Seeing the Universe in Neutrinos from the Earth's South Pole

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If you don't know what a hand is....

What can you tell me about a hand just by looking at it (you can't touch it, dissect it, make any contact with it)
If you don't know what a hand is....
The Crab Nebula

Star with gas cloud around it

Radio image

Ultraviolet image

Optical image

X-ray image
Seeing the universe in Neutrinos!
What are neutrinos?

- Elementary particle
- “Invisible” or “ghost” particle
  - No Electromagnetic Charge
  - Rarely Interact

Once in a while, interacts with stuff to create charged particles (like electrons, muons). These charged particles make light.
Why use neutrinos instead of light?
Have you ever been buried in snow?
What if you're buried 1 mile deep?

Should you see light?
Only when small particles go through very fast (Cherenkov Radiation)
Glacier at the South Pole

2.5km deep!

IceCube Lab

IceTop
81 Stations
324 optical sensors

IceCube Array
86 strings including 8 DeepCore strings
5160 optical sensors

DeepCore
8 strings-spacing optimized for lower energies
480 optical sensors

Eiffel Tower 324 m

Bedrock

Light Sensor
“Event View” video
Journey to the South Pole

New Zealand (Christchurch)

Gateway to Antarctica!
Gear issue
The Antarctic

- King Sejong (South Korea)
- General Bernardo O'Higgins (Chile)
- Esperanza (Argentina)
- Neumayer (Germany)
- SANAEE (South Africa)
- Maitri (India)
- Syowa (Japan)
- Halley (U.K.)
- Zhongshan (China)
- Davis (Australia)
- Vostok (Russia)
- McMurdo (U.S.)
- Dumont d'Urville (France)

Major research stations, governing nation in parentheses
Arriving at McMurdo
McMurdo Station
C130 to South Pole Station
“Around the World” video
Life at the station

commute

work

sleep
The screen to live by at South Pole Station

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Winter Over!
You can apply to winter over too!
http://icecube.wisc.edu/jobs/show/winter_over_pos
The IceCube Collaboration

**Funding Agencies**

- Fonds de la Recherche Scientifique (FRS-FNRS)
- Fonds Wetenschappelijk Onderzoek-Vlaanderen (FWO-Vlaanderen)
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- German Research Foundation (DFG)
- Deutsches Elektronen-Synchrotron (DESY)
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- Swedish Polar Research Secretariat
- The Swedish Research Council (VR)

University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)
How did I get here?
Doing astronomy using neutrinos was just a dream until 2013....
This was the first time neutrinos from outside our Galaxy was seen. This created buzz in scientific papers.
But where do these super-high-energy neutrinos come from?
How do you look for a star/galaxy?
RESEARCH

NEUTRINO ASTROPHYSICS

Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A

The IceCube, Fermi-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S., INTEGRAL, Kanata, Kiso, Kapteyn, Liverpool telescope, Subaru, Swift/NaSTAR, VERITAS, and VLA/17B-403 teams†

Previous detections of individual astrophysical sources of neutrinos are limited to the Sun and the supernova 1987A, whereas the origins of the diffuse flux of high-energy

evaluated below, associating neutrino and γ-ray production.

The neutrino alert

IceCube is a neutrino observatory with more than 5000 optical sensors embedded in 1 km³ of the Antarctic ice-sheet close to the Amundsen-Scott South Pole Station. The detector consists of 86 vertical strings frozen into the ice 125 m apart, each equipped with 60 digital optical modules (DOMs) at depths between 1450 and 2450 m. When a high-energy muon-neutrino interacts with an atomic nucleus in or close to the detect-

RESEARCH

NEUTRINO ASTROPHYSICS

Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert

IceCube Collaboration†

A high-energy neutrino event detected by IceCube on 22 September 2017 was coincident in direction and time with a gamma-ray flare from the blazar TXS 0506+056. Prompted by this association, we investigated 9.5 years of IceCube neutrino observations to search for excess emission at the position of the blazar. We found an excess of high-energy neutrino events, with respect to atmospheric backgrounds, at that position between September 2014 and March 2015. Allowing for time-variable flux, this constitutes 3.5σ evidence for neutrino emission from the direction of TXS 0506+056, independent of and prior to the 2017 flaring episode. This suggests that blazars are identifiable sources of the high-energy astrophysical neutrino flux.

The significance of the spatial and temporal coincidence of the high-energy neutrino and the blazar flare is estimated to be at the 3σ level (20). On the basis of this result, we consider the hypothesis that the blazar TXS 0506+056 has been a source of high-energy neutrinos beyond that single event.

 Searching for neutrino emission

IceCube monitors the whole sky and has maintained essentially continuous observations since 5 April 2008. Searches for neutrino point sources using two model-independent methods, a time-integrated and a time-dependent unbinned maximum likelihood analysis, have previously been published. For the data collected between 6000
We even had a press conference
On Sept 22, 2017 a high energy neutrino left a spectacular trail of light
Follow-up Observations of IceCube Alert IC170922

Observatories
- Earth Observatory
- Space Observatory

Detections
- Observations with detection
- Observations without detection

IceCube Neutrino Observatory
First time a possible source was located!
Where do we stand?

- We've seen extremely high energy neutrinos from outside our galaxy
- Astronomy has become truly “multi-messenger”
- What does the “night” sky look like in neutrinos? Stay tuned...