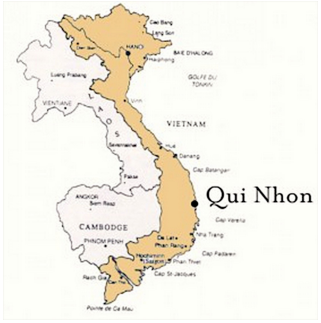
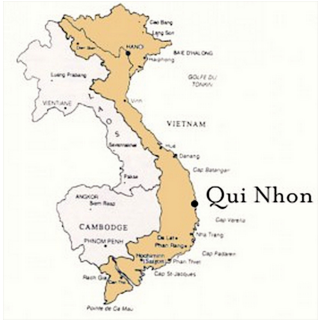



# Studying the Energetic Universe: Observatories for Cosmic Rays, Gamma Rays, Neutrinos, Gravity Waves and Dark Matter

Brenda Dingus
Los Alamos National Lab
4 August 2014



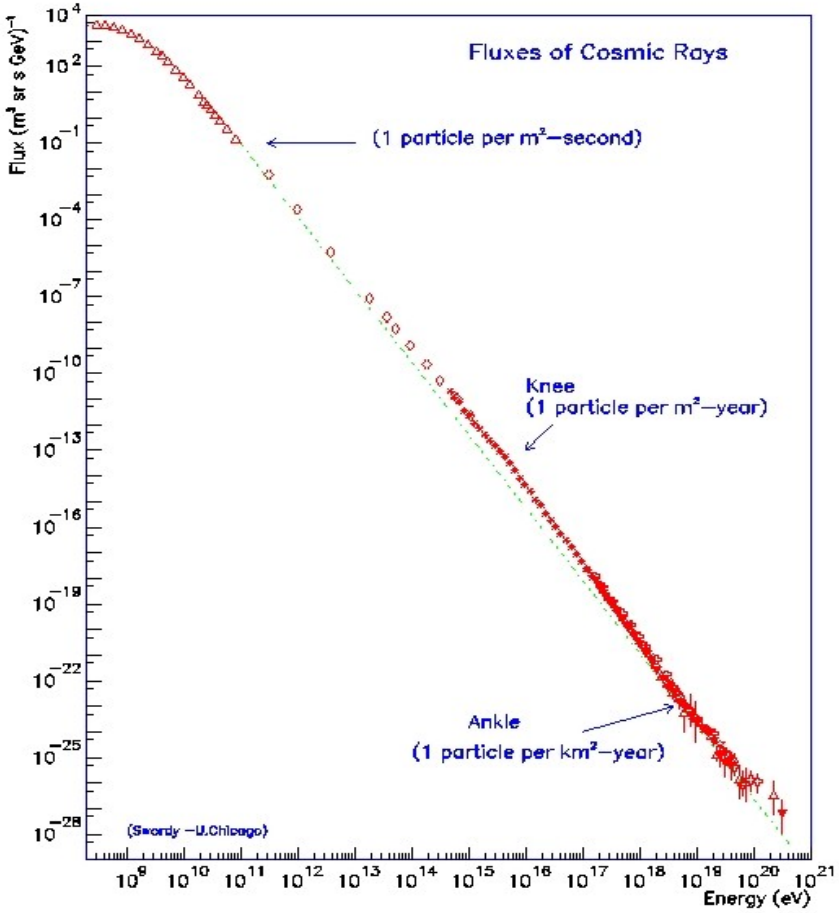

# Particle Accelerators

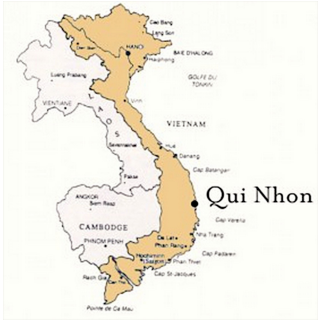
Large Hadron Collider, (LHC)

Geneva 7x1012 eV

Energy density of cosmic rays in our galaxy exceeds energy density in starlight in our galaxy

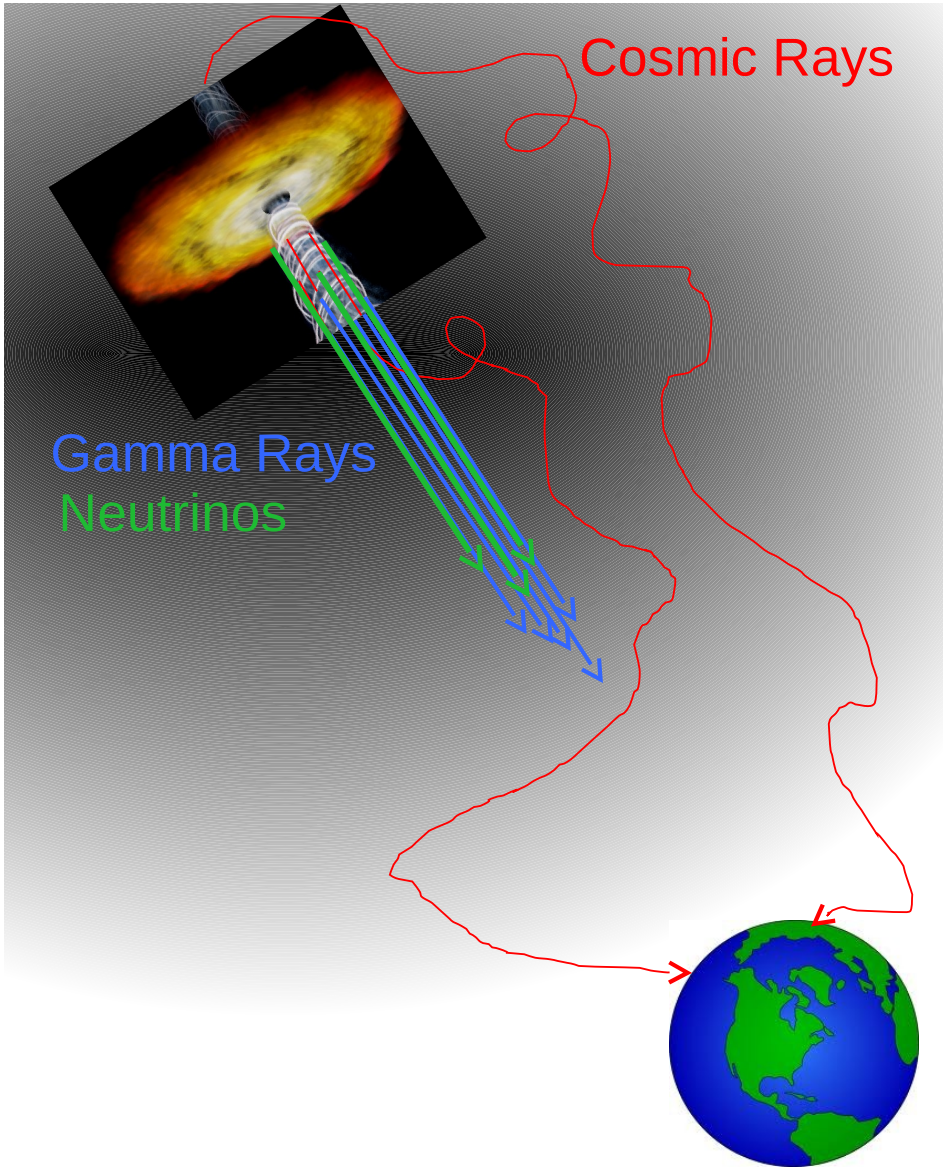
Nature accelerates cosmic rays to >1020 eV

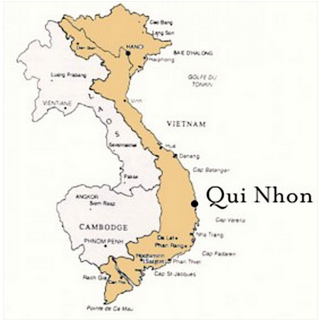




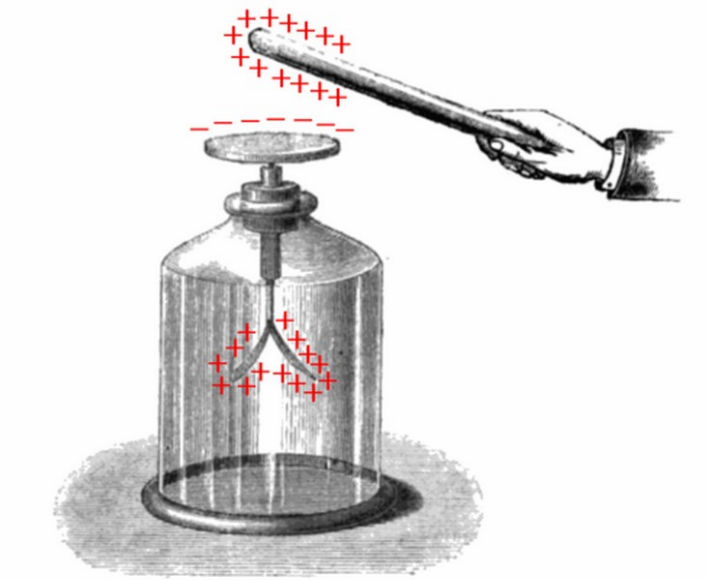

# Cosmic Ray Origins

- Cosmic rays are energetic particles that have electric charge => Directions are randomized by Magnetic Fields in the Universe
- Gamma rays and neutrinos are produced by cosmic rays near their accelerators => Directions point back to the Sources
- Sources of the most energetic cosmic rays are outside our galaxy, but still unknown
- Likely accelerators of these particles involve the intense gravitational and electromagnetic fields associated with black holes



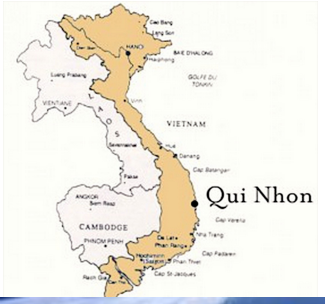


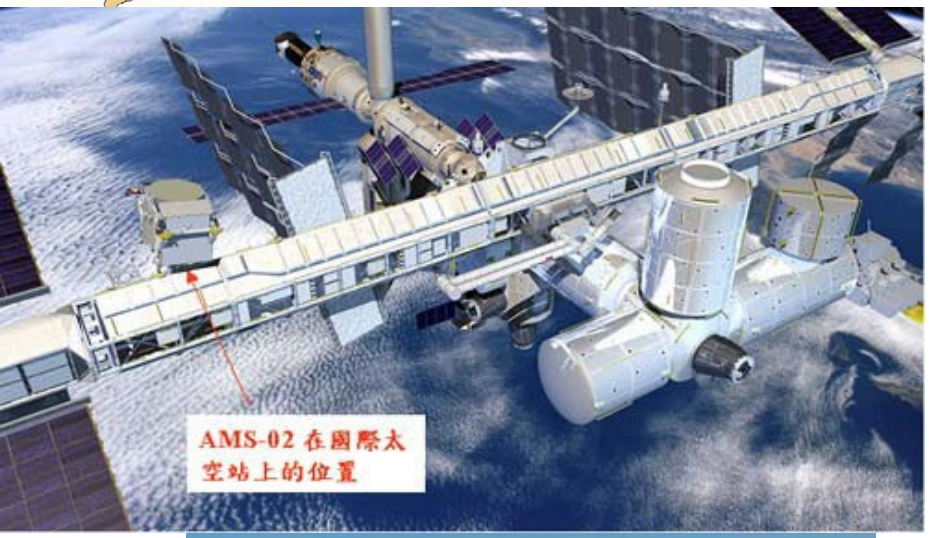

# Cosmic Rays were discovered in 1912 by Victor Hess

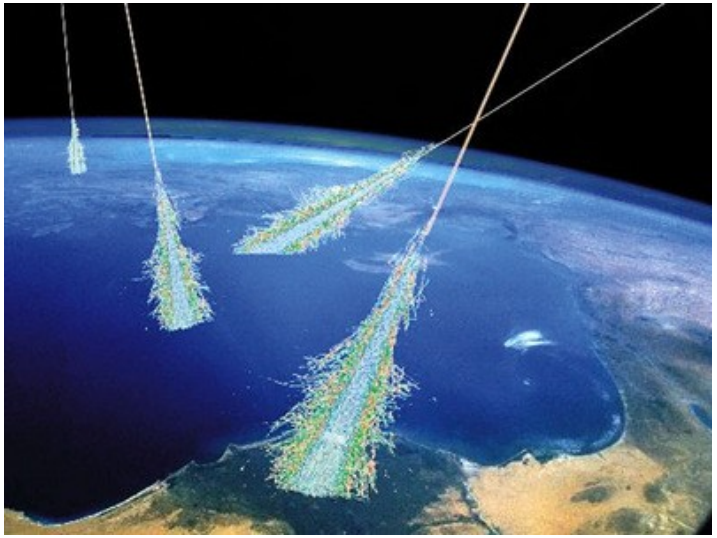


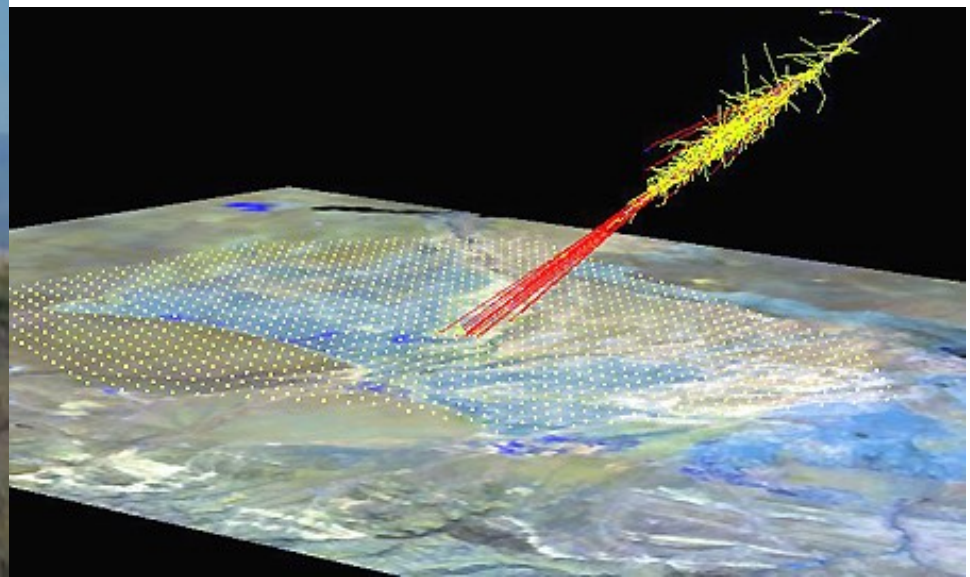
Electroscope discharged more quickly at higher altitudes proving that the radiation came from the cosmos and not from the earth.

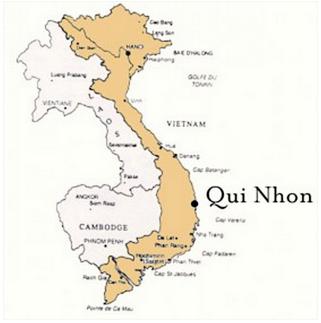
# Cosmic Ray Observatories



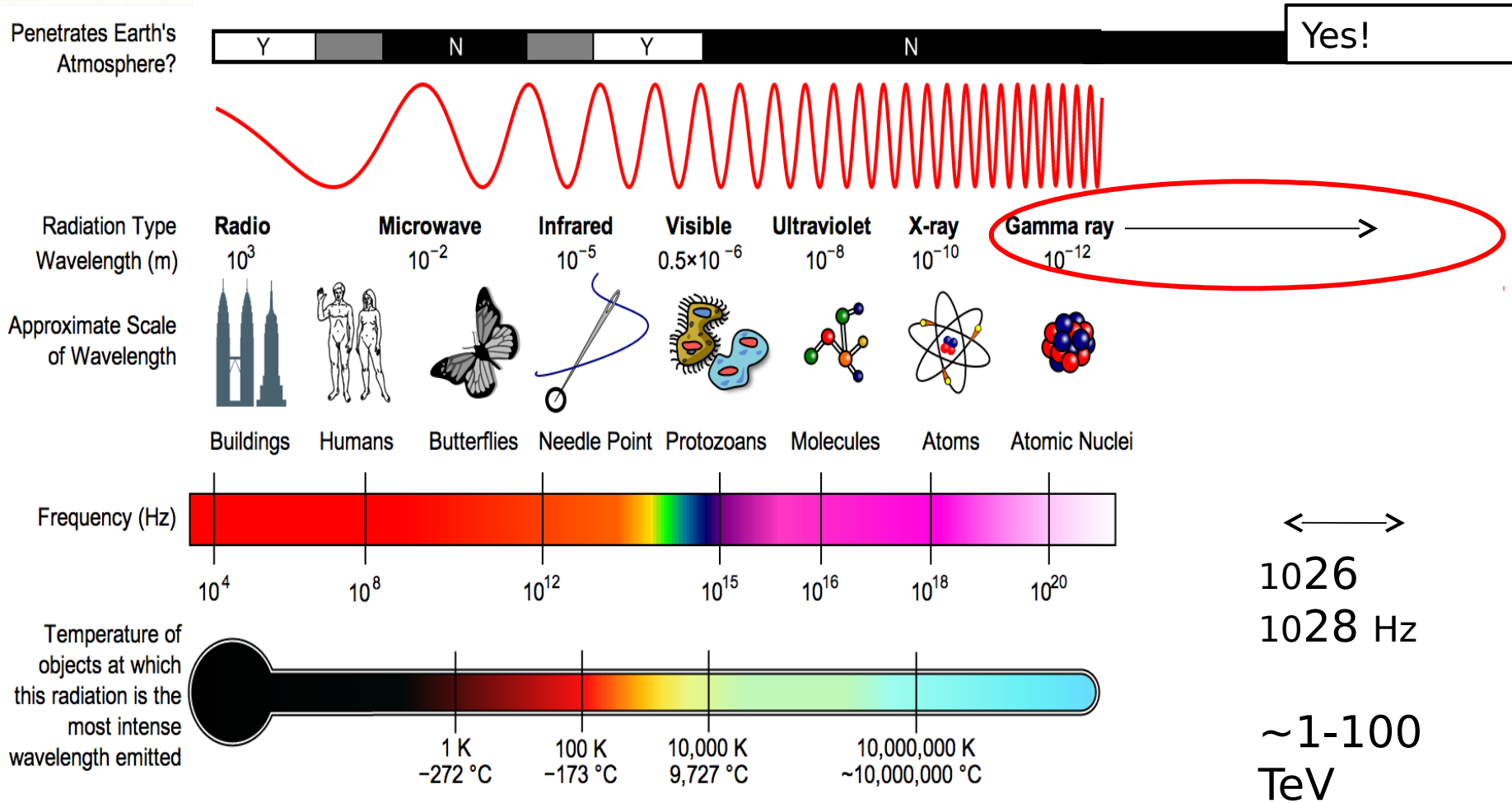








# Gamma Rays are the Highest Energy Light



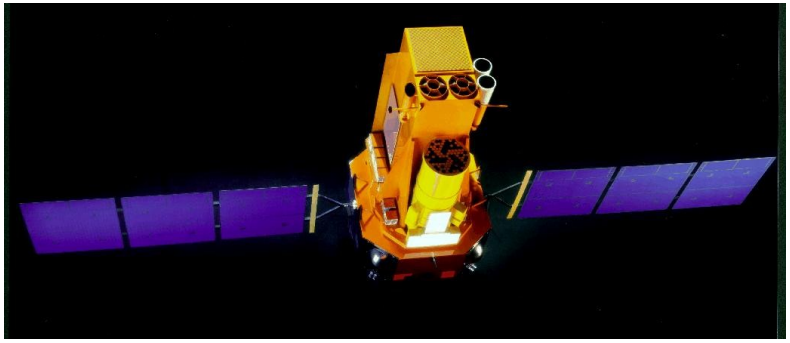

1026
1028 Hz

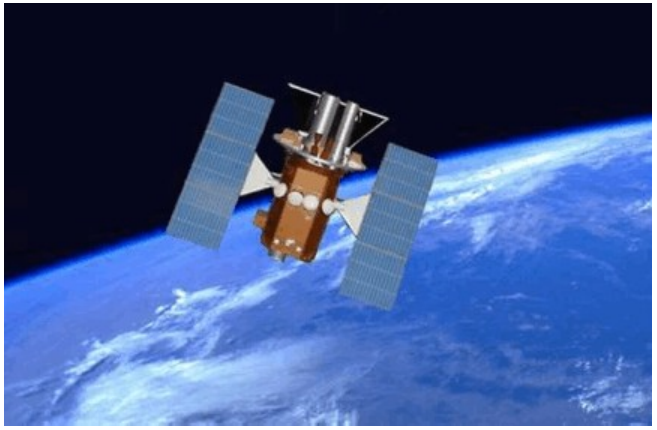
~1-100 TeV

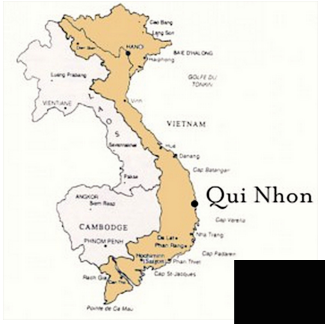
1TeV


VIETNAM
Qui Nhon
CAMBODGE

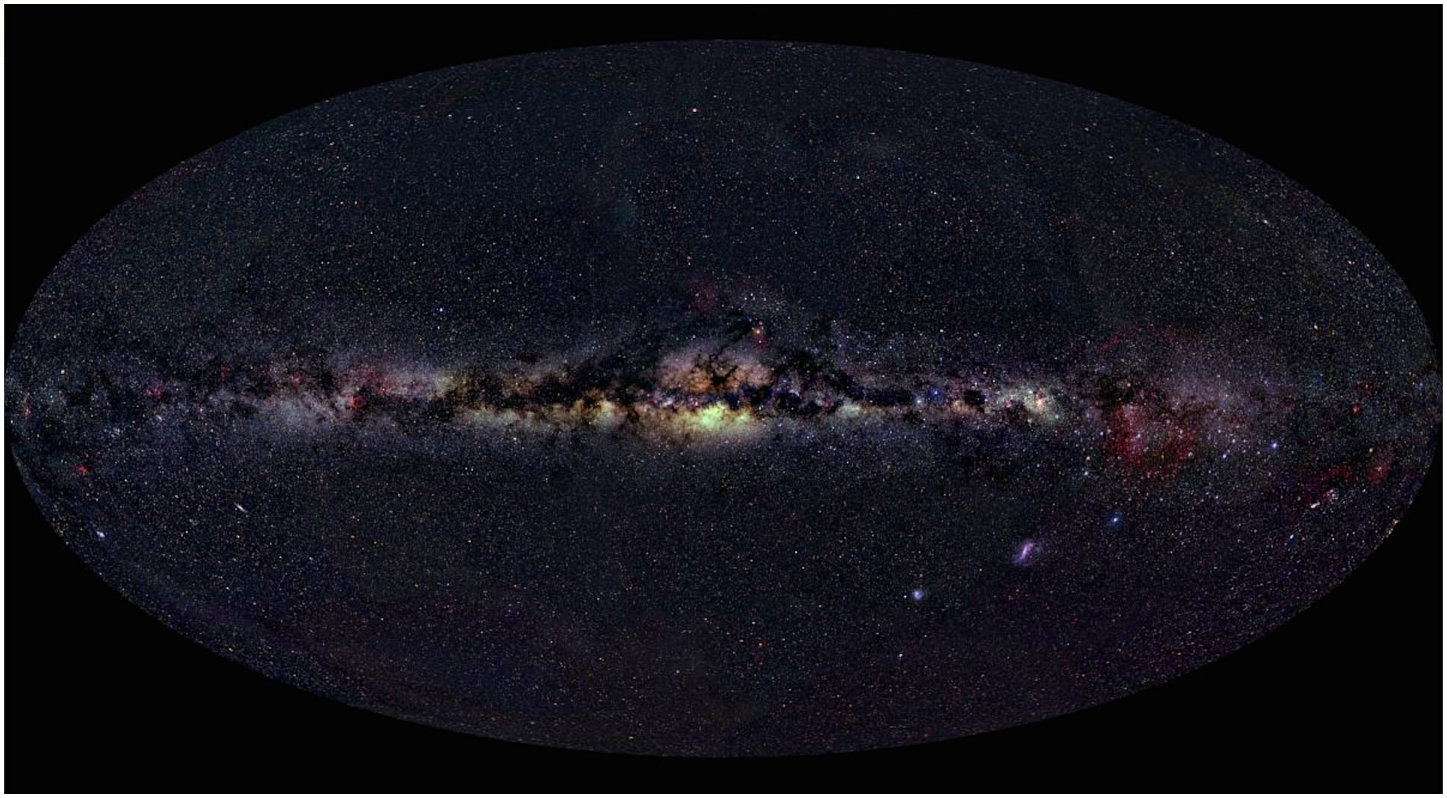

USAF
ULA
DELTA
GLAST



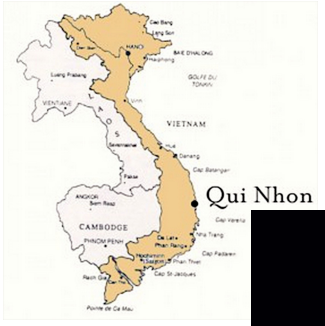




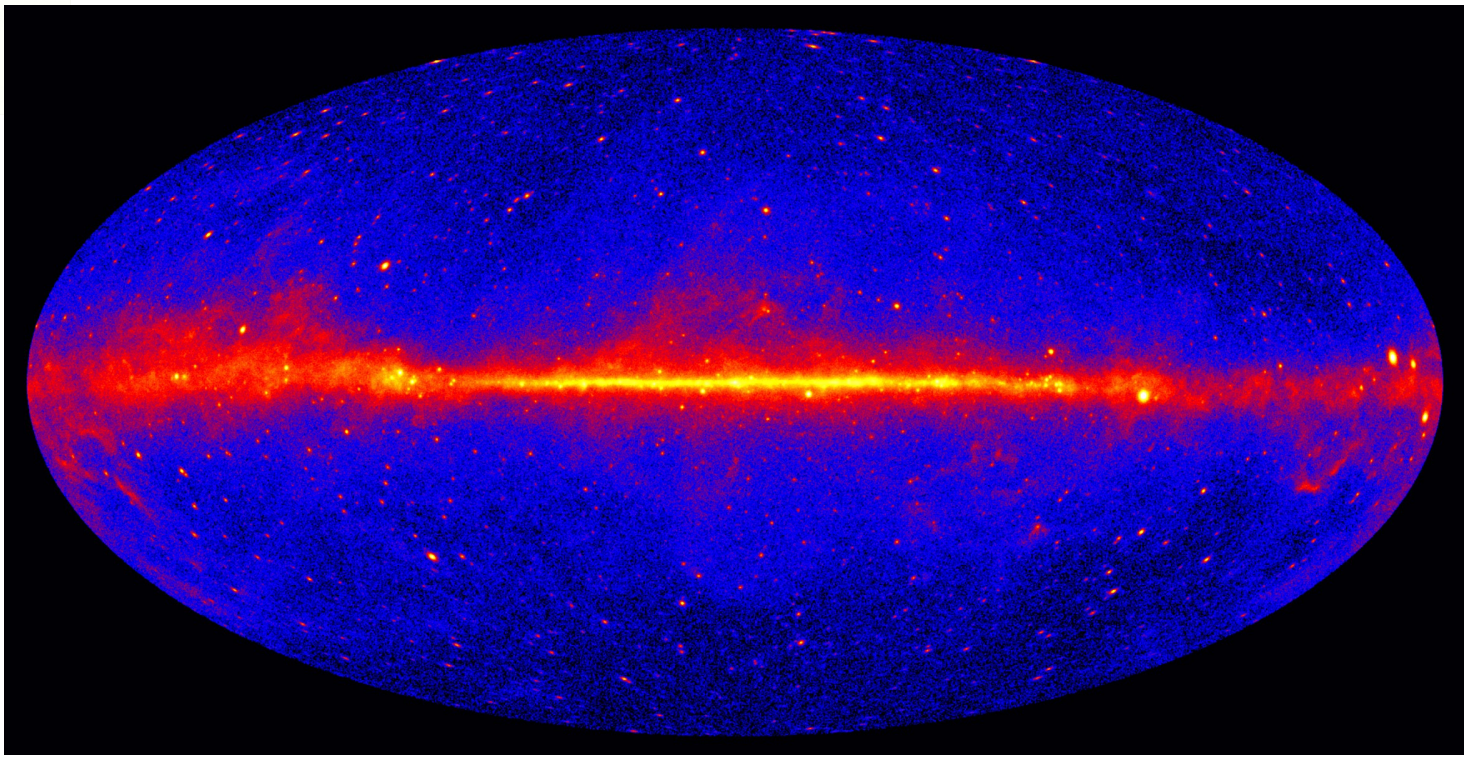

# Optical Sky



Almost all the optical light comes from  within our galaxy.
The light is due to thermal emission from hot stars.




# Gamma Ray Sky

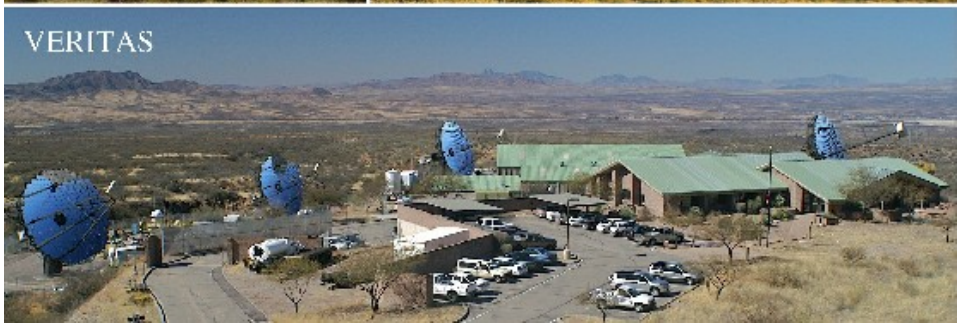


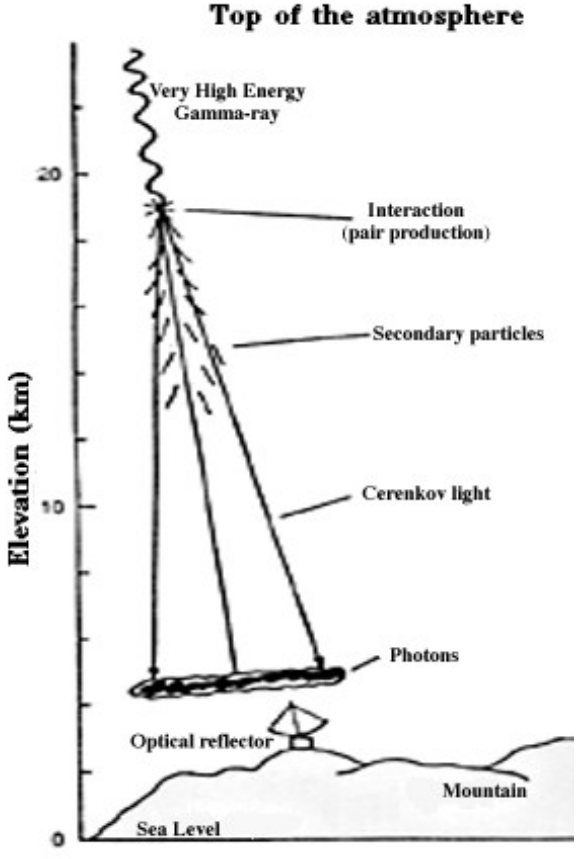
- Most of the gamma rays in the plane of our galaxy are from cosmic rays hitting the matter that obscure the optical light.
- Most of gamma rays outside the plane are due to sources outside our galaxy containing

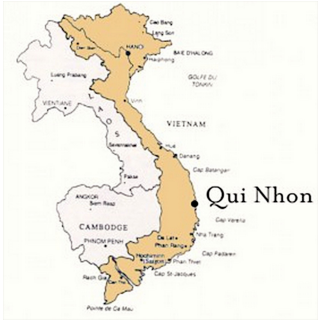

# Higher Energy Gamma-ray Deetectors



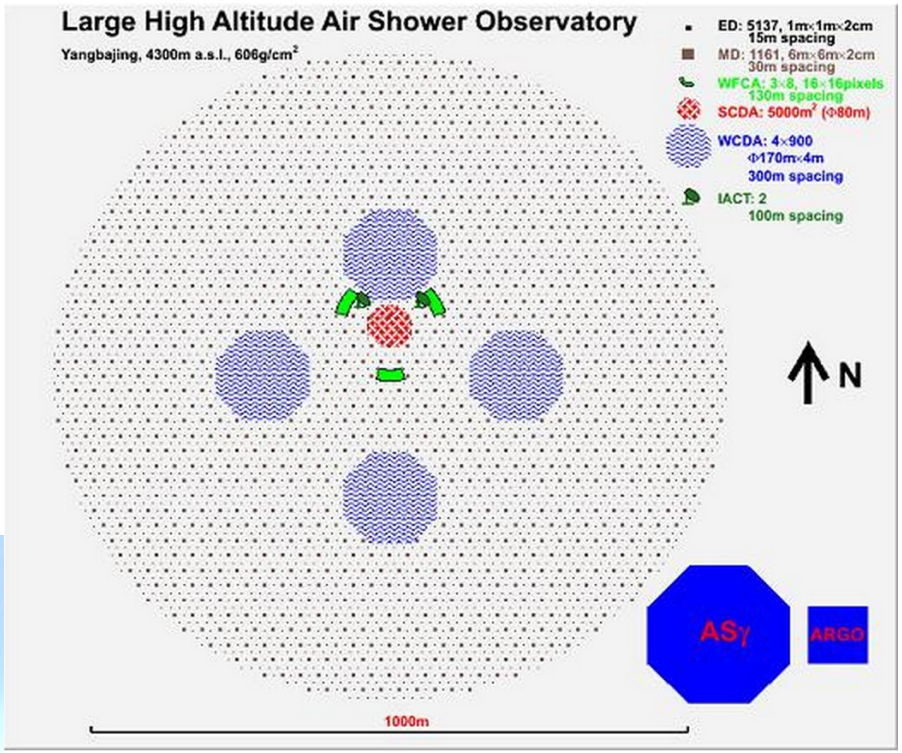




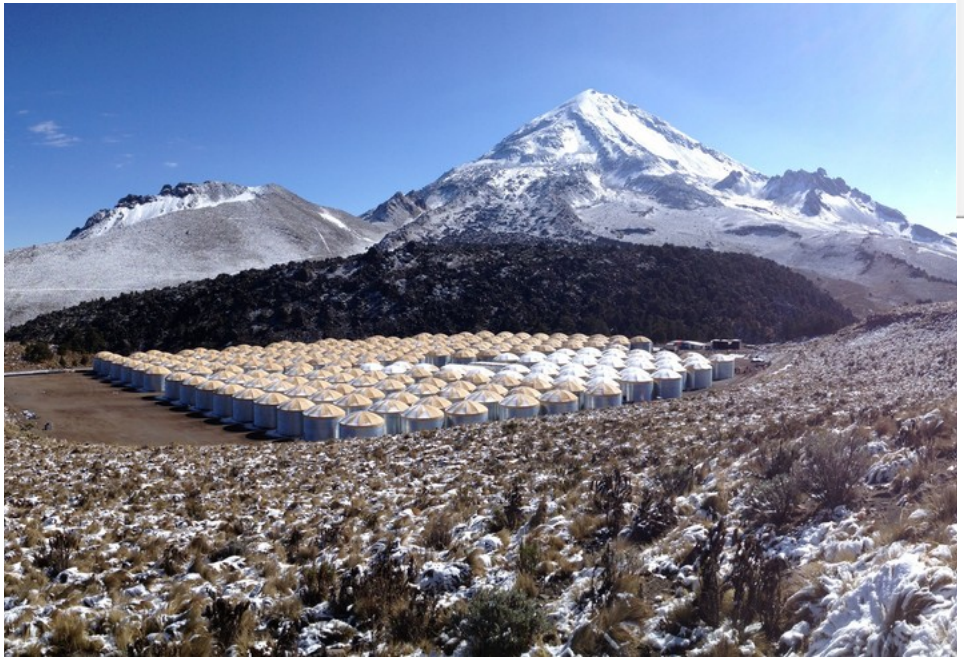





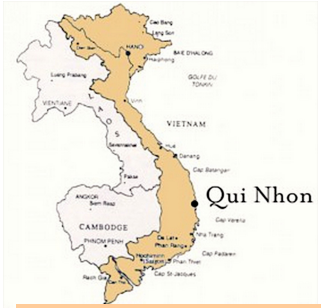

Wide Field of View, Continuously Operating Gamma-Ray Observatory




HAWC (High Altitude Water Cherenkov) Observatory in Mexico

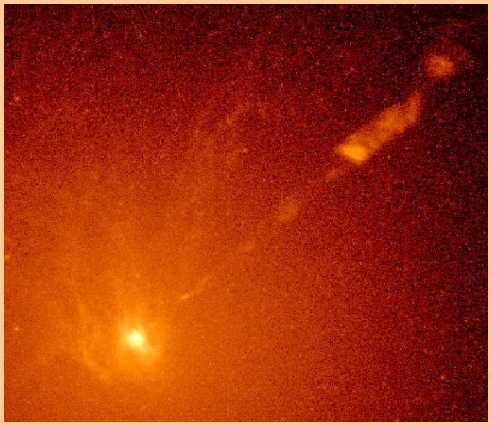


LHAASO ( Large High Altitude Air Shower Observatory) Planned in China

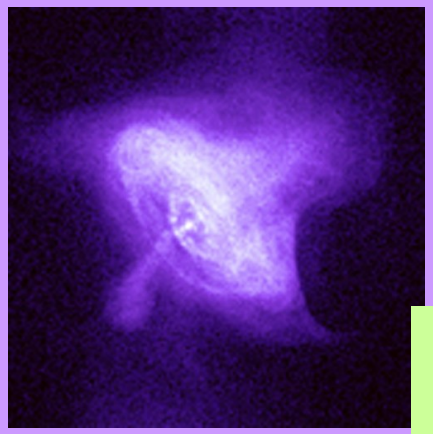



# Gamma Ray Sources are Astrophysical Particle Accelerators, but do they produce all the cosmic rays?

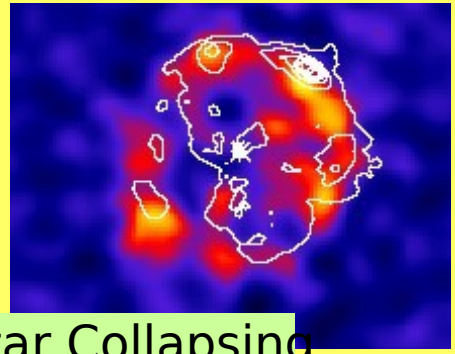
Black Hole producing relativistic jet of particles



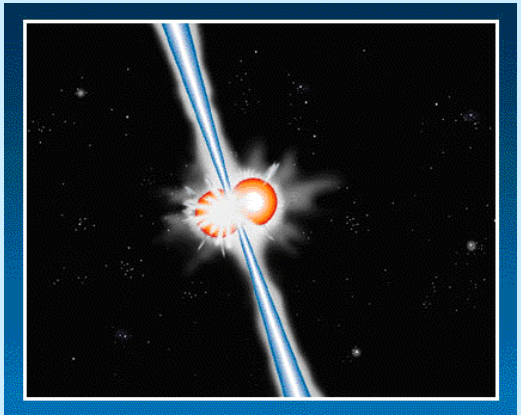
Spinning Neutron Star powering a relativistic wind



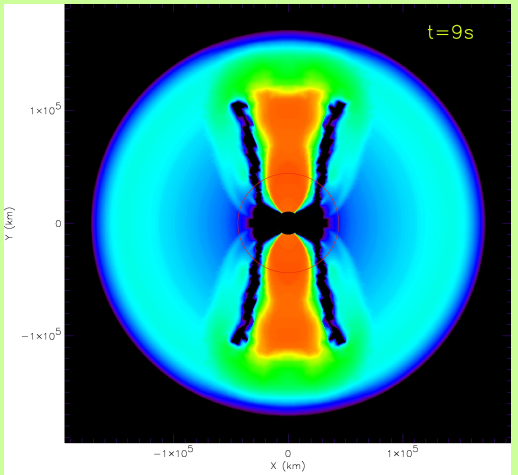
TeV image of Vela Jr. Supernova Remnant



Binary Neutron Star Coalescing

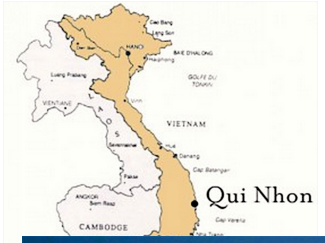


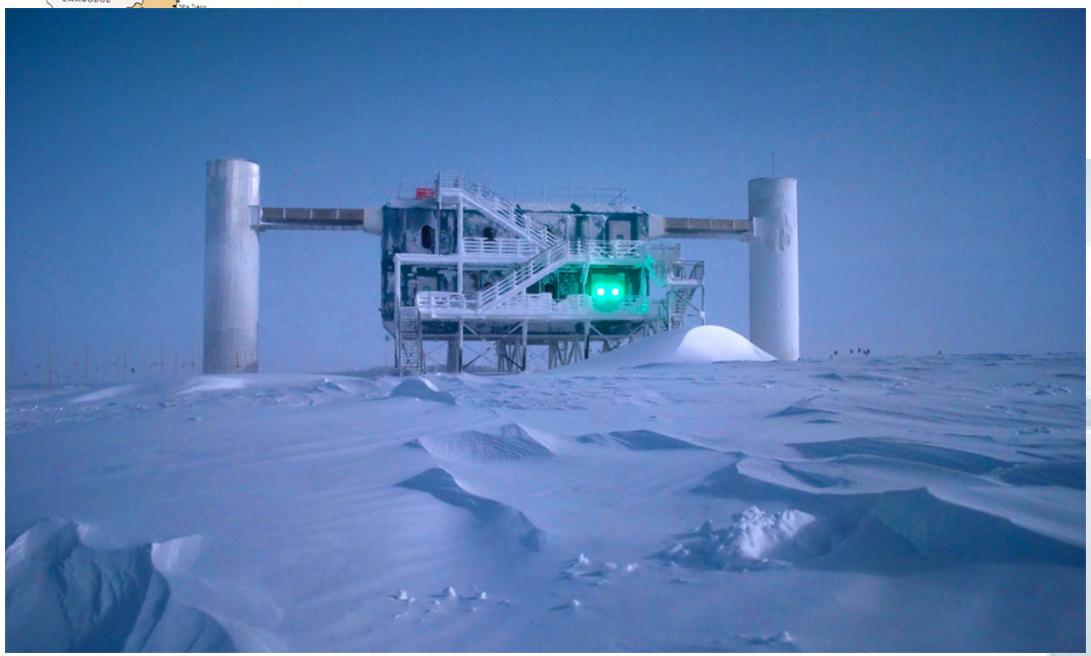
Massive Star Collapsing into a Black Hole

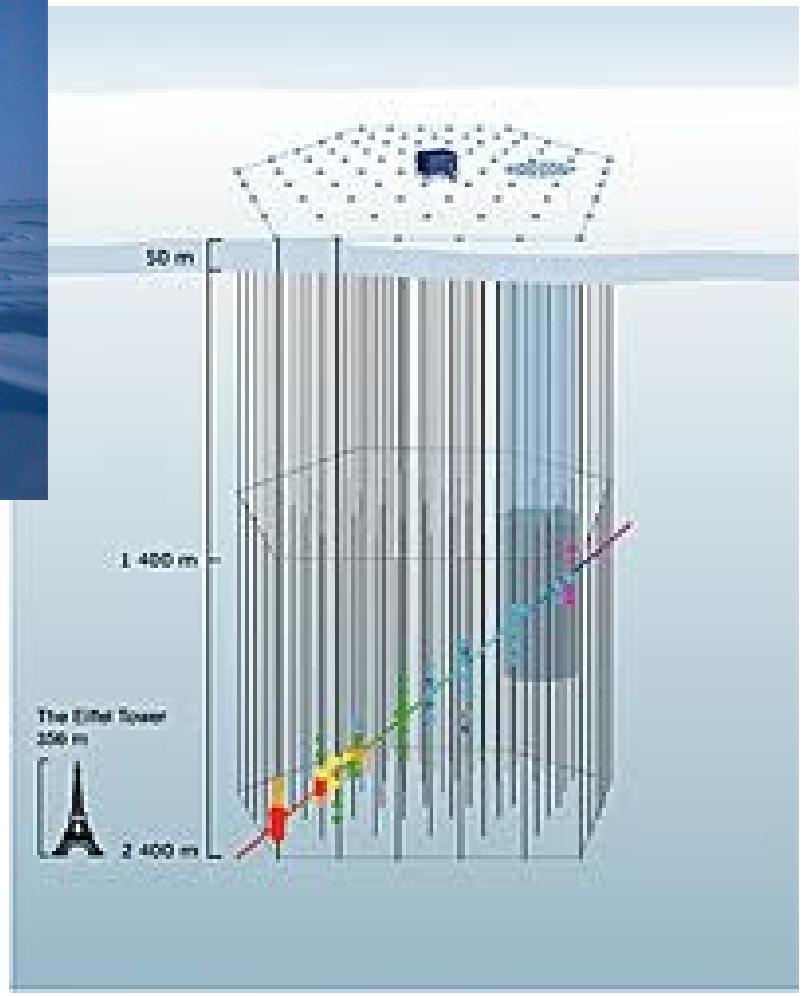



MacFadyen, Woosley, & Heger (1999)

# Ice Cube Neutrino Observatory



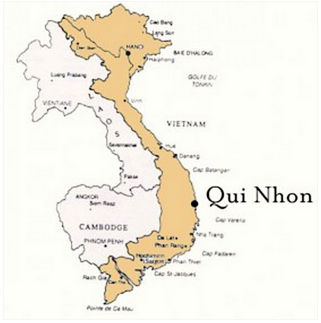





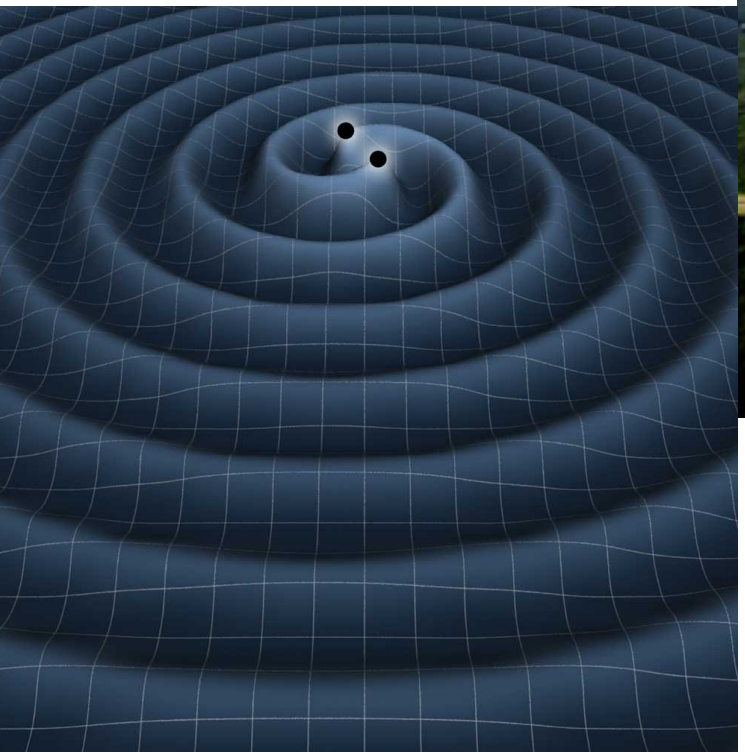


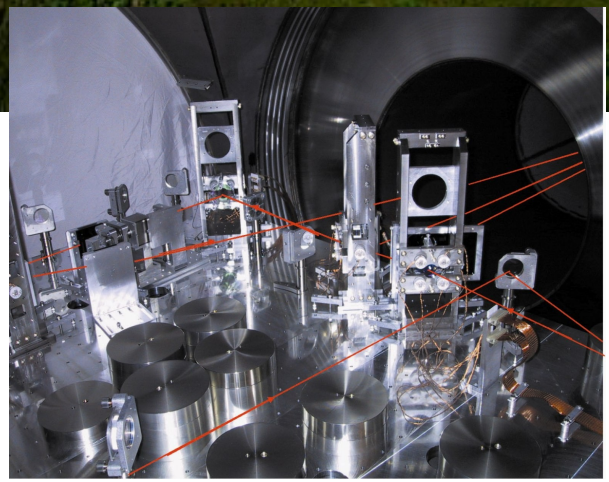
Installation of an optical module in the 2450 m deep hole

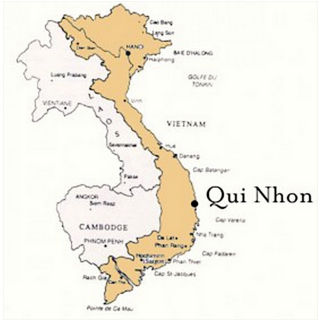

# ANTARES Neutrino Observatory


# LIGO Gravitational Wave Observatory



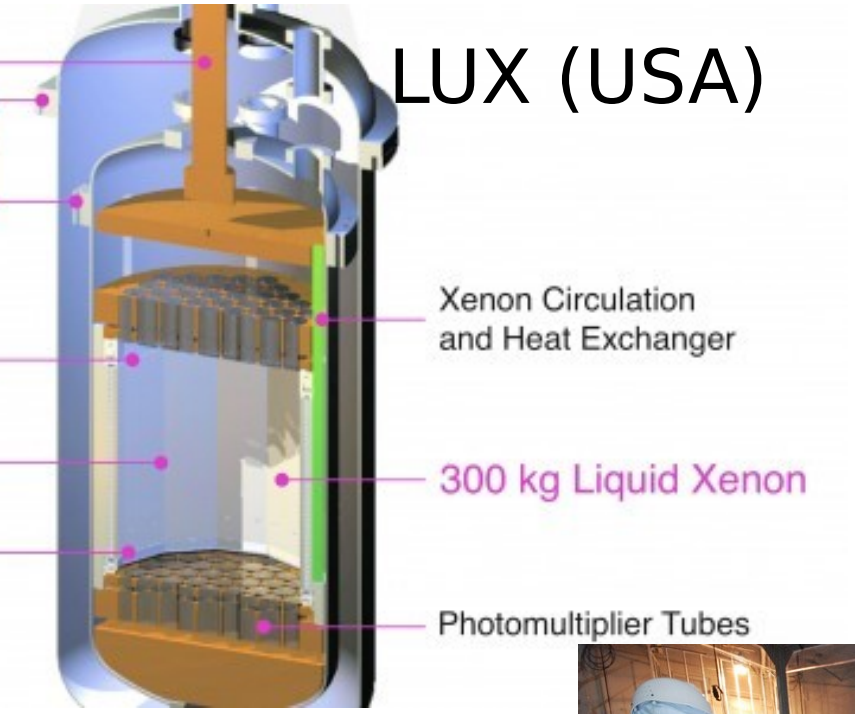




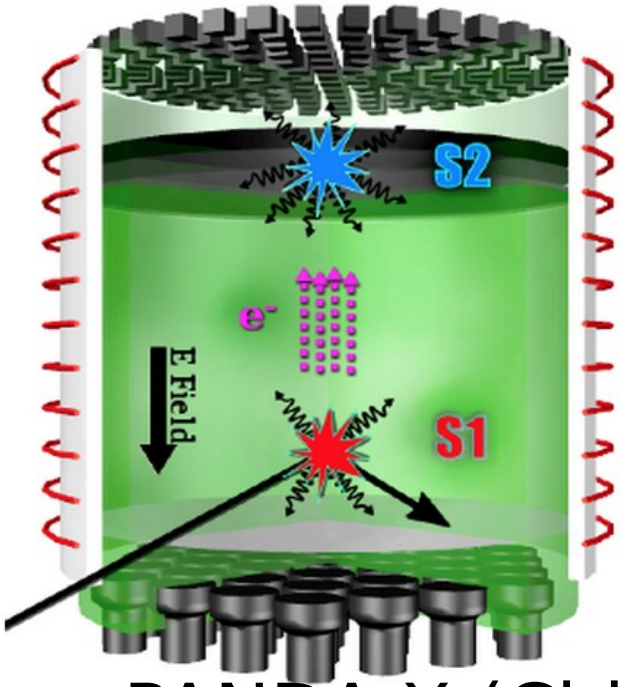

# Dark Matter exists with 10 x mass of Normal Matter

Some candidates for Dark Matter may annihilate into gamma-rays, neutrinos, or cosmic rays.


# Dark Matter Detectors Deep Underground to Reduce Cosmic Ray Backgrounds

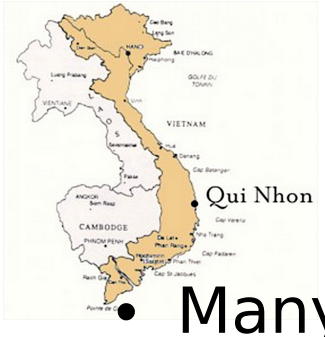



LUX (USA)




PANDA X (China)


X Mass (Japan)




# Conclusion

- Many new, exciting, and technically challenging observatories are being built around the world and are collecting data so we can understand the high energy Universe.

- We will hear more about these projects, their results, and the interpretations of their data at this conference.

- I want to thank our hosts for their hospitality. I am looking forward to an exciting and interesting week.