PROCEEDINGS OF SCIENCE

Lobster Eye X-ray Monitor and Blazars

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The X-ray sky is populated with various fascinating objects, many of which are variable or transients. Blazars are the most variable class of the Active Galactic Nuclei (AGN). Study of this kind of objects with standard instrumentation is difficult. We are introducing the Lobster Eye X-ray telescopes (LET), an ideal tools for studying variable, transient, and rare events and their possibilities of AGN/blazar analyses. It is expected that LET will contribute to study such objects as AGN, gamma-ray bursts, X-ray flashes, X-ray binaries, cataclysmic variables, stars, etc.

Workshop on Blazar Variability across the Electromagnetic Spectrum
April 22-25, 2008
Palaiseau, France

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PoS(BLAZARS2008)065

Introduction

Many impressive objects of X-ray sky are often variable or transient. Study of these objects can be very difficult and puts high demands on the basic parameters of the X-ray telescopes. They should have imaging optics together with very wide field of view and they must achieve high sensitivities. They should enable deep monitoring over wide energy range. Good resolution is also required to allow for precise localizations of objects. With regard to the mentioned requirements, X-ray Lobster Eye Telescope (LET) is the best candidate for such an instrument.

Lobster Eye Telescope

Some cameras are based on principle of refraction of light, analogously to eyes of vertebrates. The Lobster Eye telescope is inspired by the structure of the eye of lobsters, which works on principle of reflection. Lobster eye is composed of numerous squares and reflected light is focused through them onto the retina (in our conception onto a detector) (see Fig. 1).

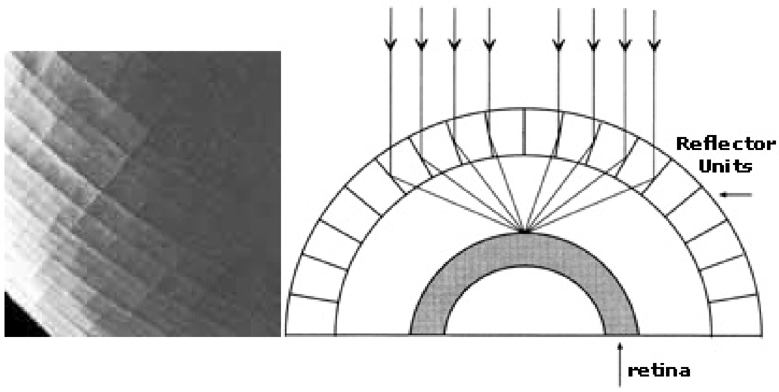

Figure 1: Rays from distant object are incoming across numerous squares, from which is Lobster eye composed. Then reflected light is focused throught them onto the retina.

The LET has X-ray optics which are proposed by Schmidt (*Schmidt et al.*, 1975) and Angel (*Angel et al.*, 1979) (see Fig. 2).

While the widely used classical Wolter grazing incidence mirrors are limited to roughly 1 square degree field of view (FOV) (*Priedhorsky et al.*, 1996; *Inneman et al.*, 2000), the FOV of LET is very wide ($\gtrsim$ 1000 square degrees). The angular resolution is less than 4 arcmin. The energy range of Lobster Eye Telescope is $0.1 - 6.0$ keV and it is expected to achieve daily limiting flux $\sim 10^{-12}$ erg cm^{-2} s^{-1}.

The prototypes of LET are designed by the Academy of Sciences of the Czech Republic. Five modules were developed and tested and we can see their basic parameters on the Fig. 3. Out of the prototypes, the model *mini 1* exhibits the most promising properties (see right panel of Fig. 4). Results of simulation for *mini 1* are compared and confirmed by experiment (see left panel of Fig. 4). Several projects with LET were proposed, but by this time, no proposals has been approved yet (*Hudec et al.*, 2006).

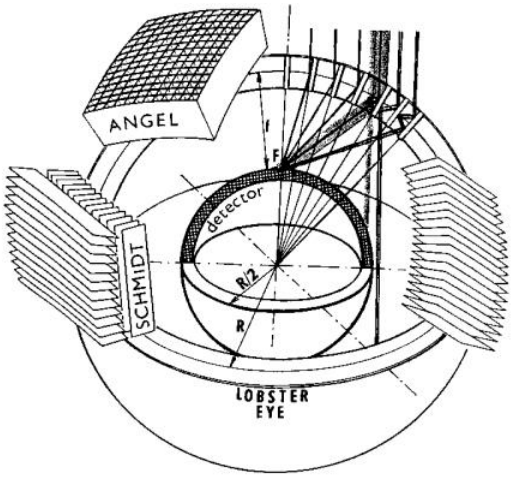

Figure 2: Lobster Eye telescope with Schmidt and Angel X-ray optics.

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	0,04	6000	7	16	3
middle	80	0,3	2	80	0,03	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	0,01	80	4	3	10

Figure 3: The table contains basic parameters of tested prototypes.

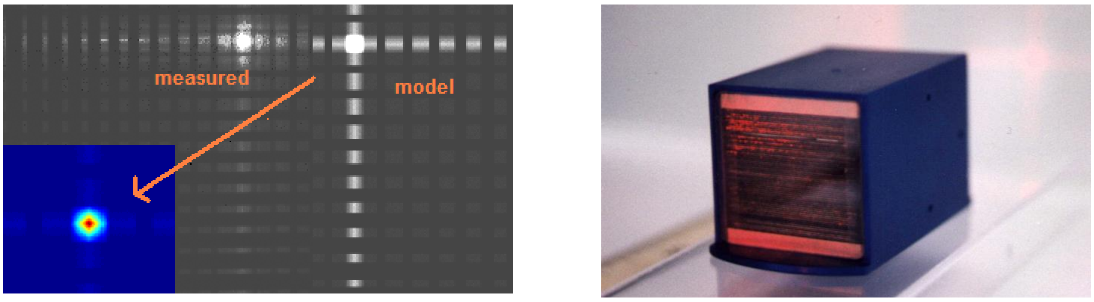

Figure 4: The image comparision between experiment and simulation (ray-tracing) for module *mini 1* is displayed on the left panel and the module itself on the right panel.

The main targets of Lobster Eye Telescope can be divided according to two work modes:

- **Alert System -** LET should detect new X-ray sources and study sudden flux changes of known sources. The most important examples are *gamma ray bursts (GRBs)* (detection rates are predicted to be around 20 – 60 GRBs per year), *X-ray flashes* (> 8 flashes per year), *supernovae (SNe) prompt X-ray emission* (10 SNe per year), *flux changes of X-ray binaries and cataclysmic variables* and *nearby stars.*

- **Long-term monitoring** with sampling rates from hours to days will include: *X-ray binaries* ($\sim$ 700 per year in the Milky Way galaxy), *cataclysmic variables (CVs)* ($\sim$ 200 CVs per year), *nearby stars* ($\sim$ 600 per year) and *AGN* ($\sim$ 4000 AGNs per year).

In the next section we will look more closely on the contribution of LET to AGN research and particularly to detection and study of variability of blazars.

Blazars

Our current understanding of Active Galactic Nuclei (AGN) is summarized in the Unified Model of AGN (on the Fig. 5). The basic idea behind it is, that all of the AGN which we observe have the same internal structure of their nucleus. All the differences among various types of AGN that we see arise from orientation dependence of the system. When we are looking directly into the jet (broad and narrow lines are visible and emission from the jet can be strong), we can see the class of AGN known as Blazars.

Blazars are the most extreme class of Active Galactic Nuclei with angle between the line of sight and jet $\lesssim 10^{\circ}$. They are very compact, highly variable energy sources. Strong variability and polarization are the most important indicators of blazars. Polarization is significant from radio to optical wavelengths and variability at all wavelengths.

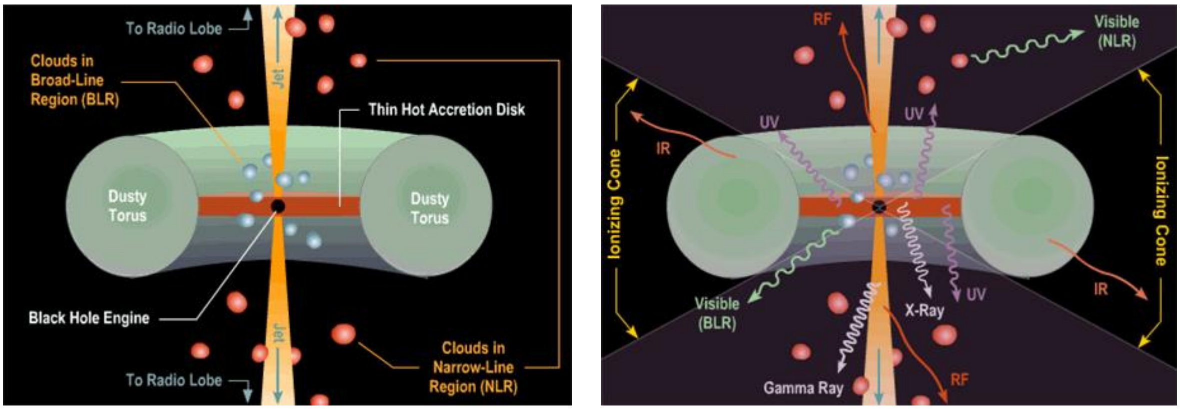

Figure 5: Unified model of AGN is shown on the left panel. The different types of radiation are emitted from individual parts of AGN (panel on the right), hence observed radiation depends on the orientation of the AGN. (Image credit: Brooks/Cole Thomson Learning)

Very actual problem is the search for correlation between variation of fluxes in different parts of electromagnetic spectrum. X-ray coverage is insufficient. For this reason, X-ray data obtained by LET can be used for searching correlation with other data.

Blazar counts prediction for LET

To show how LET can help us to study blazars, we make a prediction of how many blazars could be observed with LET. We use the data from Rosat All-sky survey bright source catalogue with total $\sim$ 18800 sources and compare fluxes of blazars with the daily limiting flux of LET.

As we see on Fig. 6, LET will be able to detect and study many blazars. Some blazars can't be detected in their quiescent state, but they will be detected with Lobster Eye telescope during flares.

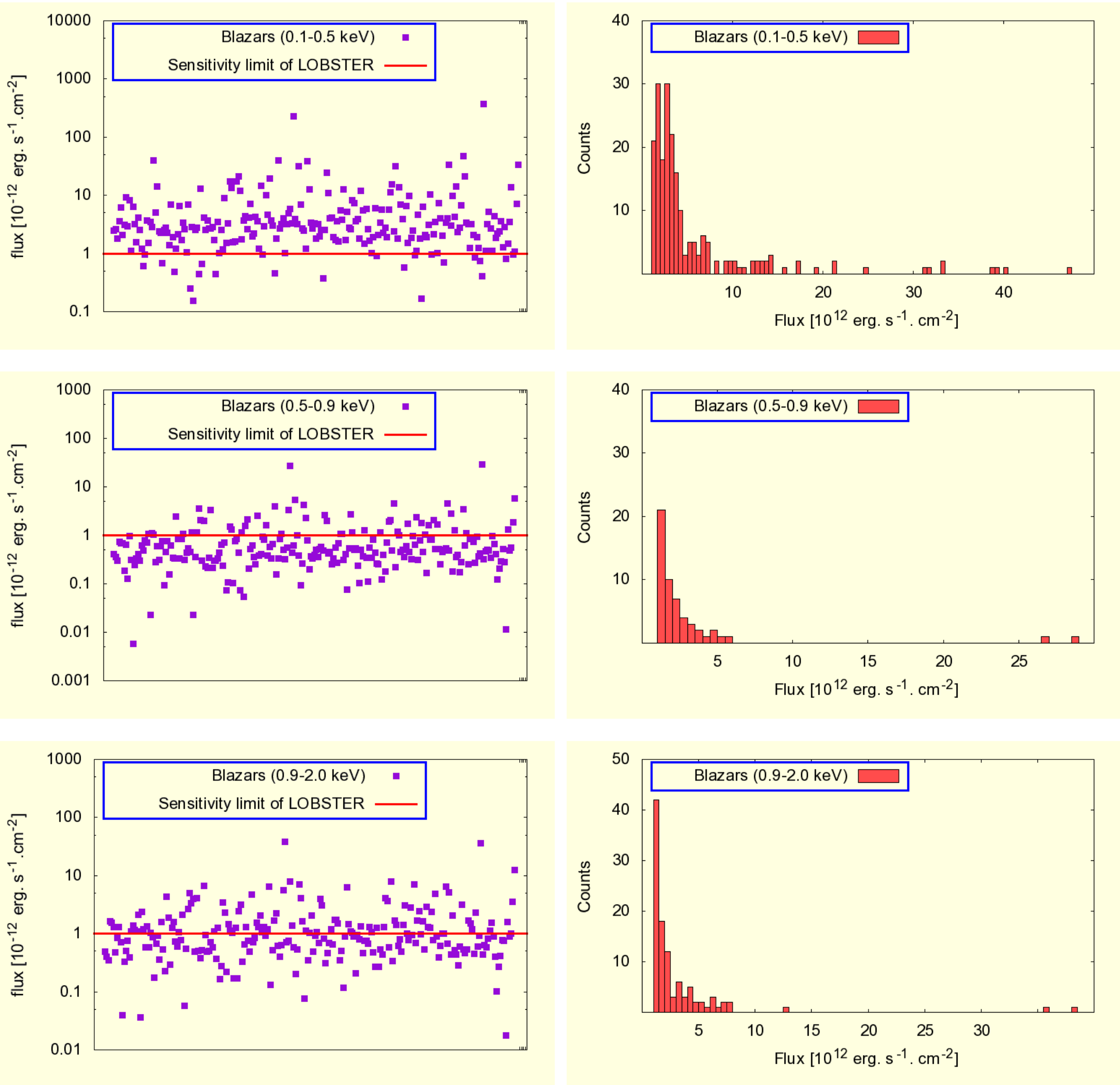

Figure 6: Graphs show fluxes of blazars for individual energy ranges compared to limiting flux for daily scanning observation of LET (left). The histograms (right) show the number of detected blazars with LET.

Conclusion

We introduced the Lobster Eye X-ray telescope, a novel X-ray telescope design with wide field of view, wide energy range and with high sensitivity. We reported on the first successful construction and tests of prototype elements. We confirm that LET is instrument that will be able to monitor objects of X-ray sky with daily limiting flux $\sim 10^{-12}$ erg cm^{-2} s^{-1} and with angular resolution < 4 arcmin in soft X-ray range.

From blazars fluxes available from the ROSAT All Sky Survey catalogue, we show that Lobster eye telescope is able to detect and to monitor a lot of blazars with daily sampling. Future missions with LET will provide an unprecedented wealth of information about these fascinating objects.

Acknowledgments

This research was partially supported by a grant 205/08/H005.

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