TeV Gamma-ray Blazar Monitoring Campaign

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Introduction

Since 1996 the observing program with the Whipple Observatory 10m Gamma-ray Telescope has been devoted to the observation of several bright TeV gamma-ray emitting AGN, including Markarian 421 and Markarian 501. This long-term monitoring gives a unique opportunity to study variations in TeV emission on both long and short-term time scales, while also providing as continuous a record as possible for use in multiwavelength campaigns.

The telescope also acts as a trigger for VERITAS in case of enhanced activity from any of the blazars being monitored.

The Whipple 10m Telescope

Presented here are the results from a search for emission variability in the data obtained on our monitored sources from October 2010 to April 2011. The results of a search for correlation between detected emission from Markarian 421 and Markarian 501 with the Whipple 10m Telescope and Fermi-LAT detector will also be shown.

Observations

From October 2010 to April 2011 5 sources were monitored, with a total of ~280 hours of data collected.

The table below shows a summary of results obtained this season which are comparable to previous seasons.

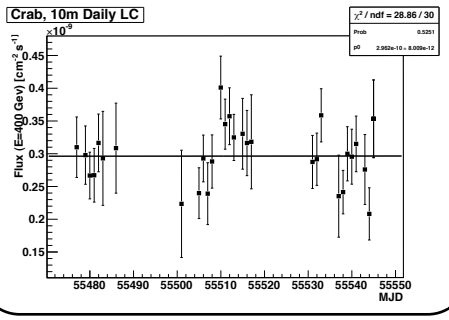
Source	RA	Dec	z	Hours on Source	Significance
1ES 0229+200	02 32 39	20 17 17	0.14	41	0.8
Markarian 421	11 04 27	28 12 32	0.031	90	29.6
Markarian 501	16 53 22	39 45 36	0.034	33	19.2
1ES 1959+650	19 59 59	65 08 55	0.047	12	4.1
1ES 2344+514	23 47 04	51 42 18	0.044	42	1.9

Methodology

When possible the Crab Nebula flux was monitored on the same nights as observations were made on the blazars. The Crab Nebula is a steady state emitter at TeV energies.

All fluxes for 10m results were calibrated from the mean number of gamma rays per minute observed on a nightly basis from the Crab Nebula. This was set to 1 Crab Unit which was then converted to flux by taking the established Crab flux at 400 GeV as this is the energy at which the Whipple 10m telescope has the best sensitivity.

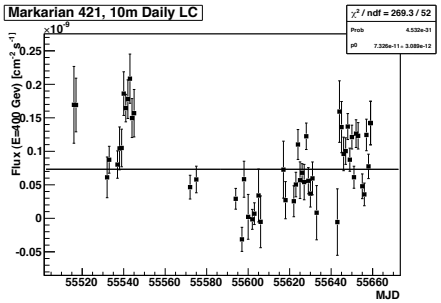
The graph below shows the daily averaged lightcurve (LC) from the Crab Nebula. A $\chi 2$ test shows a straight line to be a good fit for this data, confirming it as a steady emitter at these energies.



Sources

Markarian 421

Markarian 421 is one of the most active VHE (E>100GeV) blazars and was the first to be discovered at TeV energies [1]. Its spectral energy distribution (SED) has peaks in the keV and TeV regions and it has been known to demonstrate rapid, sub-hour scale flaring behaviour (e.g. see [2]). It has a redshift of 0.031 making it the closest known TeV blazar.

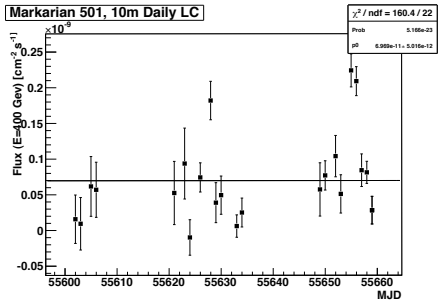


The above graphs shows the daily lightcurve for Markarian 421, showing day-scale variation. A search within each night revealed no significant evidence for hour-scale variability.

VERITAS observations were not triggered as no periods of enhanced activity (emission > 2 Crab Units) were observed.

Markarian 501

Markarian 501 was the second blazar to be discovered at TeV energies[3], it also has a well cataloged history of flaring. Whilst being at a similar distance to Markarian 421, Markarian 501 is significantly weaker on average. This source has been intensively monitored in the past and it displays quite different temporal characteristics to Markarian 421.



The above graph shows the daily lightcurve for Markarian 501, showing day-scale variation. A search within each night revealed no significant evidence for hour-scale variability.

VERITAS observations were not triggered as no periods of enhanced activity (emission > 2 Crab Units) were observed.

1ES 1959+650

This source was discovered as a TeV gamma-ray emitter in 1998 by the Seven Telescope Array [4]. In 2002, the Whipple 10m Telescope detected flaring activity from 1ES 1959+650 up to 5 times the Crab Nebula flux [5].

1ES 2344+514

The Whipple Collaboration reported a weak signal from the object between 1999-2001 [6]. As such it was chosen as a candidate likely to be observed again if it entered a period of enhanced activity.

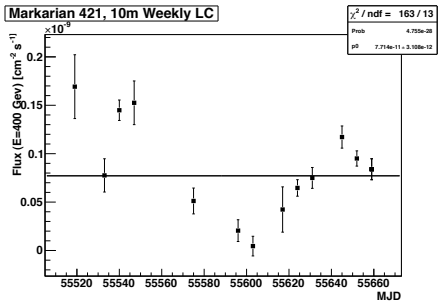
1ES 0229+200

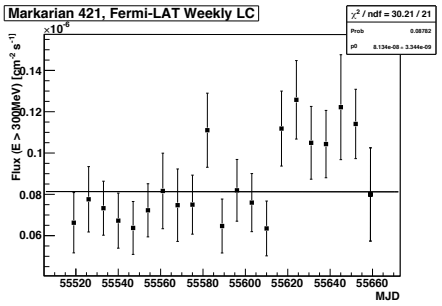
This blazar has an unusually hard TeV spectrum and as such it is an excellent candidate for extragalactic background light (EBL) studies [7].

Neither 1ES 1959+650, 1ES 2344+514 nor 1ES 0229+200 have been detected with a significance level greater than 5 sigma this season and thus no statement about their variability can be made.

Comparison with results from Fermi-LAT

Shown below are weekly averaged fluxes for Markarian 421 produced using the Whipple 10m and the publicly available Fermi-LAT data for the time period from October 2010 to April 2011.





Both the Whipple 10m telescope and Fermi-LAT see Markarian 421 as a variable emitter but no strong correlation in emission was found. A similar analysis performed for Markarian 501 also revealed no strong correlation.

Conclusions

This season Markarian 421 and 501 were both detected with high significance, and both demonstrated variability in their emission from night to night. Data from each night were examined for variability but no significant hour-scale variability was observed.

VERITAS observations were not triggered this season as no enhanced activity (emission > 2 Crab Units) has been observed.

A preliminary analysis indicates no strong correlation between emissions as detected by the Whipple 10m and Fermi-LAT for Markarian 421 or Markarian 501 on weekly time scales.

The current blazar monitoring campaign will continue through Summer 2011. More detailed analysis of the data is under way.

Whipple lightcurves are published at;
http://veritas.sao.arizona.edu/content/view/46/117/

Refereneces

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2) Gaidos, J.A. et al., Nature, 383, 319 (1996)
3) Quinn et al., 1996 ApJ 456 L834
4) Nishiyama, T. et al., in Proc. 26th ICRC (Salt Lake City), 3,370 (1999)
5) Holder, J. et al., ApJ.601:151-164,2004
6) Catanese, M. et al., ApJ 501 (1998) 616
7) Aharonian et al., A&A, 475, L9, 2007

Acknowledgments

This research is supported by grants from the U.S. Department of Energy, the U.S. National Science Foundation, and the Smithsonian Institution, by NSERC in Canada, by STFC in the UK and by Science Foundation Ireland (SFI 10/RFP/AST2748).Research with the Whipple 10m gamma-ray telescope is supported by Fermi G.I. grant NNX10A048G