GRB021104, GRB021112 and GRB021113: our annual fall outbreak of GRB in Milagro

Julie Mc Enery

December 4, 2002

1 Introduction

There were 3 bursts discovered by HETE in November 2002 which were within the field of view of Milagro. These are the first satelite detected bursts within our field of view since we switched to the new trigger. The 3 HETE bursts we got last year also happened in the fall, this seems to be anual event.

I looked at these bursts using a binned analysis with nfit>20 and a circular bin of radius 1.6 degrees placed at the HETE position. This is larger than the 1.2 degrees used in the Crab analysis to account for uncertainties in the HETE location (generally about 20 arcminutes, 90% confidence radius) and possible systematic pointing issues in milagro. I did not use an X2 cut for the results presented here. With the new trigger, and new calibrations shifting the pe scale a little, it is not obvious that we really understand what an optimal X2 cut should be. In any case, it is not clear that a strong background cut is what you want for short duration events like gamma-ray bursts, as we are often dealing with small numbers of events and may be more limited by photon statistics than by background in our sensitivity.

2 Simulations

To convert the upper limit on the number of signal events in Milagro to a constraint on the VHE flux I used the gamma-ray v32 simulations which were thrown on an E-2.4 spectrum from 100 GeV to 100 TeV.

I define an effective area as:

$$A_{eff} = (N_{cut}/N_{tot})A_{throw} \tag{1}$$

Where N_{cut} is the number of events which trigger Milagro and pass all analysis cuts (nfit >20, delangle <1.2 etc), A_{throw} is the area over which the simulations were thrown ($1000 \times 1000 \times \pi \mathrm{m}^2$) and N_{tot} is the total number of simulations thrown. Thus $A_{eff} * N_{upper}$, gives the integrated flux (at the top of the atmosphere) from 100 GeV to 100 TeV in units of photons/m^2. From this I can obtain the normalisation of the power-law spectrum. i.e.

$$N_{tot}(0.1 - 100TeV) = \int_{0.1}^{100} cE^{-2.4} \tag{2}$$

and simply solve for C. Problem solved. Usually the result is quoted in a way that gives the reader a clue about at which energy the result is appropriate.

We can quote the result as an integrated energy fluence above our median energy. i.e.

$$J(>2TeV) = \int_2^{\inf} cE.E^{-2.4} \tag{3}$$

It is equally valid to quote J(0.2-20 TeV). Obviously both ways of stating the limit are equivalent, except that we convey slightly different information about the energy response of Milagro.

I considered 3 zenith angle ranges 10-15, 15-20 and 30-35 degrees (each appropriate for one of the 3 bursts).

2.1 New Trigger

We are now using a new trigger, so all the nice warm, bubbly feelings we get from matching cosmic-ray trigger rates and moon shadow may no longer hold so true.

To try and convince myself that things looked reasonable I looked at the rates of proton events that were fit to within 30 degrees of zenith. I considered two sets of data, one from 010921 (for the old trigger) and one from 021104 (new trigger). Both of these data were taken shortly after the repairs so there were not too many dead tubes. Both were re-reconstructed with the new calibrations. The rate (theta$<$ 30 degrees) for data with the old trigger on 010921 was 1100 Hz. The rate for data with the new trigger on 021104 was 1265 Hz. Therefore, the fractional change in rate beween the old and new triggers is 1.15. There is a systematic uncertainty of 10-20 % in these rates (based on how much our trigger rates fluctuate in the absence of changing the trigger criteria). In the Monte Carlo the fractional change in triggering efficiency between the old and new triggers for proton events which fit to within 30 degrees of zenith is 1.23. Within systematic uncertainties, these numbers are in agreement, and thus there is little evidence to suggest large errors in the the MC simulation of the new trigger.

3 GRB021104

The WXM and FREGATE instruments on board HETE saw this burst. It had a duration of 26 seconds in the 8-40 keV band (GCN 1675). No optical, radio or X-ray afterglows were found. It was at a zenith angle of 13 degrees in Milagro. We were still running with the old calibrations online. So I used data re-reconstructed by David Noyes to use the new calibrations.

```
no x2 cut, duration 26 seconds, nfit>20, 1.6 degree radius circular bin
signal: 96
background: 85.1
99.9% upper limit: 46.8
$A_{eff}$ = 494.5 m$^2$
J(>2 TeV) = 1.6 * 10^-6 erg/cm^2 (over 26 seconds)
J(0.2-20 TeV) = 3.4 * 10^-6 erg/cm^2 (over 26 seconds)
```

4 GRB021112

This burst was also seen by both the WXM and FREGATE instruments on HETE. The duration was 5 seconds in 8-40 keV band and 4 seconds in the 25-400 keV band. No optical, radio or X-ray afterglows were found. Again the old calibrations were being used online, so I re-reconstructed the raw data for this burst to use the new calibrations. It was at a zenith angle of 33.5 degrees in Milagro.

```
no x2 cut, nfit >20, duration 5 seconds, 1.6 degree circular bin.
signal: 6
Background: 5.0
99.9% upper limit: 13.6
$A_{eff}$ = 185.1 m$^2$
J(>2 TeV) = 1.24 * 10^-6 erg/cm^2 (over 5 seconds)
J(0.2-20 TeV) = 2.62 * 10^-6 erg/cm^2 (over 5 seconds)
```

5 GRB021113

On 13 Nov 2002, the HETE FREGATE and WXM instruments detected a GRB. The duration was 20 seconds in the 8-40 keV band. It was also localized by the IPN network (including Integral). There were no optical, radio or X-ray afterglows found. It was at a zenith angle of 17.7 degrees in Milagro. We were running with the new calibrations online, so I used the data reconstructed online in the analysis.

```
no x2, nfit >20, duration 5 seconds, 1.6 degree circular bin.
signal: 58
Background: 53.7
99.9% upper limit: 33.6

$A_{eff}$ = 429.2 m$^2$
J(>2 TeV) < 1.25 * 10^-6 erg/cm^2   (over 20 seconds)
J(0.2-20 TeV) < 2.8 * 10^-6 erg/cm^2 (over 20 seconds)
```

6 GCN Circular

```
SUBJECT: GRB 021104, GRB 021112 and GRB 021113 - Milagro GeV/TeV Observations

Milagro observed GRB 021104, GRB 021112 and GRB 021113 at GeV/TeV
energies during the burst durations reported by the HETE WXM (26, 5
and 20 seconds respectively).  No evidence for prompt GeV/TeV emission
was found from any of these bursts. A preliminary analysis (assuming a
differential photon spectral index of -2.4) gives an upper limit on
the fluence at the 99.9% confidence level of:
```

J(E > 2 TeV) < 1.6 * 10^(-6) erg cm^(-2) for GRB 021104 and,
J(E > 2 TeV) < 1.24 * 10^(-6) erg cm^(-2) for GRB 021112 and,
J(E > 2 TeV) < 1.25 * 10^(-6) erg cm^(-2) for GRB 021113

or we could use the J(0.2-20 TeV) form to describe the limit.