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The 1.23m CAHA telescope: combining upgrades and scientific observations

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Abstract. We discuss the current status of the control system upgrade of the 1.23m telescope of the Calar Alto observatory. We also show the most recent scientific observations. The upgrade of the 1.23m telescope is being done based on the Remote Telescope System, 2nd Version (RTS2). The fast-reaction response mode for GRB alerts (typically with response times below 3 minutes from the GRB onset) still needs some development. The auto-guider camera has not been implemented in RTS2 yet, so the telescope observations are limited to exposures shorter than ∼4 minutes. We show

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the latest results of several high-energy events, mostly GRBs, followed up with human intervention during the testing phase of RTS2. We remark the very nice data gotten for GRB 101225A.

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1. Current status of the 1.23m telescope upgrade

The 1.23m telescope is a Ritchey-Crétien telescope built in 1975 by Carl Zeiss and is placed at the German-Spanish observatory of Calar Alto (CAHA). In 2008 the mechanical and hydraulic systems of the German mount of the telescope were renovated. Currently the 1.23m telescope is undergoing continuous upgrades to enable fully autonomous observations and also to respond to GRB alerts. The focal ratio of the 1.23m telescope is f/8. The total field of view is 90′ with a focal plane scale of 20.9″ per millimetre. The optical aberrations of the telescope are negligible for a field of view smaller than 15′. One of the mechanical peculiarities of the telescope is the presence of a steel sphere which, by means of a high-pressure hydraulic system, supports all the weight of the telescope.

Three instruments are available at the 1.23m telescope: the MAGIC near-infrared camera, the old optical camera based on a 2k×2k SITE#2b CCD and the recently installed DLR optical camera. The use of the MAGIC near-infrared camera is very limited, so most of the time the two optical cameras are mounted. The 2k×2k SITE#2b camera provides a field of view of $17' \times 17'$ with a pixel-scale of 0.5″/pix. The new DLR camera gives a field of view of $22' \times 22'$, based on a 4k×4k E2v ccd231-84 CCD with a pixel size of $15\mu m$. It translates to a pixel scale of 0.32″/pix. The readout time of the new camera is ∼ 25 times faster than the 2k×2k SITE#2b camera (10 seconds vs. 4 minutes). Most of the observations of the 2k×2k SITE#2b camera are done trimming the CCD to a 512 × 512 pixel window. In conditions of poor seeing (> 1.4″) both optical cameras are used in 2×2 binning mode. The readout noise for both optical detectors are low, 7 electrons for the 2k×2k SITE#2b and 5 electrons for the DLR camera, respectively. This fact is important because the auto-guider has not been incorporated yet in RTS2, so most of the deep observations are based on co-adding many short exposures of the same field. Most of the time (∼75%) the SITE#2b camera is mounted, but the new DLR camera will be mostly used in the latest semesters. A review of the 1.23m telescope can be found in Gorosabel et al. (2010a).

The 1.23m telescope is well integrated among the other facilities of Calar Alto. The maintenance of the telescope and the dome is done by the Calar Alto staff. The Calar Alto staff is also responsible for keeping the detectors at low temperature by supplying liquid nitrogen on a regular basis (usually once a day). This makes that the two optical cameras operative for the 1.23m show negligible dark current values (less than 3 electrons per hour).

The robotization of the 1.23m telescope is being carried out by the ARAE (Robotic Astronomy & High-Energy Astrophysics) group of Astrophysical Institute of Andalusia (IAA-CSIC, Granada, Spain). The ARAE group is also responsible for development, maintenance and operation of the BOOTES network of robotic telescopes (Jelinek et al. 2010). The goal of the project is to robotize the 1.23m telescope (and the associated devices, dome, etc..) so it can carry out autonomously scientific observations with all the three instruments available. The robotization is being performed based on the RTS2 software (see Kubánek et al. (2010) and references therein). The old 2k×2k CCD camera is fully integrated in RTS2. Currently we are in the process of including the new DLR camera in RTS2. Given the very low use of the MAGIC near-infrared camera, we do not foresee to include it in the RTS2 framework, at least not in the short term. Very recently we have installed the queue observing mode, so the telescope can run autonomously the whole night. With the help of integrated scripting we also determined accurate focusing offsets for each BVRI-band filter, which allows us to produce even better focused images in any of the four available bands.

2. Recent scientific results

The 1.23m telescope is usually operated in legacy interactive mode, with periods of supervised autonomous runs under RTS2. The most relevant scientific results we achieved with the 1.23m telescope before 2010 were reported in Gorosabel et al. (2010a). Here we show several high-energy events followed up in the 2010-2011 period. The observations were done with observer intervention during the testing phase of the 1.23m control software upgrade. All the observations correspond to triggers provided by the *Swift* satellite, which were observed using the 2k×2k SITE#2b camera equipped with Johnson filters.

2.1 GRB 100316A

This GRB was detected by the *Swift* Burst Alert Telescope (BAT) on 2010 March 10.099306 UT (Baumgartner et al. 2010a). X-ray observations starting 51.8 minutes after the BAT trigger with the XRT telescope on board *Swift*, which localized the afterglow with an accuracy of 4.5″ (Beardmore et al. 2010a). The duration of the GRB was ∼ 10 seconds, so it could belong to the potential family of intermediate duration GRBs (de Ugarte Postigo et al. 2011). The 1.23m telescope started observing the GRB field 11.7 minutes after the BAT trigger, revealing a R=20.5 object coincident with the XRT error circle (Gorosabel et al. 2010b). The 1.23m discovery allowed us to trigger the 10.4m GTC telescope, which equipped with OSIRIS was able to take several long-slit spectra. A paper is planned on this GRB (Sánchez-Ramirez et al. 2012).

2.2 GRB 100805A

GRB 100805A was detected on 2010 August 5.175486 UT as a single peak with a duration of ∼ 20 seconds (Hoversten et al. 2011), so likely it corresponds to a long-duration GRB. Optical observations with the Mount Palomar 60 inch telescope detected an optical source at the edge of the XRT error circle (Cenko 2010). The 1.23m telescope started I-band observations on Aug 5.1824 UT, 9.96 minutes after the GRB onset. The object is detected in two I-band frames with a total exposure time of 120 + 180 seconds. In the co-added image we measure for afterglow I∼16.9 (Gorosabel et al. 2010c), against the USNO B1.0 catalogue (Monet et al. 2003).

2.3 GRB 100814A

This GRB was detected on 2010 August 14.159850 UT as three separate gamma-ray pulses with a total duration of at least 150 seconds (Beardmore et al. 2010b), so it should be considered as a long duration GRB. Optical observations done with the 1.23m CAHA telescope detected the GRB afterglow (Schaefer et al. 2010) with a very preliminary magnitude of R∼21. 13 dithered frames were taken with a total exposure time of 2340 seconds. A proper calibration of the field is being done and a final analysis will be published elsewhere (De Pasquale et al. 2012).

2.4 GRB 100816A

This GRB was detected on 2010 August 16.026285 UT as a single symmetric pulse with a duration of ∼ 2 seconds (Oates et al. 2010). Hence, this could be a short GRB or even belong to the possible family of intermediate duration GRBs (de Ugarte Postigo et al. 2011). The 1.23m observations started on 2010 August 16.0492 UT, 32.998 minutes after the GRB onset. The data were acquired in the four BVRI bands available in the filter wheel of the 2k×2 SITE#2b CCD camera. The optical afterglow (Antonelli et al. 2010) was detected in the four bands, with a preliminary magnitude of $I \sim 19.9$ (Terrón et al. 2010). A paper containing, all the data of the 1.23m telescope in being prepared (Pérez-Ramirez et al. 2012).

2.5 GRB 101008A

GRB 101008A was detected by the BAT detector of *Swift* on 2010 October 8.696701 UT. The gamma-ray pulse had a FRED-like shape with a duration of 15 seconds (Baumgartner et al. 2010b). Due to an observing constraint, XRT could not point to the GRB position until 52.7 minutes after the BAT trigger. This fact limited the search for the optical afterglow. The observations of the 1.23m telescope started 2.38 hours after the gamma-ray event under poor weather conditions. The observations were conducted on 8.7957-8.8118 UT in the R-band. No object was detected within the XRT error circle down to a 3σ limiting magnitude of R=19.7 (Gorosabel et al. 2010d). The calibration was based on the USNO B1.0 catalogue (Monet et al. 2003).

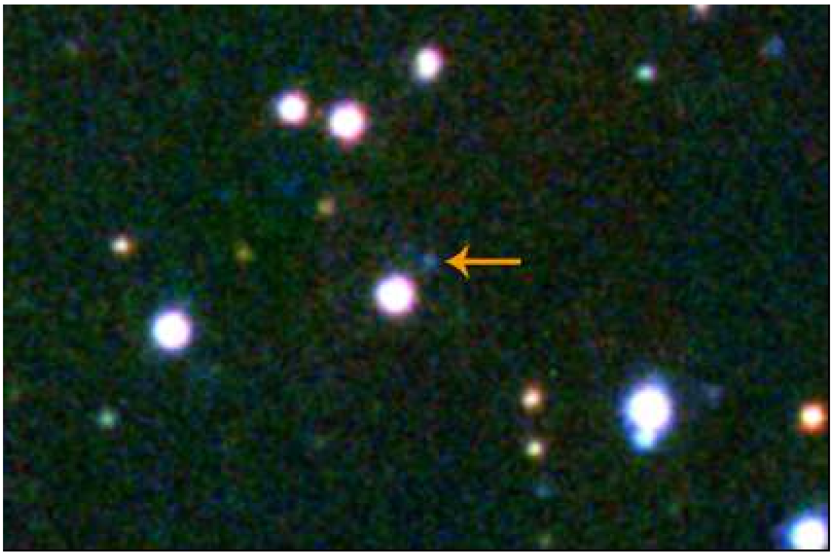

Figure 1. The optical counterpart of GRB 101225A detected with the 1.23m telescope, ∼ 1 day after the gamma-ray event. Its blue color was atypical for a standard GRB afterglow, being not consistent with a synchrotron emission. The blue color corresponds a thermal source with a temperature of 21000 K .

2.6 GRB 101225A

The observations carried out for this GRB represent our most important results achieved with the 1.23m CAHA telescope since we started its robotization in 2009. GRB 101225A was detected by Swift on December 25.776215 UT as an extremely long GRB with a duration >2000s, being one of the longest GRBs ever observed. The observations done with the 1.23m CAHA telescope started on December 26.784028 UT, 1.008 days after the GRB onset. The data were acquired in the VRI-bands with a total exposure time of 21×180s, 19×180s, and 17×180s, respectively (Thöne et al. 2010). These observations were among the first ones displaying the visible light linked to the GRB event, and they were essential to realise that GRB 101225A involved a different kind of stellar death. Our VRI-band data revealed colors atypical for a standard GRB. Its spectral shape could not be explained by synchrotron emission, as expected for a typical GRB. Fig 1 shows the optical emission of GRB 101225A as detected by the 1.23m telescope. Note the blue colors of the counterpart (indicated by an arrow). This colors is consistent with a thermal source at a temperature of ∼21000 K, which was later cooling down to ∼5000 K (Thöne et al. 2011). In contrast to standard GRBs, where the ejected material is ultra-relativistic the outflow of GRB 101225A detected by the 1.23m CAHA telescope would expand with a velocity $< 0.25\,c$. It has been proposed that GRB 101225A is the result of a merger of a neutron star and an evolved giant star burning helium in its core, placed at a redshift of $z \sim 0.3$ (Thöne et al. 2011).

2.7 GRB 110610A

GRB 110610A was localized by *Swift* on June 10.639954 UT (Marshall et al. 2011). The BAT lightcurve showed several peaks with a total duration of ~ 60 seconds. The 1.23m data were acquired in two epochs, on 2011 June 11.0013–11.1579 UT and June 11.9093–12.1599 UT (8.67-12.44 hours and 30.46-36.48 hours post GRB, respectively). The observations were performed in the I band. The co-added image reveals no optical source consistent with the XRT error circle (Goad et al. 2011). The 3σ limiting magnitude of the co-added image is I = 20.6 (Gorosabel & Kubánek 2011), calibrated against the USNO B1.0 catalogue (Monet et al. 2003).

2.8 Swift J185003.2-005627

This source had a pulse structure similar to a GRB, but the softness of its BAT gamma-ray spectrum and its proximity to the Galactic plane (only $7'$ of Galactic latitude) pointed to its Galactic origin, rather than an extragalactic GRB (Beardmore et al. 2011). The 1.23m observations were performed on 2011 June 25.03138 – 25.15559 UT, starting 39.1 minutes after the BAT trigger. Given the detection of rapid optical variability in other Galactic sources with similar high-energy properties (i.e., Swift J195509+261406, Castro-Tirado et al. (2008)), we searched for optical flares. With that aim we acquired 90 frames with an exposure time of 90 seconds per image. Given the high Galactic extinction in the direction of the source we observed in the I-band. A preliminary analysis of the individual 1.23m images shows no obvious flaring activity at the XRT position above a 3σ limiting magnitudes of I=19 (Gorosabel et al. 2011a).

2.9 GRB 110625A

Swift detected this GRB on June 25.880880 UT with a total duration ~60 seconds (Page et al. 2011). Optical and near-infrared observations done with the 3.8m UKIRT (Im et al. 2011) and 2.2m La Silla telescopes (Filgas et al. 2011) detected a constant source consistent with the XRT error circle. We observed the GRB 110625A field with the 1.23m CAHA telescope on June 25.88457–25.93027 UT (i.e, starting 5.32 minutes after the trigger). In I-band, 45 dithered frames were taken with a total exposure time of 2700s. Given the long read-out time of the 2k×2k SITE#2b CCD (~4 minutes in the 1×1 bin full-frame mode), we trimmed the CCD to a 400×400 pixel window. We detected the source at a level of I=20.6±0.35 (Gorosabel et al. 2011b). The photometric calibration of the 1.23m data was based on the USNO B1.0 catalogue (Monet et al. 2003). The error of our I-band detection is dominated by the zero point error of the USNO B1.0 catalogue. Our I-band measurement could indicate some degree of fading with respect to the i-band magnitude reported by Filgas et al. (2011). However, our magnitude is in the Vega system, whereas the i-band magnitude of Filgas et al. (2011) is in the AB system, so we are still cautious on the association of this object to GRB 110625A. A joint analysis of the UKIRT, 2.2m La Silla and 1.23m CAHA data would be required to clarify if this object is related to GRB 110625A.

2.10 GRB 110709A

This GRB was detected by *Swift* on 2011 July 9.642003 UT, showing 8 bright peaks with a total duration of ~50 seconds (Holland et al. 2011a). The observations of the 1.23m were conducted on 2011 July 9.8576–9.9042 UT, 5.18–6-29 hours after the onset of the GRB. Eight frames were acquired in the R-band with a total exposure time of 3360 seconds. No optical source was detected in the XRT error circle (Evans 2011). The 3σ limiting magnitude of our co-added image was R=22.7 (Tello et al. 2011). The calibration was based on the USNO B1.0 catalogue (Monet et al. 2003).

2.11 Swift J1822.3-1606

This event was detected by *Swift* on 2011 July 14.533184 UT, as composed by several count-rate increases. Given its low Galactic latitude, soft BAT spectrum and repeatability, this source was tentatively classified as a Soft Gamma-Ray Repeater (Cummings et al. 2011). The 1.23m observations started on July 15.90429–16.03722 UT, 1.3711 days after the BAT trigger. We searched for optical variability by taking 34 consecutive images with an exposure time of 30 seconds per frame. The observations were conducted in the I-band (Gorosabel et al. 2011c). No rapidly variable sources were found in the XRT error circle (Pagani et al. 2001). In the co-added image three objects were detected consistent with, or close to the XRT error box, called S1, S2, and S3 [1]. For S1, S2 and S3 we measured I-band magnitudes of 18.2, 19.8 and 19.8 respectively, using as photometric reference the USNO B1.0 catalogue (Monet et al. 2003). We note that S1 (the only one clearly inside the XRT error box and the most probable optical counterpart) is already detected in the 2MASS catalogue (placed at RA_{J2000}=18:22:17.946,DEC_{J2000}=-16:04:25.90). Optical and near-infrared data taken from other telescopes (1.5m OSN, 3.5m CAHA, IAC80) are currently being analyzed in order to clarify if Swift J1822.3-1606 is a Soft Gamma-Ray repeater or a Be-X-ray binary system, as suggested by Gogus et al. (2011).

2.12 GRB 110915A

GRB 110915A was detected by *Swift* on 2011 Sep 15.55607 UT with a total duration of about 95 seconds (Holland et al. 2011b). This GRB was observed with the 1.23m

[1] Following the notation of `http://www.dark-cosmology.dk/~deugarte/Swift1822/swift1822.png`

telescope on Sep 15.7984-15.8500 UT, 5.81 hours after the gamma-ray event. The 1.23m observations were done in the I-band with a total exposure time of 4500 s. We did no detect any object in the error circle given by the XRT instrument on board *Swift* (Evans et al. 2011). The 3σ limiting of the co-added image was I=21.5 (Sánchez-Ramirez et al. 2011).

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