Optically selected GRB afterglows, a real time analysis system at the CFHT(*)

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Summary. — We attempt to detect optical GRB afterglows on images taken by the Canada France Hawaii Telescope for the Very Wide survey, component of the Legacy Survey. To do so, a Real Time Analysis System called "Optically Selected GRB Afterglows" has been installed on a dedicated computer in Hawaii. This pipeline automatically and quickly analyzes Megacam images and extracts from them a list of variable objects which is displayed on a web page for validation by a member of the collaboration. The Very Wide survey covers 1200 square degrees down to $i' = 23.5$. This paper briefly explain the RTAS process.

PACS `95.75.Mn` – Image processing (including source extraction).
PACS `95.75.Wx` – Time series analysis, time variability.
PACS `95.85.Kr` – Visible (390-750 nm).
PACS `98.70.Rz` – γ-ray sources; γ-ray bursts.
PACS `01.30.Cc` – Conference proceedings.

1. – The Canada France Hawaii Telescope and its legacy survey

1˙1. *CHFT at glance*. – The CFHT is a 3.6 m telescope located on the Mauna Kea in Hawaii. Built in the late 70's, it has been recently equiped with a new instrument, Megacam. The specifications of this CCD imager are the following:

- 36 2048×4612 pixel CCDs with 0.185 arcsec/pixel resolution

- 1 square degree field of view

- 5 filters set (u^*, g', r', i', z').

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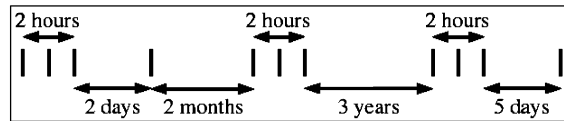
Fig. 1. – This diagram shows the observing strategy for one field (each vertical line is for one exposure, exposure time depends on the filter, but is typically of the order of 100 s).

These characteristics, combined with the excellent climatic conditions at the site, provide images with a very good quality. Moreover, the images are pre-processed in quasi-real time with a pipeline called Elixir([1]), which flattens and defringes each CCD and computes gross astrometry and photometry.

1˙2. *The Legacy Survey*. – This 5 years' project has started in March 2003, and is based on 3 different observing strategies:

– The Wide Synoptic Survey covers 170 square degrees with all the 5 Megacam filters (u^* g' r' i' z') down to approximatively $i' = 25.5$. The main goal of this survey is to study large scale structures and matter distribution in the universe.

– The Deep Synoptic Survey covers only 4 square degrees, but down to $i' = 28.4$ and through the whole filter set. Aimed mainly at the detection of 2000 type I Sne and the study of galaxy distribution, this survey will allow an accurate determination of cosmological parameters.

– The Very Wide Survey covers 1200 square degrees down to $i' = 23.5$, but only through 3 filters (g' r' i'). Initially conceived to discover and follow 2000 Kuiper Belt Objects, we'll show that this observing strategy can be used to detect optical afterglows.

1˙3. *The Very Wide Survey*. – Each field is observed several times, according to the strategy explained in fig. 1. This recurrence can be used to compare images between them in order to detect variable or transient objects, such as GRB afterglows.

2. – OSGA Pipeline

2˙1. *Night process*. – The first part of the process consists in the reduction the useful information from 700 Mo (the size of one Megacam image) to a few tens Mo. The pipeline automatically checks the presence of a new image as soon as it has been pre-processed by Elixir and starts the following treatment for each CCD:

– Conversion of FITS image to JPEG format for future display on a web page, extraction of the FITS header and addition of new entries, like magnitude and mu-max completness.

– Creation of a catalog of objects using SExtractor; in this catalog are mentioned X and Y position, RA and DEC, magnitude and mu-max, FWHM and a SExtractor flag

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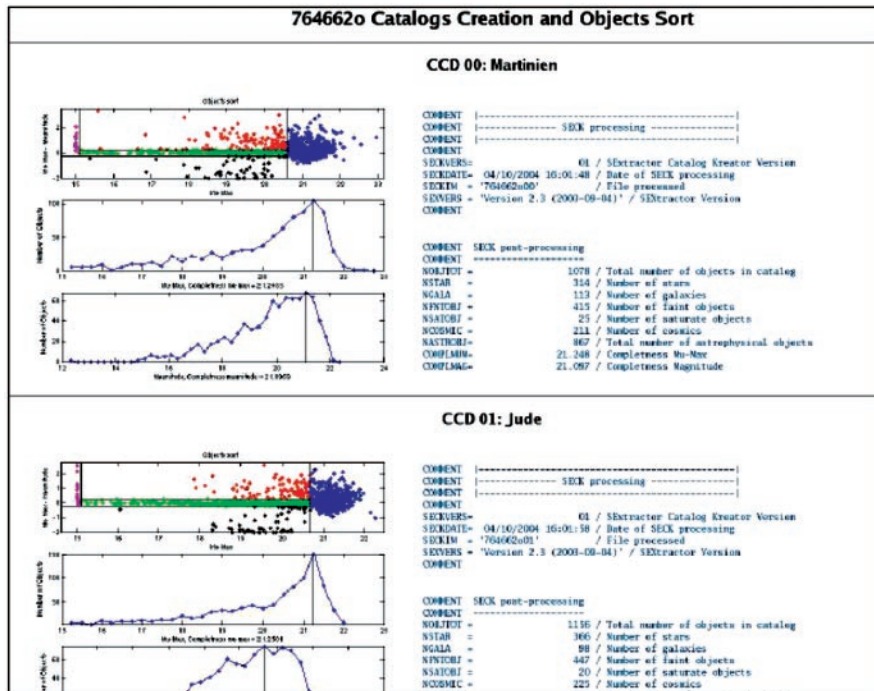([1]) See `http://www.cfht.hawaii.edu/Instruments/Elixir/`.

Fig. 2. – This is a snapshot of one of the "catalog creation" web page. For each CCD, 3 graphs show, respectively, the object sorting (where saturated objects are in the leftmost part and faint objects in the rightmost one, whereas in the central part, the box defines, from top to bottom, galaxies, stars and cosmic rays), and the mu-max and magnitude completeness. The right panels show some information added to the header, like the number of objects for each category and the value of the mu-max and magnitude completeness.

– Astrometric calibration using USNO catalog

– Sorting of objects according to their astrophysical properties into stars, galaxies, faint objects, saturated objects and cosmic rays.

The processing of one image does not last more than 3 minutes. All these results are then summarized in real time on an automatically generated HTML web page and can be viewed by everyone on the Internet. Using an interactive script, collaboration members are able to directly validate or not the night process, and so allow the second stage of the processing which involves the comparison of the image with previous images of the same field.

2˙**2.** *Day process*. – At the end of each night, the second part of the process is launched. Its goal is first to list all the possible comparisons between images just taken. To be possible, a comparison must involve images of the same field, with similar exposure times and the same filter. In a second time, the process checks if the field has already been observed during this run (a run lasts about 3 weeks), and in this case starts the comparison between the two best-quality images of each night. The comparison process can be broken down as follows:

– Classification of astrophysical objects into three categories: unchanged, luminosity variable and alone. Unchanged objects are used for photometric calibration
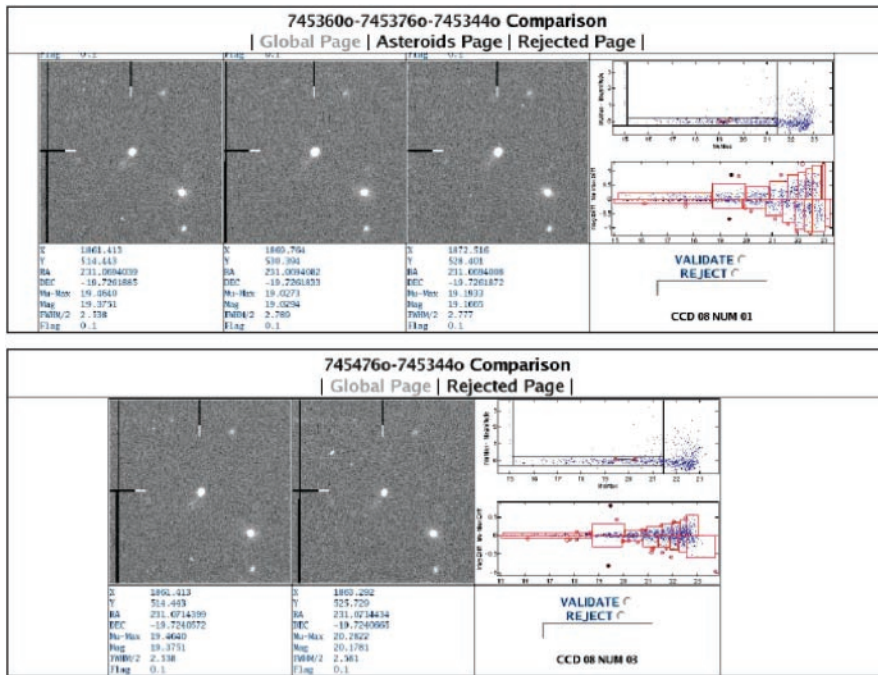
Fig. 3. – A very interesting object can be seen on these 2 snapshots. Not only it has been detected as variable in a one night triple comparison but also in a double comparison with an image taken a few days before. Although we cannot conclude about the nature of this transient source, this detection shows us that the whole process works correctly. The object is not a GRB afterglow as it appears in the DSS.

- – Research of asteroids and objects having significant variation in luminosity. Those objects are then extracted and stored in a special catalog

- – Generation of a few graphs and cut-out of thumbnails around the positions of interesting objects.

The comparison of two or three images takes less than 5 minutes. Only a few ten objects are detected as variable in a whole comparison, whereas the catalogs contain more than one hundred thousand objects. All the information about interesting variable objects and asteroids is gathered on a self-generated interactive HTML web page. Then a member of the collaboration has to reject false detections (like cosmic rays or CCD defects for instance) or validate objects which are truly variable.

3. – Conclusions

We have shown that optical afterglow detection is possible using Megacam images from the Very wide survey at the CFHT and a real time comparison pipeline. A few afterglows per year can reasonably be expected. The real time process has started in November 2004; though a few interesting objects have been detecting, no GRB afterglow has been discovered yet. Additional information on this search can be found on the web page of the RTAS `http://www.cfht.hawaii.edu/~grb/`.