Search for GRB optical counterparts with "*Pi of the Sky*" apparatus

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Abstract. "Pi of the Sky" is a detector designed to search for optical flashes of the cosmic origin in the sky. Its primary goal is to look for optical afterglows associated with the gamma ray bursts (GRB), but it is capable to detect also other optical transients of extragalactic origin. The apparatus consists of two arrays of 16 cameras each, which allow for simultaneous observation of the whole sky. Due to on-line data analysis in the real time, it has self-triggering capability and can react to external triggers with negative time delay. The prototype with two cameras has been installed at Las Campanas (Chile) and is operational from July 2004.

Keywords: Gamma Ray Bursts (GRB), afterglows, optical flashes, detectors, robotic telescopes
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"PI OF THE SKY" GENERAL IDEA

Understanding mechanisms of GRB requires information from early time after and even before the GRB itself [1]. Systematic study of early optical flashes accompanying GRB could impose strong limitations for theories explaining bursts mechanism. In order to overcome limitations of classical robotic telescopes we propose to build a system consisting of a number of CCD cameras covering as wide field of view as possible. The cameras continuously monitor the sky by taking relatively short (5-10s) exposures. The data are analyzed on-line, in search for optical transients [2], selected events can be submitted to larger telescopes to follow. The data can be stored on disks for a few days, in order to be re-examined in case late GRB trigger arrives.

APPARATUS DESIGN AND WORKING PROTOTYPE

The design assumes that the large part of the sky is observed continuously. This is achieved by two sets of 16 CCD cameras, with each camera covering $20^\circ \times 20^\circ$ field of view (FOV). The total FOV of the system is thus 2×2 steradians. The two sets observe

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the same part of the sky from distant (∼100km) locations to enable rejection of near-Earth objects by parallax. Each camera has a CCD of 2000×2000 pixels of $15 \times 15\,\mu\mathrm{m}^2$ Cameras are equipped with CANON EF f=85mm, f/d=1.4 photo lenses. This gives the pixel scale of 0.6 arcmin/pixel. The expected limiting magnitude for 10s exposures is 12^m and for 20 exposures added together it is 14^m. The apparatus is currently under construction. A prototype consisting of two cameras has been build and installed at Las Campanas Observatory (LCO) in Chile. Regular operation started in July 2004. The system consists of two custom designed CCD cameras installed on robotic mount [3].

FIRST RESULTS FROM THE PROTOTYPE

During almost one year of running the system detected about 100 optical flashes of unknown origin, which were seen by two cameras, but only on single frame. 7 flashes visible in at least two consecutive frames have been observed. It is rather improbable that these are caused by flashing satellites. One case was unambiguously identified with an outburst of the CN Leo flare star (Fig.1). This observation confirms that the system is capable of automatic discovery of true optical flashes. From 1.07.2004 to 7.08.2005 satellites observed 89 gamma ray bursts with known positions. Most interesting limits for optical counterparts of GRB set by "π of the Sky" are :

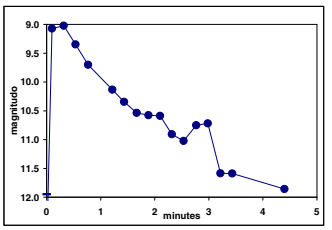

Fig.1 Outburst of CN Leo observed on 2.04.2005 at 1:13:42 UT

- GRB 040825A : $>10^m$ for t<t_0-11 s , $>12^m$ for t = t_0 , $>9.5^m$ for t>t_0+7 s
- GRB 050412 : $>11.5^m$ for t<t_0-11 s , $>11^m$ for t = t_0 , $>11.5^m$ for t>t_0+7 s
- GRB 050607 : $>12.5^m$ for t>t_0+60 s

More information can be found in ref. [4].

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REFERENCES

1. B. Paczynski, *astro-ph/0108522* (2001).
2. L. Piotrowski, *Proc. SPIE* **5484**, 290–299 (2004).
3. A. B. et al., *New Astronomy* **10**, 409–416 (2005).
4. *"Pi of the Sky" web page, http://grb.fuw.edu.pl* (2005).