IACT Tutorial

Back of the envelope

Fermi Summer School 2012

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Can my favorite source be detected with VERITAS?

A spectrum extrapolated from Fermi data can the tail be measured with VERITAS?

Taking M82 as an example
1. Is the source visible?

Declination -> is the source visible at all?

Source culminates at min Zenith angle:
abs(Obs.Latitude-Source declination)

Observable if zenith angle at culmination is < 60 degrees

Right ascension ->
what time of year does the source culminates at midnight

0 hours RA  October
+2 hours in RA each month
M82  R.A.:  09 55 52.7 (hh mm ss)
Dec.:  +69 40 46 (dd mm ss)

VERITAS latitude 32 degrees North

Culmination at 38 degree Zenith angle

Best observability (culmination at midnight local)

(10hr/2hr + October)%12 = March
1. Is the source visible to VERITAS

http://tevcat.uchicago.edu/
Source culminates at a Zenith angle of 70-32=38 degrees

Visible from December to May
Source culminates at a Zenith angle of 70-32=38 degrees

Visible from December to May
A source is flaring can we observe right now?

Visibility for VERITAS today

What is going on?

Sun set/rise

Moon set/rise

Plotted 1ES 1959 650 RA,Dec = (299.999,65.1486) for date (dd-mm-yy) 2-6-2012 (MJD= 56080) at lat,lon = 31.68,-110.86
Nominal Times (rough guesses) Start: 10:35, Stop : 10:53, dT ~ 00:17
What is the energy threshold?

Peak of the differential trigger rate distribution

\[ F(E) \times A(E) = \text{TriggerRate}(E) \]
Effective area is not determined by the size of the telescope but the size of the Cherenkov photon light pool on ground.
Effective Area

Effective area = area over which gamma-rays are being simulated
X number of triggered events/total number of simulated events

Gamma-ray showers simulated with impact points up to 750 m away from the telescopes

Observation at 20deg Zenith angle
No photon beyond 600 m triggers telescopes
Cherenkov photon density on ground
Threshold Energy

Table 1
Results of Maximum Likelihood Analyses of M82 and NGC 253

<table>
<thead>
<tr>
<th>Galaxy</th>
<th>R.A.$^a$ (deg)</th>
<th>Decl.$^a$ (deg)</th>
<th>$r_{95}^a$ (deg)</th>
<th>$F(&gt;100 \text{ MeV})^b$ (10$^{-8}$ ph cm$^{-2}$ s$^{-1}$)</th>
<th>Photon Index$^b$</th>
<th>Significance$^c$</th>
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<tr>
<td>M82</td>
<td>149.06</td>
<td>69.64</td>
<td>0.11</td>
<td>1.6 ± 0.5$<em>{\text{stat}}$ ± 0.3$</em>{\text{sys}}$</td>
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<td>-25.21</td>
<td>0.14</td>
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\[
F(E) \cdot A(E) = \text{TriggerRate}(E)
\]

\[
N E^{-\alpha} \cdot A(E) = N R'(E)
\]

Strong dependence on photon index
Rate distribution (@ Trigger)

For a photon index of -2.2
As a function of Zenith angle

\[ E_{\text{Thr}} \propto \frac{1}{\cos(ZA)^{2.7}} \]
Differential Sensitivity

Flux that gives 5 sigma excess in energy bin after 50 hours for an observation at 20 deg
For spectral reconstruction need 3 sigma excess in each bin

Need flux in $E^2 \frac{dN}{dE}$ and in erg/cm$^2$/s
For spectral reconstruction need 3 sigma excess in each bin

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\[
E^2 \frac{dN}{dE} = 5.15 \cdot 10^{-12} E^{-0.2} \text{erg/cm}^2/\text{s}
\]
@ 1 TeV & 20deg zenith: sensitivity \(\sim 6.5 \cdot 10^{-13}\)

Going from 20 deg to 40 deg -> shift in energy scale 1.7

1 TeV => 1.7 TeV

\(6.5 \cdot 10^{-13}\) erg/cm\(^2\)/s => \((1.7/1.0)^2 \cdot 6.5 \cdot 10^{-13} = 1.9 \cdot 10^{-12}\) erg/cm\(^2\)/s

Background limited regime

\(\text{significance} \propto \text{Flux} \times \sqrt{\text{time}}\)
\[ E^2 \frac{dN}{dE} = 5.15 \cdot 10^{-12} (1700)^{-0.2} \text{erg/cm}^2/s \]

= 1.16 \cdot 10^{-12} \text{erg/cm}^2/s

\[
\text{significance} = \frac{F_{\text{explored}}}{F_{5\sigma \text{ in 50 hrs}}} \cdot \sqrt{\frac{t}{50 \text{ hrs}}} \cdot 5\sigma
\]

Observation Time to obtain 3sigma @ 1700 GeV:

\sim 50 \text{ hours}

Note that this is only a rough estimate, which gives you a ball park number
Angular Resolution

Limitations

- lateral spread of shower (multiple scattering)
- gamma-ray collection efficiency
- geomagnetic field
- number of telescopes
- array geometry
- optical point spread function
- pixel size

Gernot Maier | Imaging Atmospheric Cherenkov Telescopes | Jun 2011