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Observation of Optical Transients with the Ashra prototype

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The All-sky Survey High Resolution Air shower detector (Ashra) is primarily designed to elucidate transient objects such as Gamma Ray Bursts (GRBs) not only detecting optical lights but also simultaneously very high energy γs and νs. A first run of data taking with prototype versions of the optical and the trigger systems took place in 2004-2005, allowing us to evaluate the performance of the systems and to approach an analysis strategy. The advancement of the Ashra optics has been demonstrated by our success of observing the position of GRB041211 from more than 1 hours before the burst for 2 hours continuously. We will present the results of our observations of optical transients with the Ashra prototype.

1. Introduction

GRBs seem to be the most relativistic phenomenon observed so far. There is much observational evidence that GRB outflows are highly relativistic and collimated. It is natural to expect that GRB should be accompanied not only by bright optical flashes [1] but also by very high energy γ-rays and νs [2]. Systematic study of optical flashes and very high energy particle radiations accompanying GRB could impose important limits for theories explaining bursts mechanism and their energy engines. Ashra records triggered images in unprecedented arcminute (arcmin) detail of high-energy cosmic particle interactions in the atmosphere as well as untriggered star lights as night sky background using new wide angle high resolution optics, Image Intensifier and CMOS technology. A first run of data taking with prototype versions of the optical and the trigger systems took place in 2004-2005, allowing us to evaluate the performance of the systems and to approach an analysis strategy. Full configuration of the Mauna Loa site will be reached by 2006.

2. Detector

The prototype telescope is a 2/3-scale model of the Ashra light collector unit (Figure 1). It utilizes optimized Baker-Nunn optics [3], which keeps, in principle, spot size less than 1 arcmin within the full field of view of 50°. The optical system consists of three collector lenses made of acrylic resin, spherical reflector with seven segment Al+SiO_2 coated glass mirrors, and a UV image intensifier (UVII) as the focal sphere of which effective diameters are 0.6m, 1.2m, and 0.4m respectively. In the test observation dedicated to evaluation of the performance of the optics, the output image from the fiber optic (FOP) window of the UVII is took by a commercial digital camera Cannon EOS-1Ds including 4064$\times$2704 CMOS chip with a macro close-up lense, but not by an image pipeline trigger and readout system nominally designed for the Ashra detector [4][5]. The image pipeline trigger and readout have been independently tested on a conventional alt-az TeVγ-rays Cherenkov imaging telescope. The achieved resolution is measured using star lights to be 2$\sim$3 arcmin at the center and 3$\sim$4 arcmin at the edge of the field of view. A large fraction of the light flux from the output window of the UVII is lost before the input of EOS-1Ds due to the nearly unity of the numerical aperture of the output FOP for the moment. The loss will be much recovered by the relay optics in the image pipeline system.

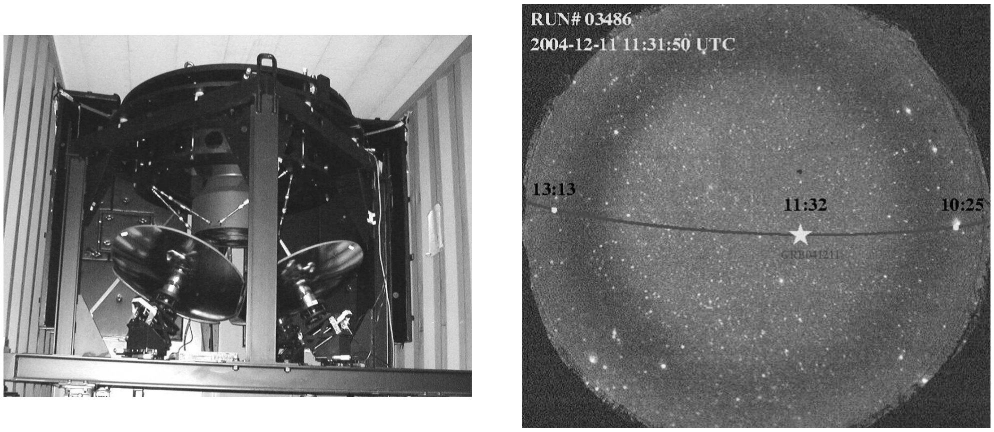

Figure 1. The 2/3 scale Ashra prototype telescope operated on Haleakala (left). An image taken by the Ashra prototype just on time of GRB041211 of which location was noticed with the WXM on HETE-2 (star mark) (right).

3. Observations

GRB041211:
We have observed the field covering the WXM error box of GRB041211 with the prototype unit of Ashra (http://www.icrr.u-tokyo.ac.jp/ ashra) at the Haleakala Observatory Site on Maui continuously between 10:25 UT (1h7m before GRB041211) and 13:13 UT (1h41m after GRB041211) on 2004-12-11 (Figure 1). We obtained about 2000 images covering the WXM error box of GRB041211 every 5s with 4s exposure time respectively. The sensitive region of wavelength is similar with the B-band. We detected no new objects in the WXM error box (Figure 2). As a result of our preliminary analysis of four sets of combined images, the following 3-sigma limiting magnitudes are derived (Table 1). Limiting magnitudes were estimated by comparison with stars in Tycho-2 Catalog. Plots of limiting magnitudes vs time are shown in Figure 2.

GRB050502b:
We have observed the field of GRB050502b (09:25:40 UT) covering the SWIFT XRT error circle (Pagani et al., GCN 3333) by the Ashra-AFT (Automated Follow-up for Transients) telescope at the Haleakala observatory in Hawaii (latitude = 20d 42' 37" N, longitude = 156d 15' 31" W, altitude = 3020m). The telescope (12" Meade LX200GPS with a KAI-2020M CCD) is served as a follow-up detector to quickly respond to triggers from Ashra optical transient survey monitor as well as from GRB satellites. The telescope automatically slewed to the GRB and took the first image of 1.4sec-exposure at 09:26:36 UT (56 seconds after the burst and 32 seconds after the BAT alert socket). We also took following 363 images of 4sec-exposure every 9 to 10 seconds (09:26:36 UT - 10:25:47 UT). These images are unfiltered to maximize the detection sensitivity, of which peak is between B and V. No new source was found within the SWIFT XRT position. From the earliest 4 images and the co-added images (3 x 4sec, 25 x 4sec), we preliminarily obtained 4-sigma limiting magnitudes of B1 and R1 in the USNO-B1.0 catalog (Table 1). Figures of limiting magnitudes vs time are shown in Figure 3. They are compared with other experiments in Figure 3).

GRB050504:
We have observed the field of GRB050504 (08:00:59 UT) covering the Integral error circle (Mereghetti et al, GCN 3348) by Ashra-P2/3 (Prototype of 2/3 scale) and Ashra-AFT at the Haleakala observatory in Hawaii (latitude = 20d 42' 37" N, longitude = 156d 15' 31" W, altitude = 3020m) in conditions of variable clouds across the field.

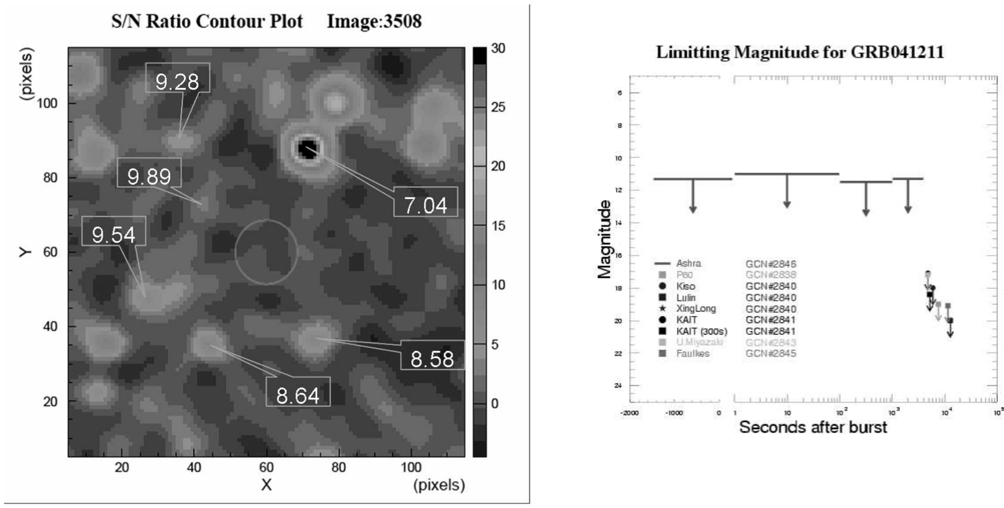

Figure 2. Signal-to-noise ratio map around the HETE-2 WXM error circle of GRB041211 (left). Our 3-sigma limiting magnitudes and comparison with other observations for GRB041211 as a function of time after GRB (right).

The Ashra-P2/3 continuously monitored the Integral field with 5sec-repeat of unfiltered 4sec exposures from 1 second before the burst. The Ashra-AFT automatically responded to the Integral trigger and took the first image of 4sec-exposure at 08:01:57 UT (58 seconds after the burst and 37 seconds after the alert socket). We also took following 10 unfiltered images of 4sec-exposure every 9 to 10 seconds (08:01:57 UT - 08:03:29 UT).

No new source was found within the Integral position by the two telescopes. We compared the co-added 10 images (10 x 4sec) from Ashra-P2/3 with BT in the Tycho catalog and the earliest 3 images and the co-added images (10 x 4sec) from Ashra-AFT with the USNO-B1.0 respectively. We preliminarily obtained 4-sigma limiting magnitudes as shown in Table 1 and compared with other experiments in Figure 3).

Table 1. Ashra-P2/3 limiting magnitudes for GRB050504 (left). Ashra-AFT limiting magnitudes for GRB050504 (right).

start after	end GRB (s)	exposure (s)	limit mag. BT
-1	49	40.0	8.0

start after	end GRB (s)	exposure (s)	limit mag. B1	R1
58	62	4.0	16.7	15.0
68	72	4.0	16.9	15.1
77	81	4.0	16.8	15.1
58	150	40.0	17.7	16.0

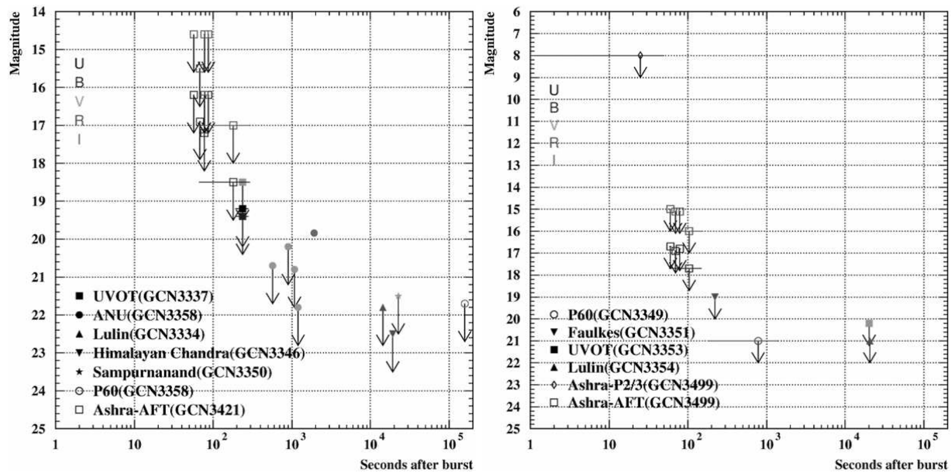

Figure 3. Our 3-sigma limiting magnitudes and comparison with other observations for GRB050502b (left) and GRB050504 (right) as a function of time after GRB.

4. Conclusions

Ashra is capable of detecting optical signals associated with GRBs just on time of GRBs. In conclusion, the prototype detectors have fairly met all our specifications of wide angle high resolution optics and image pipeline. We are thus confident to proceed with the construction of the full-scale detector station system at Mauna Loa as the first phase.

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