VERITAS Observations of Gamma-Ray Bursts

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Summary

VERITAS has been searching for very high energy (>100 GeV) emission from satellite-detected gamma-ray bursts since 2006. No significant emission has yet been detected and upper limits on the flux of well-localized bursts are presented here.

Abstract

The Fermi satellite has detected ∼300 gamma-ray bursts (GRBs), and more than ten with the Large Area Telescope (LAT). Delayed GeV emission has been detected by the LAT and in the case of GRB 090902B a 33 GeV photon was detected 82 s after T_0. This burst was determined to be at a redshift of 1.822 indicating this photon was emitted at an energy of ∼90 GeV. VERITAS is an array of four Imaging Atmospheric Cherenkov Telescopes with good sensitivity to gamma rays ranging from 100 GeV to >30 TeV. Characterizing gamma-ray burst emission at the highest energies will significantly increase our understanding of GRB physics and potentially constrain models of the extragalactic background light (EBL) and theories predicting Lorentz invariance violation (LIV). VERITAS has been performing follow-up observations of gamma-ray bursts since 2006. No evidence of emission has yet been found and upper limits on the VHE flux from these bursts are presented here.

High Energy Emission from γ-ray Bursts

Several GRB afterglow models [9, 4, 7] predict that photon energies in the hundreds of GeV or even TeV energy range are possible. The observations of the exceptionally energetic GRB 080916C [1] and GRB 090902B [6] by the Fermi satellite indicates that GRBs are capable of producing photons of at least several 10s of GeV.

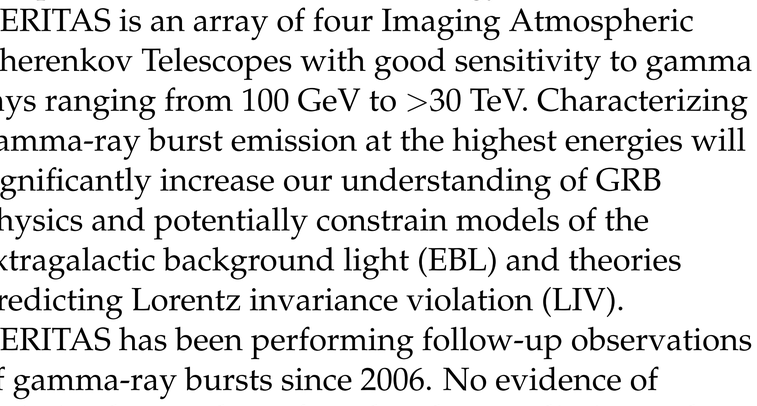

Figure 1: Photons detected by Fermi-LAT from GRB 090902B [6]

The relatively large collection area of VERITAS above 100 GeV allows for sensitive measurements of GRB emission at the highest energies. Quantifying the emission of GRBs at these energies would significantly improve our understanding of gamma-ray bursts, and potentially the EBL and LIV as well.

VERITAS - Very Energetic Radiation Imaging Telescope Array System [8]

- Average duty cycle: 12.5%
- Angular resolution: 0.1° at 1 TeV, 0.14° at 200 GeV
- Energy range: 100 GeV to 30 TeV
- Maximum slewing rate: 1°/s
- Peak effective area: 100,000 m^2
- Field of view diameter: 3.5°
- Full 4-telescope operation since September, 2007
- Observable bursts per year: ∼20

Note: Several of the statistics above are particular to the VERITAS array configuration before August, 2009

GRB Observations

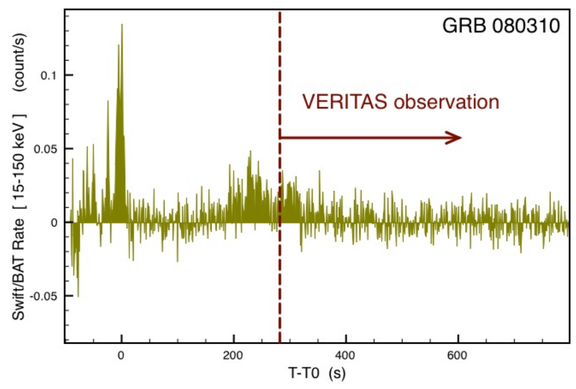

Figure 2: VERITAS Observation of GRB 080310 began during the prompt phase of the burst.

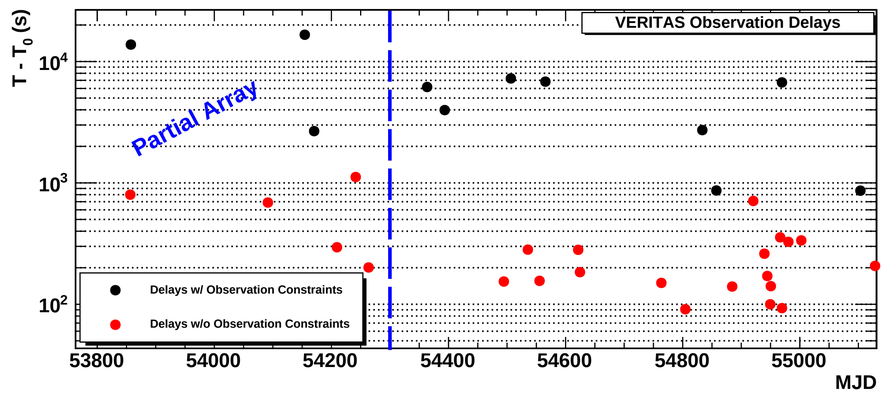

Figure 3: VERITAS Observation delays since GRB data taking began in 2006.

Gamma-ray bursts are the highest priority targets in the VERITAS observing program

- GRBs are observed for three hours after T_0
  - subject to observational limitations
- VERITAS control computers set to process GCN notices [2]
- Upon receipt of a notice, observers are instructed to point telescopes to the burst position
- Telescope slew rate is often the limiting delay to beginning GRB observations

- Average observation delays decreasing:
- Fastest response times:
  - 081024B: 91 s
  - 090518B: 93 s
- Improved understanding of instrument in "adverse" conditions improves duty cycle
  - Under moonlight
  - Low elevation
- Further studies of low elevation instrument response underway

Results

Presented here are results from VERITAS observations of 16 gamma-ray bursts which were selected for having data taken at elevations above 30° and with precise, satellite-provided source locations. Data were analyzed using the VEGAS analysis package [3]. No significant excess was found, and 99% confidence level upper limits on the VHE gamma-ray flux above the threshold $E_{\rm th}$ are calculated using the method of Rolke et al [5]. The analysis is run twice: once assuming a source spectrum of $dN/dE \propto E^{-2.5}$ and once assuming a source spectrum of $dN/dE \propto E^{-3.5}$. These correspond to the x_{stnd} and x_{soft} entries, respectively in the table to the right. ΔT is the delay from when the burst triggered the satellite to when VERITAS was tracking the target and T_{90} is the duration over which 90% of the 15 - 350 keV emission occurred.

GRB	T_{90}(s)	ΔT(s)	Obs(min)	$E_{\rm th,soft}$(GeV)	$E_{\rm th,stnd}$(GeV)	$\rm UL_{soft}$ ($\rm cm^{-2}\,s^{-1}$)	$\rm UL_{stnd}$ ($\rm cm^{-2}\,s^{-1}$)	z
070223	89	1.6×10^4	74.1	140	210	2.8×10^{-11}	2.2×10^{-11}	–
070419A	116	295	37.7	600	720	3.6×10^{-12}	8.9×10^{-12}	0.97
070521	38	1118	75.4	120	190	2.4×10^{-13}	2.9×10^{-12}	–
070612B	14	201	131.9	230	380	9.9×10^{-12}	2.0×10^{-12}	–
071020	4	3981	73.6	320	500	3.7×10^{-11}	9.4×10^{-12}	2.145
080129	49	154	30.4	230	370	2.2×10^{-11}	9.8×10^{-12}	–
080310	365	282	197.9	170	280	8.0×10^{-12}	2.6×10^{-12}	2.427
080330	61	156	107.8	120	190	1.1×10^{-11}	8.4×10^{-12}	1.51
080409	20	6829	19.0	560	1060	1.0×10^{-10}	2.2×10^{-11}	< 4.3
080604	82	271	151.9	160	260	2.1×10^{-11}	5.8×10^{-12}	1.416
080607	79	184	56.0	310	410	4.8×10^{-11}	1.8×10^{-11}	3.036
081024A	2	150	161.2	180	280	3.1×10^{-13}	5.8×10^{-12}	–
090102	27	2724	83.1	310	410	1.9×10^{-11}	1.1×10^{-11}	1.547
090418A	56	261	30.4	120	170	5.7×10^{-11}	1.5×10^{-11}	1.608
090429B	6	141	146.3	120	190	3.0×10^{-11}	1.2×10^{-11}	–
090515	< 1	356	76.8	210	330	3.3×10^{-11}	8.1×10^{-12}	–

References

[1] A. A. *et al.*Abdo. Fermi Observations of High-Energy Gamma-Ray Emission from GRB 080916C. *Science*, 323:1688–, March 2009.
[2] S. D. Barthelmy. http://gcn.gsfc.nasa.gov.
[3] M. Daniel *et al.*. Proc. 30th ICRC.
[4] A. Pe'er and E. Waxman. The High-Energy Tail of GRB 941017: Comptonization of Synchrotron Self-absorbed Photons. *Astrophys. J. Lett.*, 603:L1–L4, 2004.
[5] W. Rolke *et al.*. *NIM A*, 551:493, 2005.
[6] The Fermi GBM/LAT collaborations and The Swift Team. Fermi Observations of GRB 090902B: A Distinct Spectral Component in the Prompt and Delayed Emission. *ArXiv e-prints*, September 2009.
[7] X. Y. Wang *et al.*. Prompt High-Energy Gamma-Ray Emission from the Synchrotron Self-Compton Process in the Reverse Shocks of Gamma-Ray Bursts. *Astrophys. J. Lett.*, 546:L33–L37, 2001.
[8] T. C. Weekes *et al.*. VERITAS: the Very Energetic Radiation Imaging Telescope Array System. *Astropart. Phys.*, 17:221–243, 2002.
[9] B. Zhang and P. Meszaros. High-energy spectral components in gamma-ray burst afterglows. *Astrophys. J.*, 559:110–112, 2001.

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