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The robotic telescopes system for GRB optical follow-up in Timau National Observatory

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Abstract. The occurrence of Gamma Ray Bursts (GRBs) is yet unpredictable. Thus, follow-up observations to find its optical counterpart should be made as quickly as possible after the first detection, as well as kept being monitored on the observable area. In Southeast Asia region, two new robotic 50-cm telescopes system will be placed in Timau National Observatory, East Nusa Tenggara, Indonesia, which has about 70% of clear sky fraction with low-latitude sky coverage. In this manuscript, the possibility of implementing the system for GRB follow-up is discussed, followed by its future prospects as a multi-messenger optical follow-up robotic telescope. The current properties and status of the system are also described.

Keywords: GRB optical, robotic telescopes system, and Timau National Observatory

1. Introduction
The Gamma Ray Bursts (GRBs) are the most energetic electromagnetic flashes from celestial origin. The “prompt” gamma-ray radiation is usually detected by space-based detectors (e.g. Swift and Fermi satellite), which lasts for seconds to few minutes and is usually followed by an “afterglow” in X-ray, optical, and radio wavelengths, that could last for a few minutes to months. Roughly, there are two classes of burst based on its prompt duration: long-GRBs (>2s) and short-GRBs (<2s). Long-GRBs are usually thought as a result of a massive stellar core collapse. Meanwhile, short-GRBs are linked with the merger of compact objects, which is confirmed by multi-messenger observations, e.g. the gravitational wave GW170817 detection [1].

The coordination among independent space-based detectors and ground-based optical follow-up observatories plays a crucial role to perform early afterglow observation. Due to the nature of the random and short-lived emission, rapid follow-up of GRB satellite detections by ground-based telescopes provides important data to understand the nature of its emission. In terms of location, the observations should be performed uniformly on Earth to chase the early afterglow in the observable area [2]. A new observatory is planned to be built in Timau, Timor island, East Nusa Tenggara, Indonesia (9°35′50.2″S, 123°56′48.5″E). Based on 5-year satellite data, Timau National Observatory site has about 70% of yearly clear sky fraction [3]. Beside the main 3.8-m telescope, two 50-cm robotic telescopes are planned to be placed at the site for survey purpose (Figure 1). Because of the flexibility of robotic telescope, here we discuss the potential of the 50-cm robotic telescopes system as GRB follow-up telescopes.
Figure 1. Two robotic telescopes systems. Officina Stellare (OS) ProRC 500 f/8 set (left) and RiFast 500 f/3.8 set (right) inside a 5-m AstroHaven dome.

2. Hardware Properties

Imaging properties of the system are described in Table 1. The system consists of two individual 50 cm telescopes inside a 5-m AstroHaven clamshell enclosure. The optical assembly of the f/8.0 telescope is Officina Stellare (OS) Ritchey-Chrétien Cassegrain reflector (ProRC 500) and the f/3.8 is OS proprietary aspheric primary mirror reflector (RiFast 500). Each telescope is mounted on the Paramount Taurus equatorial fork mounting. The cameras are FLI PL16803 with a 4k×4k ON Semi-KAF 16803 sensor for the f/8.0 and FLI PL4240 with a 2k×2k e2v CCD42-40-1-368 sensor for the f/3.8. Both cameras are attached to FLI CL1-10 filter wheels with standard Bessel BVRI and LRGB filters.

Table 1. Timau National Observatory 50-cm Telescopes Specification.

|                   | OS RiFast 500 | OS ProRC 500 |
|-------------------|--------------|--------------|
| Primary Mirror Diameter | 500 mm   | 500 mm   |
| Focal Length      | 1900 mm     | 4000 mm     |
| F-Number          | 3.8         | 8           |
| Band              | BVRI and LRGB |            |
| Maneuver Speed    | <3.5°/s    |             |
| FOV               | 50’×50’    | 32’×32’    |
| Pixel scale       | 1.46”/pixel | 0.46”/pixel |
The hardware are designed to be controlled autonomously. The components of the telescopes are controlled by various programs on Windows-based PCs mostly via ASCOM interface. The imaging system (cameras, filter wheels, and focusers) are controlled by MaximDL. The mountings are controlled by The SkyX software. The whole components (including the enclosure and the weather station) are planned to be integrated and controlled by ACP Observatory Control Software. Table 2 shows the comparison between Timau National Observatory 50-cm robotic telescopes with other established GRB follow-up telescopes.

### Table 2. Comparison with other GRB follow-up telescopes.

|                      | Timau National Observatory’s 50 cm F/3.8 | Timau National Observatory’s 50 cm F/8 | OAO 50 cm [4] | Akeno 50 cm [4] | WRT [5] | Zadko Telescope [6] |
|----------------------|------------------------------------------|---------------------------------------|---------------|----------------|---------|---------------------|
| Mirror Diameter      | 500 mm                                   | 500 mm                                | 500 mm        | 500 mm         | 400 mm  | 1007 mm             |
| F-Number             | 3.8                                       | 8                                      | 6.5           | 6.0            | 14.25   | 4.01                |
| Band                 | BVRI and LRGB                             | g’ R, Ic                               | g’ R, Ic      | V R g’r’i’      | Ha OIII |
| Maneuver Speed       | <3.5% s                                   | 4%/s                                   | 9%/s          | 3%             |
| FOV                  | 50’×50’                                   | 32’×32’                                | 26’×26’       | 28’×28’        | 14.5’×14.5’ | 23’×23’            |

In order to observe the GRB quickly, the system should be able to receive the GRB alert from satellite and perform observation automatically. One of the possible mechanisms is by subscribing into Gamma-ray Coordination Network (GCN) socket via a VOEvent protocol. The notification from VOEvent will be parsed by VOEvent Receiver in ACP Scheduler. The local position of the event then will be calculated. Then, if the event fulfills the constraints (i.e. weather, observability, lunar illumination, etc.), ACP Scheduler will execute the observation. Details of the command pipeline are described in Figure 2.

![Diagram](image-url)  
**Figure 2.** Proposed automatic GRB follow-up observation pipeline on Timau National Observatory 50 cm Telescope.
The telescopes are planned to be used for many purposes, such as near-Earth objects monitoring and extrasolar planet searching as the main priorities. Thus, the implementation of the rapid GRB follow-up robotic system should be made without interfering other observations. Satellite alert could be filtered out by selecting only confirmed and sufficiently bright event to be observed.

3. Scientific Potential

The slew duration of the telescope is about 30 to 60 seconds, depending on the initial position. By considering their response time, it is obvious that the system could not potentially observe prompt phase of GRB emission which lasts for only about 20 seconds in average [7]. However, the afterglow (or the transition phase between prompt and afterglow) could potentially be observed. Considering the system capabilities for GRB follow-up, there are some science opportunities and prospects that could be studied by using this system.

3.1. Testing fireball model

In the fireball model, the standard picture of GRB emission is an expanding fireball of relativistic particle [8]. The expansion is driven by the central engine in the middle of the fireball. The super-Eddington energy release is thought to be responsible for the prompt emission and create a forward shock. The shock dissipation between high-energy particles and the surrounding medium are responsible for the afterglow emission. It is thought that reverse shock also exists, propagates back to the central engine and emits bright but short optical flashes. The forward and reverse shock properties could provide information about the explosion, ejecta, geometry, and properties of the surrounding medium [9,10].

3.2. High-z GRBs

As one of the most luminous electromagnetic sources, radiation from high redshift GRBs could be bright enough to be detected. Analysis of GRB’s optical emission could potentially probe stellar or interstellar matter properties at high-z. The high-z GRBs are also thought to originate from Population III stars [11]. Thus, optical follow-up for high-z GRBs could also probe the properties of Population III stars explosion scenario.

3.3. Multi-messenger follow-up

There are two standard scenarios to explain GRB progenitor: core-collapse of massive stars and binary merger of compact objects. The second scenario was confirmed by coordinated observation of kilonova following GW 170817 detection [1]. The GRBs are also thought as one of the few candidates of ultra-high energy cosmic-ray. Multi-messenger observations could be useful to probe high-energy particles acceleration from GRBs [12].

If the system is capable to respond to GRB alerts automatically, the telescope may also able to receive alerts from other types of messenger, such as gravitational wave or high-energy cosmic neutrino. This could be implemented by receiving the alert via GCN/TAN notices or VOEvent protocol.

4. Current Status

The telescopes are currently located in National Institute of Aeronautics and Space (LAPAN), Bandung, West Java, Indonesia. The control system is currently being developed. Hardware components are also being tested to know the characteristics and performance of each part.
Figure 3. The telescopes are temporarily installed in LAPAN Space Science Center, Bandung.

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