Design and feasibility study of hard X-ray scattering polarimeter for small satellites

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Hard X-ray Polarimetry

We have studied design and feasibility of hard X-ray polarimeters for small satellite experiments. We first started the study for the next generation Japanese X-ray satellite, NeXT, which will employ super-mirrors, which collect X-rays from 10-80keV (see the right panel). Hard X-ray polarimetry is not only un-exploited field, but also we expect larger polarization degree due to non-thermal nature of the emission.

Although the focal-plane polarimeter is not included in the current design of NeXT, we are now considering possibility of a small satellite for hard X-ray polarimetry.

Scattering Polarimeter (non-imaging)

The sensitivity of a polarimeter is scaled with \( M_{\text{MDP}} \), where M is the modulation against 100% polarized X-ray incidence, and h is the detection efficiency. We easily get \( M_{\text{MDP}} \) \( \sim 0.4 \) with scattering polarimeters, while photo-electron tracking polarimeter achieve 0.07 according to simulation. Therefore, we first consider a scattering polarimeter with Be target as shown below. We can make the design compact, if it is placed on the focal plane of hard X-ray mirror.

Current Status and Plan

A proto-type detector of imaging type scattering polarimeter was already used in a balloon experiment on September 2003. In addition, we are doing R&D to reduce detection limit of Compton-loss signal on the ground.

Scattering Polarimeter (Imaging)

Be scattering polarimeter with a single target is not capable of imaging. On the contrary, using number of plastic scintillators as target, Compton-loss is detected, which makes imaging type polarimeter (Gunji et al., 2003),

If scattering is occurred in plastic scintillator, Compton-loss signal is detected, position sensitive PMT. Scattered photons are detected with CdTe.

Summary of simulation for the imaging type polarimeter. We assume the focal plane of 4 NeXT telescopes is available as for the left non-imaging type case. 3 MDP is for 100ks,10mCrab source. Above 20keV, MDP is almost the same as for Be non-imaging type polarimeter, though energy threshold is higher than that. The polarimeter functions as imaging type only above 40keV. If a new type of PMT (prizm photo-electron surface) is available, huge improvement is expected.

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>MDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-100</td>
<td>1.7</td>
</tr>
<tr>
<td>40-80</td>
<td>2.0</td>
</tr>
<tr>
<td>60-100</td>
<td>3.3</td>
</tr>
<tr>
<td>80-100</td>
<td>10.8</td>
</tr>
</tbody>
</table>

10% observations of bright BH,NS binaries will detect polarization degree of 2%, 100ks is enough for fainter ones.

Polarization degree expected for Be scattering polarimeters on the focal plane of 4 telescopes of NeXT. MDP is defined for 3 MDP detection.

However, this type of scattering polarimeters need multi-pointing to cover extended sources.

Either type of the focal plane polarimeter presented here is not included in the current design of the NeXT satellite. Even when the collective mirror is not available, we think the imaging type scattering polarimeter is useful with collimator.

If we use scintillators instead of CdTe, as we did for proto-type, effective area of 200cm^2 is attainable. 10 of such unit on a small satellite will provide about 1/10 area of the case we considered for NeXT. However even with 200cm^2, with 100ks observations of binary sources will yield MDP of 2%. Tens of targets is expected for such a hard-xray polarimetry satellite. The polarization detected in hard X-rays must be very much different from that in soft X-rays, reflecting the non-thermal nature of hard X-rays.

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