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Lobster Eye X–ray optics for astrophysics: Recent status

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Abstract. X-ray optics in Lobster Eye arrangement represent promising complementary device to narrow field X–ray optics in common use. We present briefly recent status of design, developments, and tests of X–ray optics including Lobster Eye modules developed and tested within recent space project.

Key words: X–ray optics – X–ray telescopes – X–ray astrophysics

1. Introduction

X–ray optics in Lobster Eye (LE) arrangement represent promising complementary device to narrow field X–ray optics in common use. The wide field of view lobster telescope can e.g. detect and provide positions for fast, short lived transients such as gamma–ray bursts and X–rays accompanying gravitational waves, while the narrow field of view Wolter telescope provides high resolution images but can only point to known sources that have been discovered and positioned by other instruments such as the lobster telescope.

We present review of the recent status of design, simulations, development, assembly and tests of Lobster Eye X–ray optics including the modules developed and tested within the recent space projects. Various LE test modules were simulated, designed, assembled and tested at several X–ray test facilities. Selected results are briefly presented and discussed below.

2. Wide–Field Lobster Eye X-Ray Optics

The Lobster Eye (LE) optics mimic the arrangements of eyes of lobsters and was suggested in the 1970s for a very wide field X-ray imaging but used in space only very recently mostly due to severe manufacturing problems. Recently, advanced modules are available for both the Schmidt (Schmidt, 1975) and the alternative Angel (Angel, 1979) configurations, suitable for space applications.

Images in the eye of a lobster are formed through reflections off the internal walls of a lattice of small square-sided tubes arranged over the surface of a sphere. This design can be used in the construction of a grazing incidence system to focus X-rays.

The X-ray objective based on the lobster eye was proposed by (Angel, 1979), and similar design of a wide-field lens by (Schmidt, 1975). Each small channel is aligned along the radius of a sphere. A ray reflected twice off adjacent walls inside the channel is focused onto a spherical focal plane. Rays reflected only once are focused to a line causing background images to appear as a tapered cross. Some rays go through the lens with no reflections, contributing to diffuse background. The finite size of the tubes produces specific defocusing in the image, while the angle subtended by each tube at the focus limits the resolution of the system.

Despite these drawbacks, the great advantage of this design is an almost unlimited field of (Gorenstein, 1979; Gorenstein et al., 1996). This makes it ideal for use as an all-sky X–ray monitor. Up to 2017, no X–ray telescopes were launched using lobster-eye optics, mainly due to difficulty in manufacturing of the reflective tubes. However, improvements in multichannel plate technology has led to a proposal for a lobster-eye X-ray telescope could be placed on the International Space Station, and to an application on BeppiColombo (Fraser et al., 2010), and the alternative glass foil technology developed in the Czech Republic has lead to the construction of several first LE telescopes (Inneman et al., 1999, 2000). These efforts in the Czech Republic have started soon after announcing the idea of lobster optics (Hudec et al., 1995). The first LE module in space is the 1D LE optics on the VZLUSAT–1 minisatellite (Urban et al., 2017), see the dedicated section below.

The wide-field mirror modules offer advantageous application in astrophysics. The major scientific achievements of the X–ray astronomy in the past are closely related to the use of large X-ray imaging telescopes based mostly on the Wolter I X–ray objectives. These systems usually achieve excellent angular resolution as