

VERITAS Galactic Observation

Recent Observations of Galactic Object by the VERITAS Collaboration

Gareth Hughes for the VERITAS Collaboration

DESY

June 2012

<http://veritas.sao.arizona.edu/>



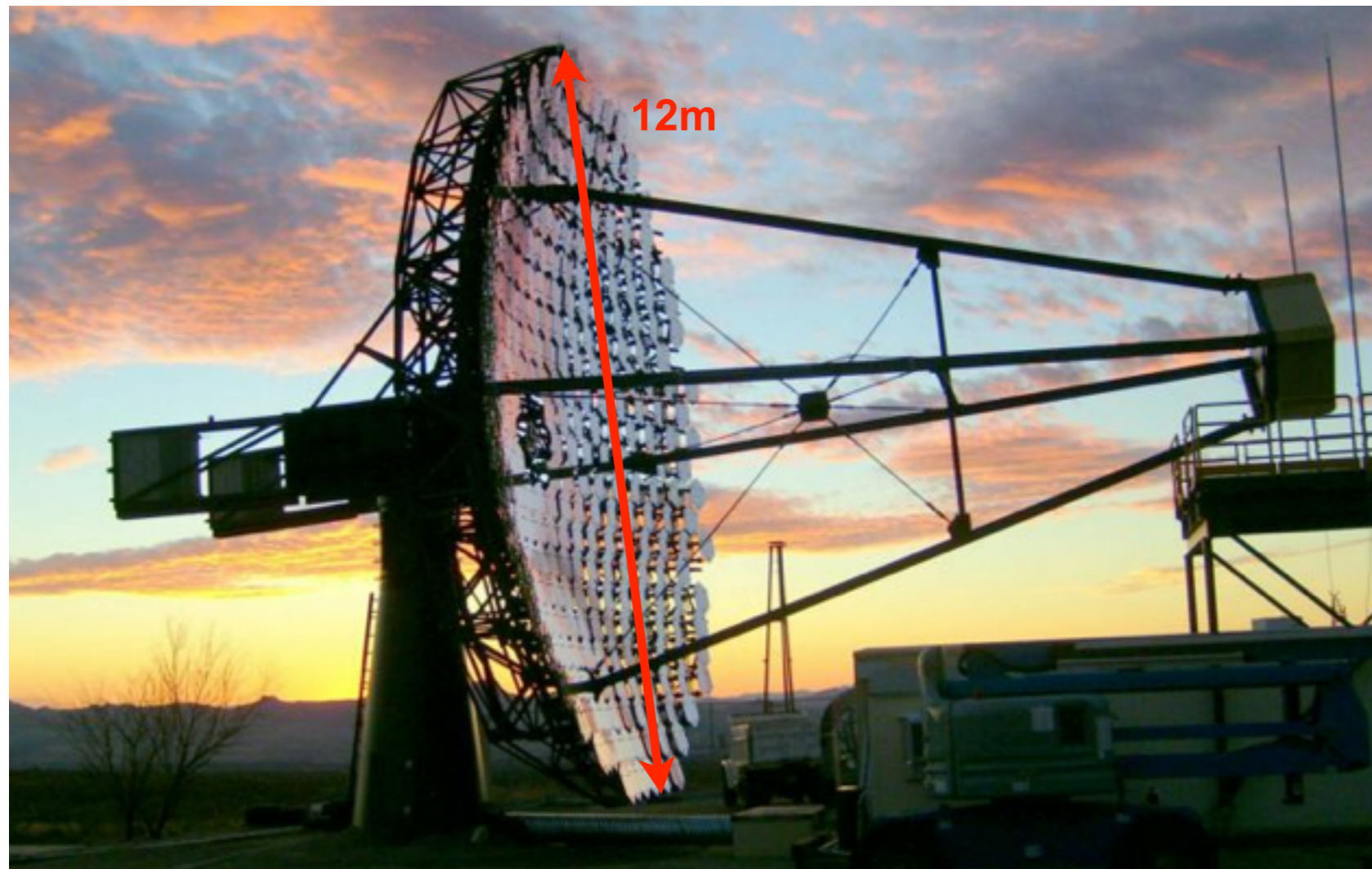
The VERITAS Collaboration



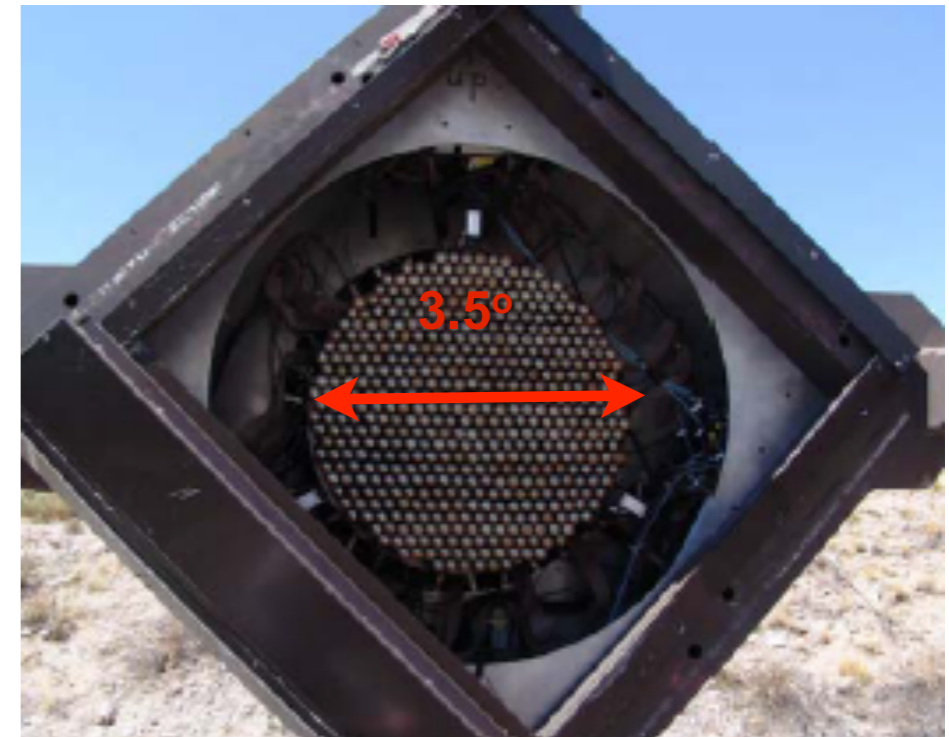
- 90 Scientists
- From 5 Countries and 22 Institutions
- Including US, Canada, UK, Ireland and Germany
- 35 Associate members (includes theorists and multi wavelength partners)



VERITAS Telescope



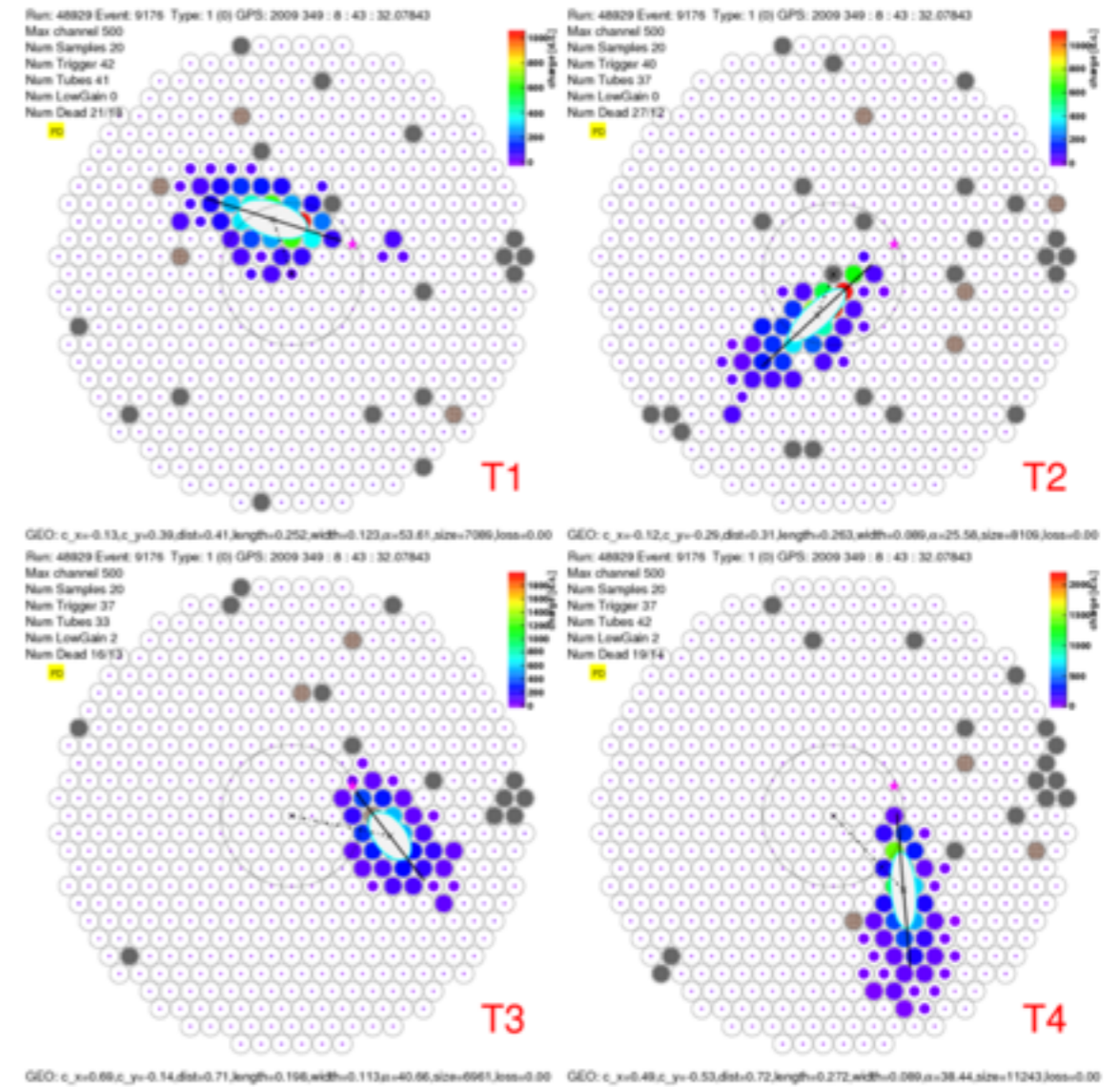
- > 4 Telescope Array ~100m baseline
- > 12m Reflector f/d ~1
- > Davies-Cotton Optics
- > 350 Facets



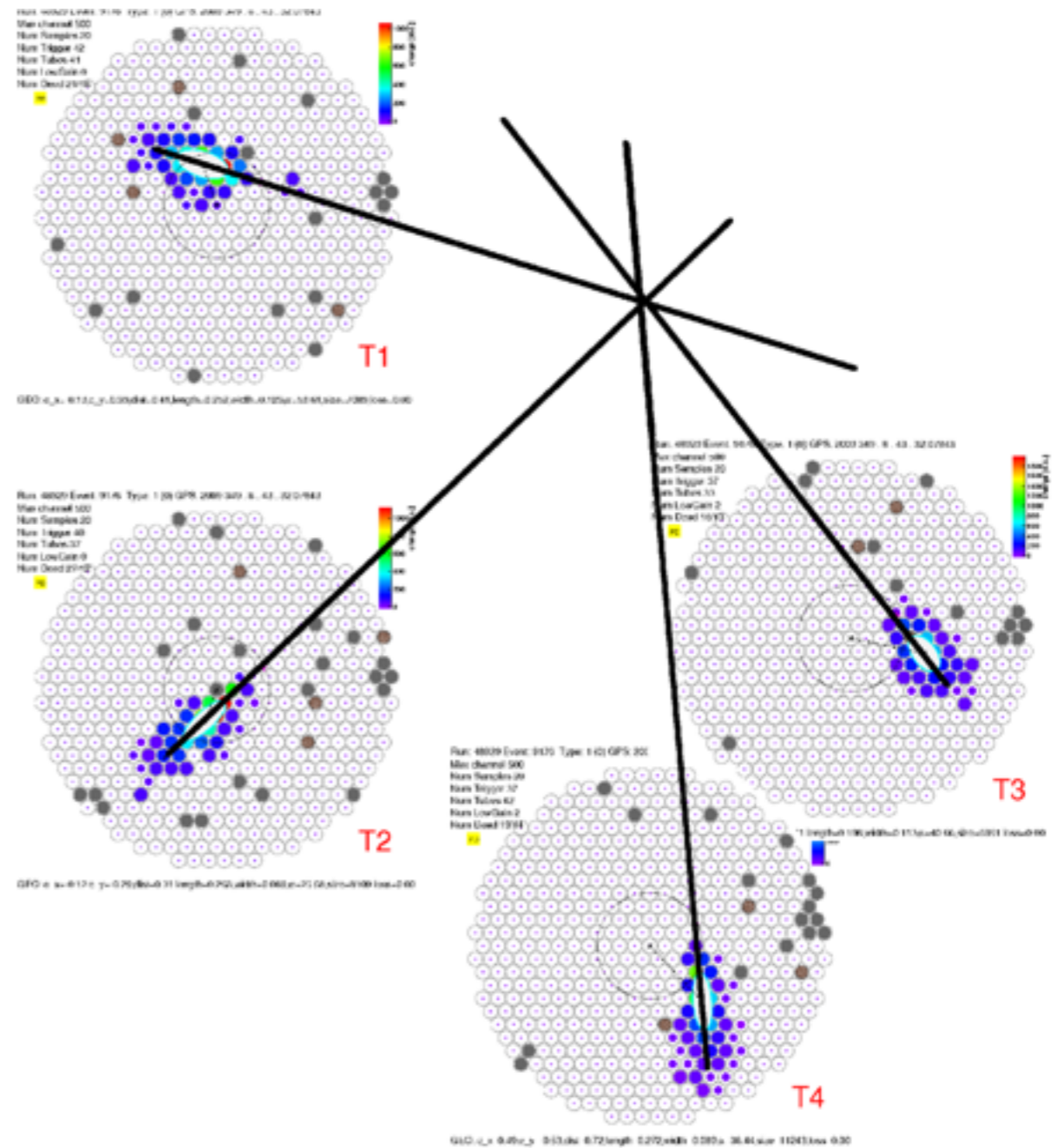
- > 499 pixel camera
- > 0.14° FoV / pixel
- > Giving a total of 3.5° FoV
- > 500 MSampling/s FADC
- > <10% Dead time



Imaging Cherenkov Technique



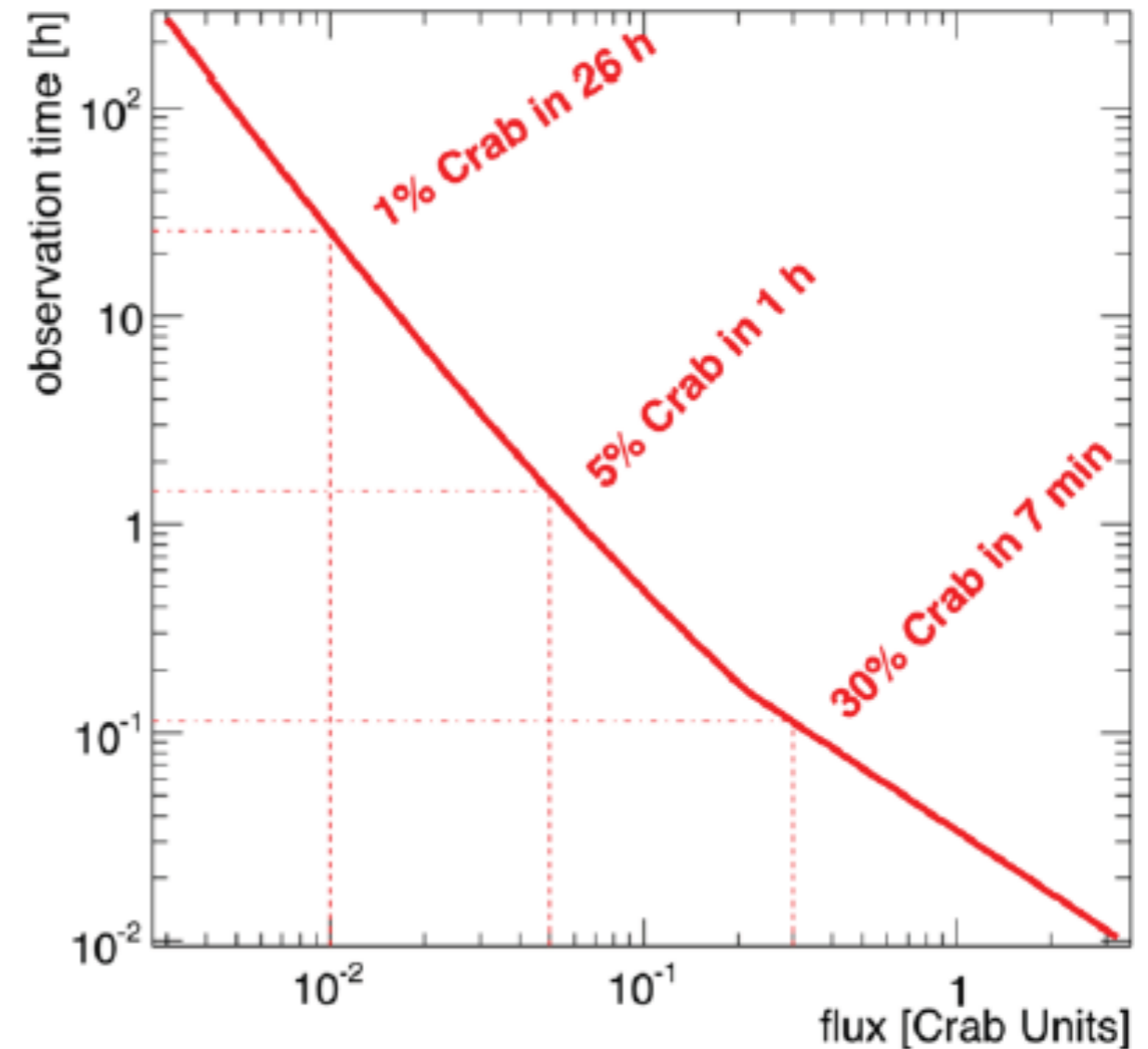
Imaging Cherenkov Technique



Detector Performance

- > Energy Range 100 GeV to 30 TeV
 - > Resolution of 25 to 15%
 - > Angular Resolution of $<0.1^\circ$ (68% containment) at 1TeV
 - > Pointing accuracy of $<50''$
-
- > Improved sensitivity from 2009 onward
 - Better angular resolution
 - > 2011 Trigger upgrade in the camera
 - > 2012 PMT upgrade giving 35% improvement in light yield

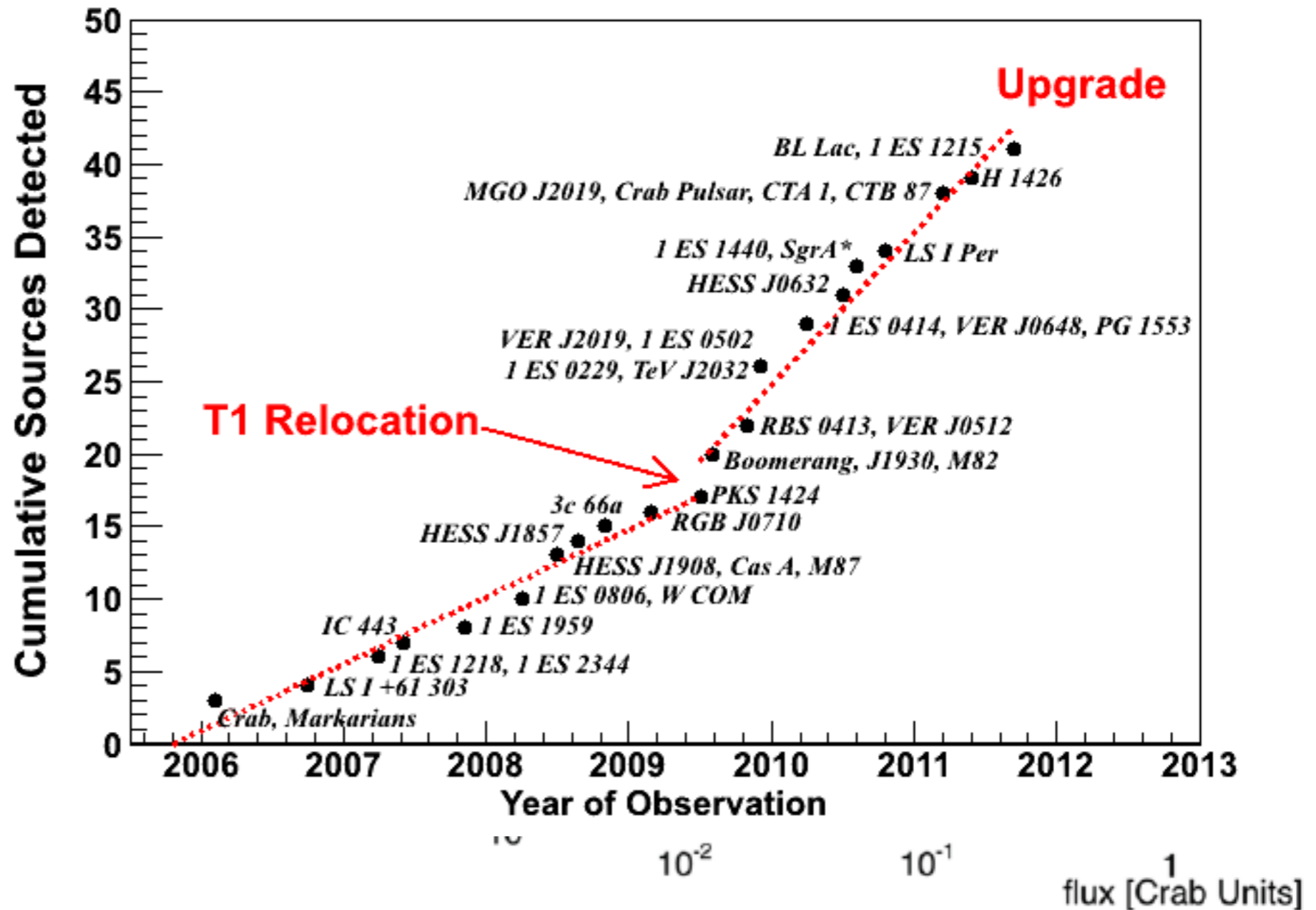
> Possible to observe a 1% Crab Source within 30 hrs



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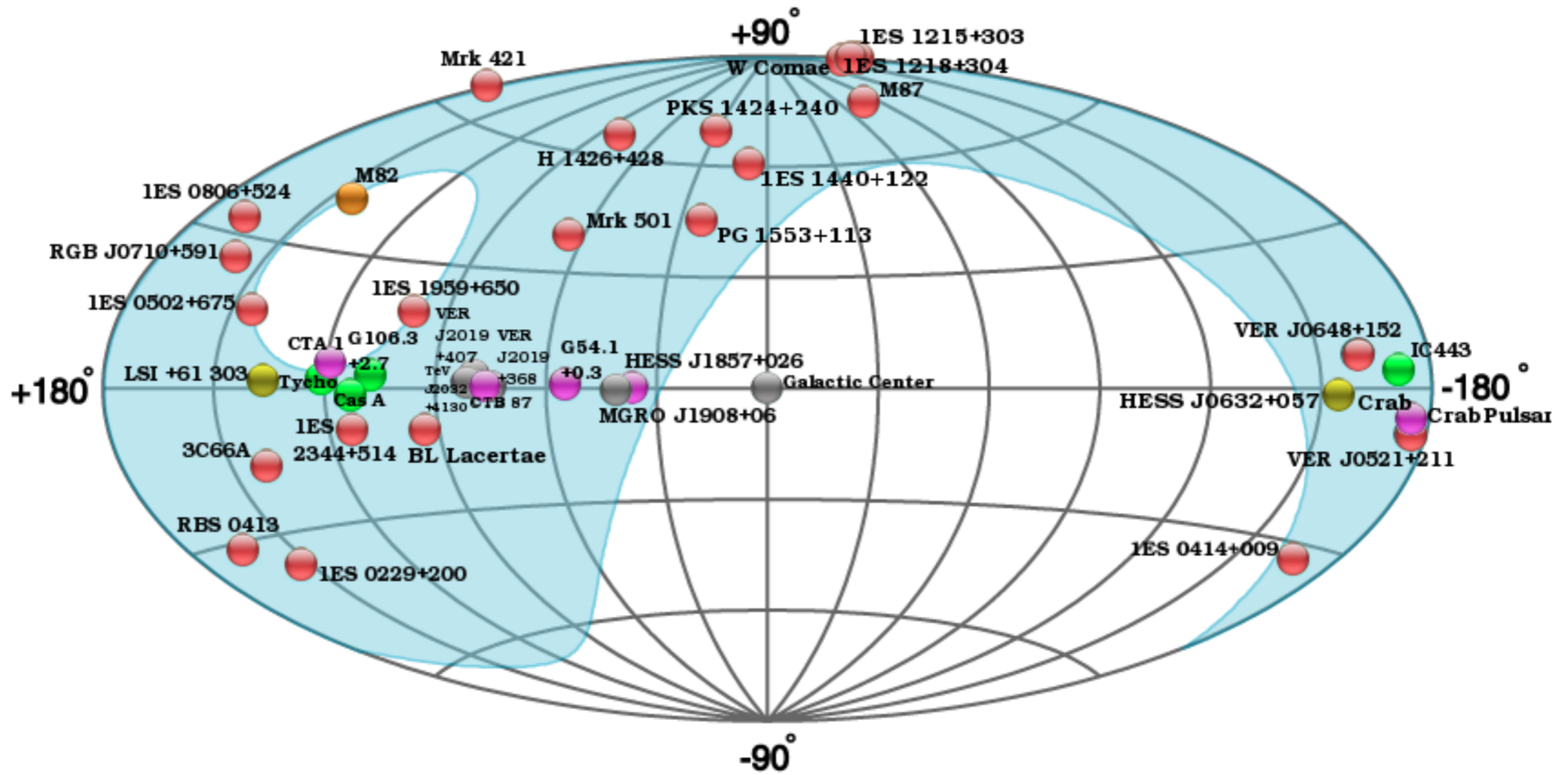
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The VERITAS Sky



Active Galactic Nuclei

PWN

Starburst Galaxies

Binaries

Pulsars

Super Nova Remnant



Tycho SNR

> Formed from Type 1a Super Nova in 1572

- Relatively young for the Milky way

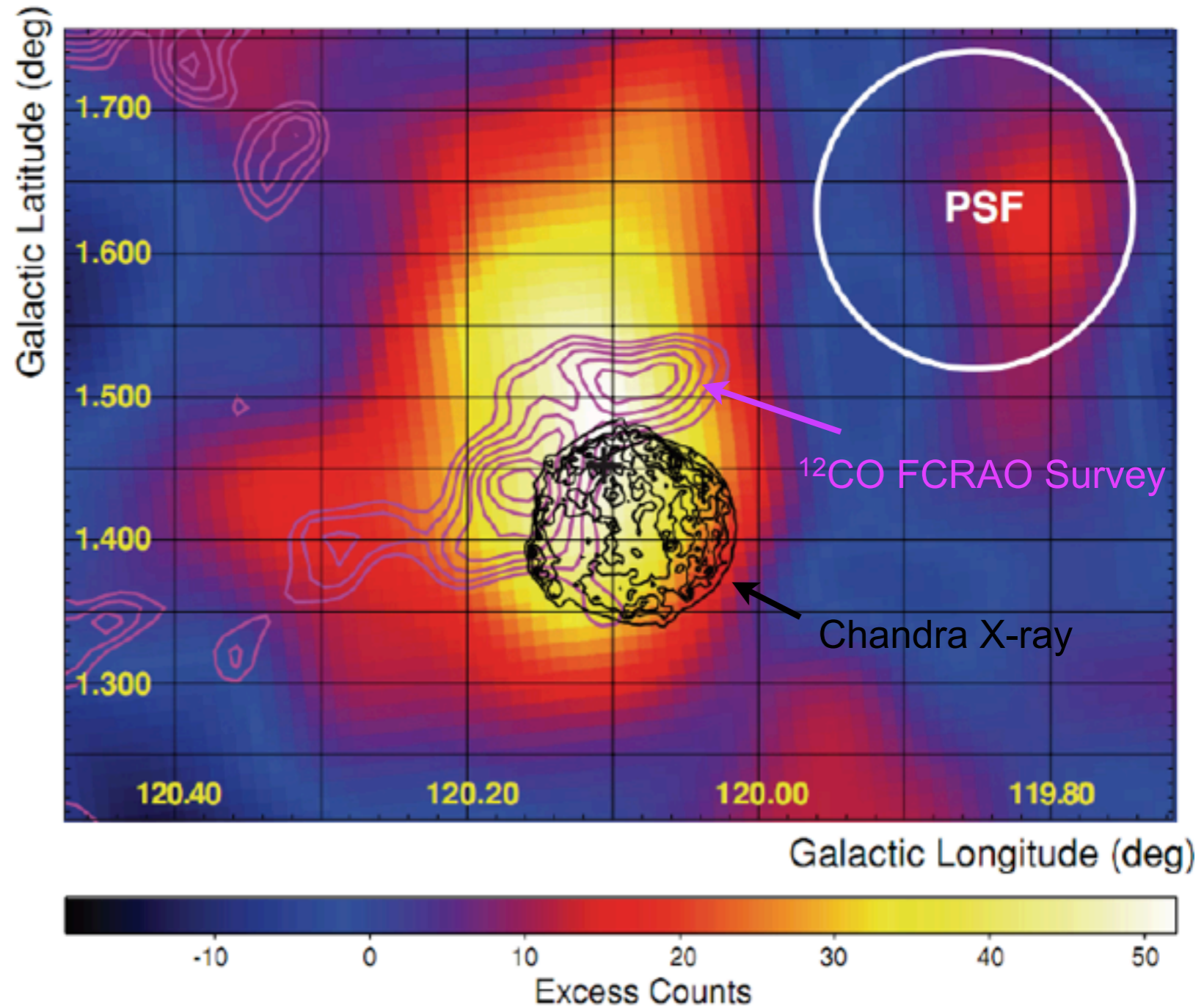
> VERITAS Observations

- 68 hrs of data taken
- Resulting in 5σ post trials
- Spectral Index of $1.95 \pm 0.51_{\text{stat}} \pm 0.30_{\text{sys}}$
- 0.9% Crab Nebulae Flux above 1 TeV

> Chandra Observations (Warren et al '05) suggest an efficient hadron accelerator

> VERITAS detection adds to evidence for magnetic field amplification within the remnant

> SED combined with FERMI data shows a good fit to accelerated proton model



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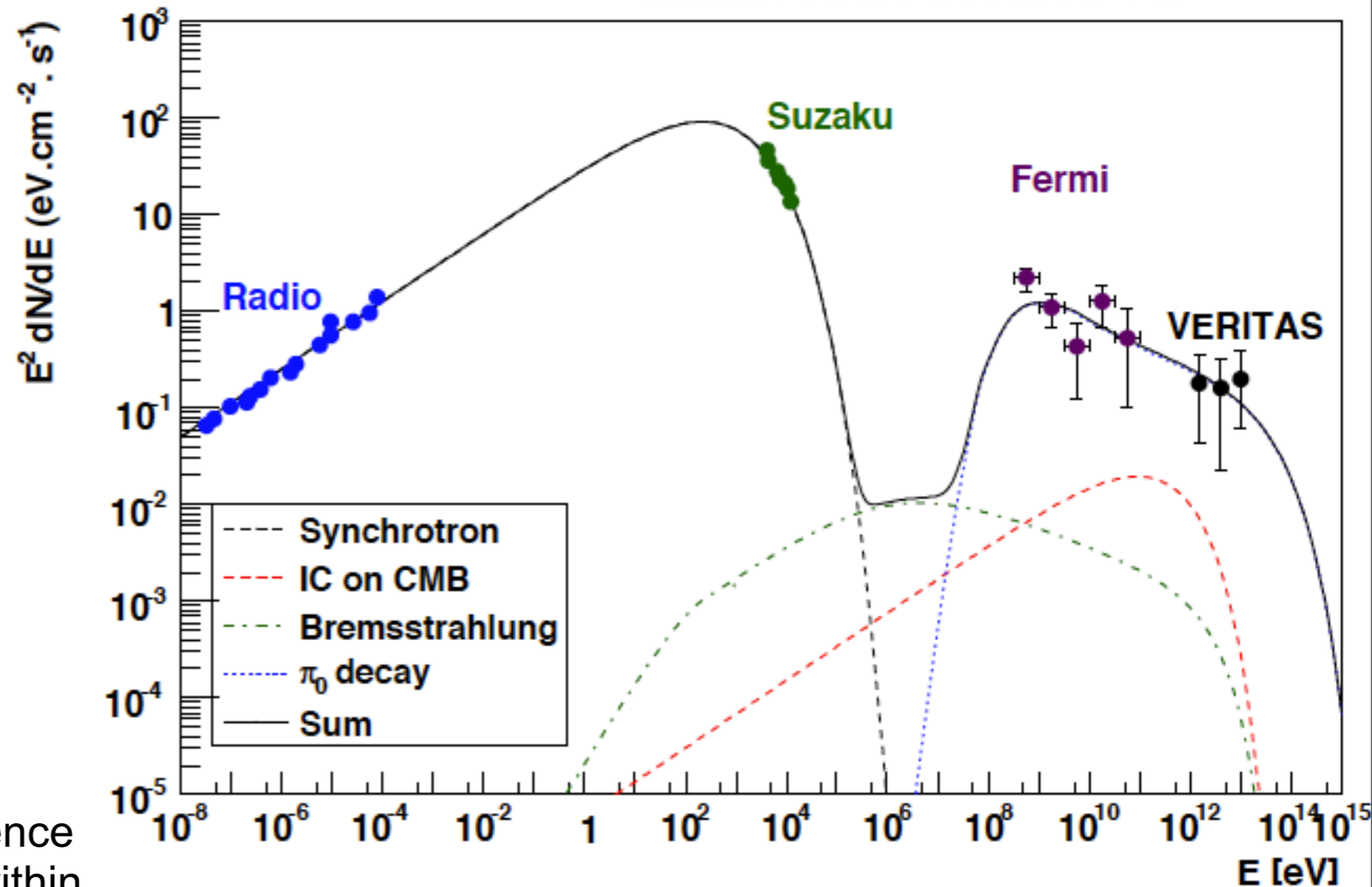
> Chandra Observations

(Warren et al '05) suggest an efficient hadron accelerator

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> SED shows compatibility with both Leptonic and Hadronic Models

F. Giordano et al. [arXiv:1108.0265v1](https://arxiv.org/abs/1108.0265v1)



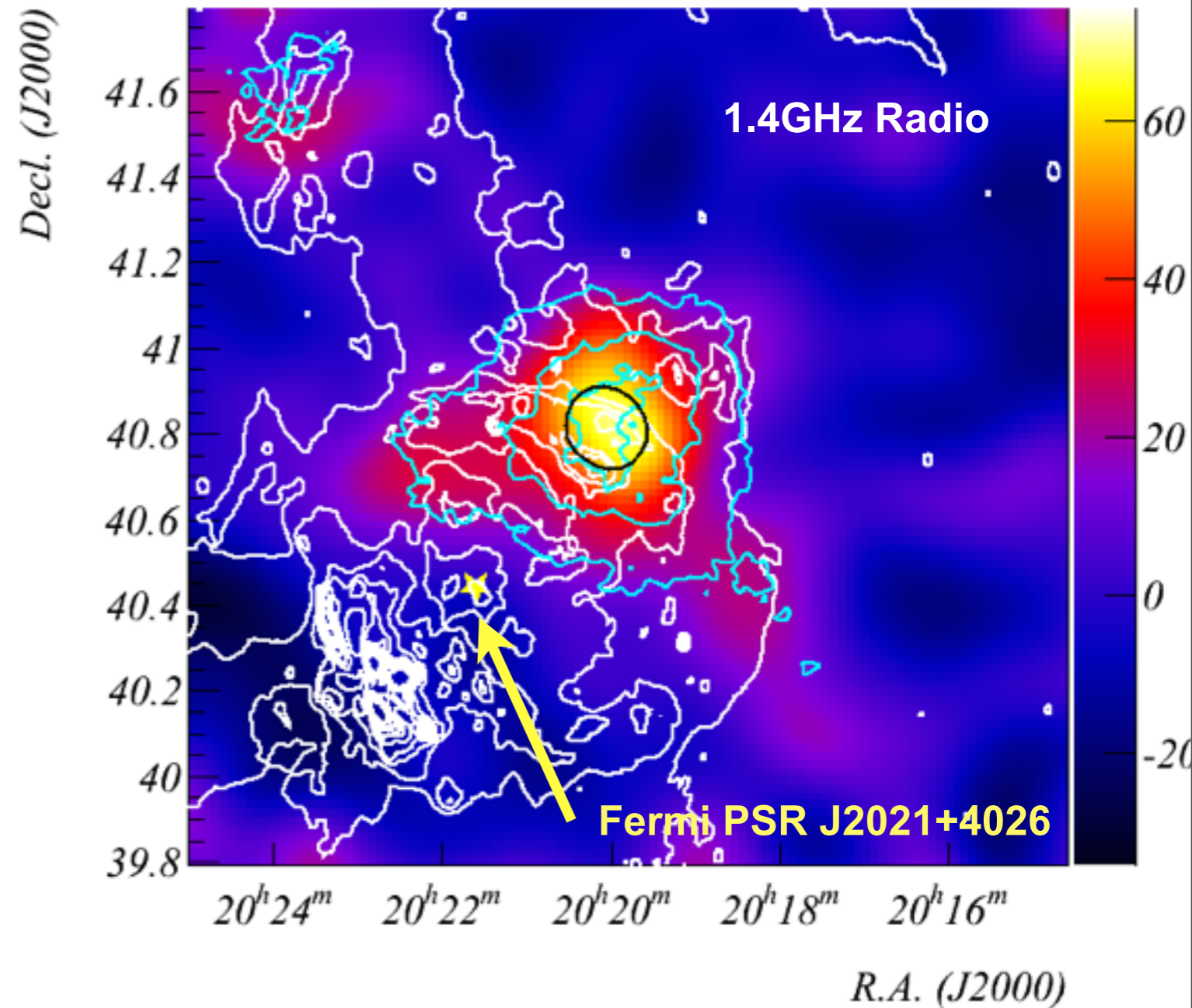
VER J2019+407 and Υ /Cygni

- SNR G78.2+2.1 (Υ /Cygni)
- 1° angular extension
- Distance of 1.7 kpc
- ~7000 years in age

- VERITAS Observations:
 - 18 hours since Nov 2009
 - 7.5 sigma detection post trials
 - Extended Emission $0.18^\circ + 0.03^\circ_{\text{stat}} + 0.02^\circ_{\text{sys}}$

- Coincident with 1FGL 2020.0+4049 (Black Circle)

- Possible over density of HI able to produce seen Υ -ray emission



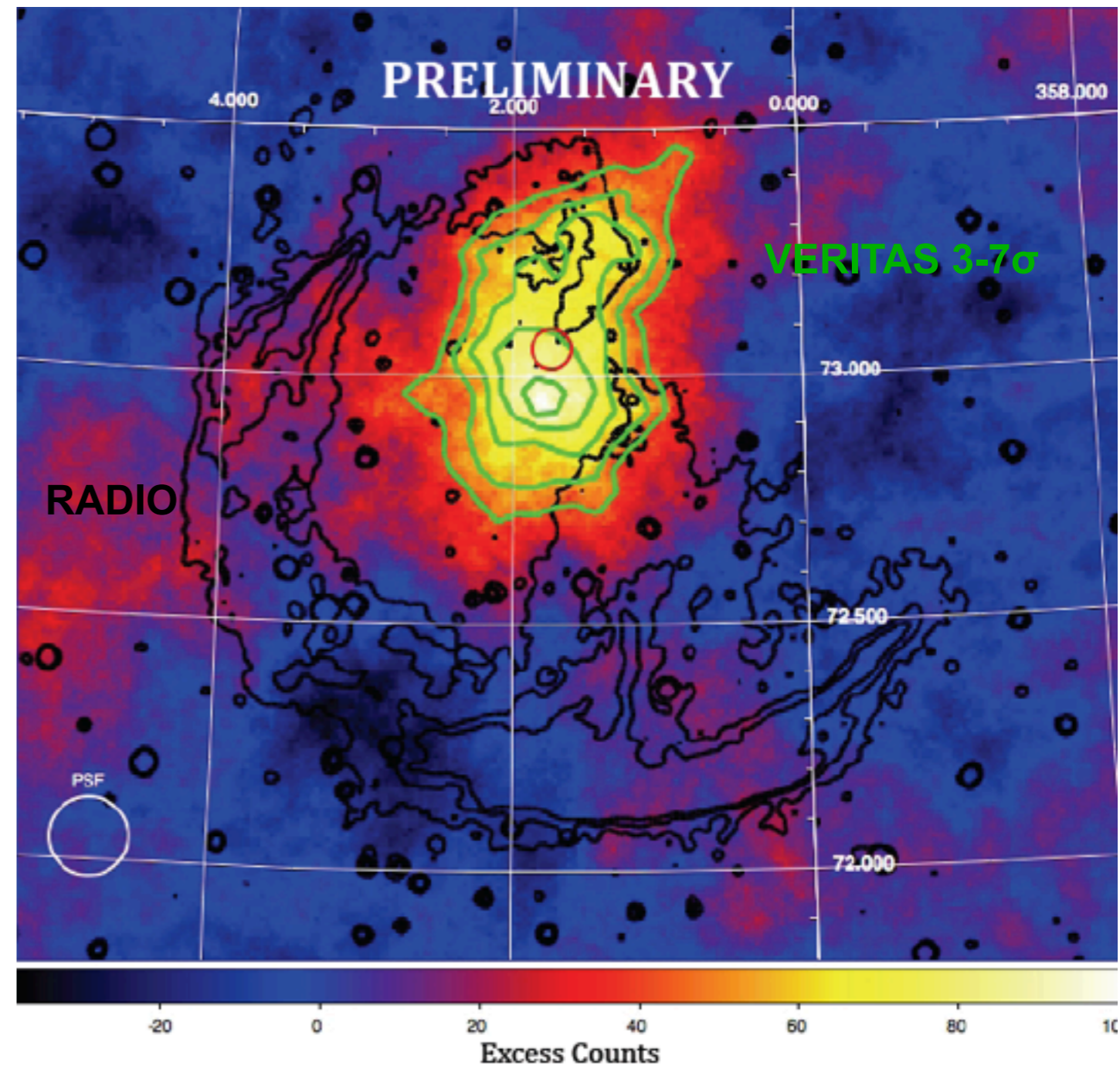
CTA 1

- Radio SNR with an X-ray PWN
- 1st Fermi Pulsar found using a blind search
- Now seen in X-ray
- Pulsar is 5' from TeV emission

- Age estimate 13 kyr
- At a distance of 1.4 kpc

- VERITAS has observed for > 25 hrs
- Resulting in a > 6 sigma detection
- Spectral Index of 2.2 with a flux of 4% Crab
- Extended asymmetric morphology

- Young Pulsar Wind Nebulae



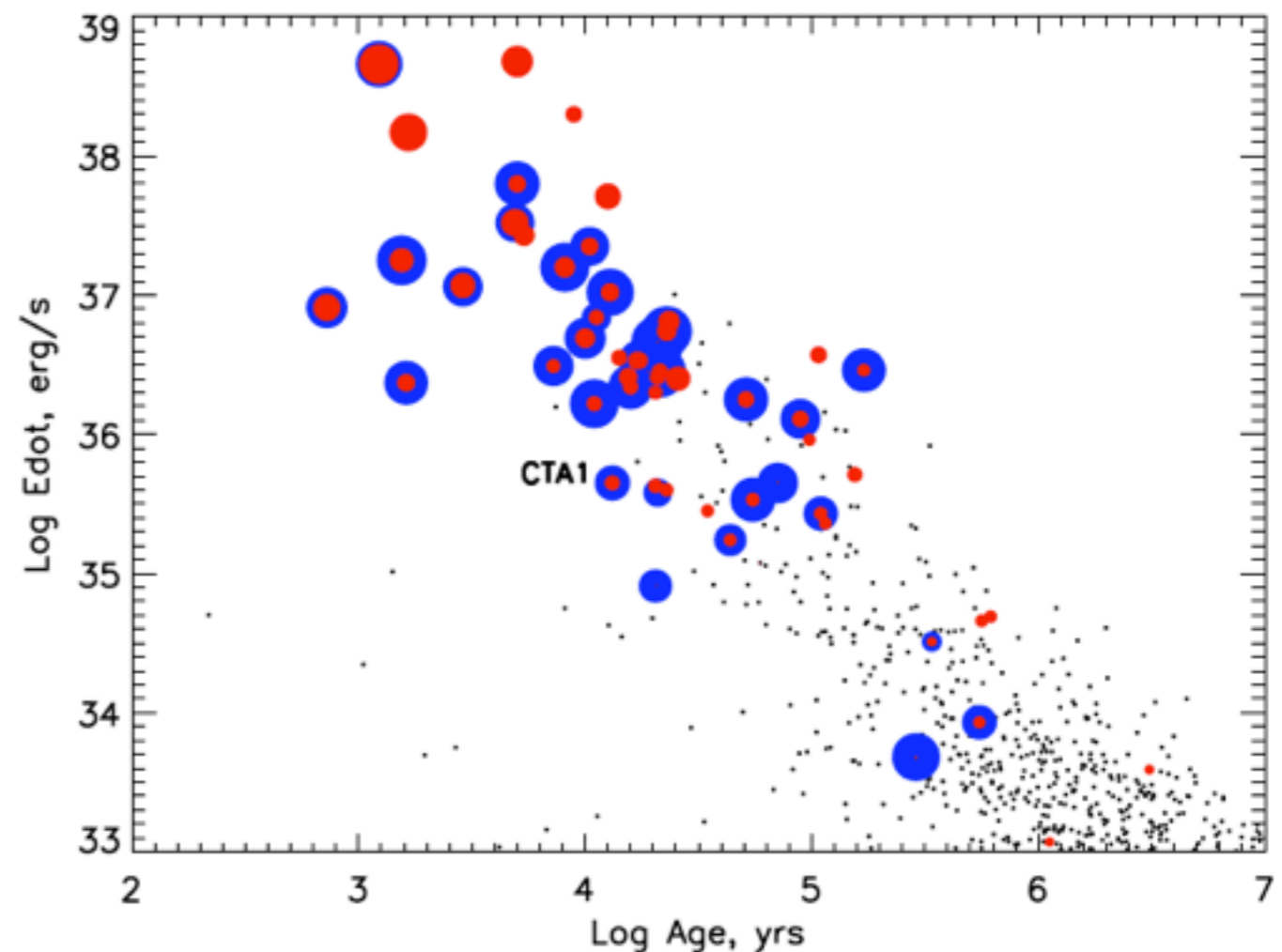
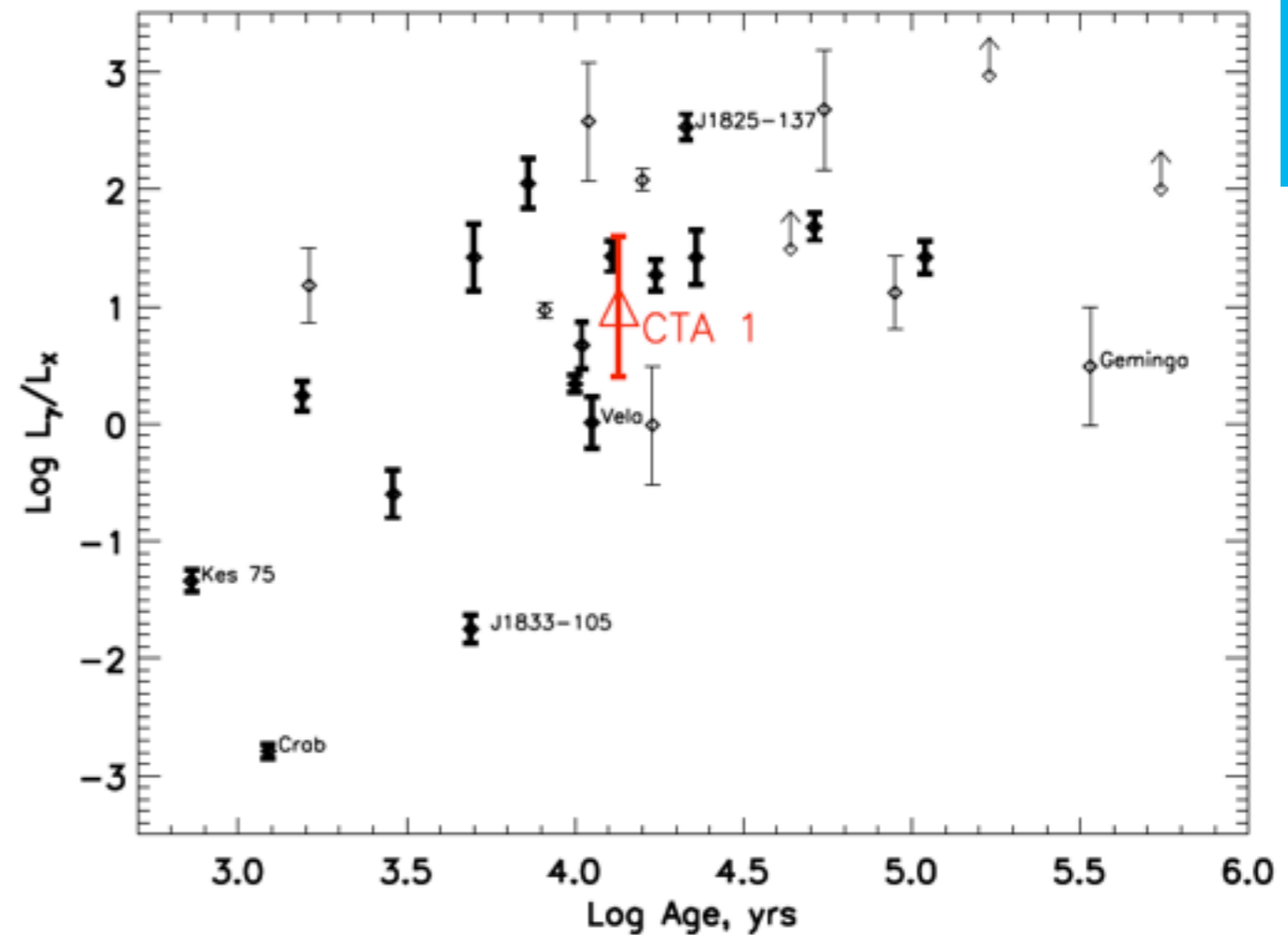
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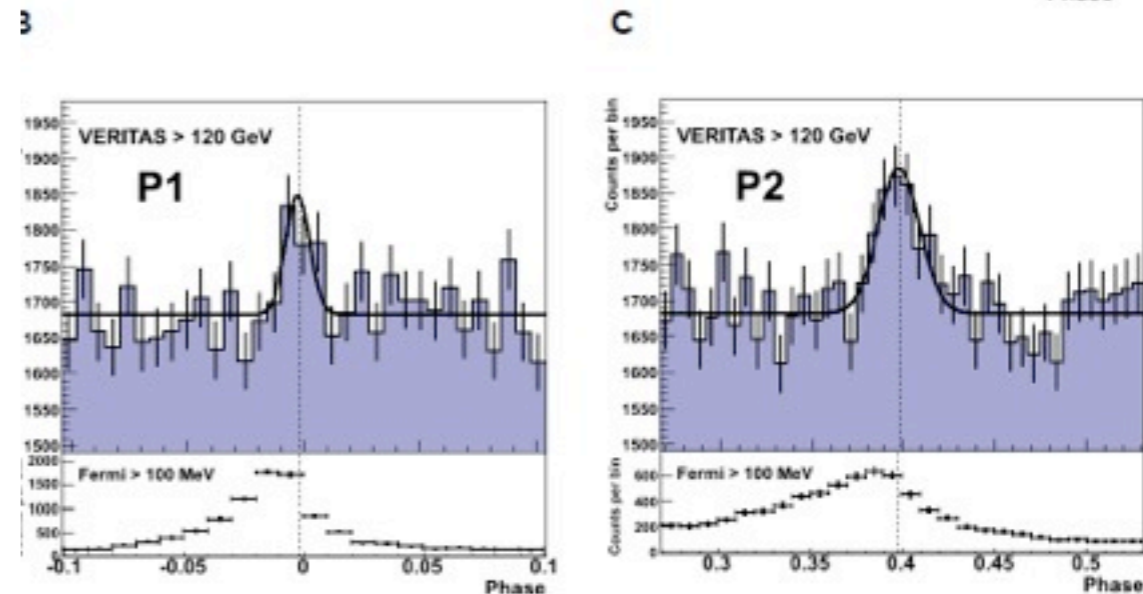
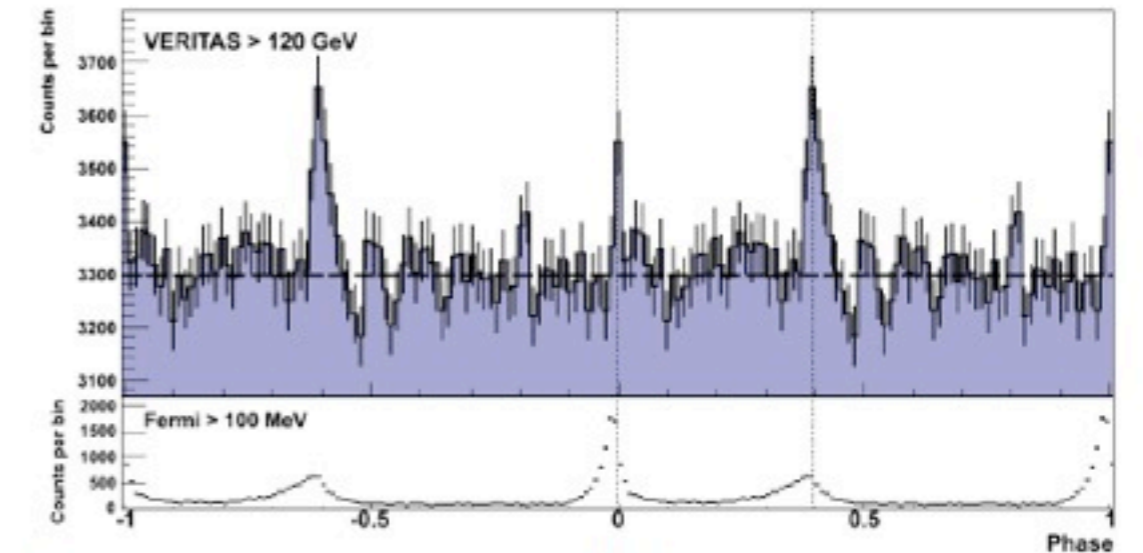
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Crab Pulsar

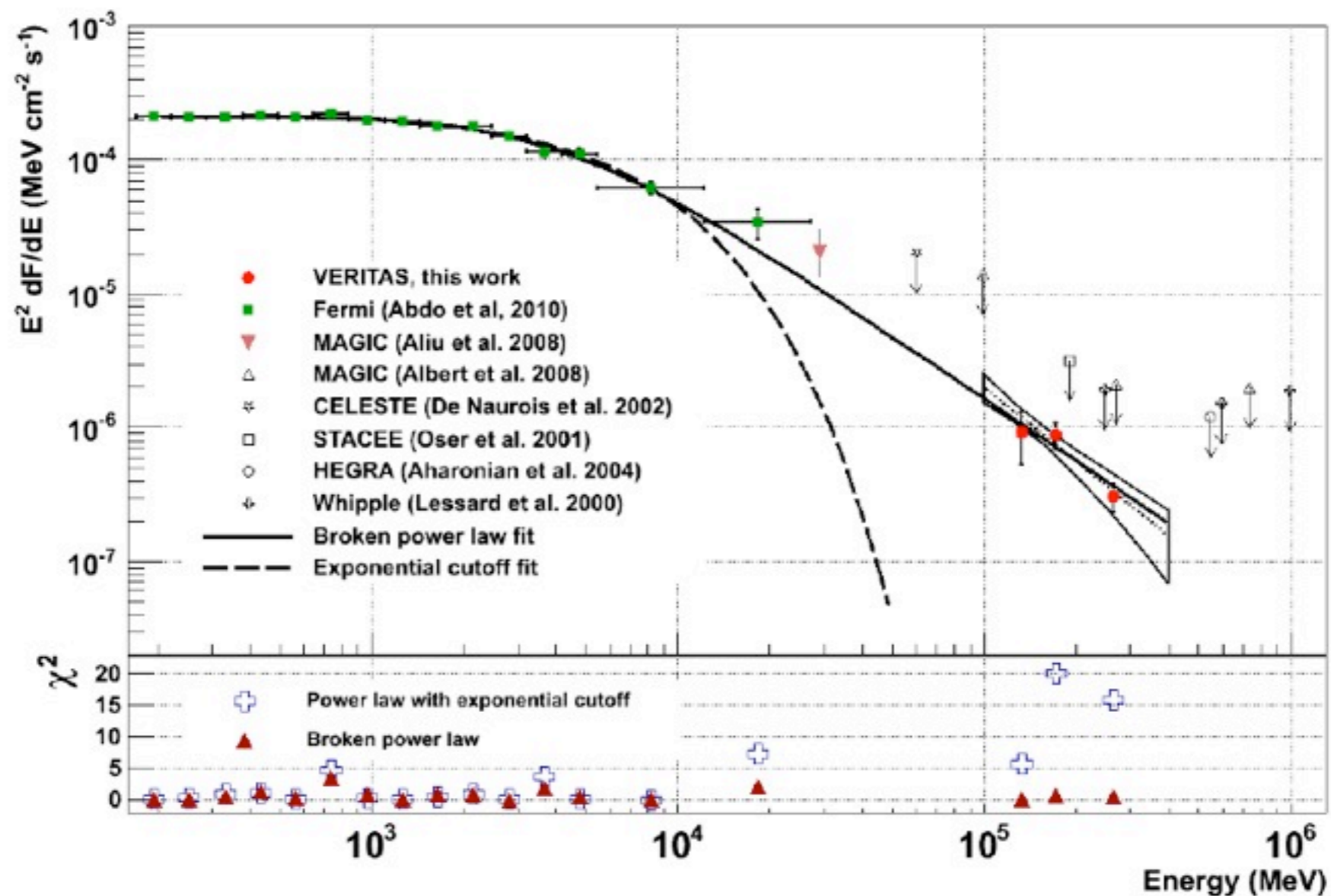
- Crab Nebulae Brightest Constant VHE emitter
- 6500 ly away
- Contains a Gamma-ray pulsar: ~33ms
- Seen by Fermi-LAT and in many other wavelengths
- Also a detection of Pulsed emission seen by MAGIC
- Theoretical Expectation: Exponential Cut off at <100GeV
- Using 107hrs of VERITAS data
- Find a 6σ result for pulsed emission
- Pulses are narrower than the lower energy Fermi-LAT results

- Region where acceleration occurs tapers towards neutron star

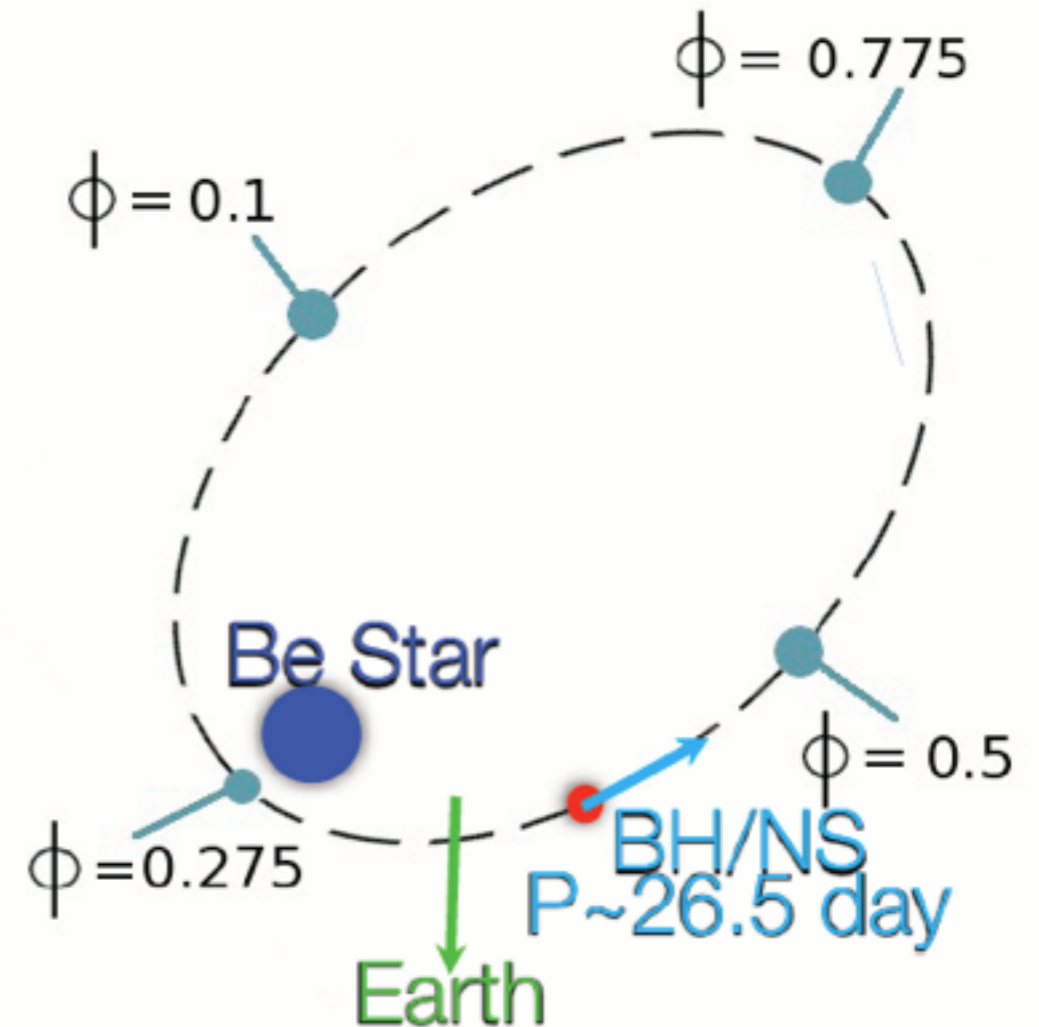


Crab Pulsar

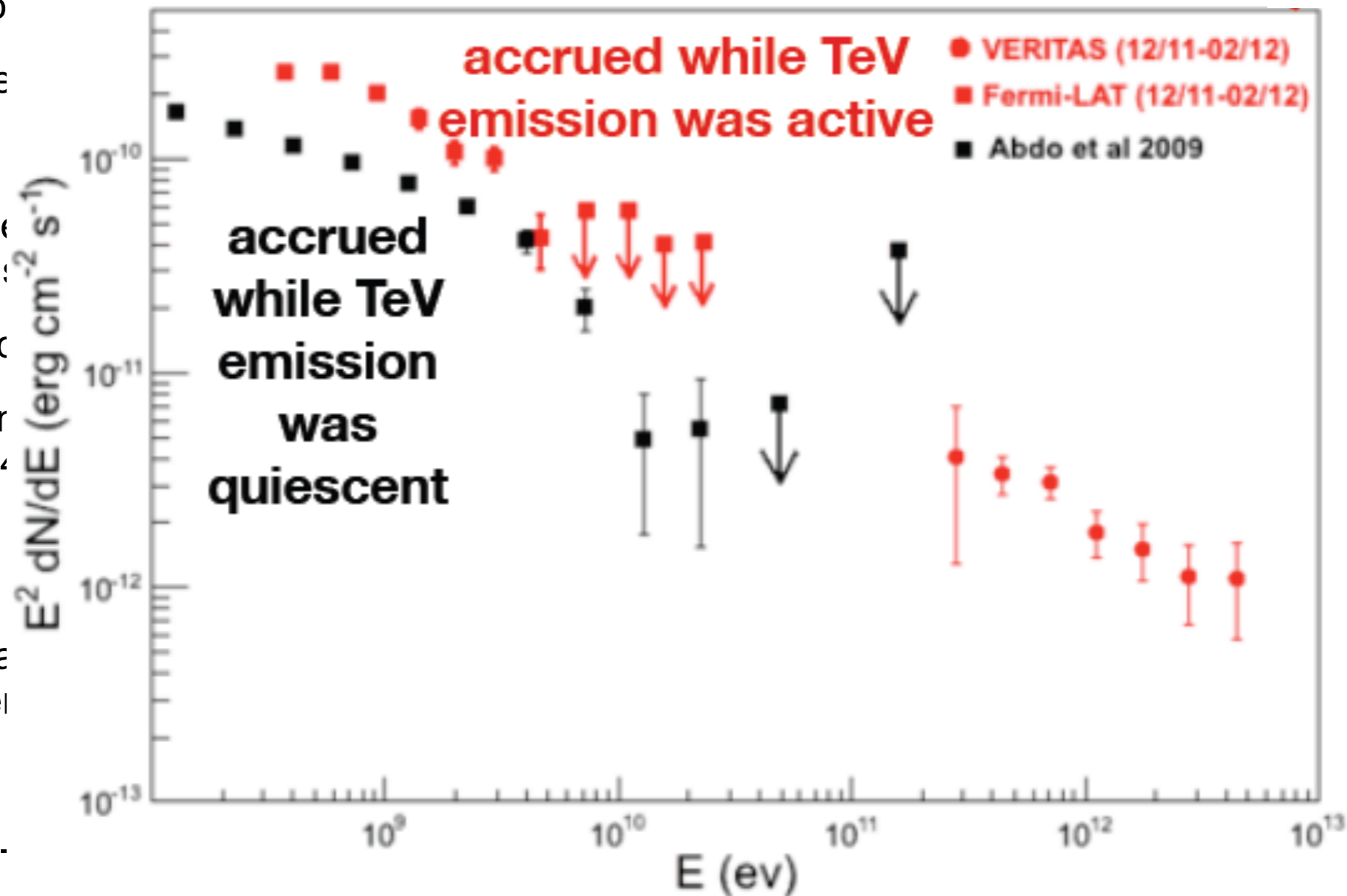
- Combined fit describes well a broken power law
- Suggests that the emission does not come from curvature radiation
- Inverse Compton could be more important at Higher Energies



- > High Mass X-ray Binary with Be companion
Black Hole or Neutron Star
- > Period of 26.5 days
- > Distance of 600ly
- > 2006 seen by MAGIC at **apastron**
Fermi also sees peak emission at apastron
- > Followed up in 2007/8 by VERITAS and MAGIC
- > Not seen again until 2010 but now at **periastron**
Index 2.4
10-15% Crab
- > Fermi has a consistent detection
However with a cut off at 6 GeV
- > Orbit-to-Orbit variation aside from normal cycle
- > Understanding the relationship between GeV and
TeV help understanding



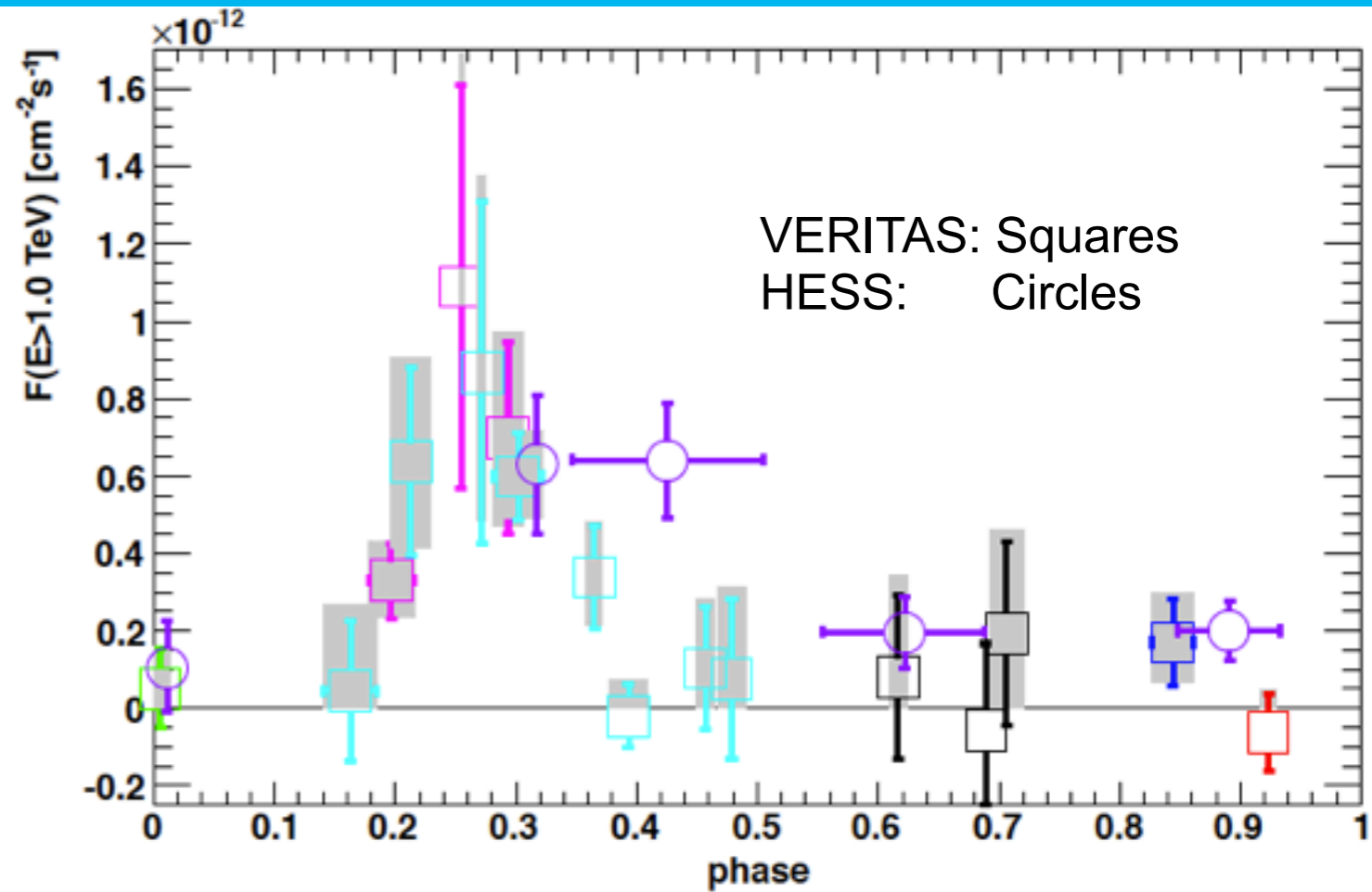
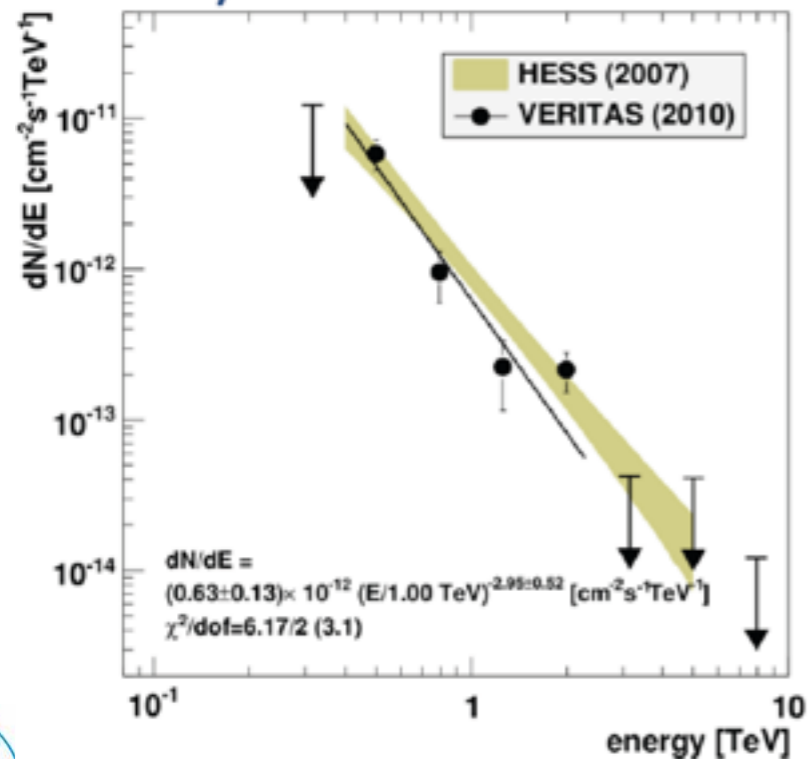
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HESS J0632+057

- > First seen by HESS in 2007/8
- > Variable point like TeV source (<2' RMS)
- > Swift X-ray shows 321 day period
- > VERITAS now has a $>12\sigma$ (above 300GeV)
- > 4% Crab Nebulae Flux

2009/2010 season

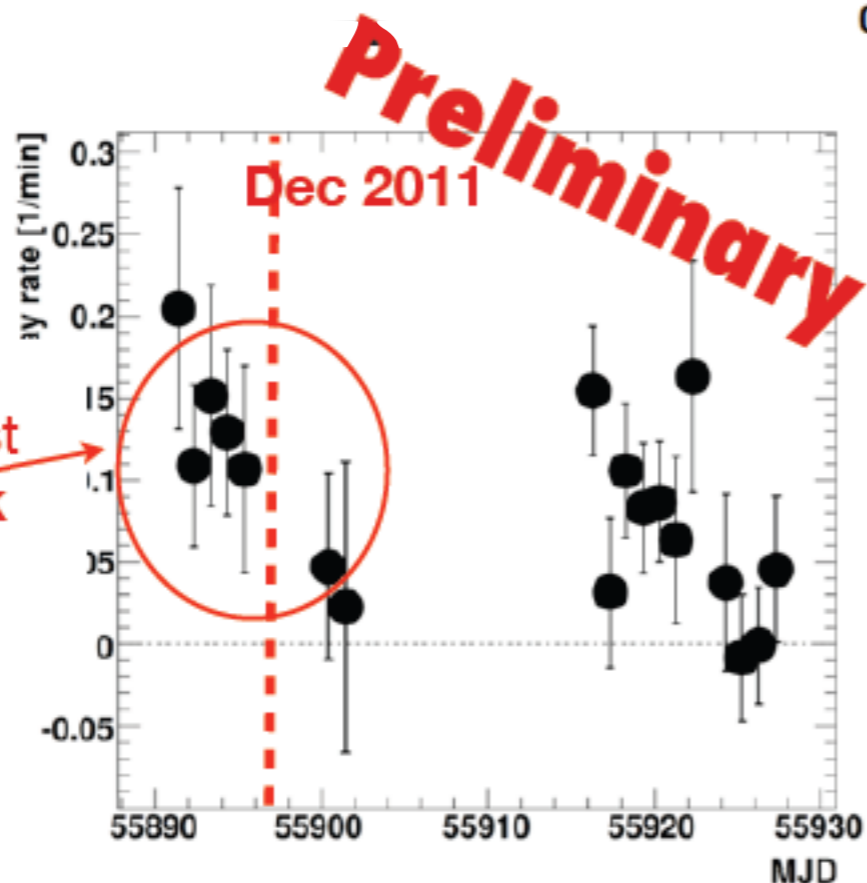
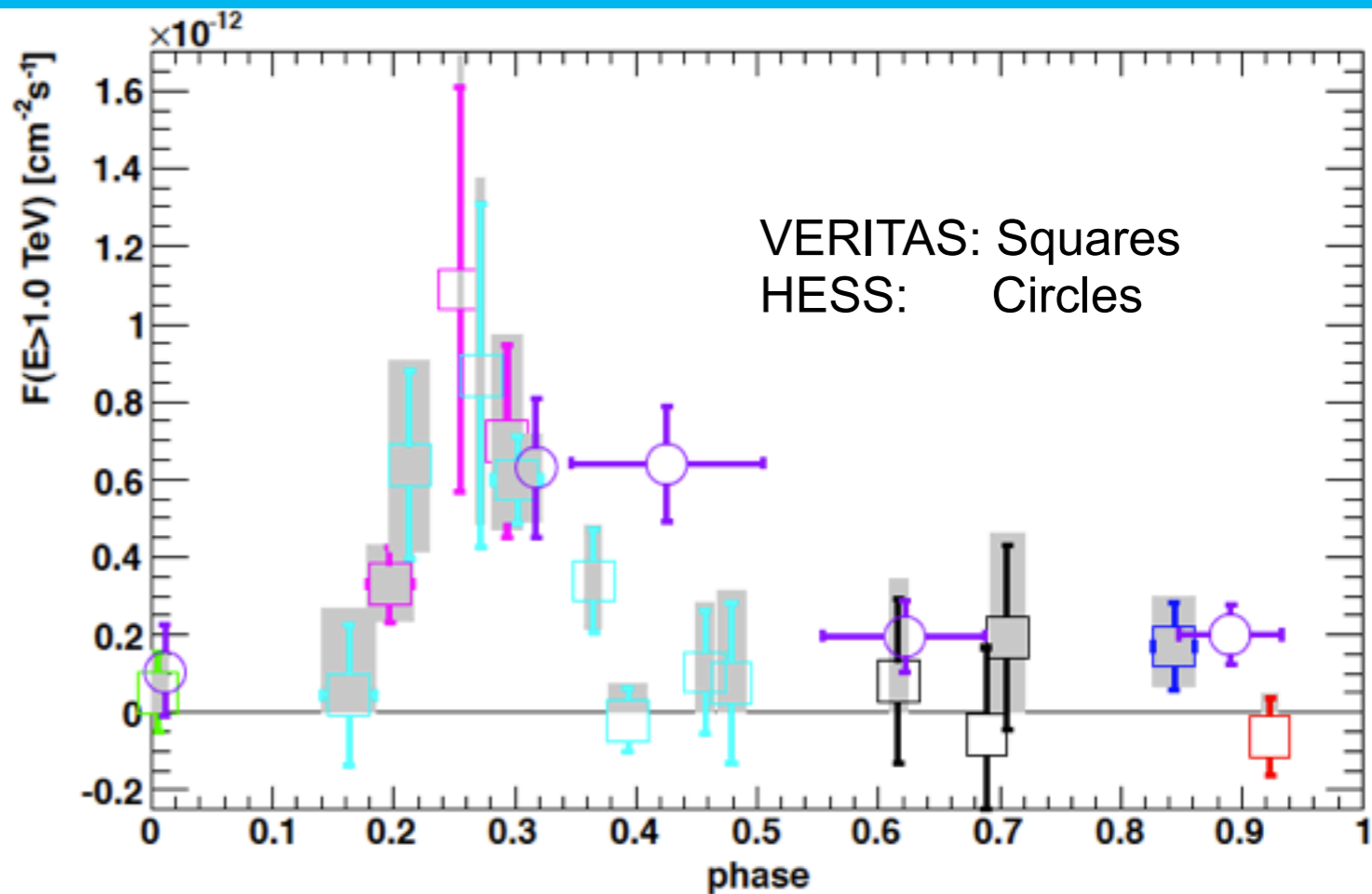


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- > Suggestions that the TeV flare are followed by the X-ray:
- > Monitoring has continued.



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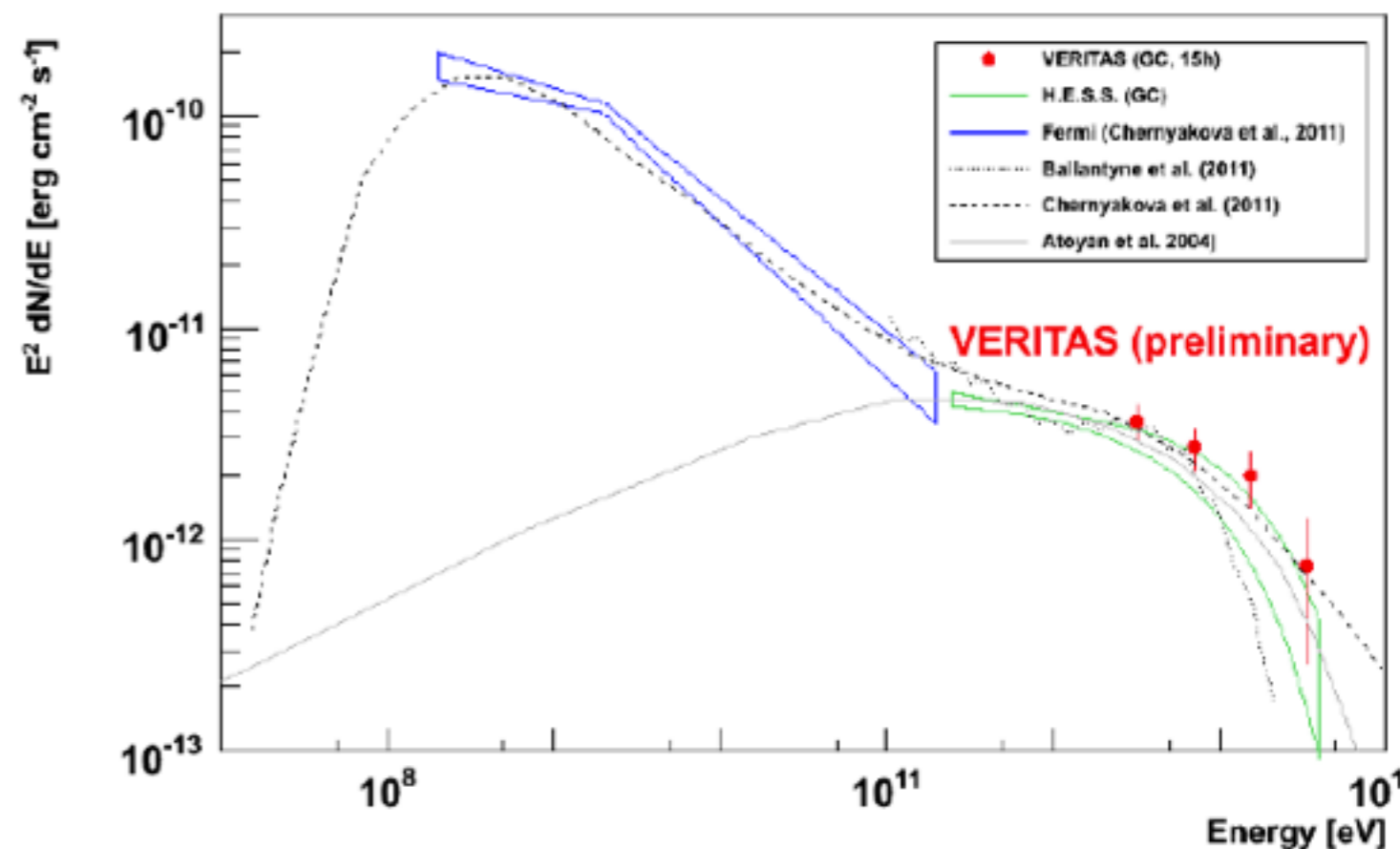
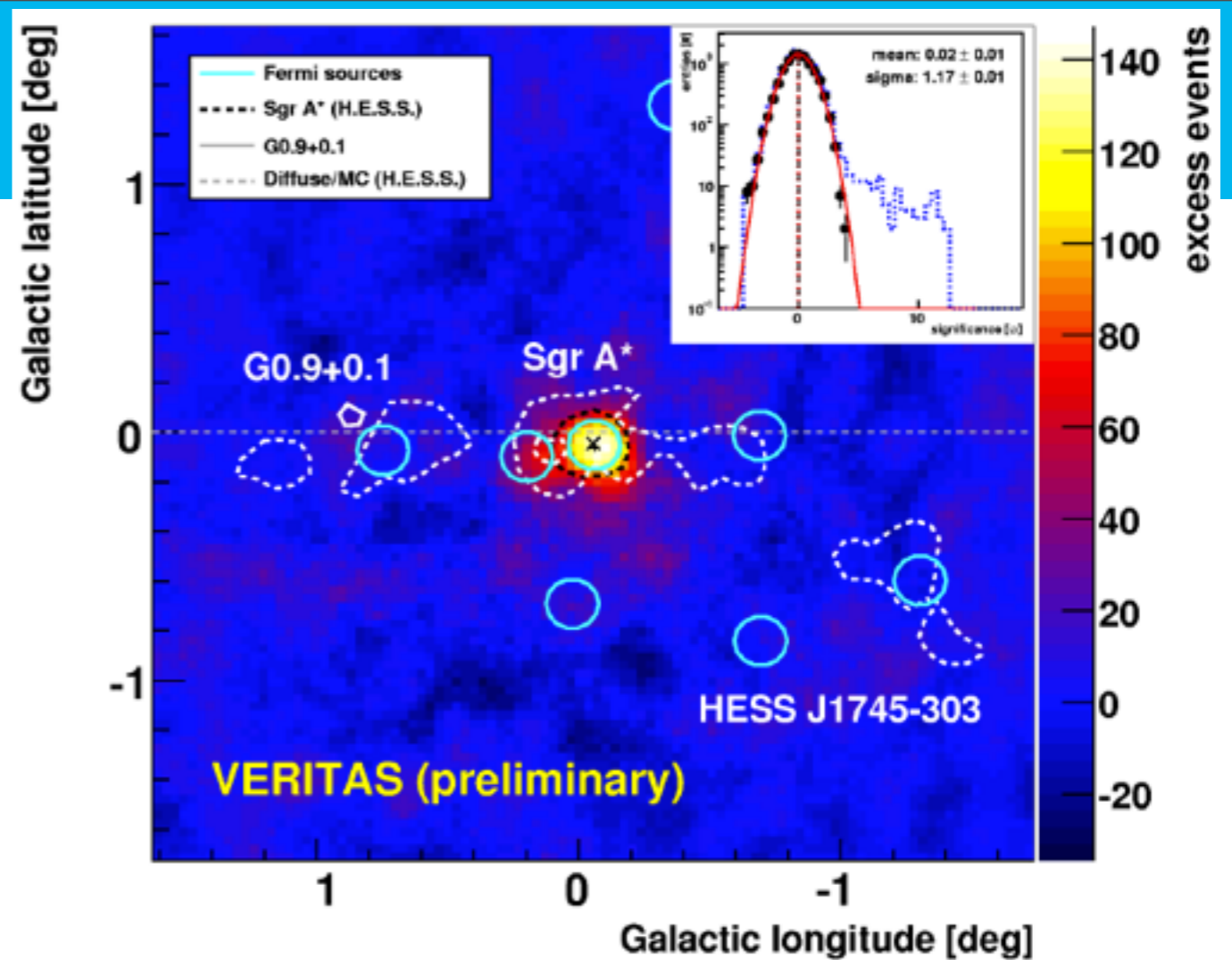


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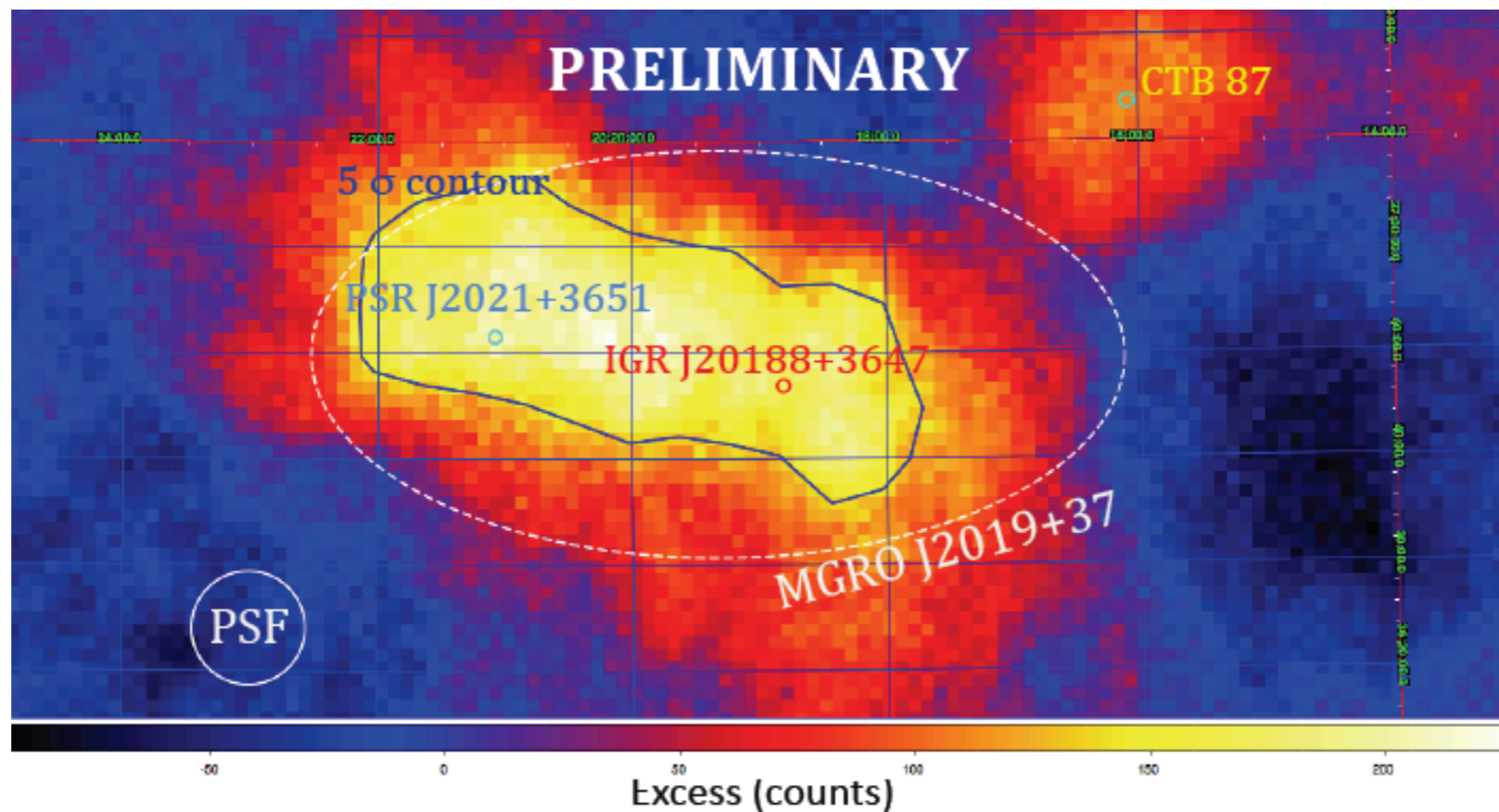


Galactic Center

- > Sgr A* Super Massive Black Hole
 - > 4×10^6 Solar Masses
 - > Many PWN, SNR and transients nearby
 - > Natural laboratory to study cosmic ray acceleration
 - > Also interesting for Dark Matter Studies
-
- > Observed by VERITAS at high Zenith angle
 - > Improved reconstruction technique used to make the measurement
 - First developed at Whipple Telescope
 - Tested using Crab data
 - > 15hrs of observations
 - > $\sim 60^\circ$ Zenith Angle
 - > 2 TeV threshold energy
 - > 12σ excess



Cygnus OB1 and CTB 87



> Cygnus OB1

- > Extended Source Detected up to 0.23°
- > For energies above 650 GeV
- > Analysis shows 7.3σ post trials
- > Consistent with MGRO J2019+37
- > Is there structure or more than one source?

> CTB 87

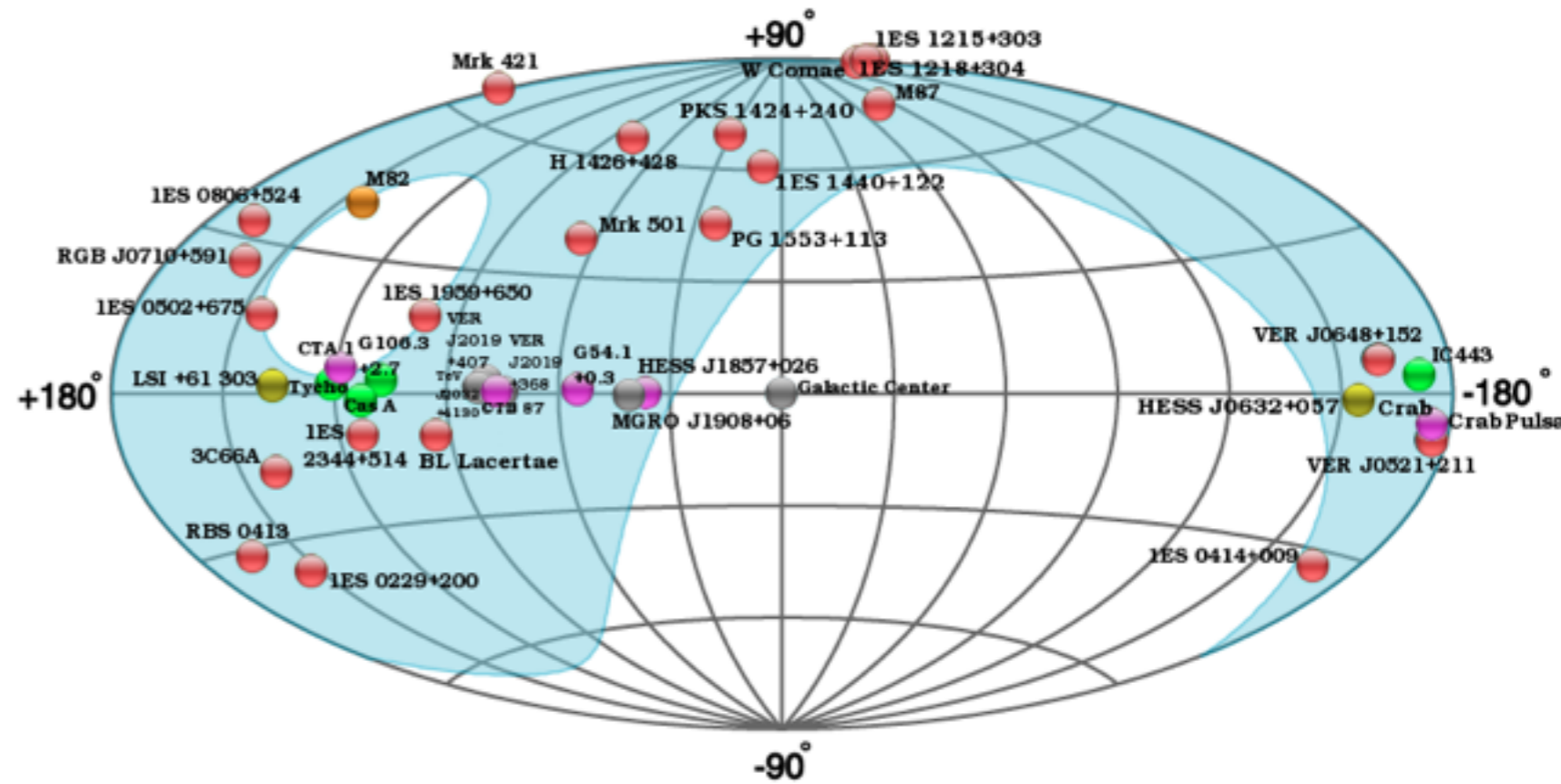
- > Point like source near CTB 87
- > 6.1σ Post Trials
- > Above 1 TeV 0.8% Crab Flux
- > Not Consistent with nearby Blazar B2013+370
- > Due to Variability

Summary

> VERITAS has an active and exciting Galactic Program

> Many new interesting results

- CTA 1 - **PWN**
- Crab Pulsar - **Not Curvature Radiation?**
- LSI +61 303 - **>10 σ 2011**
- HESS J0632 - **Binary**
- VER J2019+407 Y/Cygni
- Tycho SNR - **Protons**
- Cygnus OB1 CTB 87



> Upgrade coming this summer

- Increased Effective Area and Sensitivity

> VERITAS TAC deadline end of the summer!

