Indirect Dark Matter Searches with VERITAS

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V.E.R.I.T.A.S.
The Very Energetic Radiation Imaging Telescope Array

Instrument:
- Four 12-m telescopes
- 500-pixel cameras (3.5° FoV)
- FLWO, Mt. Hopkins, Az (1268 m)

Specifications:
- Energy threshold ~ 150 GeV
- Source location < 0.05°
- Energy resolution ~ 10-20%
VERITAS

* energy range: 100 GeV to >30 TeV (spectral reconstruction starts at 150 GeV)

* energy resolution: 15% at 1 TeV

* peak effective area: 100,000 m²

* angular resolution: 0.1 deg at 1 TeV, 0.14 deg at 200 GeV (68% values)

* source location accuracy: 90 arcseconds

* point source sensitivity: 1% Crab in < 50h, 10% in 45 min

* observation time per year: 750 hours non-moonlight, 100 hours moonlight
VERITAS

Technical Performance

Sensitivity of 1% Crab in <50 hours

Angular resolution ~0.1° (68% containment @ 1TeV)
The VERITAS Catalog

Blazars

Pulsar Wind Nebula

Starburst Galaxy!

Supernova Remnants

X-ray Binary
Dark Matter Searches

- WIMPs in mass range of 50 GeV-10 TeV are well motivated DM candidates

- Self annihilation of neutralino in this mass range leads to GeV-TeV gamma-rays (spectral cutoff@WIMP mass or "line" signature)

- FERMI, VERITAS + other IACTs well suited for search
Gamma-ray Signal from DM:

\[
\frac{d\phi(E, \vec{\psi}, \Delta\Omega)}{dE} = \left[ \frac{\langle \sigma v \rangle}{8\pi m_{\chi}^2} \frac{dN(E, m_{\chi})}{dE} \right] J(\vec{\psi}, \Delta\Omega)
\]

- Hadronization of final state pairs produces continuum gamma-ray emission

- WIMP Model Parameter Space
  - \( m_{\chi} = 100 \text{ GeV} - 10 \text{ TeV} \)
  - \( \langle \sigma v \rangle = \sim 3 \times 10^{-26} \text{ cm}^3 \text{ s}^{-1} \)
Gamma-ray Signal from DM:

\[
\frac{d\phi(E, \vec{\psi}, \Delta\Omega)}{dE} = \left[ \frac{\langle \sigma v \rangle}{8\pi m^2_\chi} \frac{dN(E, m_\chi)}{dE} \right] J(\vec{\psi}, \Delta\Omega)
\]

- Line of sight integration over target region gives astrophysical contribution
- Proportional to density squared – sensitive to small scale enhancements in the DM density

\[
J(\vec{\psi}, \Delta\Omega) = \left( \frac{1}{\rho_c^2 R_H} \right) \int_{\Delta\Omega} d\Omega \int \rho^2 ds(\vec{\psi})
\]
Targets:

- **Local Galaxies:** M32, M33
- **DSphs:** Ursa Minor, Draco, Willman I, Bootes I
- **Globular Cluster:** M5
Targets: Local Galaxies M32/M33

Andromeda

- "Cuspy" stellar profiles

- Baryon+DM interaction could compress halo and generate large boost factor for signal

- Con: Large astrophysical background, interpretation difficult....
Targets: Dwarf Galaxies

- Very high mass/light ratio (DM dominated)
- Very close
- Low astrophysical source confusion (can probably attribute any signal to DM)

Draco

Ursa Minor
Exposure 95% C.L. Flux UL
[\text{h}] \quad \text{at 1 TeV [m}^{-2} \text{s}^{-1} \text{TeV}^{-1}]

<table>
<thead>
<tr>
<th>Region</th>
<th>Exposure</th>
<th>Flux UL</th>
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<tbody>
<tr>
<td>Draco</td>
<td>19.1</td>
<td>$1.0 \times 10^{-9}$</td>
</tr>
<tr>
<td>Ursa Minor</td>
<td>19.4</td>
<td>$1.6 \times 10^{-9}$</td>
</tr>
<tr>
<td>Willman I</td>
<td>14.4</td>
<td>$2.6 \times 10^{-9}$</td>
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<tr>
<td>Bootes I</td>
<td>15.4</td>
<td>$1.5 \times 10^{-9}$</td>
</tr>
</tbody>
</table>

~1% Crab

Most Sensitive

IACT limits to date
Assuming NFW profile

- Need significant boost factor (~1000) to constrain models
AGIS/CTA can significantly constrain models

Assuming NFW profile

\( \langle \sigma v \rangle \text{ cm}^{-2} \text{ s}^{-1} \)

- Ursa Minor
- Draco
- Willman I
- Willman I (Boost = 100)

AGIS/CTA

x 100 Exposure
x 10 Sensitivity
x 5 Reduction
E Threshold
Development of future IACT observatory is currently pursued in both US (AGIS) and Europe (CTA) with the prospect for a joint instrument.

With a dedicated dwarf galaxy observing program (1000h) a next-generation IACT could rule out a significant fraction of the MSSM parameter space.

AGIS (US contribution) is a 36-telescope array employing novel optical design which combines large FoV ($\sim 8^\circ$) and good angular resolution ($\sim 4'$).
Future DM work:

- Observations continue......
- Possibility of source stacking to increase constraint
- Results from observations of globular clusters and other dwarves.
- Future IACTs+Fermi will be in position to constrain models/(detect!)