NANOX - Proposed Nano-Satellite X-ray Mission

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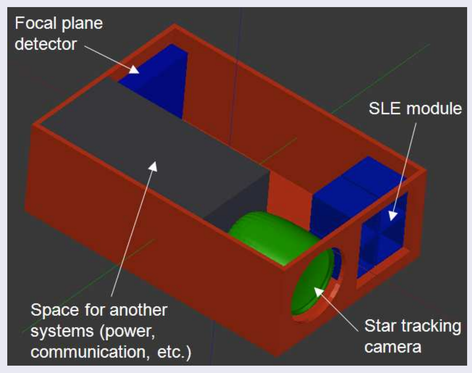
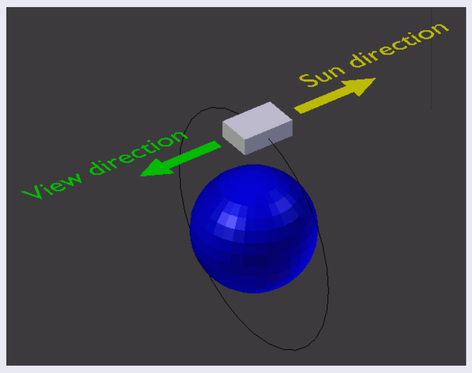
INVESTMENTS IN EDUCATION DEVELOPMENT

Motivation

Most of existing and past X-ray satellites perform pointing to a sample of object with a limited observing time allocated for a given object. This strategy enables to study faint sources with high temporal and/or spectral resolution. Mission performing long-term (weeks or months) monitoring of specific sources is lacking. However, long-term observations are required for better unterstanding of some sources, e.g. low mass X-ray binaries (LMXB) and high mass X-ray binaries (HMXB). Small and relativelly cheap nano-satellite mission could perform long-term monitoring of specific sky areas, e.g. Galactic nucleus containing plenty of such sources. There is also a technological motivation: Is it possible to do an X-ray science on a nano-satellite? Why the Schmidt lobster eye has never been used on a space mission?

Spacecraft concept - 6U CubeSat





Usage of a passive cooling is supposed. The side of the spacecraft containing heat radiators is permanently oriented opposite the Earth. The line of view of the X-ray telescope is permanently oriented (roughly) opposite the Sun.

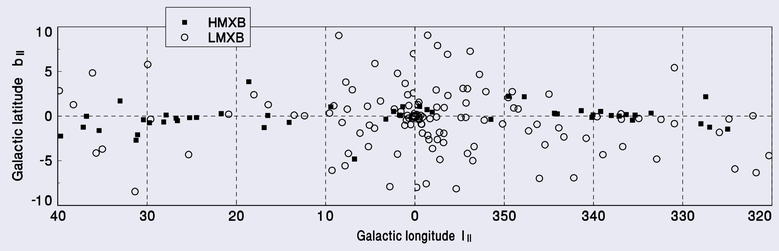
Science goals

Because of presented concept, observed area/object should lay close to the ecliptic plane. The good candidates are

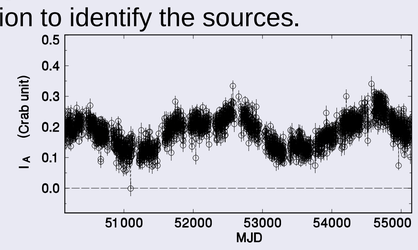
- Galactic centre
- Point opposite to galactic centre
- Crab nebula
- Large Magellanic cloud (?)

If no proper place is observable, the spacecraft can detect e.g. X-ray afterglows of gamma-ray bursts.

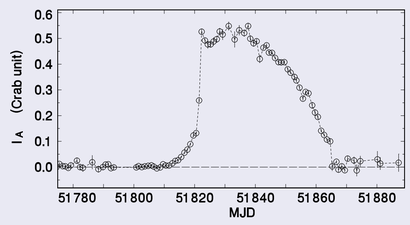
Galactic plane is the excellent area for observing HMXB and LMXB. Most of LMXB's and HMXN's are concentrated nearby the Galactic plane, namely in the center of the Galaxy



Using of small instrument with field of view in order of square degrees or more is assumed. As seen below on typical light curves, its sensitivity has to be sufficient to measure intensity in order of 100mCrab at energies of order of keV with time resolution of days. Instrument has to have sufficient angular resolution to identify the sources.



Example 1: The light curve of a persistent source GX 3+1 observed by ASM/RXTE is in the 1.5-3 keV band.



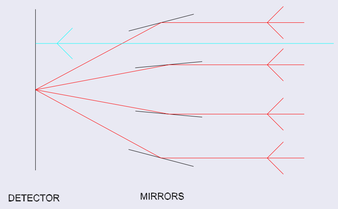
Example 2: The outburst of a transient source Aql X-1 observed by ASM/RXTE in the 1.5-3 keV band.

X-ray telescope assumptions

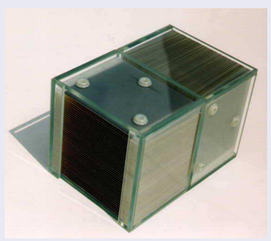
- Cooled CCD as an imager
- Optics input aperture **100** × **100**mm
- 250 mm focal length
- Energy range ca. 1 to 10 keV
- Field of view (FOV) and sensitivity have to be as large as possible

X-ray telescope based on Schmidt lobster eye (SLE) optics can follow these assumptions

One-dimensional SLE principle: Flat mirrors are arranged in an uniform radial pattern around the perimeter of a cylinder. X-rays are reflected by total external reflection. This system can provide field of view up to 100 sq. degrees and can have small mass and dimensions. Two orthogonally arranged systems in sequence form double-focusing device



One-dimensional Schmidt lobster eye principle

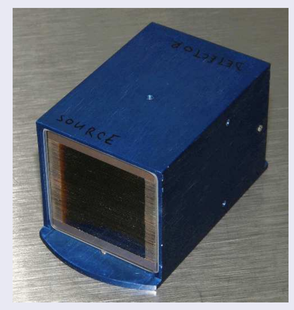


Two-dimensional Schmidt lobster eye prototype developed in Rigaku Innovative Technologies Europe, s.r.o.

Feasibility proof: Prototype SLE P-25

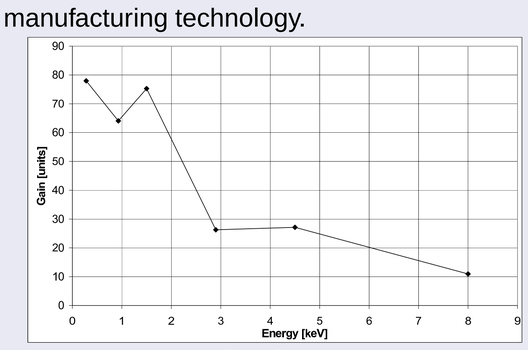
In the past, few prototypes Schmidt lobster eyes were developed in Rigaku Innovative Technologies Europe, s.r.o. One of them is called P-25. It has similar parameters as supposed on the proposed mission.

- Focal length 250mm
- Outer dimensions **35** × **35** × **50**mm
- Consists of **2** × **60** mirrors of diameters **24** × **24** × **0.1**mm
- Mirrors coated by gold
- Optimal efficiency at 1 keV X-ray photon energy

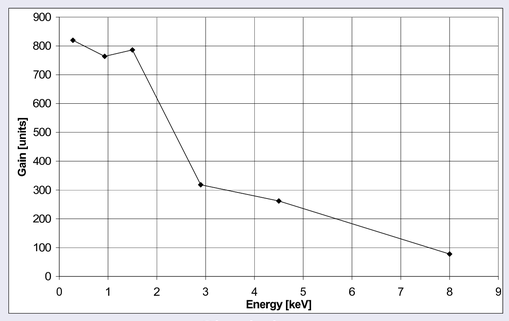


Schmidt lobster eye P25 was tested in quasi parallel beam full imaging mode using the 35 meters long X-ray beam line in XACT facility of INAF-Osservatorio Astronomico di Palermo (Italy).

- Measured FOV **2.9** ± **0.1**° is an agreement with theoretical model
- Measured spatial resolution **13** ± **1** arcmin is acceptable. Theoretical value is **5.5** arcmin.
- Measured gain as function of photon energy is shown below.
- Measured values are worse than theoretical because the specimen is older, based on worse manufacturing technology.



Experiment



Simulations

Gain is calculated as measured ratio between the flux incoming to SLE and the measured average flux of X-rays measured in the projection of the central chamber. Supposing 90% quantum efficiency of the detector, simply supposing the object is detected if at least 100 photons are focussed into spot, the resulting sensitivity for one-day monitoring is 0.46 mCrab.

Design of new SLE prototype

- Larger input area: **10** × **10**cm
- Multilayer coating to increase reflectivity at higher energies
- Better manufacturing technology
- Focal length kept at **250**mm
- Mirror thickness kept at **0.1**mm
- Mirror size **100** × **25**mm
- Number of mirrors per set 250 to 500
- Filed of view **11** × **11**°

Simulated optics properties

E [keV]	1	2	3	4	5	6	7	8	9	10
N=250	921	1129	1010	789	533	362	263	194	92	76
N=333	721	842	838	833	776	642	459	403	158	126
N=500	304	329	332	337	338	339	339	336	246	243

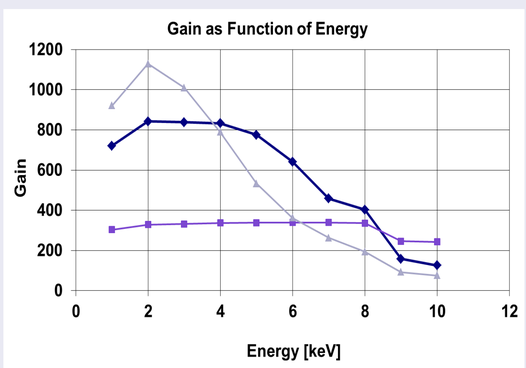
Table: Gain

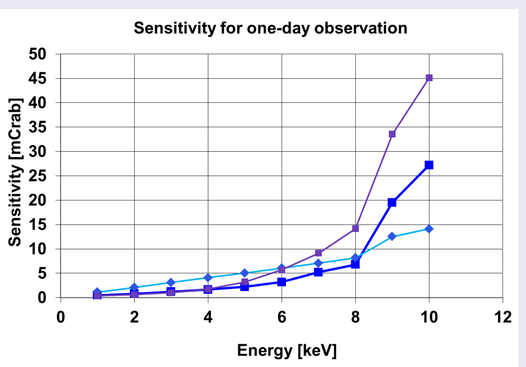
E [keV]	1	2	3	4	5	6	7	8	9	10
N=250	0.37	0.61	1	1.7	3.2	5.7	9.1	14	34	45
N=333	0.48	0.81	1.2	1.6	2.2	3.2	5.2	6.8	20	27
N=500	1.1	2.1	3.1	4.1	5.1	6.1	7.1	8.2	13	14

Table: Sensitivity for one-day observation [mCrab]

N=250	N=333	N=500
2.9	2.1	1.5

Table: Angular resolution [arcmin]





Conclusions

- The proposed mission can acquire scientifically important data for low prize.
- The optics for the presented mission is feasible.
- A new prototype of the optics is to be developed and tested.

References

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- Proc. SPIE, Vol. 8076, 80760C (2011)
- Nucl. Instr. Meth. A 633 suppl. 1 (2011) S169-S171

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