

Effective areas of astronomical X-ray optics for cubesats and rocket experiments

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The effective area is one of the main telescope parameters when justifying real space application. We discuss the estimation of the effective collecting area of an X-ray telescope by two different methods, an analytical method and a simulation algorithm, and then compare the results. The Lobster Eye type telescopes considered here are designed for rocket experiments and CubeSat flights.

1 Introduction

The Rocket Experiment (REX) was part of a dual-payload rocket campaign for NASA's sounding rocket Black Brant IX with water recovery technology. [1] This mission was a suborbital sounding rocket flight that was launched and recovered on April 4th, 2018 and targeted the Vela supernova remnant. The purpose of REX was to classify the Technology Readiness Level of on-board devices designed for space applications. The two rocket experiments REX1 and REX2 have been done in a collaboration of the Czech Technical University in Prague and the team of Professor Randall L. McEntaffer from the Pennsylvania State University.



Abb. 1 REX 1 Launch on 03.04.2018 (Kwajalein Atoll) [1]

2 Lobster Eye telescopes for the REX Missions

The astronomical devices on board REX1 (Fig. 2) were two wide-field X-ray telescopes consisting of a combination of Lobster-Eye (LE) optics for the energy range 3 - 40 keV, with an uncooled Timepix detector, and additional sensors [2] [3] [4] [5]. In this

paper we address the problem of estimating the sensitivity of astronomical X-ray telescopes of Lobster Eye type, with emphasis on the calculation of effective areas for telescopes designed for rocket and CubeSat flights. This parameter is one of the principal parameters when justifying the real space application. Indeed, the larger the effective area is, the more efficient the optical system is, able to provide images of fainter and more distant celestial targets. We discuss the estimation of the effective collecting area of an X-ray telescope by two different methods and then compare the results: An analytical method and then a simulation algorithm based on ray-tracing.

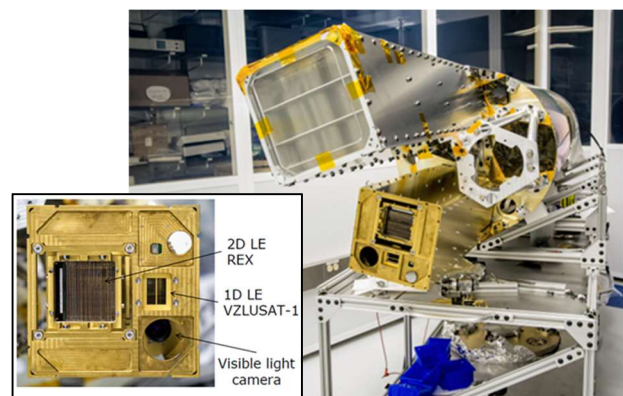


Abb. 2 Arrangement of the Multi Foil Optics for REX1 [1]

	1D optics	2D optics
Length of 1D module (mm)	56	150
Width of 1D module (mm)	29	60
Height of 1D module (mm)	31	75
Aperture (mm)	19x25	54x54
Number of foils	56	46
Foil thickness (mm)	0.145	0.3
Foil distance (mm)	0.30	0.75
Effective aperture (mm)	14x17,1	21,2x21,2
@100% reflectivity	239mm ²	448mm ²
Foil reflection surface	Au	Au
Foil surface roughness (nm)	2	2
Field of view (°)	3,5°x4,5°	0,65°x0,81°
Focal length (mm)	250	1425

Abb. 3 Parameters of the Multi Foil Optics for REX1 [1]

Optical aperture	140 x 140 mm
Dimension of foils	148 x 57 x 0.42mm
Number of foils	83
Spacing	1.26 mm
Focal length	890 mm (850/930)
FOV	4.7 x 4.3 deg
Angular resolution	5.1 x 4.7 arcmin
Effective area	6.5 cm ² @ 0.5 keV
Theoretical Gain	3 500
Transmission	56%
Energy	0.2 – 10 keV
Foil	glass + ML based on Au layer
Detector	Quad Timepix

Abb. 4 Parameters of the 2D LE optics for REX2 [6]

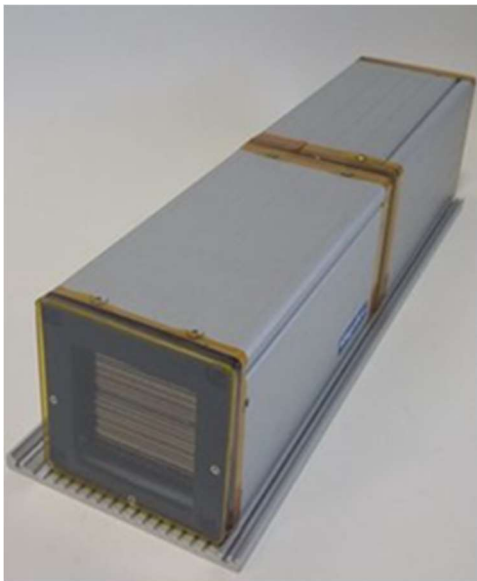


Abb. 5 The 2D LE optics for the REX2 experiment [6]

3 The analytical method

We consider that the source of the X-ray is taken to be at an infinite distance and is on the convex side of LE optic, for the application of the telescope. Analytical models are useful to approximate, even if the estimation of performance may be fast. It is also useful to determine the different parameters that impact the results.

4 The simulation method

The simulation approach was realized by Vladimir Tichy. The simulator uses a simplified ray-tracing algorithm. At first it was needed to define the mirrors we use by filling in several parameters as the pitch and the radius. We have this information in the documentation (Fig. 3 & Fig. 4). We show below the comparison between the simulation and the analytic method both for REX1 and REX2 telescopes.

The results of both methods are compared in Fig. 6. Both are in good agreement.

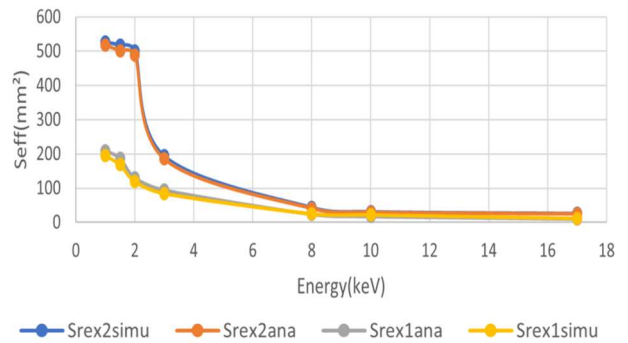


Abb. 6 Comparison of effective areas by simulation and by the analytical method for the REX1 module.

Acknowledgements

This work was performed within the Space Engineering Course at the CTU in Prague and was supported by AHEAD 2020. The AHEAD2020 project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871158. In addition this work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS21/120/OHK3/2T/13. We acknowledge the collaboration with Dr. V. Tichy and with Rigaku Prague.

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