GRB Observations around 100 GeV with STACEE

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Abstract. STACEE is an atmospheric Cherenkov detector using the large mirror area of a solar research facility to obtain a low energy threshold. The peak of a detected power law spectrum is around 100 GeV. An exciting possibility for STACEE is to follow up gamma-ray burst alerts from satellites. The low energy threshold of STACEE allows detection of gamma rays from higher redshifts than most other ground-based experiments. The STACEE instrument can be re-targeted to the position of a GRB within about four minutes of an alert to search for emission above 50 GeV. We discuss the STACEE sensitivity to high energy gamma-ray emission from GRB.

THE STACEE TELESCOPE

STACEE uses the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories outside Albuquerque, New Mexico, USA. The NSTTF is located at 34.96° N, 106.51° W and is 1700 m above sea level. The facility has 220 heliostat mirrors designed to track the sun across the sky, each with 37 m^2 area. STACEE uses 64 of these heliostats to collect Cherenkov light produced by cascades in the atmosphere.

STACEE employs five secondary mirrors on the solar tower to focus the Cherenkov light onto photomultiplier tube (PMT) cameras, as shown in Figure 1. The light from each heliostat is detected by a separate PMT and the waveform of the PMT signal is recorded by a flash ADC. A programmable digital delay and trigger system[1] selects showers for acquisition while eliminating most random coincidences of night sky background photons. Details about an early version of the instrument can be found in D. S. Hanna *et al.* [2].

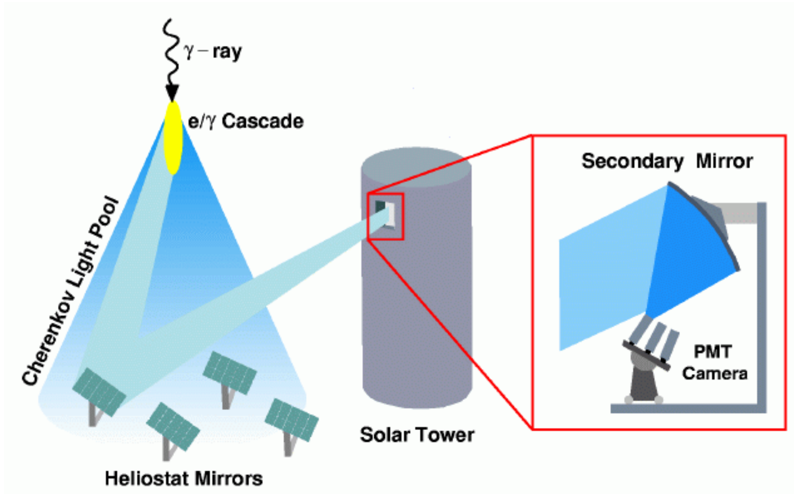

FIGURE 1. The STACEE technique. Cherenkov light produced in the atmosphere is reflected by the heliostat mirrors, which track the candidate source, to stationary secondary mirrors on the solar tower. The secondary mirrors focus the light from each heliostat onto a distinct PMT in the PMT camera.

STACEE PERFORMANCE

The large mirror area used by STACEE leads to an energy threshold – defined as the peak of a detected power law spectrum – around 100 GeV, with significant effective area as low as 50 GeV. This threshold is lower than most other current ground-based detectors. The low energy threshold opens up the possibility of detecting more distant sources, as shown in Figure 2. Collisions of high energy gamma rays with starlight photons to create electron-positron pairs attenuate the gamma-ray flux from more distant sources. The extinction becomes more severe with increasing energy, producing an energy-dependent horizon for gamma-ray observations.

The construction of the STACEE experiment is complete. However, analysis methods, including background rejection techniques, are still under development. STACEE operates with a trigger rate of about 8 Hz and a trigger threshold around 4 photoelectrons per heliostat, corresponding to a trigger threshold of about 50 GeV. Including the anticipated contributions from analysis methods under development, approximately 25 hours would be required for a 10σ detection of the Crab, which analysis techniques to reject background cosmic ray events should improve to 4 hours.

The STACEE sensitivity to a GRB will be about 2×10^{-9} cm^{-2} s^{-1} above 70 GeV (5σ in a 30 minute observation). STACEE would easily detect the flux estimated by power-law extrapolations of the EGRET data. For example, the flux from GRB940217 [3] extrapolated to STACEE energies is $\sim$50 times higher than this sensitivity.

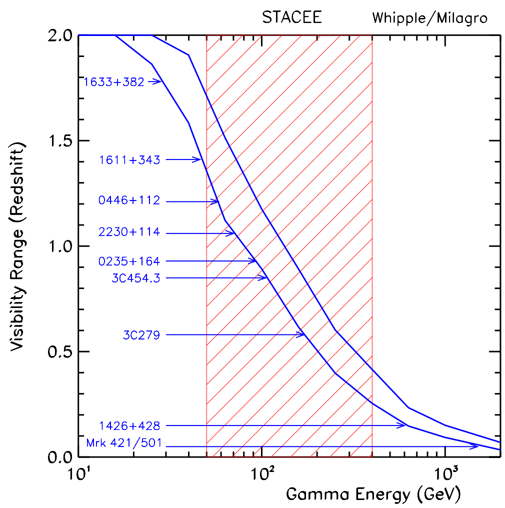

FIGURE 2. Expected gamma-ray horizon *vs.* energy. As source distance increases, lower gamma-ray energies are required to evade absorption by the extragalactic background light (EBL). The curves represent a range of plausible EBL models. The hatched band shows the region covered by STACEE that is largely inaccessible to other present generation experiments, *e.g.* Whipple and Milagro.

TABLE 1. Summary of prompt burst alerts received by STACEE since September 1, 2002

GRB	UTC Time	Spacecraft Providing Alert	Notice Delay (minutes)	Delay until Observable (hours)	STACEE Observations
021004	12:06:14	HETE	0.8	14.1	None
021112	03:28:16	HETE	81	3.2	Starting 219 min after burst; 112 min on burst position
021211	11:18:34	HETE	0.4	0.0	None; bad weather
030115	03:22:34	HETE	71	8.4	None; full moon*
030227	08:42:16	INTEGRAL	48	17.7	None
030324	03:12:43	HETE	0.4	2.0	Starting 123 min after burst; 56 min on burst position
030328	11:20:58	HETE	53	16.7	None
030329	11:37:15	HETE	73	15.2	None
030418	09:59:19	HETE	3.6	17.2	None
030501A	03:10:19	INTEGRAL	0.3	4.6	Starting 369 min after burst; 28 min on burst position
030519	14:04:54	HETE	0.6	Infinite	None
030528	13:03:03	HETE	0.6	17.6	None
030723	06:28:18	HETE	0.8	Infinite	None
030824	16:47:35	HETE	60	11.7	None

* No observations scheduled that night because there was less than 3 hours of darkness

GRB OBSERVATIONS

Observing gamma-ray bursts is a high priority for STACEE. The GCN burst alerts are monitored with a computer program which alerts the STACEE operators if one is visible from the STACEE site. The computer network link to the STACEE site has occasional outages which do not otherwise interfere with STACEE operations. To insure that burst alerts are not missed as a result of such an outage, we have recently equipped the STACEE operators with a pager which receives alerts directly from GCN. The STACEE instrument can be re-targeted to the position of a GRB within about four minutes to search for emission above 50 GeV. We also search for afterglow emission from bursts that have occurred within the previous 12 hours.

The ability of STACEE to observe the GRB source position within minutes of the first emission is very significant. EGRET detected GeV emission, including an 18 GeV photon, from GRB940217 up to ninety minutes after the start of the burst [3].

Since September 1, 2002, we have received notices containing a burst localization within 90 minutes of the burst onset for 14 GRBs, listed in Table 1. STACEE can only observe bursts within 60° of zenith and when both the sun and the moon are below the horizon. The time until these three conditions were met is given in the table. We have taken data for three of the bursts, as indicated. Preliminary analysis of the data from GRB 021112 and GRB 030501 shows no evidence for a detection. The data from the third burst were compromised by difficulties with the data acquisition system and will require further effort before a result can be obtained.

STACEE operates with a duty cycle of approximately 8%. The primary constraints are daylight and moonlight, with most of the remaining time lost because of bad weather. Once Swift is launched, we expect to have rapid observations for about 2% of the bursts, or about 3 per year, with afterglow observations within the first 24 hours for an additional 10% of the bursts, about 15 per year. These numbers assume that the bursts are found isotropically on the sky. To the extent that the Swift field of view is aligned in the anti-solar direction, the number of Swift bursts visible to STACEE could as much as double.

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