RevMexAA (Serie de Conferencias), **48**, 24–26 (2016)

RECENT PROGRESS OF THE ROBOTIC TELESCOPE SYSTEM "MITSUME"

Y. Yatsu[1], N. Kawai[1], T. Fujiwara[1], Y. Tachibana[1], T. Yoshii[1], S. Harita[1], Y. Muraki[1], H. Ohuchi[1], D. Kuroda[2], K. Yanagisawa[2], and H. Hanayama[3]

RESUMEN

Presentamos el telescopio robótico MITSuME para observaciones ópticas e IR de GRBs. El sistema de control está completamente automatizado con objeto de detectar las fulguraciones ópticas, precursores, rupturas de los chorros y otros fenómenos relevantes relacionados con GRBs. Para minimizar el tiempo de comienzo de las observaciones, hemos refinado la secuencia de control. En la actualidad MITSuME puede iniciar las observaciones tan sólo unos pocos segundos después de recibir una alerta GCN. Además, hemos instalado el mode de observación por mosaico para los eventos astronómicos inesperados descubiertos por *Fermi* y por MAXI con menos precisión en el cielo. También detallamos los resultados más relevantes.

ABSTRACT

The MITSuME robotic telescope system for optical/IR follow-up observations of Gamma-ray bursts is presented. To detect the optical flashes, precursors, jet-breakouts and the other intriguing phenomena related to GRBs, the telescope system is completely automated. To minimize the delay time of starting the observation, we had finely turned the control sequence. Currently the MITSuME can start an observation within a few tens of seconds after receiving GCN alert. In addition, we installed the "tiling observation mode" in the control system for the transient events discovered by Fermi and MAXI with low positional accuracy. We also summarize the highlight of the recent observations.

Key Words: gamma ray burst: general — instrumentation: miscellaneous — quasars: supermassive black holes — stars: black holes — techniques: miscellaneous — telescopes

Fig. 1 shows the MITSuME-Akeno observatory and its telescope. The telescope is coupled with tricolor camera (Fig. 1–left) which utilizes two dichroic mirrors for dividing the light flux into three colors (g', Rc, and Ic) therefore can measure the color of the target simultaneously. That is convenient for coarse measurement of red-shifts of GRBs and SEDs of various transient objects. The control system is fully automated to respond to GCN alert and enables quick follow-up observations within a minutes after GCN alerts (Yatsu et al. 2007).

Recently we installed an all-sky monitor developed by Hokkaido University for checking weather conditions. That consists of a commercially available DSLR and a fish-eye lens. The limiting magnitude of the sky monitor is about 6∼7 mag for 15s exposure which is not enough for scientific-use. However the system is very useful for Akeno observatory because the site is always covered by the local clouds that arise from the surrounding mountains. We are planning to use the images on the telescope controller for avoiding clouds. This will significantly extend the observable time.

Fig. 1. MITSuME Akeno Observatory and its 50 cm quasi-Ritchey Chretien reflector.

The other progress is installation of "tiling observation mode". Fermi/GBM and MAXI often provide GCN alerts with large positional errors. If we receive a GCN alert from MAXI or Fermi, the controller automatically calculate the mosaic pattern based on the error box. Although this function is still in the

[1]Deptartment of Physics, Tokyo Institute of Technology, 2-12-1 Ohokayama, Meguro, Tokyo 152-8551, Japan (yatsu@hp.phys.titech.ac.jp).

[2]Okayama Astrophysical Observatory, National Astronomical Observatory of Japan, 3037-5 Honjo, Kamogata, Asakuchi, Okayama 719-0232 Japan.

[3]Ishigaki Astronomical Observatory, National Astronomical Observatory of Japan, 1024-1 Arakawa, Ishigaki, Okinawa 907-0024, Japan.

IV Workshop on Robotic Autonomous Observatories (Torremolinos, Málaga, Spain, September 28- October 2, 2015)
Editors: M. D. Caballero-García, S. B. Pandey, D. Hiriart & A. J. Castro-Tirado

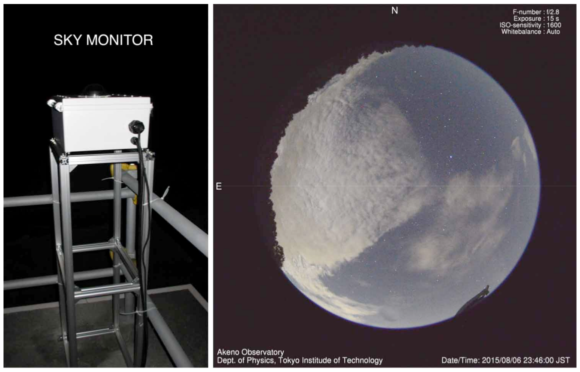

Fig. 2. Sky-monitor for checking the weather at the observatory site(left) and the obtained image(right). The clouds that arise from topographically reason frequently cover the zenith area at the observatory.

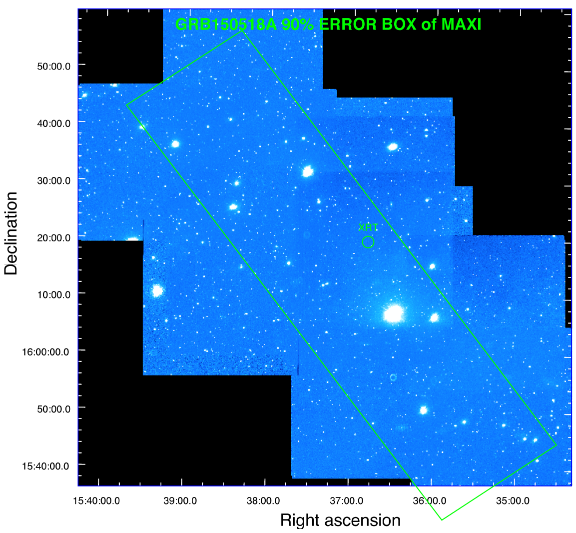

Fig. 3. Demonstration of the tiling observation-mode for GRB150518A discovered by *MAXI*.

test phase, we demonstrated for GRB150518A (Fig. 3) and 150725A discovered by MAXI (Although optical counterparts were not detected).

Table 2 summarizes the results of follow-up observations from Mar-2014 to Mar-2015. The total number of the Swift GCN alerts was 99. Except for the GRBs which were discovered in the sky around the vicinity of the sun and occurred on rainy days, MITSuME-Akeno telescope have tried to observe 34 GRBs and successfully detected four GRB afterglows. Due to the sun-angle limitation of the Swift satellite, most of GRBs were detected under the horizon, we therefore could not start follow-up observation immediately. Taking into account these conditions, our system can detect optical counterparts for 4∼5 GRBs per year.

TABLE 1

SUMMARY OF GRBS OBSERVED WITH MITSUME-AKENO TELESCOPE

GRB	g'[mag]	Rc[mag]	Ic[mag]	Time since Trigger
140302A	>20.8	>19.9	>19.3	8.5h
140311A	>19.1	>19.4	>17.7	15h
140318A	>20.8	>20.1	>19.6	11.5h
140331A	>18.5	>17.8	>17.5	4.5h
140408A	>20.1	>19.6	>19.1	3.5h
140423A	20.49±023	19.83±0.15	19.72±0.22	66min
140430A	>19.2	>19.5	>19.2	15h
140502A	>20.8	>20.2	>19.4	5.5h
140512A	>19.8	>19.3	>18.6	19.5h
140515A	>20.8	>20.5	>19.4	1.5h
140614B	>19.7	>19.8	>18.9	6.5h
140629A	15.06±0.04	14.25±0.03	13.83±0.03	6min
140903A	-	-	-	19h(Cloudy)
140907A	19.2±0.2	18.2±0.2	17.3±0.1	58min
140916A	-	-	-	6h(Cloudy)
140930A	-	-	-	14h(Cloudy)
141015A	>20.7	>20.1	>19.3	5.5h
141026A	>21.8	>21.4	>20.5	2h
141109A	>20.4	>19.4	>20.1	10.5h
141109B	>19.4	>19.0	>18.4	11h
141121A	20.8±02	19.71±0.1	19.4±0.2	10h
141130A	>20.9	>20.3	>18.4	19h(Cloudy)
141212A	>19.6	>19.0	>18.3	61sec
141212B	>19.0	>18.8	>18.3	7h
141220A	>21.4	>20.8	>20.4	10h
141221A	>21.3	>20.8	>20.2	9h
141225A	>22.1	>21.7	>20.4	18h
150101A	>21.8	>21.4	>20.5	1.5h
150120A	>20.7	>20.5	>19.4	7.5h
150120B	>20.6	>20.6	>19.6	5h
150211A	>20.7	>20.3	>19.0	4h
150212A	>20.7	>20.5	>19.4	7h
150213B	>20.3	>19.9	>19.0	17h
150222A	-	-	-	4h(Cloudy)

In addition to those GRBs, we have been continuously monitoring 50 bright AGNe for more than 7 years. Fig. 4 (upper panel) shows the long-term optical light curves of 3C454.3. The color-magnitude diagram shows "redder when brighter" behavior indicates that the emission in the quiescent phase is dominated by the disk-component in the optical energy band. These results can be found in Tachibana et al. (2016).

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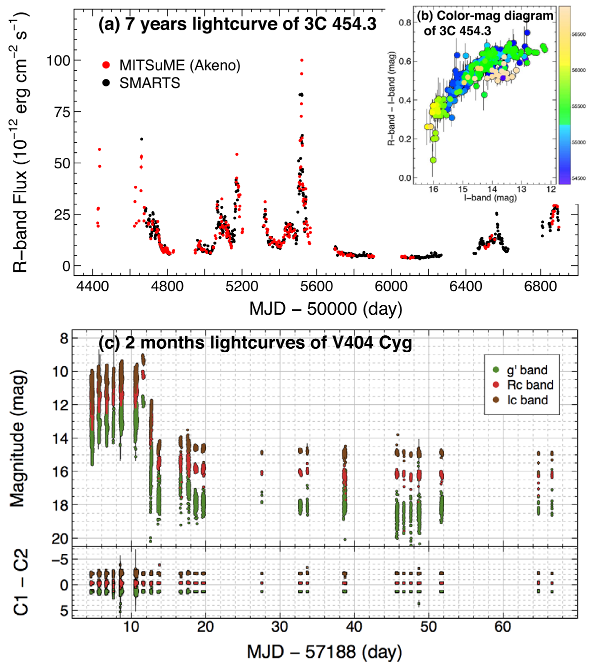

Fig. 4. Long-term light curves of 3C 454.3 (Upper panel) and V404 Cyg (Lower panel) whose intraday variablility was remarkable.

MITSuME is also monitoring galactic transients cooperate with the Japanese X-ray All sky monitor MAXI. The recent exciting event was the flare of the BH binary V404-Cyg from June 2015 (Fig. 4–lower panel). We had observed that object for 2 months with MITSuME-Akeno and Ishigaki observatories. Although it was rainy season in Japan, we successfully obtained multi-color data. We are now summarizing long-term / high time-resolution light curves, and temporal variation of SEDs comparing with the *Swift* and *Fermi* data. These results are found in Tanaka et al. (2016) and Yoshii et al. (2016).

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