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# Small robotic telescopes for HEA in Ondřejov

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**Abstract** We report on two small-aperture robotic telescopes called BART and D50 operated in Ondřejov. Both telescopes are capable of automatic observation of gamma-ray-burst optical counterparts. The coordinates of the GRBs are taken from GCN alerts distributed via internet. The telescopes observe other interesting high-energy sources when there is no GCN alert. The smaller telescope, BART, has an aperture D of 254mm. The bigger telescope, D50, has an aperture D of 500mm. Both telescopes are controlled by GNU software RTS2 and are accesible through internet. We describe the two telescopes and related SW and show some results such as our first observed optical counterpart of a GRB.

**Keywords** robotic telescopes · BART · D50

## 1 Introduction

The high-energy-astrophysics (HEA) group of the stellar department of the Astronomical Institute AS CR in Ondřejov operates two small-aperture robotic telescopes called BART and D50. Both telescopes are capable of automatic observation of optical counterparts of gamma-ray bursts. The coordinates of the GRBs are taken from GCN alerts distributed via Internet. The telescopes observe other interesting high-energy sources when there is no GCN alert (selected INTEGRAL fields of view or, in future, GAIA fields of view).

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## 2 Advantages

The advantage of these two telescopes lies in the possibility of observing at a time when other (distant) telescopes do not have a clear night sky, or when the object of interest is either in the day sky or below the horizon. There are only a few telescopes for observing GRB locations in central Europe. Both telescopes are inexpensive because we used commercial low-cost optical tubes, astronomical CCD cameras, a mount, and other devices. Another advantage is their accessibility. Students can reach the observing site easily and learn to observe; moreover, development and maintenance are easier than with a robotic telescope at a large distance. In this respect, telescopes located near Universities and large Institutes can serve as training and educational devices.

## 3 The BART telescope

The Burst Alert Robotic Telescope (BART) is the first robotic telescope in the Astronomical Institute AS CR. The goal was to build a small-aperture telescope devoted to fast follow-up observation of GRBs to search for their optical counterparts. It is made of easily accessible parts and devices. It has been observing since the year 2001. The development of the devices and software required for autonomous operation continued in the following years.

The main parts of the BART telescope are a Schmidt-Cassegrain Meade LX200 optical telescope assembly, a CCD camera and a Losmandy HGM Titan equatorial mount with Gemini GoTo positioning system. The Meade telescope has an aperture of 254mm and a focal length of 1.6m. The telescope is equipped with an FLI Maxcam CM8 CCD camera with a Kodak KAF-1602



**Fig. 1** The BART telescope on its equatorial mount; wide-field camera at the top

CCD chip, an FLI filter wheel with Johnson photometric BVR<sub>12</sub> filters, and an FLI digital focuser. The field of view is  $30 \times 20$  arc minutes. There is a wide-field camera attached to the main telescope body. This camera consists of a Rubinar teleobjective and an FLI IMG6303 CCD camera with a Kodak KAF-6303 CCD chip. The Rubinar teleobjective has a focal length of 500mm and a focal ratio of 5.6. The field of view is  $3.1 \times 2.1$  degree. All these devices are connected to a PC by USB, except for the mount, which uses the RS232 serial port. They are controlled by RTS2 software. The telescope is located in an observation room with a sliding roof. The roof is driven by an electromotor and can be opened or closed remotely by the PC. There is a precipitation detector connected to the PC to ensure that the roof is closed if it rains or snows.

#### 4 The D50 telescope

The D50 telescope is the second robotic telescope of our HEA group. It is located near the BART telescope. The goal was to build a low-cost alert telescope bigger than the BART for the follow-up observing of GRBs and other interesting high-energy sources. It allows us to see fainter objects. The first testing observation began in January 2008. The observing is not fully automated yet.

The D50 is a Newtonian telescope with a primary parabolic mirror with a diameter of 500mm and a focal length of  $f=1.975\text{m}$ , giving a focal ratio of 3.95. The mirror is aluminium-coated. It has been hand-shaped by our group member Dr. Cyril Polášek. The secondary

flat mirror is  $100 \times 141$  mm and also has an aluminium coating. This telescope is equipped with an FLI IMG4710 CCD camera with back-illuminated chip (E2V CCD47-10), a Televue Paracorr PSB-1100 coma corrector, an FLI digital focuser, and an FLI filter wheel with Johnson photometric BVRI filters. The effective focal length with the coma corrector is 2277mm. The field of view is  $20 \times 20$  arc minutes with a resolution of 1.18 arc-sec/pixel. The limiting magnitude of the main telescope in the V filter is 17.7 mag (V) for 10 seconds of exposure time. This extrapolates to  $\sim 20$  mag for 10 minutes of exposure time. There is also a small wide-field camera attached to this telescope. This uses a 500mm Rubinar teleobjective and an FLI CM8 CCD camera with Kodak KAF-1602 CCD chip. Its field of view is  $1.58 \times 1.05$  degree. The wide-field camera is parallel to the main telescope axis. It is used for centering the field of view of the main telescope and for checking its position during the observation. The telescope has shielding against stray light inside the frame, made of a double layer of black fabric. The telescope is supported by a restored old equatorial fork mount with new stepper motors and controllers. All these devices are connected to a PC and controlled by RTS2 software. The telescope is located in a small observing house with a sliding roof. The roof is driven by an electromotor and can be opened or closed remotely by the PC.

#### 5 The RTS2 software

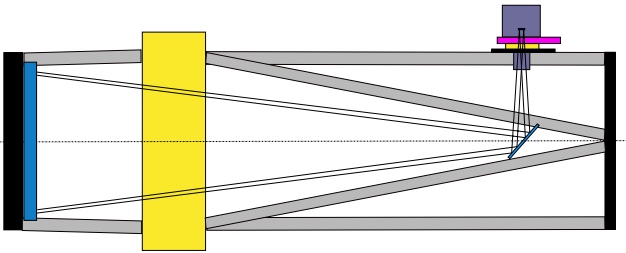
Both telescopes are controlled by RTS2 software [2, 3] written by Mgr. Petr Kubánek and are accessible through the Internet. RTS2 means Remote Telescope System, 2nd version. It is an integrated open source package for remote telescope control under the Linux operating system. It can control various cameras, photometers, mounts and dome controllers. RTS2 can perform a whole observation from choosing targets from a database, opening and closing the roof, moving the telescope, taking exposures and calibration images, processing images and storing their WCS coordinates and other data in the SQL database. There is a module for receiving and processing the GCN gamma-ray-burst alerts. It immediately moves the telescope to the coordinates received through the alert message and starts the observation according to a script for GRBs. Every object in our database has its own identification number and observing script. The script describes the length and number of expositions and photometric filters used for each observation of an object. The RTS2 software package includes a program for monitoring the actual state of all devices and daemons and for changing selected state parameters. It can run remotely us-



**Fig. 2** The D50 telescope on its equatorial fork mount



**Fig. 4** The D50 telescope with the uncovered primary mirror



**Fig. 3** The optical layout of the D50 telescope; left: the primary mirror; top right: the CCD camera

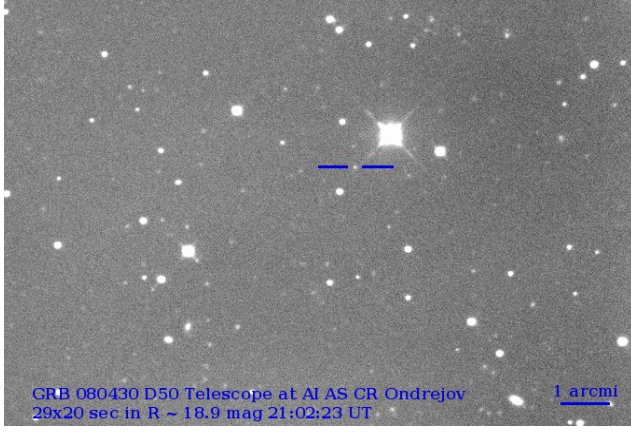


**Fig. 5** The primary mirror in the D50 telescope

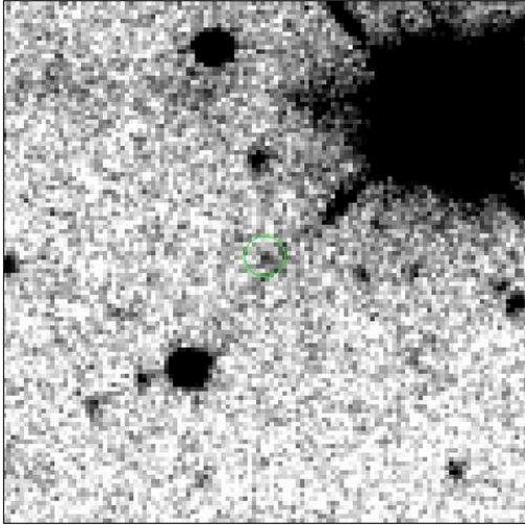
ing alphanumeric terminals or their emulators (xterm). It also includes several utilities for adding new targets and their observing scripts, generating a list of targets stored in the database or showing information about selected target. There are more robotic telescopes controlled by RTS2, e.g. BOOTES in Spain, FRAM in Argentina and Watcher in South Africa.

## 6 GRB080430

We celebrated the first successful detection of the optical counterpart of the gamma-ray burst GRB080430 by the D50 telescope on 30 April 2008. The object was seen at 18.9 mag in the R filter one hour after the detection by the satellite. One day after the detection it



**Fig. 6** The first image of the optical counterpart of GRB taken by the D50 telescope ( $R=18.9\text{mag}$ ) on 30 April 2008

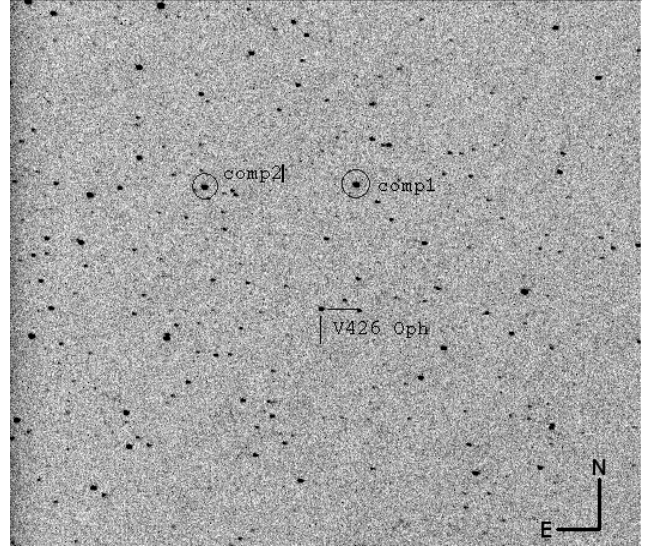


**Fig. 7** The image of GRB080430 taken by D50 approximately 27 hours after the detection ( $R=20.2\text{mag}$ )

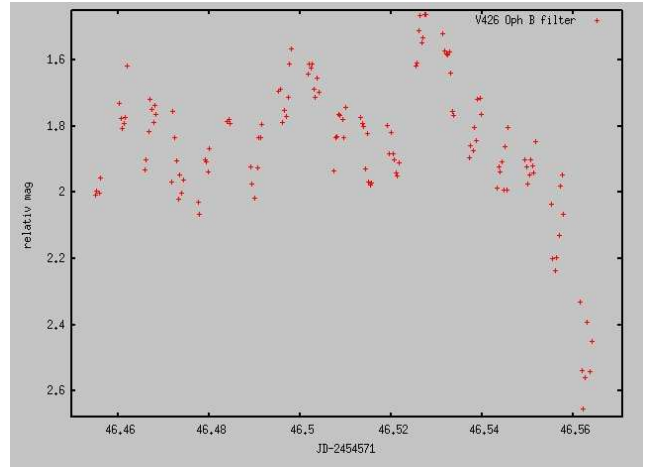
was seen at about 20.2mag (see Figs. 6, 7). The results have been published in GCN circular #7651. The gamma-ray burst lasted about 30s. The object is very distant: its redshift is 0.75, as measured from its optical spectrum. We also observed other high-energy objects, such as INTEGRAL gamma-ray sources. One example of such a candidate is the potential intermediate polar V426 Oph (see Figs. 8-10). Thanks to the D50 telescope we can observe many more objects than in the past, nature permitting.

## 7 Image data and archiving

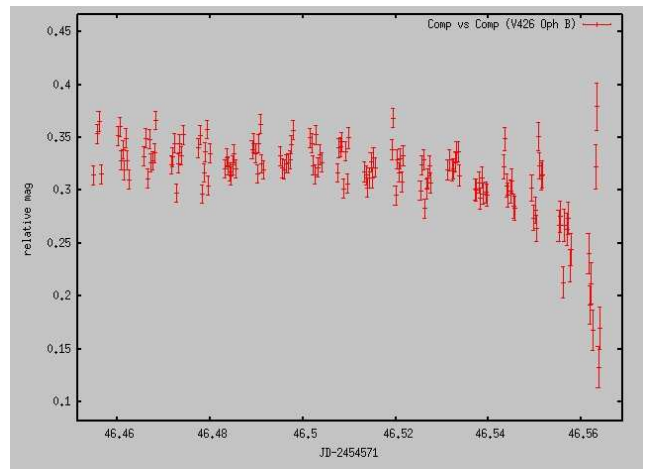
The two telescopes can produce huge amounts of image data - 1,9GB per hour. The data are stored on a local disc array and from time to time they are transferred via a local network to our data archive. This



**Fig. 8** A field with the marked object V426 Oph



**Fig. 9** The lightcurve of V426 Oph observed by the D50 telescope



**Fig. 10** The difference of two comparison stars near V426 Oph observed by the D50 telescope

is a disc array made of twenty hard drives located in one external box which is connected via Infiniband cable to the server. We have actually 6TB of data space and we plan to upgrade part of the array every year. There is a possibility to save space by using data compression. In a data compression process data are stored more effectively without loss of a single bit in the case of a lossless algorithm. There are also lossy algorithms, which compress the relevant information and discard the rest. The lossy algorithms can compress data much more effectively than the lossless ones.

We use the FITS data format for images produced by our telescopes. It is the standard for astronomical image data. There are some astronomical software packages for data processing and reduction that can process the images in FITS format, for instance IRAF. The FITS format supports several types of lossless data compression. It is easy applicable to our own program code by using the (C)FITSIO program library accessible at the website of the FITS support office at NASA/GSFC.

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