Results from the AMANDA Neutrino Telescope

and

Status of the IceCube Neutrino Observatory

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March 13, 2005
Rencontres de Moriond
"Very High Energy Phenomena in the Universe"
La Thuile, Italy
The AMANDA-II Detector

- 19 Strings
- 677 Optical Modules
- ~200 m diameter
- ~500 m height
- completed in 2000

Inner part: B10 detector (1997)
- 10 strings
- 302 Optical Modules
High Energy Phenomena for Neutrino Telescopes

- SuperNova Explosions
- Atmospheric Neutrinos
- Dark Matter Candidates (WIMPs)
- Gamma Ray Bursters
- Active Galactic Nuclei
- Magnetic Monopoles
- Topological Defects
- GZK-Neutrinos

Energy scales:
- MeV
- GeV
- TeV
- PeV
- EeV
## Classification of Signals in AMANDA

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse, steady:</td>
<td>Integrated flux from many sources (strongest flux)</td>
</tr>
<tr>
<td></td>
<td>Signal exceeds background above a certain energy</td>
</tr>
<tr>
<td></td>
<td>No individual sources are identified</td>
</tr>
<tr>
<td></td>
<td>All flavor search</td>
</tr>
<tr>
<td>AGN, GRB, TD</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point source, steady:</td>
<td>Identification of individual sources (weak flux)</td>
</tr>
<tr>
<td></td>
<td>All sky search, or candidate catalog</td>
</tr>
<tr>
<td></td>
<td>Muon channel only (pointing required)</td>
</tr>
<tr>
<td>AGN, SuperNova Remnants,</td>
<td></td>
</tr>
<tr>
<td>Galactic Sources</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point source, transient:</td>
<td>Search in coincidence with detected phenomena</td>
</tr>
<tr>
<td></td>
<td>Time and space correlation reduces background dramatically</td>
</tr>
<tr>
<td>GRB, Flary Sources</td>
<td></td>
</tr>
</tbody>
</table>
AMANDA's Field of View

downgoing atmospheric muons

- **UHE analysis**
- **Point Source searches**
- **atmospheric neutrinos**
- **Earth WIMPs**

- **EeV**
- **PeV**
- **GeV**

**solar WIMPs**

**searches for diffuse neutrino fluxes**
Natural Ice as Detection Medium

Detailed knowledge of measured ice properties

Scattering

Absorption

Modelling in the Simulation

\[
\frac{dN}{dt \, d\rho}(p_e, t)
\]
Atmospheric Neutrinos -- The Test Beam

First measurement of the atm. $\nu_\mu$ 's flux above TeV

- About 600 selected up-going $\nu_\mu$ events (year 2000)
- Energy loss prop. to the muon energy → Energy determination via neural network and unfolding
- Spectral index $\sim -2.7$
- Agreement with Frejus measurement

Volkova parametrization

PRELIMINARY
Set limit on cosmic neutrino flux:

How much signal following $E^{-2}$ is allowed within the uncertainty of the highest energy bin?

$$E^2 \phi_{\nu\mu} (63\text{TeV} < E < 2.5\text{PeV}) < 2.6 \times 10^{-7} \text{ GeV cm}^{-2} \text{s}^{-1} \text{sr}^{-1}$$
UHE Analysis in AMANDA

At $>\text{PeV}$ huge muon range
Large energy depositions

⇓
very bright events

Earth opaque $\Rightarrow$
Signal concentrated at horizon

MC $2.6 \cdot 10^{19}$ eV

Experiment

MC $4.4 \cdot 10^{18}$ eV
Extensive Investigation of systematic uncertainties. (Ice properties, CR primaries, Muon propagation...)

Background simulation describes data on all stages

Analysing 1997 data:

\[ N_{\text{bgr}} = 4.6 \pm 1.2 \text{ events} \]
\[ N_{\text{exp}} = 5 \text{ events} \]

Current analysis with A-II (2000)

Astroparticle Physics 22 (2005) 339-353
Overview Diffuse Searches

AMANDA:
1) upward muons (1997)
2) upward muons (2000)
3) Cascades (2000)
4) UHE (1997)
6) UHE sensitivity (2000)

Baikal:
The Sky-plot (live-time 807 days, 00-03):
3329 neutrino candidates (up-going)
3438 expected from simulations
< 5% misreconstructed down-going events

No significant clustering observed
Consistent with atm. neutrinos

Search for excess of events compared to background for
- selected sources
- the full northern sky,
  (binned/unbinned method)
Steady Point Source Search

Search for excess events from the direction of known $\gamma$-ray emitters

<table>
<thead>
<tr>
<th>Candidate Source</th>
<th>$z$</th>
<th>Luminosity distance</th>
<th>$N_{\text{observed}}$</th>
<th>$N_{\text{back}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ES 1959+650</td>
<td>0.047</td>
<td>219 Mpc</td>
<td>5</td>
<td>3.71</td>
</tr>
<tr>
<td>Markarian 421</td>
<td>0.03</td>
<td>140 Mpc</td>
<td>6</td>
<td>5.58</td>
</tr>
<tr>
<td>QSO 1633+382</td>
<td>1.8</td>
<td>14000 Mpc</td>
<td>4</td>
<td>5.58</td>
</tr>
<tr>
<td>QSO 0219+428</td>
<td>0.44</td>
<td>2600 Mpc</td>
<td>4</td>
<td>4.31</td>
</tr>
<tr>
<td>CRAB</td>
<td>1.9 kpc</td>
<td></td>
<td>10</td>
<td>5.36</td>
</tr>
</tbody>
</table>

$\Rightarrow$ No statistically significant excess from 33 objects
Building a Neutrino Observatory -- IceCube

- 80 strings with 60 optical modules each
  4800 OMs

- Detector volume 1km$^3$
  - Sensitivity well below Waxman-Bahcall bound

- Optimised for TeV-PeV neutrinos
  - 17m OM spacing
  - 125m interstring spacing

- Surface Array (IceTop)

- Build up finished by 2010
UHE in IceCube

Simulations with AMANDA-B10 and IceCube
12-16 strings will be deployed per year

IceCube integrates AMANDA and data analysis will use the growing detector

7) Sensitivity for one year $\nu_\mu$ only
Summary

AMANDA has searched the sky for high energy neutrinos.

So far no source or no diffuse flux of high energy extraterrestrial neutrinos has been identified.

Significant limits have been set, more analyses are under way.

IceCubes first string with 60 OM\textsubscript{s} was deployed in January 2005.

All OM\textsubscript{s} communicate and deliver data as expected. IceCube will significantly increase the sensitivity.
title here
Searching for Time Variable Point Sources

The 1ES1959+650 Case

No statistical significant excess in the time correlation analysis was found

i.e. 5 events on a background of 3.71 within a window of 40 days

A-posteriori investigation:

3 of 5 events are within 66 days partly covered by a multi-wavelength campaign (May 2002)

Due to the analysis setup and as blindness was violated, a probability for a random coincidence can not be quoted