Cosmic Ray Accelerators with

ICECUBE

E. Resconi, MPI-K Heidelberg
for the IceCube Collaboration

Socor 2009
2009: 58+1 strings deployed
59 IceTop Stations

2011: 80+6 strings planned
80 IceTop Stations
2009: 58+1 strings deployed
59 IceTop Stations

2011: 80+6 strings planned
80 IceTop Stations
The IceCube Collaboration

USA:
Bartol Research Institute, Delaware
University of California, Berkeley
University of California, Irvine
Pennsylvania State University
Clark-Atlanta University
Ohio State University
Georgia Tech
University of Maryland
University of Alabama, Tuscaloosa
University of Wisconsin-Madison
University of Wisconsin-River Falls
Lawrence Berkeley National Lab.
University of Kansas
Southern University and A&M
College, Baton Rouge
University of Alaska, Anchorage

UK:
Oxford University

Netherlands:
Utrecht University

Switzerland:
EPFL

Belgium:
Université Libre de Bruxelles
Vrije Universiteit Brussel
Universiteit Gent
Université de Mons-Hainaut

Germany:
DESY-Zeuthen
Universität Mainz
Universität Dortmund
Universität Wuppertal
Humboldt Universität
MPI Heidelberg
RWTH Aachen

Japan:
Chiba University

New Zealand:
University of Canterbury

33 institutions, ~250 members
http://icecube.wisc.edu
Cosmic Ray & Gamma & Neutrinos

Proton-Proton Interaction: All-Products Energy Spectrum

![Graph showing energy spectra for different energies](image_url)
Search in our Galaxy: The Crab a “low” energy source

Crab Upper Limit (IceCube 22 + AMANDA)
A. Gross, C. Roucelle et al., for the IceCube Coll., ICRC 2009

\[ \gamma \text{ (H.E.S.S, ref)} \]
\[ \nu \text{ (pp)} \]

PRELIMINARY

\[ \Gamma_{\nu} = -2.39, \quad E_{\nu \text{ cutoff}} = 7 \text{ TeV} \]

PRELIMINARY

IC22+AMANDA upper limit

\[ \nu \text{ (pp)} \]
The "Knee": Search in our Galaxy

Galactic Plane Scan: IceCube 22 + AMANDA
A. Gross, C. Roucelle et al., for the IceCube Coll., ICRC 2009

Pre-trial p-values

NO SIGNIFICANT STRUCTURE OBSERVED
The “Knee”: Search in our Galaxy

PROSPECTS for Soft Spectra Sources:

- Dedicated Search for Extended Cygnus Region
  (\gamma-rays Point Sources + Diffuse Emission)

- IceCube40 + AMANDA under processing
Above the “Knee”: extra-galactic Or ... everything we don’t know

- Point Source Search
  - Northern Hemisphere
  - Southern Hemisphere
  - Flaring Sources

- GRBs
- Diffuse Flux Search
Above the “Knee”: extra-galactic
Or … everything we don’t know

- Point Source Search
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- GRBs
- Diffuse Flux Search
<table>
<thead>
<tr>
<th>Detector</th>
<th>Energy Window (TeV)</th>
<th>Exposure Time (days)</th>
<th>Limit ((\text{TeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMANDA-B10 (1997-99)</td>
<td>(\sim 1 - 1000)</td>
<td>623</td>
<td>(4.0 \times 10^{-10})</td>
</tr>
<tr>
<td>AMANDA-II (2000-04)</td>
<td>1.6 - 2600</td>
<td>1001</td>
<td>(5.5 \times 10^{-11})</td>
</tr>
<tr>
<td>AMANDA-II (2005-06)</td>
<td></td>
<td></td>
<td>(7.0 \times 10^{-11})</td>
</tr>
</tbody>
</table>
Limit (L) Sensitivity (S) (TeV⁻¹ cm⁻² s⁻¹)

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<th>Limit (L) Sensitivity (S)</th>
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</thead>
<tbody>
<tr>
<td>IC9 (2006)</td>
<td>~ 5 - 1000</td>
<td>137</td>
<td>1.2 ⋅ 10⁻¹⁰ (L)</td>
</tr>
<tr>
<td>IC22 (2007)</td>
<td>~ 5 – 5000</td>
<td>240</td>
<td>~10⁻¹¹ (S)</td>
</tr>
<tr>
<td>IC22 + AMANDA</td>
<td>~ 0.5 - 10</td>
<td></td>
<td>Only for specific</td>
</tr>
<tr>
<td>IC80</td>
<td>~ 5 - 5000</td>
<td>3 years</td>
<td>2 ⋅ 10⁻¹² (S)</td>
</tr>
</tbody>
</table>
IceCube-22 sky-map, 275.70 days, 5114 events

Location: equatorial coordinates
RA: 153.375° = HA: 10h13m30s (J2000.0)
Dec: +11.375° = 11d22m30s

Pre-trial: p-value = $7 \times 10^{-7}$
Post-trial: p-value = 1.3%

PRELIMINARY

C. Finley for the IceCube Coll., 4th TeVPA Workshop Beijing, China 2008
- This can happen in 1.3% of random cases
- Compatible with a fluctuation of the background
- No evidence of specific time behaviour
IceCube 40 new analysis
... and
IceCube 59 is taking data

IceCube 40 preliminary results based on 6 months ~ ready for ICRC09
Above the “Knee”: extra-galactic
Or ... everything we don’t know

- Point Source Search
  - Northern Hemisphere \((E_{\nu} \sim \text{TeV} – \text{PeV})\)
  - Southern Hemisphere \((E_{\nu} \sim 100 \text{ TeV} – \text{EeV})\)
  - Flaring Sources

- GRBs
- Diffuse Flux Search
Pre-trial p-values

NO SIGNIFICANT STRUCTURE OBSERVED

R. Lauer for the IceCube Coll., 2nd Heidelberg Workshop, “High-Energy Gamma-rays and Neutrinos from Extra-Galactic Sources”
Above the “Knee”: extra-galactic Or … everything we don’t know

- Point Source Search
  - Northern Hemisphere
  - Southern Hemisphere
  - Flaring Sources

- GRBs
- Diffuse Flux Search
Flaring/Periodic Sources: Multi-wavelength

**Active Galactic Nuclei**
- Mkn 421
- Mkn 501
- 1ES1959+650
- 3C273
- 3C454
- S5 0716+71

**X- and $\gamma$-rays**

**GeV $\gamma$-rays**

**X-ray Binary Systems**
- SS433
- LSI +61 303
- Cyg X-1
- Cyg X-3
- ...

**Radio Periodicity**

Elisa Resconi
Flaring/Periodic Sources: Multi-wavelength

Flares Tested in IceCube 22: M. Baker et al., for the IceCube Coll, ICRC 2009

3C 454.3: July 24-30, 2007; Nov. 11-21, 2007

1ES 1959+650: Nov 25-28, 2007; Dec 2-7, 2007 (1 event)

Cygnus X-1: August 8, 2007

S5 0716+71: September 7-12, 2007; October 19-28 2007 (1 event)

In ~ 10% random cases: 2 coincidences
Above the “Knee”: extra-galactic

- Point Source Search
  - Northern Hemisphere ($E_{\nu} \sim$ TeV – PeV)
  - Southern Hemisphere ($E_{\nu} \sim$ 100 TeV – EeV)
  - Flaring Sources

- GRBs
- Diffuse Flux Search
GRB080319B (Naked eye)

0 events on-time with 9 strings. In IceCube: ~ 1 event
IceCube 22, Northern Hemisphere Search

A. Kappes et al., for the IceCube Coll, ICRC 2009

41 GRBs (Swift) stacked

- Prompt time window: $\gamma$ time
- Precursor time window: -100s
- Extended time window: -1h +3h

Waxman-Bahcall model
PRL 78, 2292 (1997)
Above the “Knee”: extra-galactic

- Point Source Search
  - Northern Hemisphere ($E_\nu \sim$ TeV – PeV)
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- GRBs
- Diffuse Flux Search
Cosmic Ray & Gamma & Neutrinos

Proton luminosity → Upper bound HE ν flux


Elisa Resconi
Diffuse Flux Searches: Deviation from Atmospheric Neutrinos

Searches for a Diffuse Flux challenges:
- Theoretical models: uncertainties
- Detector systematic effects
Kotoyo Hoshina et al, for the IceCube Coll, ICRC 2009

IceCube Collaboration, astro-ph/0711.0353
IceCube 22 ⇒ IceCube 40: Crossing W&B

And ... IceCube measures the Large Scale Anisotropy

IceCube 22
~4.3*10^9 downward going (in-ice) muon events
median angular res. ~3 deg
median energy ~14 TeV
0.06% large scale anisotropy

R. U. Abbasi, P. Desiati et al., for the IceCube Coll, ICRC 2009
Conclusions

IceCube construction: in 2 seasons done

IceCube data taking and analysis on-going

IceCube is searching for cosmic accelerators in the entire sky

Not mentioned:
- Shadow of the Moon (more than 5σ)
- Search for GZK neutrinos
- Search for Dark Matter, Exotics
- IceTop