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SKY MONITORING WITH LOBSTER

R. Hudec[1,2] and V. Tichý[2]

RESUMEN

El monitoreo del cielo en rayos-X representa una extensión de la energía espectral muy valiosa al monitoreo del cielo en óptico. Los monitores de todo cielo de Lobster–Eye están capacitados para proveer una sensitividad relativamente alta y una resolución temporal buena en el rango de energías de rayos-X suaves hasta los 10 keV. La resolución temporal fina puede ser utilizada para alertar a telescopios ópticos para el seguimiento y análisis multiespectral en la luz visible.

ABSTRACT

The X–ray sky monitoring represents valuable energy spectral extension to optical sky monitoring. Lobster–Eye all–sky monitors are able to provide relatively high sensitivity and good time resolution in the soft X–ray energy range up to 10 keV. The fine time resolution can be used to alert optical robotic telescopes for follow–up and multispectral analyzes in the visible light.

Key Words: X-rays: general

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Introduction

The wide–field sky monitoring in various spectral ranges provides valuable data for multispectral complex analyzes of astrophysical sources. The X–ray monitoring is especially important as the sky in X–ray energies is rich in variable and transient sources of both galactic as well as extragalactic origin. Among physically most important transient sources, the detection of Gamma Ray Bursts (GRBs) in X-rays confirms the feasibility of monitoring, detecting and study of these phenomena by their X-ray emission (either prompt or afterglow, e.g. Amati et al.2004, and Fontera et al., 2004). For classical GRBs, the X–ray afterglows are detected in ~ 90 % of the cases (De Pasquale et al., 2003). Moreover, there are X-ray rich GRBs, (hypothetical) orphan GRBs (detectable in X-rays but not in gamma-rays due to different beaming angle) and X–ray Flashes (XRFs). These events cannot be predicted, and are relatively rare, hence very wide-field instruments are required, able to provide all–sky monitoring.

Wide field X–ray telescopes with optics are generally expected to represent an important tool in future space astronomy projects, especially those for sky monitoring and surveys in X-rays. The Lobster–Eye (LE) wide field X-ray optics has been suggested by Schmidt (Schmidt, 1975, orthogonal stacks of reflectors) and by Angel (Angel, 1979, array of square cells). In principle, up to 180 deg FOV may be achieved with these devices, but usually the developed and tested modules have smaller FOV and the larger coverage is provided by arrays of multiple modules. Obviously this X-ray optics is able to achieve very wide fields of view (FOV, 1000 square degrees and more) while the widely used classical Wolter grazing incidence mirrors are limited to roughly 1 deg FOV (Priedhorsky et al., 1998, Inneman et al., 2000).

Lobster X–ray Monitors

The LE optics in Schmidt arrangement are based on perpendicular arrays of double–sided X–ray reflecting flats. In the first prototypes developed and tested, double–sided reflecting flats produced by epoxy sandwich technology as well as gold coated glass foils were used (Inneman et al., 1999). Later, micro Schmidt lobster eye arrays with foils thickness as low as 30 microns were developed and tested in order to confirm the capability of these systems to achieve fine angular resolutions of order of a few arcmin. The thin foils are separated by 70 microns gaps in these prototypes. On the other hand, large lobster eye systems with Schmidt geometry have been designed and constructed, achieving dimensions up to $300 \times 300 \times 600$ mm (Fig.1). Their optical and X-ray optical tests have confirmed the expected performance according to calculations (computer ray–tracing). The calculations and the measurement results indicate that the lobster eye telescope based on multi array of modules with thin and closely spaced

[1]Astronomical Institute, Academy of Sciences of the Czech Republic, CZ–251 65, Ondrejov, Czech Republic (rene.hudec@asu.cas.cz).

[2]Czech Technical University, Faculty of Electrical Engineering, Technicka 2, CZ–160 00 Praha 6, Czech Republic (hudecren@fel.cvut.cz).

Fig. 1. The LE laboratory samples (Schmidt arrangements) assembled and tested in the Czech Republic

MODULE	size	plate thickness	distance	length	eff. angle	focal length	resolution	field of view	energy
	d(mm)	t(mm)	a(mm)	l(mm)	a/l	f(mm)	r(arcmin)	(°)	(keV)
macro	**300**	0.75	10.80	300	0.036	6000	7	16	3
middle	**80**	0.3	2	80	0.025	400	20	12	2
mini 1	**24**	0.1	0.3	30	0.01	900	2	5	5
mini 2	**24**	0.1	0.3	30	0.01	250	6	5	5
micro	**3**	0.03	0.07	14	0.005	80	4	3	10

glass foils (analogous to those already assembled and tested, see Fig. 1) can meet the requirements of space projects similar e.g. to the ESA ISS Lobster mission (including the angular resolution and with better transmission) and can hence represent an alternative to the alternative MCP technique (Fraser et al., 2002).

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Astrophysics with LOBSTER Monitor

The LOBSTER X–ray monitors use focusing optics increasing significantly the signal to noise ratio, hence sensitive (limiting flux of 10^{-12}erg cm^{-2}s^{-1}) limits can be achieved for daily scanning observation). The X–ray sky monitoring with large FOVs (e.g. FOV of 6 $\times$ 180 deg can be assembled on the space vehicles) is expected to contribute significantly to various fields of recent astrophysics (Sveda et al., 2009). A few most important examples are given and very briefly discussed below. It is evident that a majority of these sources is observable also in visible light and in many cases accessible to medium aperture or even small aperture robotic telescopes. (1) Gamma Ray Bursts (GRBs). Detection rates of nearly 20 GRBs/year can be obtained for the prompt X–ray emission of GRBs, taking into account the expected GRB rate 300/year. (2) X-ray flashes. Detection rates of nearly 8 X–ray flashes/year are expected, assuming XRF rate of 100/year. (3) X-ray binaries. Because of their variability in X-rays they will be one of major targets in LE observations. Almost all galactic XRB are expected to be within the detection limits. (4) Stars. Because of the low X-ray luminosity of ordinary stars, only nearby stars are expected to be observable. We estimate the lower limit of ordinary stars observable by the LE monitor as 600.(5) Supernovae. The LE monitor should be able to detect the theoretically predicted thermal flash lasting for $\sim$ 1000 sec. Together with the optical SNe detection rate and estimates of the LE FOV we estimate the total number of SNe thermal flashes observed by the LE experiment to $\sim$ 10/year (Sveda et al., 2005).(6) AGNs. Active Galactic Nuclei will surely be one of the key targets of the LE experiment. LE will be able to monitor the behavior of the large ($\sim$ 1000) sample of AGNs providing long-term observational data with good time sampling (hours). (7) X–ray transients. The LE experiment will be ideal to observe X-ray transients of various nature due to its ability to observe the whole sky several times a day for a long time with a limiting flux of about 10^{-12}erg cm^{-2}s^{-1}. (8) Cataclysmic Variables. Cataclysmic Variables (CVs) are very active galactic objects, often showing violent long-term activity in both the optical and X-ray passband (outbursts, high/low state transitions, nova explosions) as well as rapid transitions between the states of activity.

Conclusions

The various prototypes of LOBSTER modules have been produced and tested successfully, demonstrating the possibility to fly these devices on satellites and space probes. Promising results were obtained in studies of LE X–ray monitors for small satellites (including nano and picosatellites) and related tests (Tichy et al., 2009a, 2009b, 2011).

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