End-to-End Test of the Mirror and Polarimeter of PRAXyS

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Abstract

The Polarimeter for Relativistic Astrophysical X-ray Sources (PRAXyS), NASA 's small explore mission, will allow us to measure the polarization of the X-ray in the 2–10 keV energy band. We carried out an end-to-end test of the X-ray optics combining a grazing incidence X-ray mirror and a Time Projection Chamber Polarimeter for PRAXyS at the NASA Goddard Spacecraft Center 100m X-ray beamline in June and July 2016. To simulate the spacecraft rotation canceling out instrumental false polarization, the X-ray tube, mirror and polarimeter in the test were designed to rotate around the beamline axis independently. The optics was tested with 2.7 keV, 4.5 keV and 6.4 keV X-rays (and bremsstrahlung X-rays) at several combinations of angles. We checked uniformity of the mirror and performance of the polarimetry.

Key words: X-ray Polarimeter, X-ray mirror, The Polarimeter for Relativistic Astrophysical X-ray Sources (PRAXyS) mission

1. Introduction

Although polarimetry in the soft X-ray has been expected to provide a new aspect of astronomy, it is still untouched for a long time. The PRAXyS mission was designed to achieve high sensitivity polarimetry in the 2-10 keV X-ray using two identical telescopes consisting of a grazing incidence X-ray mirror and a polarimeter (**?**). The mirror focuses X-ray onto the polarimeter placed on a focal plane 4.5m away from it. The polarimeter contains Gas Electron Multipliers (GEMs) developed by RIKEN (**?**) and 128 read out strips on a 121μm pitch, and is filled with dimethyl ether at 190 Torr. Using time projection chamber techniques, the polarimeter images two-dimentional trajectories of the photoelectrons generated by incident X-ray photons (**?**). A modulation curve is described as $N(\phi) = A + B\cos^2(\phi - \phi_0)$, where A and B are constants, and ϕ_0 is the polarization angle of the source. The modulation amplitude is given as $\mu = A/(2A + B)$.

2. Experimental Configuration

We carried out an end-to-end test of the X-ray optics consisting of the X-ray mirror and 1/4 engineer model of the polarimeter on Summer 2016 at the 100m beamline of NASA/GSFC. The polarimeter was operated in the same way as that tested in **?**. An electron-impact X-ray tube was used for the X-ray source, and Rh, Ti and Fe were used for its metal target. In order to study the instrumental effects for the polarimetry, the X-ray source, mirror and polarimeter were installed and independently allowed to rotate around the beam axis.

3. Data analysis and Results

3.1. X-ray Spectra and Modulaction curves

Figure **??** shows spectra of the X-ray from Rh target taken by the polarimeter. The spectral line at 2.7 keV is fluorescence line of Rh Lα. The continuum distribution of the bremsstrahlung emission reaches 9 keV which corresponds to the voltage of the X-ray tube.

Figure **??** (a) and (b) are modulation curves extracted

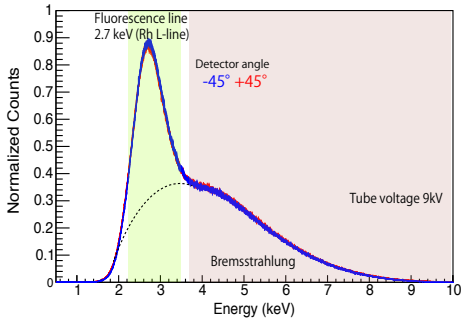

Fig. 1. Example spectra of the X-rays from the Rh target in the X-ray tube working at 9kV.

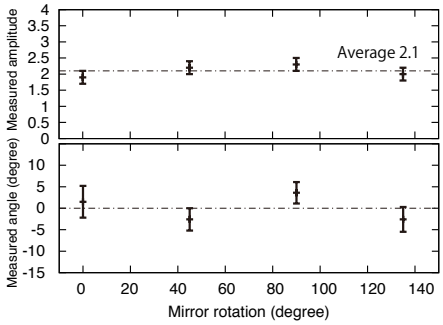

Fig. 3. The amplitude (Top) and angle (Bottom) of the modulation curve as functions of the rotational angle of the mirror.

from the fluorescence line and bremsstrahlung continuum, respectively. These curves include the response of the polarimeter as well as the beam modulation. For the response correction, we merged X-ray data taken at the polarimeter angle 45° and −45°, and obtained pseudo unpolarized X-ray data. Using this data, we made response-corrected modulation curves as shown in Figure **??** (c) and (d). The amplitude of the modulation is small in 2.7 keV as $0.5 \pm 0.1\%$, because fluorescence X-ray photons are unpolarized. On the other hand, bremsstrahlung photons are generally polarized. The modulation amplitude of of the bremsstrahlung continuum is $2.0 \pm 0.1\%$. The measured polarization angle is 1.0 ± 1.4, which consistent with the rotation angle of the X-ray tube.

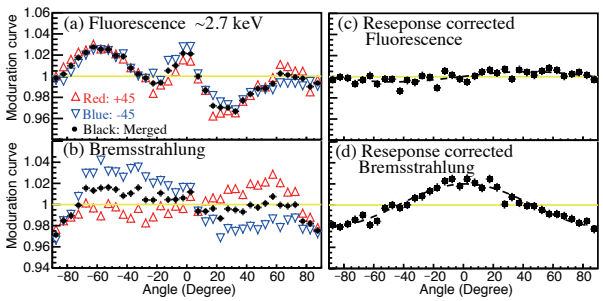

Fig. 2. (Left) Modulation curves made from (a) fluorescence and (b) bremsstrahlung X-rays. Up triangle and down triangle indicate the polarimeter angle 45° and −45°, respectively. Black indicates pseudo unpolarized data made by merging the data of the polarimeter angle -45° and -45°. (Right) Response-corrected modulation curves.

3.2. Mirror Rotation

To verify whether that the mirror made any false polarization, we rotated the mirror at 0°, 45°, 90° and 135° and fixed the rotational angle of the X-ray tube at 0°. The measured peak angles and amplitudes are constant within 1-2 σ errors across the all mirror angles as shown in Figure **??**, which means that the systematic errors introduced by the mirror is small.

3.3. Source Rotation

To change the polarization angle of the X-ray beam, we rotated the X-ray tube around the beam axis at -25°, 0°, and 16°, and took the X-ray data with the polarimeter. The polarization angle is expected to be parallel with the scattering plane of the electrons. Figure **??** plots changes of the measured polarization angles of the bremsstrahlung continuum with the rotational angles of the X-ray tube. The measured polarization angles correspond to the rotation angles of the X-ray tube.

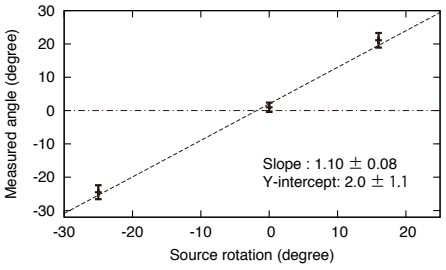

Fig. 4. Changes of the measured polarization angles with the rotational angles of the X-ray tube.

4. Summary

We performed an end-to-end test of the mirror and polarimeter for PRAXyS at the 100m X-ray beamline in NASA/GSFC. The measured amplitude was not changed with the mirror rotation within 1-2 σ errors, which means that the false modulation introduced by the mirror was less than ~ 1 %. The polarization angles of the bremsstrahlung X-rays were correctly measured across the tested angles of the X-ray tube. Further analysis is ongoing for the other data sets.

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