



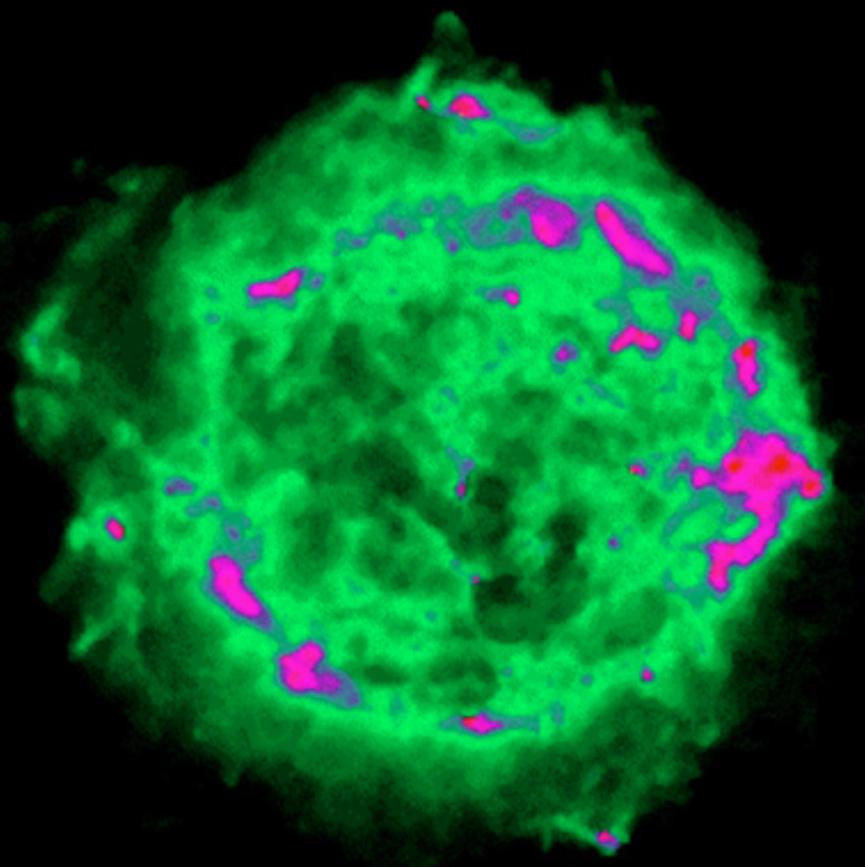
# A detailed study of Gamma-ray emission from Cassiopeia A using VERITAS



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For The VERITAS Collaboration



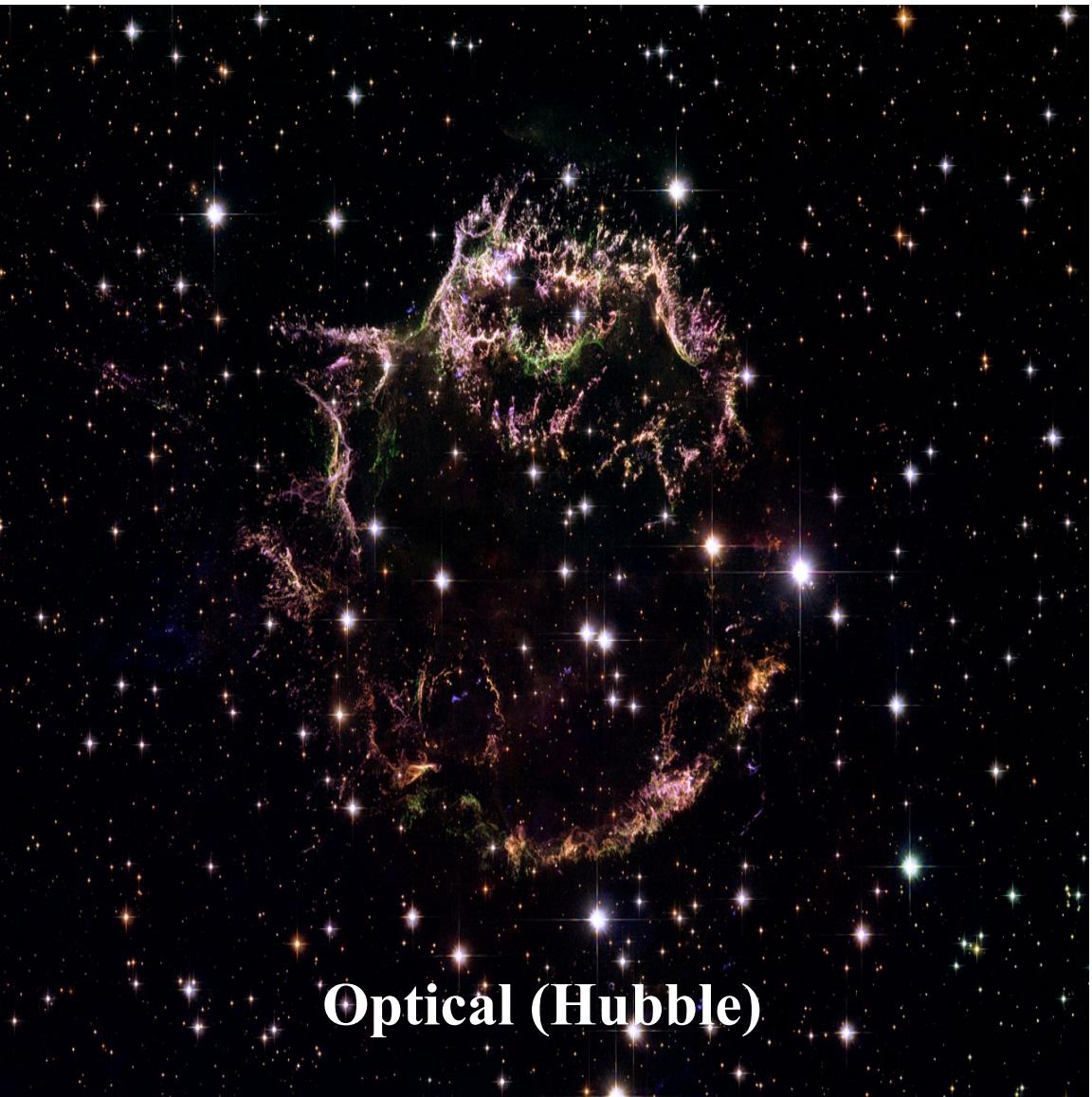
# Brief Introduction



Radio (VLA)

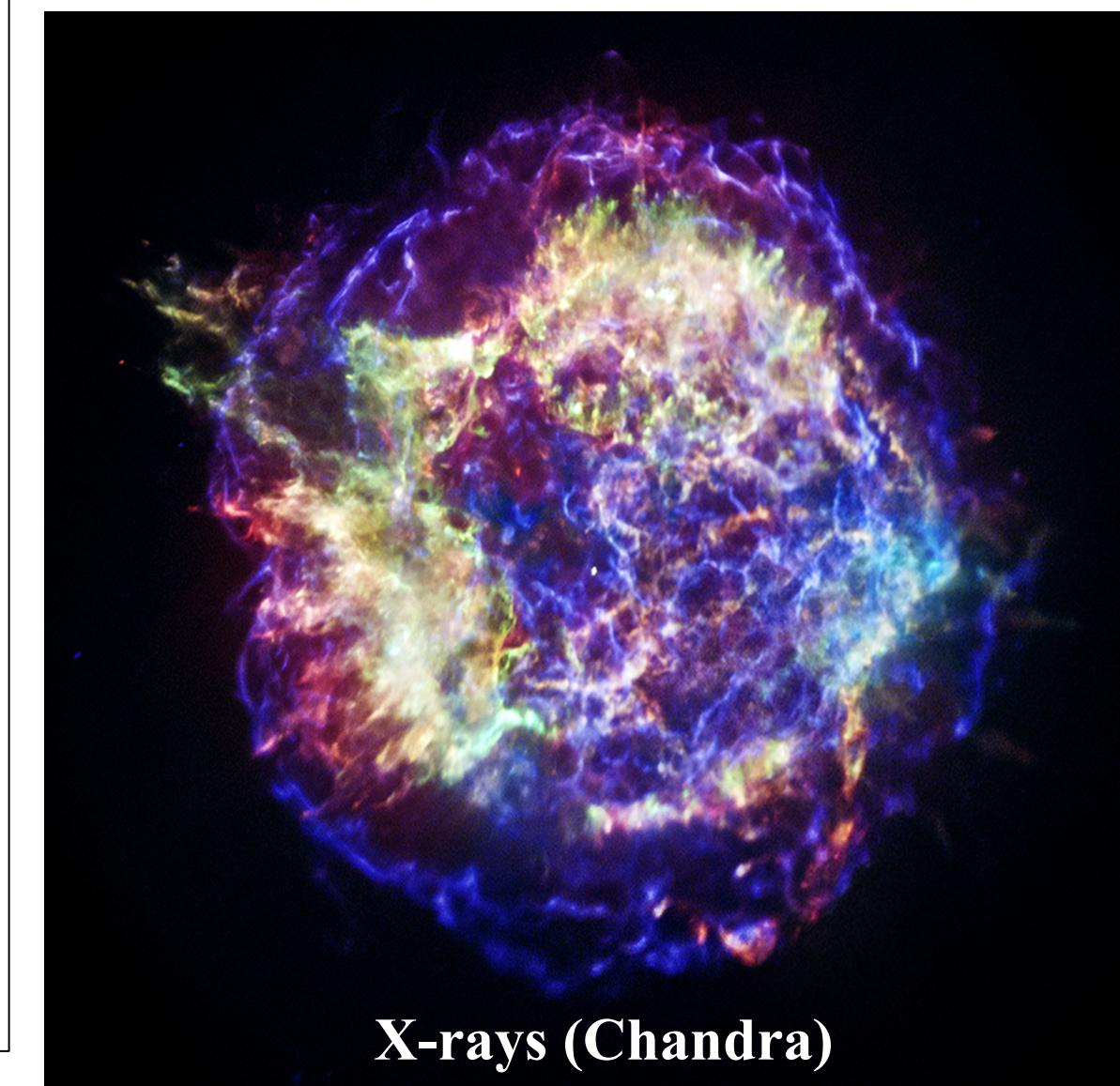


IR (Spitzer)



Optical (Hubble)

- **Young supernova remnant (~350 Years)**
- **Distance ~ 3.5Kpc**
- **Angular size ~2.5'**
- **Best studied in all wavelengths**
- **Particle acceleration at both forward and reverse shock**
- **Observed as point-like source in gamma rays**

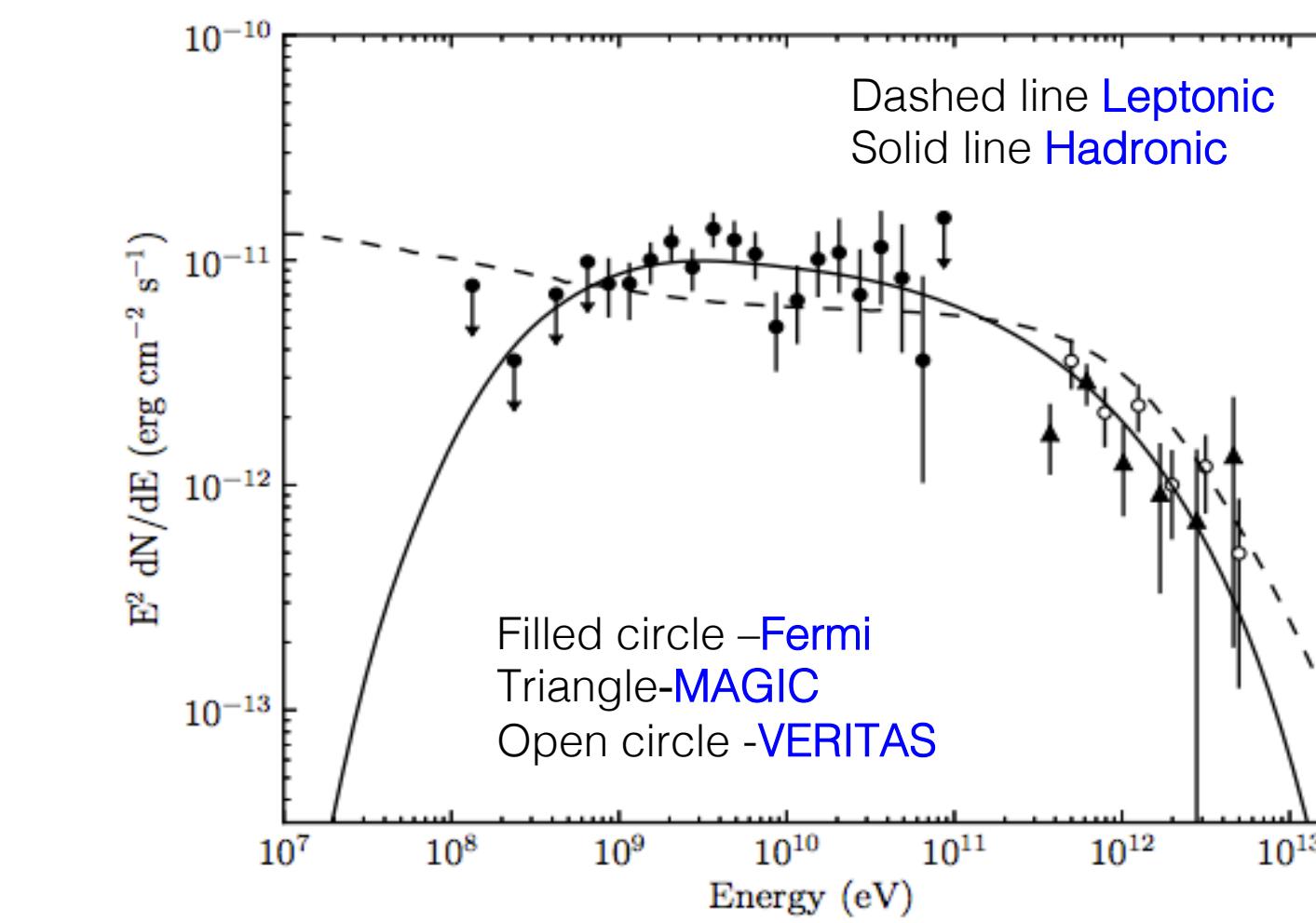
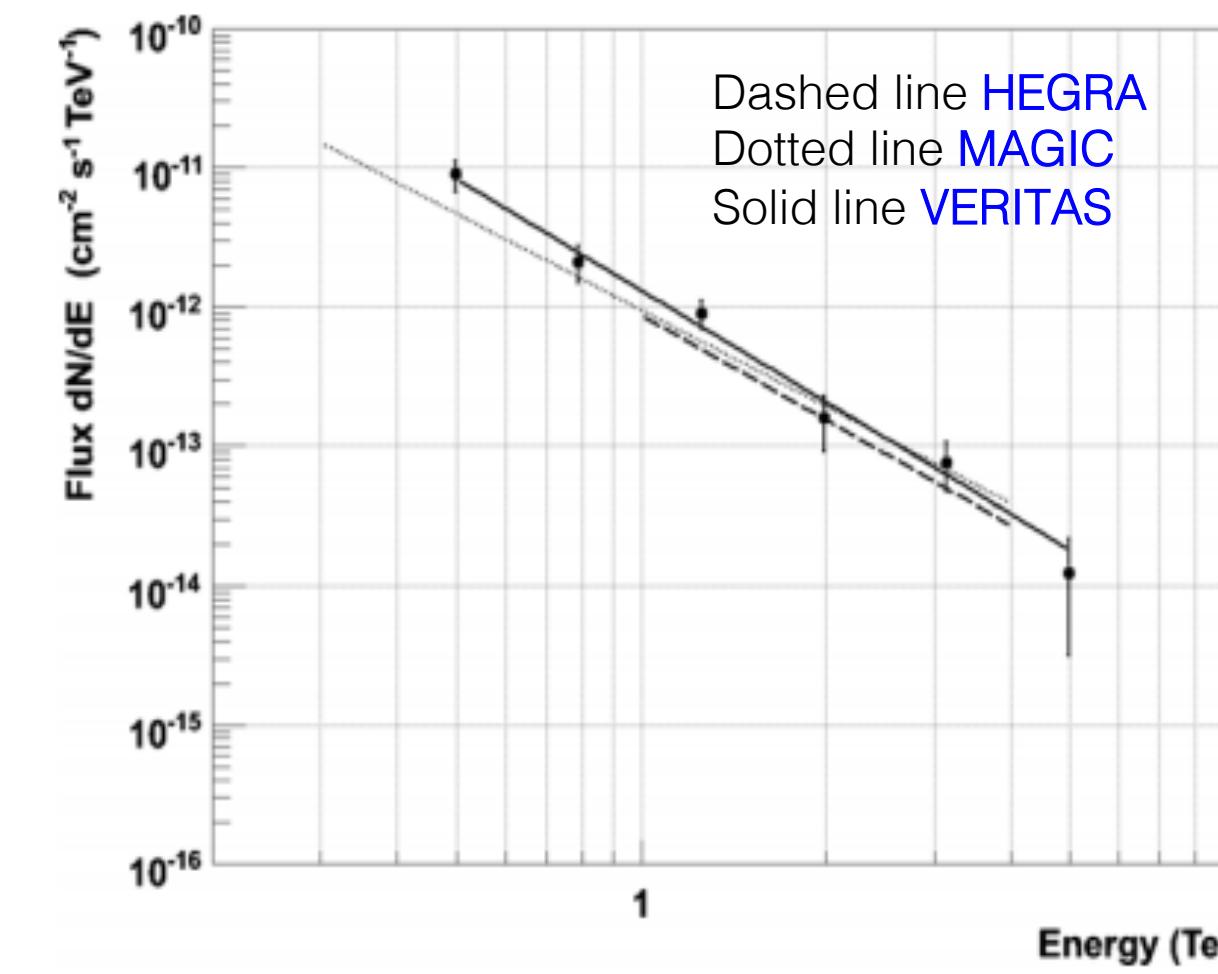
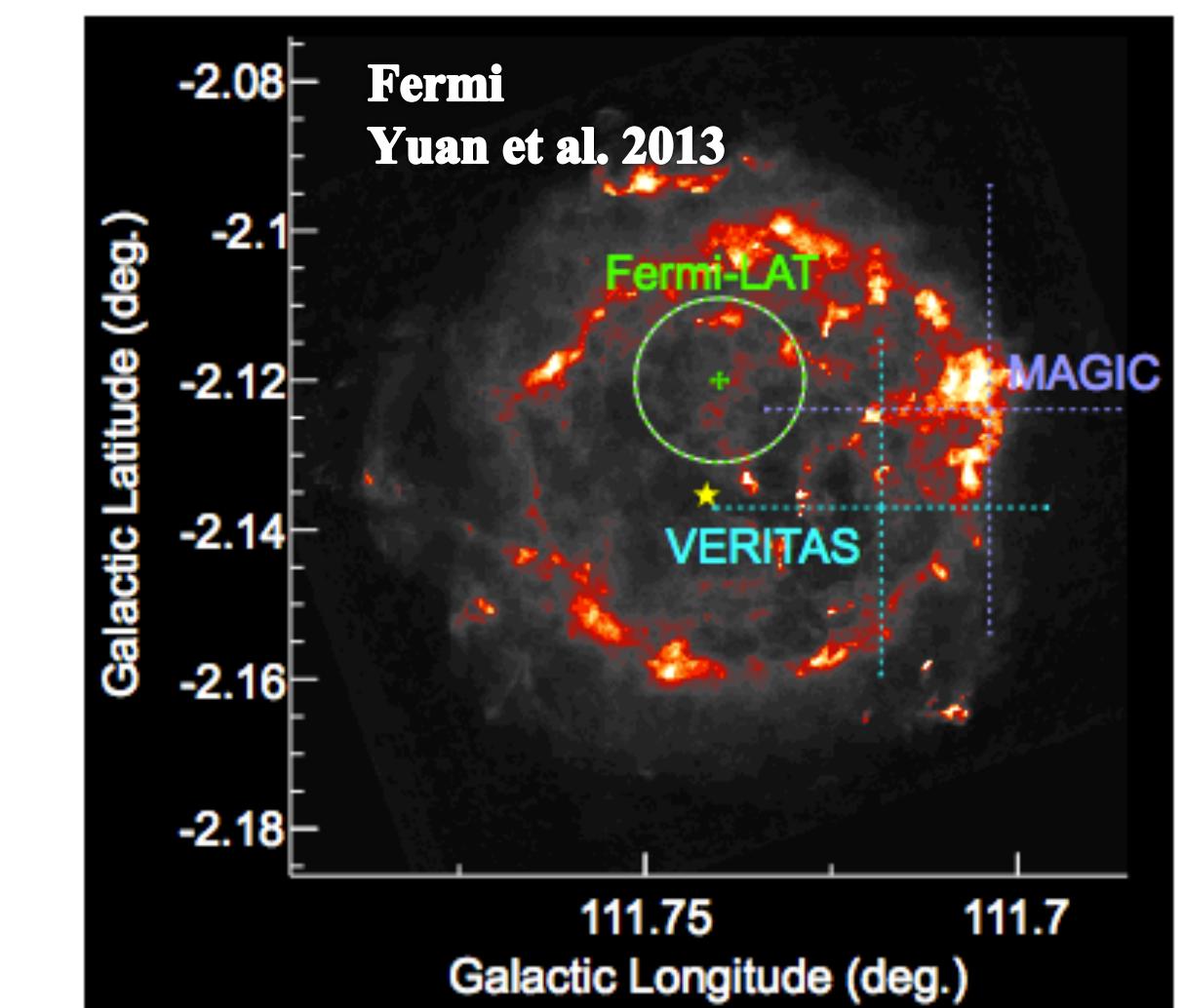
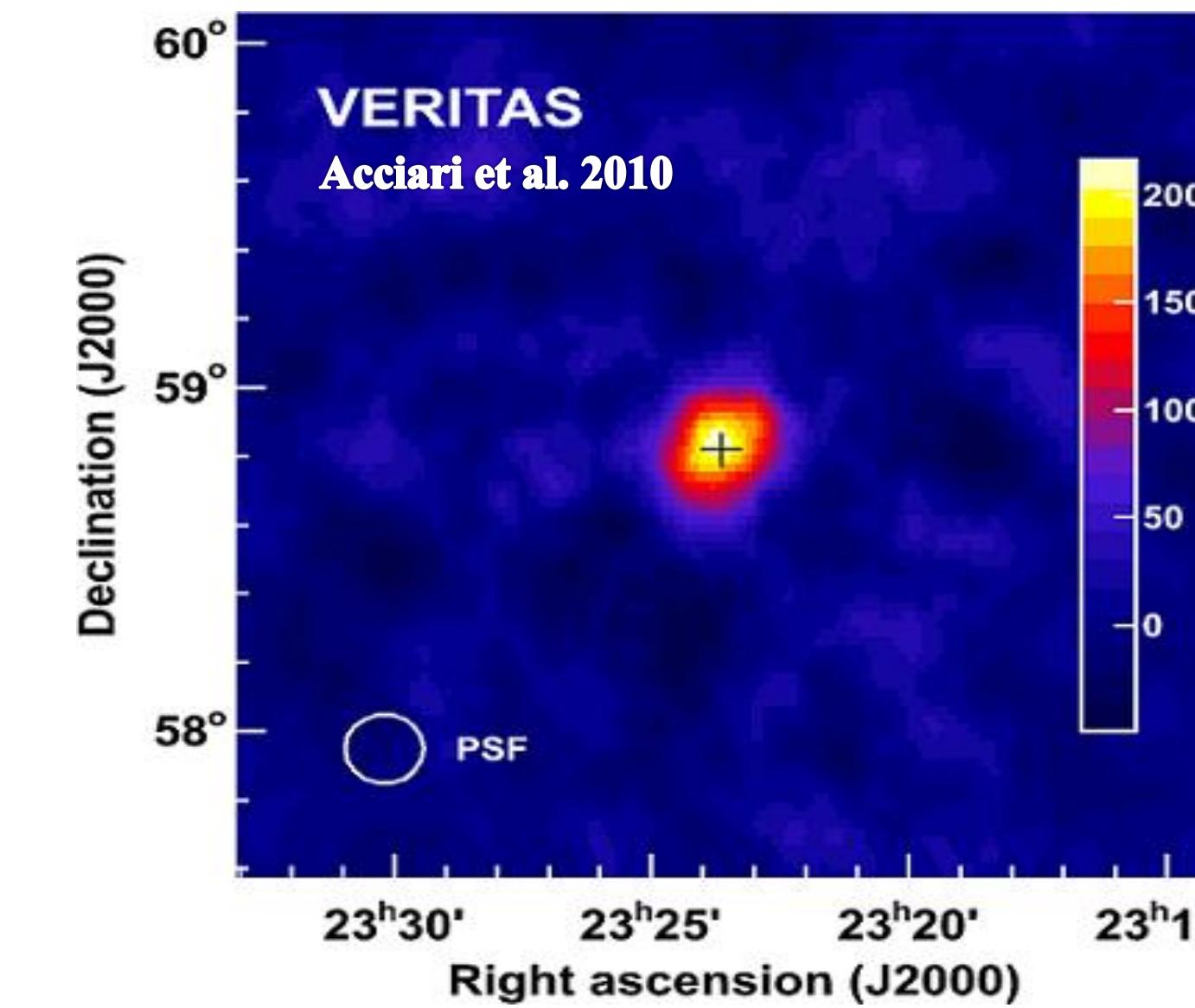
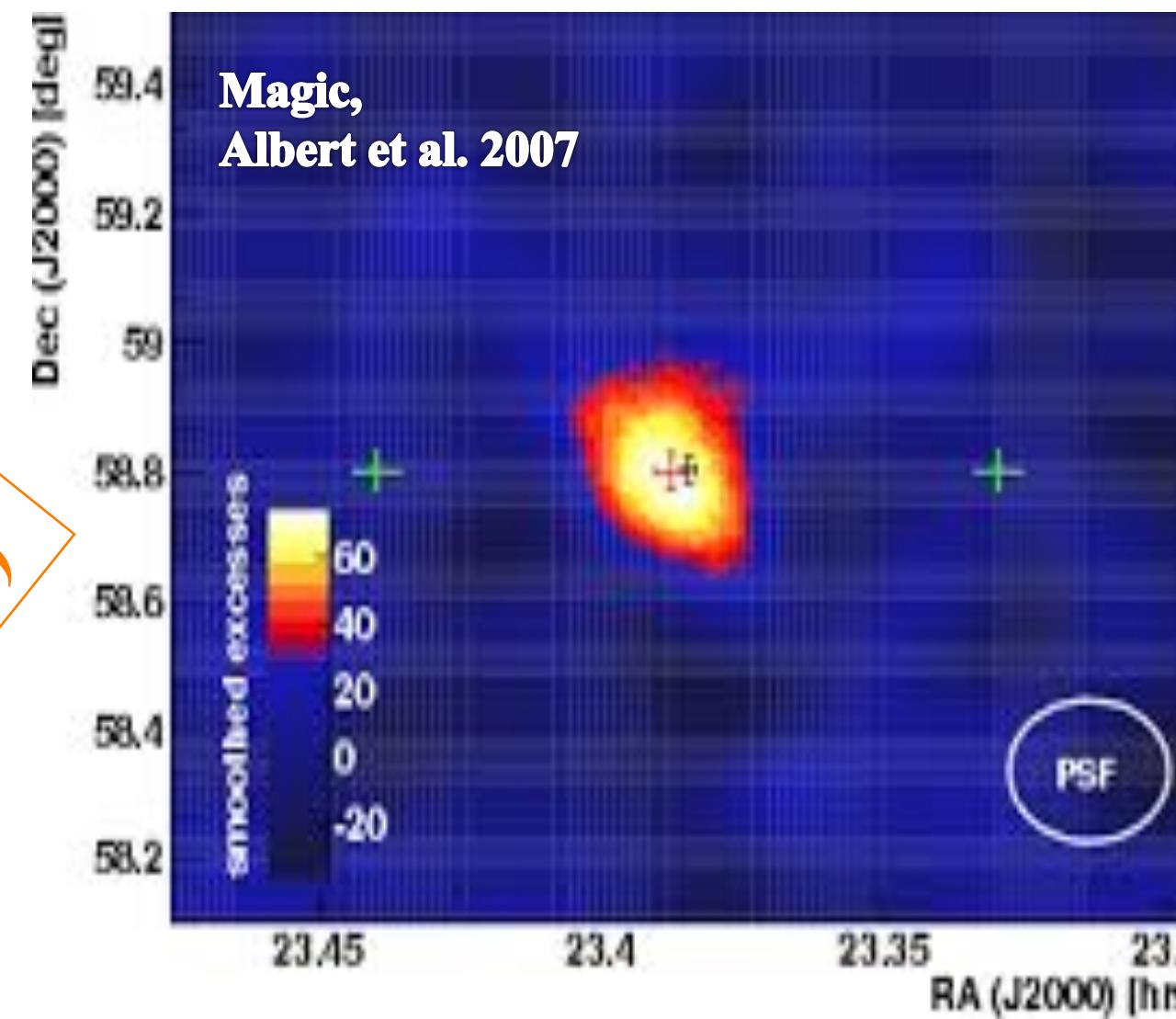


X-rays (Chandra)



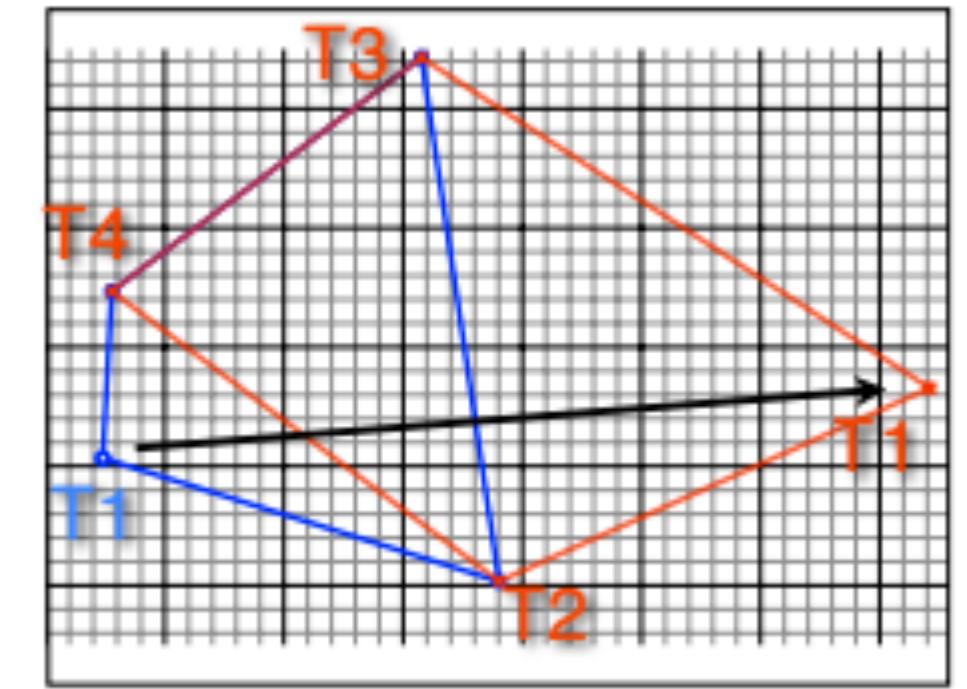
# Previous results in HE/VHE Gamma-rays

First detected by HEGRA  
(Aharonian et al. 2001)



# Total amount of data (~64 hours)

Epoch	Time (hours)
Before T1 relocation (Sep-2007 to Nov-2007)	18
After T1 relocation (Dec-2011)	2
After Camera upgrade (Small Zenith Angle, Large Zenith Angle) (Sep-2012 to Dec-2013)	43 (19,25)



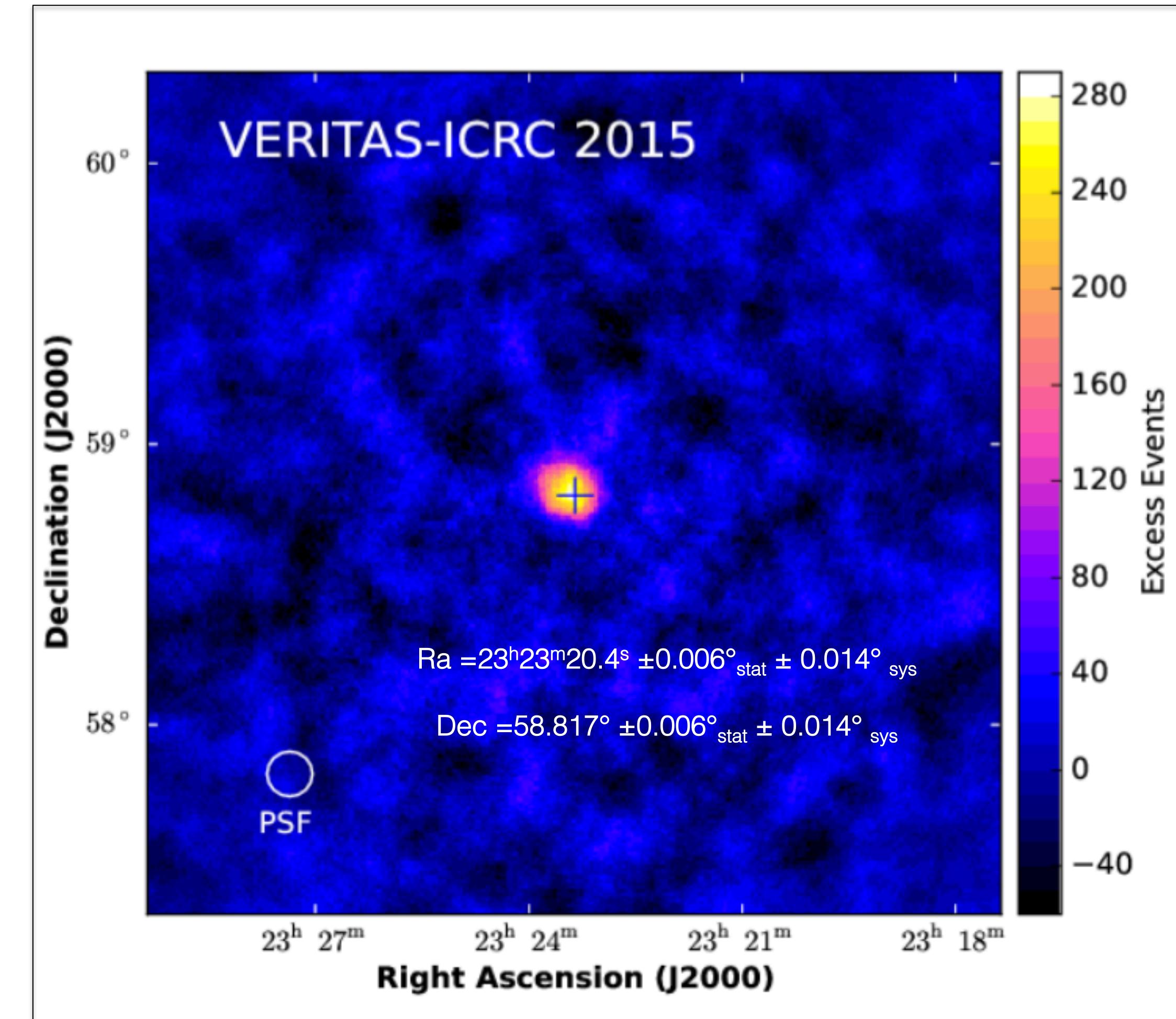
Before T1 relocation  
After T1 relocation  
After camera upgrade

**Significance = 13  $\sigma$**



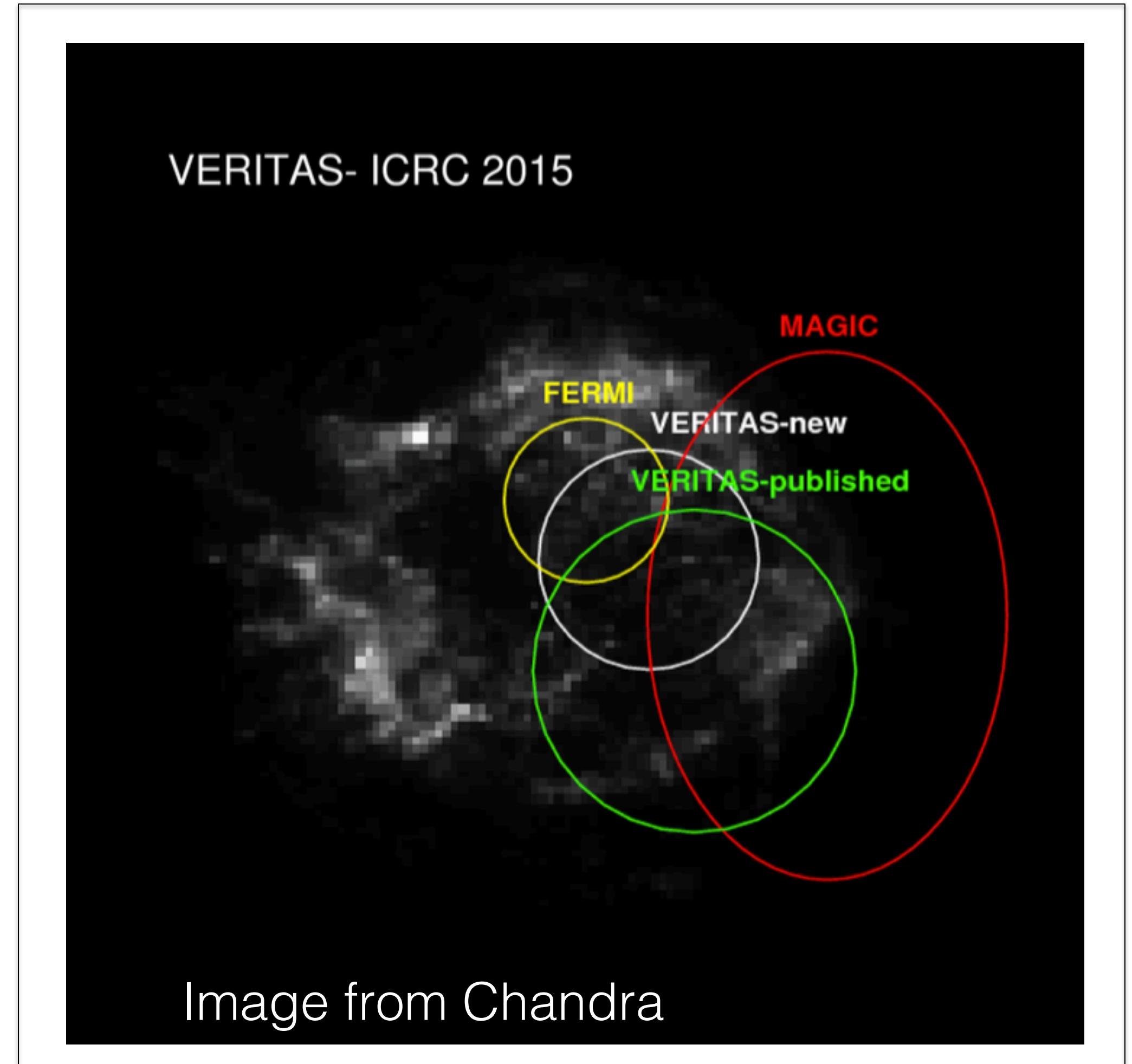
# Gamma-ray Excess map

- Skymap of only 2012-13 data (SZA, Significance =  $11\sigma$ )
- Emission is consistent with point source and work going on calculating the upper limit on the extension of source
- Cross shows the position of gamma-ray emission determined by fitting 2D-Gaussian function on the uncorrelated excess map
- Position is **limited by the systematic error** in the pointing of telescopes



# Centroid position comparison

- The position measured in high energy (by Fermi) and very high energy (By VERITAS, MAGIC) are consistent within errors
- (Taking both statistical and systematic error in account)



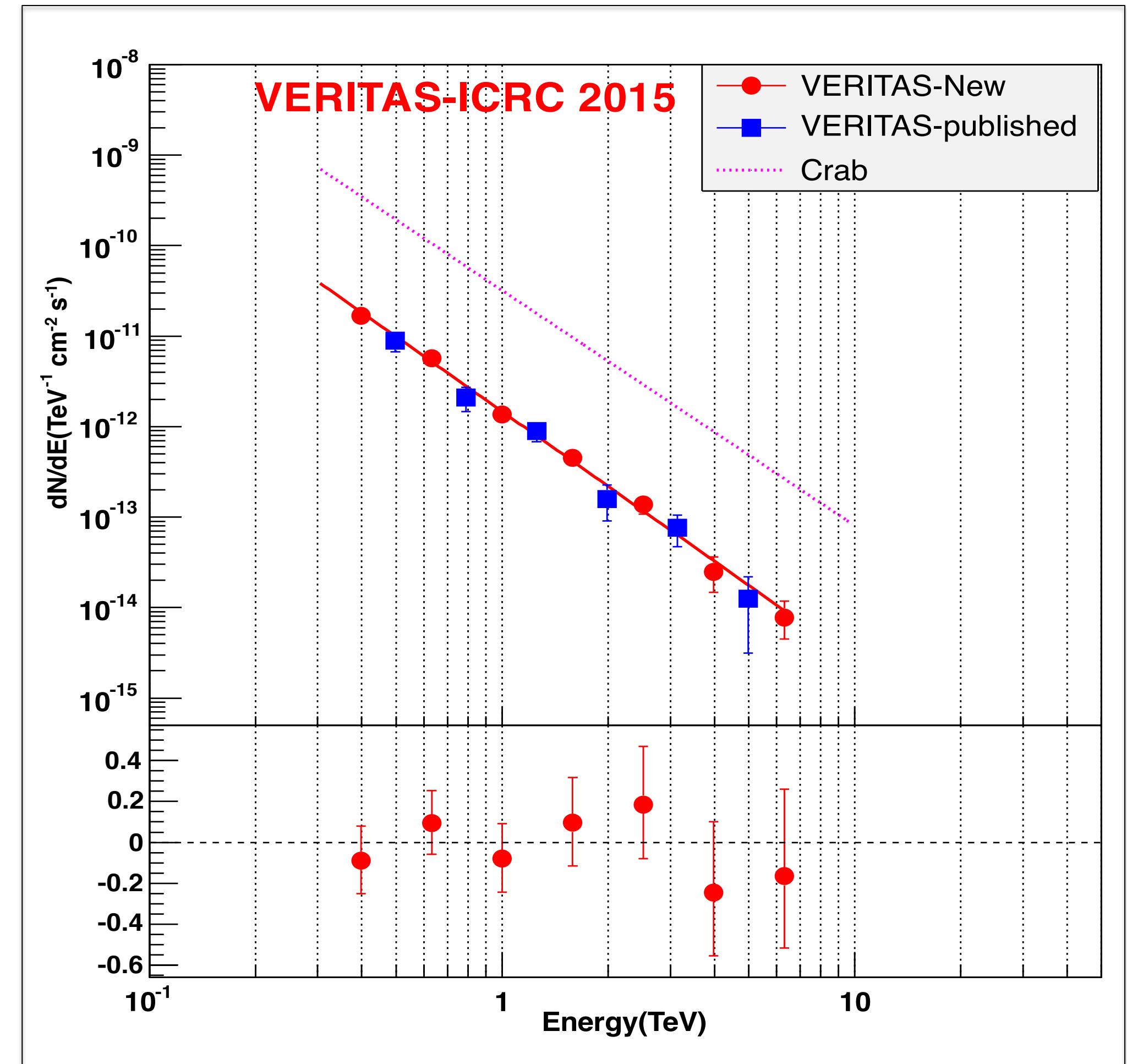
(after Grefenstette et al. 2015)



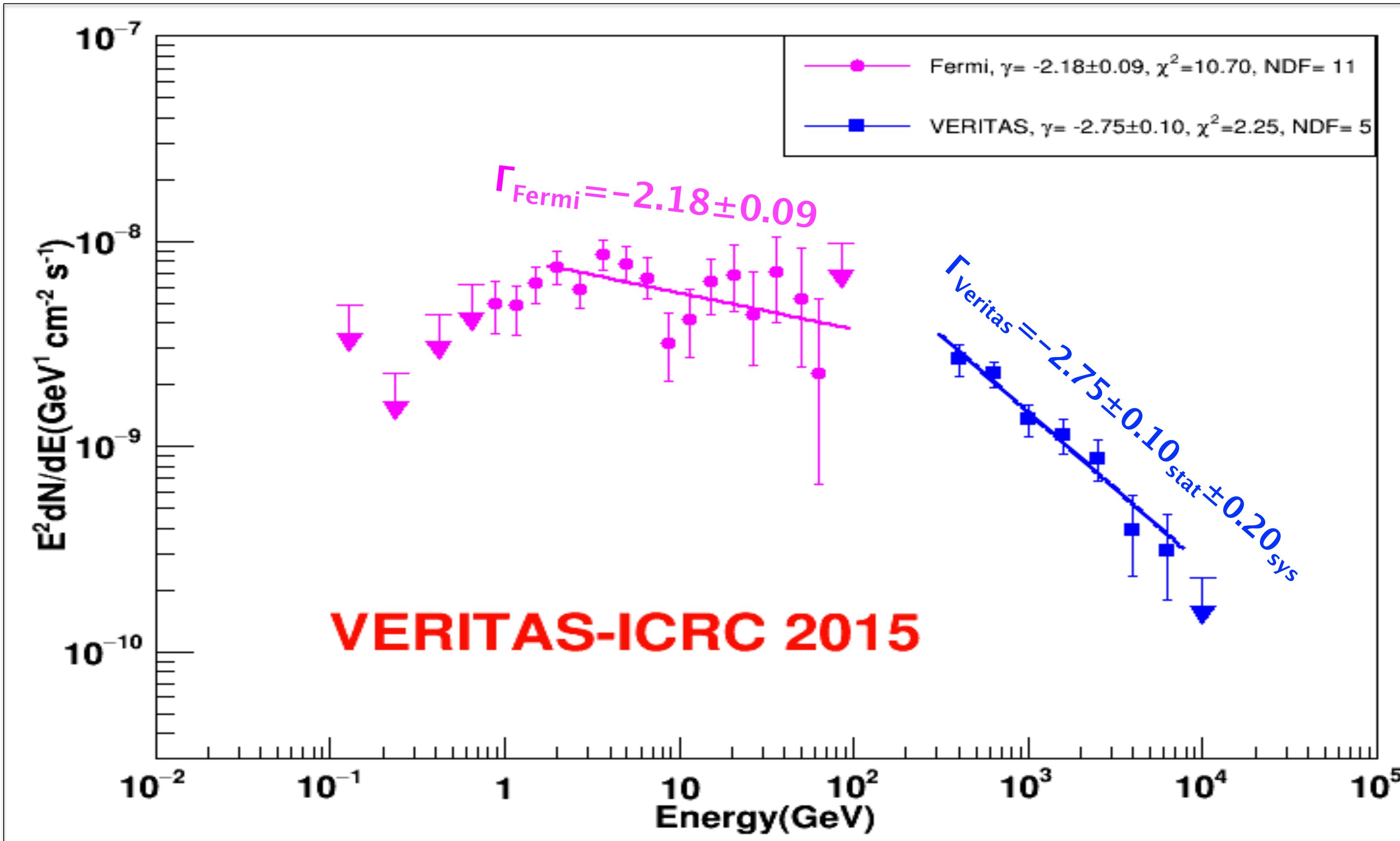
# Energy Spectrum

$$\frac{dN}{dE} = (1.26 \pm 0.18) \times 10^{-12} (E/1\text{TeV})^{-2.61 \pm 0.24_{\text{stat}} \pm 0.20_{\text{sys}}} \text{TeV}^{-1} \text{cm}^{-2} \text{s}^{-1} (\text{published})$$
$$\frac{dN}{dE} = (1.45 \pm 0.11) \times 10^{-12} (E/1\text{TeV})^{-2.75 \pm 0.10_{\text{stat}} \pm 0.20_{\text{sys}}} \text{TeV}^{-1} \text{cm}^{-2} \text{s}^{-1} (\text{this - work})$$

- Statistical error is reduced by 60% from the published data
- Extends the energy spectrum at both higher and lower energy



# Fermi+VERITAS data



\*Fitting range for Fermi  
(2 GeV to 100 GeV)

\*Fitting range for VERITAS  
(300 GeV to 7 TeV)

Yuan et al. 2013



# Fitting different functional model on combined data set

Probability of PL/BPL = 0.010 (~2.5 sigma)

Probability of PL/CPL = 0.0045 (~2.8 sigma)

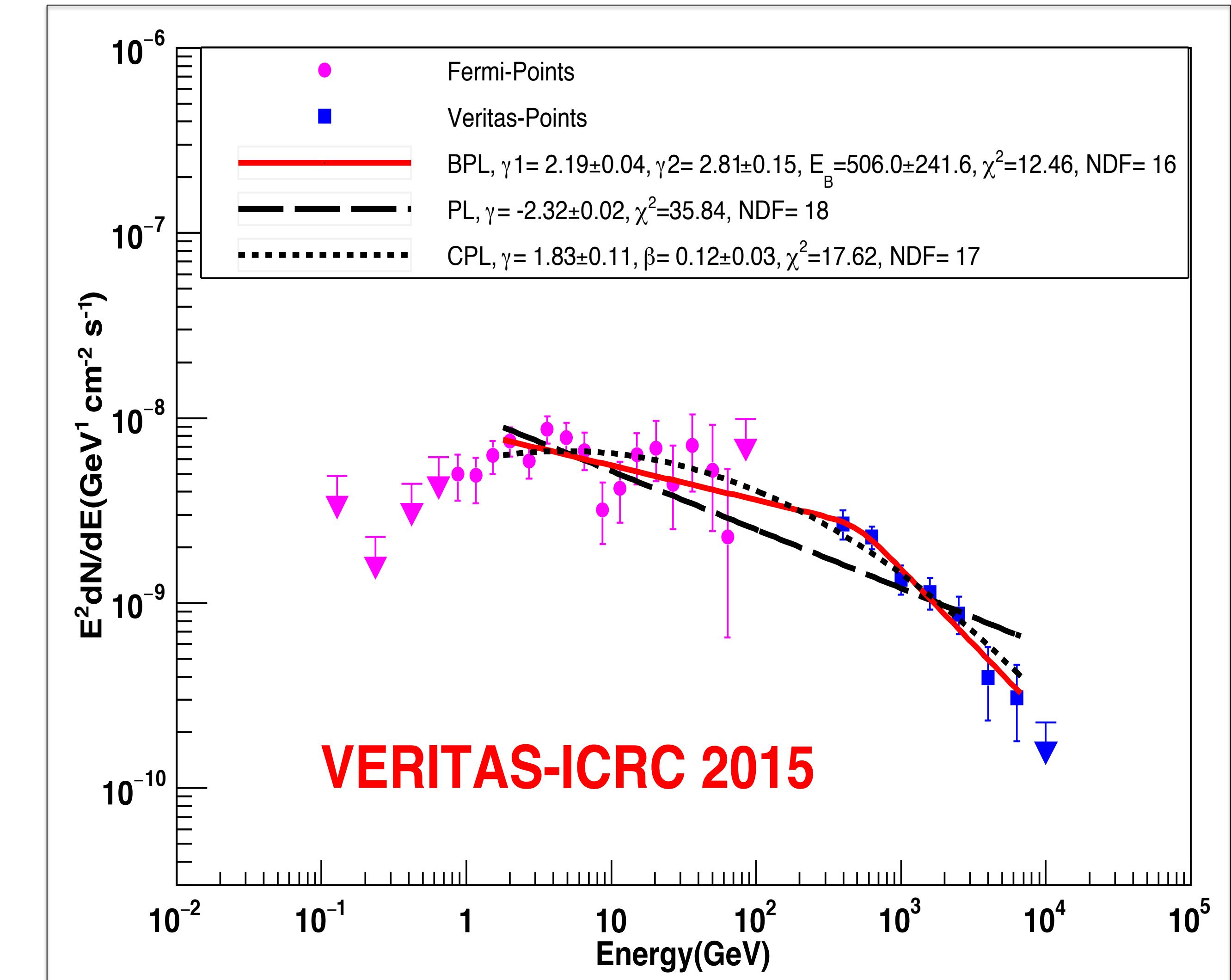
Note\*

BPL—Broken Power Law

PL—Power Law

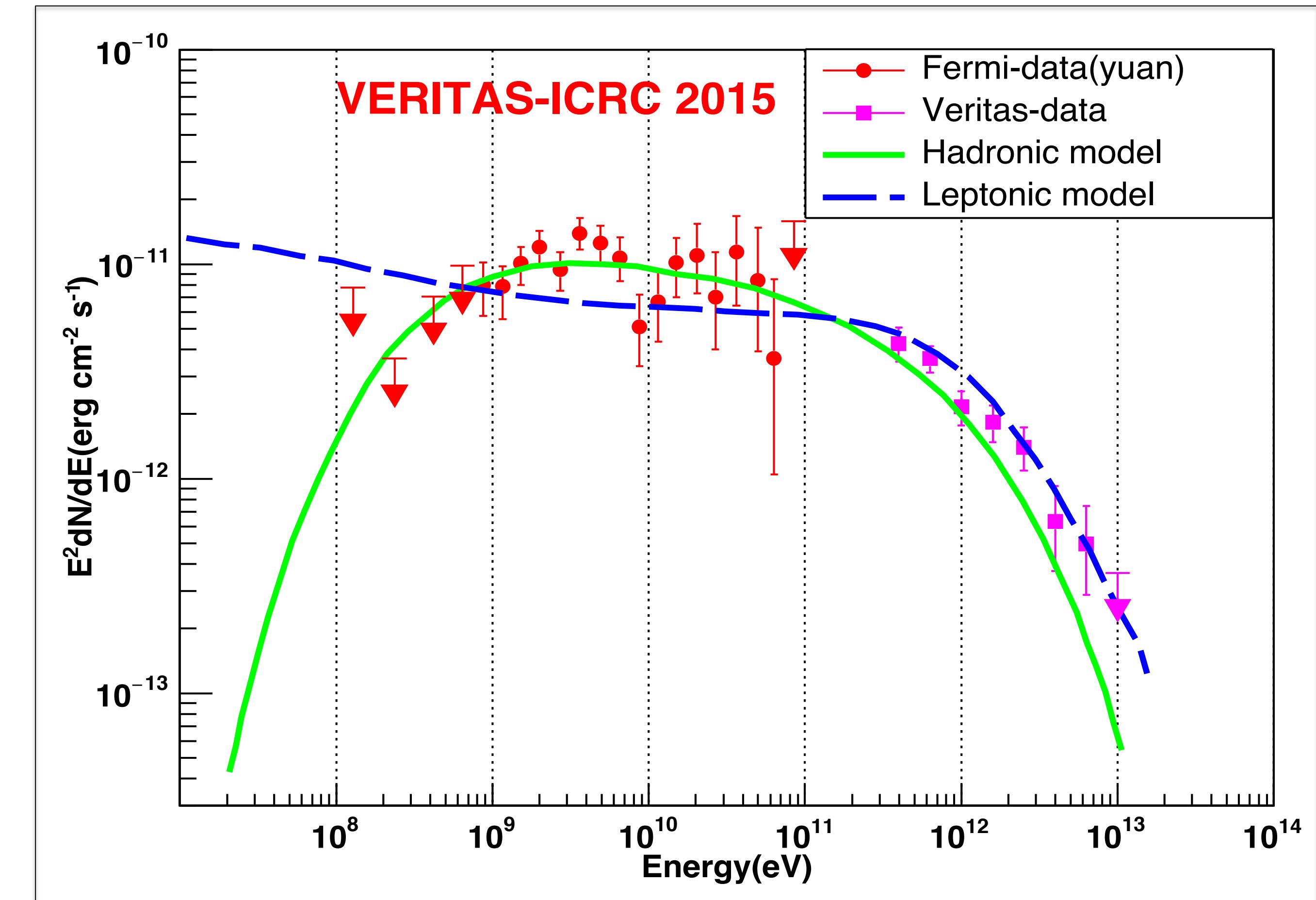
CPL—Curved Power Law

\*Statistical errors only for VERITAS



# Radiation models

- Hadronic model is preferred at lower energy (Yuan et al. 2013)
- At higher energy both leptonic and hadronic mechanism may contribute (Saha et al. 2013)



Yuan et al. 2013



# Summary and Future work

## Summary

- Cover a broader energy range
- Reduced the statistical error on spectral index by ~60%
- Updated spectrum will be helpful to constraint models
- Position is mainly limited by the systematic errors

## Future work

- Fermi-LAT pass 8 analysis
- Upper limit on source extension

