Post-launch Calibration of the Planet-B Extreme Ultraviolet Scanner

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1. Introduction

Planet-B, which will arrive at the Mars in early 2004, is the first Mars explorer of Japan. Extreme Ultraviolet scanner (XUV) onboard Planet-B was a newly developed telescope for measuring an amount of helium gas and ions, which emit resonantly scattered light, on Martian atmosphere and ionosphere. XUV observed moonlight at a distance of 80 Earth radii (R_E) when Planet-B was in parking orbit around Earth. We study the validity of pre-launch laboratory calibration, such as sensor efficiency, line of sight (LOS), and field of view (FOV) of XUV, with analyzing observation data of the Moon.

2. Pre-launch Calibration

XUV aims at detecting resonantly scattered light emitted from He and He^+ at wavelengths 58.4nm(HeI) and 30.4nm(HeII), respectively. XUV is a normal-incidence telescope, which consists of a multilayer-coated mirror, two bandpass thin metal filters, and microchannel plates(MCPs) with multi-anodes. The mirror has 20 alternating Mo(4.1nm)/Si(12.4nm) layers with a peak reflectivity at 30.4nm. In front of MCPs, two bandpass metal filters are installed. One is Al(129.9nm) filter for eliminating longer wavelength light, which strongly emit from planetary atmosphere such as Oxygen and Hydrogen. The other is separated into 2 parts for 2 channels. One side is consists of Al(142.9nm) and the other Al(142.9nm)/C(30.8nm). Al part transmits both HeI and HeII. On the other hand, Al/C part transmits HeII and reduces HeI. The total sensitivity of XUV is shown in Fig. 1 [1].

Observation channel has geometrically a 4 x 4 degree of FOV. Fig. 2 shows calculated efficiency when photons are injected from various directions into the whole optics isotropically. The center area of FOV has a uniform efficiency. Fig. 3 shows the laboratory calibration of FOV with a sharp EUV beam. The incident angle is moved in the arrow direction in Fig. 2. The results of the calculation and the laboratory calibration are in good agreement.

3. Observation for Post-launch Calibration

XUV observed the Moon at a distance of about 80 R_E; therefore an apparent diameter of the Moon was approximately 0.4 degree. The moonlight can be treated as a point source because the apparent diameter is 1/10 size of FOV. The raw data is shown in Fig. 4. Counts are represented with the encoded color. Verti-

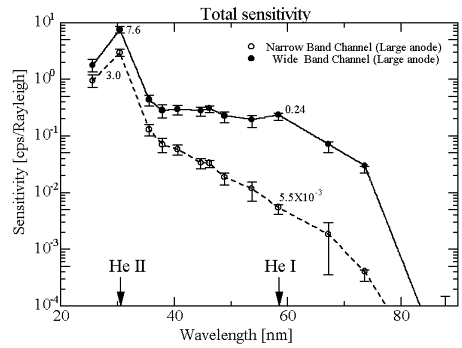

Fig. 1. Total sensitivity of XUV in pre-launch evaluation

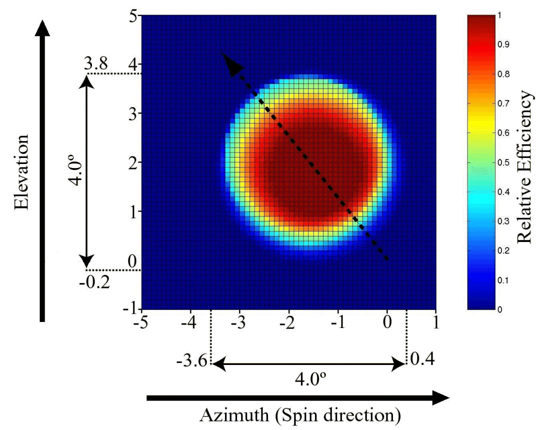

Fig. 2. Optical calculation of efficiency in FOV

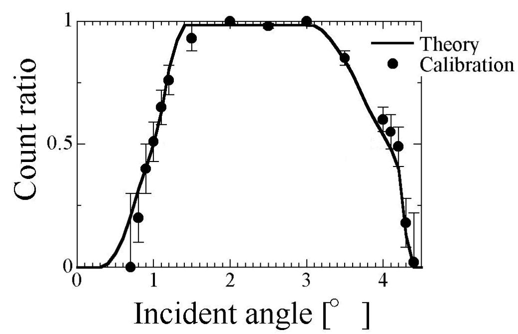

Fig. 3. Pre-launch calibration and optical calculation of FOV

cal axis represents the direction along scanning, and horizontal axis corresponding to time axis along orbiting. XUV detected moonlight in sector No. 8.

The expected count N_{obs} is expressed with the photons from the Moon $I_\lambda(\alpha)$, and the efficiency $\eta_\lambda(azimuth, elevation, t)$ at a certain direction per exposure time t as follows.

$$N_{obs} = \int_\lambda \int_t I_\lambda(\alpha) \quad \eta(azimuth, elevation, t) \quad dt\, d\lambda$$

$I_\lambda(\alpha)$ is expressed with solar irradiance πF_λ, aperture area a, solid angle subtended by the Moon as seen from XUV $d\omega_{Moon}$, total average reflectivity of the Moon b_λ, phase angle between Planet-B and the Sun as seen from the Moon α, scattering function in FUV range $\Sigma_{FUV}(\alpha)$, retrodirective function which represents lunar opposition effect $B(\alpha, g)$, and compaction parameter g as follows.

$$I_\lambda(\alpha) = \frac{\pi F_\lambda}{\pi}\, a\, d\omega_{Moon}\, b_\lambda\, \frac{1}{2}\left[1+\sin\frac{\alpha}{2}\tan\frac{\alpha}{2}\ln\left(\tan\frac{\alpha}{4}\right)\right]\Sigma_{FUV}(\alpha)\, B(\alpha, g)$$

Solar irradiance in observation is calculated from SOLAR2000/EUV flux model [2]. Scattering function and retrodirective function is used same as in FUV and Visible region [3, 4]. Reflectivity of the Moon around 30nm is assumed as 0.2% from EUVE spectrometer observation [5]. As a result, photons from the Moon are only dependent on phase angle α.

$\eta_\lambda(azimuth, elevation, t)$ is calculated from total sensitivity calibrated before launch as shown in Fig. 1 and relative sensitivity in FOV as shown in Fig. 2. Azimuth and elevation is calculated from orbit and attitude data of Planet-B at observation time.

Fig. 5 shows 400 spin accumulation count corresponding to 41.2-sec accumulation and the estimation count with the above method. The red scatters represent the observation count and the blue broken curve is the estimated one. However, those are slightly different. The observation is antecedent about 3 hours to the estimation. This antecedence corresponds to 0.7 degree of declination of LOS. The calibrated curve considering that effect gives green broken line.

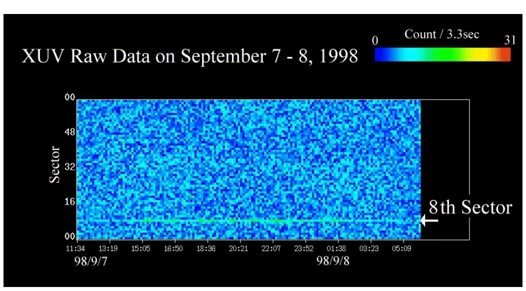

Fig. 4. XUV raw data in observation of the Moon

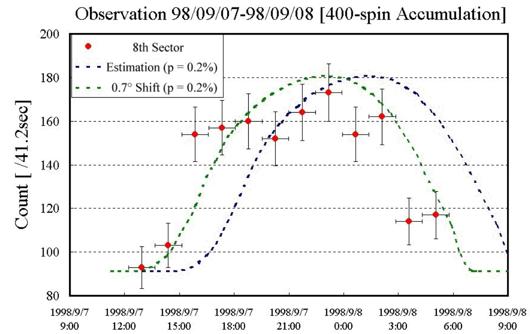

Fig. 5. Onboard calibration using moonlight observation in Sector No. 8

4. Results and Conclusions

This study is about onboard calibration with natural EUV source to validate the accuracy of sensor efficiency, FOV and LOS. The maximum count in observation is in good agreement with the estimated count. As a result, the fatal damage to XUV compared to prelaunch calibration did not occurred. Extent of FOV, which is 4 degree in elevation, was examined from the duration time when XUV observed the Moon. LOS was miss aligned approximately 0.7 degree in declination with 0.1-degree accuracy.

Those results demonstrate the capability of onboard calibration of XUV. In the future SELENE mission, which is a Japanese lunar explorer, Upper Atmosphere and Plasma Imager / Telescope for Extreme Ultraviolet (UPI/TEX) will be carried. This telescope has a wide aperture and a position-sensitive detector with more highly performance than XUV. TEX aims at taking an image of terrestrial plasmasphere from lunar orbit steadily. In additional, TEX observes the Moon and make an EUV map, which possibly indicates space weathering effect on the surface [6]. The onboard calibration of TEX is a significant phase for evaluation of observation.

References

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