Improvement of the observational performance by the pre-collimator. In addition, the flux estimation of the extended X-ray emission such as the Cosmic X-ray Backgrounds is also found to have large uncertainty due to the stray lights from the outside of the XRT FOV. We thus plan to mount the pre-collimator, which is comprised of cylindrical blades aligned with each primary mirror, onto the XRTs to reduce these stray lights. We report the reduction effect and the improvement of the observational performance by the pre-collimator.

§1 Introduction: Stray lights

The stray lights are classified as below by their passes inside the XRT:

- The stray lights work as a diffuse background in the detector field of view (FOV), and then causes the degradation of the detection limit.

The stray lights that pass through the XRTs are categorized into the following types:

1. Direct:
   - X-rays from a source located far from the telescope boresight reach the detector field of view (FOV). These X-rays, called stray lights, create a ghost image and then reduce the signal-to-noise ratio.

2. Primary only:
   - X-rays from a source located near the telescope boresight, but outside of the HXI FOV. In this case, the X-rays are blocked by the primary reflector.

3. Secondary only:
   - X-rays from a source located near the telescope boresight and also within the HXI FOV. This is the most critical type of stray lights to consider.

4. Backside:
   - X-rays from a source located far from the telescope boresight also reach the detector field of view (FOV). These X-rays, called stray lights, create a ghost image and then reduce the signal-to-noise ratio.

§2 Pre-collimator structure

The pre-collimator structure should be designed to block the secondary only component.

- Direct and Primary only components are created only at 1/1 pair of the reflectors, otherwise these passes are not allowed due to the tight packaging of the reflector shells.
- Reflector substrates are made of bare aluminum with mil-finished surface. Thus, the reflectivity for soft X-rays ($<10$keV) is sufficiently low ($<50\%$ of the theoretical values). For hard X-rays, the backside reflection is negligible (in part of the X-rays may transmit into the substrate and then be reflected on the P/C multilayer. However, we have not verified this reflection in the Spring-8 experiments yet).

To reduce the stray lights, we suggest that the pre-collimator should be mounted in front of the HX telescopes. The pre-collimator structure is the same as that mounted on the Suzaku XRT (Mori et al. 2005; Serlemitsos et al. 2007; see the below photograph): it consists of a number of the coaxially-oriented cylindrical blades, which are placed onto the corresponding primary reflector.

Schematic view of the pre-collimator structure (right figure) and the summary of the current design parameters (right table)

Expected stray-light reduction by the pre-collimator mount. We investigated two cases where aluminum ($t=150\mu$m) or stainless ($t=50\mu$m) is used as a blade material. The blade height is assumed to be 50mm. The pre-collimator reduces the stray lights from a source at 20°-30° off-axis by $>10\%$. Since the blade height is shorter than that required to block the stray lights from a 10°-20° off-axis source, a 10 – 30% of the stray lights remains at the edge of the detector. The aluminum blade is transparent to hard X-rays ($>50$keV). Thus, the reduction rate becomes less than 90% even at 20° – 30° off-axis angle.

§3 Trade-off studies

The pre-collimator consisting of a number of the blades makes the XRT vignetting narrower, although it has the advantage of the effective reduction of the stray lights without any loss of the on-axis effective area. The XRT FOV, which is defined to be FWHM of the vignetting function, decreases with the increase in the pre-collimator blade height.

We examined another trade-off, i.e., the blade material. We compared the detection limit of a point source when mounting the pre-collimator with aluminum or stainless blade. Here the backgrounds compared to the source flux are the Non X-ray Background (NXB), Cosmic X-ray Background (CXB) and the NXB emission from the outside of the XRT FOV (as stray lights). The detection limit is calculated only by the photon statistics ($>3\sigma$ limit). Since the NXB is a dominant factor of the sensitivity as shown in the right panel, the X-ray transmission of the aluminum blade is negligible.

§4 Expected Performance: Scientific Observations

The origin of the stray lights is a bright point source located outside of the XRT FOV or a diffuse source extended over the HXI FOV, such as clusters of galaxies and the CXB. Thus, the stray lights hamper the survey of the high source-density region. One of the good examples is the Galactic center. We simulated the pointing observation of the Galactic center utilizing the ray-tracing simulator.

Energy range : $4-70$keV

The green circles represent the bright point sources with fluxes larger than J1mCrab in the INTEGRAL/IBIS catalogue (Krivonos et al. 2007). The dashed squares are source-free regions. However, the stray lights from the nearby sources severely contaminate these regions. When mounting the pre-collimator, the stray lights cut completely.

Surface brightness profiles of a flat sky cloud

The numbers of the 10.88keV photons accumulated in the HXI F.O.V are $1.09\times10^{-7}$ (R = 60 arcmin flat sky without PC)

82203 (R = 6.5 arcmin flat sky without PC)

$8.628\times10^{3}$ (R = 6.5 arcmin flat sky with PC)

A $33\%$ of the photons is the stray lights from the outside of the HXI FOV. The stray lights from the outside of the HXI FOV are blocked by the AI blade pre-collimator. The stray-light cutoff is negligible.

§5 Summary

- We proposed to mount the HXT pre-collimator consisting of the aluminum blades with 50mm height and 150um thickness. The current design parameters are based on the trade-off studies (the XRT FOV and the detection limit of the HXT + HXI).
- We performed some simulations of the scientific observations (Galactic center and CXB) using a ray-tracing simulator and verified the expected performance of the pre-collimator.