# Apparatus to Search for Optical Flashes of Extragalactic Origin

**"Pi of the Sky" Collaboration**

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## ABSTRACT

An apparatus is described to search for optical, point-like flashes in the sky at the time scale of seconds. Such flashes are expected to accompany gamma ray bursts (GRB) observed routinely by satellites and proven to be of extragalactic origin. So far only one such flash has been recorded, because standard methods of observational astronomy are not suitable for the time scale of seconds.
In this paper, a novel approach is proposed based on experience from particle physics experiments. An apparatus is described which monitors the sky continuously. The large data stream is analysed on-line and potentially interested events are selected by a multilevel trigger system.
In the first phase of the project the apparatus consists of two CCD cameras, especially designed for this project and a robotic mount used to scan interesting regions of the sky. In the second phase the experiment will consists of two sets of 16 cameras on fixed mounts, covering almost all visible sky.

**Keywords**: Gamma Ray Bursts (GRB), optical observations of large sky areas, all sky surveys, CCD cameras, optical flashes of sky, robotic telescopes

## SUMMARY

Perhaps the most powerful cosmic processes ever observed are gamma ray bursts (GRB) [1]. They stand for one of the most difficult and most interesting puzzles of today's astrophysics. Those are 0.1-100 s short pulses emitted by extragalactic sources. Energy of typical burst is estimated to be of the order of $10^{51}$ erg. Intensity of the burst is often higher than the total background from all other sources in the sky.

So far, phenomena responsible for GRB have not been unambiguously identified. There are hints that certain type of supernovae explosions could be the source of bursts energy. Among other hypothesis are neutron star collisions leading to black hole creation or quark star collapse. Certainly, in such kind of processes extremely high energy density states are created. Study of those processes may bring new information about fundamental interactions involved in processes responsible for bursts and give new direction to particle physics.

In order to proceed with understanding the physics of GRB one needs to observe them also in wavelengths different than gamma rays. It is natural to expect that GRB should be accompanied by bright optical flashes [2]. The outcome of optical searches has been rather limited so far. Only about 30 GRB (out of several thousand detected by satellites) were identified with optical sources. All but one were observed by large telescopes, many hours after the GRB. Only once a bright optical flash was observed, a few seconds after GRB trigger [3]. It was caught by ROTSE group equipped with a small robotic telescope. A flash was observed as bright as $8.6^m$ and could be seen by eye with simple binocular. This is only a single observation, but it stands as a proof that such flashes exist, hence the search is not hopeless.

Systematic search for such phenomena with typical astronomical equipment is rather difficult. Professional telescopes with long focal length are designed to observe faint objects and they have extremely narrow field of view (typically $30\times30$ arcsec$^2$). More suitable for this kind of search are small telescopes of relatively short focal lengths (135-500mm) with robotic mounts [4]. They are guided by satellite signals towards a given position in the sky. Unfortunately, also in this case the delay of the signal received from the satellite and the inertia of the device itself make the chance for the flash observation within a minute to be rather small.

In the present paper we propose an approach completely different from the classical one. Two major drawbacks of classical robotic telescopes are long trigger signal propagation time and large mechanical inertia of the device. The former one can be overcome by self-triggering and/or pipeline memory. The later one can be eliminated by a static design. The static design implies full hemisphere coverage to achieve high efficiency. This in turn leads to large data volumes. With required time resolution of the order of seconds the data stream is impractical to write on any mass storage. Most of the data analysis must be done in real time. Only small fraction of the data can be stored, which calls for a multi-level trigger system.

We have designed a system, which consists of two sets of CCD cameras installed on fixed mounts and working in coincidence. Each set contains 16 cameras covering almost all visible sky. A single camera is equipped with lenses of focal length $f$=50mm and aperture $d$=$f$/1.4. It covers $35° \times 35°$ field. Exposure time of 5s should give limiting magnitude about $11^m$. The camera contains a $2000 \times 2000$ pixels CCD with 15 μm pixels. It is cooled with a stack of Peltier modules. The electronics is designed for fast readout of 2 MHz / pixel in order to read the entire chip in 2s. Clocking and control of the camera is realised with an FPGA, which makes the system flexible. Digitisation is performed with 16-bit ADC. On board RAM makes possible to read out the previous frame while the next one is under exposure. The data are readout with USB 2.0 interface. Communication with PC ad overall camera steering is performed by Cypress FX2 processor. The processor software and FPGA configuration can be upgraded remotely via USB interface. Special attention was given to a shutter design. Assuming 5s exposures all night for a couple of years the shutter must sustain over $10^7$ cycles.

In the first phase of the project only two cameras are used, working in coincidence. They are placed on a two-axes motorized mount with a "go-to" capability. The mount is based on the design made for the ASAS project [5]. It can reach any point in the sky in 20 seconds with precision of the order of arc second. The system has been already built and it is being currently tested.

The apparatus will be installed this summer in Las Campanas Observatory in Chile. By the time of the conference we expect to have the first results.

## REFERENCES

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