Recent Results from the VERITAS Gamma-ray Observatory

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McGill University

for the
VERITAS Collaboration

ICHEP 2010

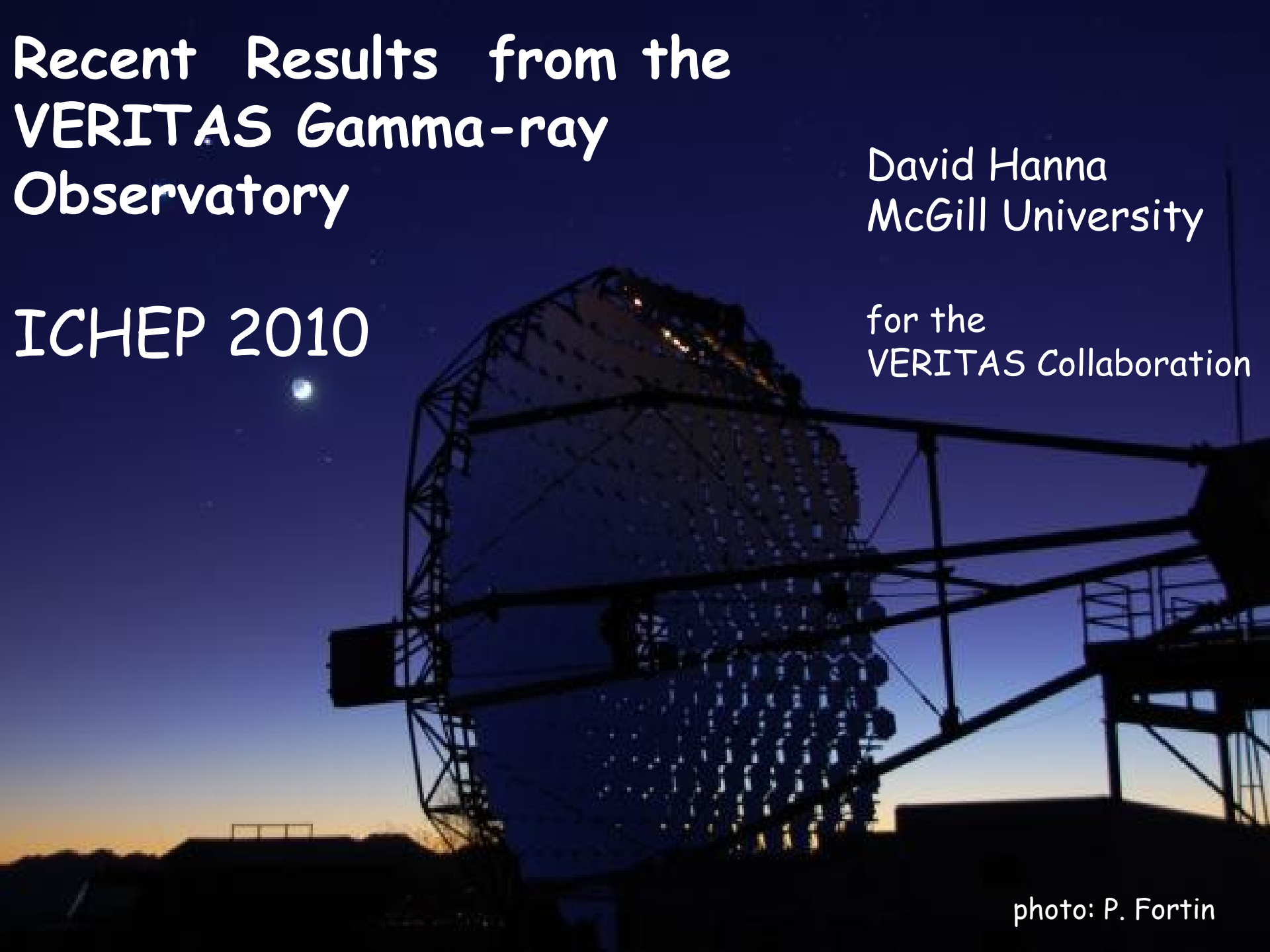


photo: P. Fortin

VERITAS Collaboration

- 90 scientists
- 22 institutions
- 4 countries

US (DOE, NSF, SAO)

Adler Planetarium
Argonne Nat Lab
Barnard College
DePauw U
Grinnell College
Iowa State U
Purdue U
SAO
UCLA
UCSC
U of Chicago
U of Delaware
U of Iowa
U of Minnesota
U of Utah
Washington U

Canada (NSERC)

McGill U

Ireland (SFI)

U College Dublin
National U Ireland Galway
Cork Inst Tech
Galway-Mayo Inst Tech

UK (STFC)

Leeds U

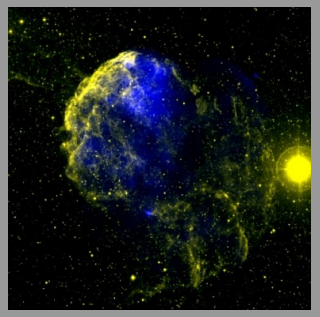
also ~ 35 associate members
theorists, MWL partners
(IceCube, Fermi, Swift etc)

VERITAS Science

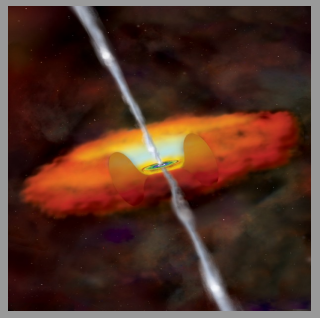
Study of very-high-energy gamma rays

(VHE: 100 GeV – 30 TeV)

known sources are:



- galactic
  - pulsar wind nebulae (PWNe)
  - supernova remnants (SNRs)
  - binary systems



- extra-galactic
  - active galactic nuclei (AGNs)
  - starburst galaxies

possible sources are:

- WIMP annihilation in galaxy cores
- primordial black hole (PBH) evaporation

VERITAS Science

Connection to (astro) particle physics

- instrumentation and techniques (see later)

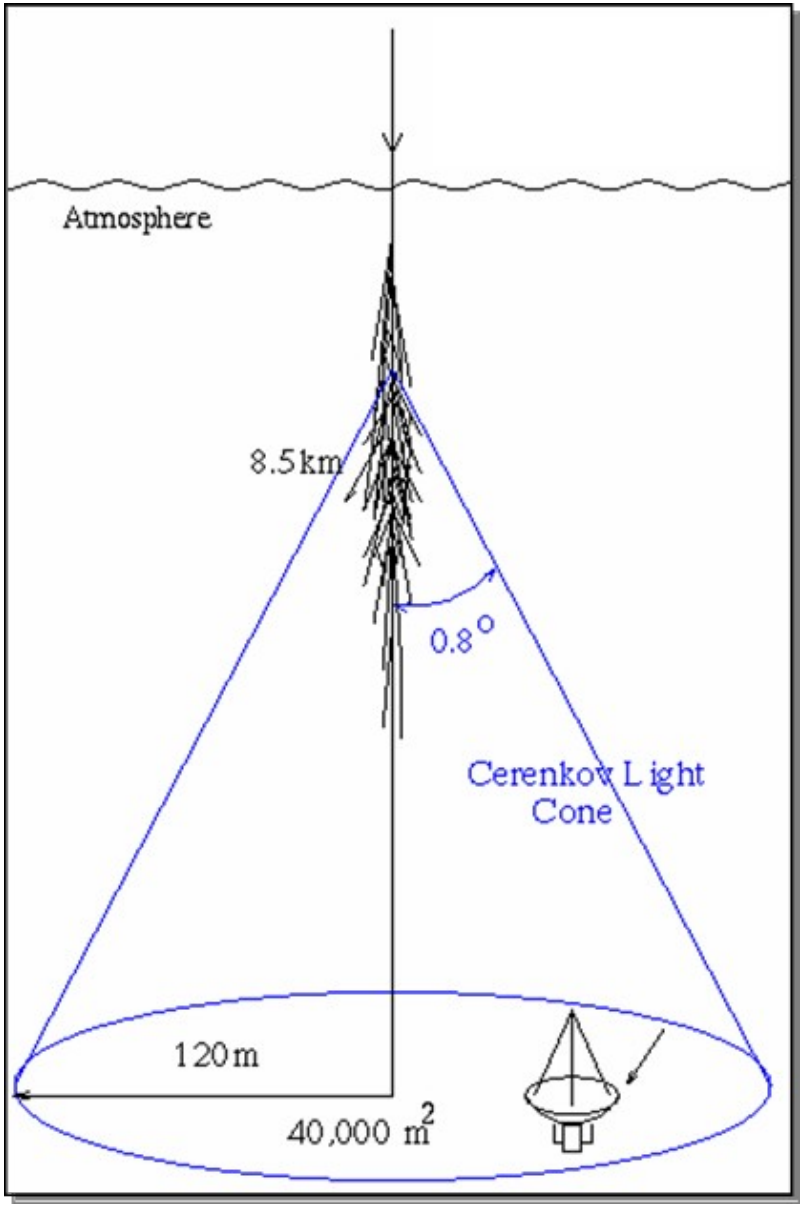
- origin of cosmic rays
  - where are the accelerators?
  - how do they work? what energies?
  (relevant to Auger, HiRes, etc)

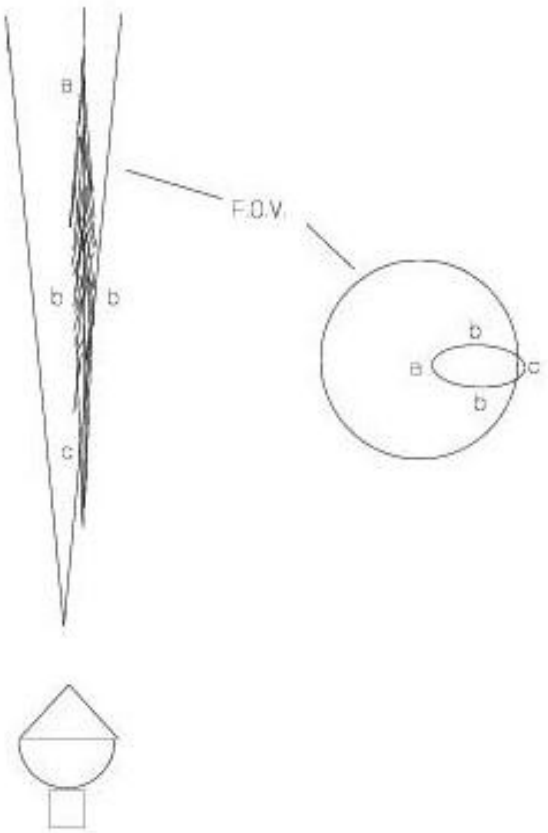
- understanding the nature of particle accelerators
  - what is being accelerated? (electrons, protons?)
  (relevant to IceCube, Antares, etc)

- astrophysical details of AGNs
  - can use flares to look for effects of quantum gravity
  but only if the start times are well understood

- increase discovery space
  - e.g. larger mass reach for WIMPs

Mechanics of TeV Gamma-ray Astronomy





air shower forms an image on the focal plane

images from gamma rays are different from images due to charged cosmic rays

(good for background rejection)

VERITAS Detector

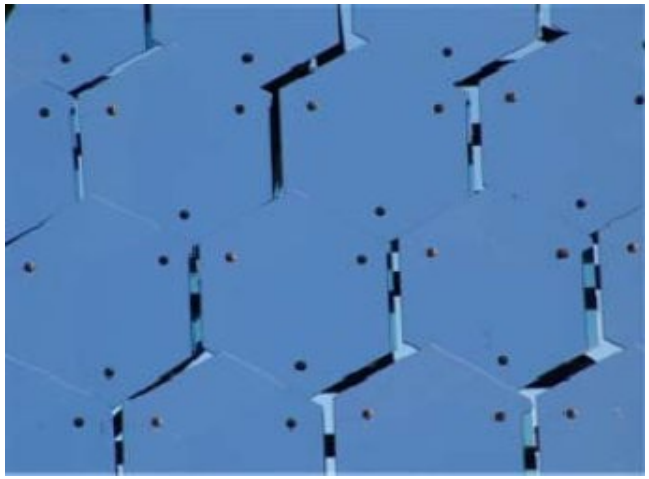
located in southern Arizona

- 1.3 km asl on Mt Hopkins (Whipple Observatory basecamp)
- 800 hours/year under dark skies
- 200 under partial moonlight
- summer monsoon (July-August)

built between 2005 and 2007 (prototype in 2003)

- fully operational since September 2007
- T1 moved during summer 2009 to improve array layout

Each Telescope

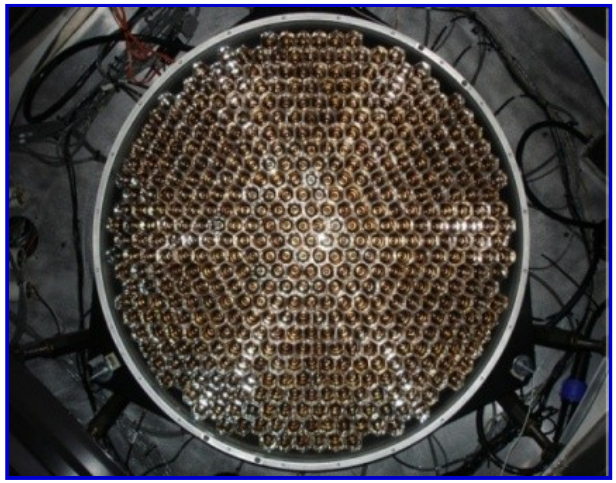


Reflector

- 12 m diameter
- 12 m focal length
- 110 m² area
- 349 hexagonal facets
  - spherical – 24 m radius
  - Davies-Cotton mounting

Camera

- 499 29mm PMTs
- 0.15º separation
- 3.5º field-of-view



Trigger and Readout

-three-level trigger

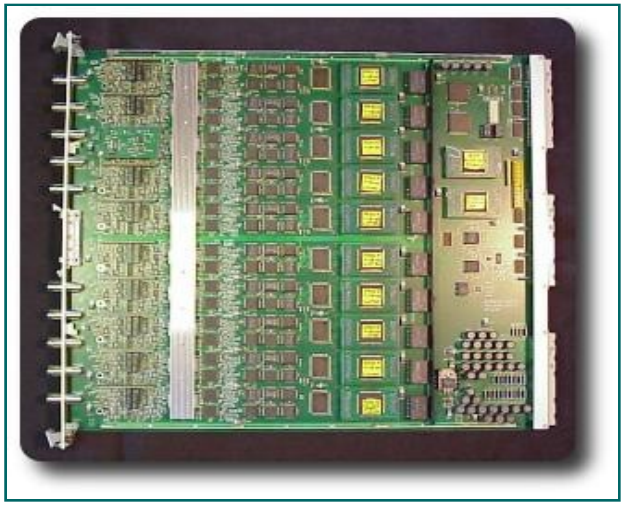
1. constant fraction discriminator on each PMT

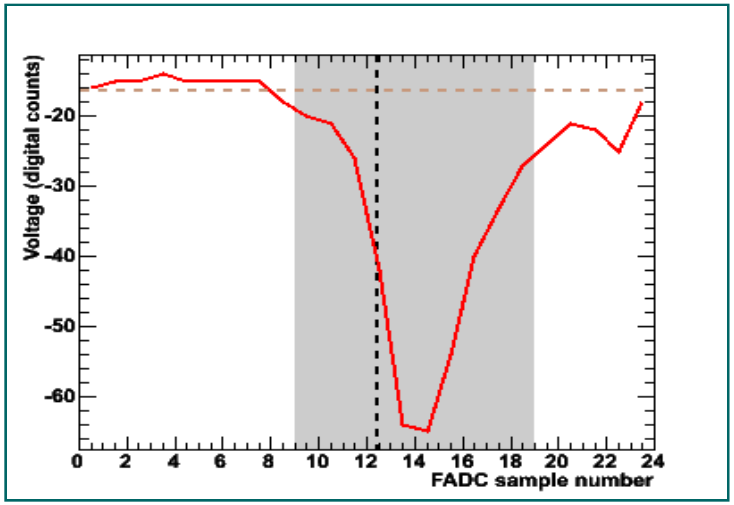
2. pattern trigger on every telescope
(require hits on adjacent PMTs – typically 3)

3. array trigger (require 2 or more telescopes)

-500 MS/s Flash-ADC on every channel (8-bit dual gain)

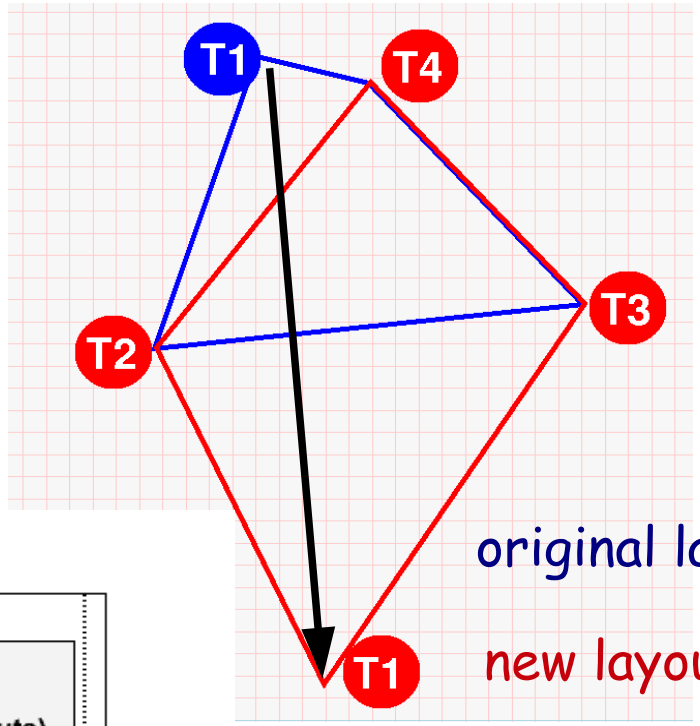
Typical trigger rate: 300 Hz (10% deadtime)

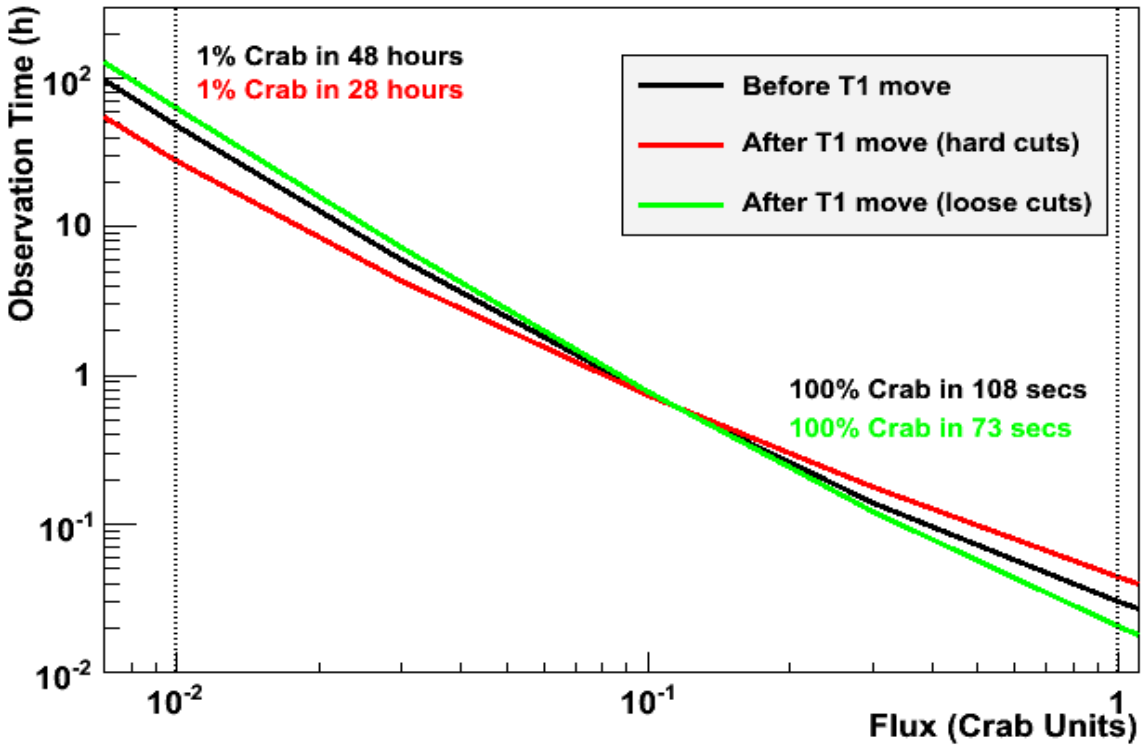




VERITAS Performance

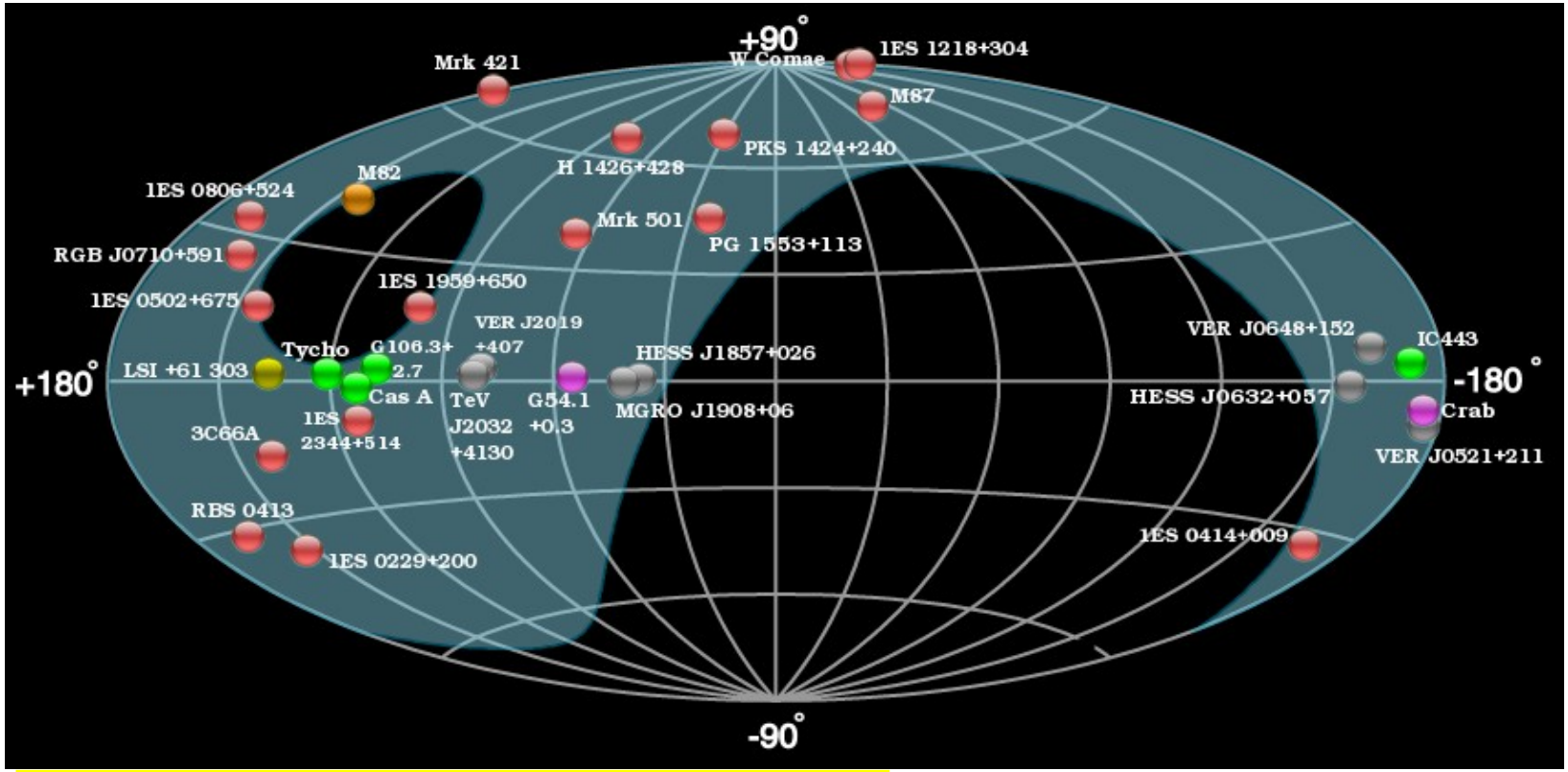
- energy resolution: 15% - 20%
- effective area >100,000 m^2
- spectral reconstruction: E > 150 GeV
- angular resolution (per event): r_{68} = 0.1°
- energy range: 100 GeV - 30 TeV





VERITAS Science Results

32 detections (15 discoveries)
- 18 extragalactic
- 7 galactic
- 7 unidentified



VERITAS catalog June 2010
(tevcat.uchicago.edu S Wakely & D Horan)

VERITAS Science Results

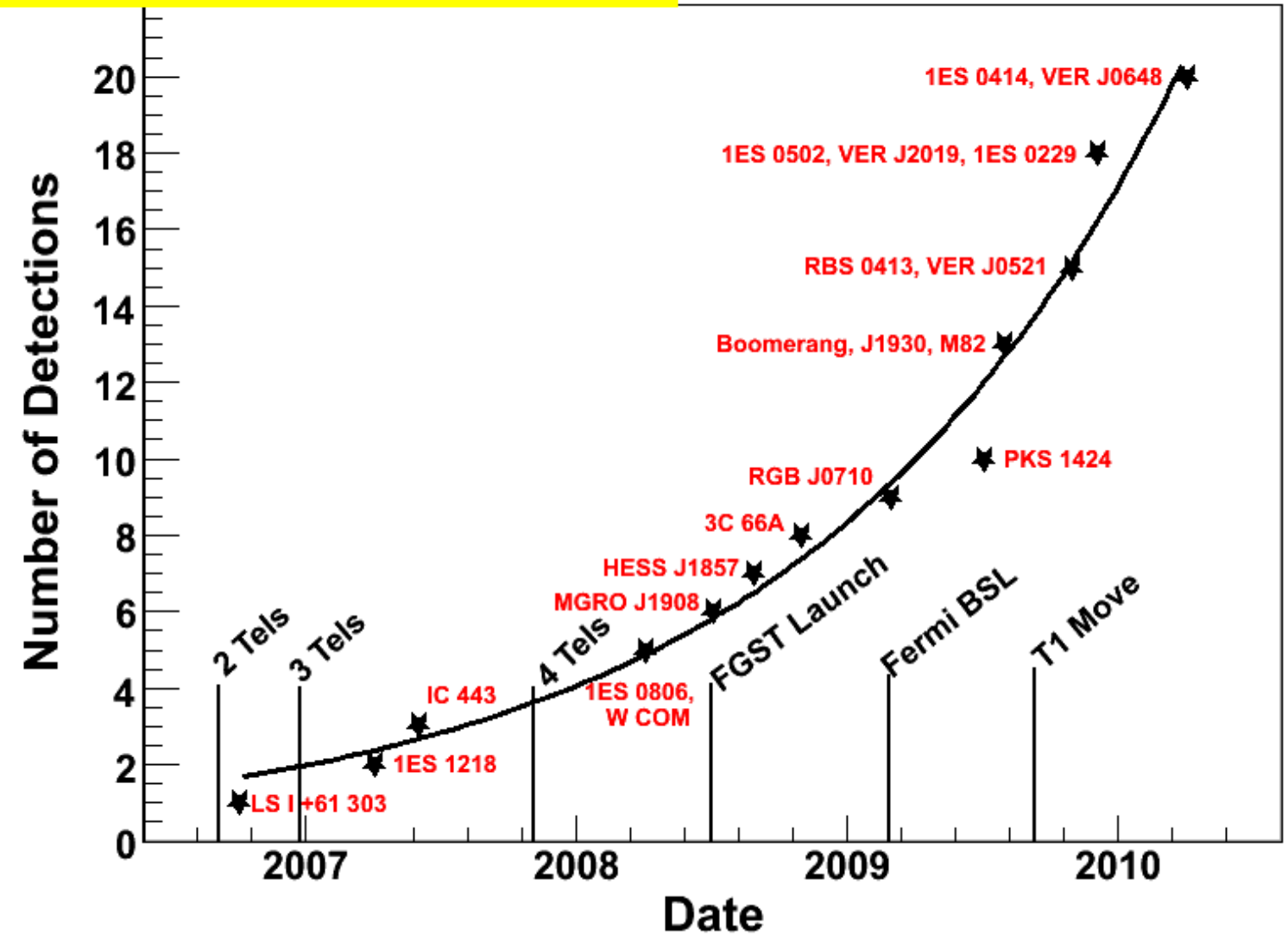
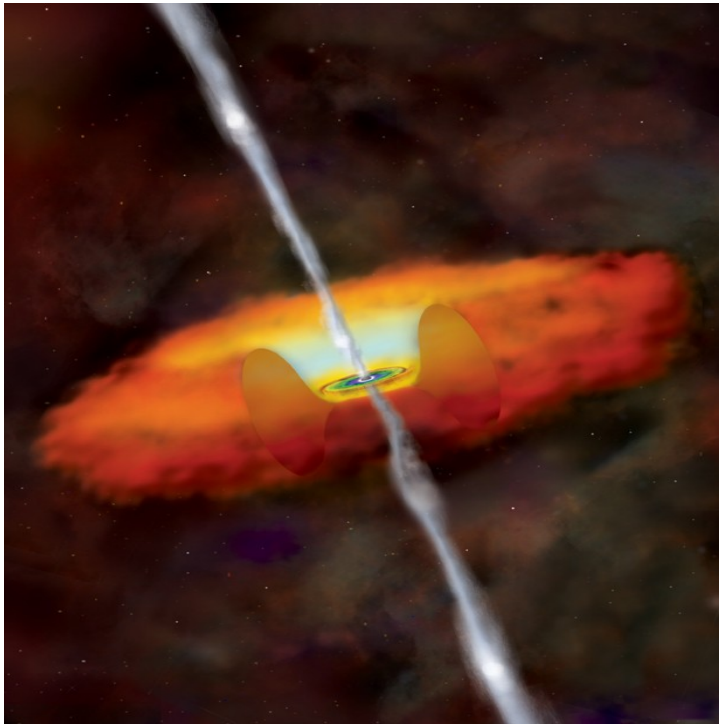


Fig: Dr Andy Smith, Argonne National Laboratory

VERITAS Science Results



Extragalactic

- mostly blazars
- multiwavelength campaigns important

aim is to understand jet production by supermassive black holes and the physics behind gamma-ray production therein

- leptonic?
- hadronic?

also measure the extragalactic background light (EBL) by observing its effect on blazar spectra

$\gamma_{TeV}\ \gamma_{EBL}$ --> e^+e^-

VERITAS Science Results

PKS 1424+240

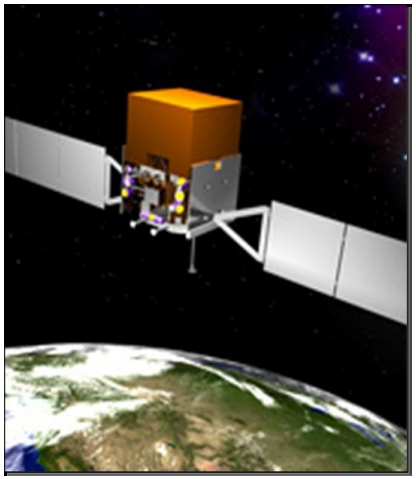
ApJL, 708, 100 (2010) (joint with Fermi LAT, Swift, MDM)

first VHE detection of an AGN as a result of a Fermi follow-up

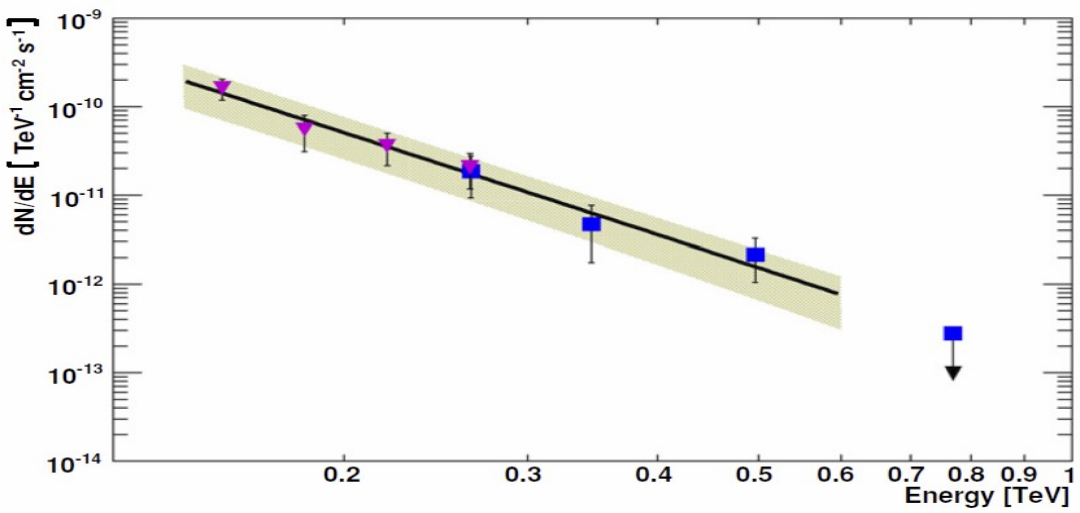
BL Lac object with unknown redshift
(0.06 < z < 0.66 from optical measurements and modeling)

steep power-law (3.8) above 140 GeV
(break from Fermi - EBL?)

flux steady at 5% Crab during observations
(Feb 19 – June 21, 2009)



further interpretation needs redshift!



VERITAS Science Results

1ES 1218+304

ApJ, 709, 163 (2010)

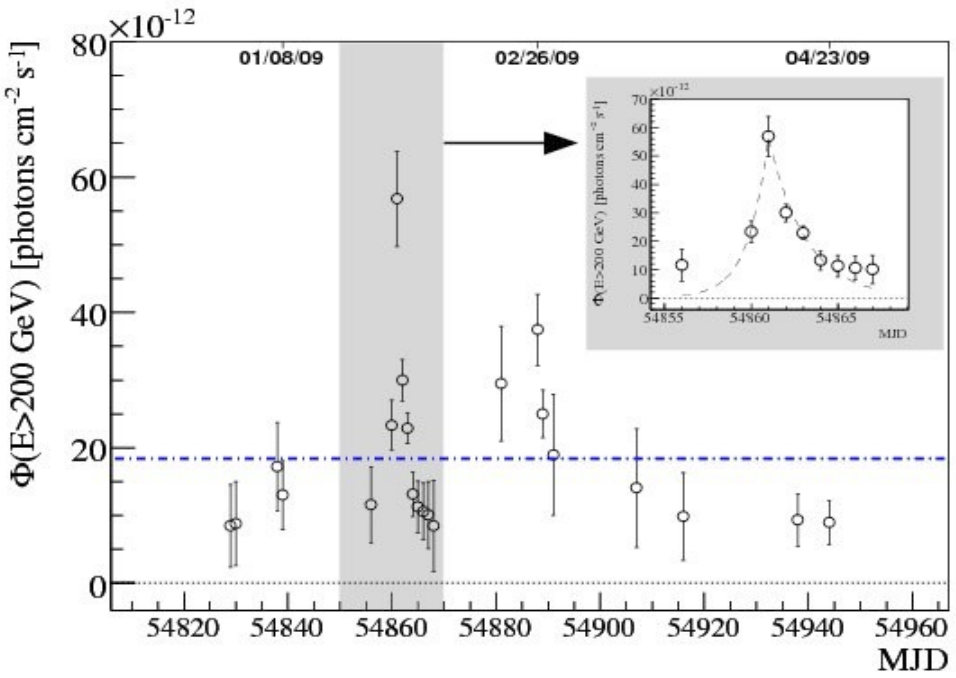
BL Lac object with known redshift (z=0.182)

power-law (3.1) above 200 GeV
- hard for this large a redshift (expect EBL absorption)
- instrinsic spectrum must be even harder – explain with (pc) extended jet

strong flare 7% → 20% Crab observed
Jan 25 - Feb 5, 2009

time scale limits size of emission region
(< 0.01 pc)

challenge to leading model of hard AGN spectra



VERITAS Science Results

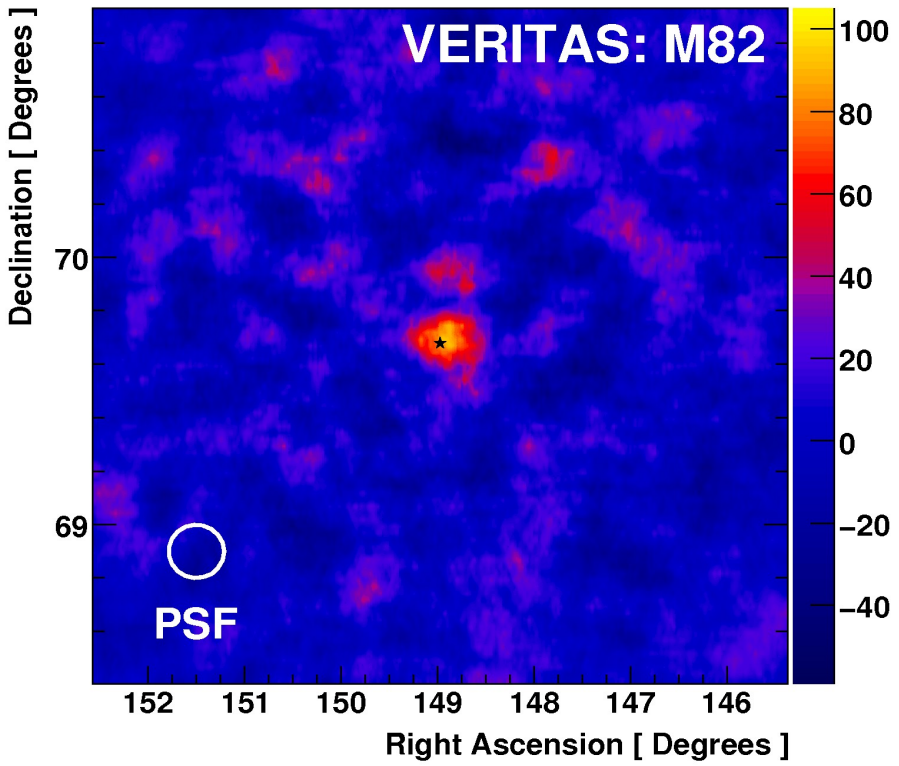
M82

Nature 472 770-772 (2009)

first observation of VHE gamma rays from a starburst galaxy (SG)
(140 h over two years to detect the source – 0.9% Crab)

5 sigma (post trials) for E > 700 GeV

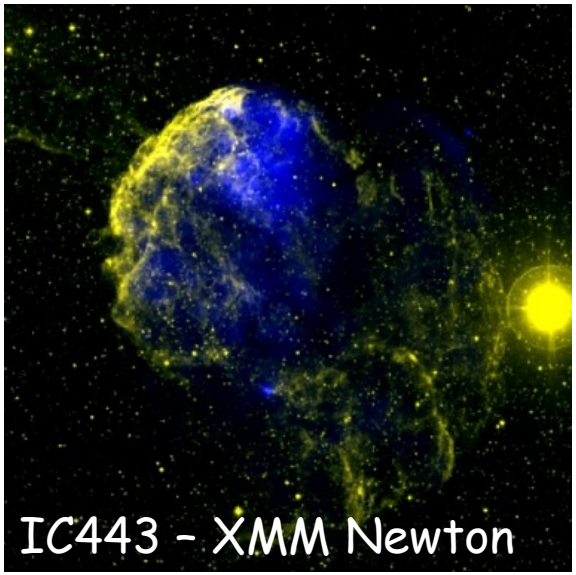
SGs have high rates of star birth (and death)
- many supernovae and stellar winds
- copius cosmic-ray production
- gamma-ray production from CR collisions



establishes starburst galaxies as a new class of VHE source

supports notion of SNRs as sources of cosmic rays

VERITAS Science Results



IC443 – XMM Newton

Galactic

- supernova remnants (SNRs) and pulsar wind nebulae (PWNe)

- binary systems

- sky survey in the Cygnus region

VERITAS Science Results

Cassiopeia A ApJ, 714, 163 (2010)

young (~330 yr) shell-type SNR

expanding into vacuum – 'easy' to model

VERITAS detection

22 hours (Oct/Nov 2007) 8.3 σ

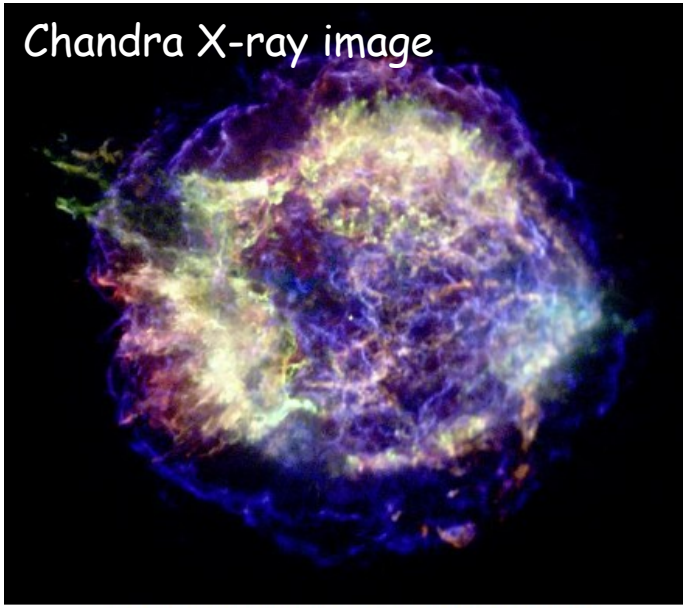
consistent with point source

power law (2.6 +/- 0.2 +/- 0.2) 0.4 – 4 TeV

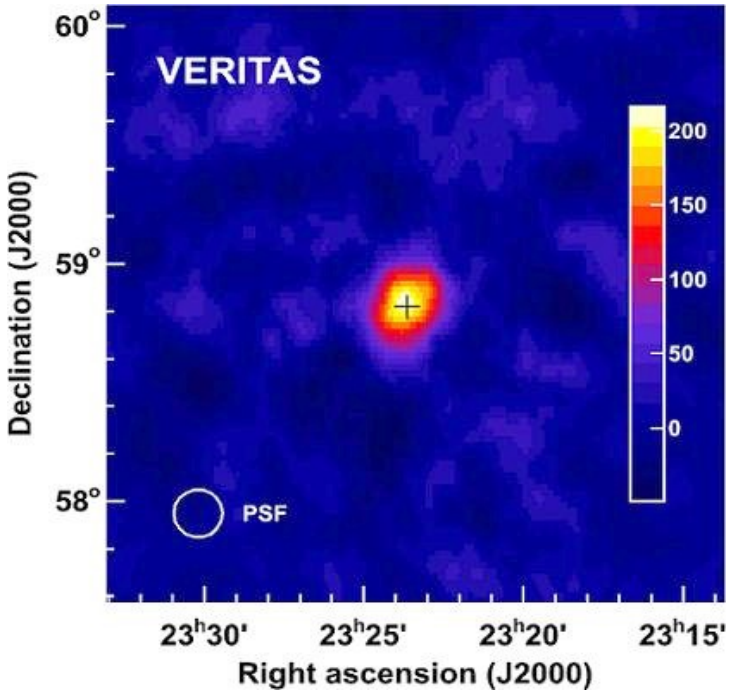
flux (> 1 TeV) ~3.5% Crab

modeling (Fermi-LAT) of Fermi and VHE data

hadronic favoured over leptonic
but either can be made to work



Credit: NASA/CXC/MIT/UMass Amherst/M.D.Stage et al.



VERITAS Science Results

Tycho (G120.1+1.4)
remnant of a supernova event (1572)

X-ray data (blue filaments) imply electrons
with energies up to ~10 TeV

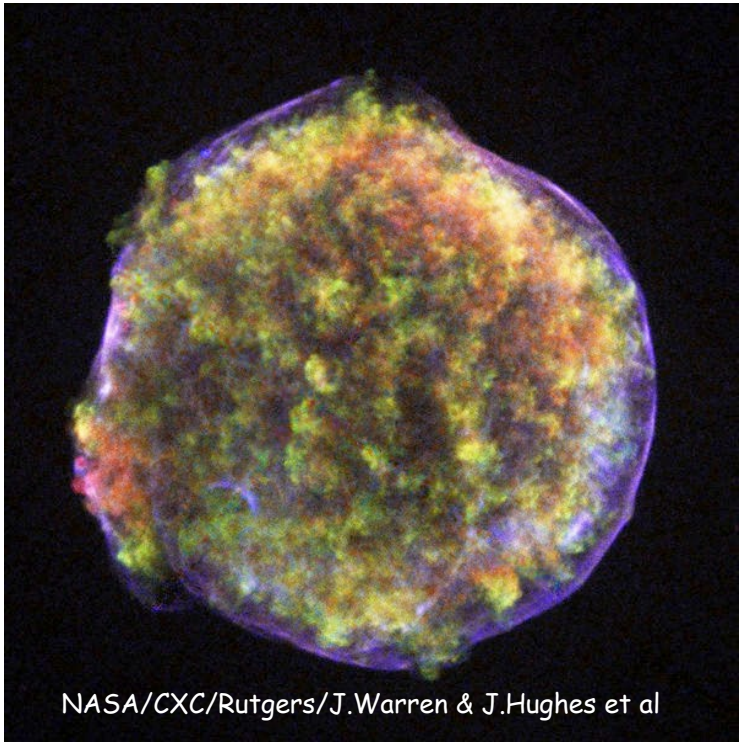
also evidence for efficient hadronic particle acceleration

other gamma-ray observations:

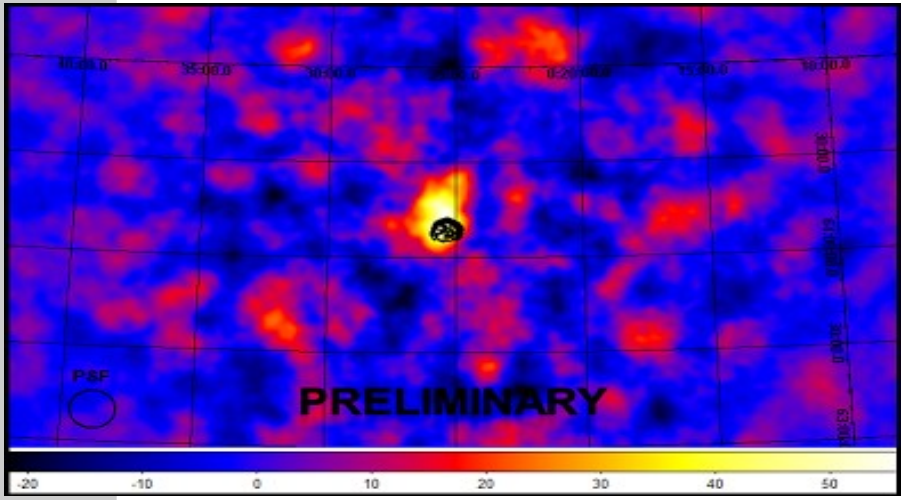
- no detections from EGRET/Fermi
- or from Whipple/HEGRA/MAGIC

VERITAS detection:

- 67 hours (2008 and 2010) (mean zenith 38°)
- 5σ post-trials
- 1% Crab above 1 TeV
- peak significance close to molecular cloud
  - possible interaction?



NASA/CXC/Rutgers/J.Warren & J.Hughes et al



VERITAS Upgrade

Motivation:

- increased effective area
- better background suppression
- better angular resolution
- lower energy threshold
- faster slewing time

Result is improved sensitivity

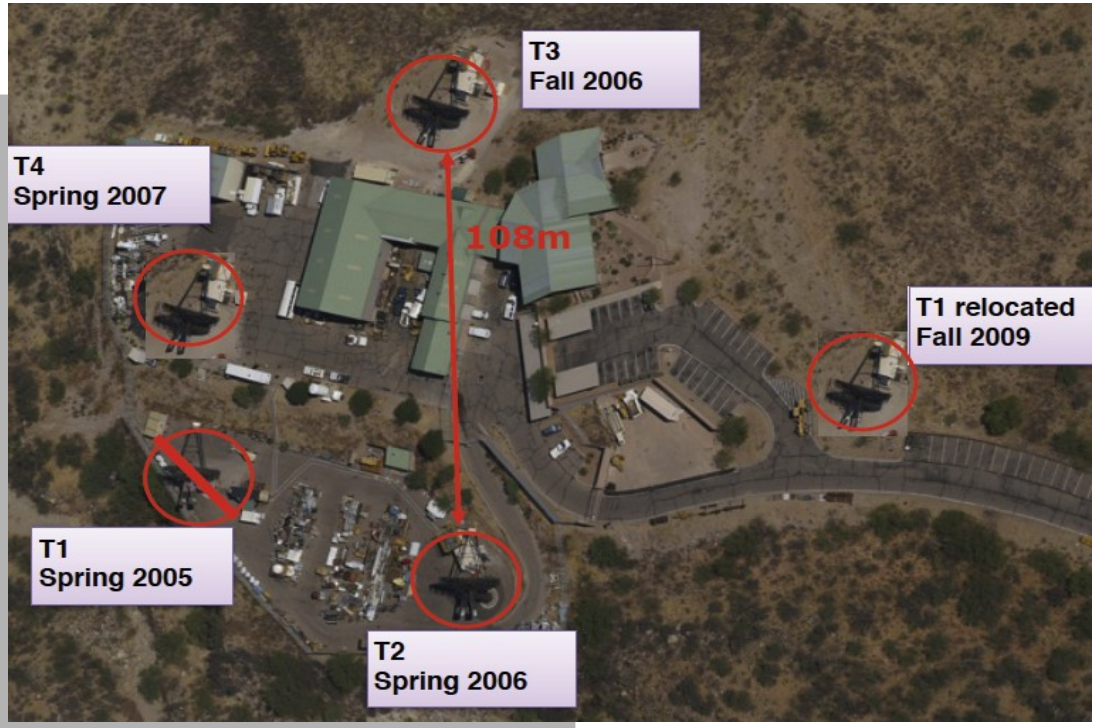
- faster detection for a given source strength
- detect weaker/more distant sources

VERITAS Upgrade

T1 relocation

- improve array layout
  - longer baselines
  - eliminate muon triggers

- done in summer 2009
  - simultaneous with
  - improved facet alignment

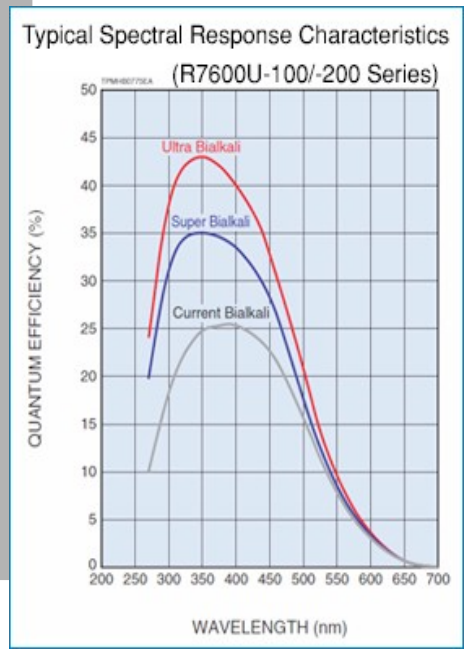


Super Bialkali PMTs

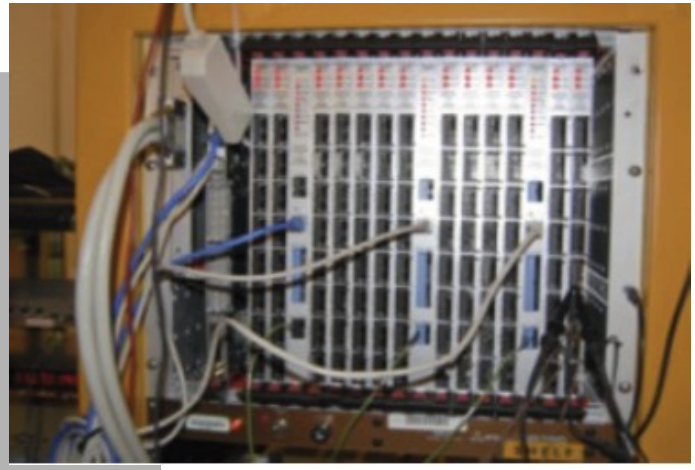
- higher QE; 50% increase in photon detection efficiency
(like getting a bigger mirror)

- funded – now deciding what PMTs to buy
(checking QE, afterpulsing, etc)

- install in 2012



VERITAS Upgrade



FPGA-based level-2 (pattern) trigger

- tighter coincidence window (factor two)
- improved diagnostics
- input for future L4 (gamma/hadron discrimination)
- 50% NSB reduction obtained in tests
- funded; install summer 2010

Faster slewing for telescopes

- improved response time for GRBs
- presently under study

Summary

VERITAS is running smoothly ~1000 hours/year

Currently the most sensitive VHE instrument in the world

Fermi is a valuable path-finder and MWL partner

Plenty of new results recently published and forthcoming

Upgrade program will extend VERITAS reach