Improving VERITAS Sensitivity to Gamma-Ray Bursts

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Abstract. Rapid follow-up observations of gamma-ray bursts above ∼100 GeV are an important part of the VERITAS observing program and results from these observations are the subject of another contribution to this conference [1]. Here, we present work under way to improve the sensitivity of VERITAS for future observations of GRBs.

Keywords: gamma-ray bursts, gamma-ray instrumentation
PACS: 95.55.Ka,95.85.Pw,98.70.Rz

VERITAS, the Very Energetic Radiation Imaging Telescope Array System, is a state-of-the-art instrument [2, 3] to study gamma rays in the very-high-energy (VHE) regime, >100 GeV, to advance our knowledge and understanding of VHE gamma-ray sources. It is an array of four 12-m imaging atmospheric Cherenkov telescopes, installed at the basecamp of the Whipple Observatory in southern Arizona in the United States. In addition to the study of known VHE source classes, an important goal of the VERITAS project is the search for new types of VHE emitters, such as gamma-ray bursts (GRB).

GRB observations are the highest priority observing target for VERITAS, preempting any other planned observation or target of opportunity. VERITAS is staffed and observations are taken on candidate gamma-ray sources on every moonless night of the year when weather allows. Bursts are observed whenever they are at least 20° above the horizon. Upon receipt of a Gamma-ray Bursts Coordinates Network (GCN) socket notice, the observer is immediately alerted and the burst coordinates are automatically loaded into the telescope control computer. The operator terminates the observation in progress and immediately slews the telescopes[1] to the source and commences observations. The observations are usually taken in 20 minute integrations; the time resolution is $<1\ \mu$s and the deadtime per event $\sim 400\ \mu$s. Depending on the position of the burst, the Sun and the Moon, observations can continue for up to six hours, typically for three hours.

The VERITAS fluence sensitivity on short time scales is similar to that of the *Fermi*-LAT, better for hard spectra and not quite as good for soft spectra. For a spectrum with photon index of 2, the VERITAS fluence sensitivity is about an order of magnitude better than the LAT. The present VERITAS νF_ν sensitivity to afterglow emission averaged over the three hours after a burst is 4×10^{-12} erg cm^{-2} s^{-1}. We discuss four areas of work underway that would improve either the response time or the sensitivity to bursts: an upgrade to the telescope cameras, an upgrade to the telescope trigger system, increasing the slewing speed of the telescopes and scanning GBM error circles which are larger than the telescope field of view.

CAMERA UPGRADE

The VERITAS cameras currently use 28 mm diameter Photonis XP 2970/02 photomultiplier tubes (PMTs) with conventional bialkali photocathode. The cameras will be upgraded in summer 2012 to use photomultipliers with higher quantum efficiency.

The Hamamatsu R10560-100-20MOD photomultiplier has been selected for this upgrade. It has a Super Bialkali photocathode with peak quantum efficiency of about 35% at about 350 nm. Figure 1 shows the photon detection efficiency at 450 nm we have measured for a sample of 20 new tubes of this type, compared to a sample of 30 of the Photonis tubes removed from the VERITAS cameras after several years of operation.

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[1] The telescopes are on alt-az mounts, and currently slew at a rate of 1°/s independently on each axis.

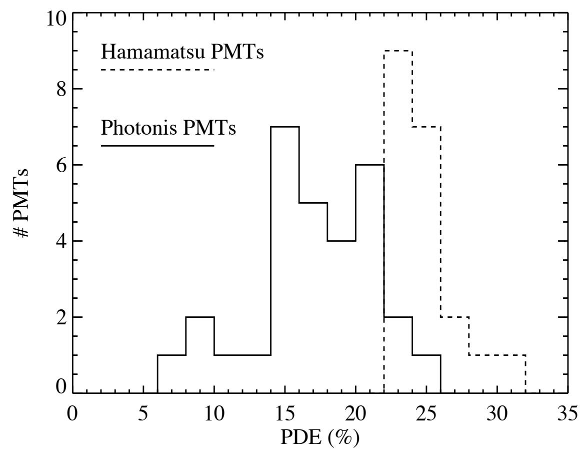

FIGURE 1. Photon detection efficiency (PDE), which is the product of quantum efficiency and collection efficiency, measured at 450 nm for samples of Hamamatsu R10560-100-20MOD (dashed line) and Photonis XP 2970/02 (solid line) PMTs.

The combination of the PMT upgrade and trigger upgrade (see below) is expected to lower the VERITAS hardware energy threshold from about 100 GeV to around 60 GeV.

TRIGGER UPGRADE

A three-level trigger system discriminates flashes of Cherenkov light produced by particle showers in the atmosphere from the night sky background and light from single muons. The first level is a constant fraction discriminator on each PMT signal, requiring a signal of about 5 photoelectrons. At the second level, a pattern trigger running independently on each telescope is satisfied if there is a coincidence of CFD hits in three nearest-neighbor PMTs in that telescope's camera. The final level requires coincident pattern triggers from at least two telescopes.

A new set of pattern triggers has been built for installation in summer 2011 on all four telescopes. It uses a shorter 4 ns coincidence window than the existing trigger, which will reduce the rate of accidental coincidences from night sky background and allow the discriminator thresholds on the individual photomultiplier tubes to be lowered.

FASTER SLEWING

The VERITAS telescopes have a 3.5° field of view. Consequently, the likelihood of a burst occurring by coincidence in the field of view is small, and VERITAS must be retargeted to GRB positions obtained from the GCN.

The fastest response achieved so far has been 91 seconds, and the median response time is 230 seconds when the Sun, the Moon or the weather are not constraints. For burst afterglows following typical power-law lightcurves, such as shown in Figure 2, the possibility of detection would be considerably improved with observations at earlier times.

We are studying the possibility of increasing the telescope slew speed from the present value of 1° per second, with a goal to reach 2° per second or more, so that retargeting can be completed more quickly.

An initial test using the present drive system achieved a speed of 1.4° per second. A gearbox upgrade to the telescope positioners might reach the 2° per second goal. Work is still required and is under way to ensure that the telescopes can handle the potential stresses they would experience when slewing faster.

COVERING LARGER ERROR CIRCLES

The VERITAS field of view is smaller than the error circle for many bursts detected by the Fermi Gamma-ray Burst Monitor (GBM). As seen in Figure 2, if gamma-ray emission extends to very high energies, VERITAS would be able

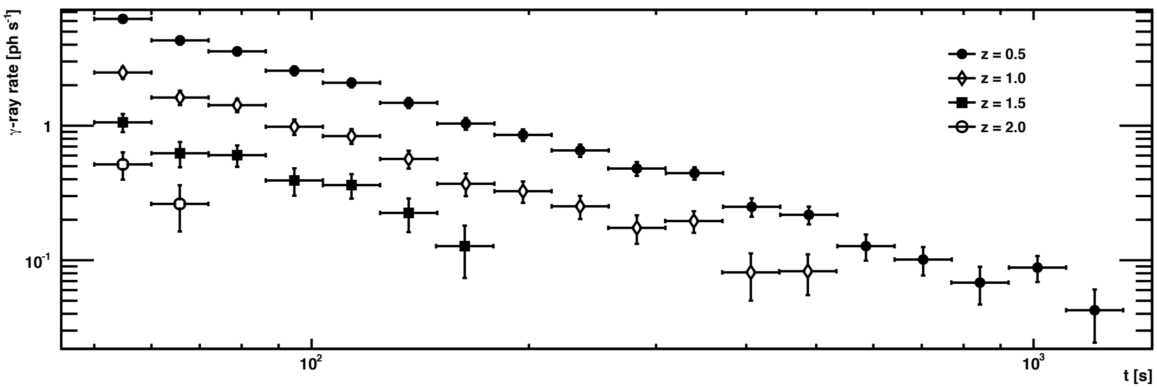

FIGURE 2. Simulated VERITAS lightcurves for GRB 090902B, assuming the temporal and spectral powerlaws measured by the Fermi LAT [4] and EBL absorption [5] for different redshifts. Each point shown has at least 3σ significance.

to detect some bursts with exposures as short as ten seconds. By scanning the GBM error circles, we would not only increase the possibility of finding the burst emission, but would be able to determine the burst position to an accuracy of a few arcminutes, allowing followup observations at other wavelengths. We are working to implement a tiling strategy for VERITAS observations to cover these larger error circles. Raster-scanning code already exists for doing telescope mirror alignment, and the capability to follow circular "orbits" on the celestial sphere was recently added to the tracking software. We are studying strategies to adapt these tools for covering the GBM error circles.

SUMMARY

Improvements under way will make VERITAS a more sensitive instrument for GRB studies. Upgrades to the trigger and focal plane cameras will lower the energy threshold and increase the effective area for events around 100 GeV and below, allowing possible detection of fainter or more distant bursts. Faster slewing would reduce the elapsed time from burst onset to VERITAS observations, improving the sensitivity to rapidly fading afterglows. Raster scanning of Fermi GBM error circles might allow detection and localization of bursts that would otherwise be outside the VERITAS field of view.

ACKNOWLEDGMENTS

This research is supported by grants from the U.S. Department of Energy, the U.S. National Science Foundation, the Smithsonian Institution, by NSERC in Canada, by Science Foundation Ireland, and by STFC in the UK. We acknowledge the excellent work of the technical support staff at the FLWO and the collaborating institutions in the construction and operation of the instrument. Lloyd Gebremedhin, Douglas Long and Kyle Kaplan assisted with the PMT measurements presented.

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