High Energy Neutrino Telescopes

ARIANNA Facility:
US, Sweden, Taiwan, Germany, Denmark

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UC Irvine, 2017
Why Neutrinos?

- Little mass, no electric charge, stable
- **Unlike photons**, neutrinos can escape from just about any environment
- **Unlike photons**, they penetrate through just about anything in the way
- **Like photons**, they travel in straight lines, so you can look back to see what made them

Only known particle messenger that can travel from distant extragalactic sources if $E > 10^{11}$ GeV; not protons, not photons
The IceCube Detector

Array of 80 sparse and 6 dense strings

5160 optical sensors

Completed in 2010

“Optical”
“Radio” Neutrino Telescopes

1 station in array of 36 x 36, 1 km spacing

ARIANNA


1 station of 37, 2 km spacing

ARA

Energy Spectrum is either $\sim E^{-2.5}$

Icecube has detected astrophysical with energies up to a few $x 10^6$ GeV.

The energy spectrum is uncertain
HE Neutrino landscape 2017

• Energy Spectrum may be $\sim E^{-2.1}$ and cutoff

Icecube has detected astrophysical with energies up to a few $10^6$ GeV.

The energy spectrum is uncertain.
Cosmogenic (GZK) Neutrinos

- Created from collision of CR and CMB photons if $E_{\text{CR}}/A > \sim 5 \times 10^{10}$ GeV

Calculations depend on:
1. Composition [p, mix, Fe]
2. Evolution of sources
3. Highest energy, $E_{\text{max}}$
4. Injection Spectrum
5. End of Gal. CR

Smallest $\nu$ flux from all proton CR is $10^{-8}$
1st Gen Radio Neutrino Detectors

- Optimized ARIANNA 5 year sensitivities (including published livetimes and analysis efficiency)

Modified from K-H Kampert and M. Unger, 2012

- Year round operation
- By Wind Gen power
- Prototype began operating in 2016

Non-observation at $10^{-9}$ implies $p < 10\%$ of CR.
1st Gen Radio Neutrino Detectors

- Optimized ARIANNA 5 year sensitivities (including published lifetimes and analysis efficiency)

Modified from K-H Kampert and M. Unger, 2012

Continue IceCube flux to $10^9$ GeV if $dN/dE \sim E^{-2.5}$
1st Gen Radio Neutrino Detectors

- Optimized ARIANNA 5 year sensitivities (including published livetimes and analysis efficiency)

Modified from K-H Kampert and M. Unger, 2012

Graph showing energy vs. event rate improvement at $10^{11}$ GeV by 10
Plans

• Submit proposal for Gen 1 radio neutrino telescope to NSF in 2018
  – $10M in hardware, ~$25M total cost
  – 4 year construction
  – Data taking begins with installation of 1st station

• Gen 2 will reach $E^2 dN/dE \sim 10^{-10} \text{ GeV cm}^{-2} \text{s}^{-1} \text{sr}^{-1}$
  – Radio Component of IceCube Gen2
  – Construction begins no earlier than 2025
Thank You!

Shown: (Left to right) Joulien Tatar, Chris Persichilli, James Walker, Corey Reed
Backup Slides
Hexagonal Radio Array (HRA): 2012–present

Moore’s Bay, 110 km from McMurdo Station
Current status of ARIANNA - HRA

7 regular stations

“Cosmic Ray” station 1

“Cosmic Ray” station 2
Commentary

• IceCube neutrinos, especially those above $10^{15}$ eV provide strong incentive to probe to higher energies with larger detectors.

• Pilot programs of next generation of EHE neutrino radio-based detectors are completed (e.g., ARIANNA-HRA), and projects are gaining experience with sustained operation.

• Radio-based HE neutrino detectors optimized for EeV (though with capability to $10^{16}$ eV).

I believe the Antarctic neutrino projects will coalesce around common technique within the next year to produce a “mature” proposal supported by the community.
Multi-messenger Observatory

(ARIANNA all flavor-ν)

While some flavor identification may be possible, it will be very difficult in my opinion.
Multi-messenger Observatory
(ARIANNA Cosmic Ray)

Energy spectrum between $3 \times 10^{17} \text{ eV}$ and $10^{20} \text{ eV}$

Anisotropies in southern sky
Multi-messenger Observatory
(ARIANNA nu-tau)

Prototype tower deployed in 2016
Measure RF noise
Evaluate Angular resolution
Interference from scattering?
Nu-tau Detection with Radio

Flavor ratio is intriguing probe for ν
1) source physics  2) oscillation
3) decay          4) mass hierarchy

Concept:
ν_τ station consists of 3 towers with 2 dual pol LPDA
EHE $\nu$ detectors: Comments

EHE neutrino detectors:

- Contribute to ongoing quest to understand EHE CRs
  - Neutrino measurements provide independent confirmation of GZK mechanism
  - Combined with CR and photon measurements, can help to constrain source class, evolution, $E_{\text{max}}$, and composition of CR
  - Direct measurements of CR
- Search for new physics
  - Beam of EeV neutrinos can uncover new physics at $\sim 5-10 \times E_{\text{cm}}$ of LHC through cross-section and spectral modifications
- Search for new sources:
  - EeV neutrinos must point back to sources and direction can be measured with good precision (and current procedures can be improved).
ARIANNA Characteristics

Peak response at "sweet spot" of GZK spectrum

Energy Resolution
Details of waveform give energy info