



Fermi-Jansky: Our evolving understanding of AGN  
Saint Michaels, MD - November 10-12 2011

# Blazar observations above 100 GeV with VERITAS

Manel Errando

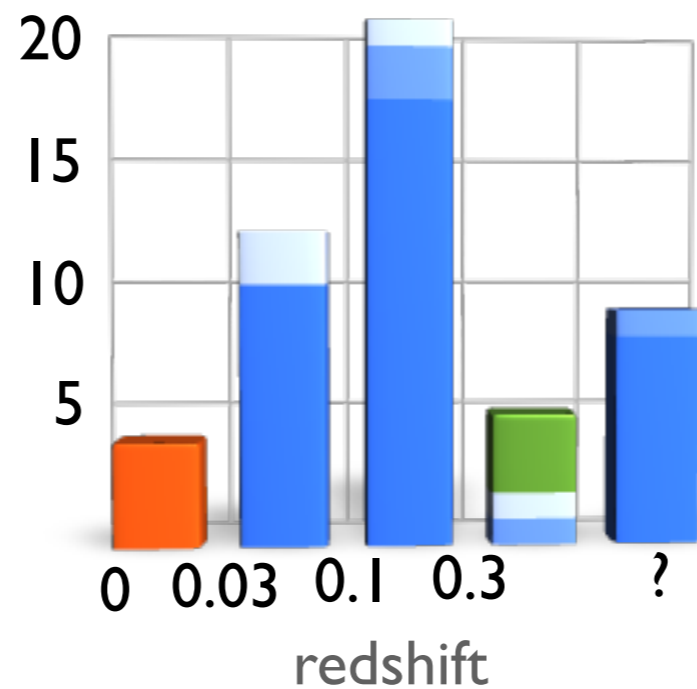
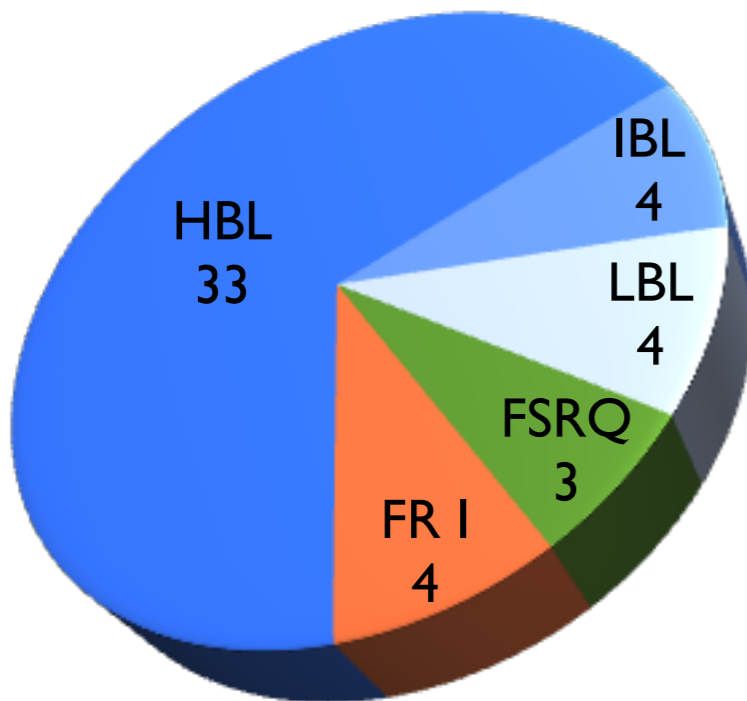
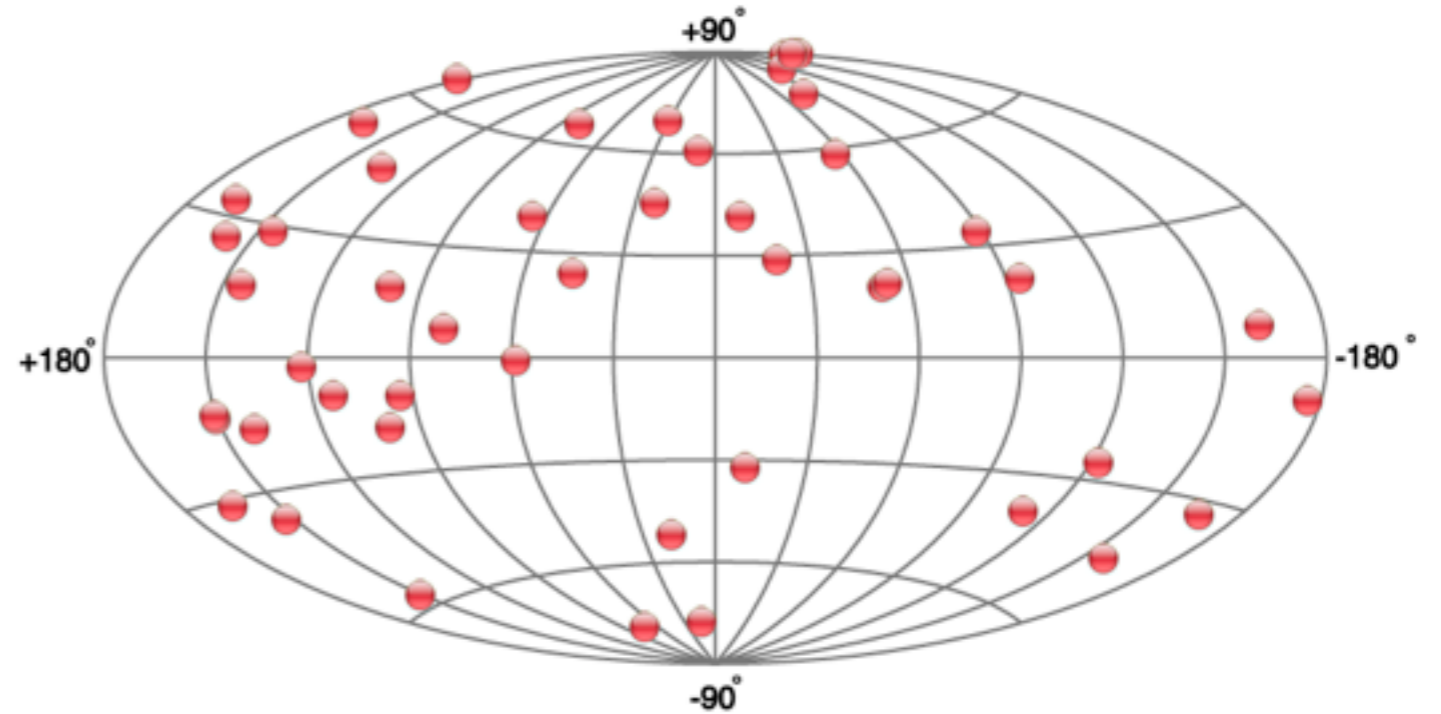
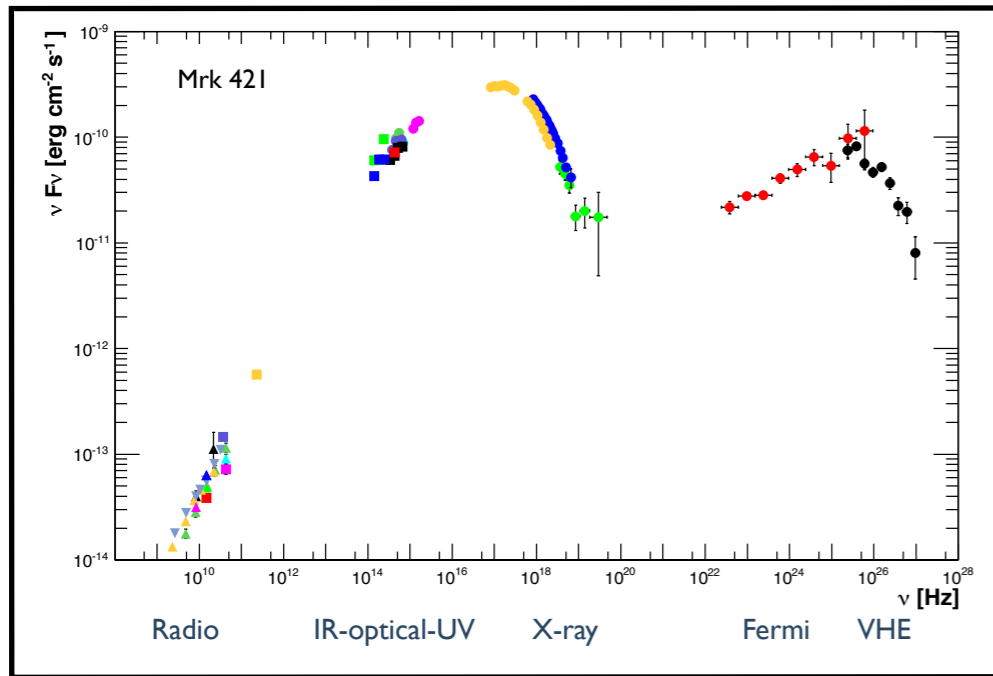
(Barnard College / Columbia University)

**BARNARD**  
THE LIBERAL ARTS COLLEGE  
FOR WOMEN  
IN NEW YORK CITY

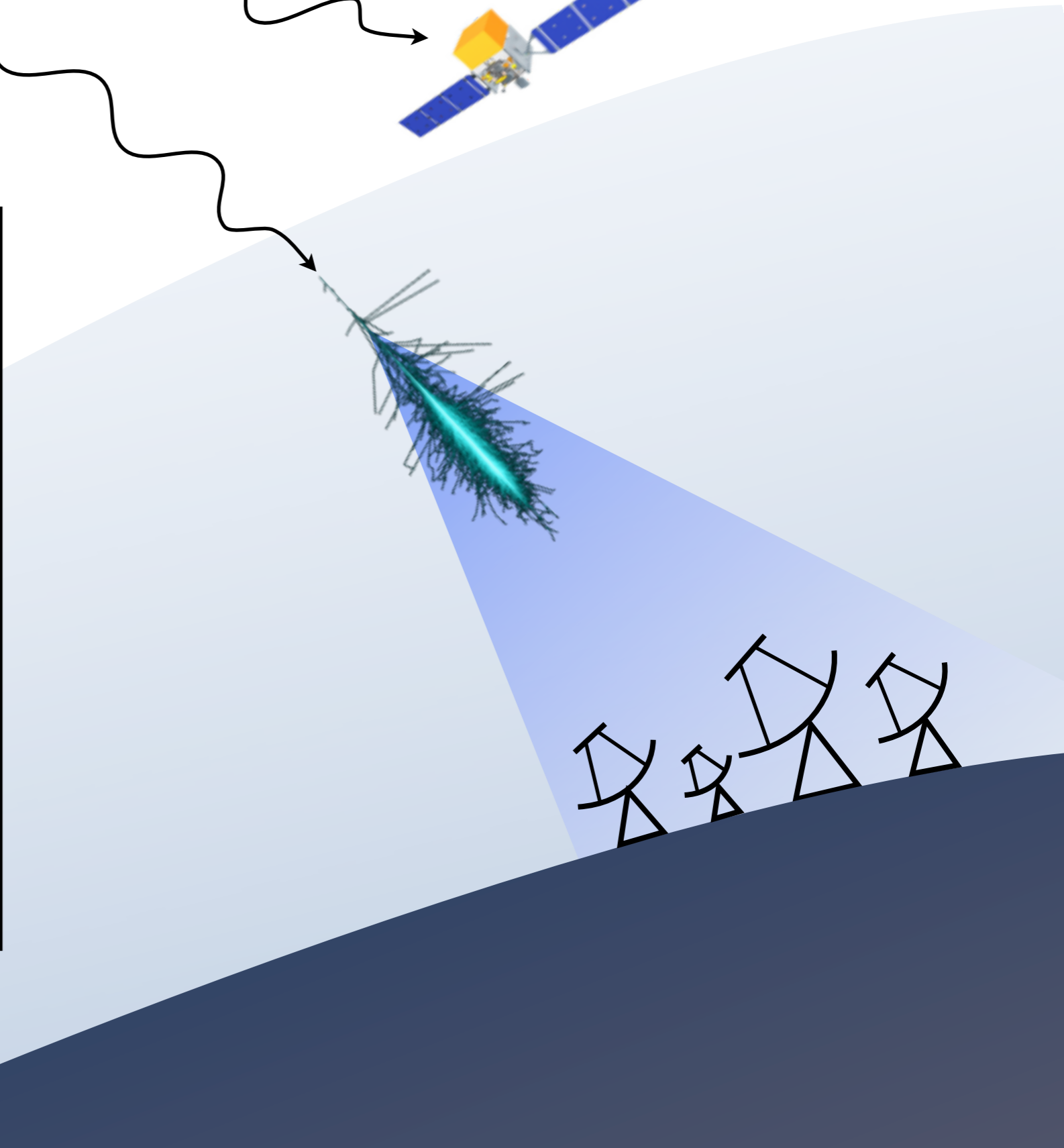
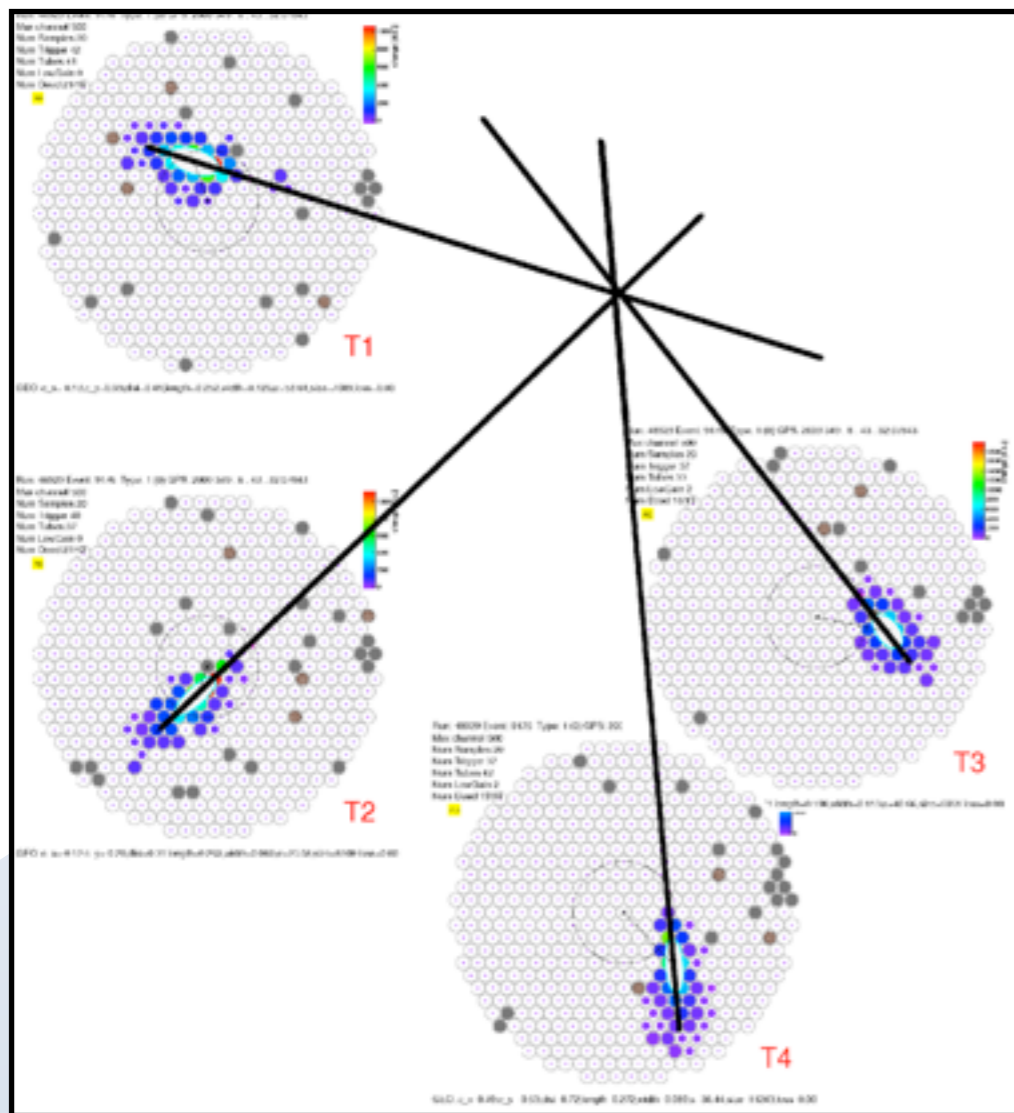
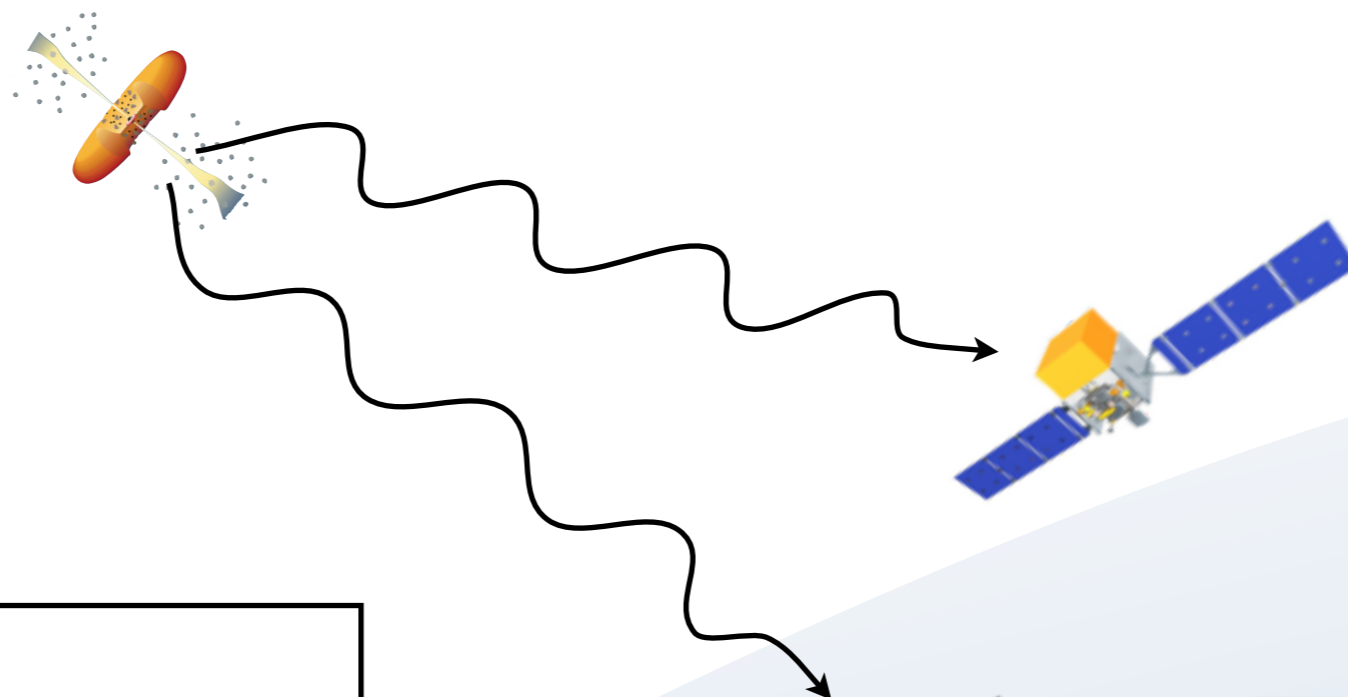


- TeV blazars
- The VERITAS observatory
- VERITAS blazar program
- New blazar discoveries
- Mrk 421 flare
- BL Lac flare
- Conclusions

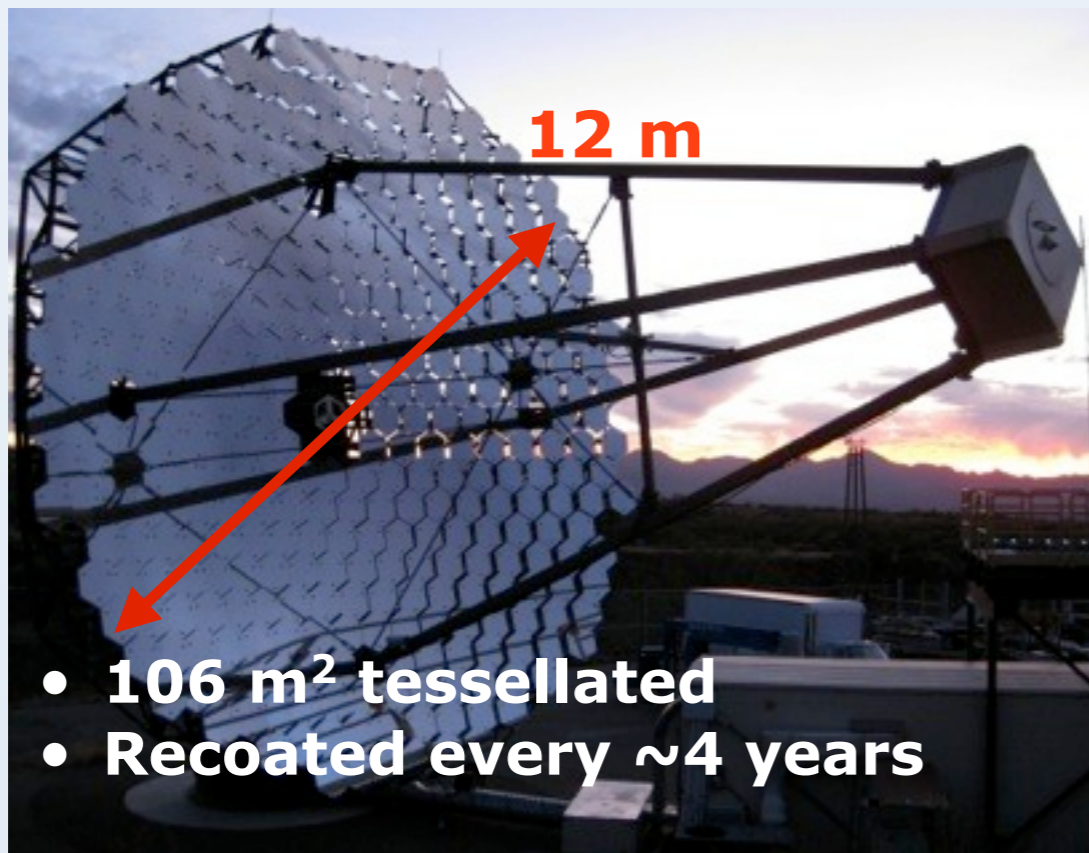
# TeV AGN population



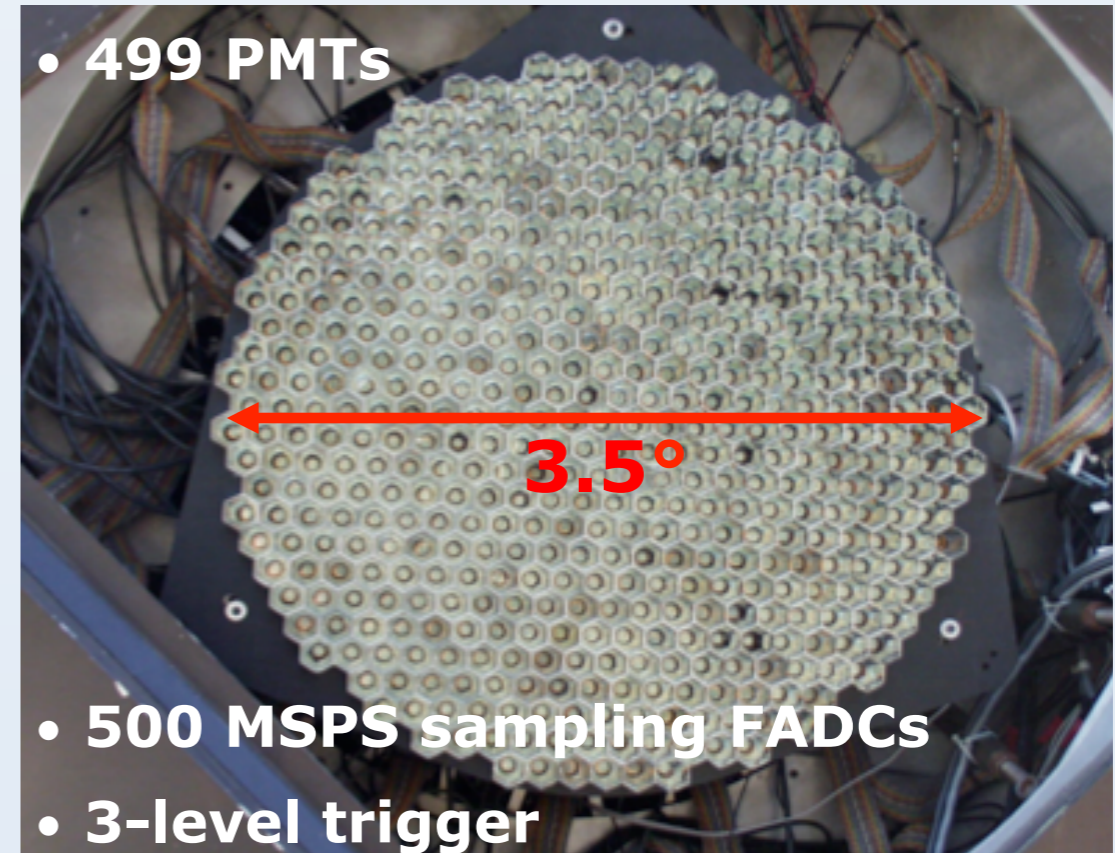
	$\Gamma$	low state	$t_{\text{var}}$
HBL	harder	detectable	$\sim 3$ min
IBL		weak	1 day
LBL		not seen	$\sim 15$ min
FSRQ	softer	not seen	$\sim 10$ min



- Situated at 1280m altitude at Whipple Observatory in Arizona

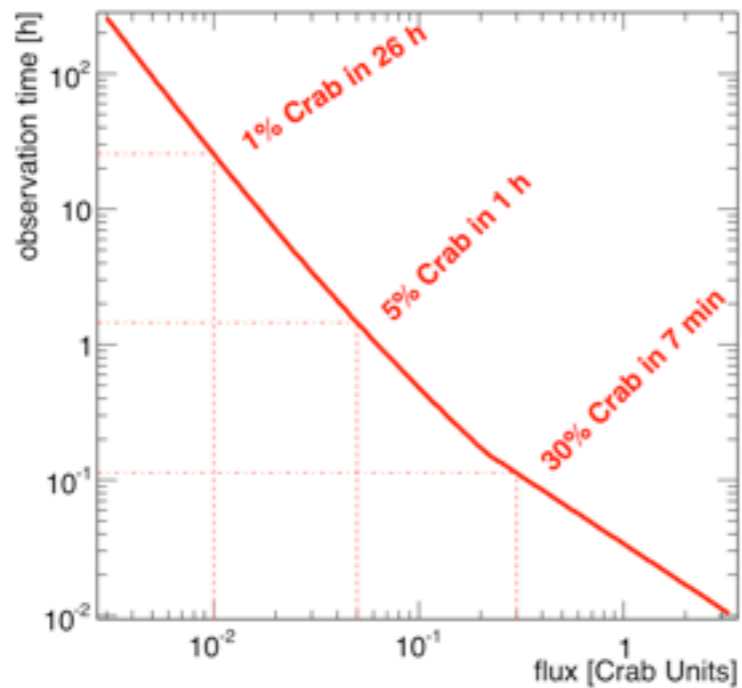


- 106 m<sup>2</sup> tessellated
- Recoated every ~4 years



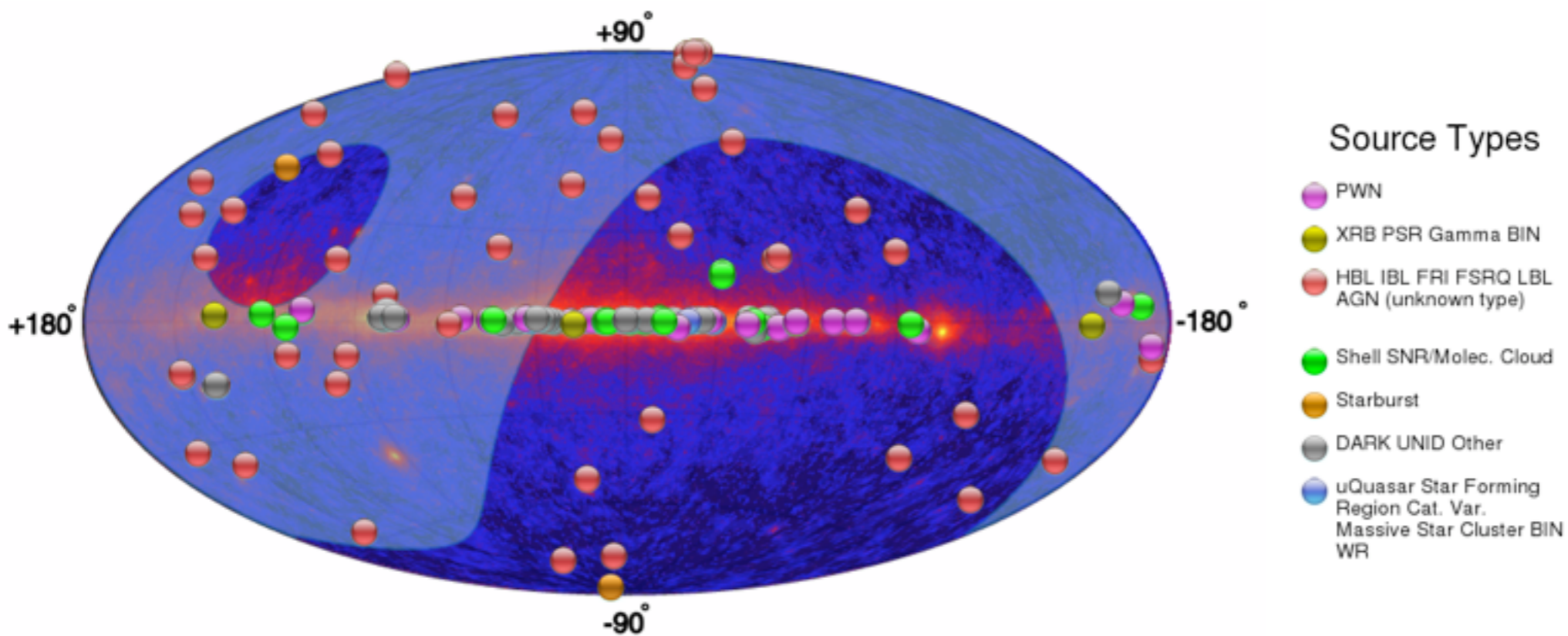
- 499 PMTs
- 500 MSPS sampling FADCs
- 3-level trigger

# VERITAS observatory



## VERITAS

Location	31°40'N, 110°57'W, 1.3km
Array configuration	4 x 12m telescopes
Energy range	100 GeV < $E_\gamma$ < 30 TeV
Energy resolution	15 - 20%
Field of view	3.5°
Angular resolution	< 0.1°
Sensitivity	1% Crab in 26hr
Duty cycle	10-12% (1000hr\yr)



# VERITAS AGN program

Name	Class	z
M 87	FR I	0.004
Mrk 421	HBL	0.031
Mrk 501	HBL	0.034
1ES 2344+514	HBL	0.044
1ES 1959+650	HBL	0.048
BL Lacertae	LBL	0.069
W Comae	IBL	0.102
RGB J0710+591	HBL	0.125
1H 1426+428	HBL	0.129
1ES 1215+303	LBL	0.130?
1ES 0806+524	HBL	0.138
1ES 0229+200	HBL	0.140
1ES 1440+122	HBL	0.163
RX J0648.7+1516	HBL	0.179
1ES 1218+304	HBL	0.182
RBS 0413	HBL	0.190
1ES 0414+009	HBL	0.287
1ES 0502+675	HBL	0.341?
PG 1553+114	HBL	0.350
3C 66A	IBL	0.444?
PKS 1424+240	IBL	?
VER J0521+211	HBL	?

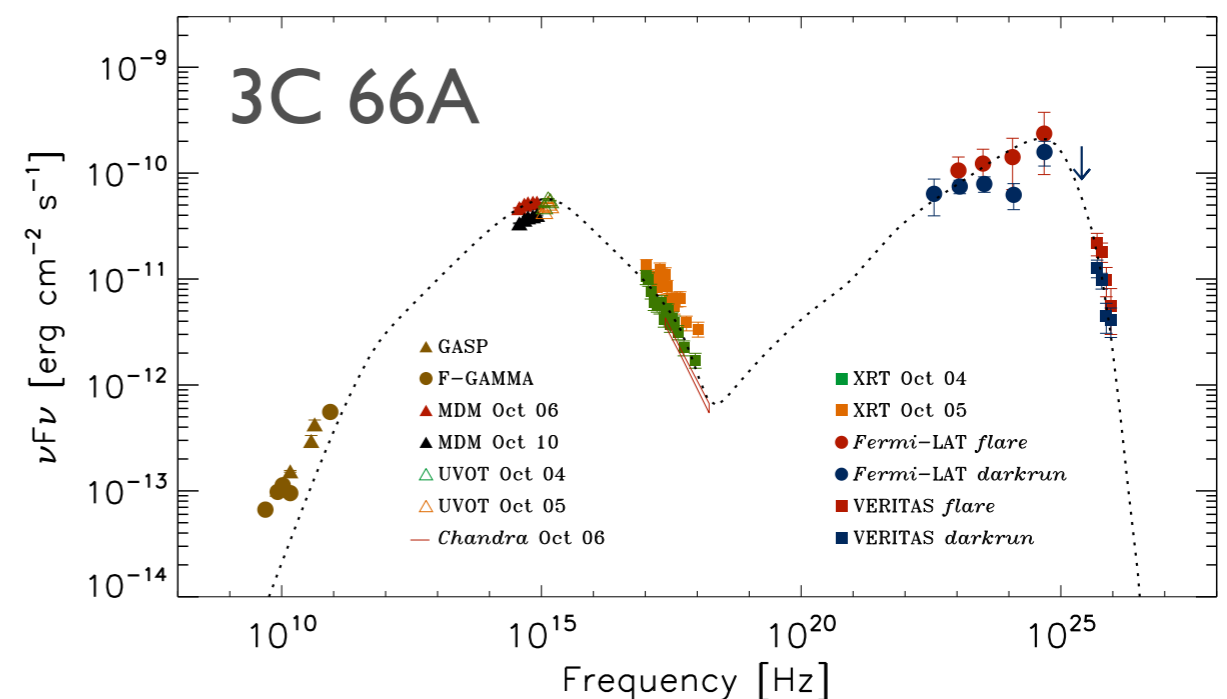
- Multi-year plan to observe 14 northern TeV blazars
  - Mid-distance hard spectrum HBLs
  - Bright nearby HBLs
  - All northern IBLs and LBLs
- Discovery program
  - Most of it is ToO based (optical, Fermi-LAT)
  - Extensive program for FSRQs
  - Accumulating long exposures on good candidates
- Multiwavelength campaigns

# VERITAS blazar discoveries

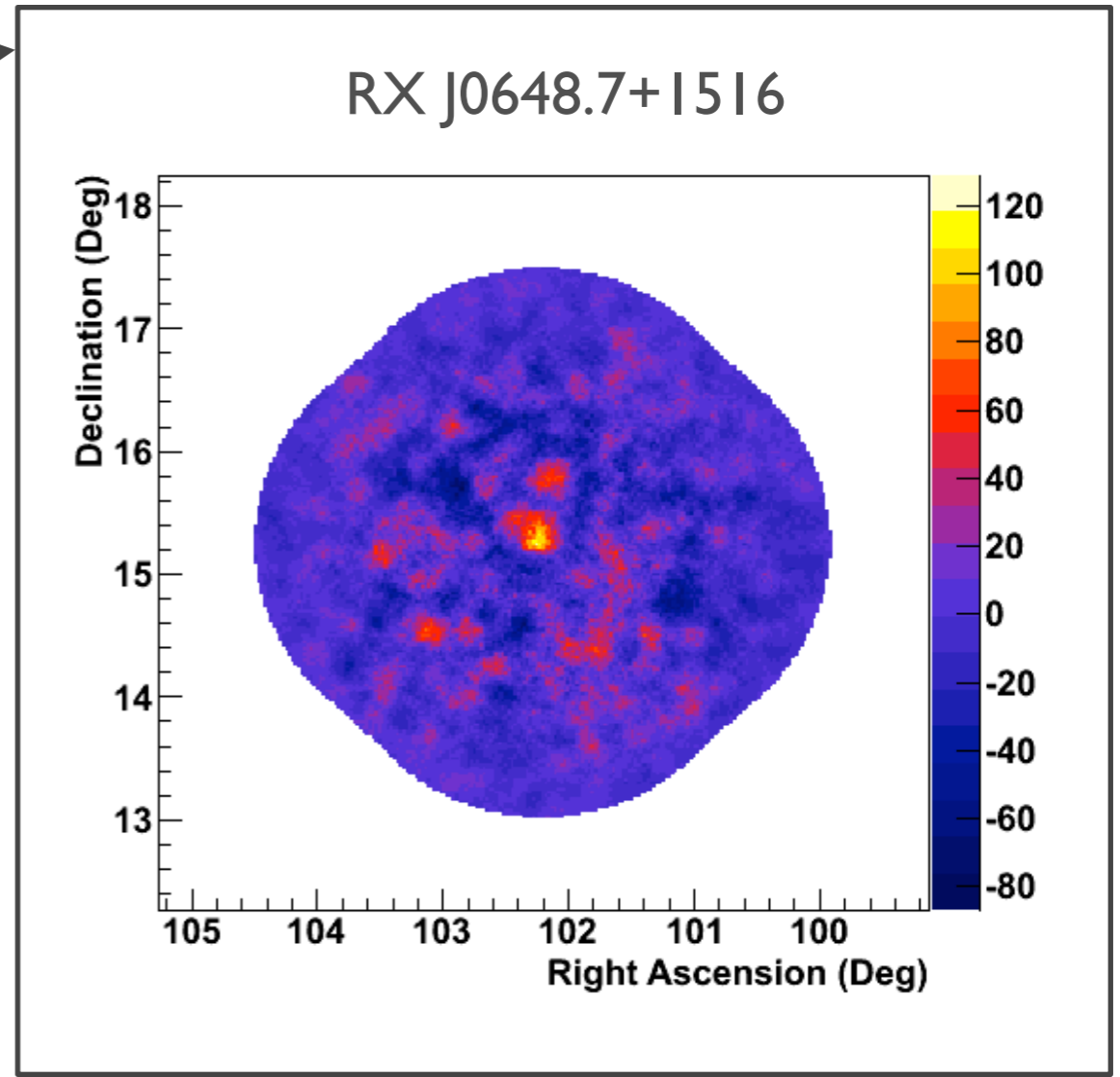
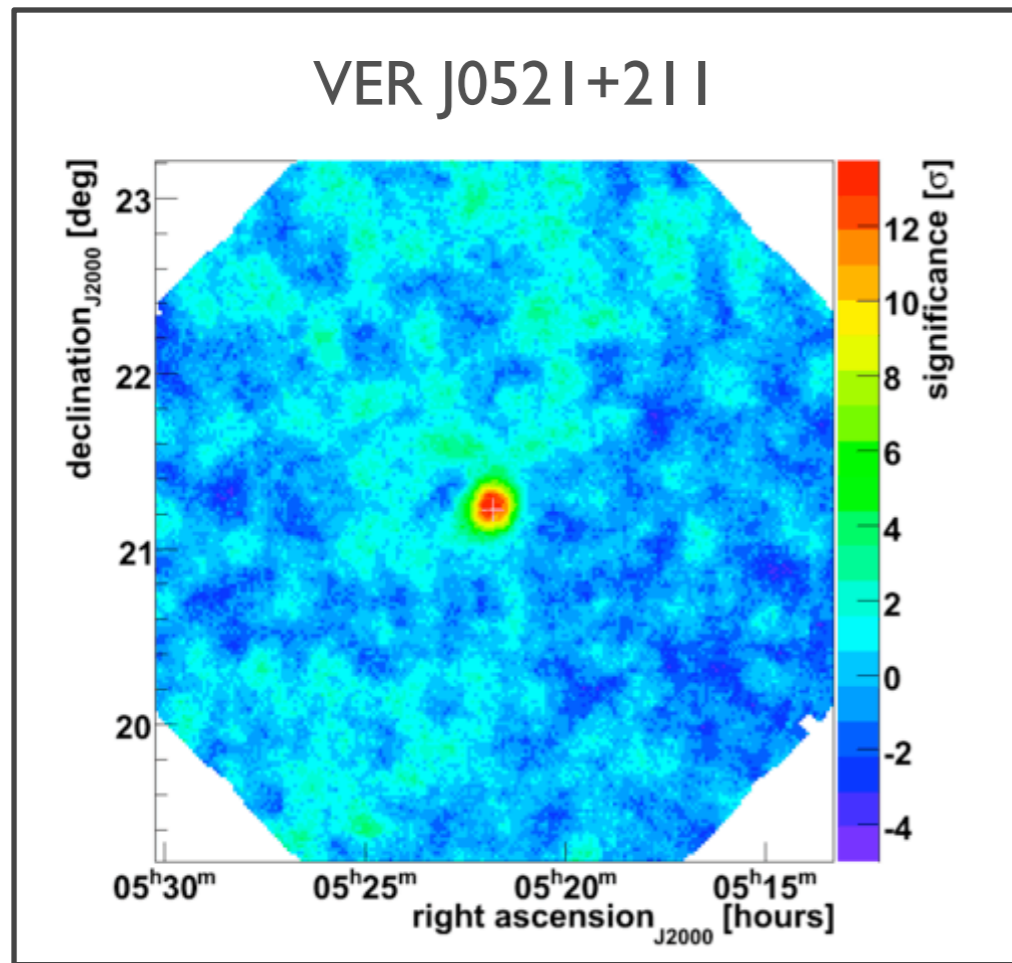
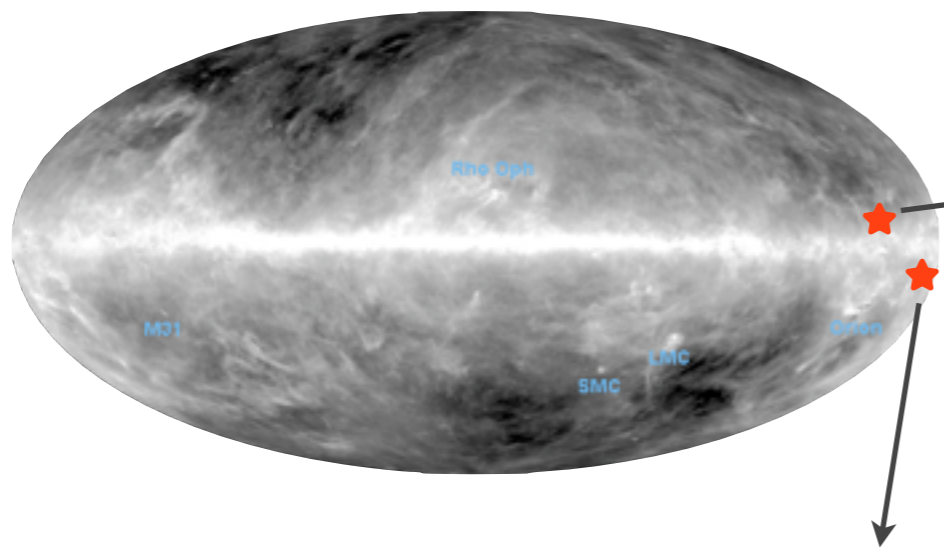
AGN	z	$\log_{10}(v_{\text{synch}})$	Flux [ % Crab Nebula ]	$\Gamma_{\text{VERITAS}}$	$\Gamma_{2\text{FGL}}$
1ES 0806+524	0.138	16.6	2%	$3.6 \pm 1.0$	$1.94 \pm 0.06$
W Comae	0.102	14.8	Flares (9% & 23%)	$3.8 \pm 0.4$	$2.02 \pm 0.03$
3C 66A	0.444?	15.6	Varies (Avg. ~ 6%)	$4.1 \pm 0.4$	$1.85 \pm 0.02$
RGB J0710+591	0.125	21.1	3%	$2.7 \pm 0.3$	$1.53 \pm 0.12$
PKS 1424+240	?	15.7	5%	$3.8 \pm 0.5$	$1.78 \pm 0.02$
RGB J0521.8+2112	?	HBL	Varies (Avg. ~ 5%)	$3.5 \pm 0.2$	$1.93 \pm 0.03$
RBS 0413	0.190	17.0	2%	$3.2 \pm 0.7$	$1.55 \pm 0.11$
1ES 0502+675	0.341?	19.2	6%	$3.9 \pm 0.4$	$1.49 \pm 0.07$
RGB J0648.7+1516	0.179	HBL	2%	$4.4 \pm 0.8$	$1.74 \pm 0.11$
1ES 1440+122	0.162	16.5	1%	$3.4 \pm 0.7$	$1.41 \pm 0.18$

Abdo et al. 2010

- All VERITAS discoveries in the TeV band triggered MWL observations and SEDs are published with GeV (Fermi-LAT), X-ray (Swift, RXTE), optical & radio data.
- Typically SSC models reproduce the SED of HBLs, while low-frequency-peaked objects seem to prefer SSC + EC.

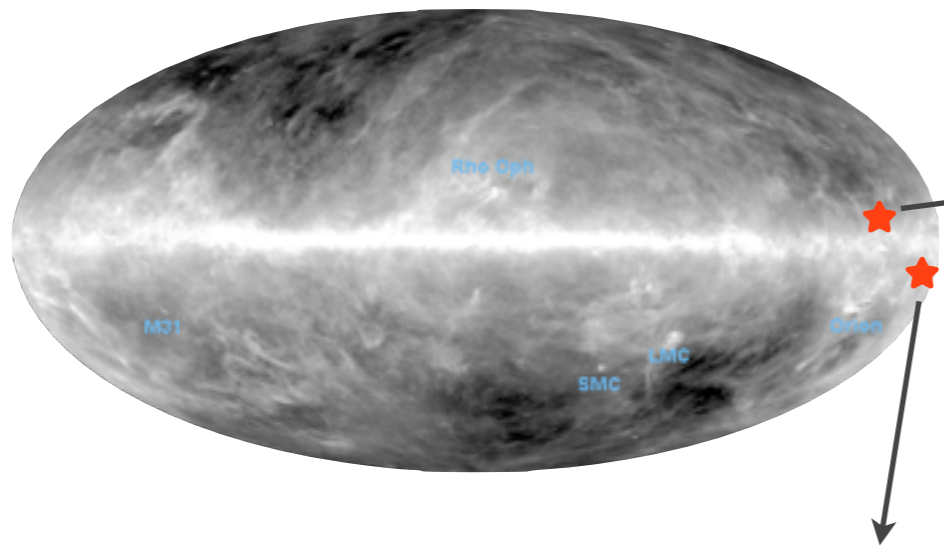


# New low-latitude blazars

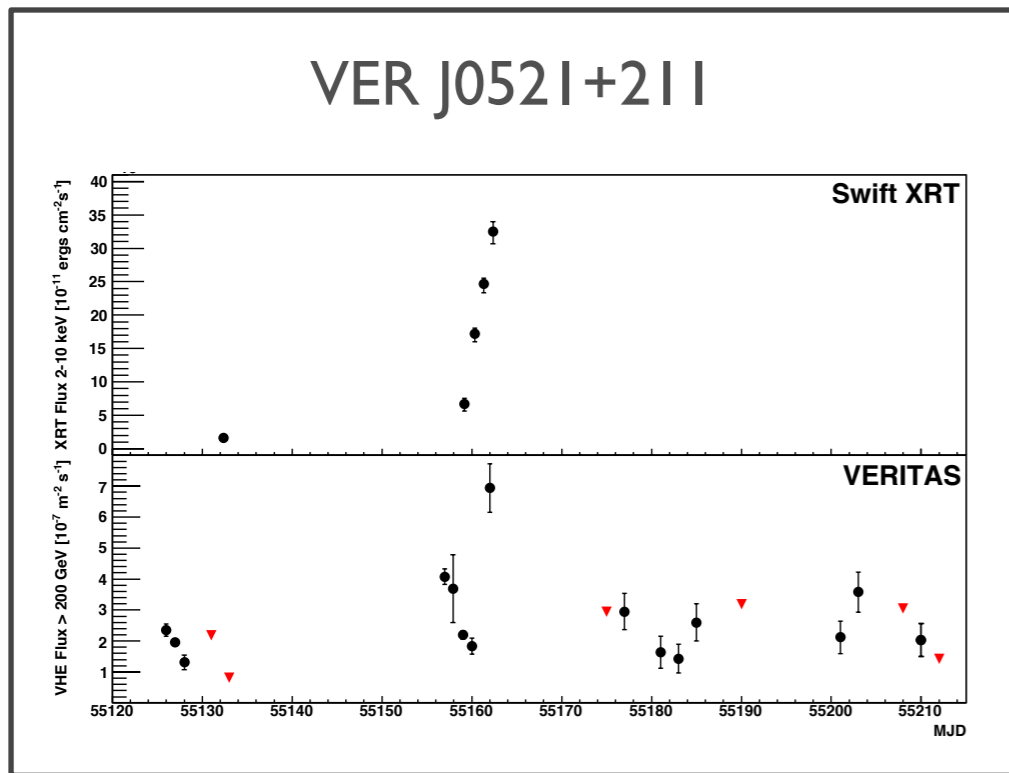
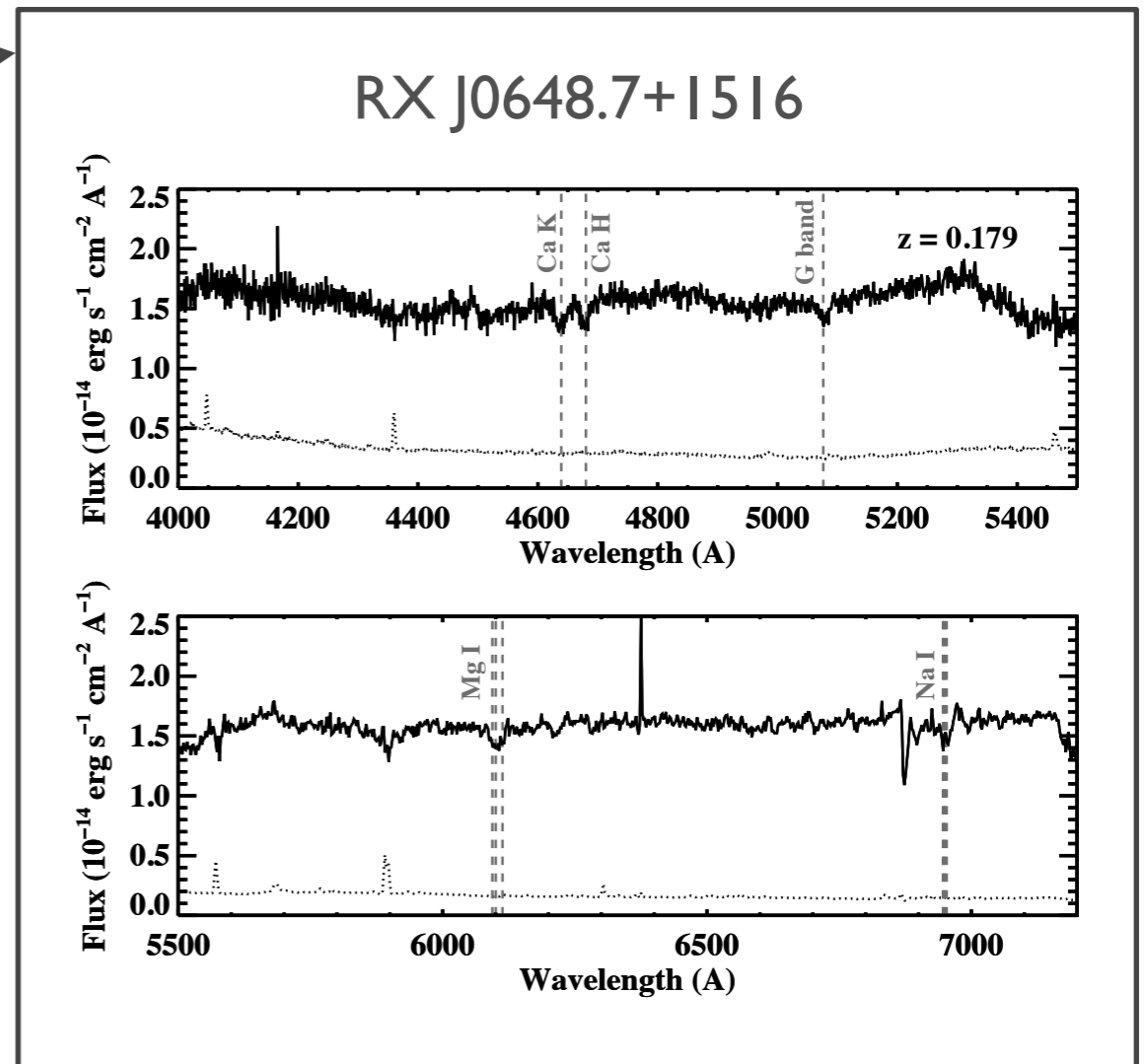




# New low-latitude blazars



Aliu et al 2011, arXiv:1110.5949



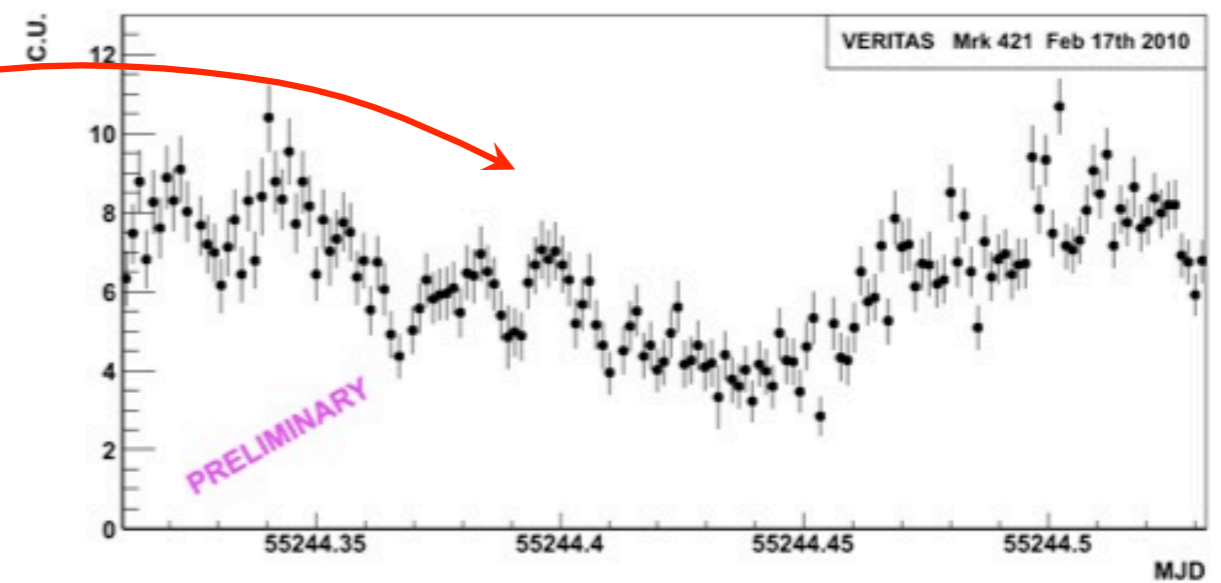
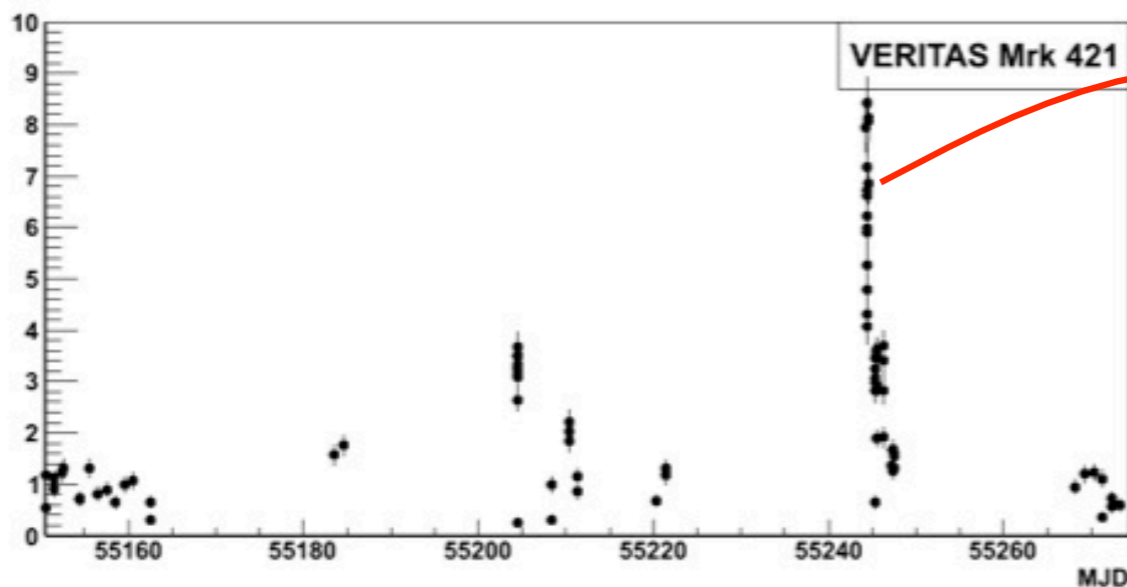
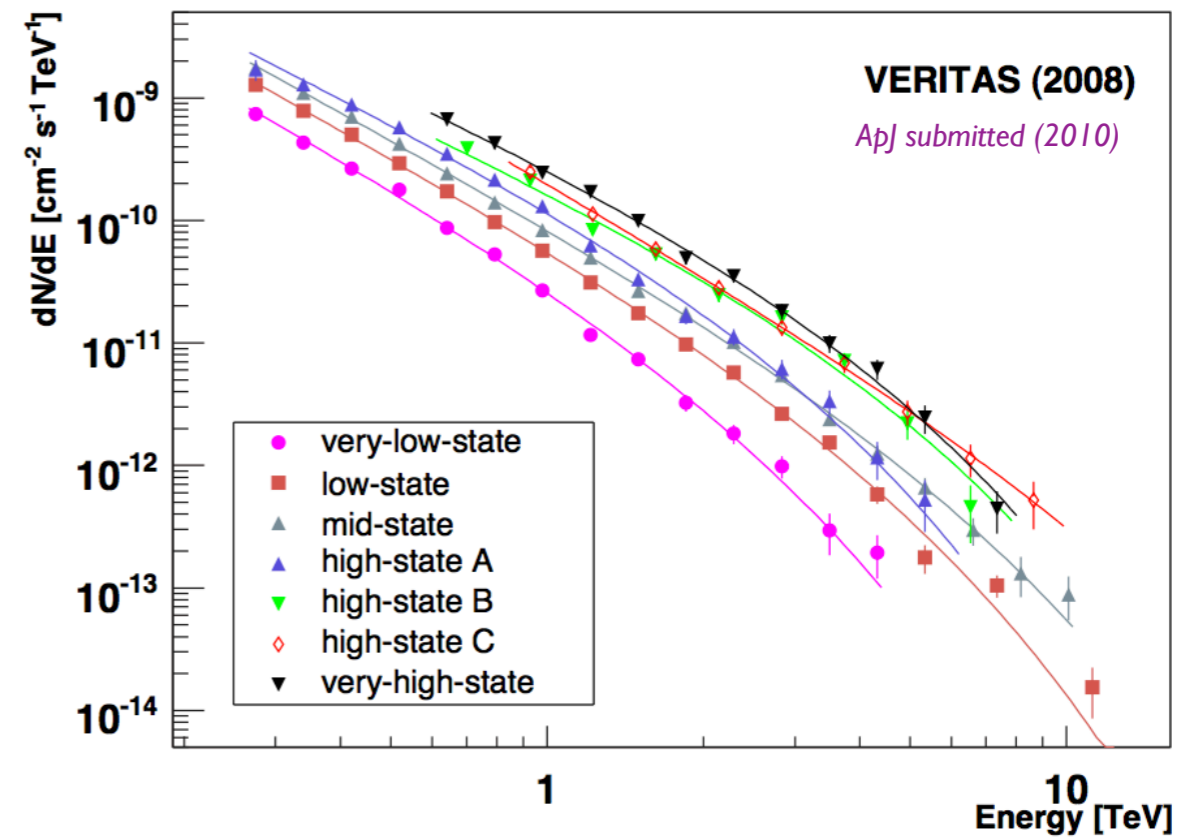
Redshift of 0.179

Aliu et al, in prep.

# Mrk 421

- Major flares in 2008 and 2010
- Huge flare on Feb 17 2010
  - Flux reaches  $\sim 10$  crab
  - doubling times  $\sim 5$ -10min
  - $10\sigma/2$ min bin

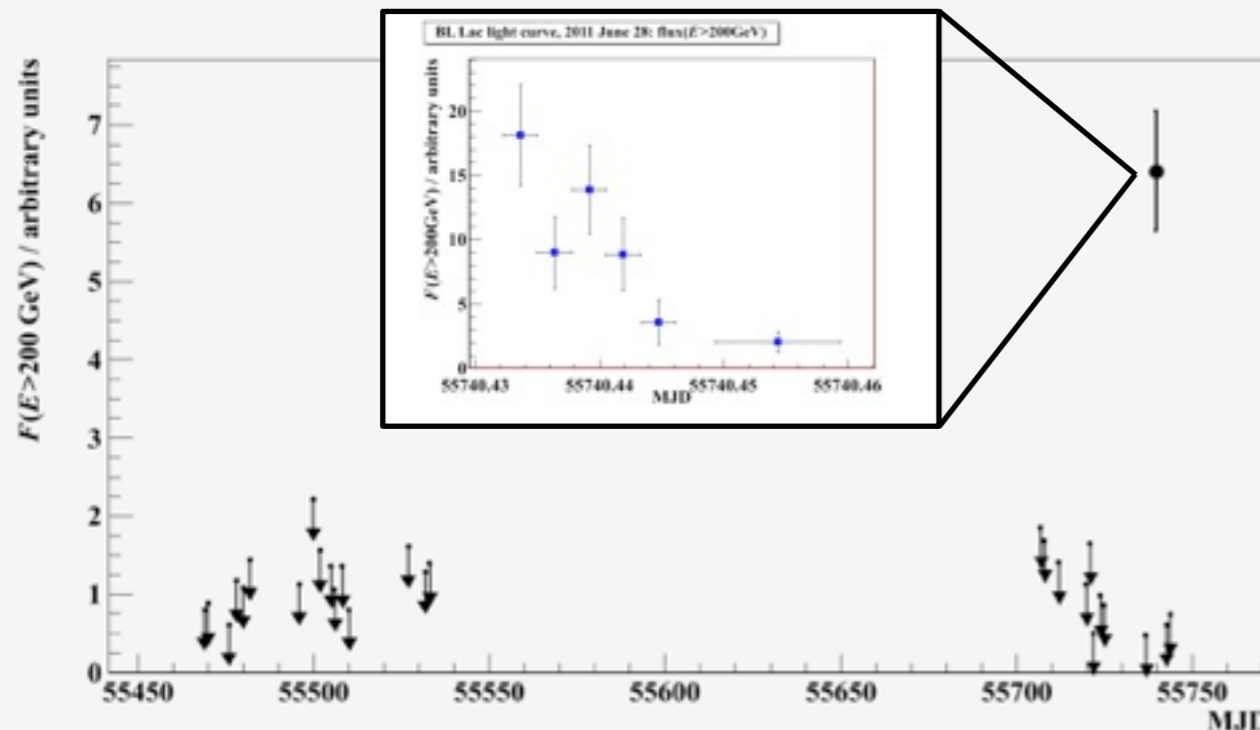
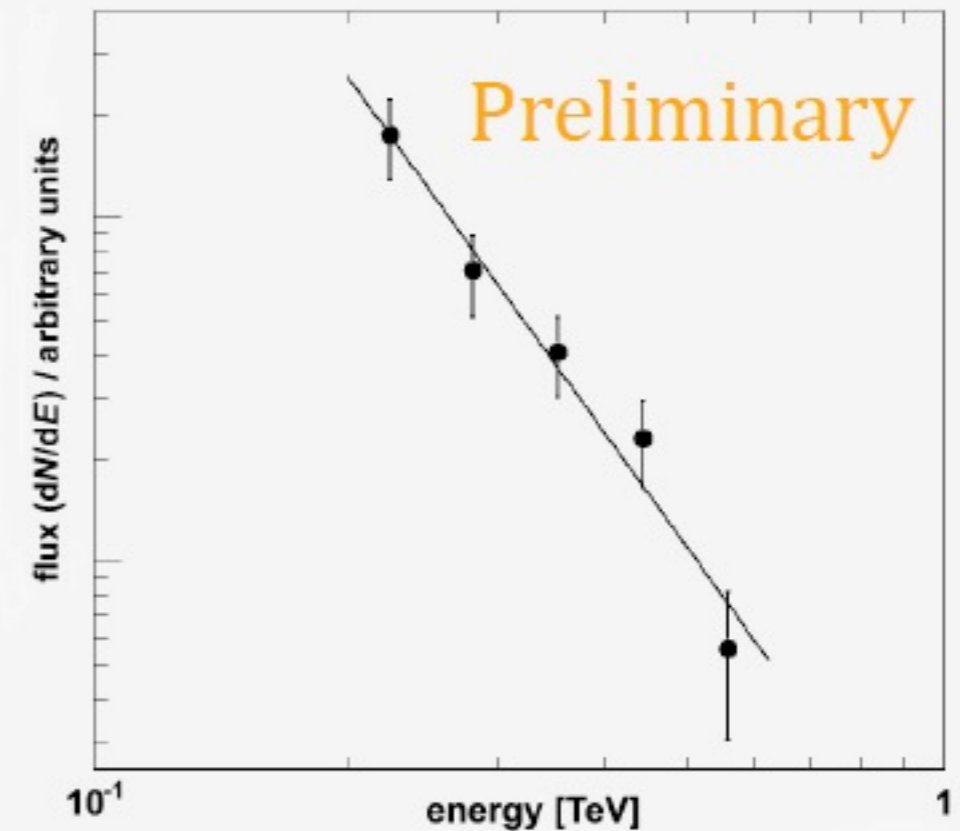
Aliu et al, in prep.



# BL Lac flare

- Very bright flare observed in June 28
- $20\sigma$  in a 20 min run
- Intra-night variability
- Coincident with a 'extreme hardening' of the GeV spectrum measured by Fermi

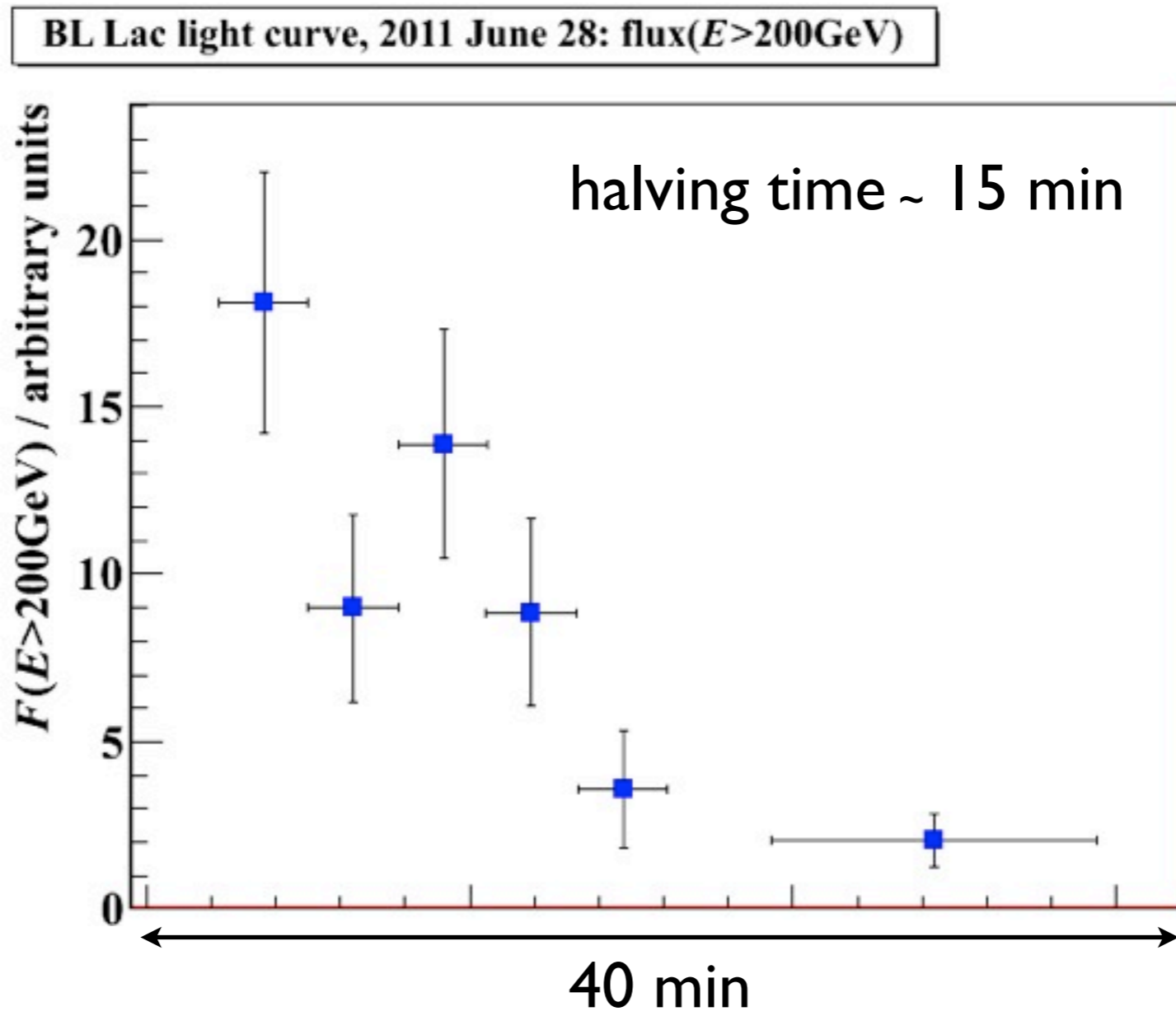
BL Lac photon energy spectrum, 2011 June 28, 20-minute observation



BL Lacertae

Aliu et al, in prep.

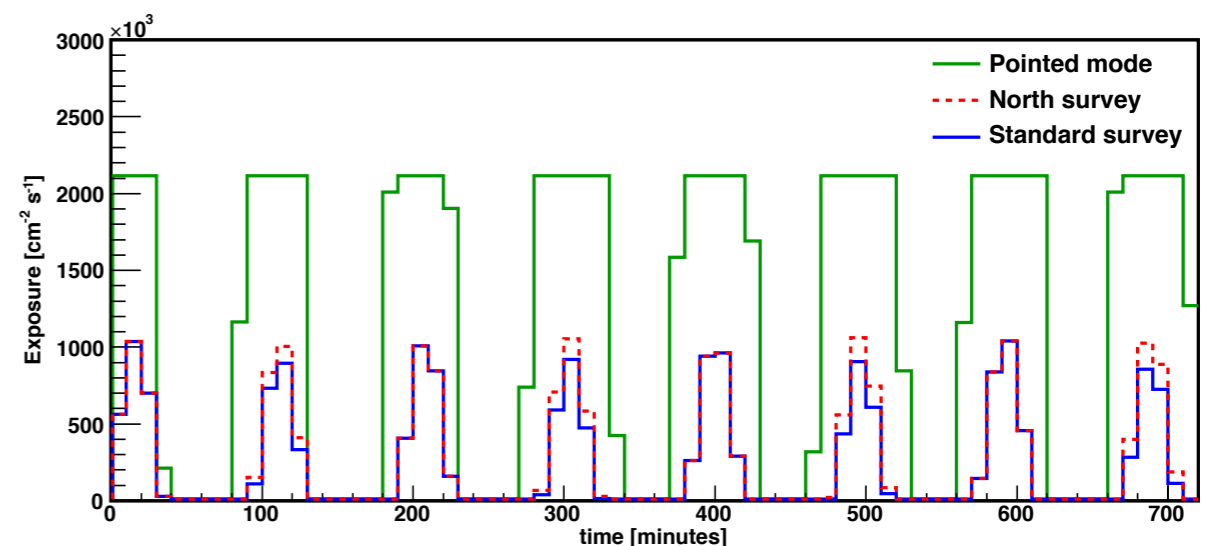
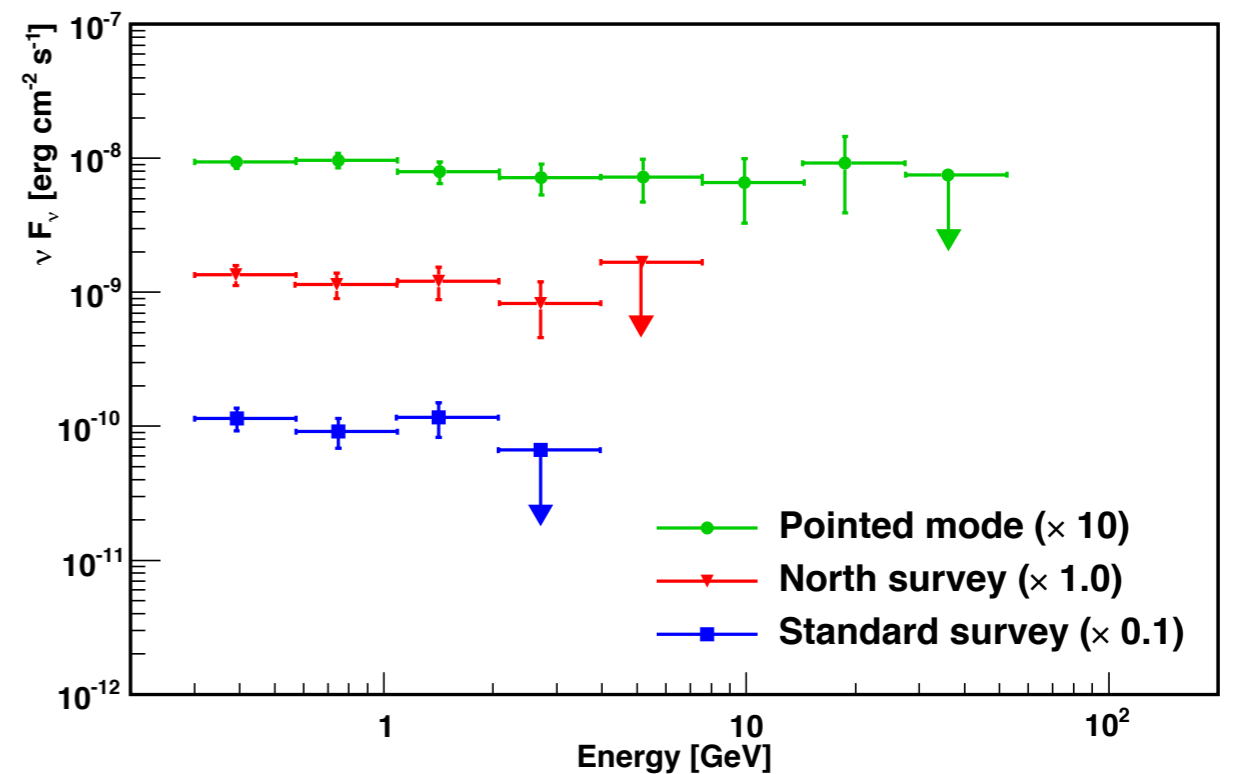
# BL Lac flare



Aliu et al, in prep.

# Multiwavelength observations

- Diagnostic to better understand GeV spectral features in LBLs and FSRQs: see if the spectrum continues beyond 100 GeV
- Extensive MW campaign to observe flaring FSRQs (3C 279 and 4C 21.35) from radio to TeV energies.
- Approved *Fermi*-LAT pointed observations simultaneous with X-ray and ground-based observations.
- Coverage at VHE (VERITAS & MAGIC), gamma-ray (*Fermi*), X-ray & UV (*Swift*), Optical-IR (SMARTS, MDM, KVA, ...) and radio (OVRO).



# Summary

- VERITAS is monitoring a sample of northern TeV blazars
- Continuous observations allow better studies of spectral and flux variations, sub-hour variability
- Multiwavelength program with GeV, X-ray, optical coverage
- Discovery efforts continue: new HBLs, extend to LBLs, FSRQs
- Good synergy with Fermi:
  - Trigger for gamma-ray high states
  - Good sampling of Compton peak

