

VERITAS

Performance & Latest Results



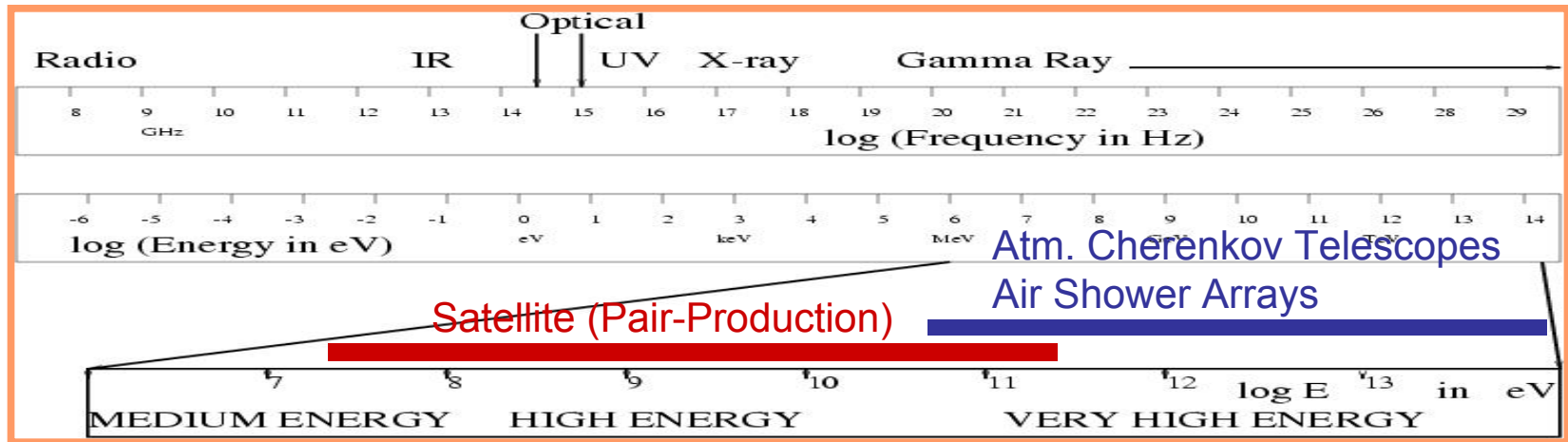
Rene A. Ong*, for the VERITAS Collaboration
(*University of California, Los Angeles)



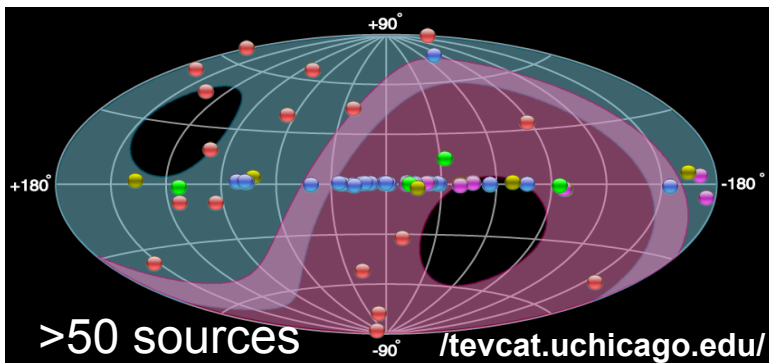
OUTLINE:

- VHE Astronomy and Atmospheric Cherenkov Telescopes
- VERITAS Characteristics & Performance
- New Discoveries and Highlights from First Year of Operation
- Future Plans

VHE γ -ray Astronomy in one slide

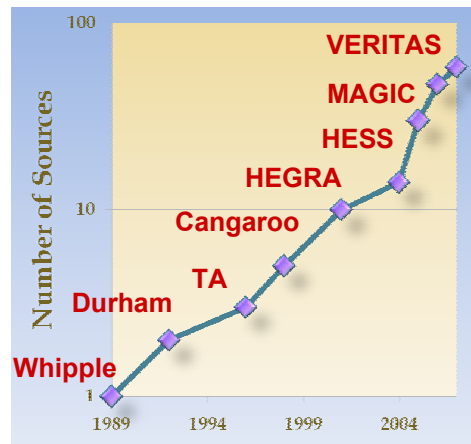


VHE Sources, c 2007

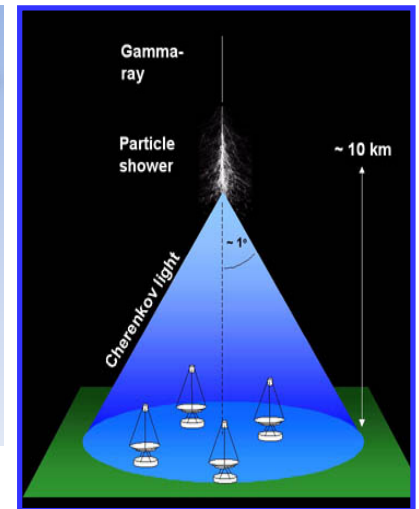


- AGN
- Pulsar Wind Nebula
- X-ray Binary
- Shell Type Supernova
- Radio Galaxy
- UNID

Sources vs Time



Imaging ACT Arrays



Explosion in source count in last 4 years, but many of the sources are still unidentified.

VERITAS



A Decadal Survey (2000) Project

Support comes from:
SI, DOE, NSF (U.S.)
PPARC (U.K.)
NSERC, (Canada)
SFI (Ireland)

Detector Design:

- Four 12m telescopes.
- 500-pixel cameras (3.5°).
- Site on Mt. Hopkins, AZ (1300m)

Performance:

- Energy range 100 GeV–50 TeV.
- Collection area $\sim 10^5 \text{ m}^2$.
- Gamma-ray resolution $\sim 3'-6'$.
- Energy resolution $\sim 15\%$.

**Very Energy Radiation Imaging
Telescope Array System (VERITAS)**

VERITAS Collaboration



U.S.:

Adler Planetarium
Argonne National Lab
Barnard College
DePauw Univ.
Grinnell College
Iowa State Univ.
Purdue Univ.
Smithsonian Astrophys. Obs.
Univ. of California, Los Angeles
Univ. of California, Santa Cruz
Univ. of Chicago
Univ. of Delaware
Univ. of Iowa
Univ. of Massachusetts
Univ. of Utah
Washington Univ., St. Louis

Canada:

McGill Univ.

U.K.:

Leeds Univ.

Ireland:

Cork Inst. Tech.
Galway-Mayo Inst. Tech.
Nat. Univ. Ireland, Galway
Univ. College Dublin

+ ~25 Associate Members

VERITAS Telescopes



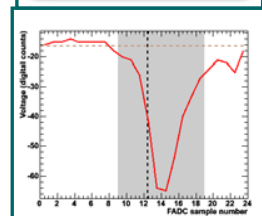
12m reflector



Imaging Camera
500 1" PMTs

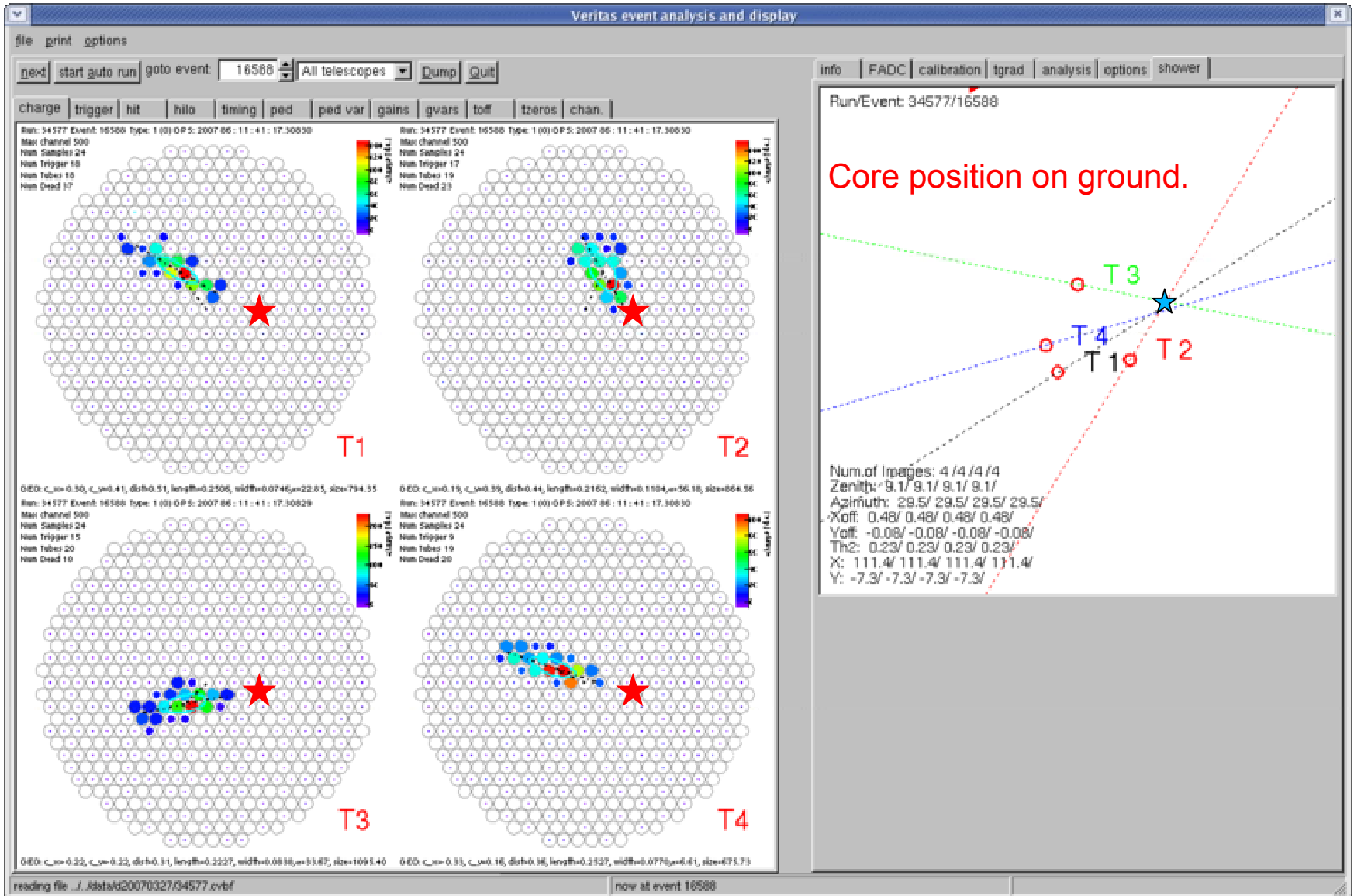


500 MS/s FADC



First Light Celebration
28 April 2007

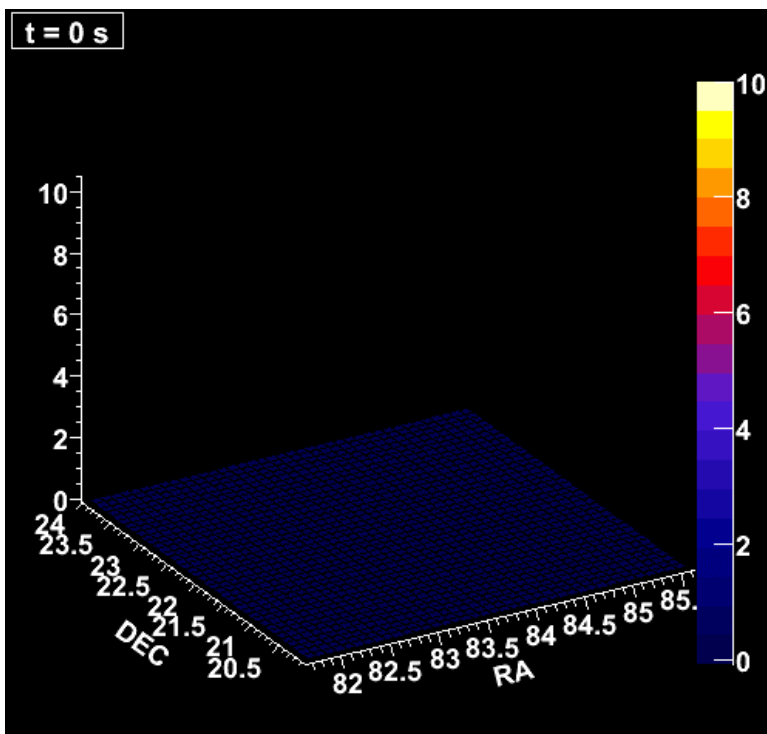
Typical 4 Telescope Event





VERITAS Performance

Crab Nebula: Standard Candle

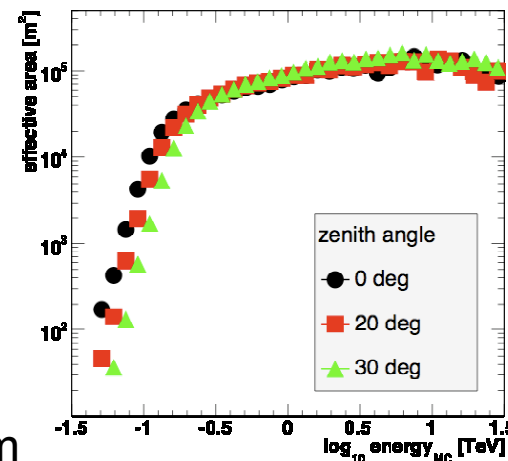


Sensitivity:

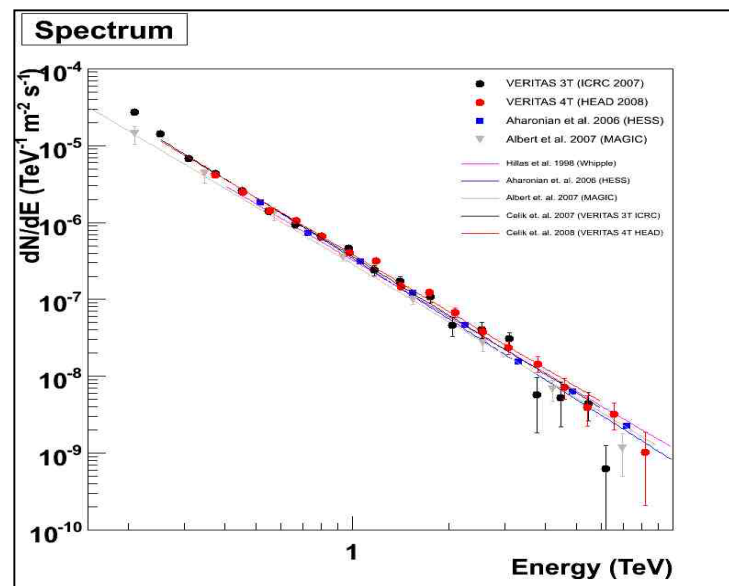
- 1 Crab \sim 90 s (5σ)
- 0.10 Crab \sim 1 hr
- 0.03 Crab \sim 10 hrs

Effective Area

$10^4 - 10^5 \text{ m}^2$



Crab Nebula
Energy spectrum



(Celik et al, HEAD 12.09)



VERITAS Science Program

Observations:

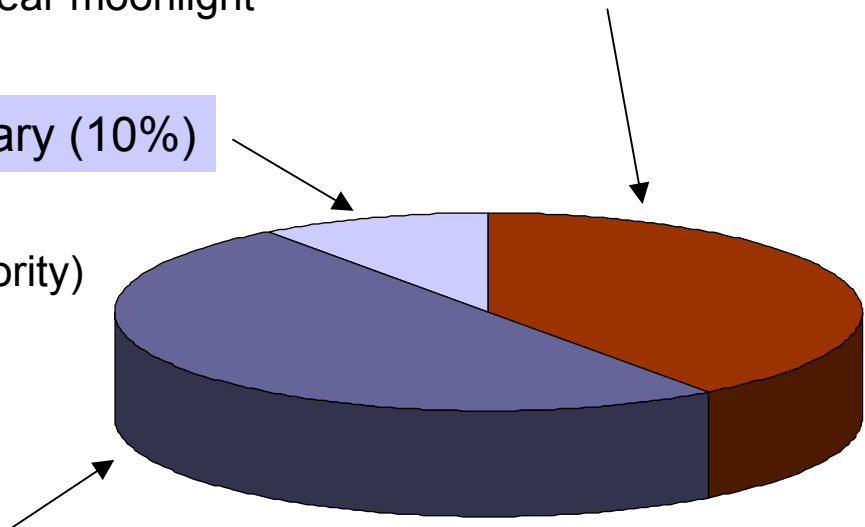
~ 800 hrs / year

+ ~ 200 hrs / year moonlight

Bulk Program (40%)

Discretionary (10%)

ToO's
GRB's (priority)
etc.

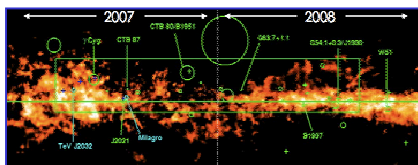


Science Groups:

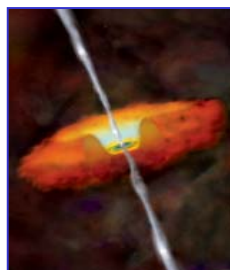
- Astroparticle Physics
- Blazars★
- Dark Matter★
- Extragalactic Sources★
- Galactic Compact★
- Galactic Diffuse
- GRB's
- PWN & SNR's★
- Unidentifieds

★ Results at HEAD 2008

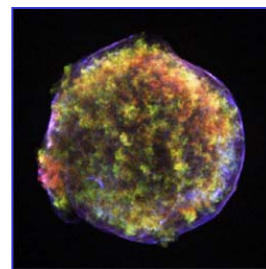
Key Science Projects (50%)



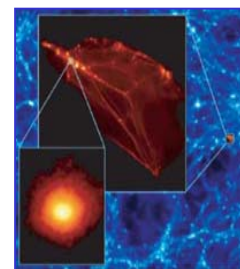
Sky Survey
(Cygnus region)



BLAZARS



SNRs/PWN



Dark Matter

VERITAS Science Highlights (so far)



2006:

- Jul – Detection of Crab Nebula and blazars Mrk 421 and Mrk 501 with 2 telescope array.

2007:

- Mar – Detection of XRB LSI +61 303 and confirmation of γ -ray variability.

First Light Celebration

- Apr – Co-Discovery of SNR IC443.
- Jul – Detection of blazar 1ES1218+304, 2nd most distant VHE source.
 - Detection of M87, only non-blazar extragalactic VHE source.

2008: **NEW STUFF !**

- Jan – Detection of blazar 1ES 2344+514, TeV flare correlated with X-ray.
- Mar – Discovery of blazar 1ES 0806+524 (ATEL #1415).
 - Discovery of blazar W Comae, one of only two LBL's seen (ATEL #1422).
- Apr – Detection of SNR Cas-A.
 - M87: Evidence for day-scale variability, correlated with X-ray flare.
 - IC443: Measurement of source extension.
 - . . .

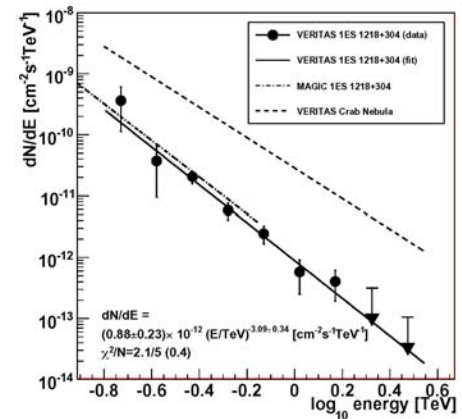
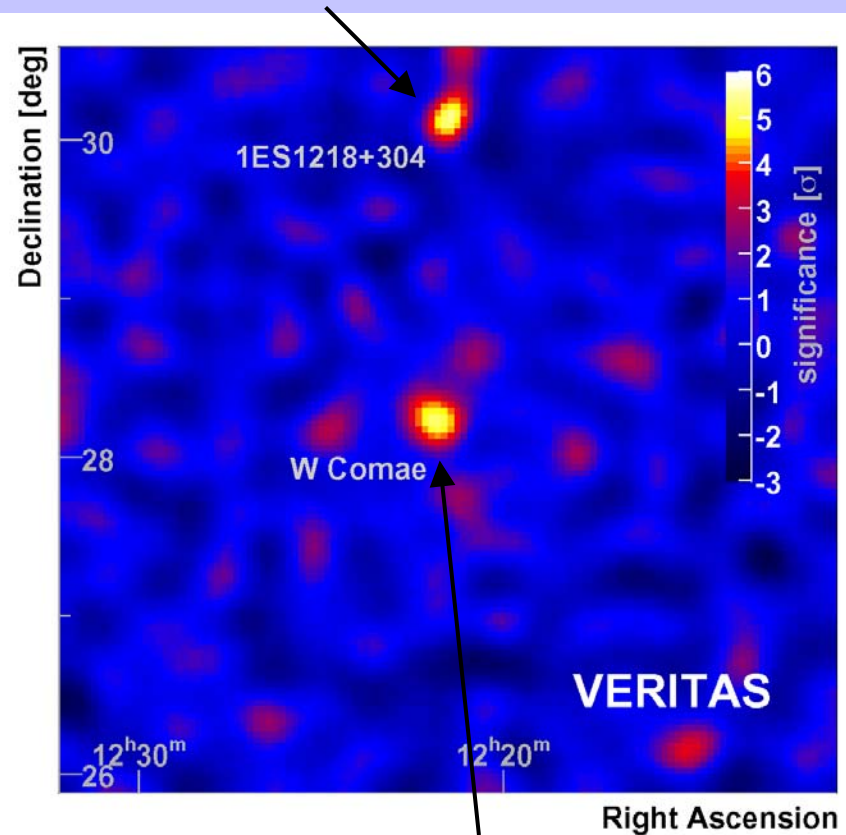
NB: a VERITAS Detection is $>5\sigma$ post-trials significance in two independent analyses.



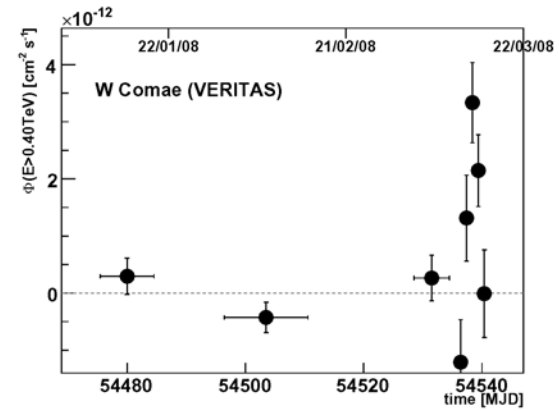
Blazar W Comae (and 1ES 1218 +304 !)

1ES 1218 +304:
High-Freq. Peaked BL Lac (HBL)
z = 0.182, one of the most distant VHE sources.

1ES 1218 Spectrum
~9% Crab, steeper



W Comae (ON 231):
Low-Freq. Peaked BL Lac (LBL)
Z= 0.102, one of only two VHE LBL's known.



W Comae Light Curve
Strong flare 18 Mar 08.

(Fortin et al., HEAD 26.24)



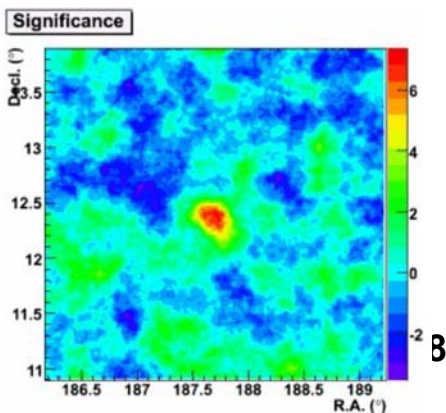
M87



HST
M87

Giant radio galaxy in Virgo. Misaligned jet. M87 is first non-blazar VHE source.

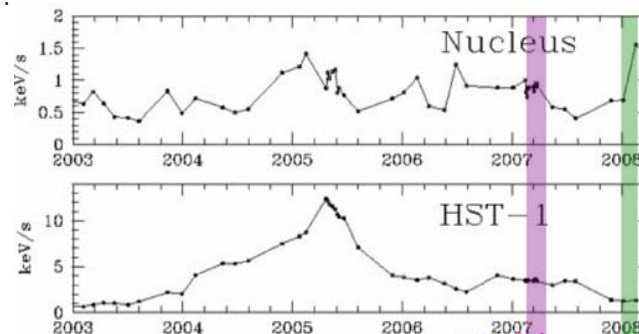
VERITAS Observations



2007: 3-tels, 44 hrs, 5.9σ .
2008: 4-tels, 32 hrs, 7.2σ .

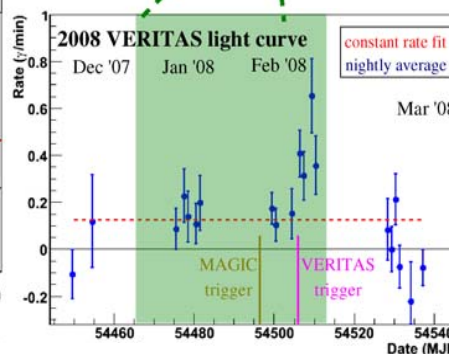
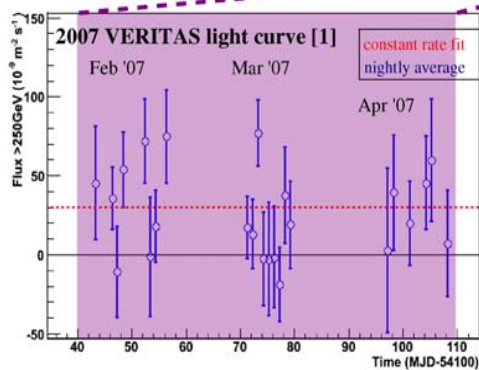
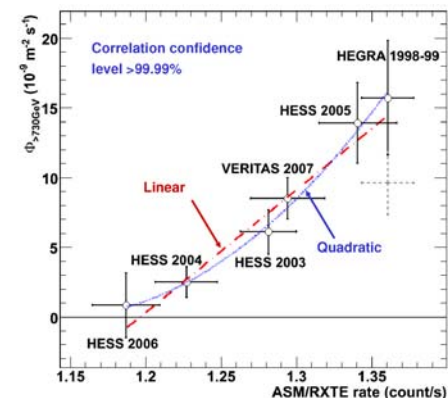
VERITAS-Chandra Light Curves

- 2007: no striking pattern.
- 2008: VHE flare consistent with X-rays from core.



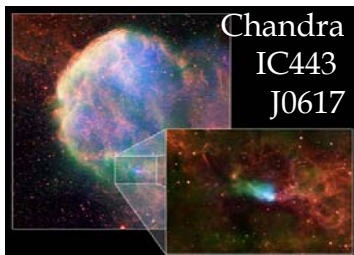
VHE-X-ray Long-Term Correlation

- Linear relation seen.



(Hui et al., HEAD 26.25)

SNR IC 443

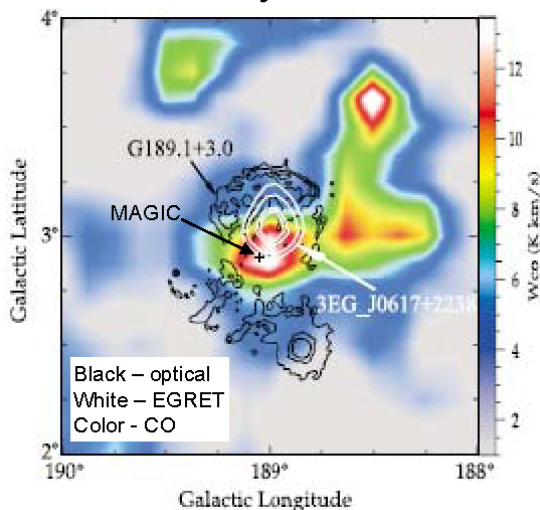


Age ~ 30,000 yrs
 Distance ~ 1.5 kpc
 Shell seen in radio, optical

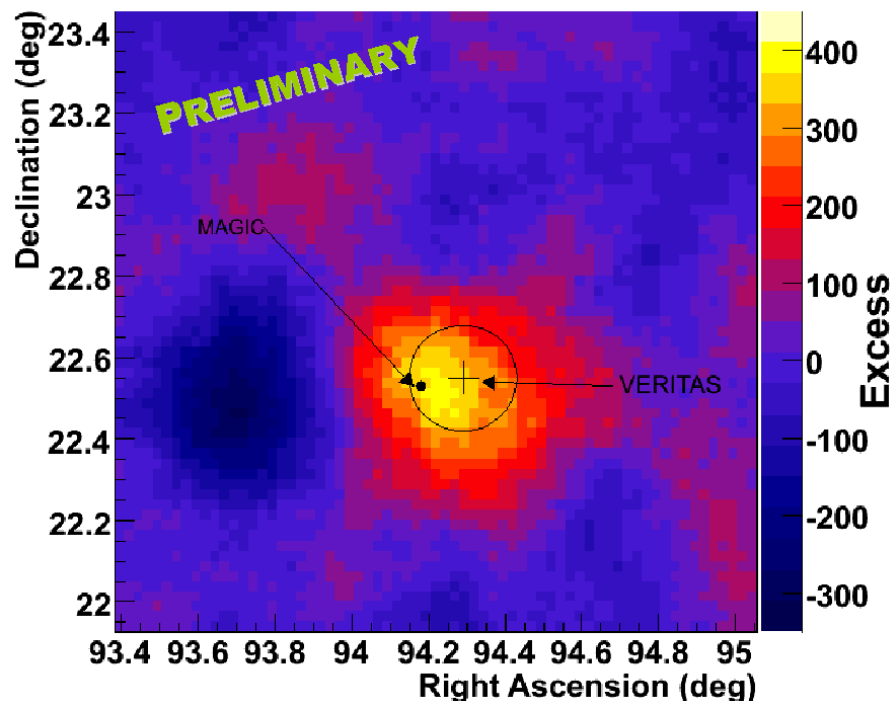
VERITAS Observations

- ~ 34 hrs data (2007).
- 8.25σ excess, $0.19 \pm 0.02 \gamma/\text{min}$.
- Flux ($>200 \text{ GeV}$) ~ **3% Crab**.
- Extension measured $\sigma \sim 0.13^\circ \pm 0.02^\circ \pm 0.04^\circ$.
- VERITAS position consistent with MAGIC, cloud.

Gamma-ray Observations



Shell & molecular cloud interaction.
 HE emission centered on remnant (EGRET).
 VHE emission centered on cloud (MAGIC).



(Humensky et al., HEAD 38.05)

VERITAS Detections and HEAD papers



	Source	Type	Redshift	HEAD Paper	Comments
Galactic	Crab Nebula	PWN		(Celik, 12.09) p	Standard Candle
	LSI +61 303	XRB		(Maier, 10.12) p	26.5d periodicity
	IC 443	SNR		(Humensky, 38.05)	VERITAS co-discovery
	Cas-A	SNR		(Ergin, 31.08) p	
		Galactic Sources:		(Konopelko, 38.02)	
Extragalactic	M87	FR I	0.004	(Hui, 26.25) p	
	Markarian 421	BL Lac	0.030	(Reyes, 20.06)	1 st Extragalactic VHE Source
	Markarian 501	BL Lac	0.034	(Kildea, 41.01) p	Whipple 10m
	1ES 2344+514	BL Lac	0.102	(Horan, 20.05)	
	W Comae	BL Lac	0.102	(Fortin, 26.24) p	VERITAS discovery
	1ES 0806+524	BL Lac	0.138	(Fortin, 26.24) p	VERITAS discovery
	1ES 1218+304	BL Lac	0.182	(Fortin, 26.24) p	2 nd most distant VHE source

Dark Matter limits DSph galaxies (Wood, 18.06)

= WED/THU HEAD Sessions



What's Next for VERITAS ?

LOTS !

- Observing: we are in first year of 5+ year program.
- (Galactic) Sky Survey – first results this summer.
- Spectra and modeling: source mechanisms.
- Images: extended sources (SNRs, PWN, etc.).
- MWL studies: radio, optical, X-ray, γ -ray.
- GLAST overlap: alerts, correlated science, calibration ...
- Instrument Upgrades: new cameras, etc.
- ... (stay tuned) ...



END