 to 01 Aug 2009. During this time there were nine passes through the geotail. C1XS was operating during eight of these passes and measured the spectra resulting from energy deposition of particles in the X-ray detectors. Even outside the geotail the background in the detector results from energy deposition by particles in the lunar environment. While inside the geotail we find that the energy deposition in the 15- 20 keV range increases considerably. The background flux observed is entirely due to particles because even during flares the scattered solar flux does not contribute significantly to the spectrum in this energy range. Figure 2 shows these short bursts as C1XS encounter energetic particles. In order to understand the nature of the incident particles, we modeled the particle energy deposition in the X-ray detectors using GEANT4.

GEANT4 simulation: GEANT4 is a simulation toolkit that helps in modeling interaction of particle or photons in matter. A geometrical model of C1XS detectors mounted below copper collimators and Al filter was constructed. Protons and electrons of energy ranging from a few keV to MeV were incident upon the detector in order to determine the energy range of particles that deposit in the 1-20 keV operating range of the detector.

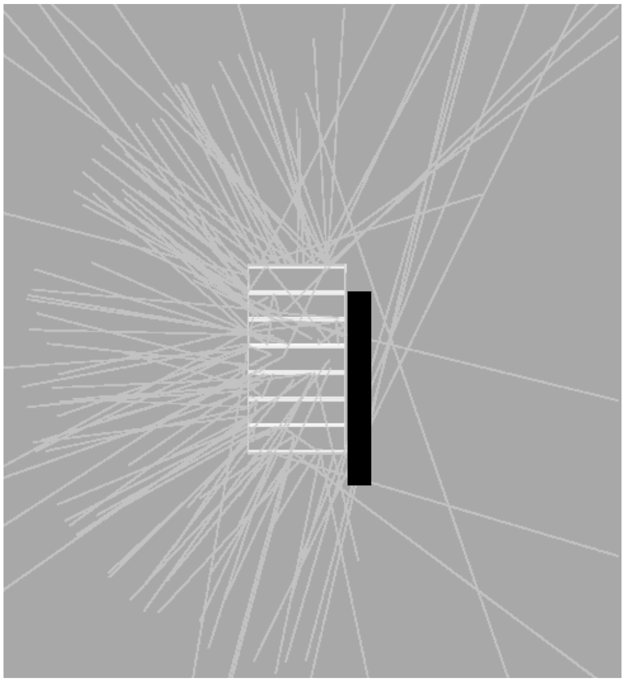

Figure 3: Particle interactions in C1XS simulated using GEANT4. Lines are particle tracks. The collimator stack above the detector is also shown.

Results: Electrons in the energy range of 10-33 keV deposit most of their energy in C1XS detectors (the fraction deposited in this energy range decreasing gradually) while for protons the range is 200-230 keV. As the energy of the particles increase beyond a few MeV, they become minimum ionizing particles (MIPs). These high energy particles (greater than a few MeV) deposit energy in the 18-19 keV range in C1XS detectors. The counts in the 18-19 keV band can thus act as a proxy for charged particle intensity measurements. (Figure 4). The particle bursts in Figure 2 can arise from various factors including time dependent changes in the geotail particle spectrum and non-uniform bunching of particles in the geotail. Converting the observed count rate in C1XS to absolute charges particle intensity requires cross calibration data which is currently unavailable and hence not pursued here.

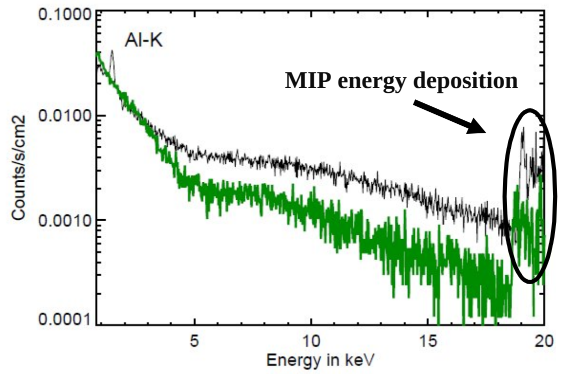

Figure 4: C1XS background spectra showing MIP signature in the 18-19 keV energy range. The lower green line is the spectrum outside geotail while the upper black line is the spectrum inside geotail. The Al-Kα line arises due to the excitation of characteristic x-rays from the visible light blocking filters.

Summary: The detector background in C1XS is found to be due to deposition of energy by low energy particles in the lunar environment. Particles in the MeV range become MIPs and deposit energy in the 18-19 keV range. We find sudden increase in particle flux as Moon passes the geotail. Finer temporal variations are also observed possibly correlated with the geotail structures. Thus background measurements provide a complementary set of data to study the geotail while in a lunar orbit.

References

[1] Grande et al, (2009) , *PSS*, 57,717, [2] Huovelin et al, (2002) *PSS*, 50, 1345 [3] Agostenilli et al., (2003) *NIM A*, 506, 250