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TeV Observations of EGRET Unidentified Sources

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Most of the sources detected by EGRET are not yet identified with astrophysical objects known at longer wavelengths. Some of these sources are variable and some of them may be extended. Milagro, a large field of view (~2 sr), high (>90%) duty factor, TeV gamma-ray observatory is ideal for searching for TeV emission from these sources. There are 68 unidentified EGRET sources within the declination band from 5 to 70 degrees to which Milagro has sufficient exposure. Of these 68 sources, 29 are within 10 degrees of the Galactic plane. TeV fluxes for all 68 sources are constrained by the Milagro observations, and one of these sources, 3EG0520+2556, is consistent with one of the most significant excesses in the Milagro survey of the entire declination band from 5 to 70 degrees. The Milagro excess at this location shows evidence of being extended and when fit to a Gaussian the sigma is 0.8± 0.4 degrees.

1. Introduction

The 3rd EGRET catalog[1] lists 271 sources of which 170 are not identified with astrophysical sources that are known at other wavelengths. Various attempts to search deeper at other wavelengths have resulted in a few potential identifications. However, most of these sources are still unknown.

Identification of a TeV counterpart would constrain the physical mechanisms in the source as well as be very beneficial in finding a counterpart at longer wavelengths. TeV detectors have better angular resolution than EGRET and could improve the localization of the source and observe whether it was extended or a point source. An extended source might indicate a supernova remnant and comparison with x-ray and radio images could show whether TeV emission is associated with shocks or molecular clouds. The large effective area of TeV detectors has resulted in the measurement of more rapid variability than is possible for the statistics limited satellite detectors, like EGRET and GLAST. Simultaneous variability at multiple wavelengths is one of the strongest indications of an association with an active galactic nucleus. Also, the TeV spectrum may give clues to the origin. For example, extragalactic sources will be attenuated at the highest energies by the absorption of these gamma rays with the extragalactic background of infrared to optical photons. Given a model for the extragalactic background photons and an absence of attenuation in the source, the cutoff energy of the TeV spectrum gives the redshift of the source.

2. Milagro Analysis

The data from the Milagro Gamma Ray Observatory is ideal for searching for TeV emission from the EGRET unidentified sources. Milagro's ~2 sr field of view and ~90% duty cycle has been used to observe the Northern Hemisphere sky for the last 5 years. There are 68 EGRET unidentified sources with Declination between 5 and 70 degrees with 19 (29) of these sources at Galactic latitude less than 5 (10) degrees. The combined Milagro data set from 20 July 2000 to 5 May 2005 is searched for steady emission from these 68 sources.

The EGRET confidence intervals for the source localization are well matched to Milagro's point spread function which is approximately a Gaussian of sigma 0.7 degrees. The one sigma uncertainty in the point source location for EGRET is typically less than 0.5 degrees. The optimum bin size for searching for a point source in the Milagro data is a square of 2.1 degrees on a side. However, if the source location is uncertain by 0.5 degrees, the optimum bin size increases by a factor of $\sqrt{0.5^2 + 0.7^2}/0.7 = 1.2$. Thus the analysis technique is very similar to that used for point sources except for a slightly larger bin size. Details on that analysis can be found in [2] along with the results of the Milagro survey of the northern hemisphere sky for TeV point sources.

3. Results

No significant emission was detected for any single source and the ensemble of the 68 sources is consistent with no excess signal over the background as can be seen in the distribution of Figure 1. Flux upper limits are derived for all 68 sources and are shown in Figure 2 where they are compared with the EGRET fluxes. These upper limits are mostly below the line of equal flux at EGRET and Milagro energies implying steeper differential photon spectra than E^{-2}. Most of the EGRET unidentified sources have measured spectra, and the extrapolation of these spectra to TeV energies is also greater than many of the Milagro upper limits implying a cutoff in the high energy spectrum before TeV energies.

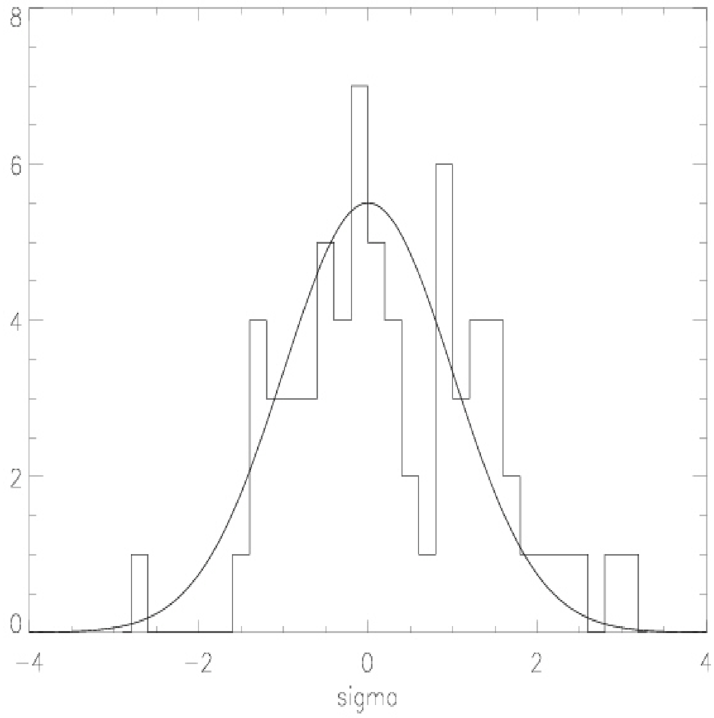

Figure 1. The distribution of the excess or deficit at each of the 68 EGRET unidentified source locations. The units of the x-axis is standard deviations (sigmas) of the Gaussian distributed background. The line shows a Gaussian of sigma equal one centered at zero as would be expected if no emission was detected from the sources.

The most significant excess of 3.1 sigma is from 3EG0520+2556. This source is coincident with the most significant unidentified excess in the Milagro point source survey[2], which was 4.9 sigma for that data set. These significances are pretrials. In the case of the EGRET unidentified source analysis, there are 68 trials for the 68 sources searched. However, for the case of the all sky survey, the trials are much larger. In both cases this source does not warrant claims of a detection, yet further observations are called for. Analysis of the 4.9 sigma excess from the earlier data showed that the excess is not distributed like a point source, with the best fit of a Gaussian has a sigma of 0.8 ± 0.4 degrees.[3] Observations of this source with the Whipple atmospheric Cherenkov telescope yielded upper limits below the Milagro flux estimate for this source.[4] However, these upper limits are for a point source and would be considerably higher for an extended source.

The next two largest excesses are associated with a larger region of excess TeV emission located in the Galactic plane and are discussed in more detail by A. J. Smith at this conference.[5]

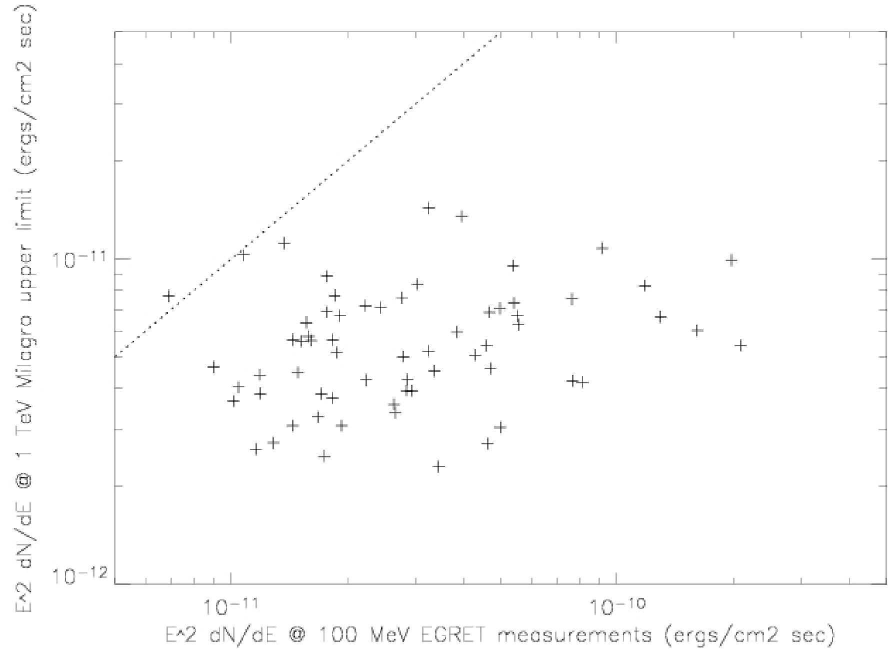

Figure 2. The Milagro flux upper limits are plotted versus the EGRET measured fluxes. Both axis are multiplied by E^2 to give units of ergs cm^{-2} sec^{-1}. For an E^{-2} differential photon spectrum, the value of E^2 dN/dE is independent of energy and the line of equal flux is shown as a dotted line. The spectra measured by EGRET are typically close to E^{-2}, so the fact that most of the points are below the line implies the spectra steepen above EGRET's energy range.

4. Discussion

Atmospheric Cherenkov telescopes have also searched for TeV emission from some of the EGRET unidentified sources, but due to the pointed, narrow field of these detectors, their observations are typically only for a few hours. Observations with the Whipple atmospheric Cherenkov telescope were recently published for 21 EGRET unidentified sources for typical durations of the observations from 2 to 5 hours. [6] One source had a much deeper exposure of 40 hours. No significant emission was detected and the flux upper limits range from 2 - 6 x 10^{-11} cm^{-2} sec^{-1} above 350 GeV. If the source spectrum is $E^{-2.4}$, then the upper limits on E^2 dN/dE are from 0.8 – 2.4 x 10^{-11} ergs cm^{-2} sec^{-1} at 350 GeV.

The upper limits presented here are for a larger number of sources, 68, and are at slightly higher energies. Milagro's effective area increases slower with energy than atmospheric Cherenkov telescopes, but for a spectrum of $E^{-2.5}$ the median energy is ~ 3 TeV increasing slightly at larger declinations.[2] These upper limits imply that the source spectra of the EGRET unidentified sources do not extend to TeV energies assuming the EGRET measurement was indicative of the average > 100 MeV flux. GLAST will obviously increase our understanding of the EGRET unidentified sources; however, deeper and simultaneous TeV observations will still be very useful.

5. Acknowledgements

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