Neutrino Astronomy

Ph 135

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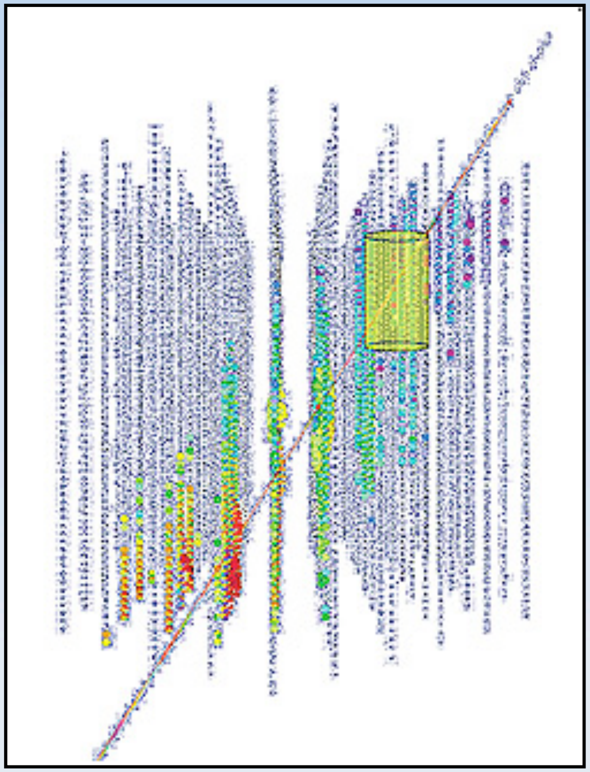


Why do Astronomy with Neutrinos?

- Stars, active galactic nuclei, etc. are opaque to photons
- High energy photons are absorbed by the CMB beyond ~100 Mpc
- 10^{20} eV protons, which should be created with neutrinos, have been seen
- Can be used to observe possible dark matter reactions
- In short: we can probe new phenomena and look farther back

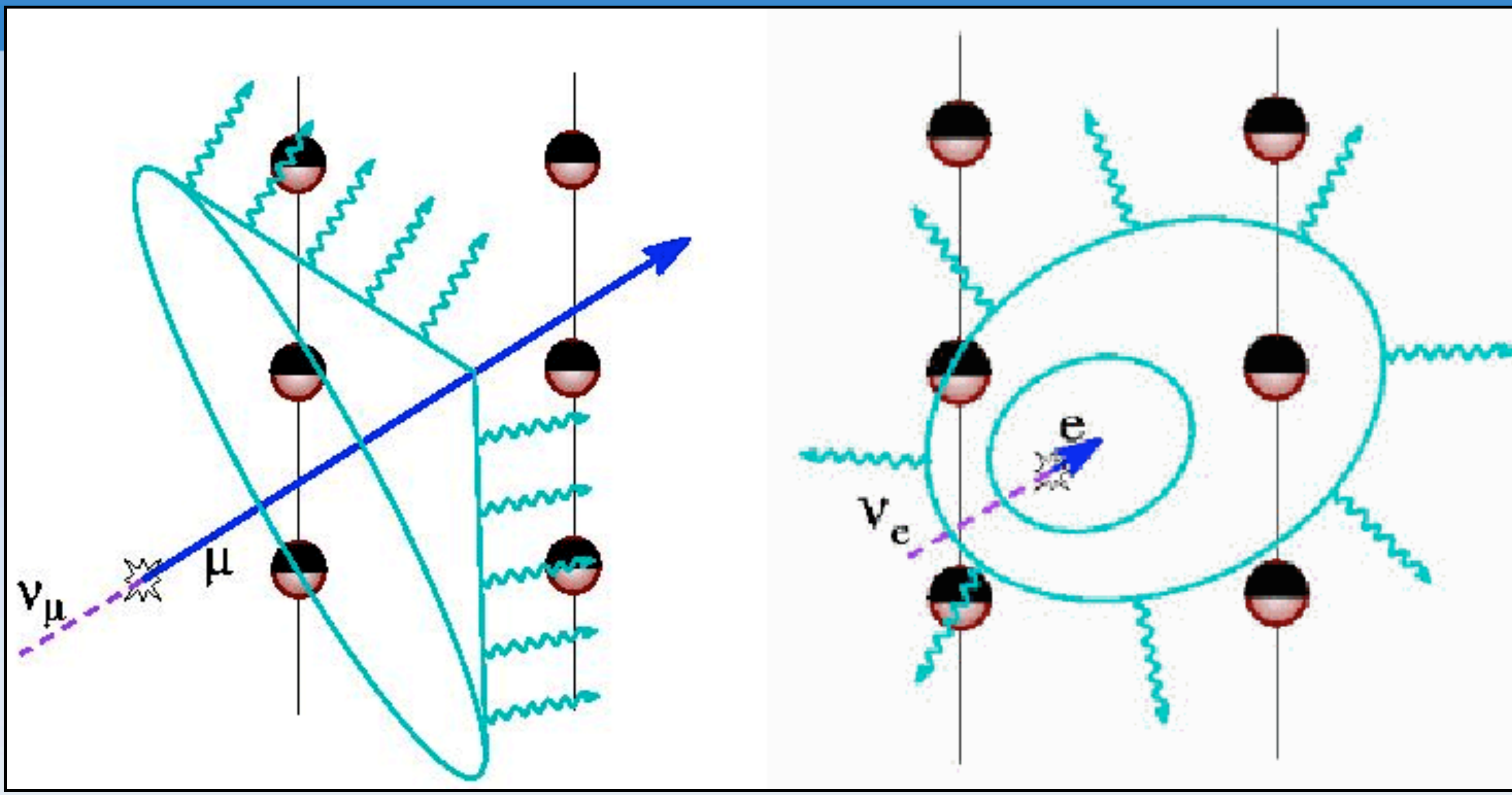
Why do Astronomy with Neutrinos?

- Three main areas of research:
  - Astronomy
    - More information about high-energy protons and γ rays
  - Particle Physics
    - Extremely long baseline for neutrino oscillation studies
  - Dark Matter Searches
    - Many dark matter candidates would leave neutrino signatures

The Detector

- A neutrino interacts with matter in the telescope, creating a muon or a hadronic or electromagnetic shower
- The muon (or shower) emits Cherenkov radiation as it travels through the ice
- Photomultipliers pick up the Cherenkov radiation and can infer the direction of travel
- To select only neutrino events, only tracks coming through the Earth are kept

The Detector



Picture from AMANDA II Web Site: http://www.amanda.uci.edu

Advantages of Neutrino Astronomy

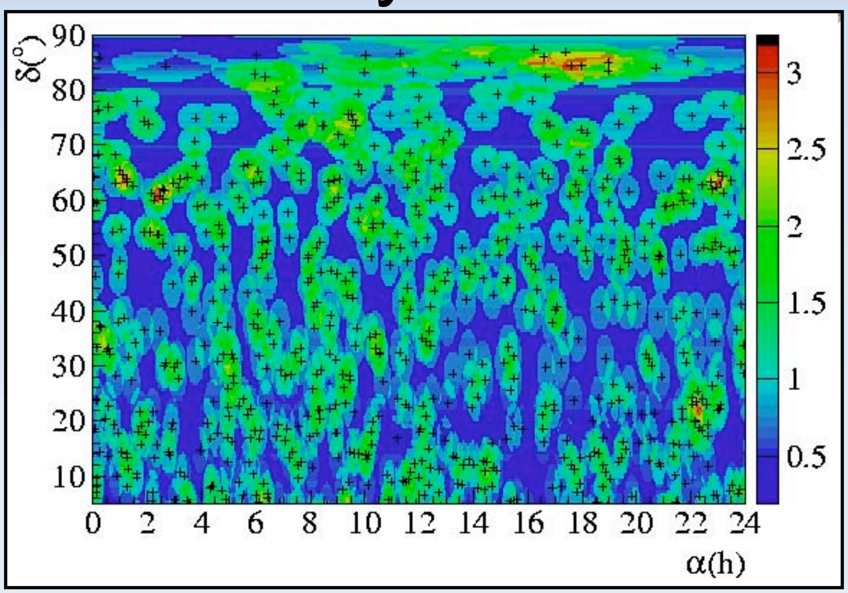
- Can see through nearly anything
- Wide viewing angle

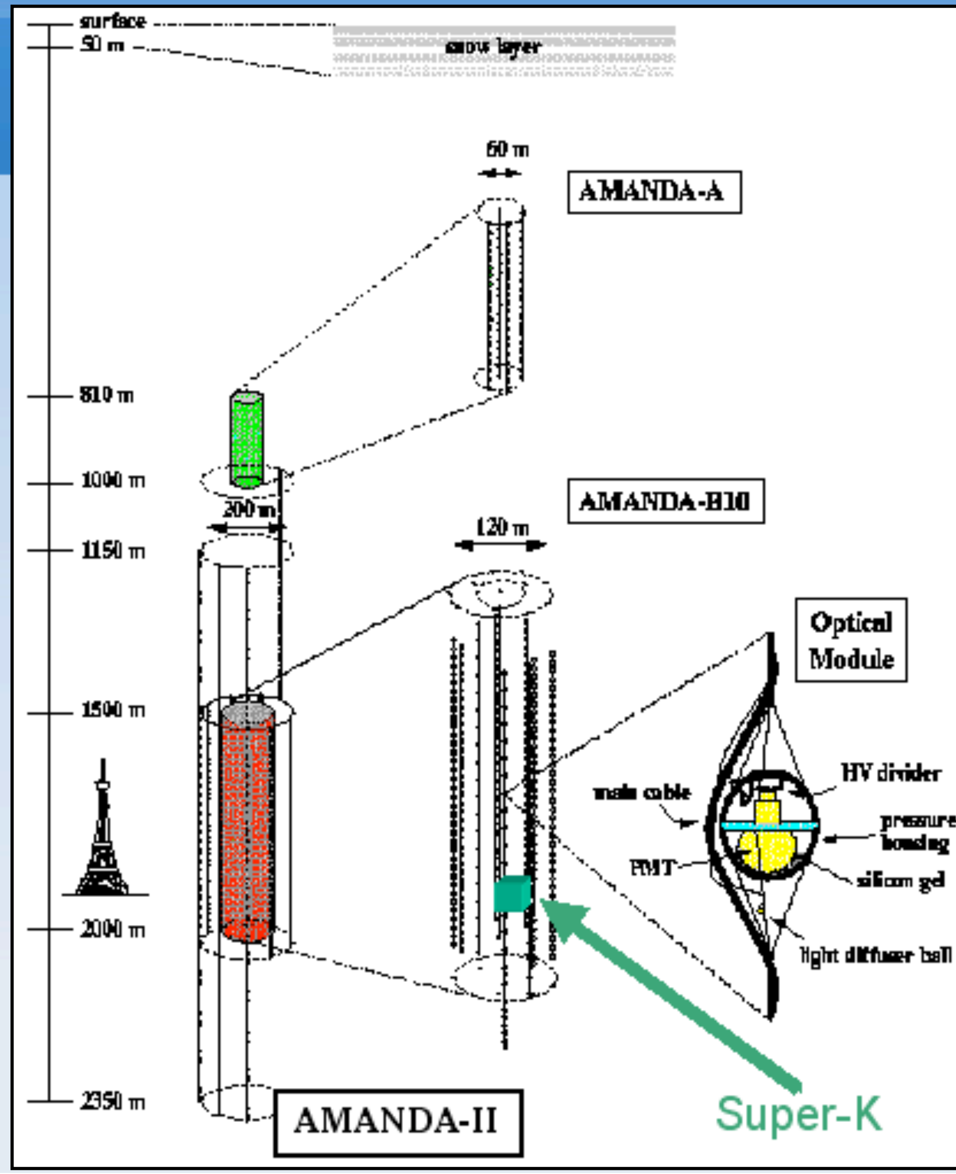
Disadvantages of Neutrino Astronomy

- Need gigantic telescopes
- Still see very few events

AMANDA

- Many arrays (A, B10, and II) at the South Pole
- Operational since January 1997



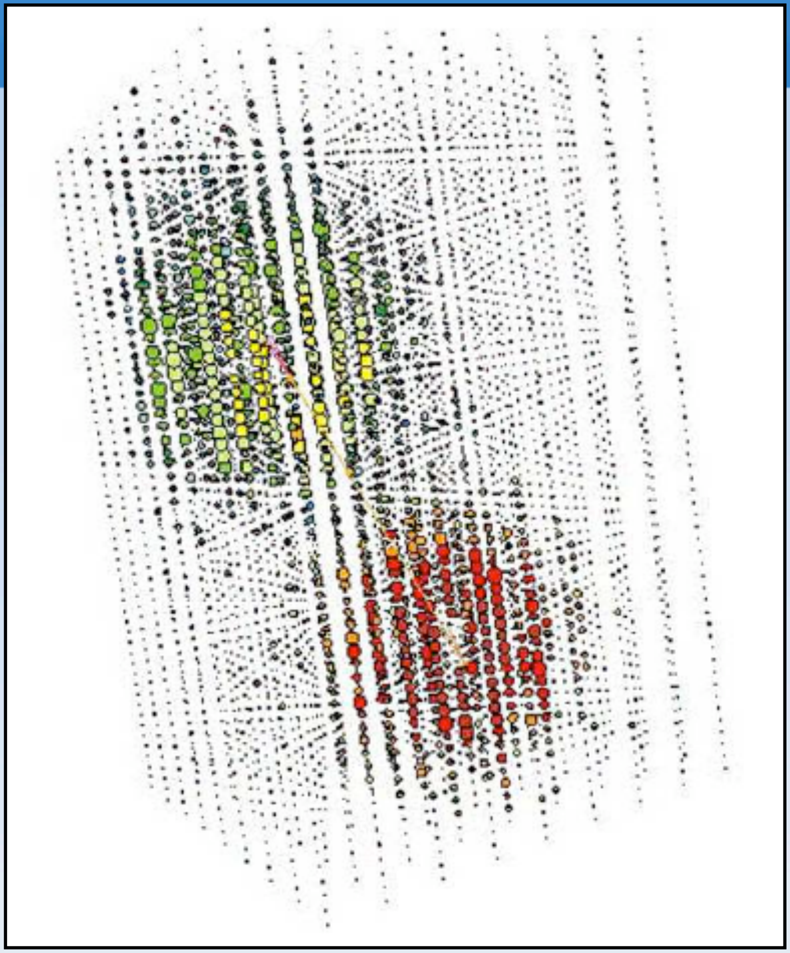


ANTARES

- Astronomy with a Neutrino Telescope and Abyss environmental RESearch
- Currently under construction, 5/12 strings completed
- 1000 photomultipliers, 0.1 km^2 planned
- Data will combine with AMANDA to provide better sky coverage

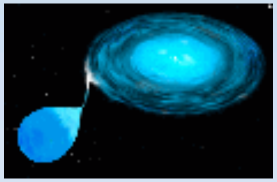
IceCube

- Next generation of neutrino telescopes
- 4200 photomultipliers, 1 km^2 telescope area
- 1^{O} angular resolution for muons, 10^{O} for showers
- 30% resolution in log of energy for muons, 20% in energy for showers



Astronomy

- Extremely high energy protons (over 10^{20} eV) have been observed
- Expected to come from supernova remnants and neutron stars accreting matter from companions



- These processes are expected to generate neutrinos as well, which would point back to their source

Astronomy

- Active Galactic Nuclei are the most luminous known objects in the Universe ($10^{35} - 10^{41}$ W)
- Some emit relativistic jets with γ rays exceeding 10^{12} eV
- Theoretical models of AGNs have large uncertainties
- Any observations of these sources (such as neutrino emissions) are helpful

Astronomy

- *γ* ray bursts are extremely violent releases of energy (10^{45} J in ~1 sec in *γ rays alone*)
- We don't have a good theory about the mechanism of *γ ray bursts*
- *By observing the afterglow, we can determine what happens, but not how it starts*

Neutrino Physics

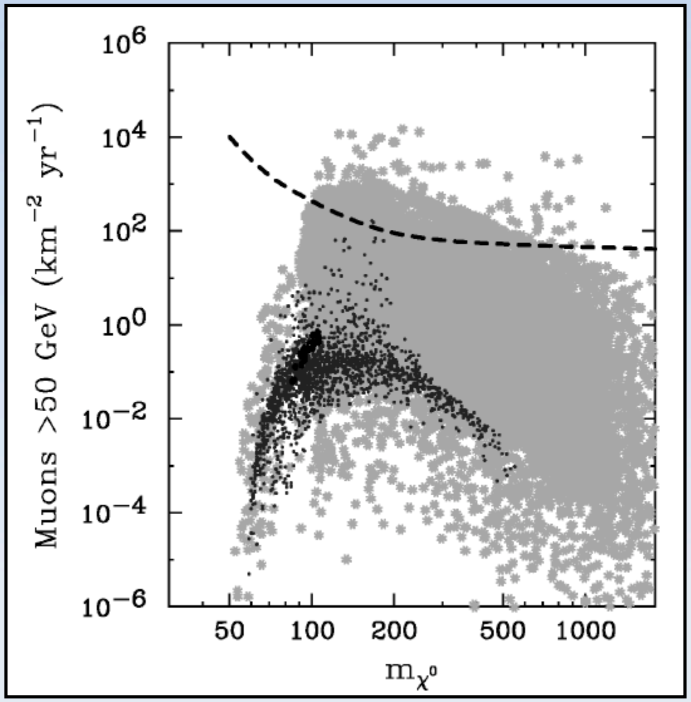
- A neutrino telescope can see atmospheric neutrinos produced on the other side of the Earth
- This gives a very long baseline for neutrino oscillation observations
- Much more accurate neutrino oscillation measurements, possibly including a sterile neutrino

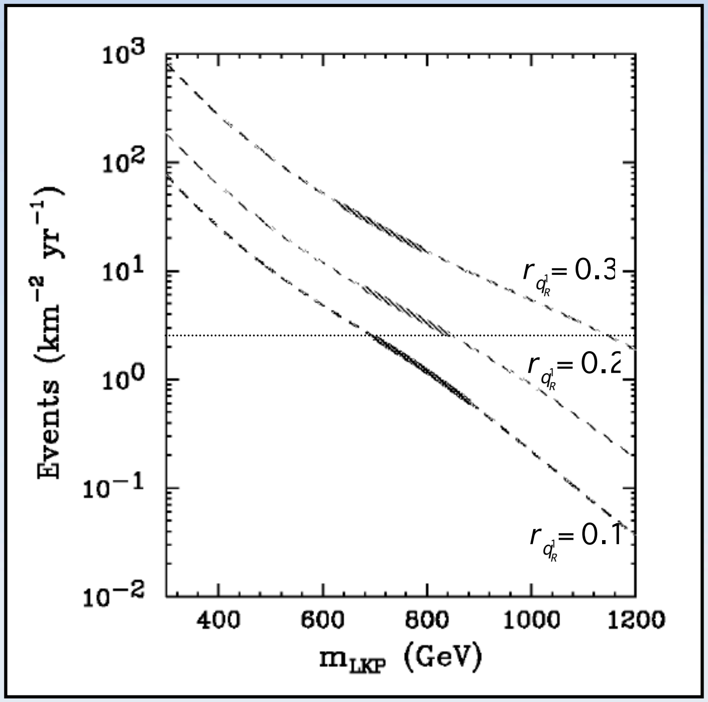
Dark Matter Searches

- WIMPs can get trapped in gravity wells and annihilate at great rates
- γ rays would be absorbed, but neutrinos could be detected
- Neutrinos have energies 1/3 - 1/2 of WIMP mass
- Kaluza-Klein dark matter annihilates into neutrinos at a higher rate than WIMPs

Dark Matter Searches

- Both dark matter candidates would lead to an increased neutrino rate from the Sun:



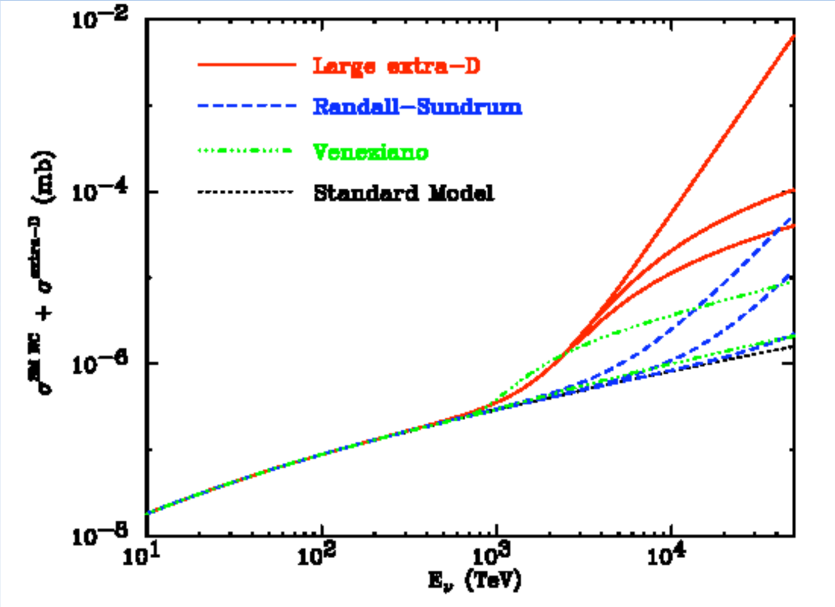


Possible Exotic Results

- Neutrino telescopes are essentially detectors for extremely high energy accelerators (10 PeV)
- We might see new physics at energy scales this high

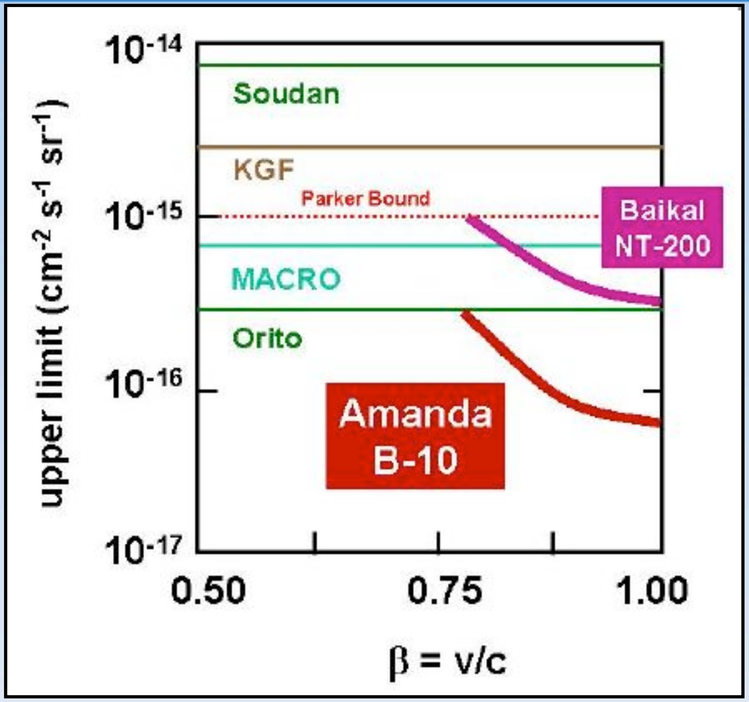
Quantum Gravity

- Earth becomes opaque above ~100 TeV
- Angular distribution can give cross section
- Don't need known luminosity of source



Magnetic Monopoles

- Magnetic monopoles would have a large equivalent charge
- Cherenkov radiation goes as charge squared
- AMANDA has improved the bound on monopole flux density



References

- Francis Halzen, Astroparticle Physics with High Energy Neutrinos: from AMANDA to IceCube
- Dan Hooper, High Energy Neutrino Astronomy: Opportunities for Particle Physics
- Gianfranco Bertone, Dan Hooper and Joseph Silk, Particle Dark Matter: Evidence, Candidates and Constraints
- ANTARES web site: http://antares.in2p3.fr