High-energy neutrino astronomy with IceCube

Ignacio Taboada
Georgia Institute of Technology

SLAC Summer Institute 2010
Neutrinos as astronomical messengers

Cosmic accelerator

Photon

CMB star-light

Neutrino

Cosmic ray

I Taboada / Georgia Tech

Aug 10, 2010
Build a BIG detector (~1 km³ of water)
Build underground
Use Earth as a filter
Cherenkov Detection
High-energy neutrino detection: traditional way

IceCube is in fact a 4π sr detector

Build a BIG detector (~1 km³ of water)
Build underground
Use Earth as a filter
Cherenkov Detection
The IceCube collaboration. Approximately 250 people

Canada:
U Alberta

USA:
U Alabama, Tuscaloosa
U Alaska, Anchorage
UC Berkeley
UC Irvine
U Delaware
Georgia Tech
U Kansas
LBNL
U Maryland
Ohio State U
Pennsylvania State U
U Wisconsin-Madison
U Wisconsin-River Falls
Clark Atlanta U
Southern U, Baton Rouge

UK:
Oxford

Belgium:
U Libre de Bruxelles
Vrije U Brussel
U de Mons
U Gent

Switzerland:
EPFL, Lausanne

Sweden:
Uppsala U
Stockholm U

Germany:
U Mainz
Humboldt U, Berlin
DESY, Zeuthen
U Dortmund
U Wuppertal
MPI Heidelberg
RWTH Aachen
Bonn
Bochum

Japan:
Chiba U

New Zealand:
U Canterbury

Barbados:
U West Indies

Antarctica:
South Pole Station

Taboada / Georgia Tech

Aug 10, 2010
IceCube performance

- Low noise rates: ~300Hz (SPE/sec)
  - Rate with correlated pulses ~500Hz
  - Supernova MeV \( \nu \) detection!
- High duty cycle: >97%
- 32 / 4790 DOMs dead (0.7%)
- Event rates (79 strings)
  - Muons: ~1.8 kHz
  - Neutrinos: ~220/day
Observation of the Moon shadow

(14 Moon cycles – IC40)
Atmospheric muon neutrinos

I Taboada / Georgia Tech  Aug 10, 2010
All Sky Point Source Search. IC40

Preliminary

24h

0h

pre-trial

I Taboada / Georgia Tech

Aug 10, 2010
All Sky Point Source Search. IC40

Preliminary

Northern hemisphere
Background: atmospheric neutrinos
14121 upgoing events

Southern hemisphere
Background: atmospheric muons
Reduced by $10^{-5}$ using energy cut
22779 downgoing (high energy) muon events

Livetime = 375.5 days
Hottest location in the all-sky search is:
Ra=113.75, Dec=15.15

All-sky p-value = 18%
not significant, no evidence for neutrino source
# Stacked Source Search

<table>
<thead>
<tr>
<th>Catalog</th>
<th># Sources</th>
<th>Model</th>
<th>p-value</th>
<th>N$_{s}$</th>
<th>$\gamma$</th>
<th>$\nu_\mu + \nu_\tau$ upper limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milagro</td>
<td>17</td>
<td>E$^{-2}$ uniform</td>
<td>0.32</td>
<td>7.6</td>
<td>-2.6</td>
<td>$\Phi_{90} = 24.5$</td>
</tr>
<tr>
<td>Milagro</td>
<td>6 (SNR)</td>
<td>Halzen et al (2008)</td>
<td>0.02 (*)</td>
<td>15.2</td>
<td>-2.9</td>
<td>SF = 7.2</td>
</tr>
<tr>
<td>Starburst Galaxies</td>
<td>127</td>
<td>E$^{-2}$ prop to FIR flux</td>
<td>1.0</td>
<td>0.0</td>
<td></td>
<td>$\Phi_{90} = 58.6$</td>
</tr>
<tr>
<td>Clusters of Galaxies</td>
<td>5</td>
<td>Model A</td>
<td>0.78</td>
<td>0.0</td>
<td></td>
<td>SF = 2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model B</td>
<td></td>
<td></td>
<td></td>
<td>SF = 4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isobaric</td>
<td></td>
<td></td>
<td></td>
<td>SF = 4.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Central AGN</td>
<td></td>
<td></td>
<td></td>
<td>SF = 2.0</td>
</tr>
</tbody>
</table>

Likelihood method provides signal normalization and spectral index consistent with the data

(*) A posteriori source selection $\Phi_{90}$ in units of $10^{-12}$ TeV$^{-1}$.cm$^{-2}$.s$^{-1}$

SF: model scaling factor
Cosmic Ray Anisotropy

Tibet-III
(5° smoothing)

Preliminary
IceCube-40
(3° smoothing)

I Taboada / Georgia Tech
Aug 10, 2010
Neutrinos from GRBs

IceCube in coincidence with Fermi/GBM has a 95% of detection potential of Waxman-Bahcall model at 5 $\sigma$ in one year. Within 5 years, IceCube will extensively sample the allowed parameter space of the Waxman-Bahcall model.

117 Northern hemisphere GRBs, reported mostly by Fermi.
DeepCore Science Potential

Indirect dark matter search (Sun, Center of galaxy)
$4\pi$ sr neutrino astronomy (>10 GeV)
Neutrino oscillations
Conclusions and outlook

✓ IceCube construction almost completed
✓ IceCube meeting or exceeding its design requirements
✓ IceCube is a $4\pi$ sr detector
✓ IceCube already producing scientific results.
  – Point sources, diffuse, GRBs, Atmospheric neutrinos, cosmic rays, Target of opportunity programs, indirect Dark Matter search, etc ...
IC22+AMANDA, optimized for soft spectra sources

Galactic Plane Scan

Preliminary

Galactic Latitude (deg)

Galactic Longitude (deg)
IC22+AMANDA, optimized for soft spectra sources

Cygnus Region (selected a-priori)
IC22+AMANDA, optimized for soft spectra sources

Cygnus region

2.3 $\sigma$, 1% p-value

Preliminary
Optical Follow-Up

Iridium satellites

SN/GRB

Fast reaction to GRB alerts

IceCube

Northern hemisphere IceCube CPU

ROTSE III