Characterization of a lobster-eye type X-ray telescope

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Abstract. Lobster-eye type X-ray telescopes use reflecting plano mirrors under grazing incidence and can observe a large field of view. As part of a Bavarian-Czech cooperation, two telescopes were build, equipped with mirrors coated with gold and iridium. Their X-ray characterization was carried out at the PANTER test facility, which simulates parallel starlight incident on the telescopes. The telescopes have an angular resolution of about 4 arc minutes in X-rays and a focal length of about 2 meters. The used X-ray mirrors reflect and focus visible light as well; their functionality in the optical regime was checked in laboratory tests. Now another test campaign will be carried out to examine the telescope resolution for real objects of the visible night sky and the imaging properties for star constellations.

1 Introduction

Astronomical X-ray optics were under development in the Aschaffenburg Competence Center ACCASI ("Aschaffenburg Competence Center for Astronomical and Space Instrumentation") since several years [1]. As part of a Bavarian-Czech cooperation between the Technical University of Aschaffenburg and the Technical University of Prague [2], two geometrically identical telescopes, called HORUS, were built (Fig.1).

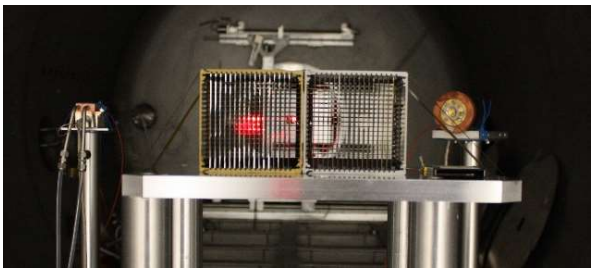

Fig. 1. The two HORUS telescopes, installed next to each other in the vacuum test chamber of the PANTER test facility, are waiting for the "First Light Event". (Photo: MPE/PANTER)

One of these telescopes was equipped with conventional gold-coated mirrors, manufactured by the Czech project partners. The 34 X-ray mirrors of the second telescope use an innovative tri-layer coating system made of chromium and iridium, which was applied in the Aschaffenburg coating laboratory [3]. Both telescopes work according to the bionic principle of a reflecting lobster eye [4]. The optics works with two consecutive reflections on mutually perpendicular mirror surfaces. This enables a large field of view with many square degrees in diameter, which, however, comes at the price of reduced angular resolution.

2 The X-ray test facility PANTER

The extensive characterization of the two HORUS telescopes was carried out at the X-ray test facility PANTER of the Max Planck Institute for Extraterrestrial Physics. The measurements took place in a 12 meter long vacuum chamber of 3.5 meters in diameter, with the X-ray source being 120 meters away. An almost parallel X-ray beam reaches the test chamber through a tube, which is also evacuated and has a diameter of one meter. This experimental set-up simulates incident parallel radiation from cosmic X-ray sources. On Earth, the atmosphere absorbs such radiation, while it spreads unhindered through the vacuum of space or in the evacuated test facility. Usually, X-ray optics of large international satellite projects (e.g. in cooperation with ESA, NASA, IKI) are characterized in the PANTER test facility - but this time the two telescopes from Aschaffenburg and Prague are tested.

3 Successful start: "First light event"

On March 8th, 2021, the mirrors of the Aschaffenburg HORUS telescope saw the X-ray light for the first time, an event known as "First Light". In times of the Corona pandemic, unfortunately, the Aschaffenburg scientists could not be present on site, they were connected via video conference directly to the PANTER control room.

During the test campaign of 195.441 seconds duration (approx. 54 hours) 536 individual measurements were carried out at the two telescopes (Fig. 2), thereby photon energies and angles of incidence were varied. Hereby a

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total number of 11,153,574 X-ray photons were individually detected, analysed and digitally processed by the sensitive CCD camera of the PANTER facility, using a prototype the eROSITA satellite camera [4].

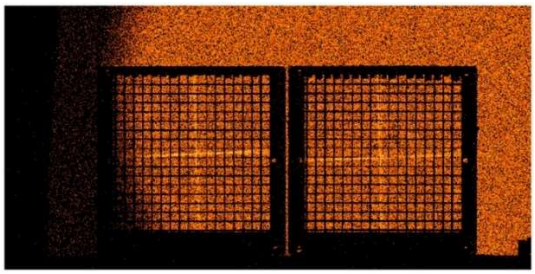

Fig. 2. The shadow of the two HORUS telescopes in X-ray illumination. (Photo: MPE/PANTER)

4 Mirror coatings are more effective

After evaluation of the measurement data, the two wide-angle X-ray telescopes have an angular resolution of around four arc minutes (Fig. 3) and a focal length of around two meters. In direct comparison with the gold-coated telescope, the new chromium-iridium tri-layer mirror coatings bring in some energy ranges the X-ray light up to 30% more effective on the focus point [3, 4]. The rich measurement datasets have been evaluated in detail, especially with regard to the imaging quality (on the optical axis and away from it), based on the analysis of individual focus images (Fig. 3).

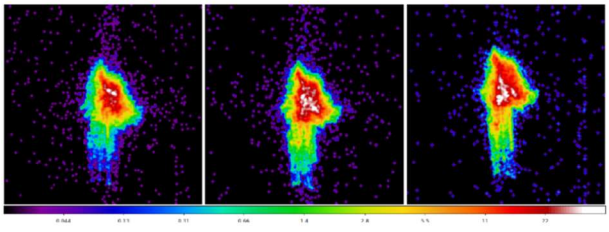

Fig. 3. The double reflection spots of the iridium coated telescope using a low energy continuum band. From left to right: Measurements at 1º, 1.6º and 2.2º. (Photo: MPE/PANTER)

5 Outlook

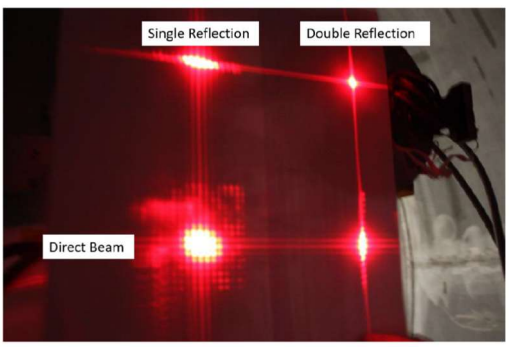

Fig. 4. Focal plane image with the laser alignment showing the location of the direct beam through the optic, two single reflection on the top and to the right side of the image, and the double reflection on the top right corner. Here the telescope optic was rotated by 2.3º in pitch and yaw. (Photo: MPE/PANTER)

As mentioned before, these Lobster eye X-ray mirrors reflect visible light in applicable quality as well. Therefore, visible light was used for a pre-alignment in standard atmosphere. An image of the laser pre-alignment inside the PANTER vacuum chamber is shown in Fig. 4. Now another test campaign is planned to examine the resolution for real objects of the visible night sky and the imaging properties of star constellations (Fig. 5). The measurements will take place at the MPE telescope in Garching and will be compared with parallel measurements using a classical astronomical telescope. The analysis of these data will provide valuable insights for the use of Lobster-Eye telescopes for intended satellite-based X-ray observations.

Fig. 5. Set-up for the night-sky measurements; here tested in the laboratory with a laser beam array. (Photo: TH Aschaffenburg)

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