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

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Brief Introduction

- 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
Previous results in HE/VHE Gamma-rays

First detected by HEGRA (Aharonian et al. 2001)
Total amount of data (~64 hours)

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before T1 relocation (Sep-2007 to Nov-2007)</td>
<td>18</td>
</tr>
<tr>
<td>After T1 relocation (Dec-2011)</td>
<td>2</td>
</tr>
<tr>
<td>After Camera upgrade (Small Zenith Angle, Large Zenith Angle) (Sep-2012 to Dec-2013)</td>
<td>43 (19,25)</td>
</tr>
</tbody>
</table>

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
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)

Image from Chandra

(after Grefenstette et al. 2015)
Energy Spectrum

\[
\frac{dN}{dE} = (1.26 \pm 0.18) \times 10^{-12} \left( \frac{E}{1\text{ TeV}} \right)^{-2.61 \pm 0.24_{\text{stat}} \pm 0.20_{\text{sys}}} \text{ TeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1} \text{ (published)}
\]

\[
\frac{dN}{dE} = (1.45 \pm 0.11) \times 10^{-12} \left( \frac{E}{1\text{ TeV}} \right)^{-2.75 \pm 0.10_{\text{stat}} \pm 0.20_{\text{sys}}} \text{ TeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1} \text{ (this work)}
\]

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

\[ \Gamma_{\text{Fermi}} = -2.18 \pm 0.09 \]

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

\[ \Gamma_{\text{VERITAS}} = -2.75 \pm 0.10 \]

*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
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)
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