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Goddard Robotic Telescope – Optical follow-up of GRBs and coordinated observations of AGNs

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Abstract

Since it is not possible to predict when a Gamma-Ray Burst (GRB) will occur or when Active Galactic Nucleus (AGN) flaring activity starts, follow-up/monitoring ground telescopes must be located as uniformly as possible all over the world in order to collect data simultaneously with *Fermi* and *Swift* detections. However, there is a distinct gap in follow-up coverage of telescopes in the eastern U.S. region based on the operations of *Swift*. Motivated by this fact, we have constructed a 14″ fully automated optical robotic telescope, Goddard Robotic Telescope (GRT), at the Goddard Geophysical and Astronomical Observatory. The aims of our robotic telescope are (1) to follow-up *Swift*/*Fermi* GRBs and (2) to perform the coordinated optical observations of *Fermi* Large Area Telescope (LAT) AGN. Our telescope system consists of off-the-shelf hardware. With the focal reducer, we are able to match the field of view of *Swift* narrow instruments ($20' \times 20'$). We started scientific observations in mid-November 2008 and GRT has been fully remotely operated since August 2009. The 3σ upper limit in a 30 s exposure in the R filter is ∼15.4 mag; however, we can reach to ∼18 mag in a 600 s exposures. Due to the weather condition at the telescope site, our observing efficiency is 30–40% on average.

Keywords: Gamma ray; Burst; AGN; Optical

1. Introduction

The γ-ray emission which comes from extremely energetic γ-ray sources such as Gamma-Ray Bursts (GRBs) and Active Galactic Nuclei (AGNs) (especially blazars) is believed to be produced by accelerated particles in a relativistic jet with bulk Lorentz factors of ∼100 for GRBs and ∼10 for AGNs. A GRB jet is formed when a massive star ($>10\ M_\odot$) collapses into a black hole (Woosley, 1993; Paczyński, 1998; MacFadyen and Woosley, 1999). On the other hand, an AGN jet is a continuous outflow from an active supermassive black hole ($10^{6-9}\ M_\odot$) (e.g. Urry and Padovani, 1995). Although the energy scale and bulk motion of jets differ by an order of magnitude between GRBs and AGNs, their radiation processes are expected to be similar. Therefore, understanding radiation processes in the context of shock physics and particle acceleration using both GRBs and AGNs will provide a deeper understanding of the fundamental physics in these extreme environments.

Recent observations of prompt GRB optical emission by ground/space robotic telescopes are providing key data

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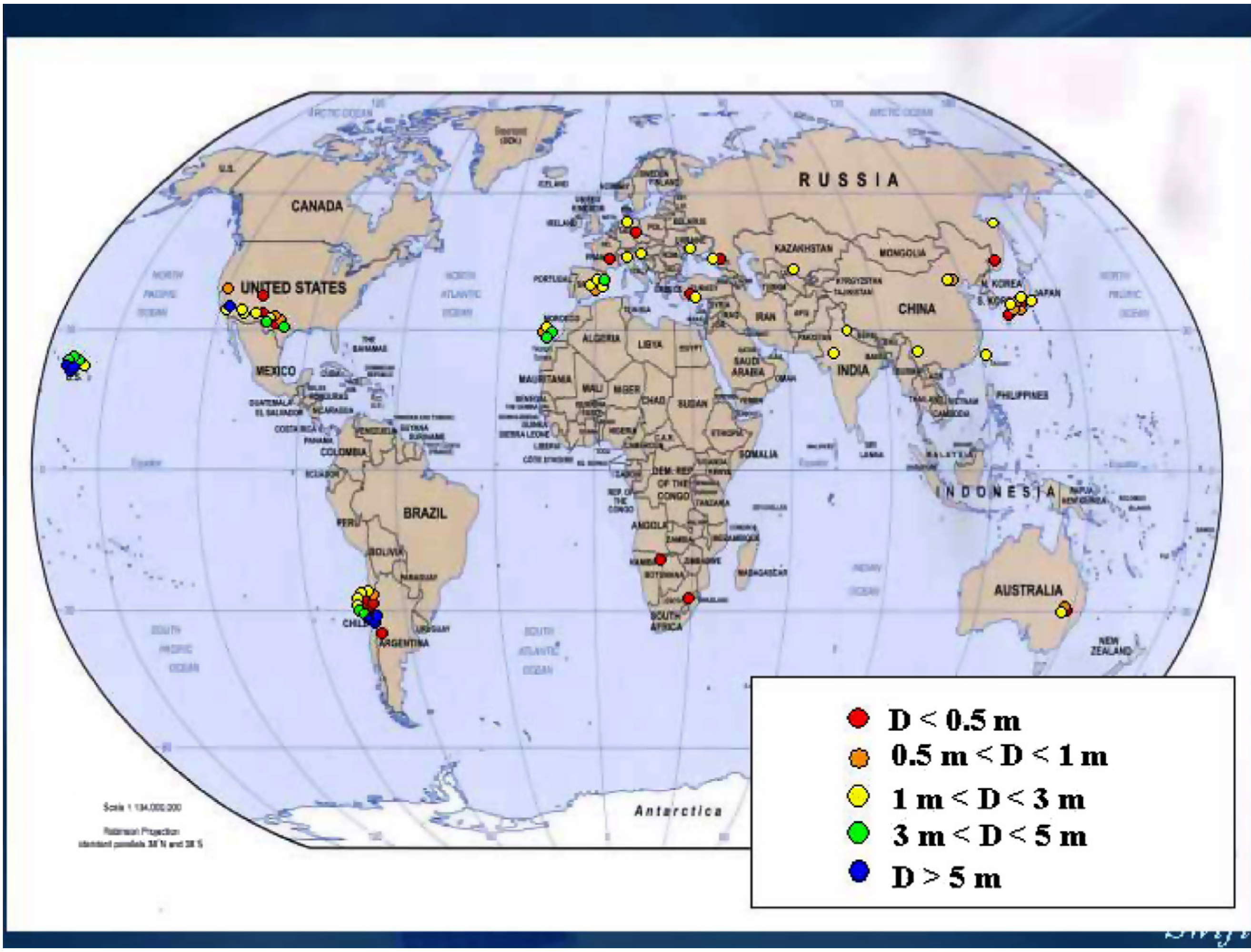

Fig. 1. Distribution of the GRB follow-up telescopes (information from GCN Circular of the Swift GRBs from September 2006 to March 2007).

for understanding the radiation mechanism of GRBs. The observations of GRB 050820A by RAPid Telescope for Optical Response (RAPTOR; Vestrand et al., 2006) and GRB 061121 by *Swift* UV/Optical Telescope (UVOT; Page et al., 2007) indicate that there are at least two components in the prompt optical emission. One component is optical emission correlated with the prompt γ-ray emission. The other component is a smoothly rising and decaying component during the prompt γ-ray phase. The first component could be interpreted as emission from an internal shock because of the similar variability between the optical and γ-ray bands. The second component could be due to an external shock interacting with the inter-stellar matter. However, the Robotic Optical Transient Search Experiment (ROTSE) has shown that there are a couple of cases where the early optical emission does not correlate with the γ-ray emission (e.g. Rykoff et al., 2005). The extremely bright prompt optical emission from GRB 080319B observed by TORTORA and 'PI of the sky' challenges the standard picture of the GRB emission model (Racusin et al., 2008).

Blazars form a sub-group of radio-loud AGNs and show an extreme variability at all wavelengths (Urry, 1999). The most accepted scenario is that a rotating supermassive black hole surrounded by an accretion disk with an intense plasma jet closely aligned to the line of sight is responsible for the blazar emission. However, fundamental understanding of the radiation process in blazars requires extensive monitoring campaigns at all wavelengths. In particular, properties of variability (including flares) and spectra from simultaneous data in various wavelengths provides key information for a physical understanding of blazars.

2. Motivation and telescope specification

Since it is not possible to predict when a GRB will occur or when AGN flaring activity starts, follow-up/monitoring ground telescopes must be located as uniformly as possible all over the world in order to collect data simultaneously with *Fermi* and *Swift* detections. Based on the operations of *Swift*, however, we notice a distinct gap in follow-up coverage in the eastern U.S. region (Fig. 1). This fact motivated us to construct a fully automated optical telescope at the Goddard Space Flight Center. If there is no GRB to