Pi of the Sky Telescopes in Spain and Chile

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Abstract

Pi of the Sky is a system of robotic telescopes designed for observations of short timescale astrophysical phenomena, e.g. prompt optical GRB emissions. The apparatus is designed to monitor a large fraction of the sky with 12–13^m range and time resolution of the order of 1–10 seconds. In October 2010 the first unit of the new Pi of the Sky detector system was successfully installed in the INTA El Arenosillo Test Centre in Spain. We also moved our prototype detector from Las Campanas Observatory to San Pedro de Atacama Observatory in March 2011. The status and performance of both detectors is presented.

Keywords: Gamma Ray Burst (GRB), prompt optical emissions, optical flashes, nova stars, variable stars, robotic telescopes.

1 Introduction

Pi of the Sky [4] is a robotic telescope designed for observations of short timescale astrophysical phenomena, especially for prompt optical counterparts of Gamma Ray Bursts (GRBs). Other scientific goals include searching for nova and supernova stars and monitoring interesting objects such as blasars, AGNs or variable stars. The apparatus design allows us to monitor a large fraction of the sky with good range and time resolution. The Pi of the Sky project involves scientists, engineers and students from leading Polish academic and research units: the Andrzej Soltan Institute for Nuclear Studies, the Center for Theoretical Physics (Polish Academy of Science), the Institute of Experimental Physics (Faculty of Physics, University of Warsaw), Warsaw University of Technology and the Space Research Center (Polish Academy of Science).

The detector was designed mainly to search and observe prompt optical counterparts of GRBs during or even before gamma emission. To manage this goal it is necessary to develop advanced and fully automatic software for real-time data analysis and identification of flashes [2]. The standard approach assumes reaction to satellite alerts distributed by the Gamma Ray Burst Coordinates Network (GCN) [1] and moving the telescope to the target as fast as possible. This approach does not allow us to observe an optical emission from the source exactly at the moment of or before the GRB explosion, which is crucial for understanding the nature of GRBs. Pi of the Sky applies an innovative solution, which assumes continuous observation of a large part of the sky to increase the possibility of catching a GRB and a self-triggering system to detect flashes. The observations of the famous "naked-eye" GRB080318B have confirmed the usefulness of this strategy.

2 The prototype

Tests of hardware and software were performed with a prototype, which is just a small version of the final detector. The prototype is equipped with two custom-designed 442A 2 048 × 2 048 CCD cameras equipped with Canon telephoto lenses with focal length $f = 85$ cm, $f/d = 1.2$ and covering a $20^\circ \times 20^\circ$ field of view. The pixel size is $15 \times 15\ \mu\mathrm{m}^2$, which corresponds to 36 arcsec in the sky. The CCD is cooled with a two-stage Peltier module up to 40 degrees below the ambient temperature. Both cameras observe the same field of view with a time resolution of 10 seconds. The limiting magnitude for a single frame is 12^m and rises to 13.5^m for a frame stacked from 20 exposures. This rather short magnitude range is determined by the system design and by the observational strategy. All observations are made in white light and no filter is used, except for an IR-cut filter in order to minimize the sky background. Since May 2009 we have had a Bessel-Johnson R-band filter installed on one of the cameras in order to facilitate absolute calibration of the measurements. The prototype worked at the Las Campanas Observatory (LCO) in Chile from June 2004 till the end of 2009 (see Figure 1). In 2008 the prototype automatically recognized and observed the prompt optical emission from the famous "naked-eye" GRB080319B. These spectacular observations confirm the efficiency of the flash recognition algorithms and the usefulness of the observational strategy.

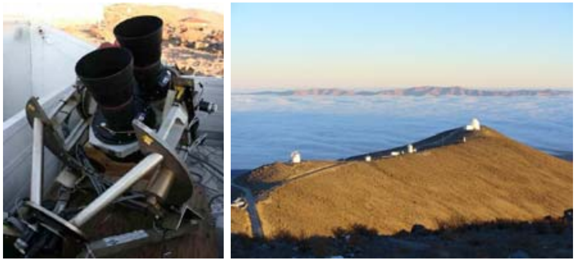

Fig. 1: Pi of the Sky prototype (left) located at the Las Campanas Observatory (right)

2.1 Moving the prototype from LCO to SPdA

In March 2011 the prototype was moved from LCO and installed in the San Pedro de Atacama Observatory (SPdA) (see Figure 2). The new location is situated approximately 740 km north of the previous location and about 2 400 meters above sea level. Thanks to the shorter distance to the equator, the observed part of the sky is larger than that at LCO. The new site was selected because of the good and stable weather conditions. The sky is clear or almost clear for more than 80 % of the night. In 2010 there were 309 observing nights. The SPdA hosts several robotic telescopes, e.g. the 40 cm telescope from the Institute of Astrophysics of Andalusia, the 40 cm telescope used for exoplanet work on behalf of the Microfun project, and a variety of “tourist” telescopes. The observatory is coordinated by Alain Maury, who provides support, general maintenance and improvements for these telescopes. Alain Maury’s weather station also provides real-time information about weather conditions.

Fig. 2: Pi of the Sky prototype (left) located in the new dome at SPdA (right)

3 New detector unit in Spain

The prototype is only a small version of the final detector. In October 2010 the first unit of the Pi of the Sky detector system was successfully installed in the INTA El Arenosillo test centre in Mazagón near Huelva, Spain, on the coast of the Atlantic Ocean. The final system consists of 4 CCD cameras on one specially designed equatorial mount (see Figure 3). The custom-designed cameras are an improved version of the cameras developed for the prototype system operational in Chile. Cameras with STA0820 2k $\times$ 2k CCD chips are equipped with EF Canon lenses with a focal length $f = 85$ mm ($f/d = 1.2$) and together cover a $40^\circ \times 40^\circ$ field of view.

Fig. 3: New Pi of the Sky unit located in Spain

3.1 Observation mode

The custom-designed equatorial mount located in Spain is an improved version of the mount developed by G. Pojmanski for the prototype system operational in Chile. The original design was scaled up to hold 4 cameras and, thanks to the mechanism for deflecting the cameras (see Figure 4), it enables work in two operation modes:

- Common-target (DEEP), when all cameras point at the same object
- Side-by-side (WIDE), with cameras covering adjacent fields (see Figure 5).

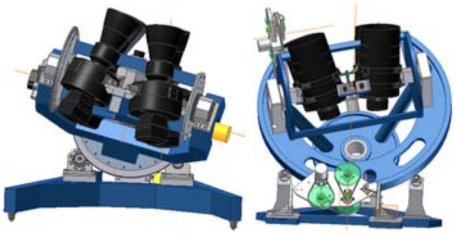

Fig. 4: Mount design with 2 CCD cameras (prototype in Chile)(left) and for 4 CCD cameras (new detector unit in Spain) (right)

Fig. 5: Two modes: side-by-side (left) and common target (right)

With harmonic drives, encoders and control solutions based on Ethernet and the industrial CAN standard, the new design of the telescope mount provides much better pointing accuracy and a shorter reaction time than the prototype.

4 The ultimate system

The full Pi of the Sky system will consist of two sites equipped with 12 custom-designed CCD cameras on 3 equatorial mounts each, separated by a distance of about 100 km. The first new unit has already been installed near Huelva, and we are planning to install the second site near Malaga (see Figure 6). Pairs of cameras will work in coincidence and will observe the same field of view. The system is designed to identify and remove the reflections from the satellites by the parallax and eliminate cosmic rays by analyzing the coincidence on both cameras. This will significantly improve our real-time flash recognition algorithms, while a test performed by the prototype revealed that the most common background sources are flashes due to cosmic rays and near-Earth flashes from Sun light reflections from satellites. The whole system will be capable of continuous observations of about two steradians of the sky, which roughly corresponds to the field of view of the BAT instrument on board the Swift satellite [3]. The final system will largely allow the elimination of time for re-pointing the telescope to the coordinates from GCN and the dead time for decision process and signal propagation from the satellite to GCN and from GCN to a ground-based telescopes.

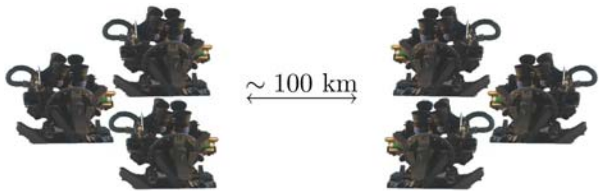

Fig. 6: Scheme of the final system

5 Summary

The prototype working in the period 2004–2009 in the Las Campanas Observatory was successfully moved and installed in the San Pedro de Atacama Observatory (SPdA) in March 2011. In October 2010 we managed to install the first unit of the new Pi of the Sky detector system in the INTA El Arenosillo Test Centre in Spain. Both Pi of the Sky instruments operate in the fully autonomous mode, practically without any human supervision and search for short timescale astrophysical phenomena.

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