GIGANTIC TELESCOPES FOR TINY COSMIC MESSENGERS

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GRC —THE WELLINGTON SCHOOL

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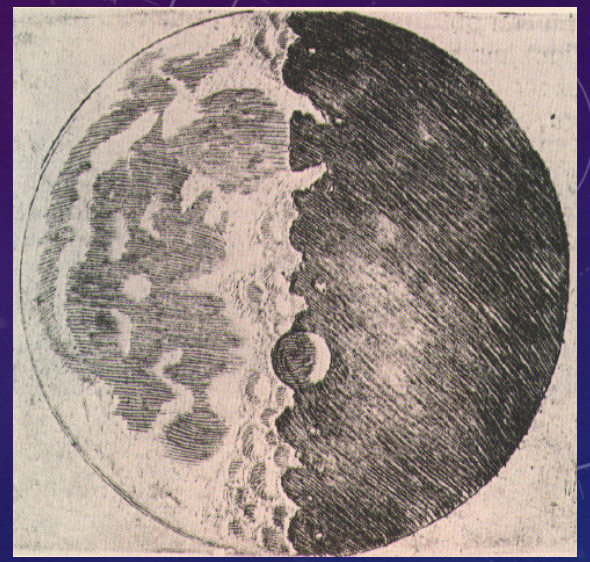
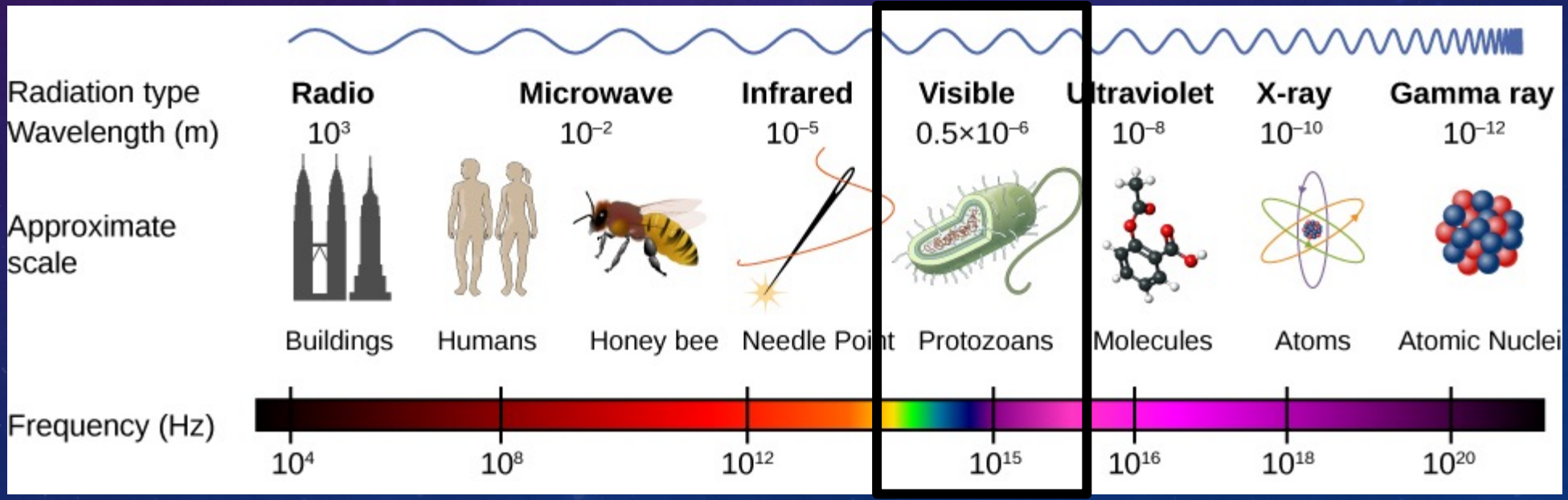
ABOUT ME

- Fourth (!) year PhD Student and NSF Graduate Research Fellow
- Study neutrino particle astrophysics with Prof. Amy Connolly
- Studied x-ray astronomy in undergrad (also tried and hated condensed matter)
- Graduated in 2014 from Washington University in St. Louis
- Originally from St. Louis, MO

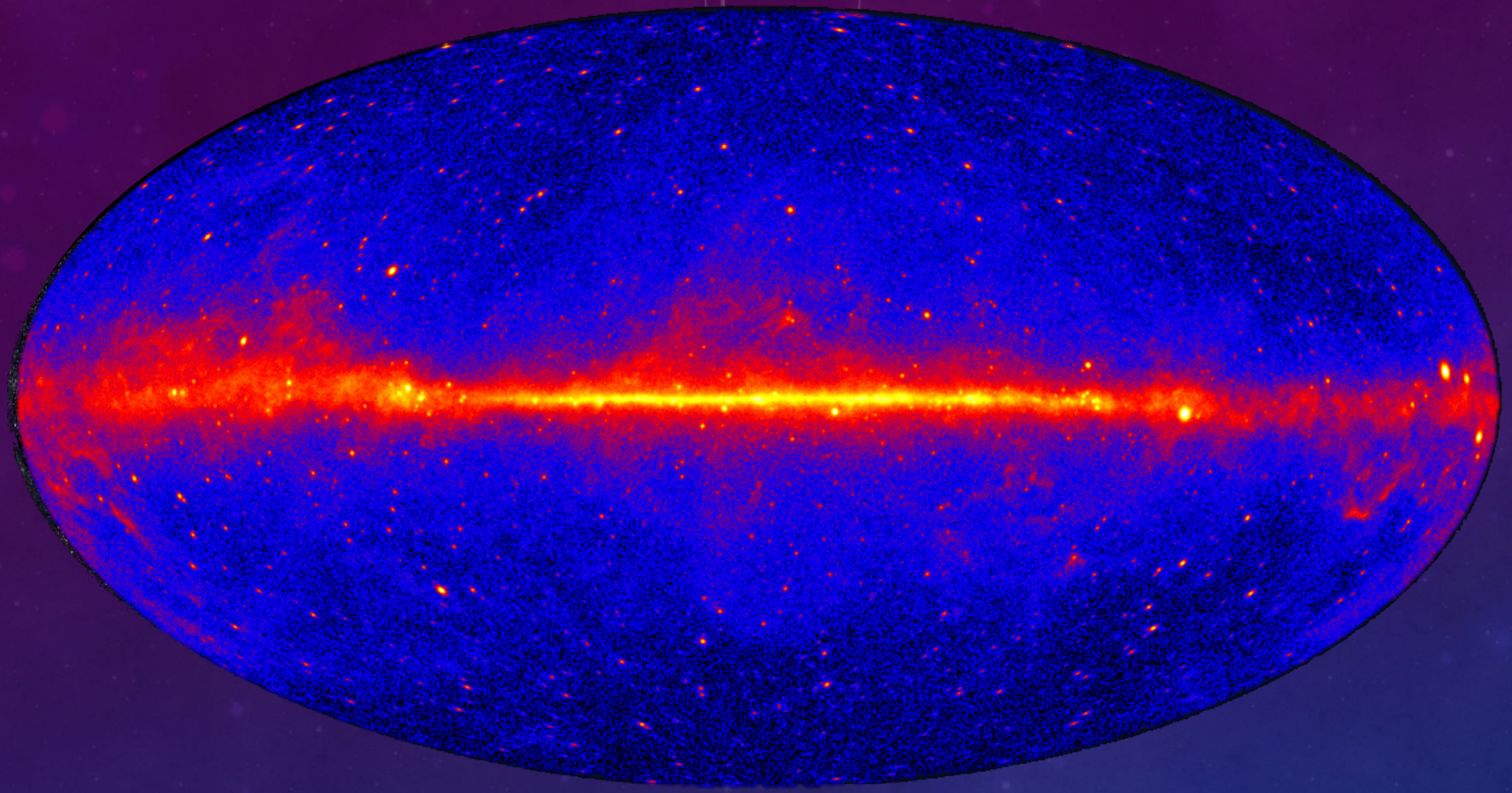
TELESCOPES

- Telescopes help us look at the sky
- Traditionally use *light*
- 1610: Galileo used *visible* light



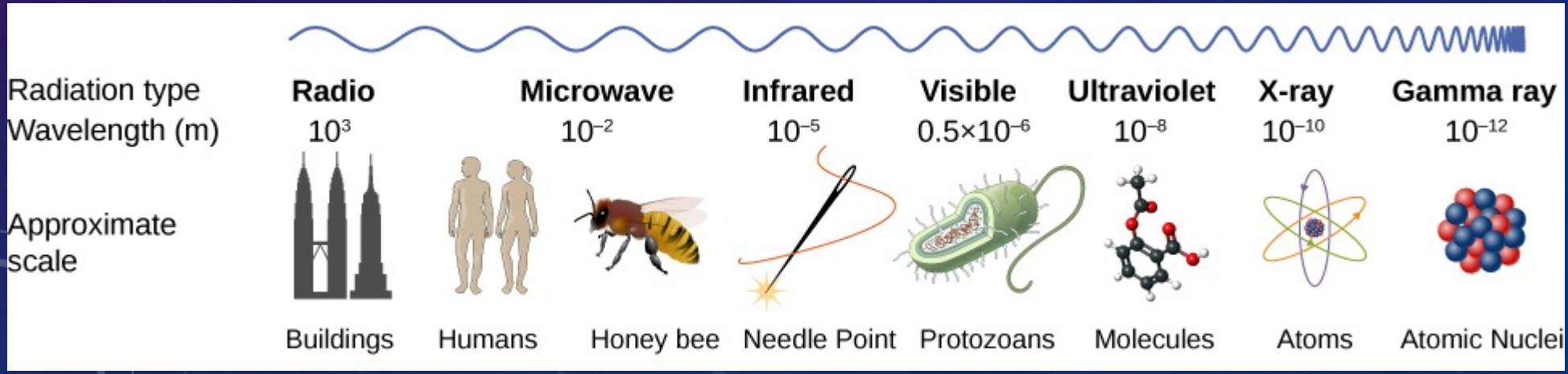


THE NIGHT SKY



Fermi Gamma-ray Space Telescope

Gamma Rays

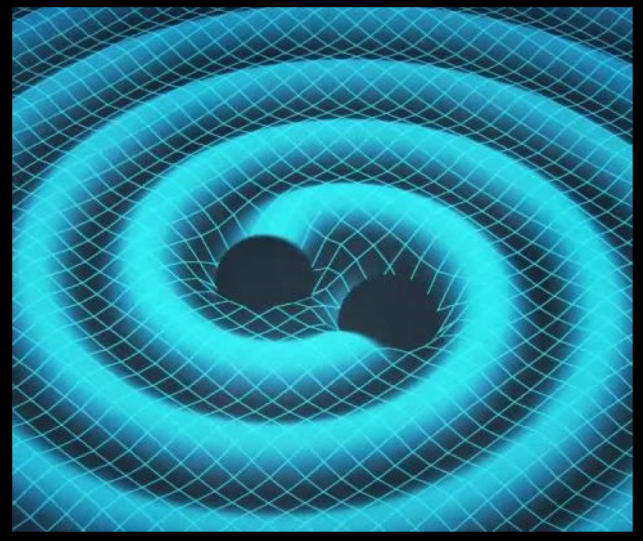


OTHER MESSENGERS

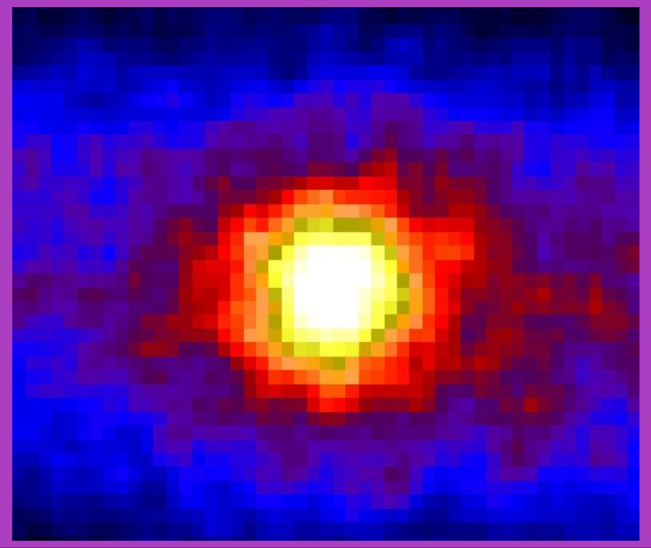
Photons
Light

Cosmic Rays
Protons,
Neutrons,
Electrons

Gravitational
Waves



Neutrinos



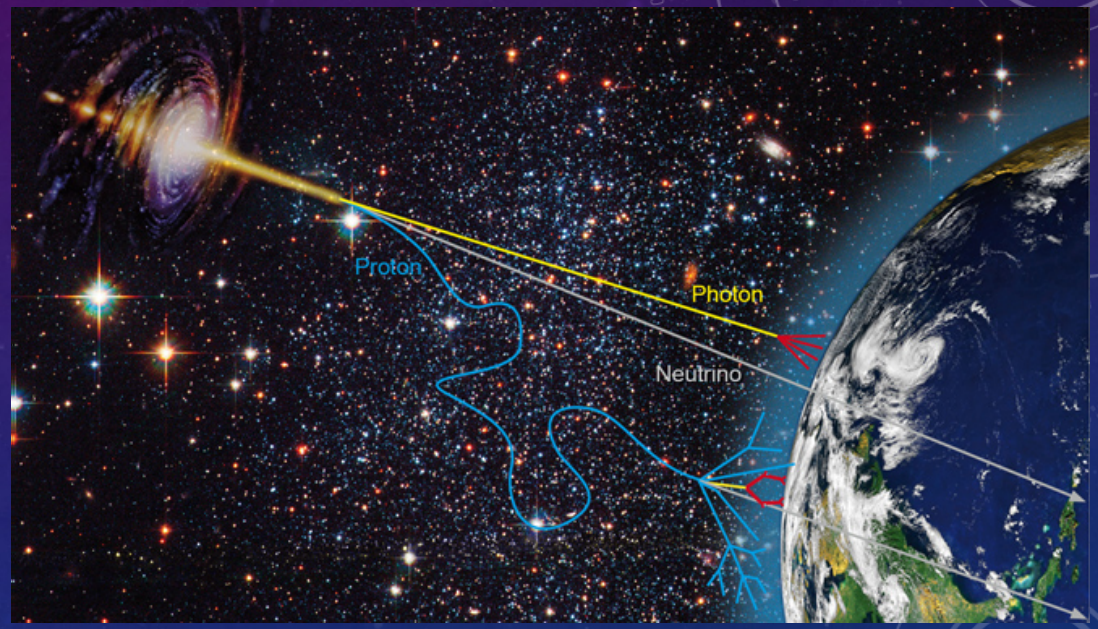
WHY ARE NEUTRINOS USEFUL?

<u>Astrophysics</u>: Only probes of the highest energies at cosmic distances

- Cosmic rays
  - Bend in magnetic fields
  - Interact with the Cosmic Microwave Background (CMB):

$$p + \gamma \rightarrow n + \pi^{+}$$

- Gamma rays interact with the CMB



<u>Neutrinos have attractive properties</u>

- Weakly interacting: travel far, don't get stopped
- Chargeless: not deflected by magnetic field → point back to source!

WHERE *SHOULD* NEUTRINOS COME FROM?

- "Cosmic Flux": Destroyed cosmic rays decay into neutrinos

$$p + \gamma \rightarrow e^{+} + \nu_e + \bar{\nu}_\mu + \nu_\mu$$

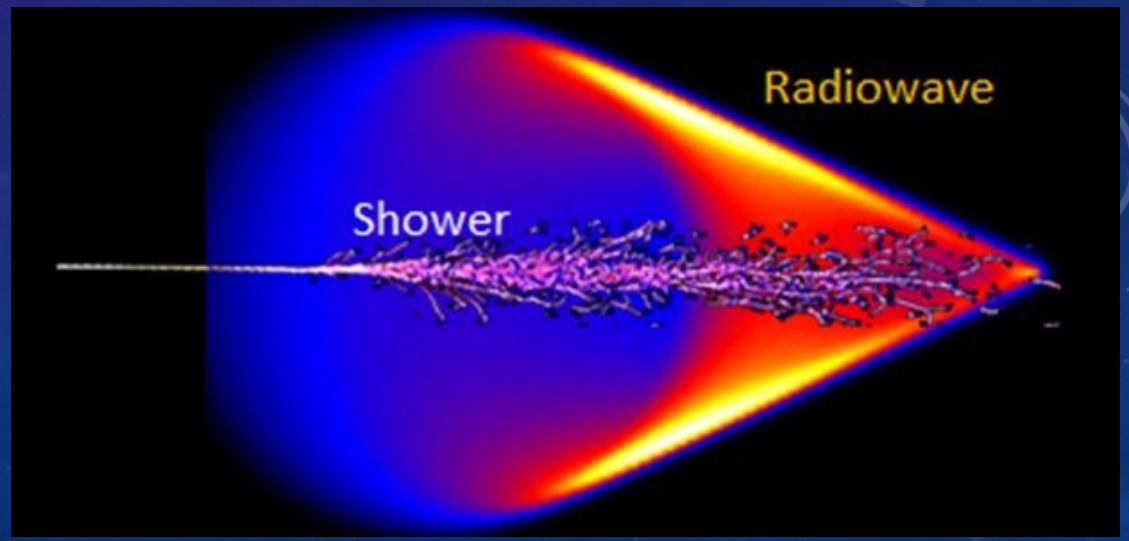
- "Source Flux": Neutrinos from powerful space objects

Active Galactic Nucleus Centaurus A.
(ESO public image release)

WHAT DOES A NEUTRINO INTERACTION LOOK LIKE?

- Neutrinos find nuclei, and scatter *inelastically* (basically blow up the atom!)

- In ice and water, the resultant shower moves faster than light
- Generate an sonic boom, but in *light*
  - Get burst of blue light: Cherenkov radiation
  - And a burst of radio waves: Askaryan radiation



LIFE IS HARD

- Searching for neutrinos with energy $>10^{17}$ eV

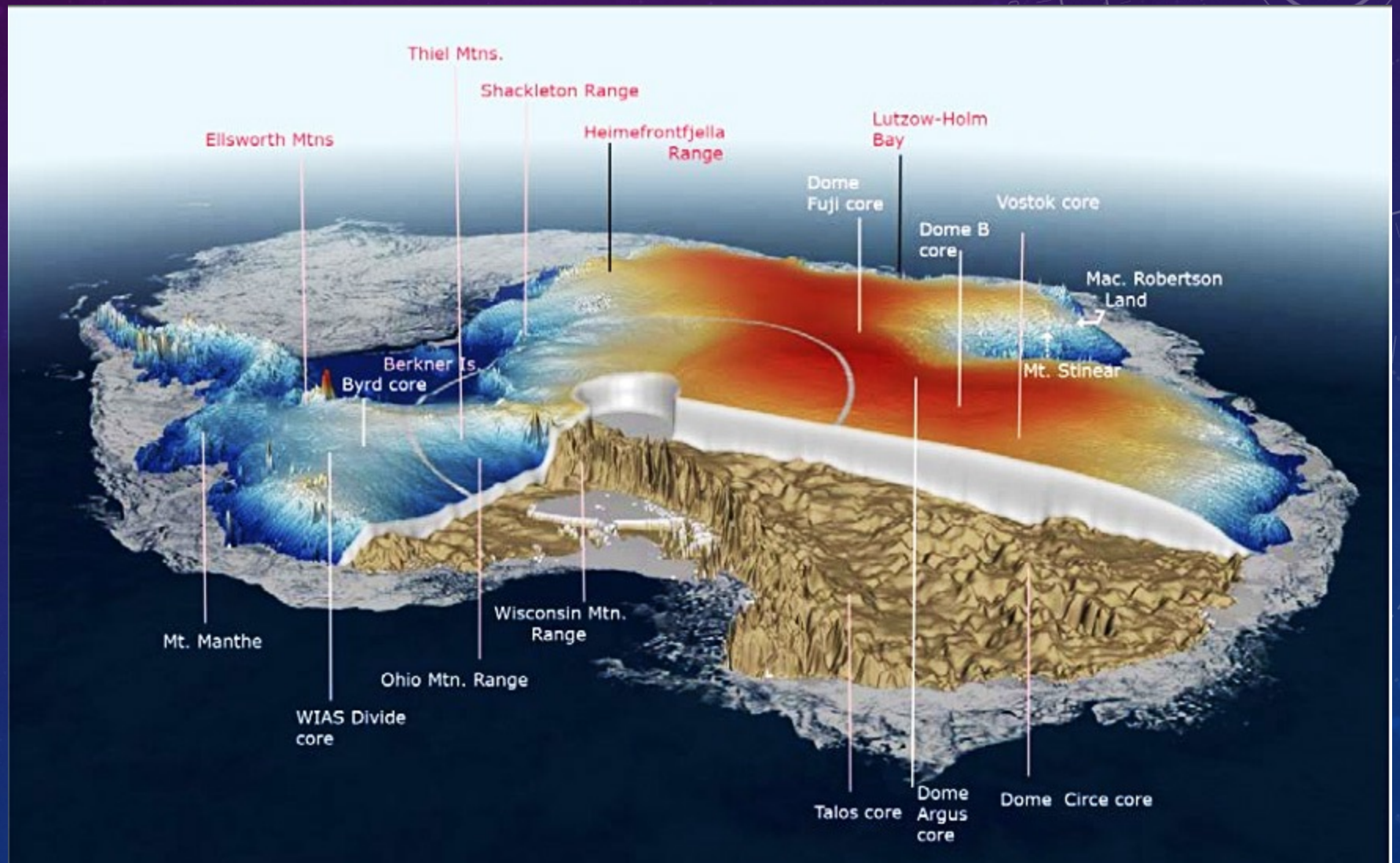
  (about the energy of a slow curling stone)

- They have small fluxes and even smaller cross sections

- In a detector the size of the horseshoe:
  - Passes through: once in a year
  - Interacts: once in a decade

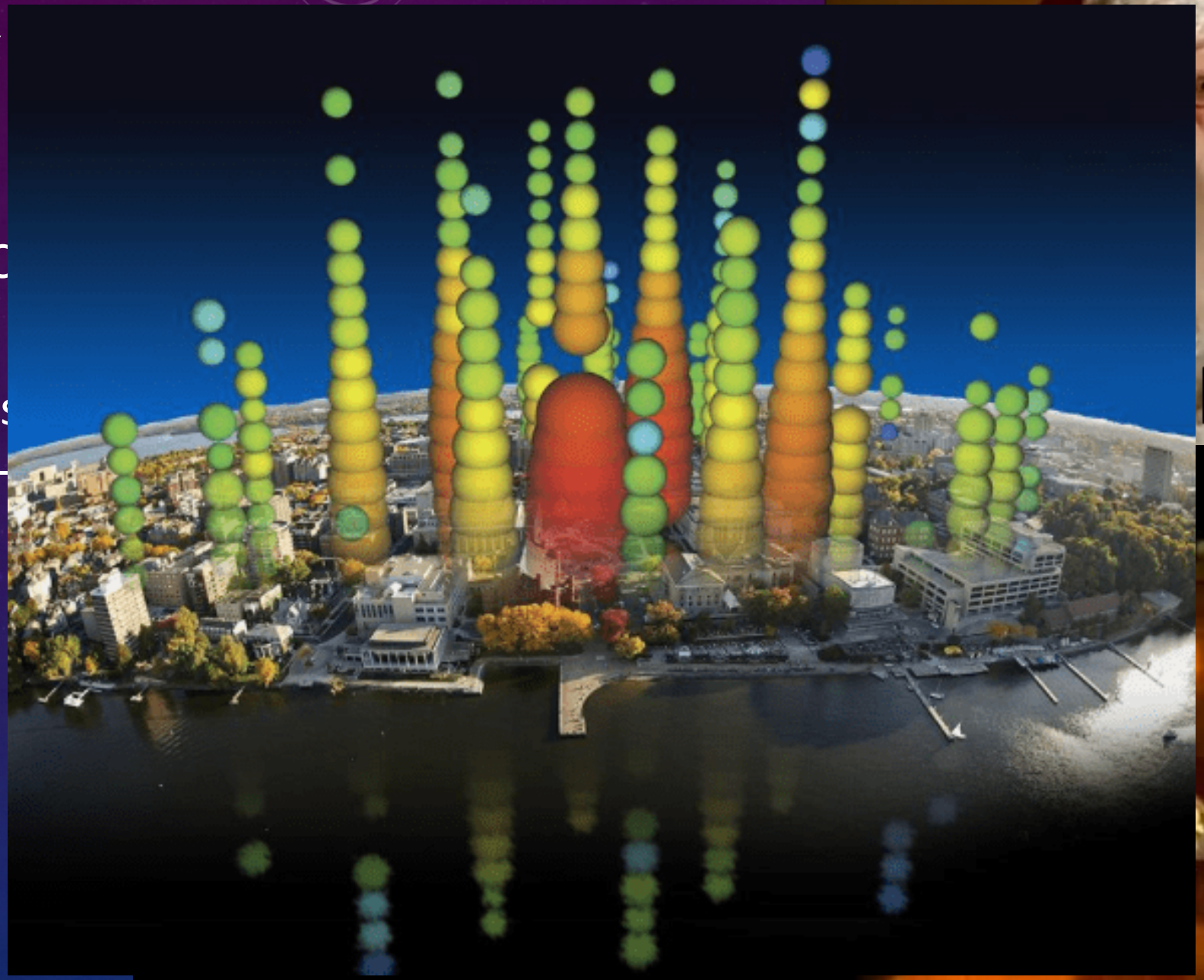
TO MAKE A DETECTION

- Challenge: Need a radio clear medium & lots of it
- Answer: Antarctica



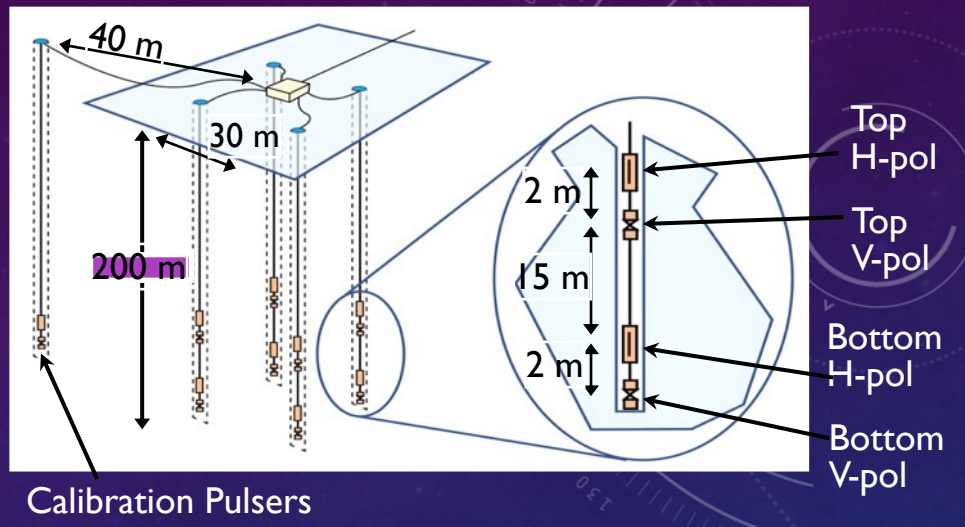
DO THEY

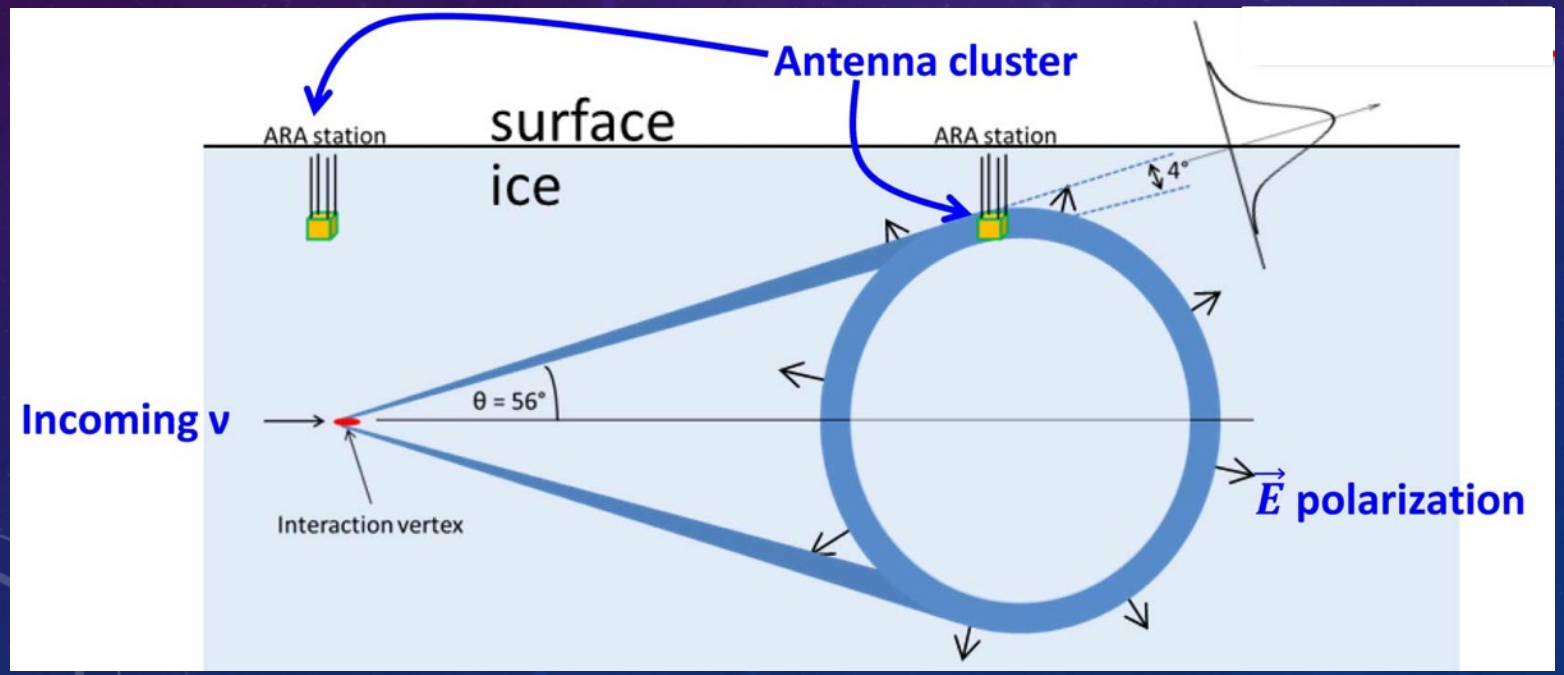
- Yes!!
- 2012: IceC
  neutrinos
- Today's dis
  energetic-



ASKARYAN RADIO ARRAY

- Drill holes 200m deep at South Pole, and drop antennas down!
- 16 antennas in cubical lattice at 200m depth
- Two different polarization antennas (8 Vpol, 8 Hpol)

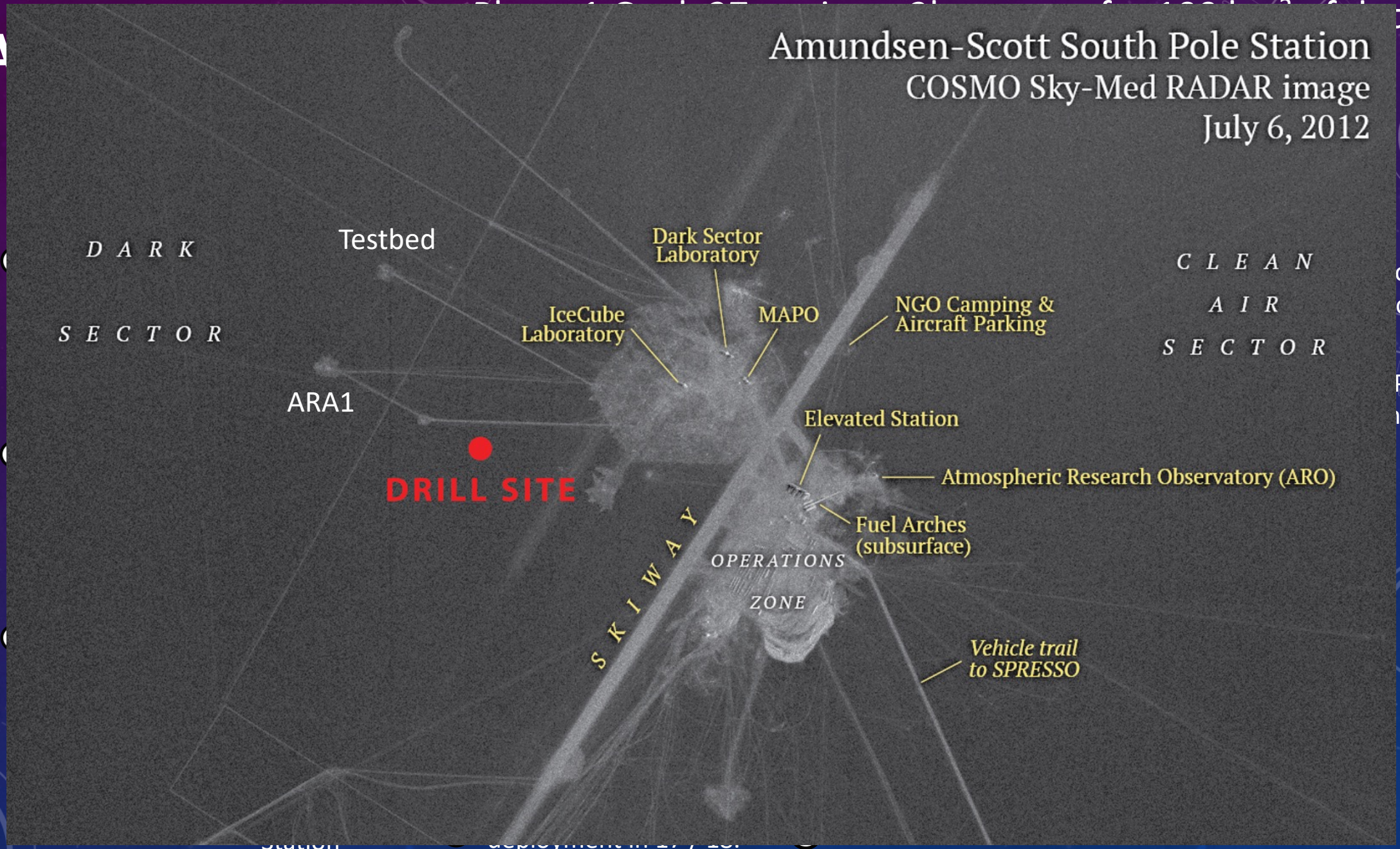




VPol Antenna

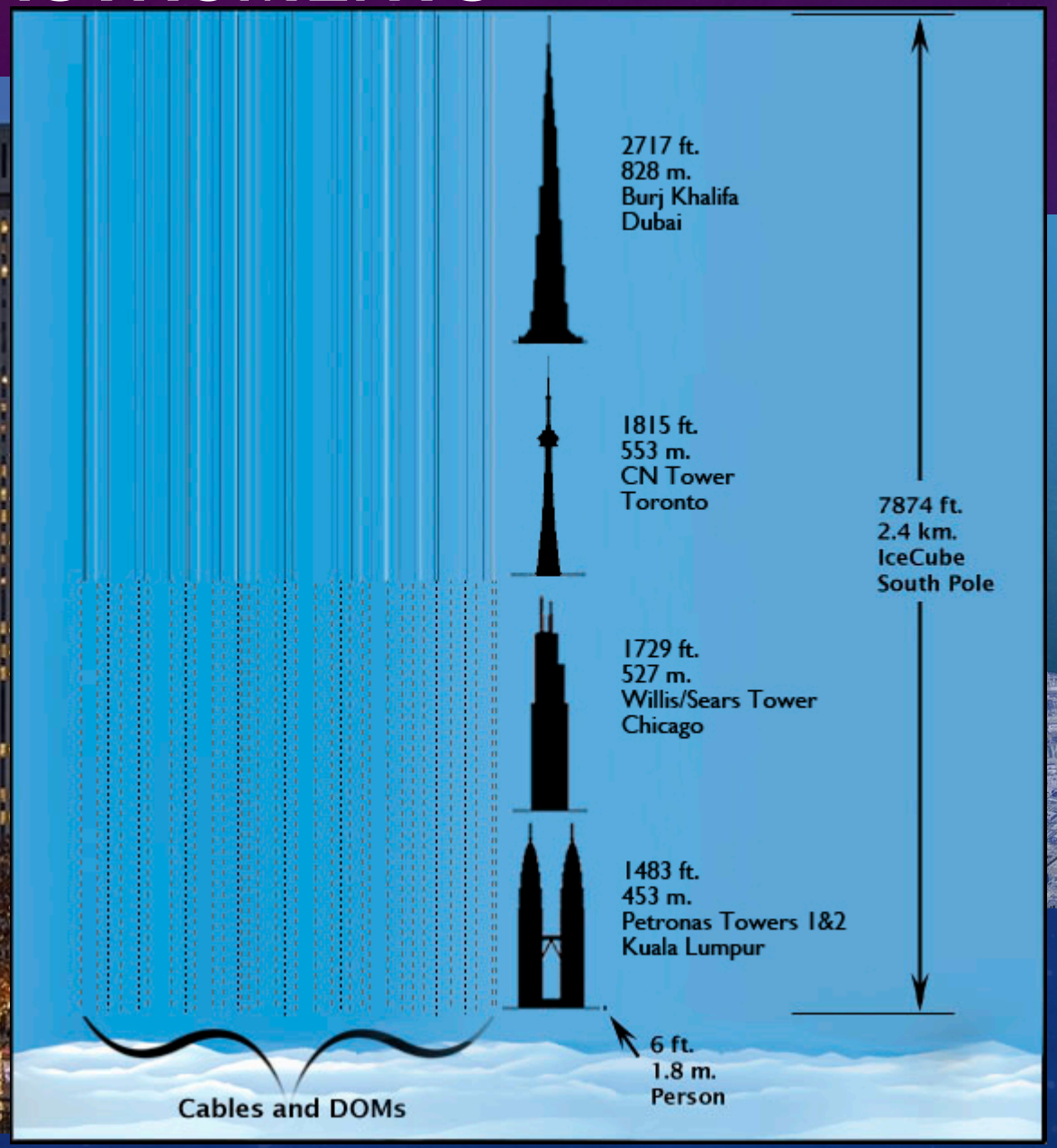
HPol Antenna

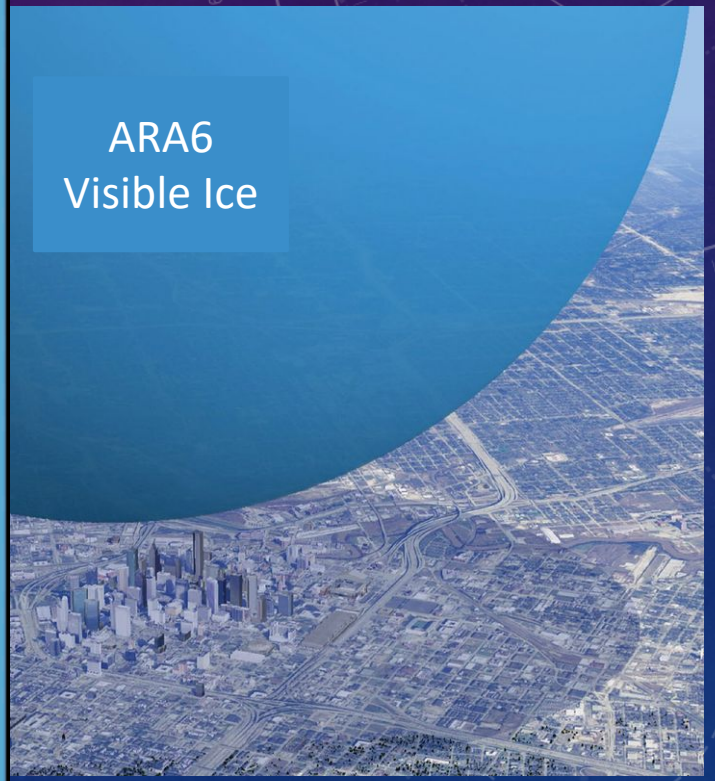
STA


Amundsen-Scott South Pole Station
COSMO Sky-Med RADAR image
July 6, 2012
DARK
SECTOR
Testbed
ARA1
DRILL SITE
Dark Sector Laboratory
IceCube Laboratory
MAPO
NGO Camping & Aircraft Parking
CLEAN AIR SECTOR
Elevated Station
Atmospheric Research Observatory (ARO)
Fuel Arches (subsurface)
SKIWAY
OPERATIONS ZONE
Vehicle trail to SPRESSO

GARGANTUAN INSTRUMENTS

One Nationwide Plaza
146m = 485 ft

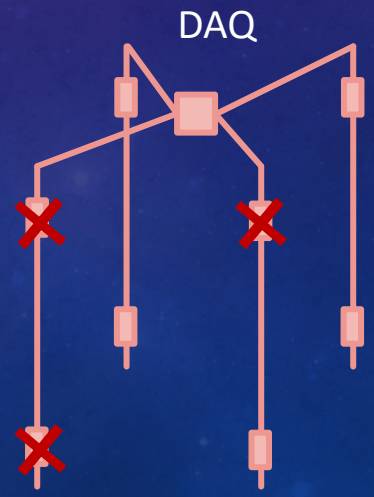


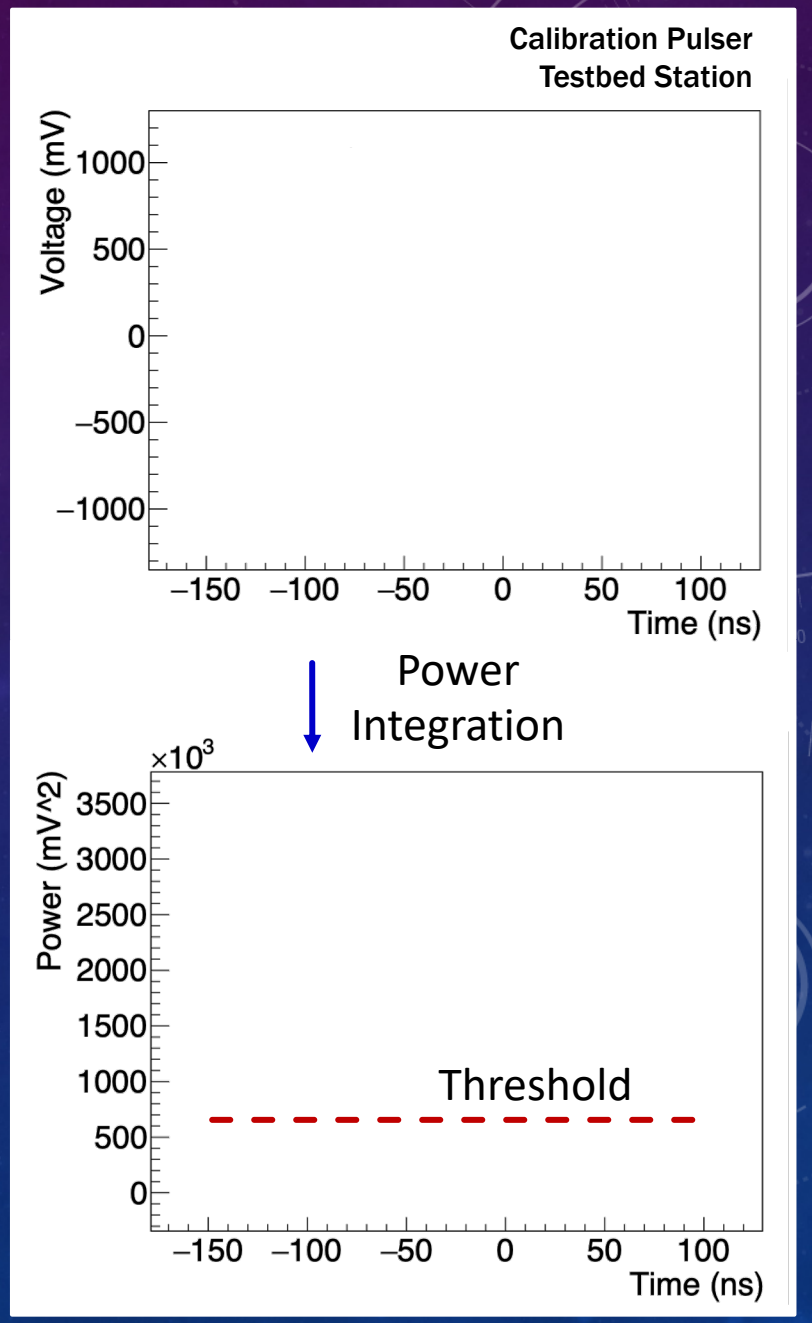


WHAT DOES DATA LOOK LIKE?

- 16 waveforms (like you'd see on oscilloscopes)
- Looking for a *threshold crossing* in power
- Wait until 3/8 antennas register a spike, then readout and store the data
- 10^8 events/station/year!
- Principal backgrounds:
  - Ice itself makes radio noise
  - People! (cell phones, radio…)

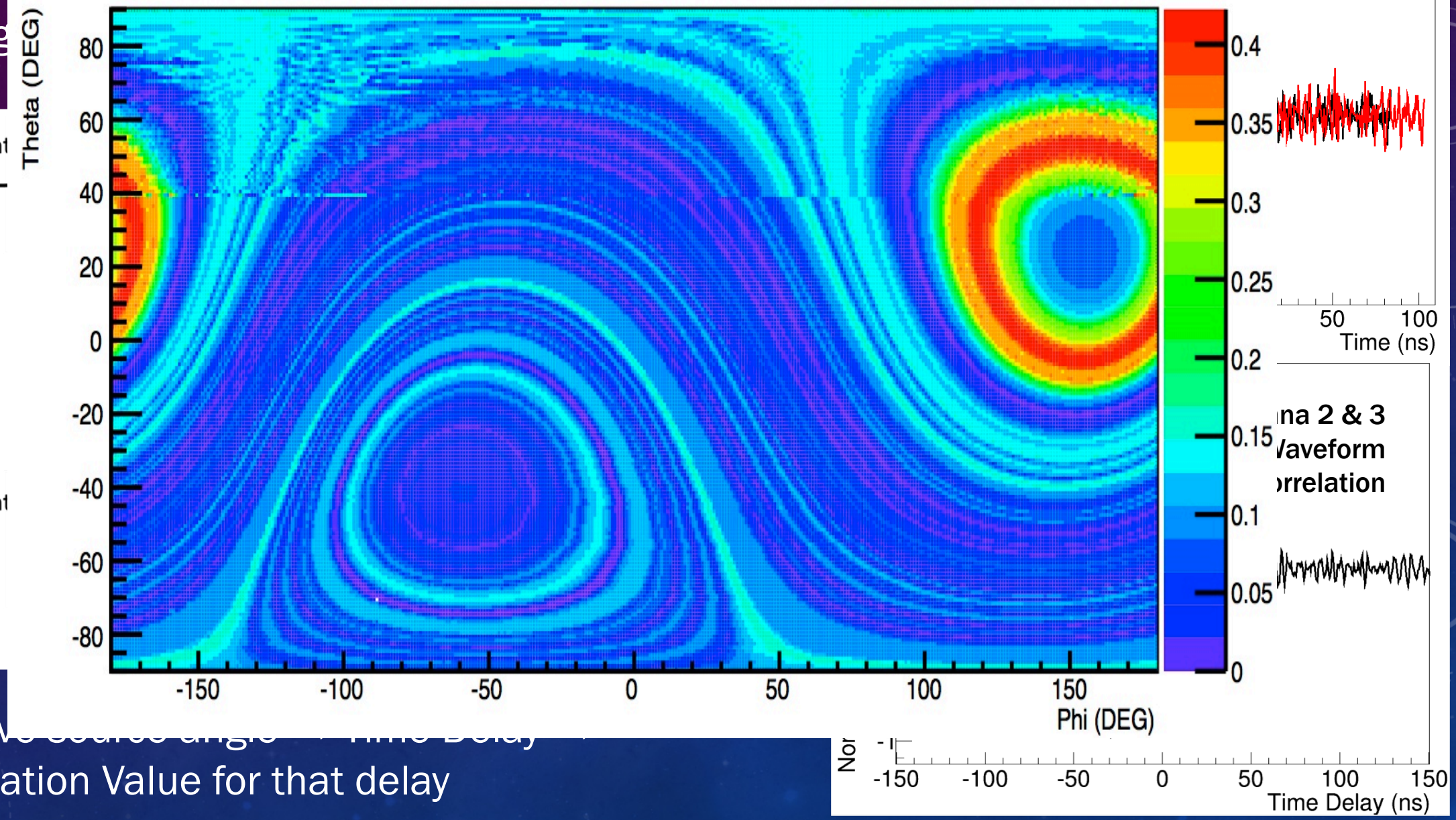
$\neq$ ν





DATA ANALYSIS: INTERFEROMETRY

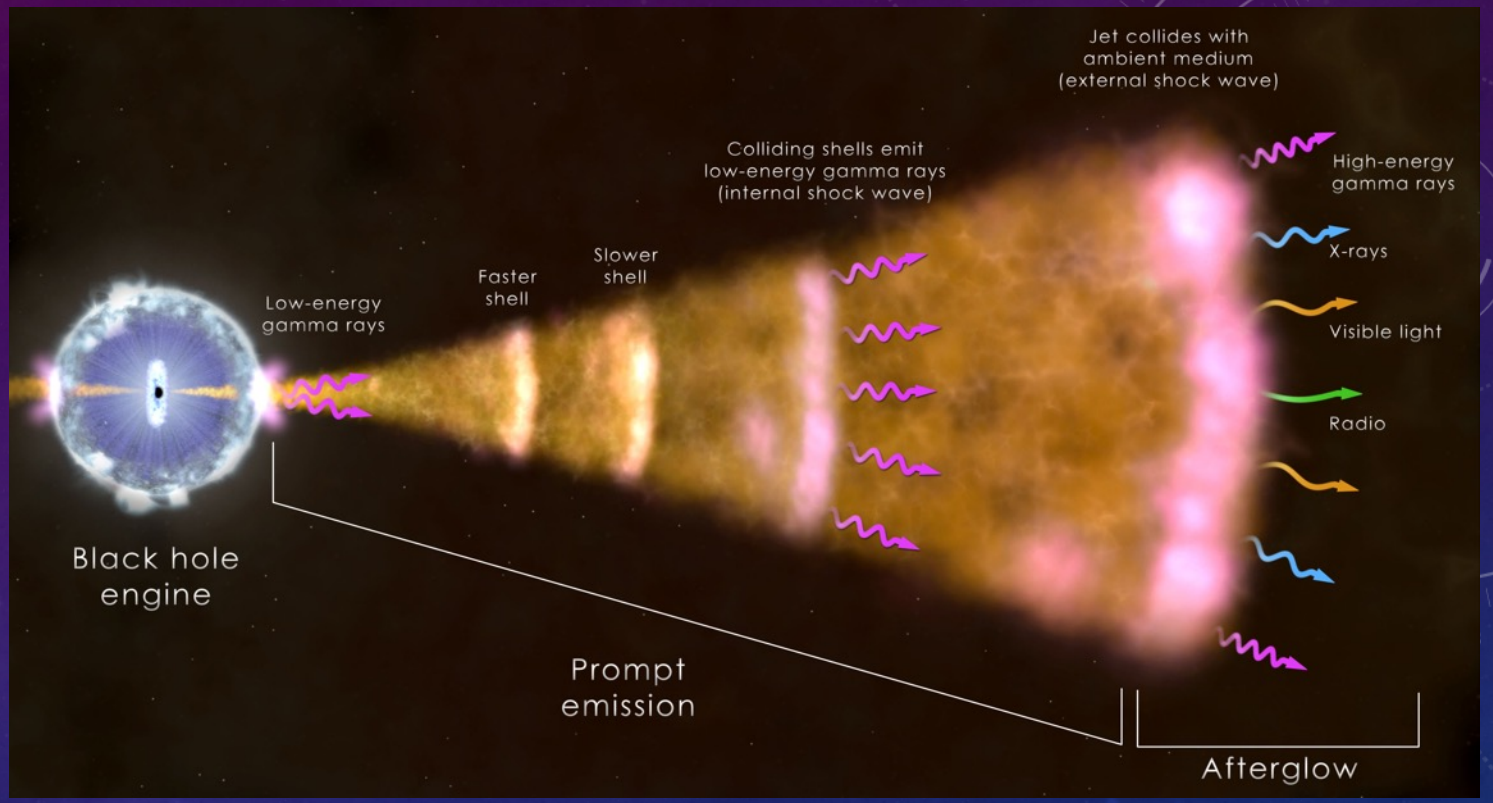
- Timing



- Punitive source angle → Time Delay → Correlation Value for that delay

RESULTS

- Have searched for
  - *Diffuse* emission (neutrinos from anywhere, anytime)
  - *Correlated* emission (neutrinos from GRBs)

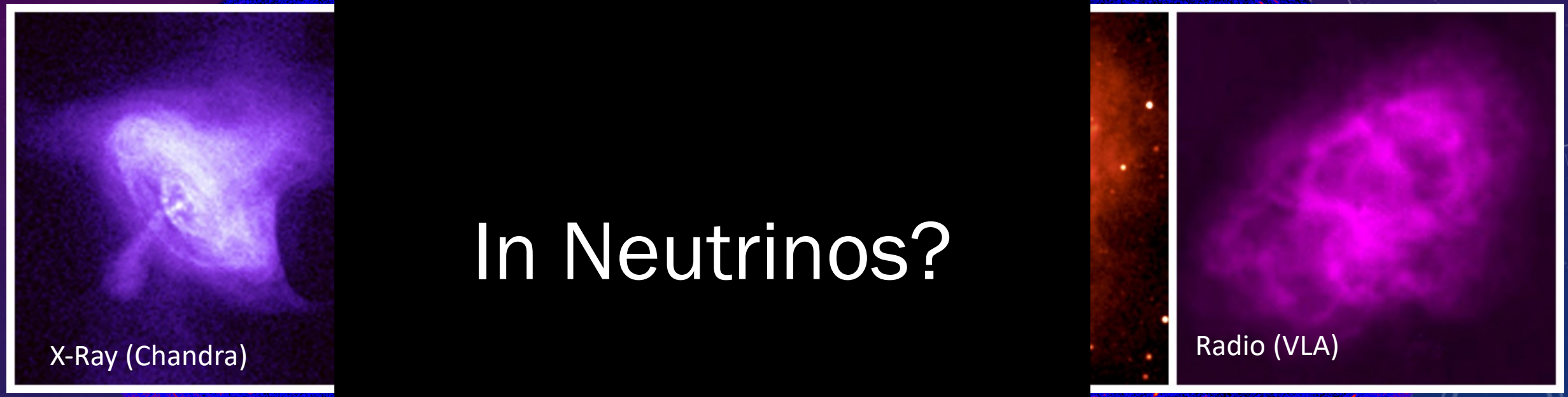


- No neutrinos yet!
  - It's not surprising
  - 3/37 isn't a very big detector!

- But, we think we're getting close

THE WORLD THROUGH NEUTRINO EYES?

Photo Credit: NASA Fermi Satellite



In Neutrinos?

THANK YOU!
QUESTIONS?

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- The OSU Center for Cosmology and Astroparticle Physics
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