The High-Altitude Water Cherenkov Gamma-Ray Observatory

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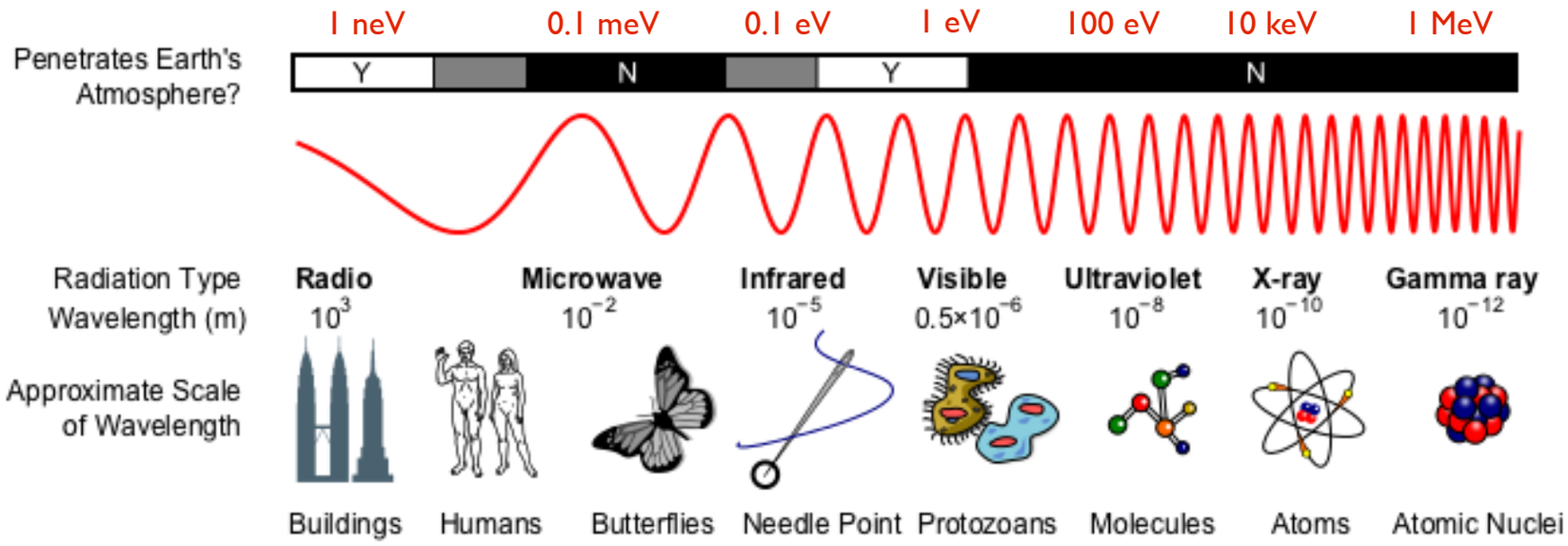
IceCube MasterClass
AN AUTHENTIC ASTROPHYSICS RESEARCH EXPERIENCE

Multiwavelength Astronomy

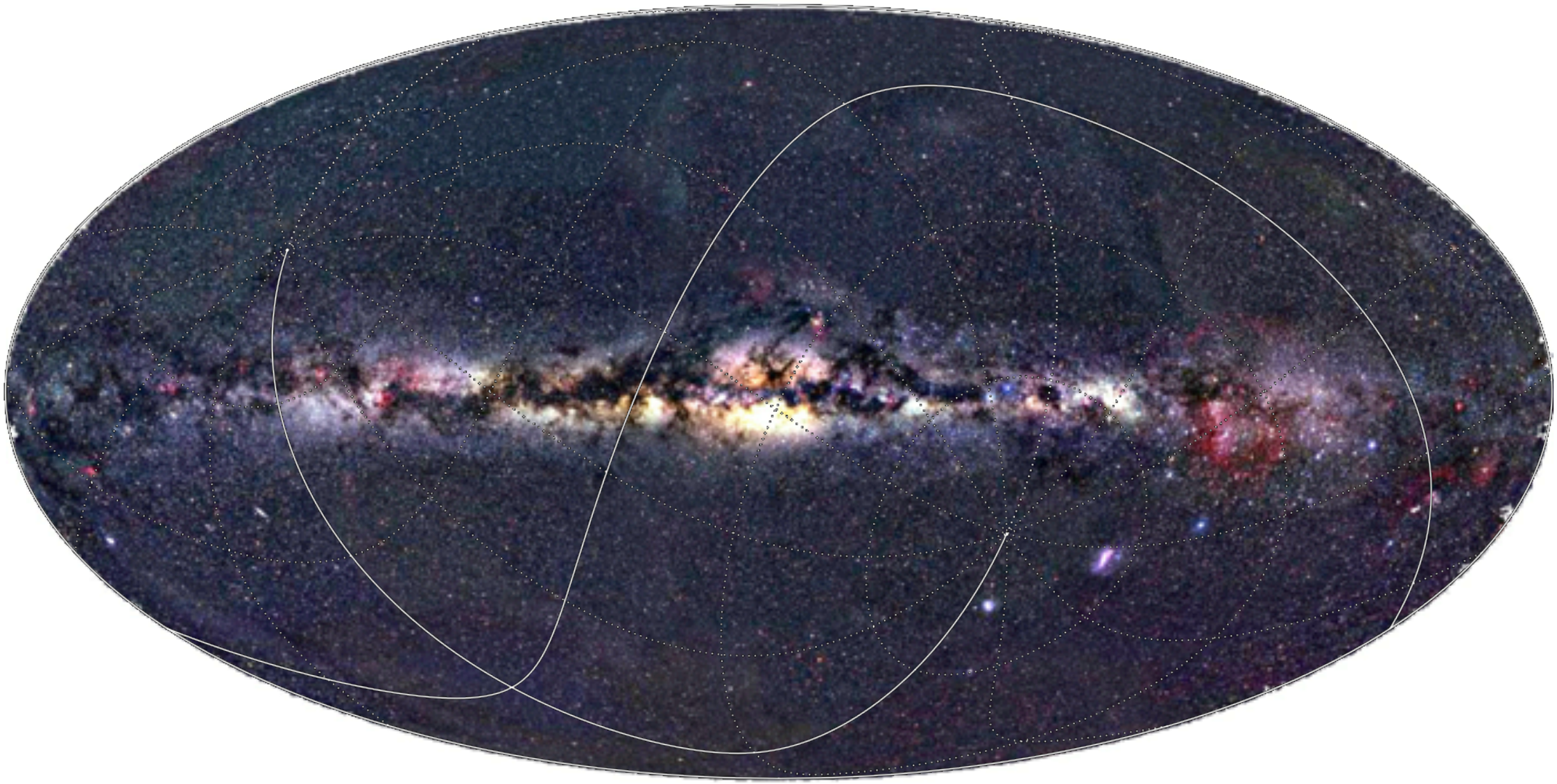
- Astronomy using TeV radiation (wavelength $\lambda = 10^{-18}$ meters)



- Why try to detect gamma rays?
  - Learn about the highest energy particles in the universe
  - Study very high energy acceleration
  - Probe the structure of the universe (cosmology)

Optical Astronomy

- The optical universe: 400 - 750 nm, or 1.5 - 3 eV



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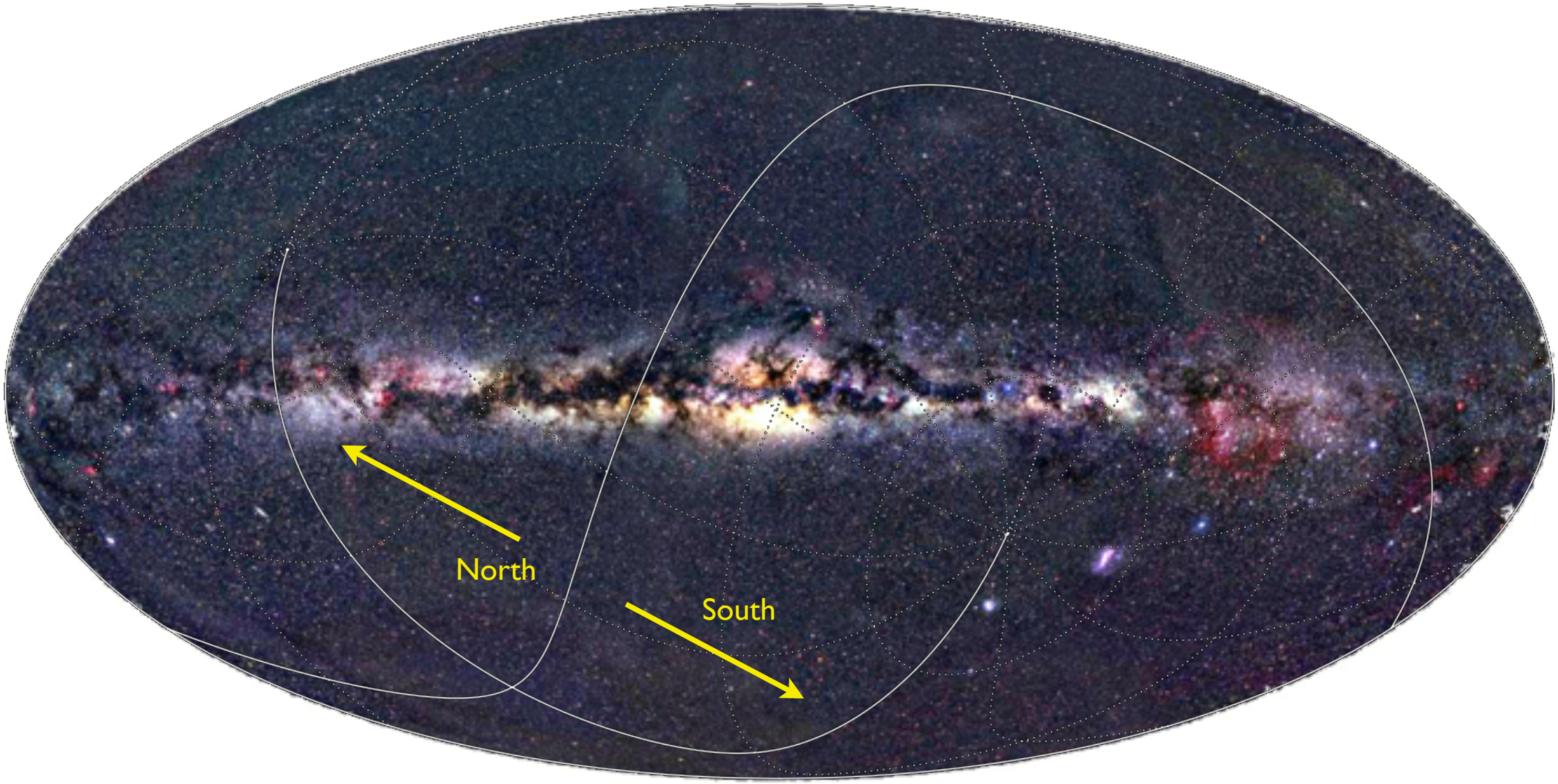
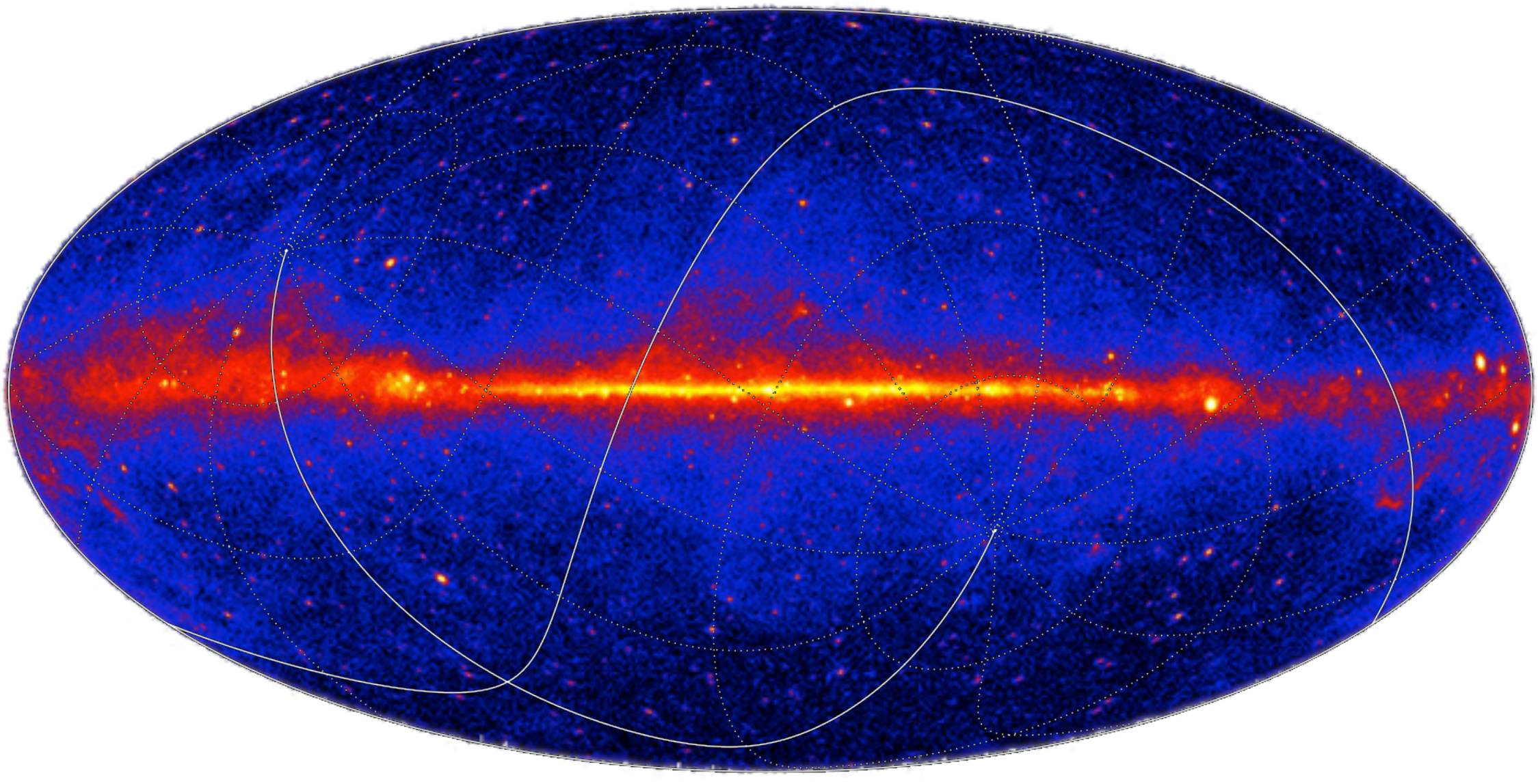
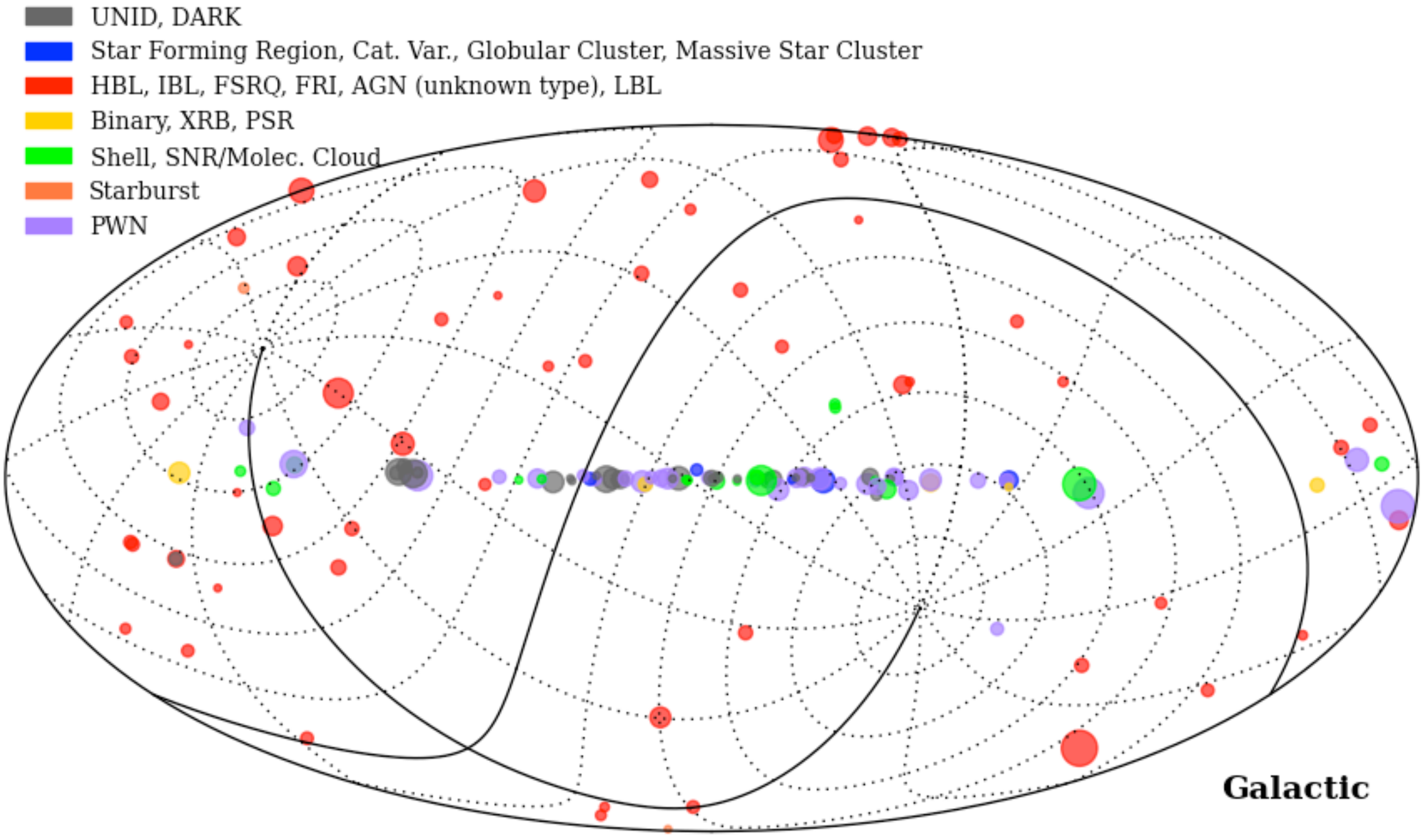


GeV Gamma-Ray Astronomy

- GeV band: 100 MeV - 100 GeV, or 10^{-17} - 10^{-14} m

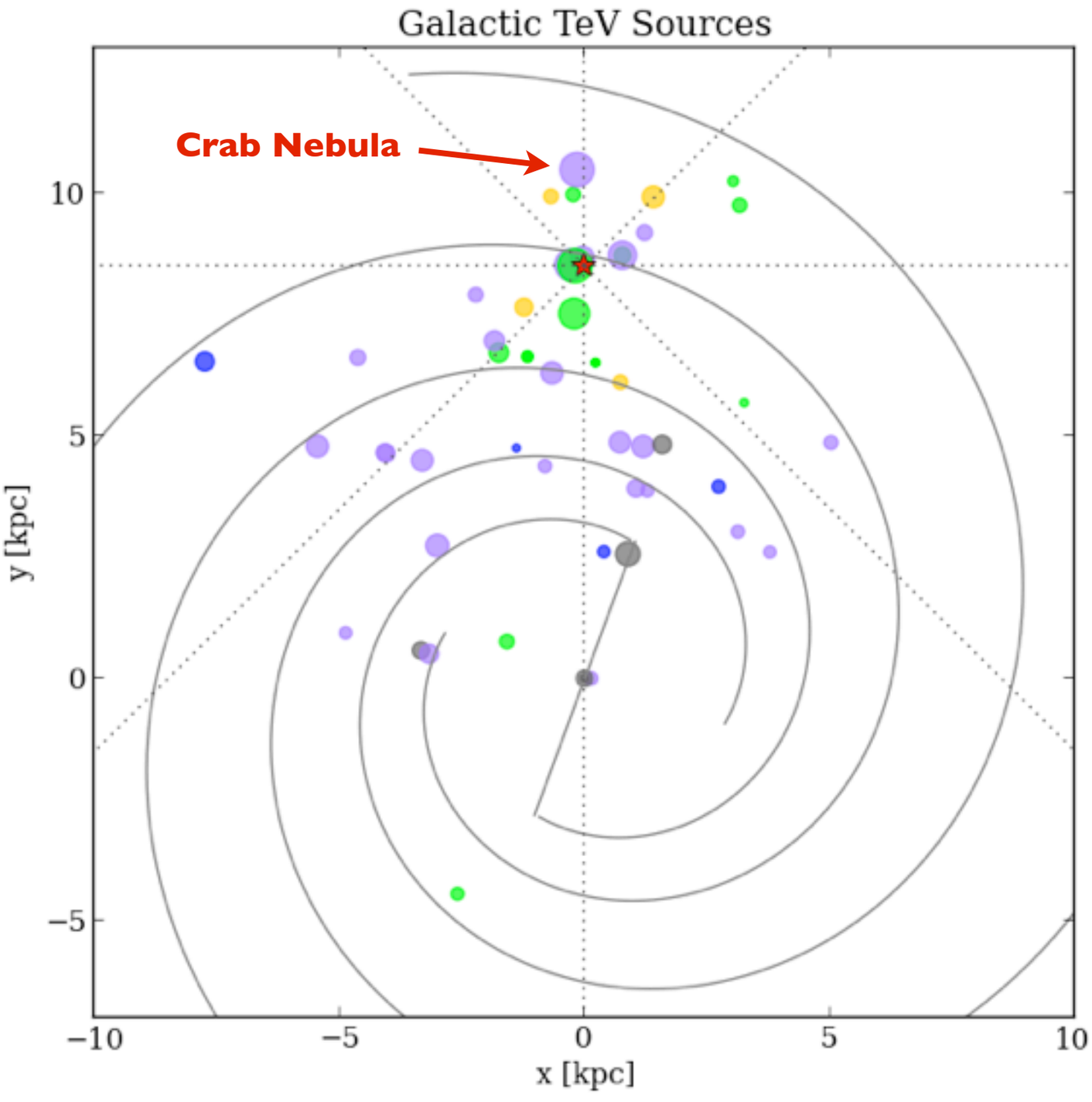


TeV Gamma-Ray Astronomy

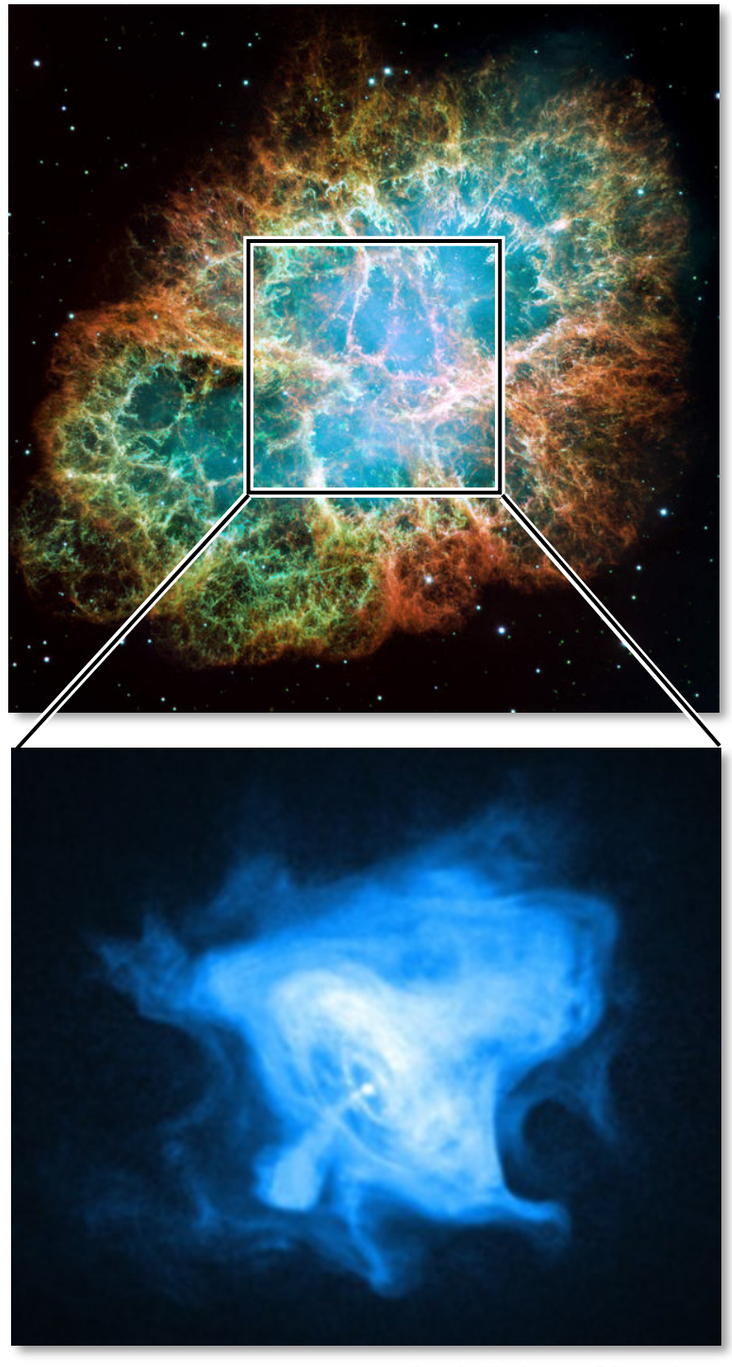


- TeV band: 100 GeV - 100 TeV, or 10^{-20} - 10^{-17} m

Galactic Gamma-Ray Sources



Crab Nebula: Hubble



Crab Pulsar: Chandra

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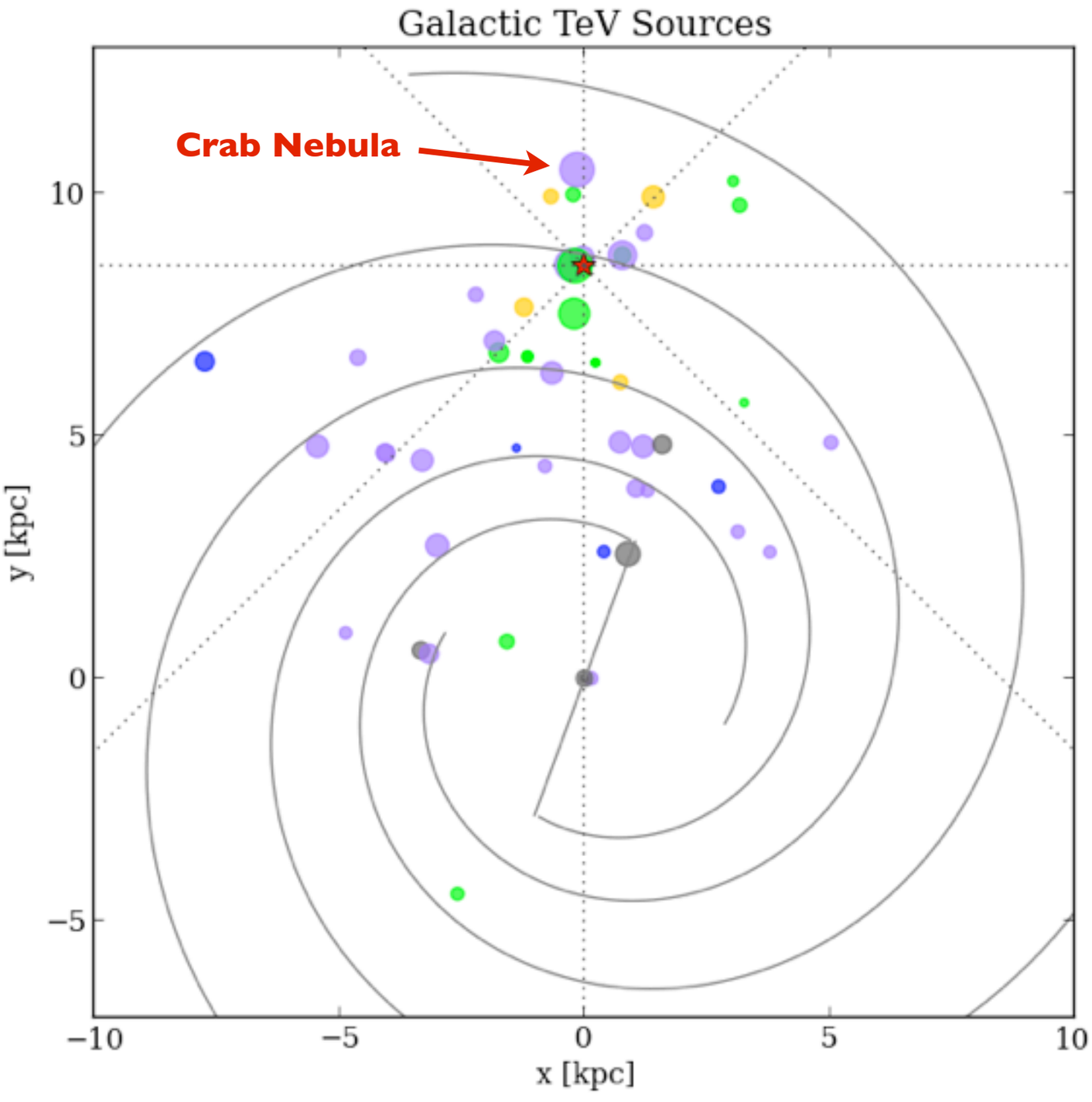

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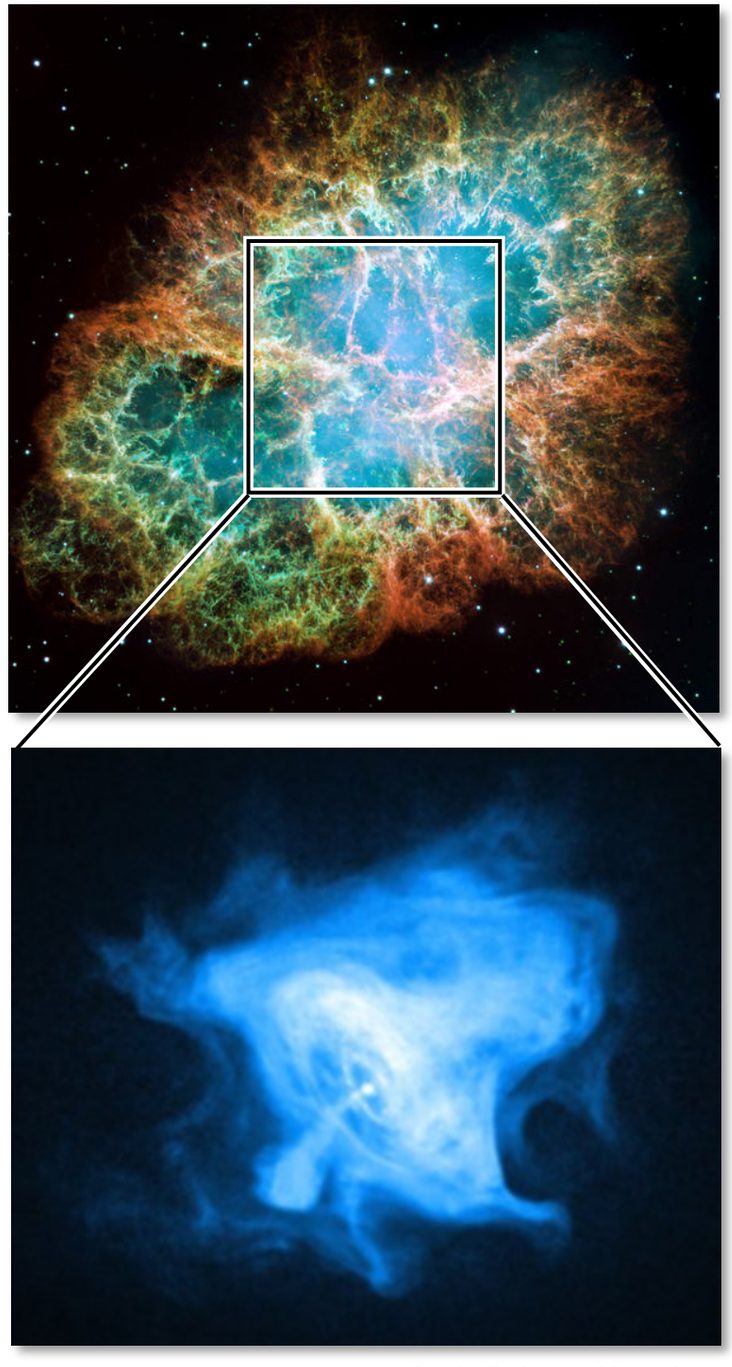
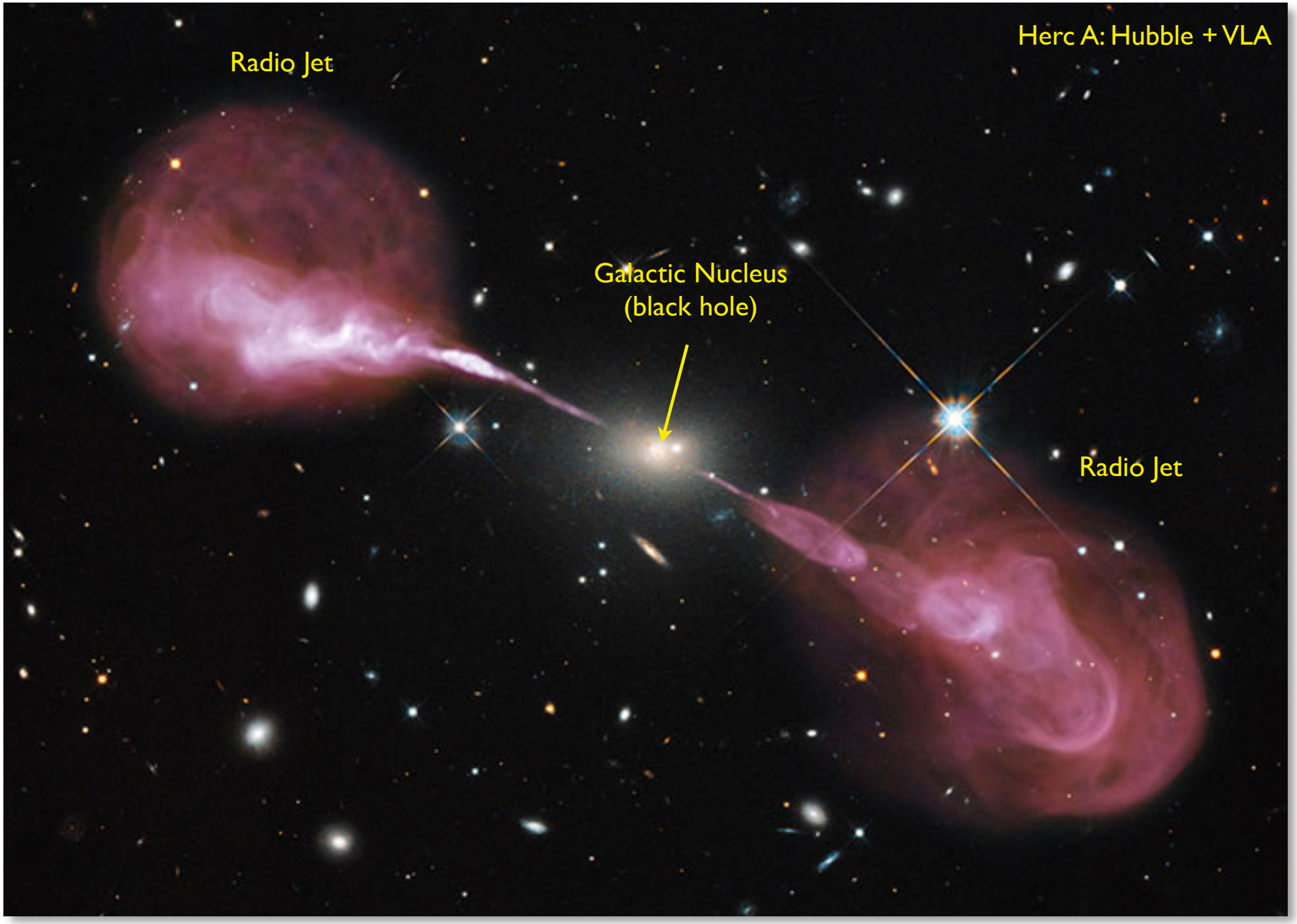


Crab Pulsar: Chandra

Extragalactic Source (AGN)



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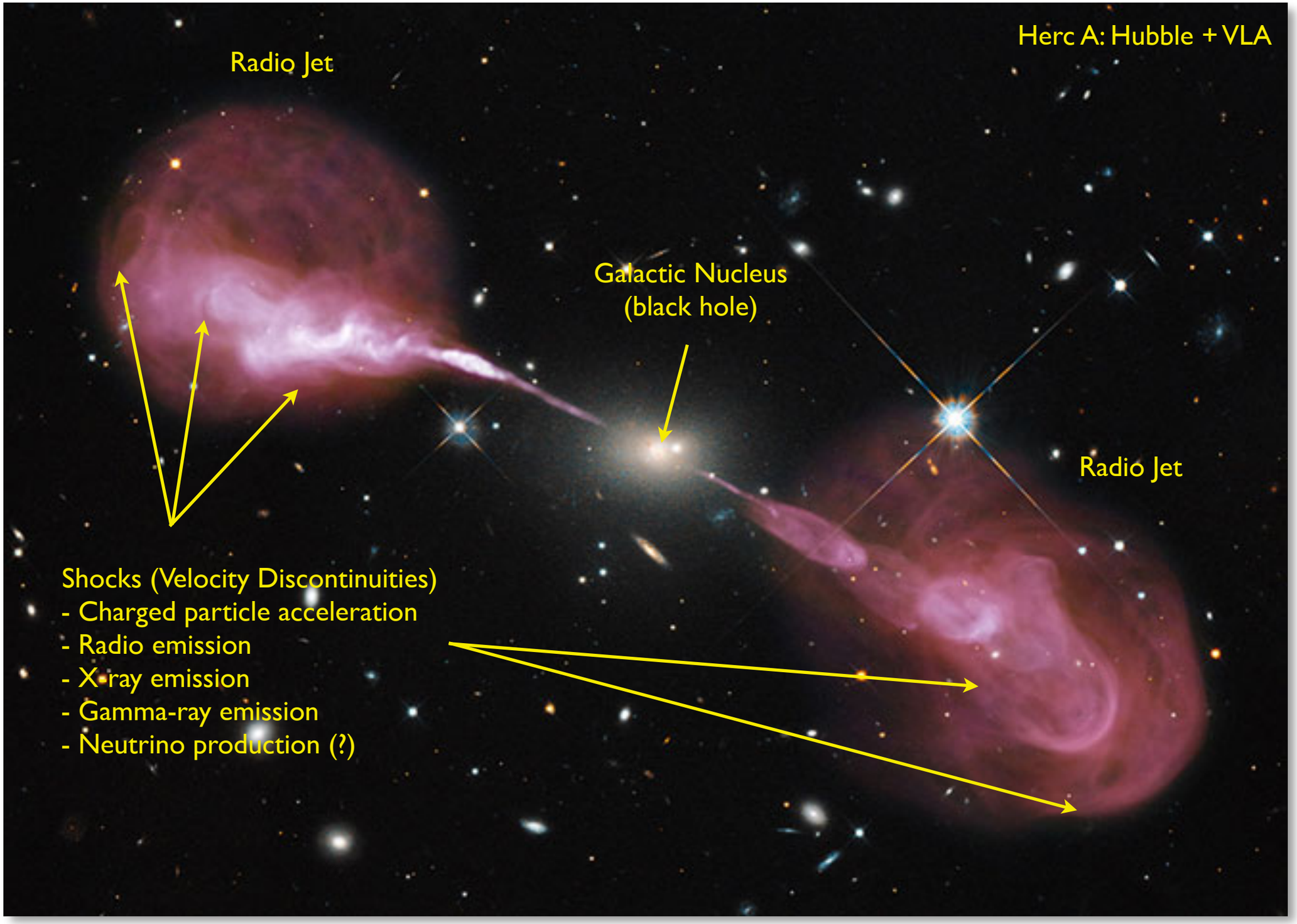

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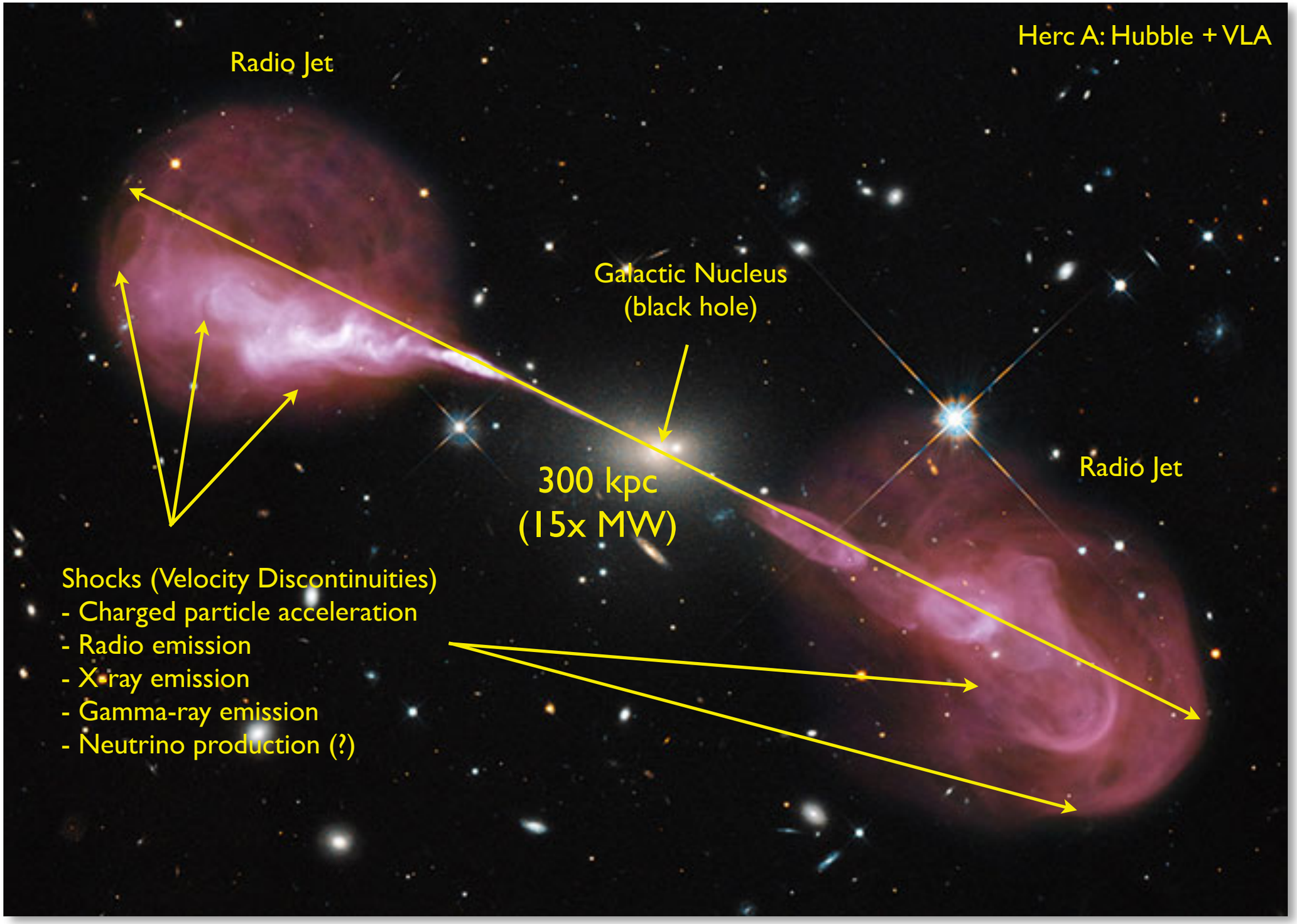
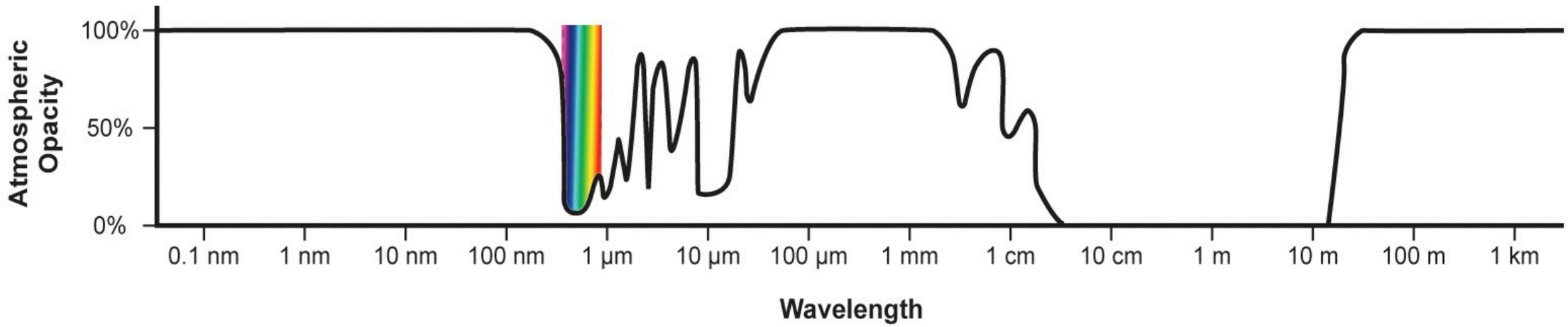


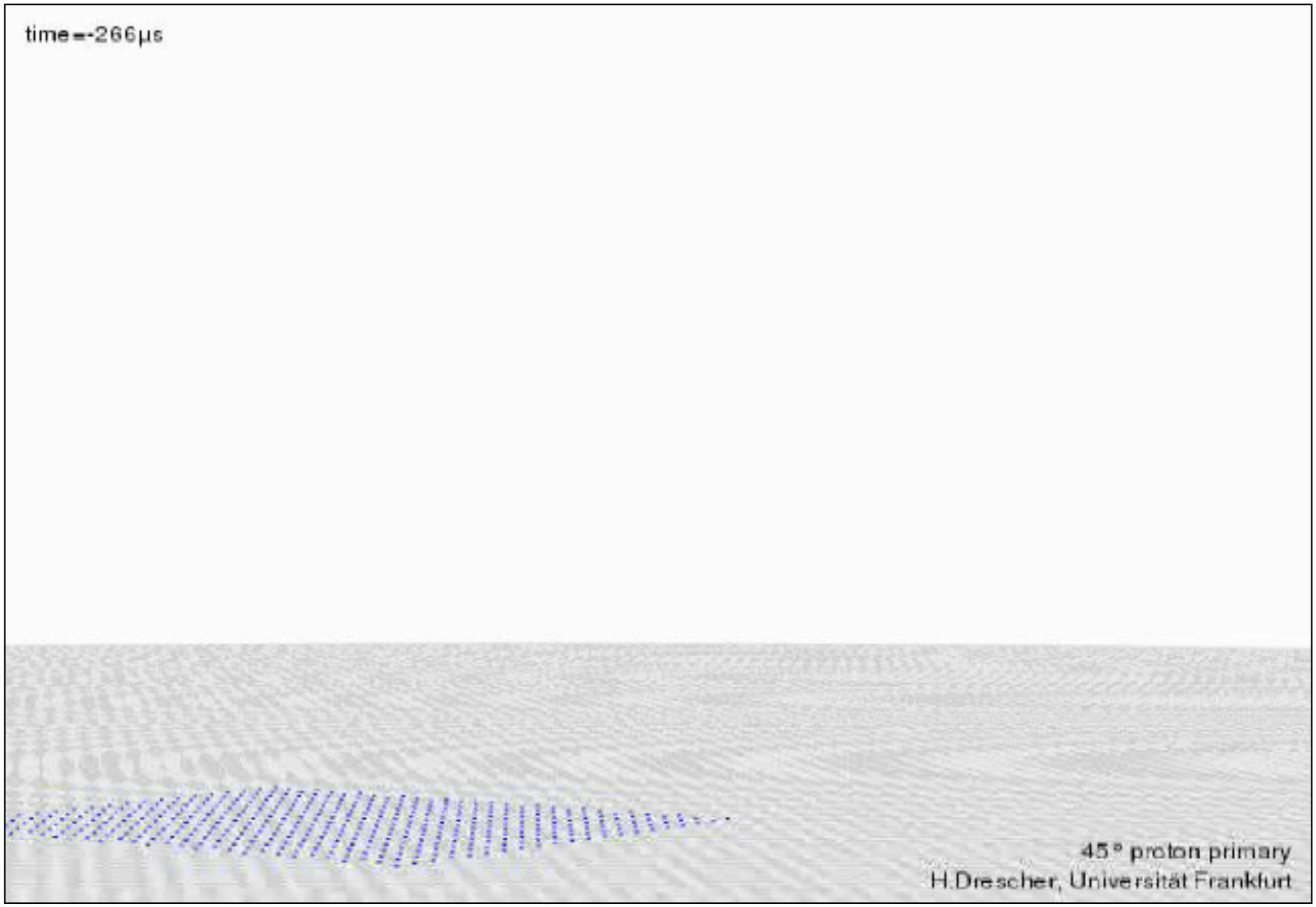
Detecting TeV Gamma Rays

- Flux of TeV gamma rays at Earth is 1 particle/day in 1 m x 1 m area. Too small to use a satellite!

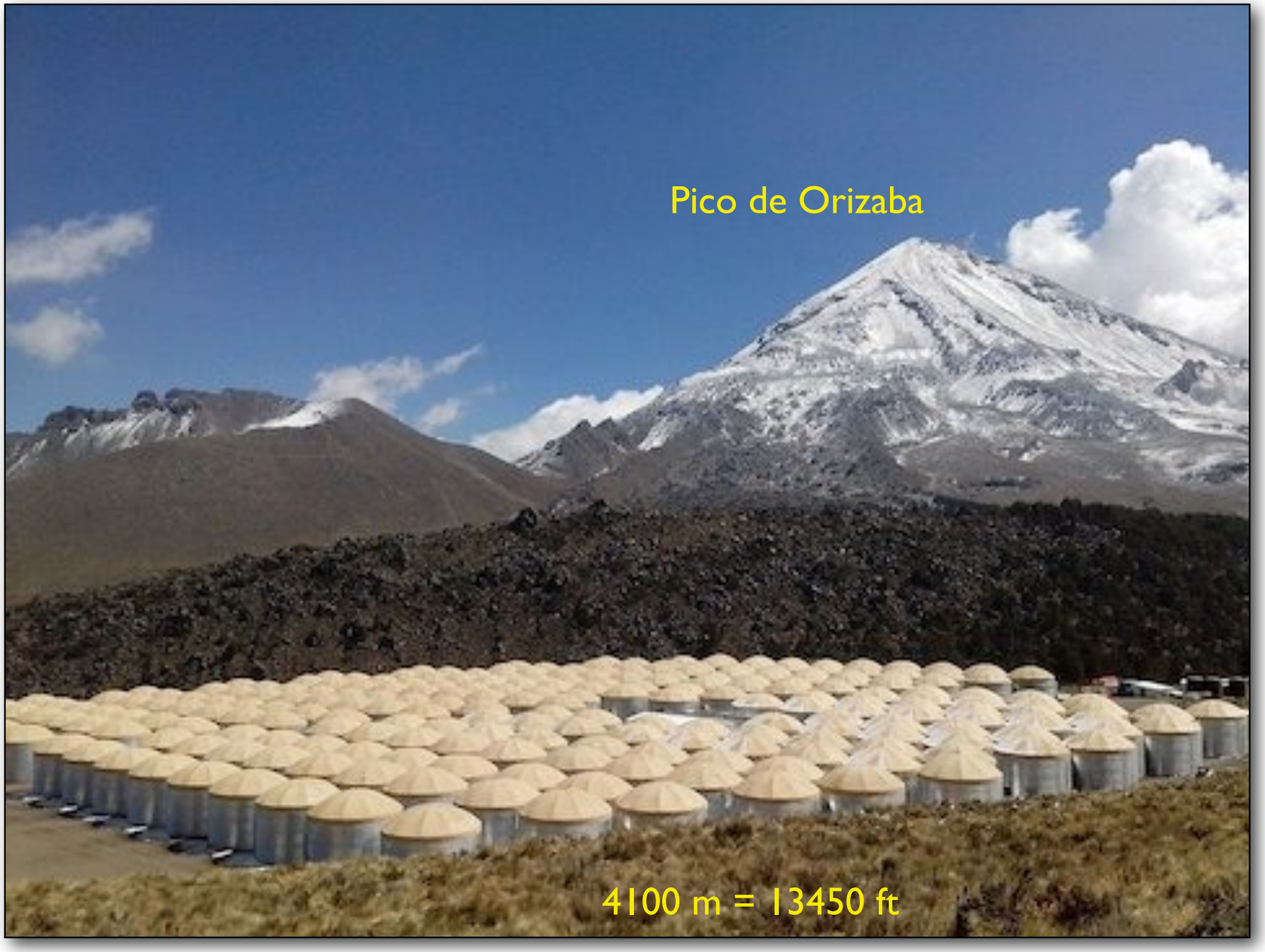


- But, the atmosphere is opaque to TeV gamma rays
- They produce air showers which we can observe

Cosmic Ray Air Shower (Proton)



HAWC Observatory



HAWC Gamma-Ray Observatory

- The **H**igh-**A**ltitude **W**ater **C**herenkov Observatory is under construction near Puebla, Mexico
- Goals: observe gamma rays and cosmic rays from half the sky each day
- Statistics:
  - 4100 m above sea level
  - 19° N latitude
  - 300 water tanks
  - 1/6th of sky in FOV
  - Covers 100 GeV to 100 TeV

HAWC Site

NASA Earth Observatory

HAWC Site

NASA Earth Observatory

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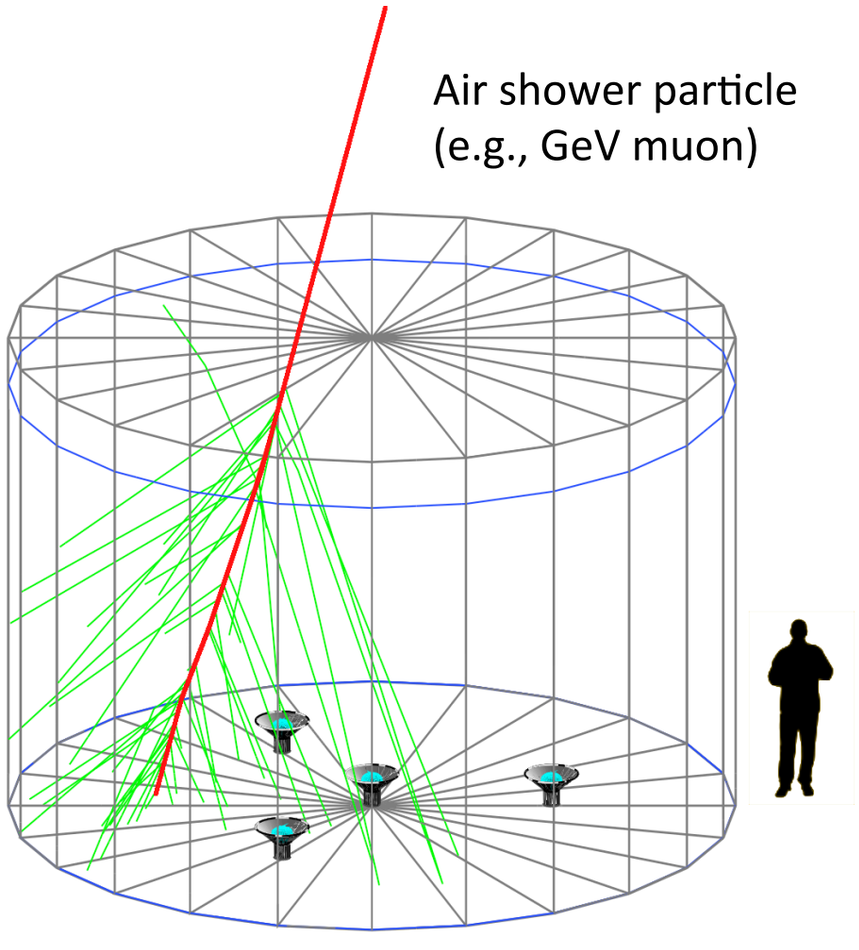
Water Cherenkov Detectors

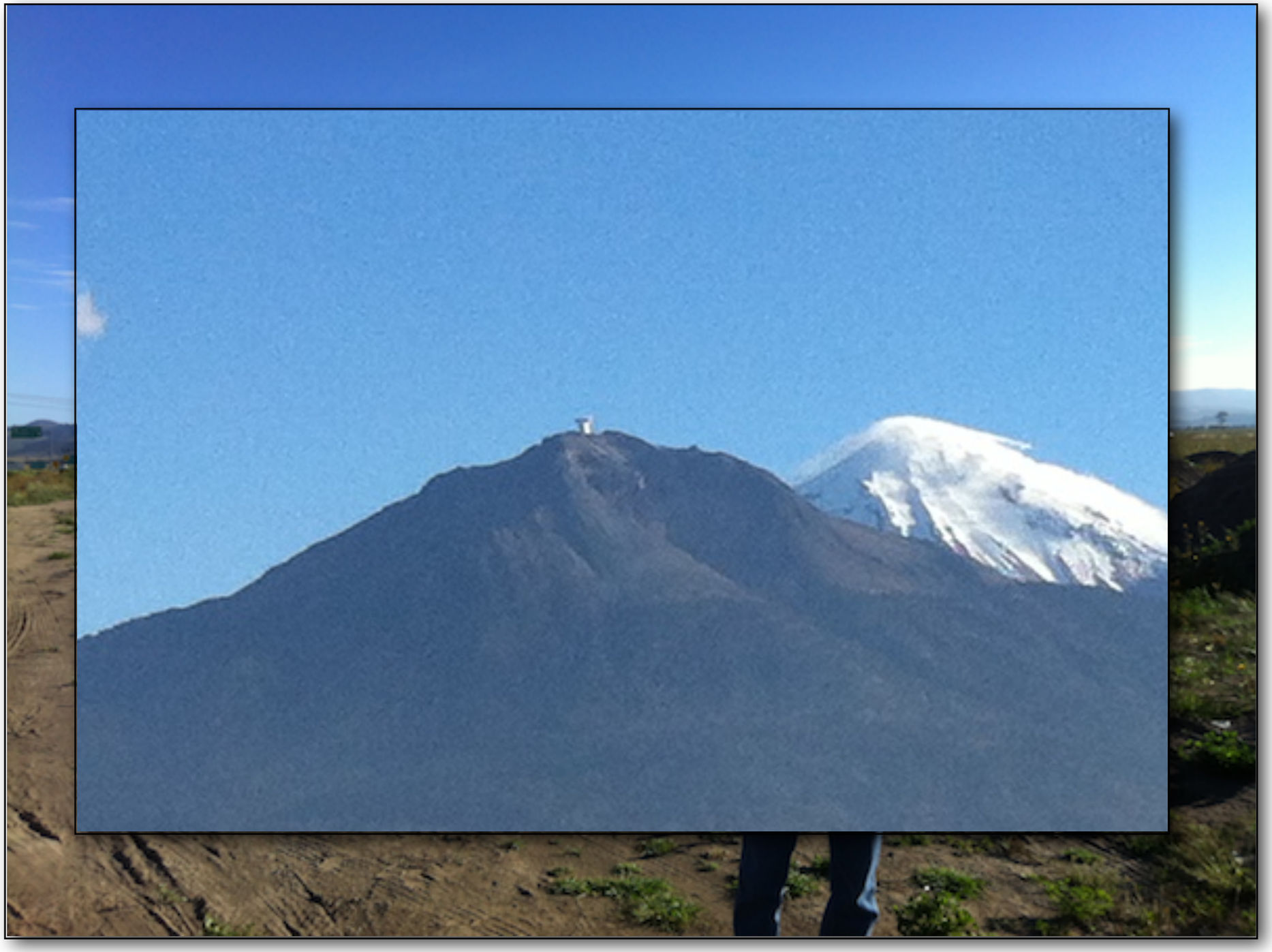
- Array of 300 water tanks: 7.3 m diameter, 5 m height
- 200,000 L water per tank, 4 phototubes observe Cherenkov light from shower particles



HAWC Deployment

Going Up the Mountain

Going Up the Mountain



Going Up the Mountain

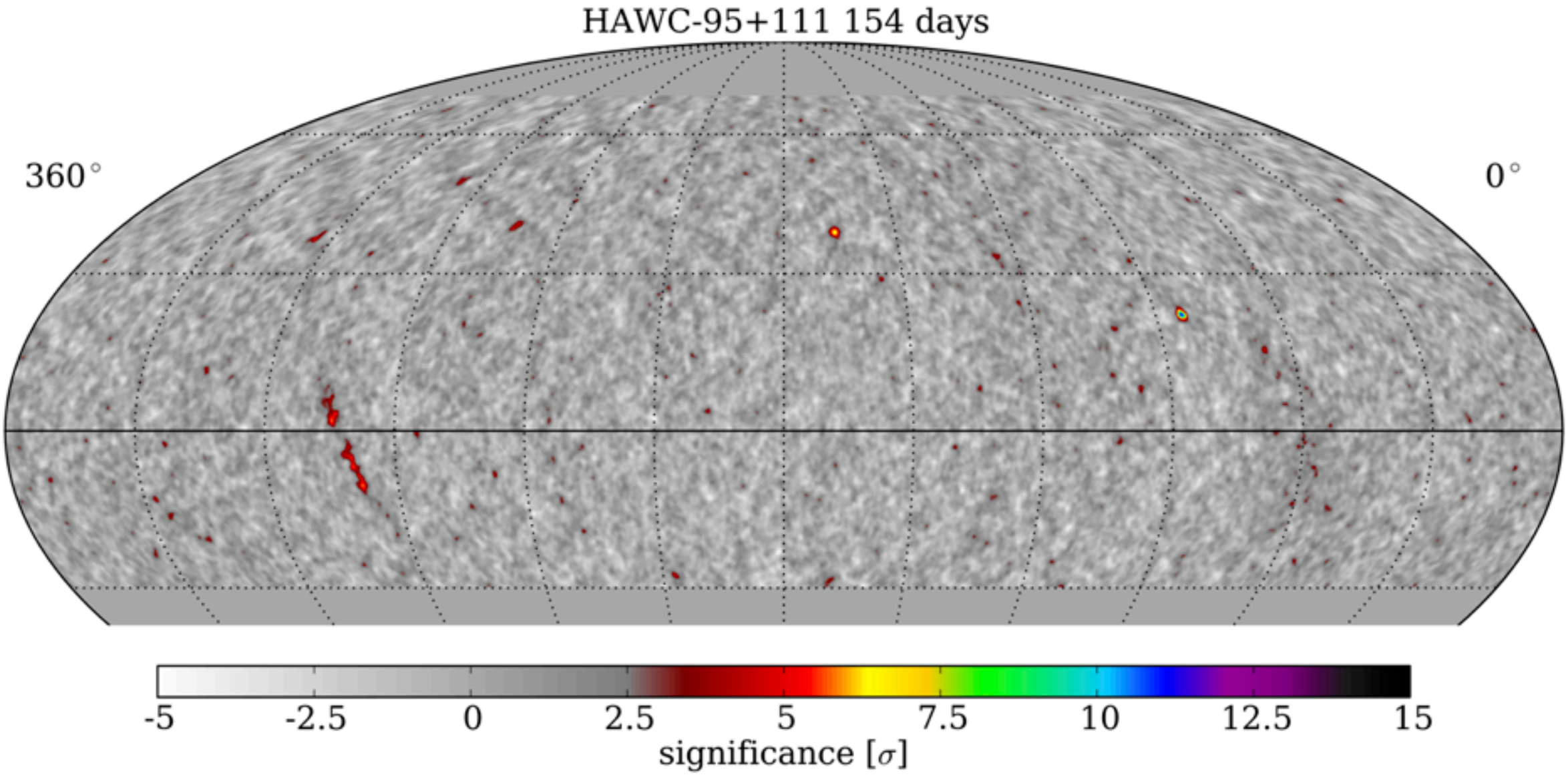
Going Up the Mountain

Life Near the Site

Life Near the Site

Data: Galactic Survey

- 5 months of HAWC-95+111 data (June-Nov 2013)



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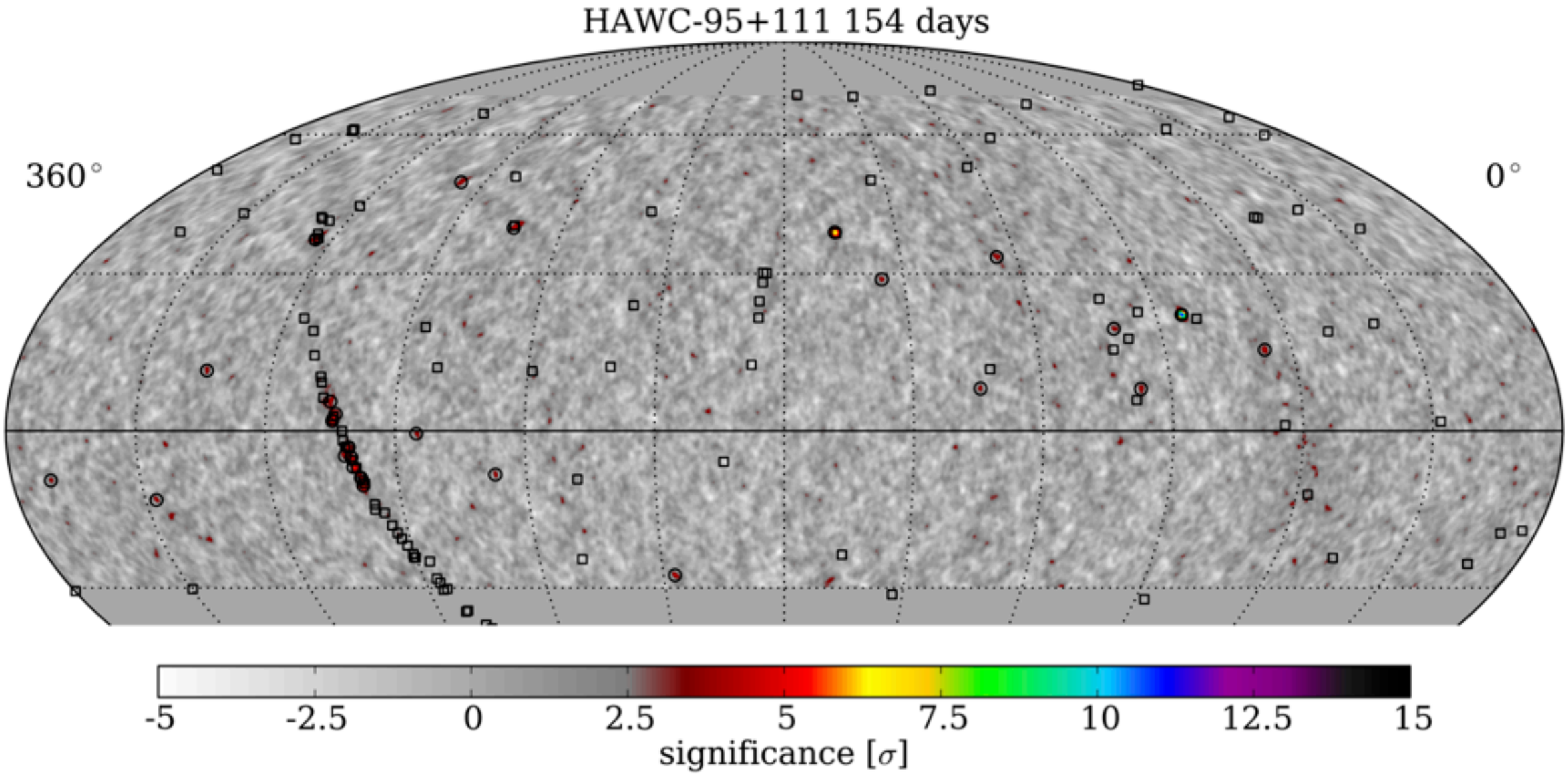

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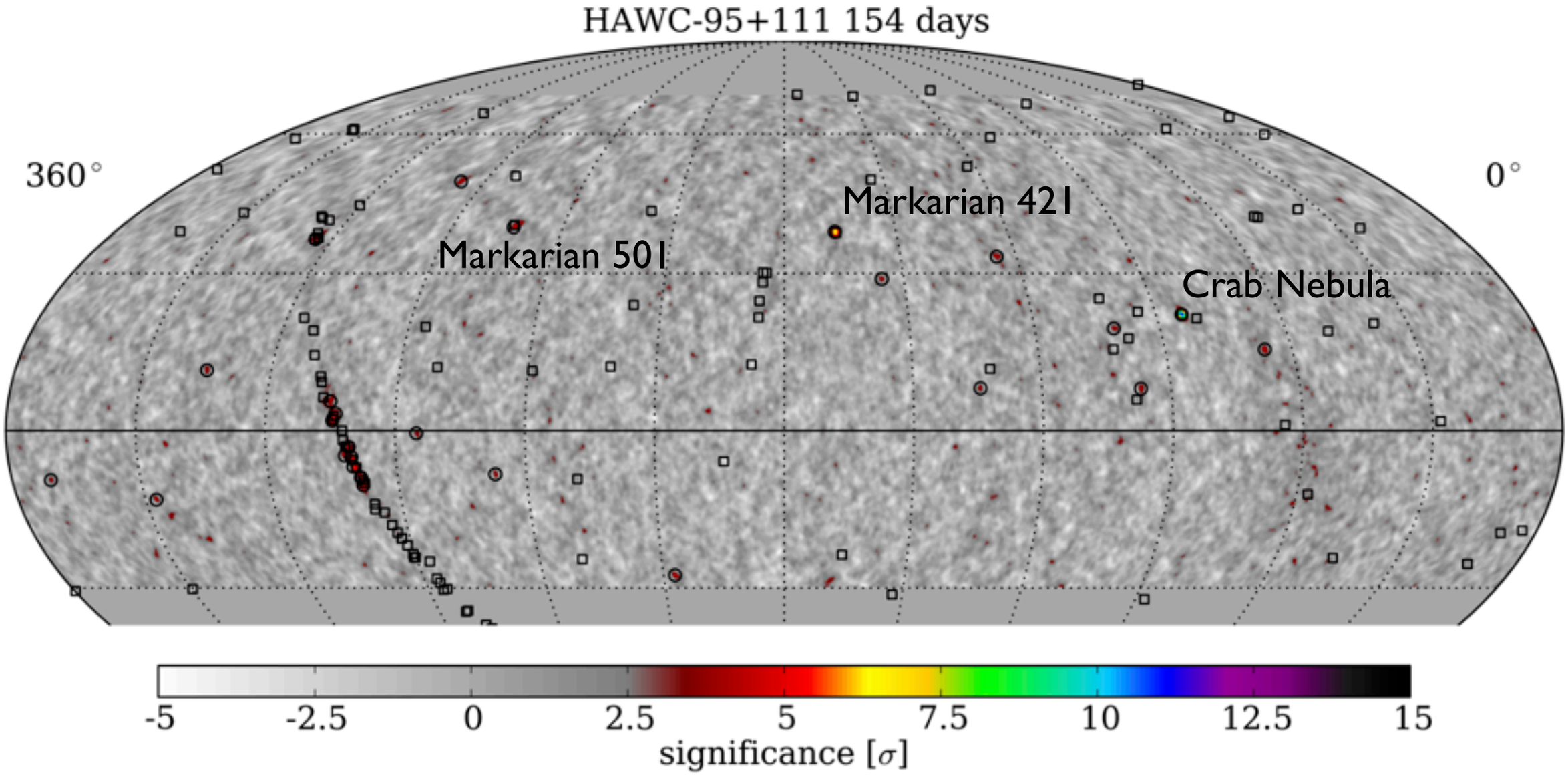
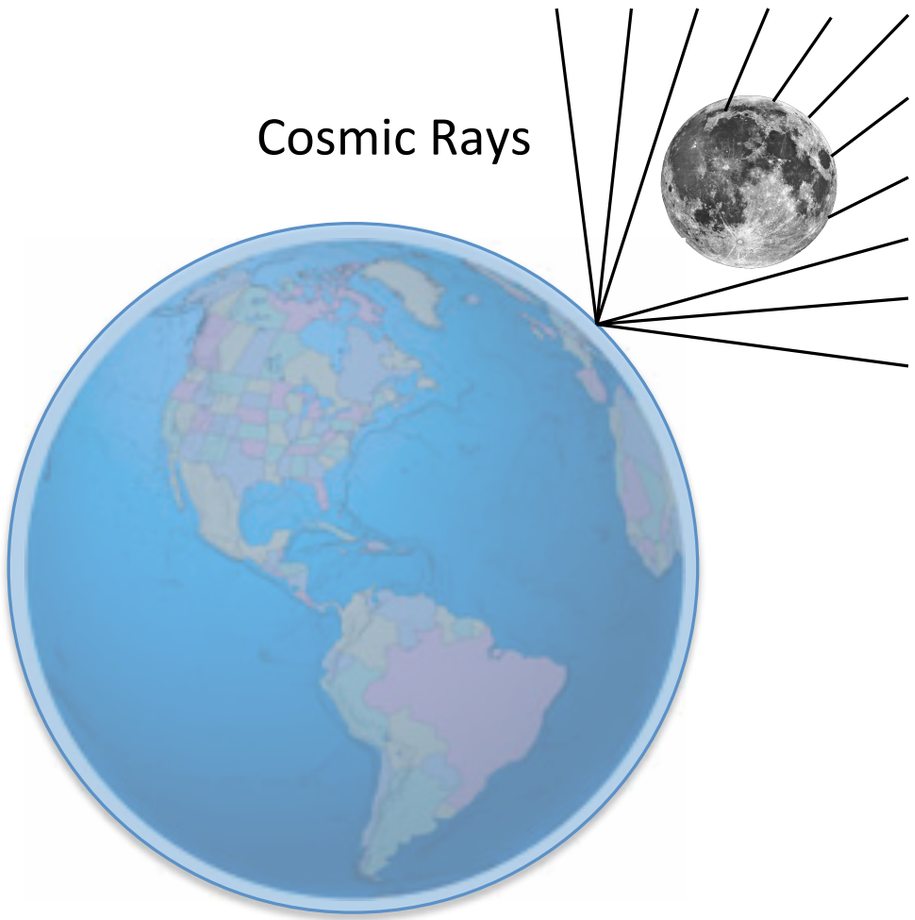
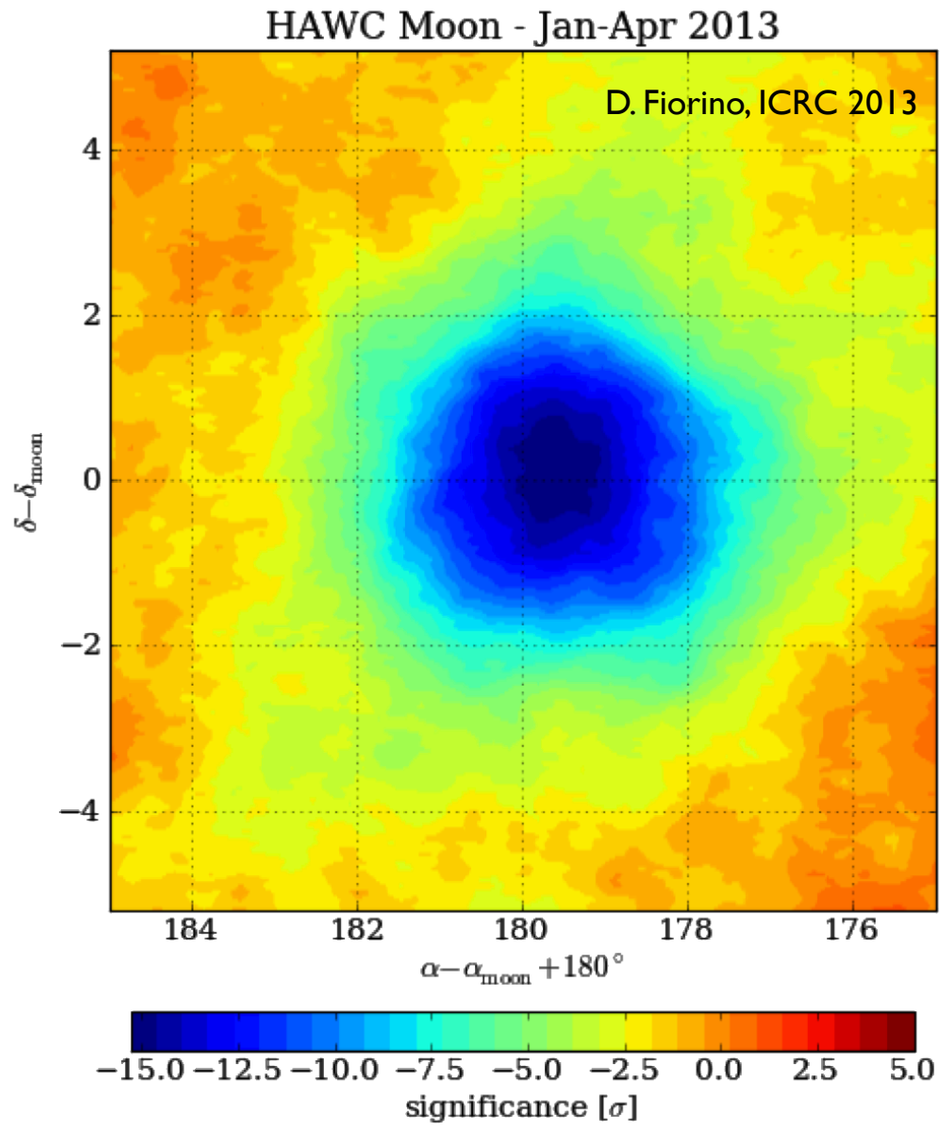


Other Weird Things We Can Do with HAWC

Data: Moon Shadow

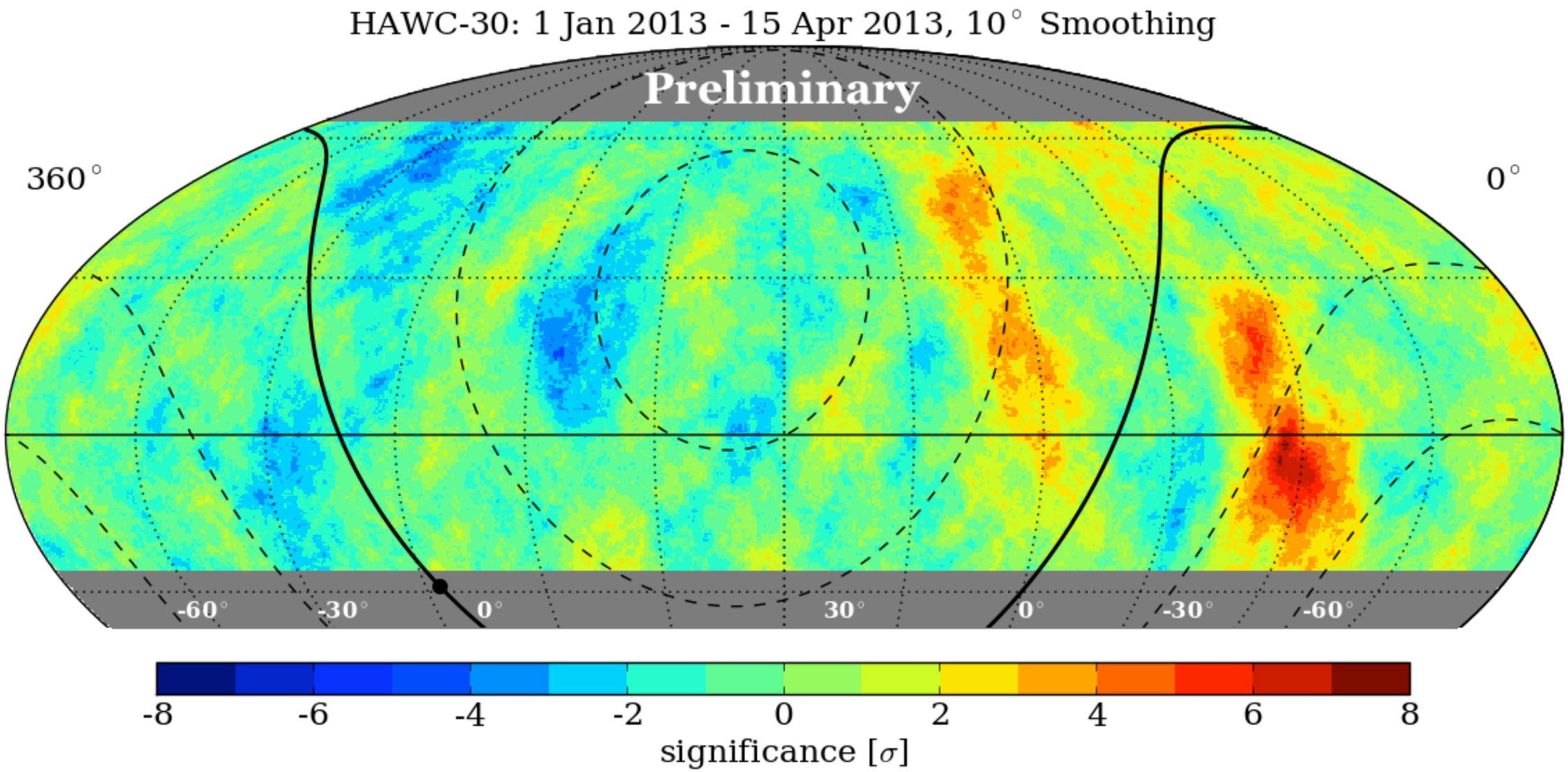
- Cosmic rays are blocked by the moon
- We can see a “shadow” in direction of moon; use this to calibrate detector





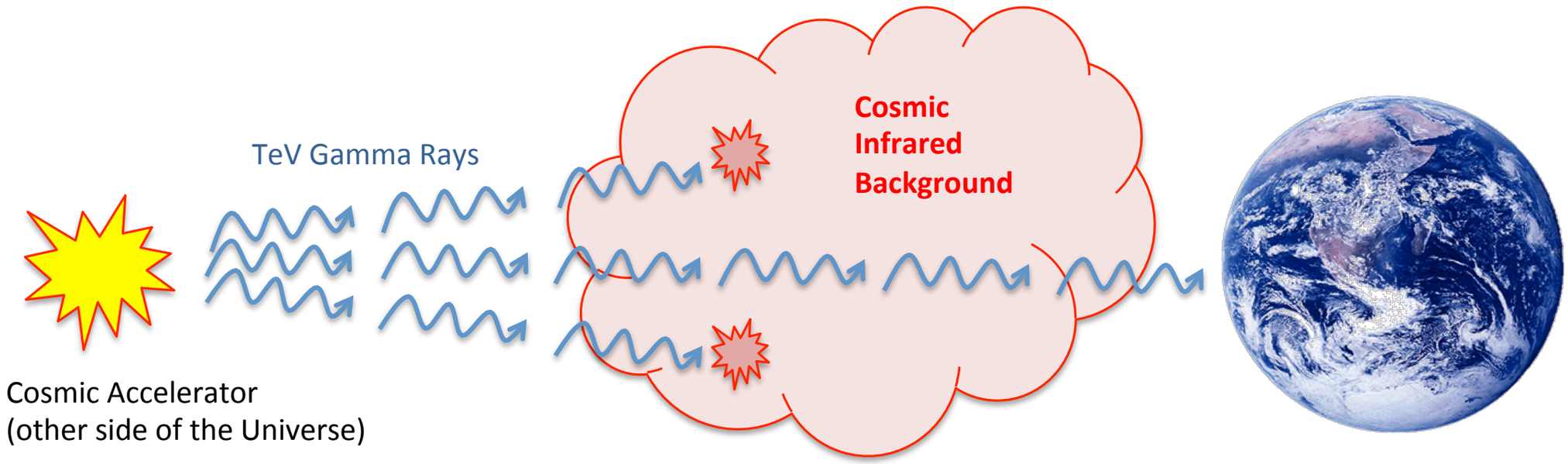
Cosmic Ray Anisotropy

- Galactic cosmic rays (H + He) are slightly anisotropic when they arrive at Earth. Effect is small: 0.1%



Cosmology: IR Background

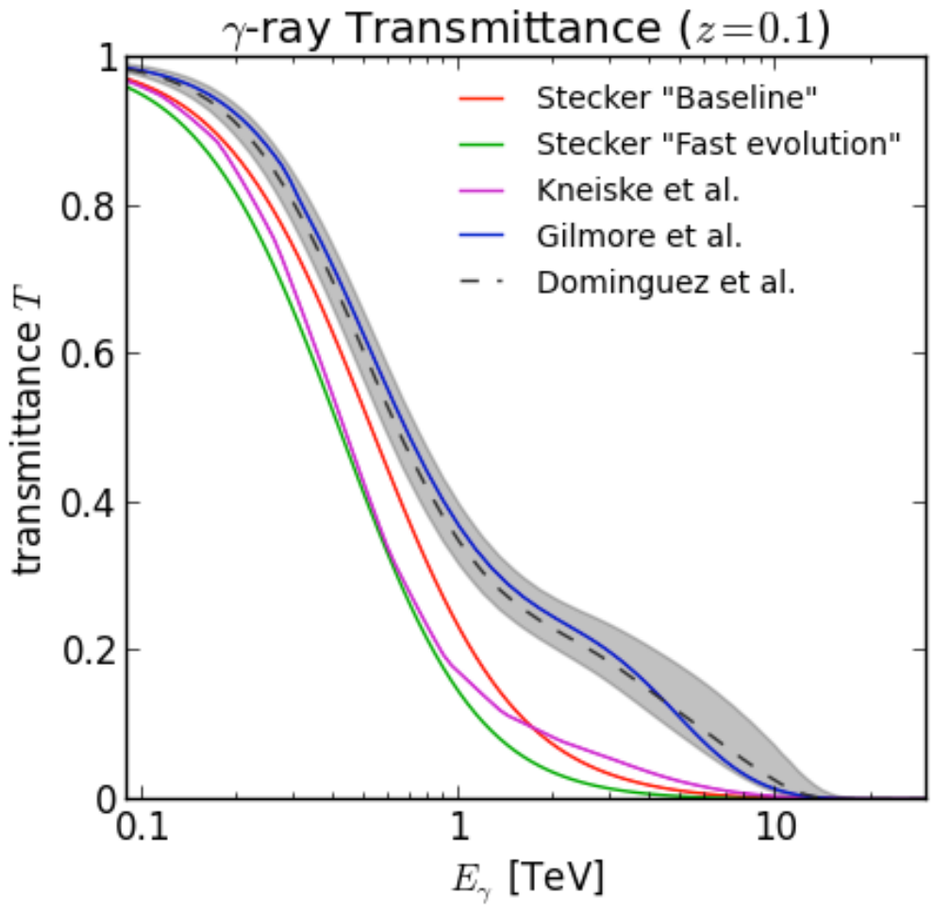
- TeV gamma rays are absorbed by the cosmic infrared background

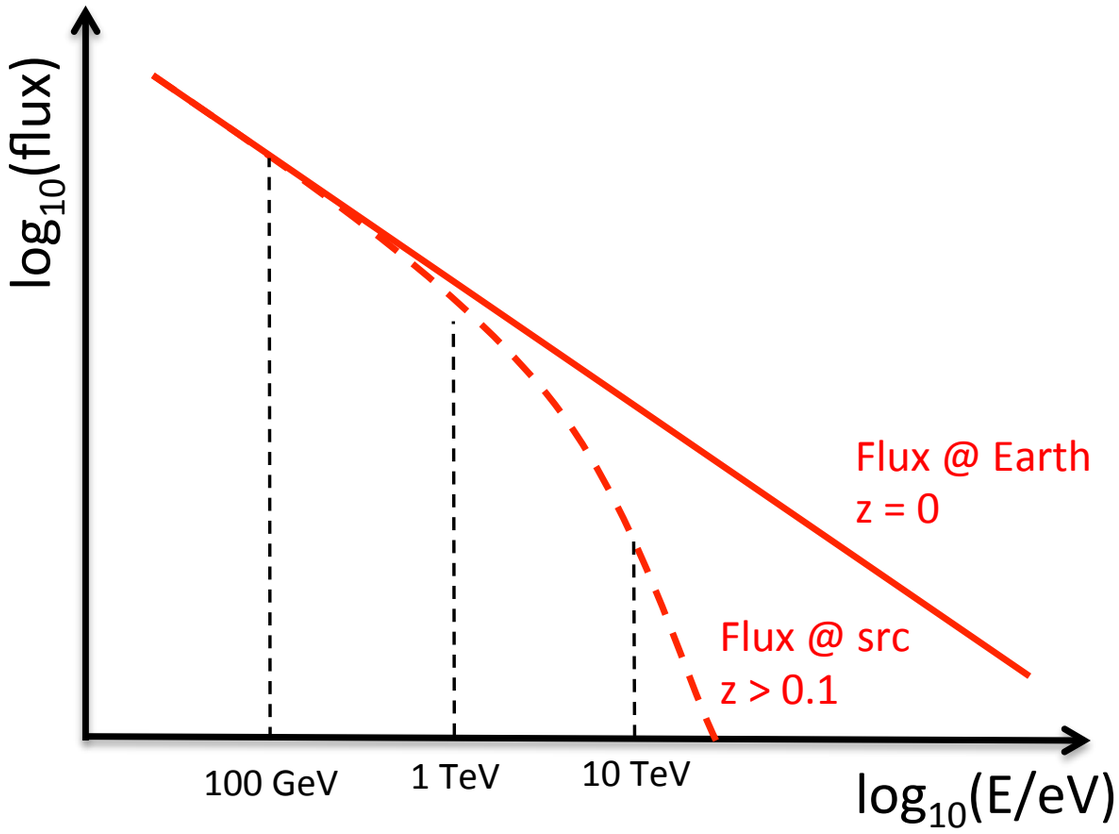


- This is redshifted light from the first stars; very important for models of evolution of universe

Detecting the IR Background

- Due to absorption, energy spectra of distant sources "cut off" more than they would w/o IR background

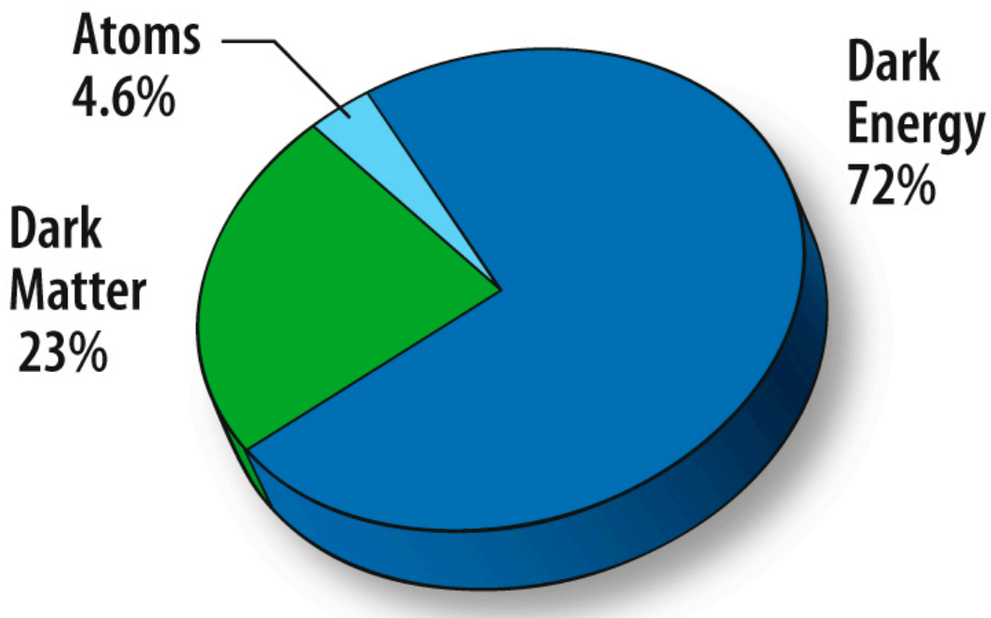




- Try to "de-absorb" spectra and estimate IR flux

Dark Matter Detection

- Dark matter: unknown gravitationally-bound, non-baryonic component of the universe

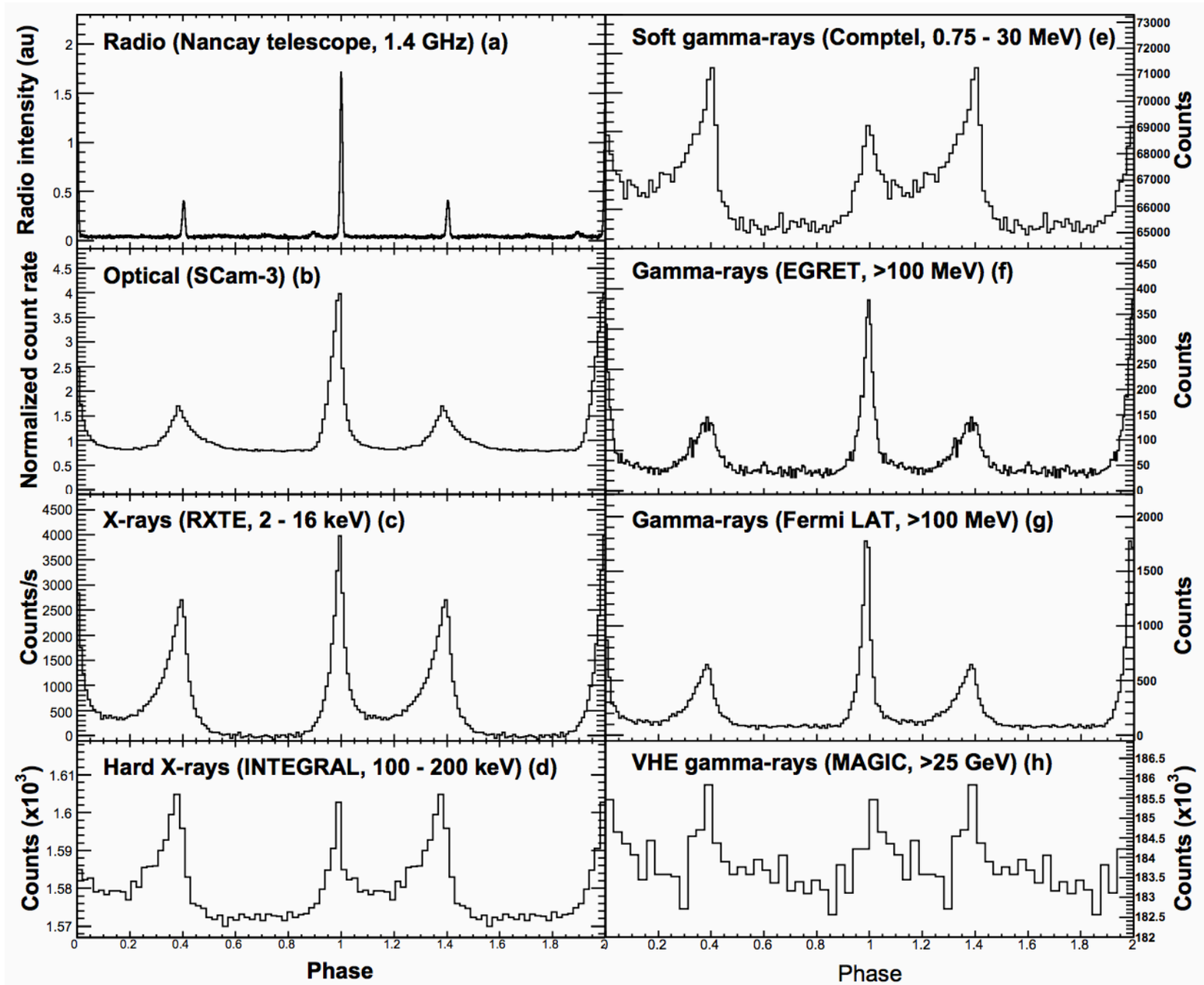


Bullet Cluster (Hubble + Chandra)

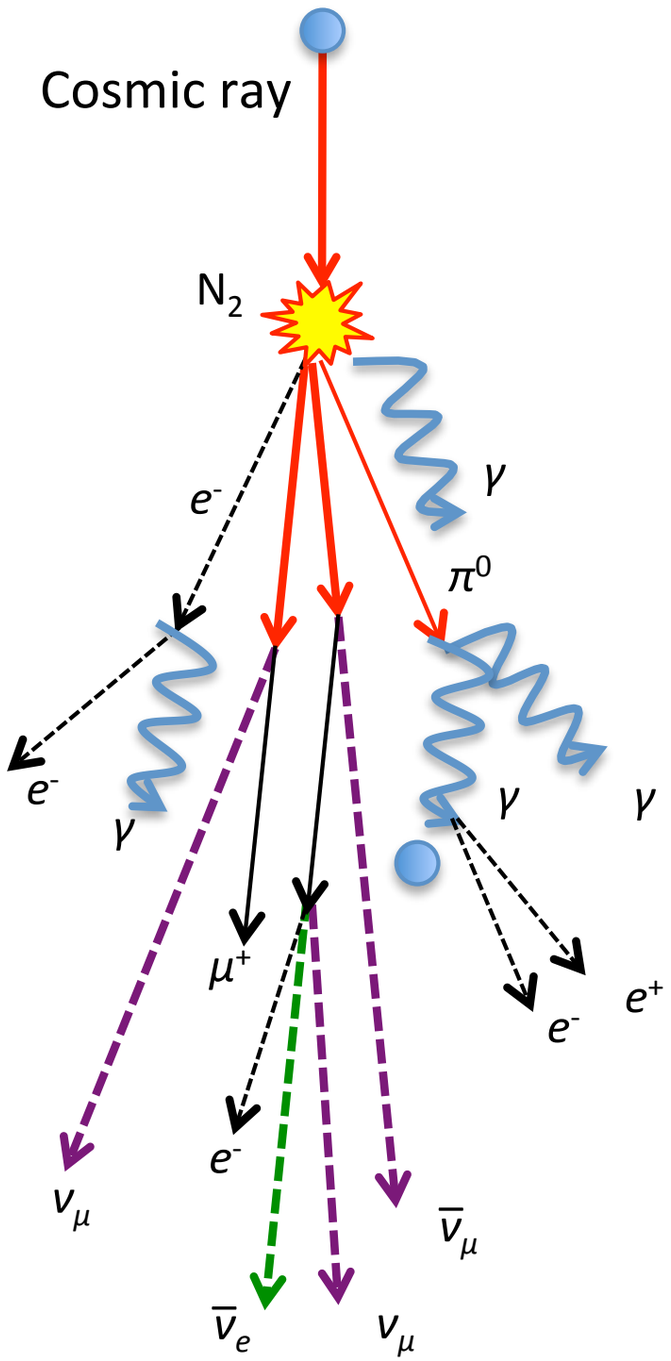
- Could be massive particles which decay to gamma rays
- Strategy: look for astrophysical objects with low luminosity, look for anomalous gamma-ray emission

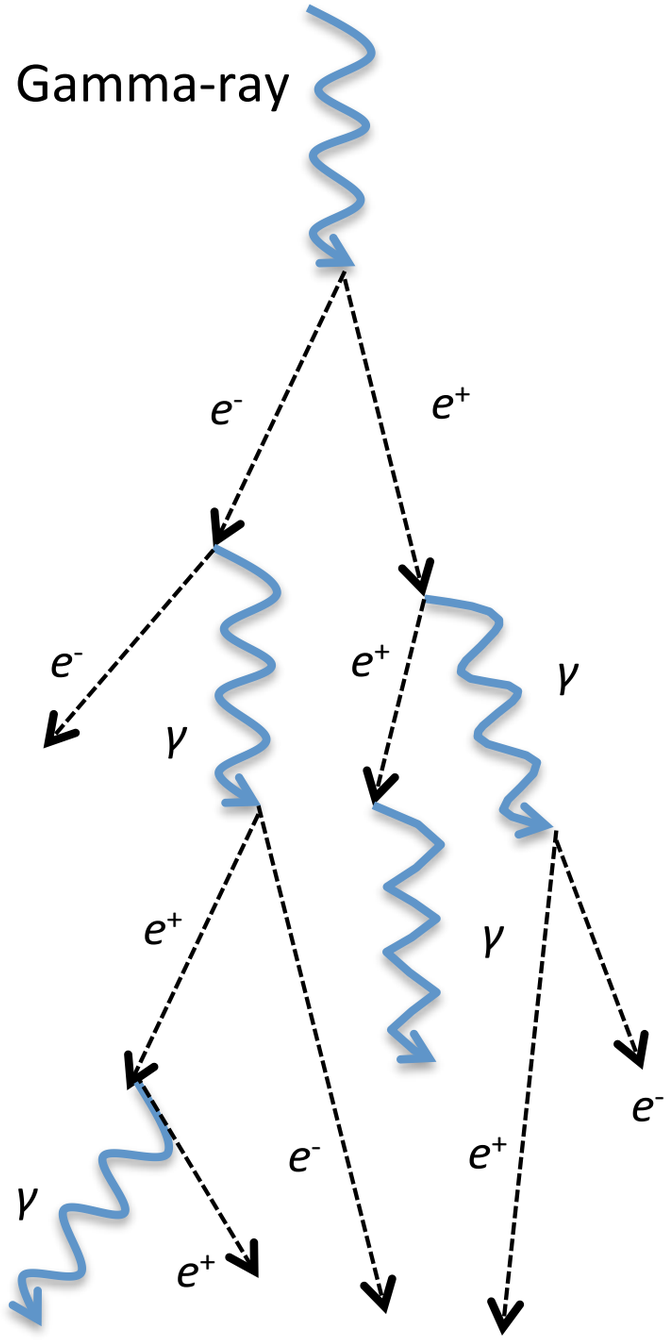
Lorentz Invariance Violation

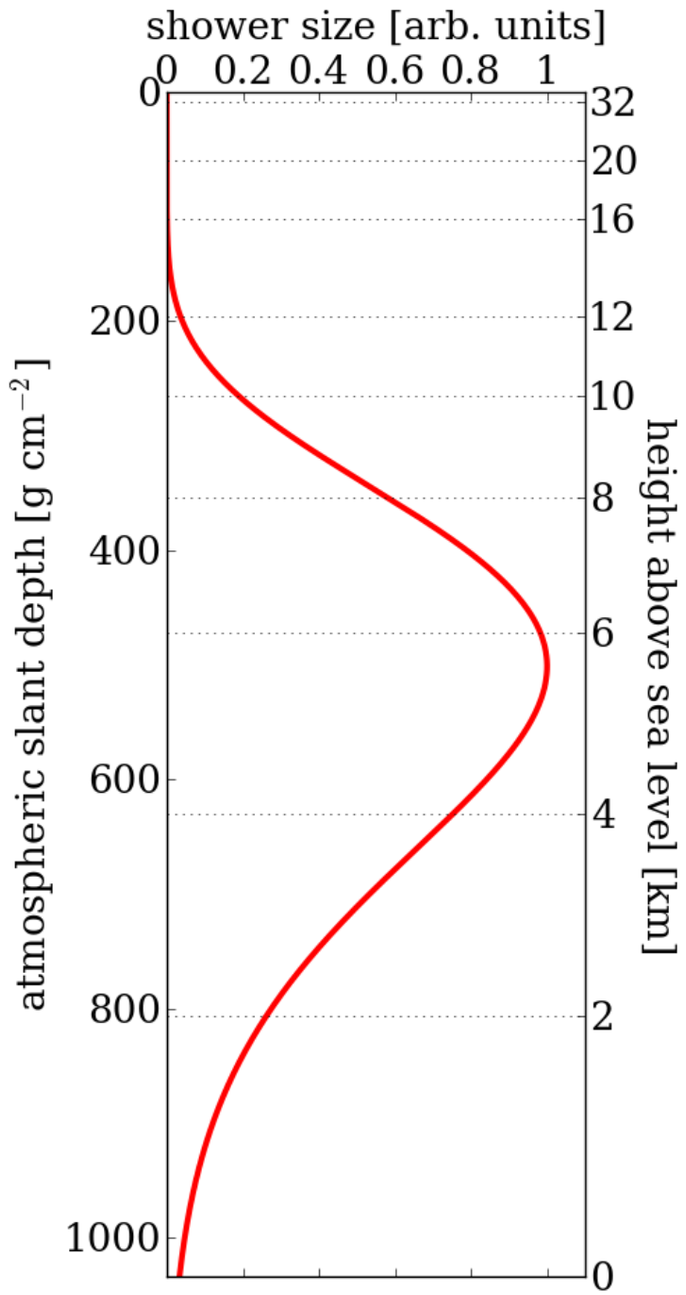
- Is the speed of light constant?
- Or does it change as photon energy increases?
- Search transient signals in X-rays, gamma rays, etc.
- See if signals align in time



Air Shower Development

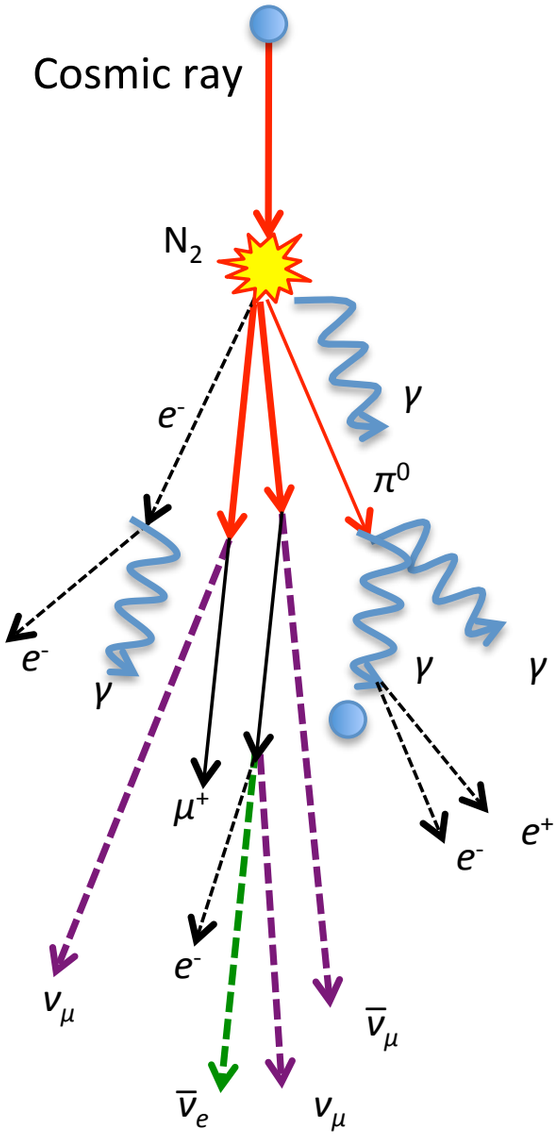


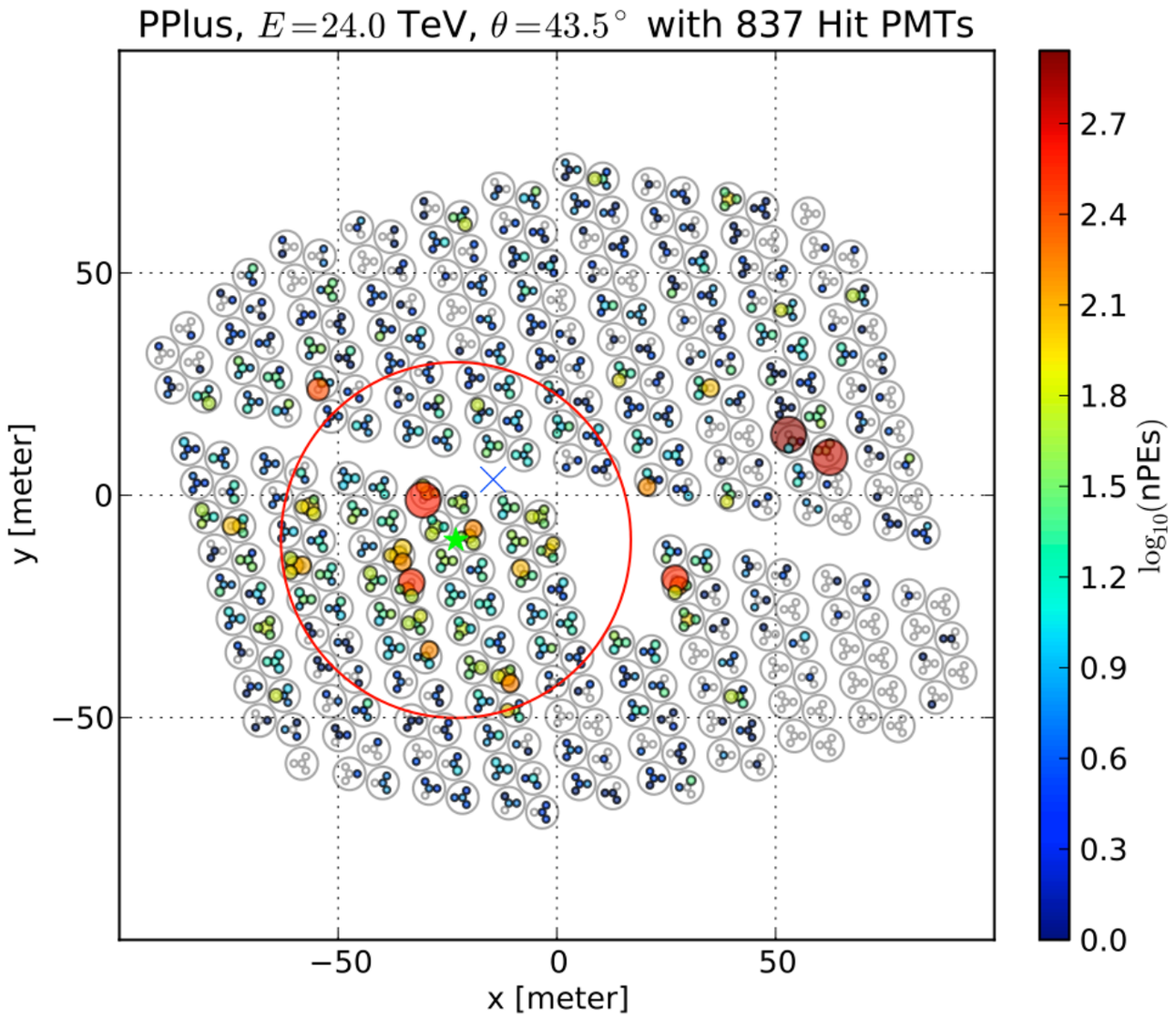




Background Rejection: Proton Tagging

- Look for large hits far from shower core (99% rejection at 10 TeV)





Signal: Gamma-Ray Tagging

- No large hits far from core: probably a gamma-ray