IL NUOVO CIMENTO Vol. 28 C, N. 4-5 Luglio-Ottobre 2005
DOI 10.1393/ncc/i2005-10147-8

REMIR: The REM infrared camera to follow up the early phases of GRBs afterglows(*)

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(ricevuto il 23 Maggio 2005; pubblicato online il 28 Ottobre 2005)

Summary. — REMIR is a near-infrared camera, covering the 0.95–2.3 μm range with 5 filters (z,J,H,Ks and H_2), mounted at one of the Nasmyth foci of the REM (Rapid Eye Mount) telescope. REM is a fully robotic fast-slewing 60 cm telescope, primarily designed to follow-up the early phases of the afterglow of GRBs detected by dedicated instruments onboard satellites (like SWIFT, a satellite entirely dedicated to GRBs science launched the 12 November 2004). Moreover REM hosts a slitless spectrograph covering the range 0.45–0.95 μm, with 30 sample points and with the possibility to perform broad-band V,R,I photometry (ROSS, REM Optical Slitless Spectrograph). The main task of REMIR is to perform realtime NIR observations of GRBs detected by gamma-ray monitors onboard satellites, looking for any possible infrared transient source. As soon as a transient source is detected in the IR images, larger telescopes are promptly alerted to perform early spectroscopy of the afterglow. All the above operations are performed in a fully automatic way and without any human supervision. We present the results of on-site tests that have been done to characterize the REMIR camera and the performances of the dedicated reduction pipeline AQuA (Automatic Quick Analysis), suited for fast transients detection.

PACS 98.70.Rz – γ-ray sources; γ-ray bursts.
PACS 95.85.Jq – Near infrared (0.75–3 μm).
PACS 95.75.Rs – Remote observing techniques.
PACS 01.30.Cc – Conference proceedings.

(*) Paper presented at the "4th Workshop on Gamma-Ray Burst in the Afterglow Era", Rome, October 18-22, 2004.

1. – The REMIR camera

REMIR [1] is a standard focal reducer with a final focal ratio = 5.3, allowing a plate-scale of 64.4 arcsec/mm, corrisponding to about 10 × 10 arcmin^2 field of view on the 515 × 515 pixel^2 array (1 pixel = 18.5 μm), a Single Working Quadrant HgCdTe Rockwell. The camera is equipped with 4 broad-band filters (z, J, H and Ks), 1 narrow-band filter on 2.212 μm H_2 transition, and a low-resolution grism (R about 60). A Stirling cryo-cooler provides the 77 K temperature to the array and to the pupil stop placed on the optical bench, in front of the filter wheel.

2. – REMIR calibration

Many on-site tests have been done in order to characterize the array performances, in term of read out noise, gain, dark current, flatfielding, linearity, cosmetic and a estimation of the camera on-sky performance limits.

- *Gain and Read Out Noise*: a stack of 22 frames, taken at different light level (4000–48000 ADU), has been used to derive these parameters using the variance method. The gain resulted to be 4.8 e-/ADU but the RON resulted too high (140 ADU), probably due to a non-perfect flatfielding and dark subtraction. Then, histogram method has been used to estimate the RON, calculating the standard deviation for each column of a stacked frame obtained by a set of frames with very short integration time: this gives a value of RON of about 18.9 ADU = 88.8 e- (see fig. 1). However, this value is too high with respect to the maximum value of 20 e- expected; probably a non-perfect ground connection and power supplies interferences are responsible for the extra noise.
- *Linearity*: the Rockwell array shows an extremely good linearity, greater than 99.99% between 5000 and 45000 ADU (see fig. 2).
- *Cosmetic*: bad pixels have been determined as pixels that exceed the mean value dark frame distribution. The array has a total number of 6000 bad pixels, mainly concentred in two dead columns on a side and near the left and bottom edges, leaving the central part almost free of groups of bad pixels.
- *Dark Courrent*: a non-perfect contact between the camera baffle and the array mounting generate an evident light gradient responsable of the big value found for dark current of 0.6 ADU/s = 2.9 e-/s, against the 0.1 e-/s expected. In the next servicing at La Silla, the camera will be opened and a new baffle will be inserted.
- *Flat Field*: dome images have been selected, instead of sky images, to obtain the best flat field image to correct pixel-to-pixel response.
- *Limiting Magnitude*: a first estimation of the camera performances is based on exposure taken on GRB040511. The data has been reduced with the dedicated pipeline AQuA [2] and gave a limiting magnitude at a 3 sigma level of 17.7, 17.4 and 16.9 for the J, H, and Ks filters, respectively, at $t = 30$ s.

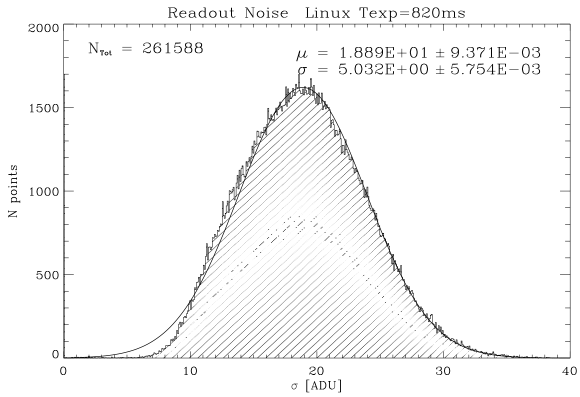

Fig. 1. – The histogram used to estimate the RON.

3. – AQuA: the REMIR camera dedicated reduction pipeline

AQuA (Automatic Quick Analysis) [2] is a software designed to manage data reduction and prompt detection of near-infrared afterglow of GRBs observed by REMIR. The main task is to perform images analysis in a fast and fully automatic way. The pipeline consist of 3 logical blocks: REMIR_SS, AQUAMAIN and AQUARED.

REMIR_SS is a daemon listening and interpreting messages from the general manager software REMOS (REM Operating Software [3]). REMOS checks for triggers from different sources, telescope position and status, meteo conditions and secondary science schedule, producing alerts that are broadcasted to the whole REM subnetwork. AQUAMAIN checks continuously all the connected sub-units (camera, data processing unit and messages from REMIR_SS) and elaborates concurrent alerts and messages to decide the operating strategy. In particular AQUAMAIN receives from REMOS, via REMIR_SS, different kind of alerts, depending on the type of observation to perform and the target type. If the alert is a PRIMARY SCIENCE type (GRBs, late GRBs, SGR) a transient detection algorithm (DecOAR, see below) is applied to detect/confirm/follow-up a GRB

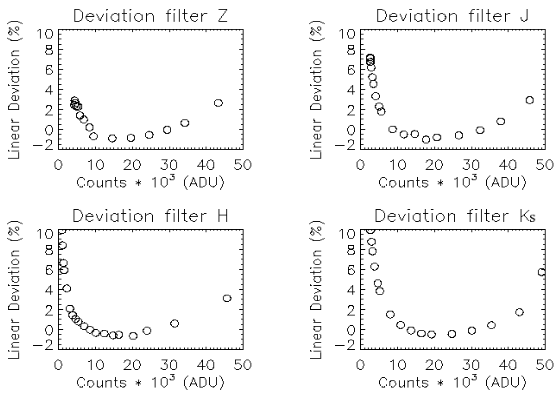

Fig. 2. – The non-linearity curves for the REMIR array.

afterglow. Images are usually processed by AQUARED: it takes the incoming images from the camera and reduces them through the usual procedure used for NIR images. The images are then astrometerized using a list of object extracted from 2MASS catalog and a standard photometry software (SExtractor) [4] runs to produce the photometric catalog of objects in the field. Reduction is performed by the software PREPROCESS [2].

Every time REMOS sends to AQuA a primary science alert and a new catalog is generated by AQUARED, the transient detection algorithm (DecOAR) is applied. After performing some tests, a grade is assigned to possible transient candidates. When the pruning process leaves only one candidate, with a grade above a threshold, it is marked as a safe transient detection and released to REMOS for further management (alert to larger telescope, release of a GCN and the like). To assign the grade, first DecOAR compare the reduced image with 2MASS catalog: for the very first image, marking objects not found in the catalog and establishing a first potential candidate list. A higher grade is assigned if a potential candidate is not found on the 2MASS being brighter than the mag limit than if it is fainter. Then, starting from the second image of the sequence, catalogs are compared with the already existing list of potential transients, if any: objects that varied have their transient grade upgraded. A further source of grade assignement is the comparison of images themselves: images are subtracted to the first of the sequence to produce a difference image, that is processed to build a catalog of all the objects that varied. This differential photometry, moreover, is the only possible strategy when the field is very crowded as in globular cluster cores. During processing REMOS is interrogated to check if there are any known transients available from other instruments, especially ROSS [5], XRT and UVOT aboard SWIFT.

Usually, the transient detection strategy is the following: the observations start in the H filter, since the S/N ratio and the z-range of visibility are optimized. If the transient is not detected, the exposure time is increased first, then the filter is changed. If transient is detected, the filters are rotated to ensure a proper coverage in wavelength of the afterglow event, and the exposure time is adjusted on the basis on real-time analysis of the light curve. The surce is observed until the afterglow fades out.

Performance of the whole pipeline is tested processing different kind of fields with a single-proc Athlon XP (1742MHz CPU) and a bi-processor Athlon/MP (1659 MHz CPUs) computers [6]. The main requirement is that data processing should be run faster than image data flow. The reset-read-read technique, usually employed for REMIR observations, implies that the scientific image with the shortest exposure time is acquired in 13.2 s: this is the time to compare the performances with. Preprocessing and photometry of the same field (standard star FS5, few sources) with the single-proc and two-proc needs, respectively, 10.43 s and 5.12 s. Preprocessing and photometry of the crowded field of globular cluster M4 on the two-proc needs 12.29 s. The same analysis performed on the simulated and observed field of the GRB040511 on two-proc gives as result, respectively, 11.79 s and 8.63 s.

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