The High-Altitude Water Cherenkov Gamma-Ray Observatory

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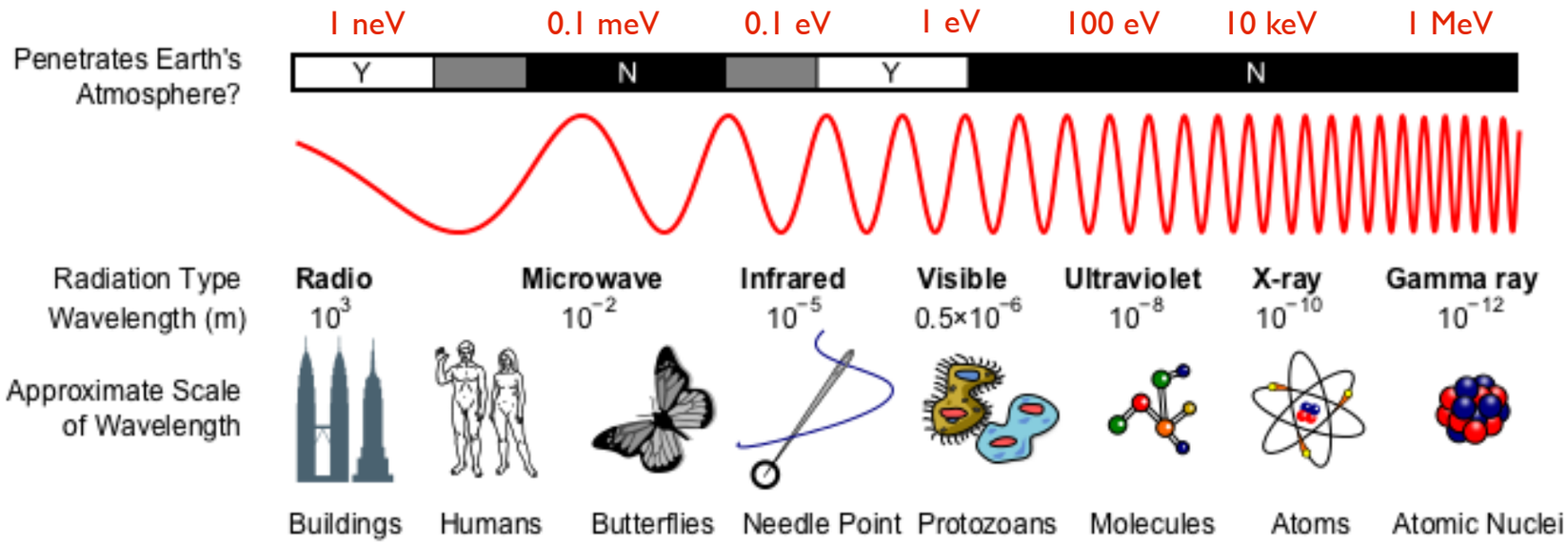
IceCube MasterClass
AN AUTHENTIC ASTROPHYSICS RESEARCH EXPERIENCE

Multiwavelength Astronomy

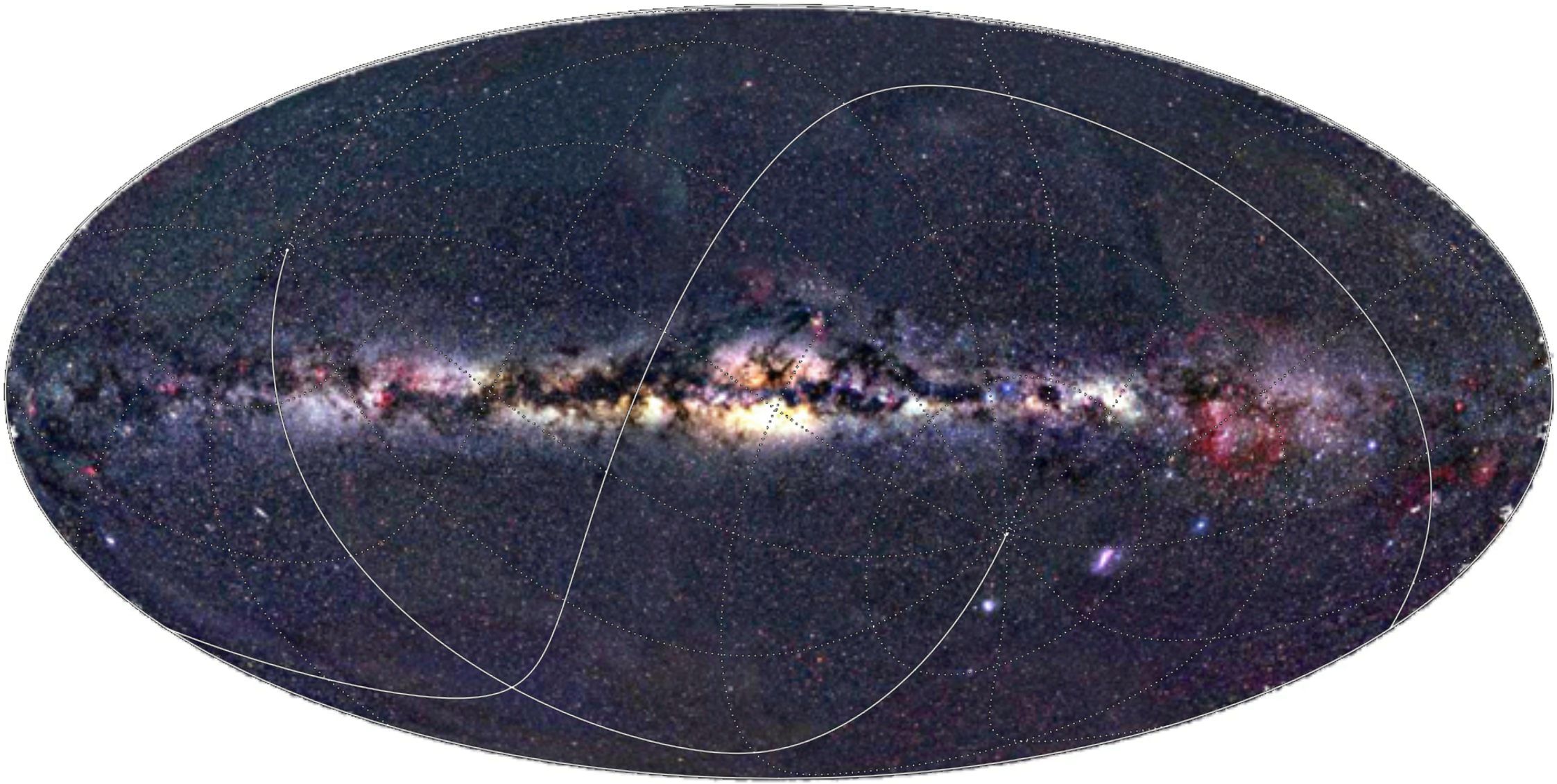
- Astronomy using TeV radiation (wavelength $\lambda = 10^{-18}$ meters)



- 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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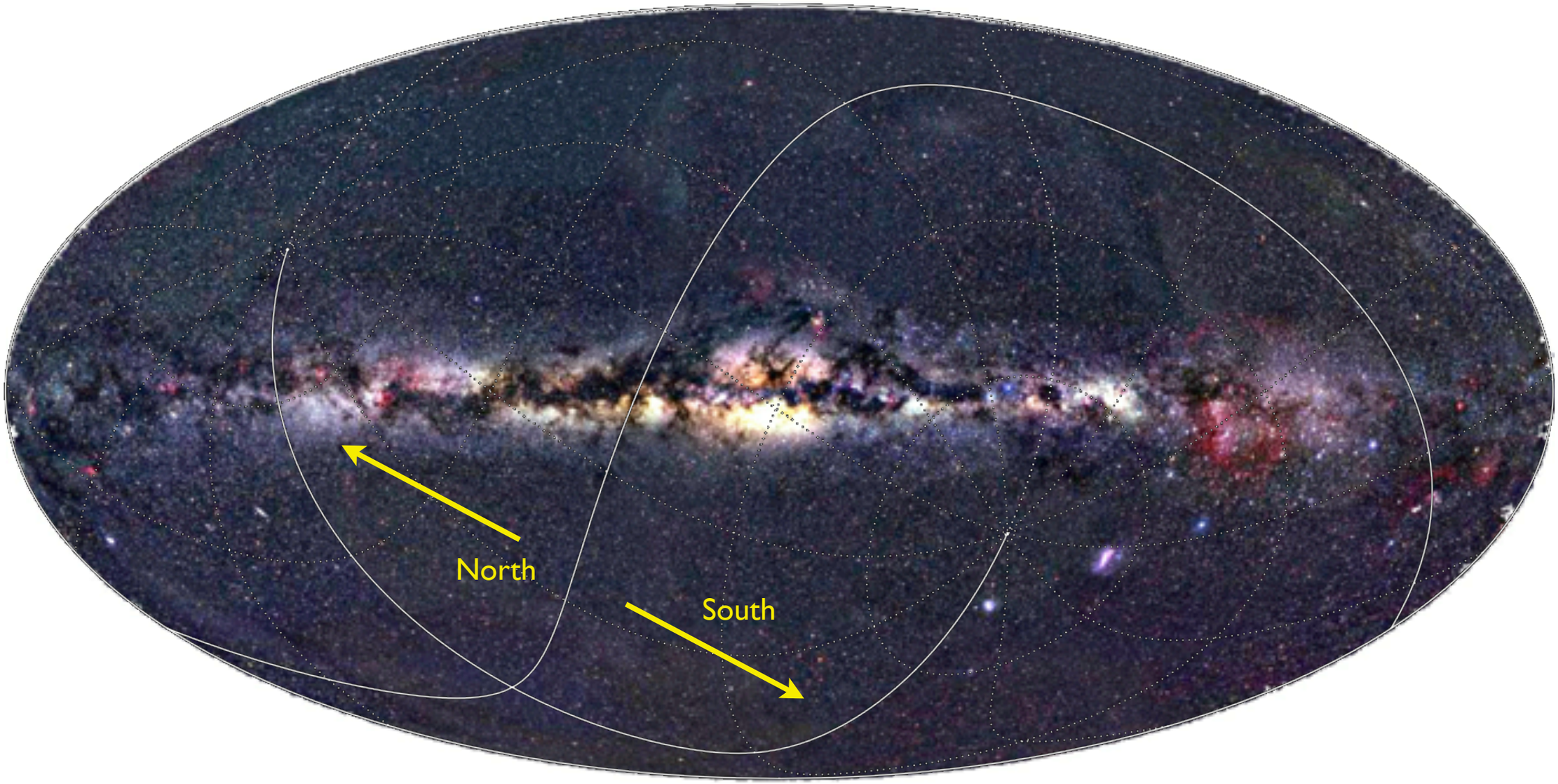
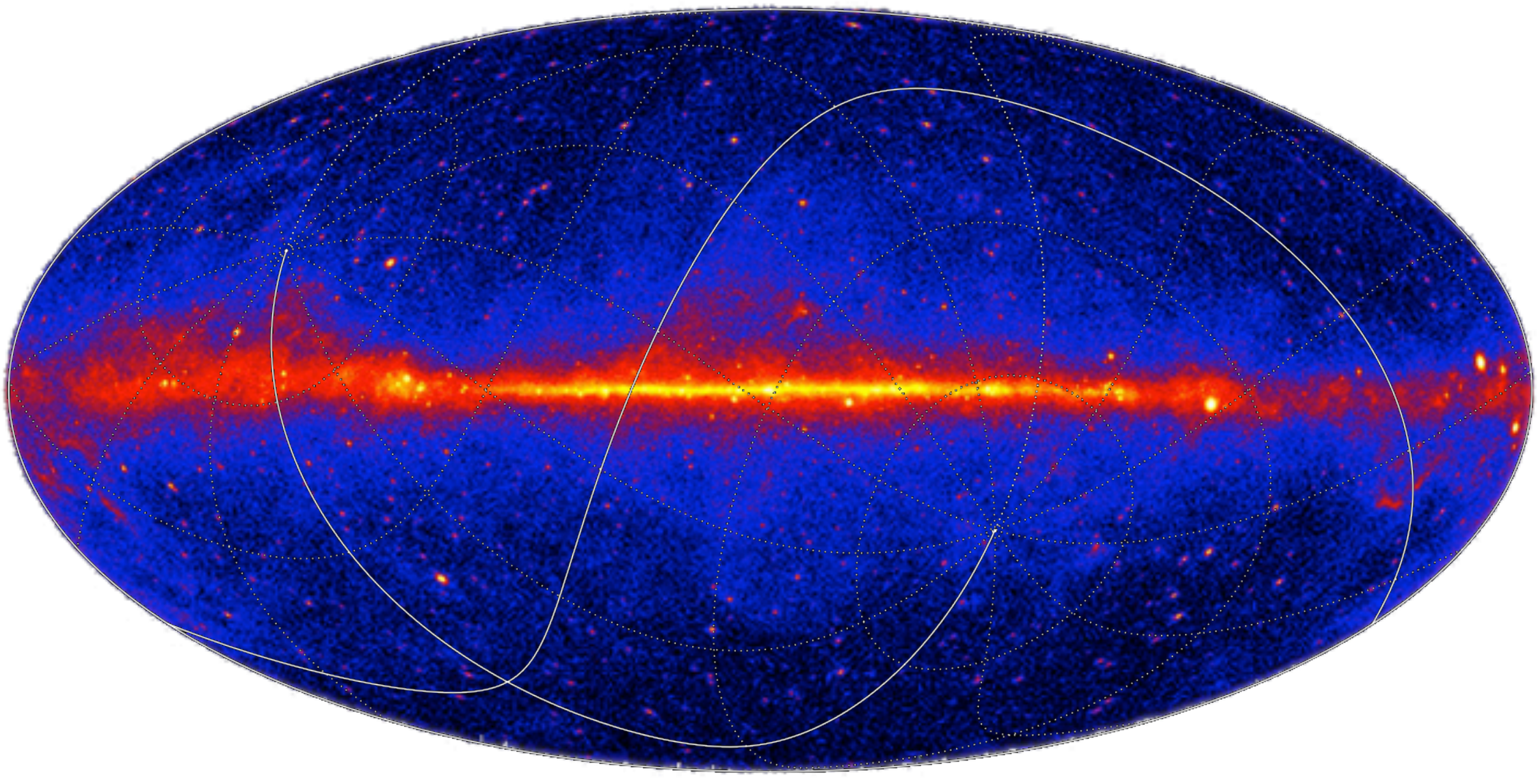
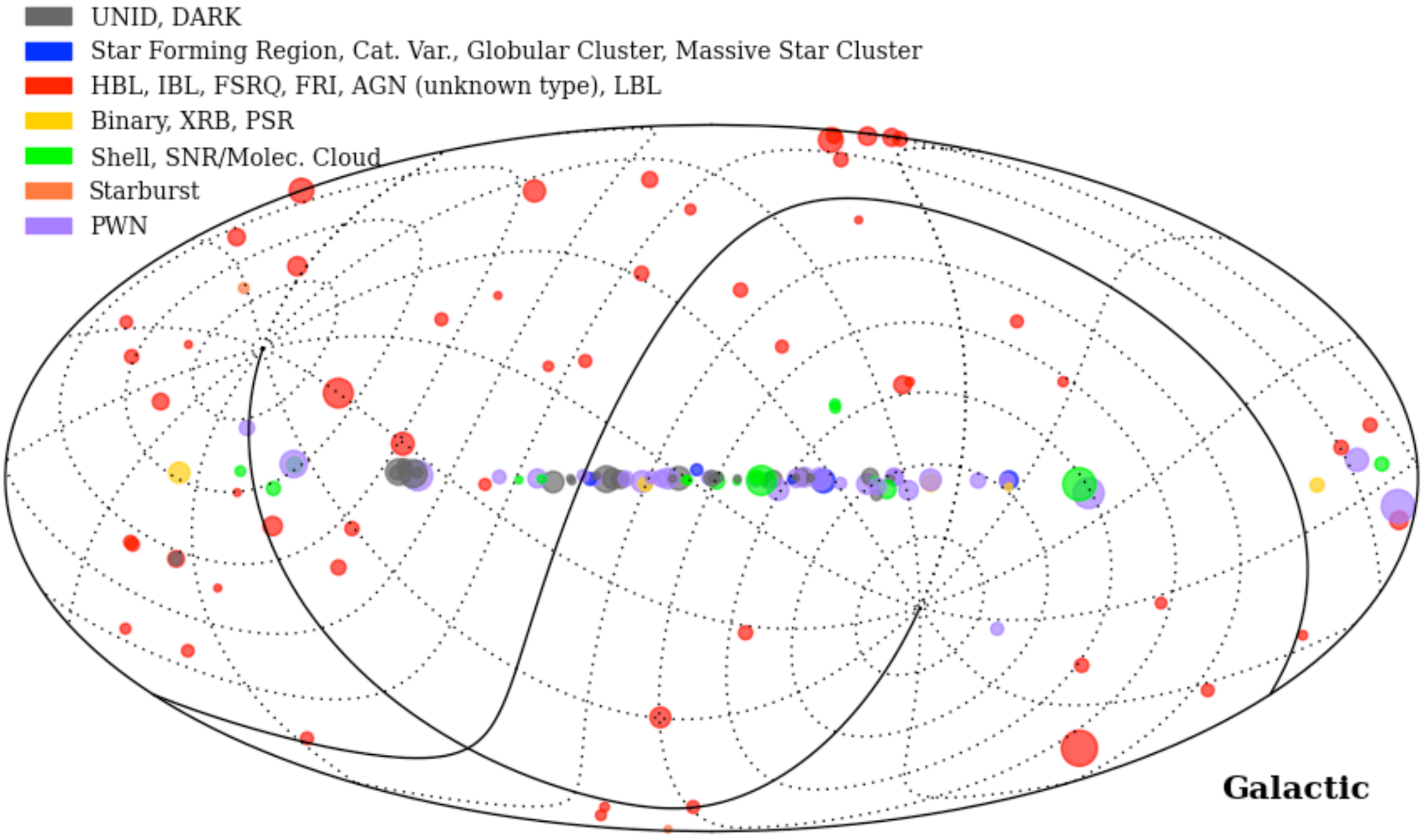


GeV Gamma-Ray Astronomy

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

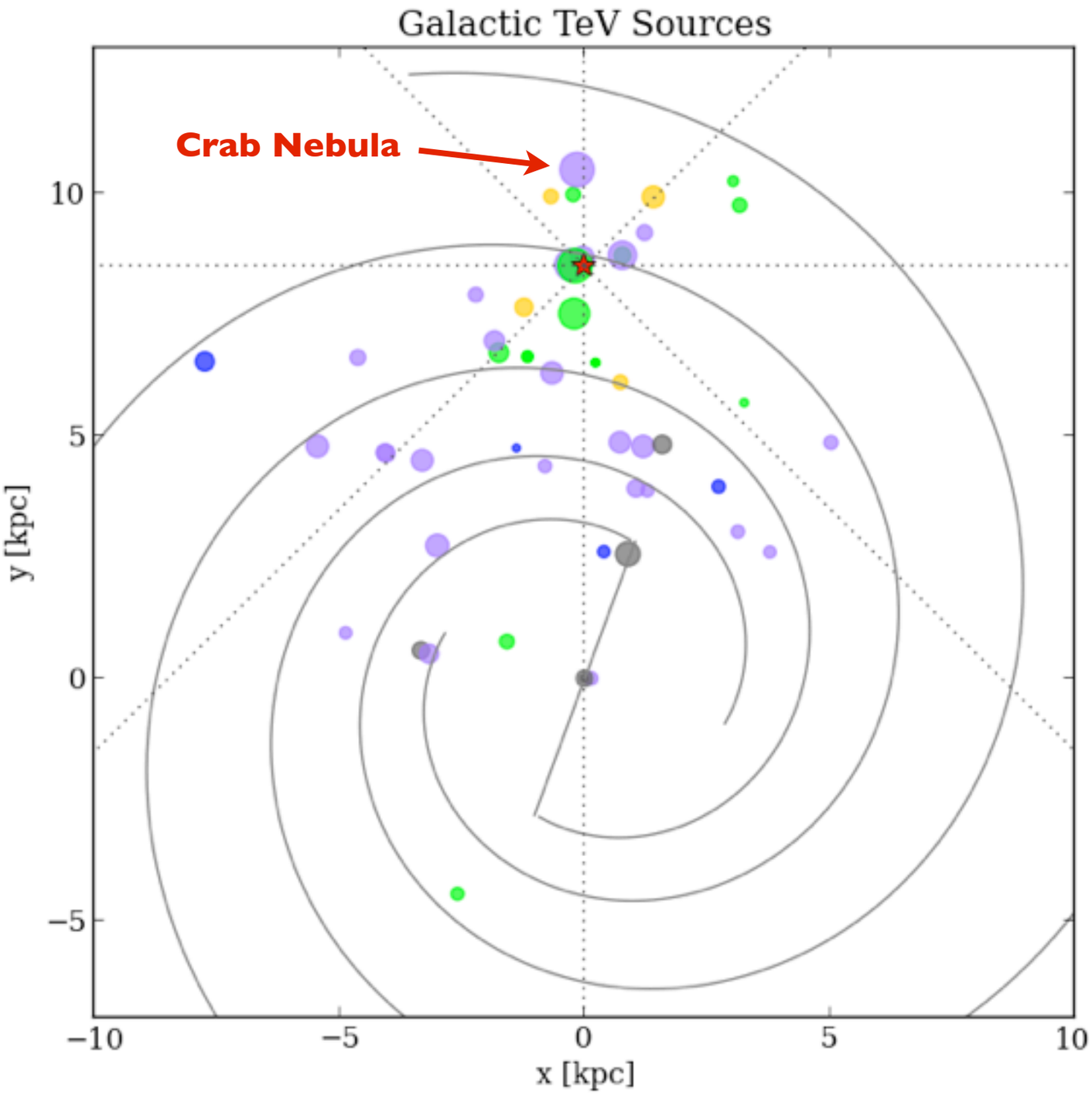


TeV Gamma-Ray Astronomy

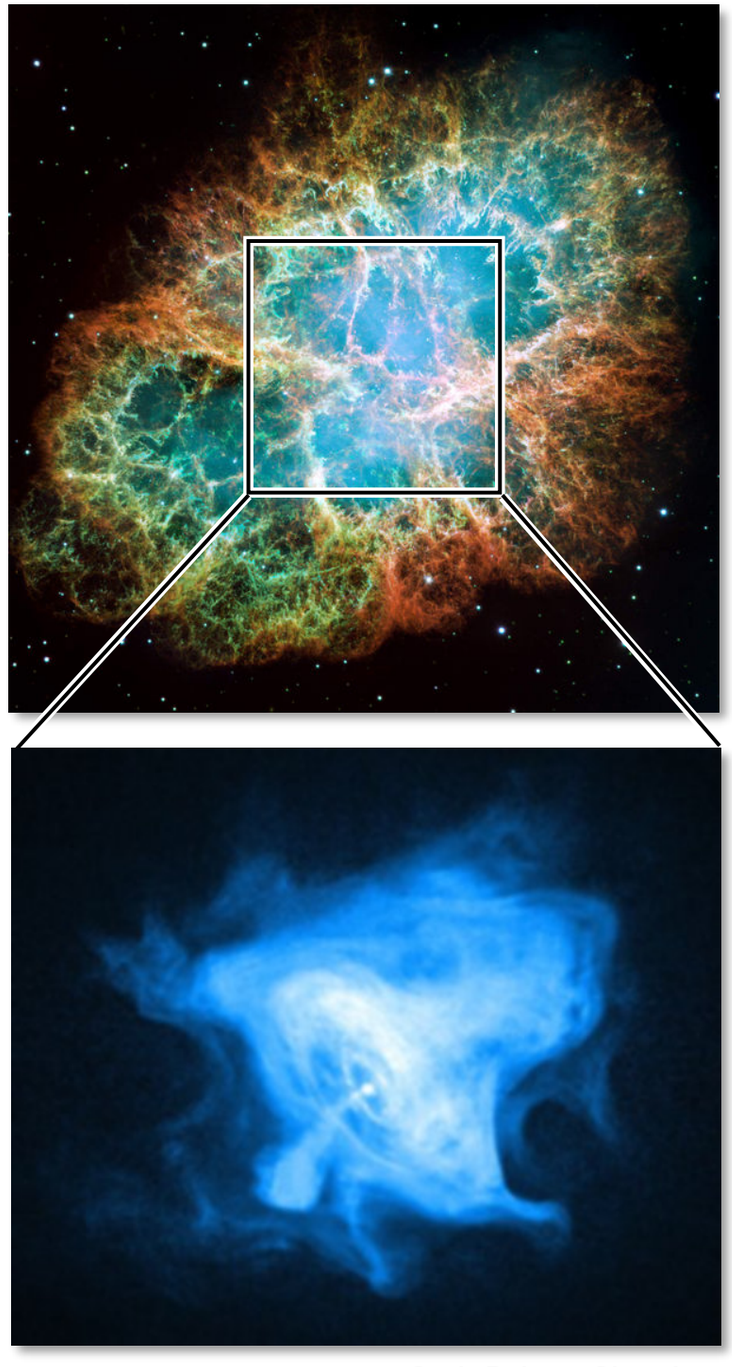


- TeV band: 100 GeV - 100 TeV, or 10^{-20} - 10^{-17} m

Galactic Gamma-Ray Sources

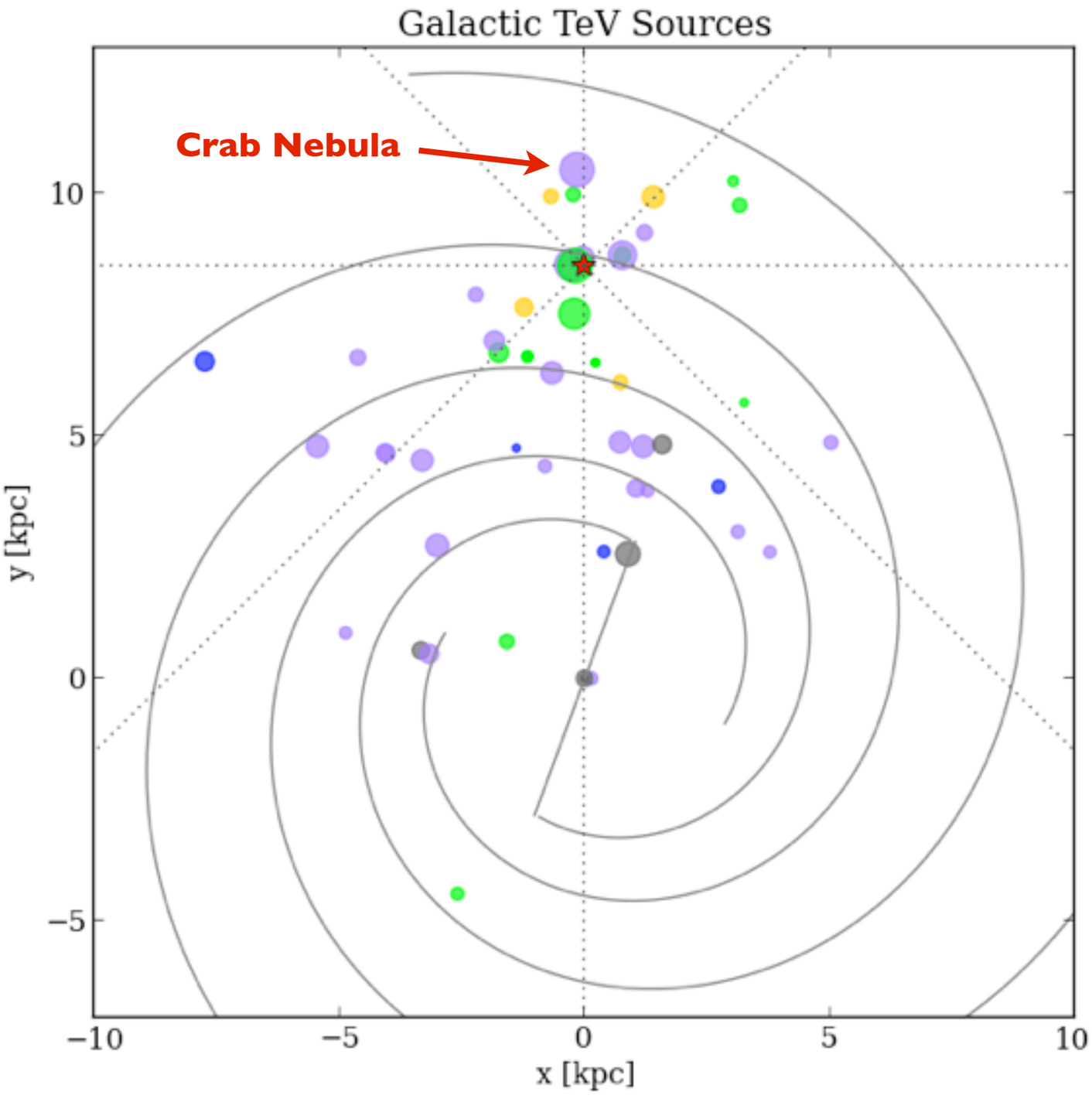


Crab Nebula: Hubble



Crab Pulsar: Chandra

Galactic Gamma-Ray Sources



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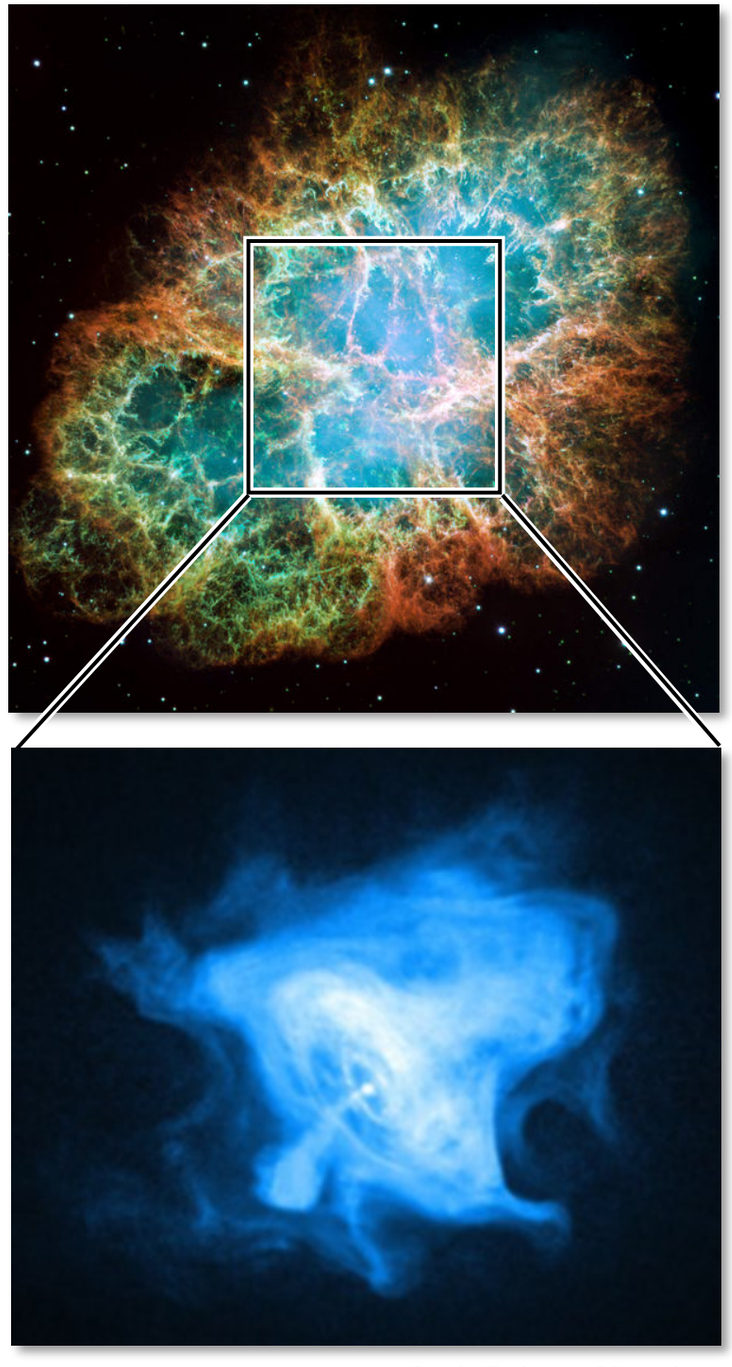
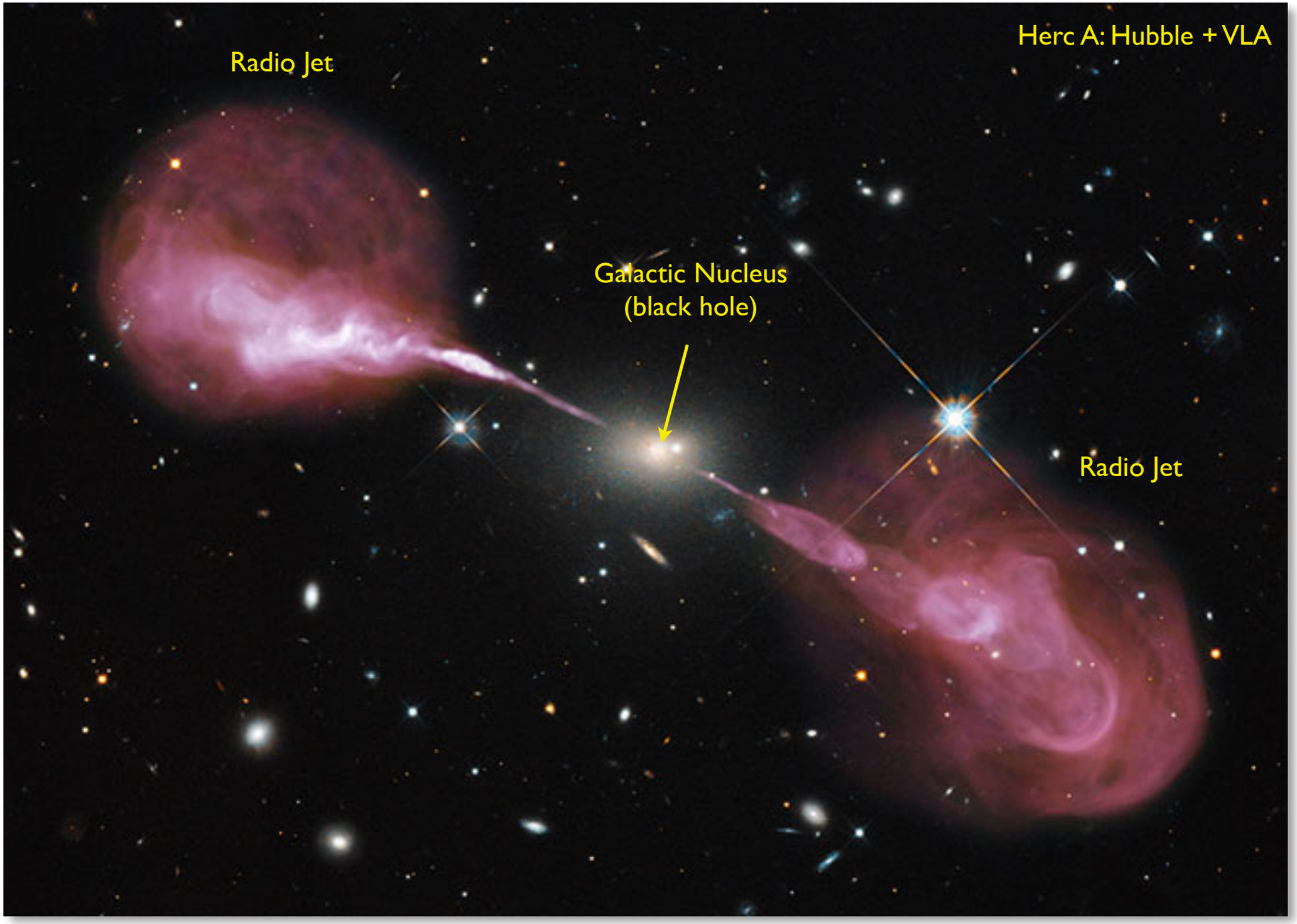


Crab Pulsar: Chandra

Extragalactic Source (AGN)



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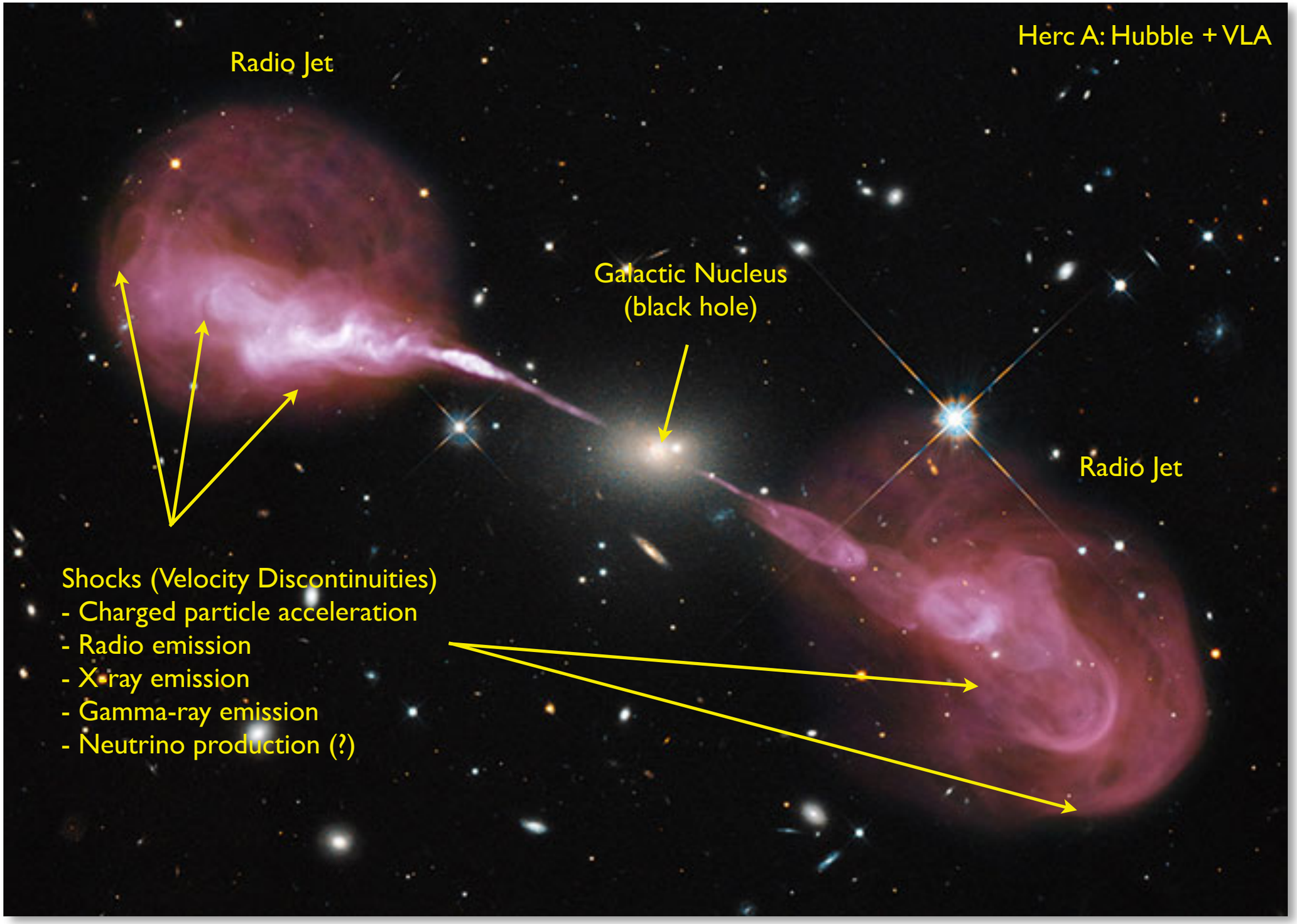

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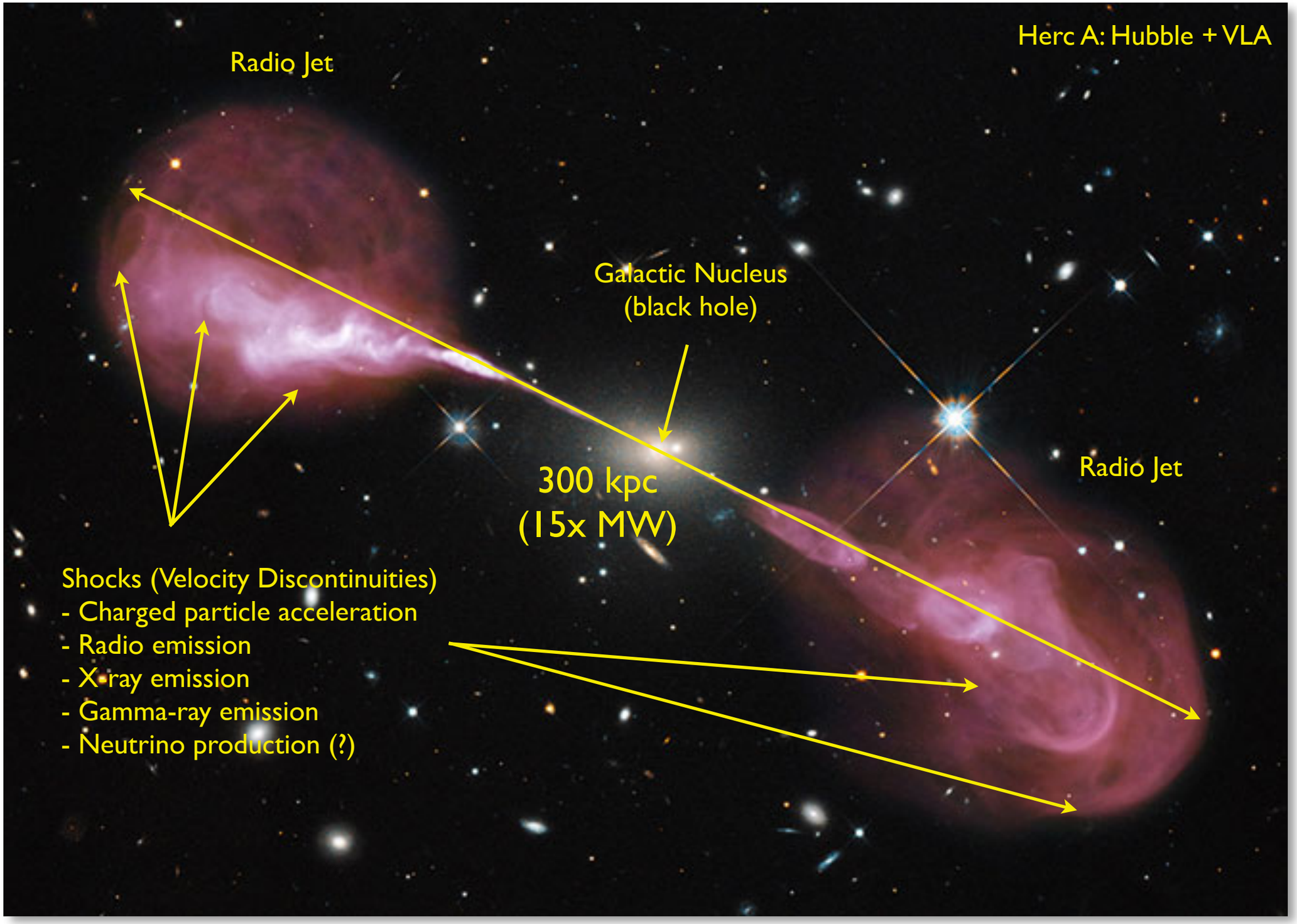
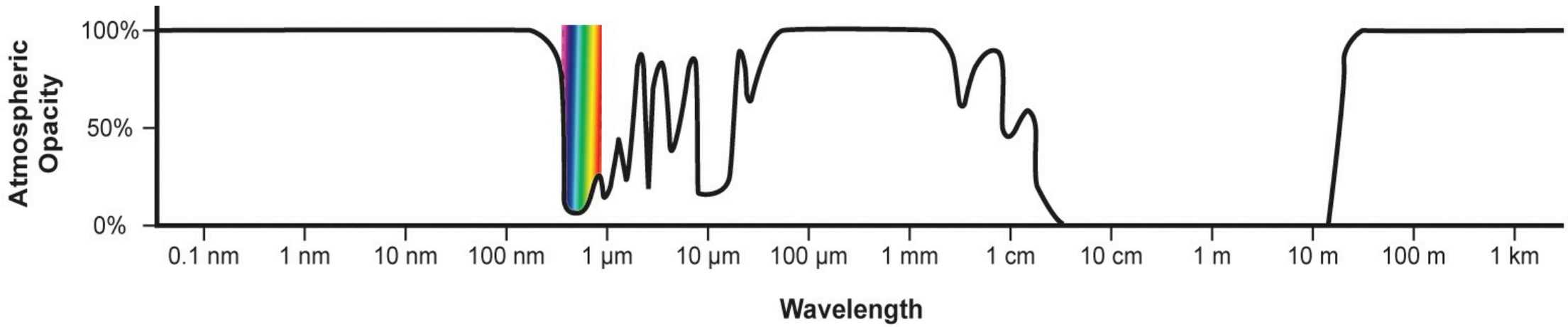


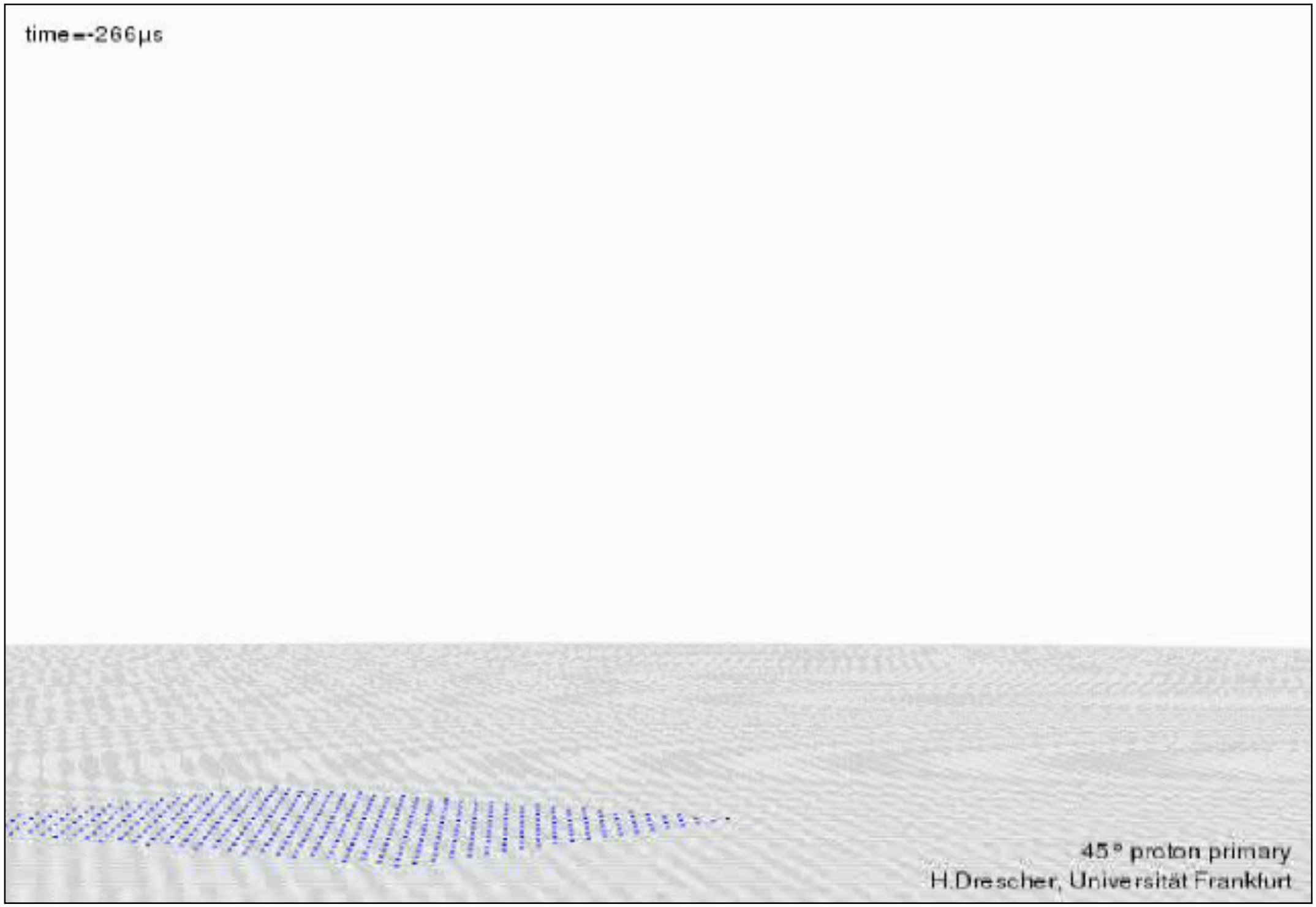
Detecting TeV Gamma Rays

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

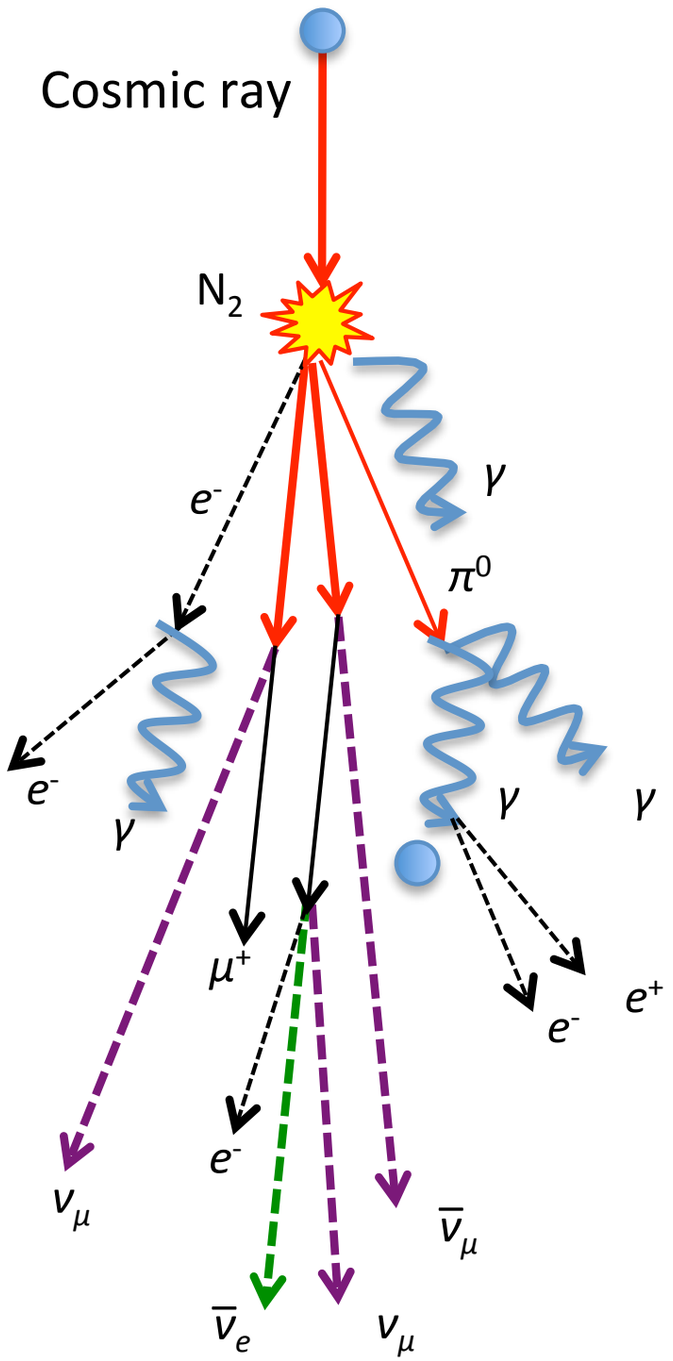


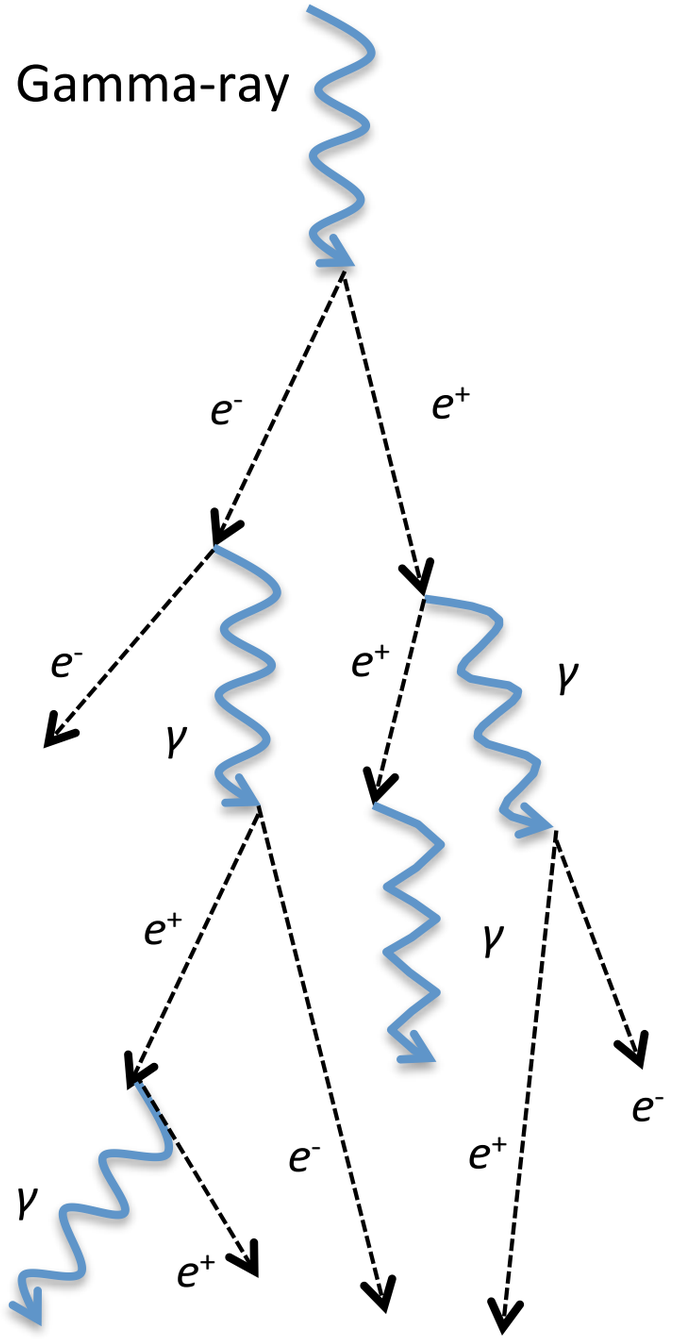
- But, the atmosphere is opaque to TeV gamma rays
- They produce air showers which we can observe

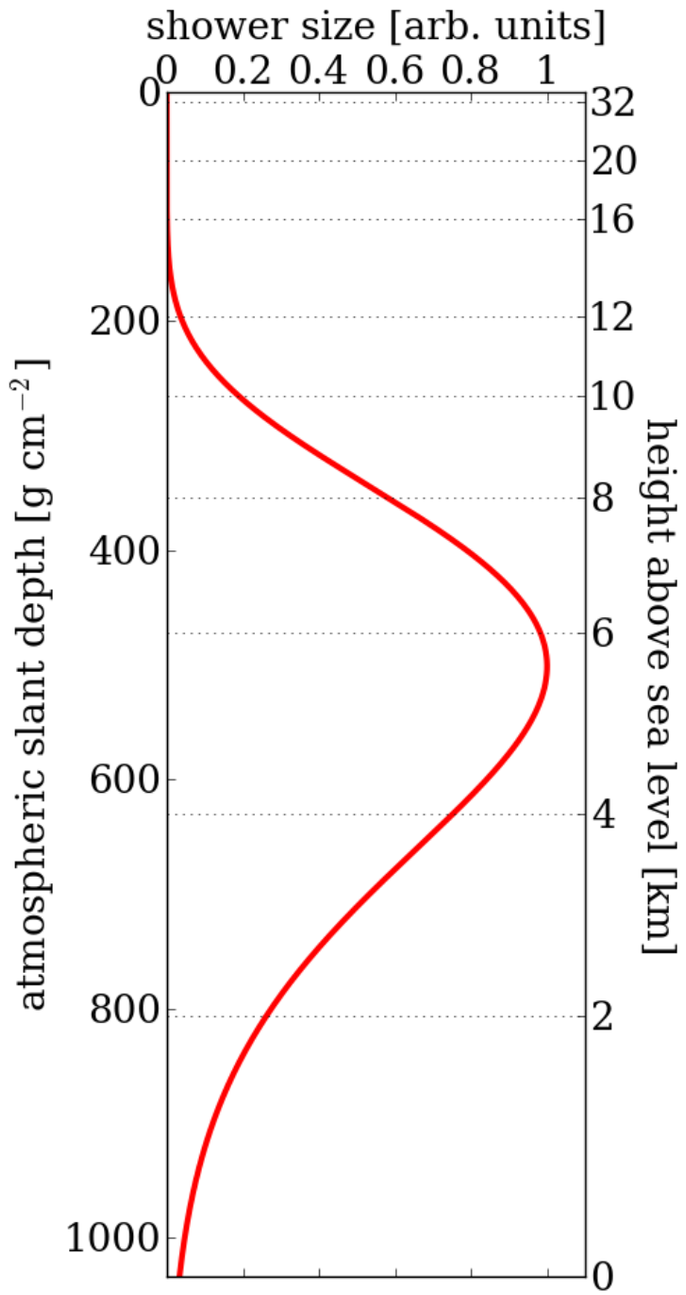
Cosmic Ray Air Shower (Proton)



Air Shower Development



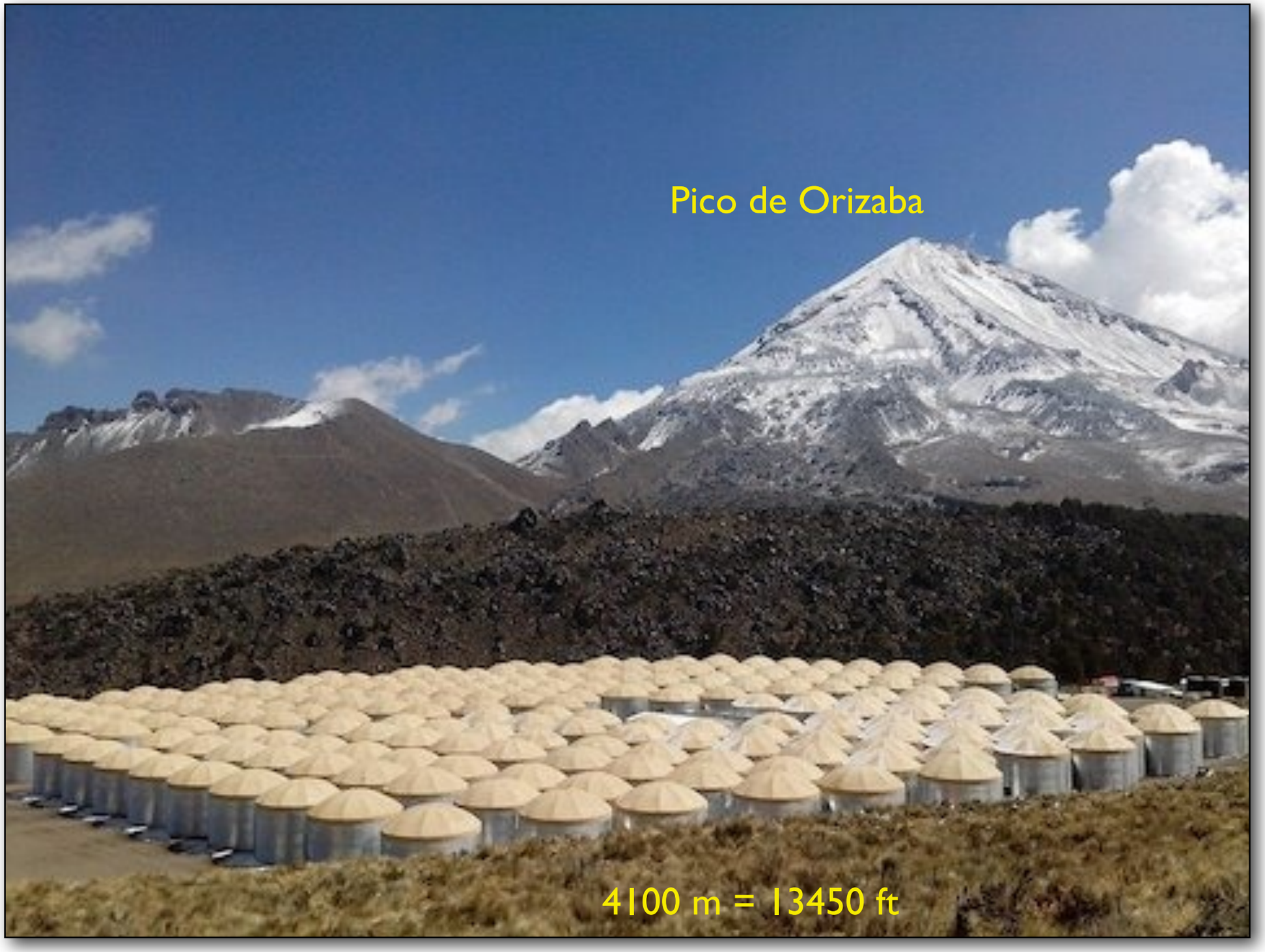




HAWC Gamma-Ray Observatory

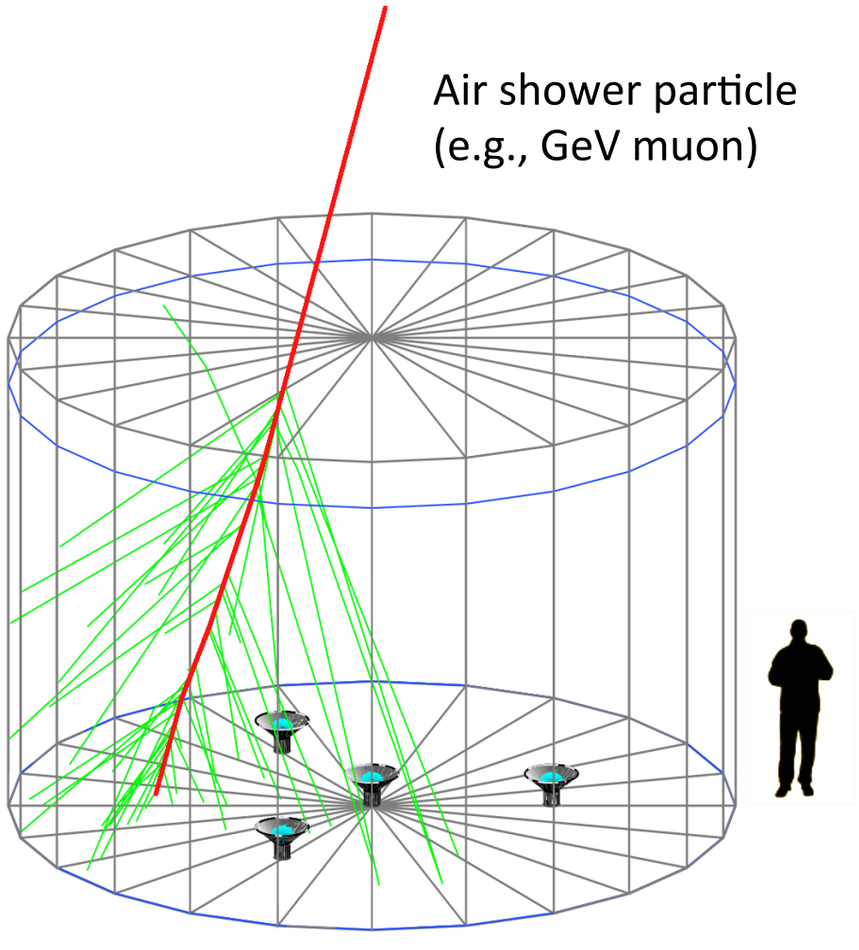
- The **H**igh-**A**ltitude **W**ater **C**herenkov Observatory is under construction near Puebla, Mexico
- Goals: observe gamma rays and cosmic rays from half the sky each day
- Statistics:
  - 4100 m above sea level
  - 19° N latitude
  - 300 water tanks
  - 1/6th of sky in FOV
  - Covers 100 GeV to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

HAWC Observatory



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: May 2014

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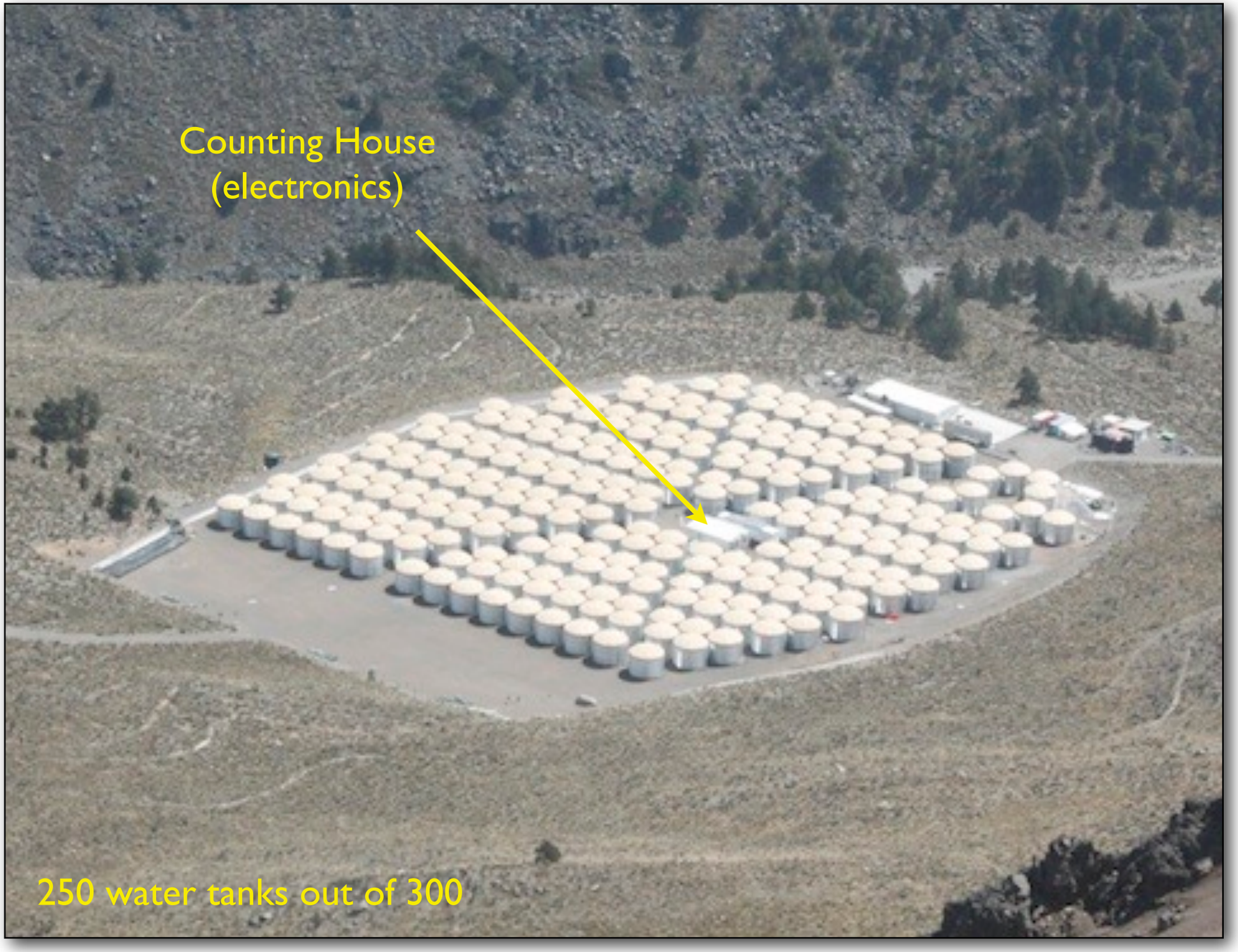

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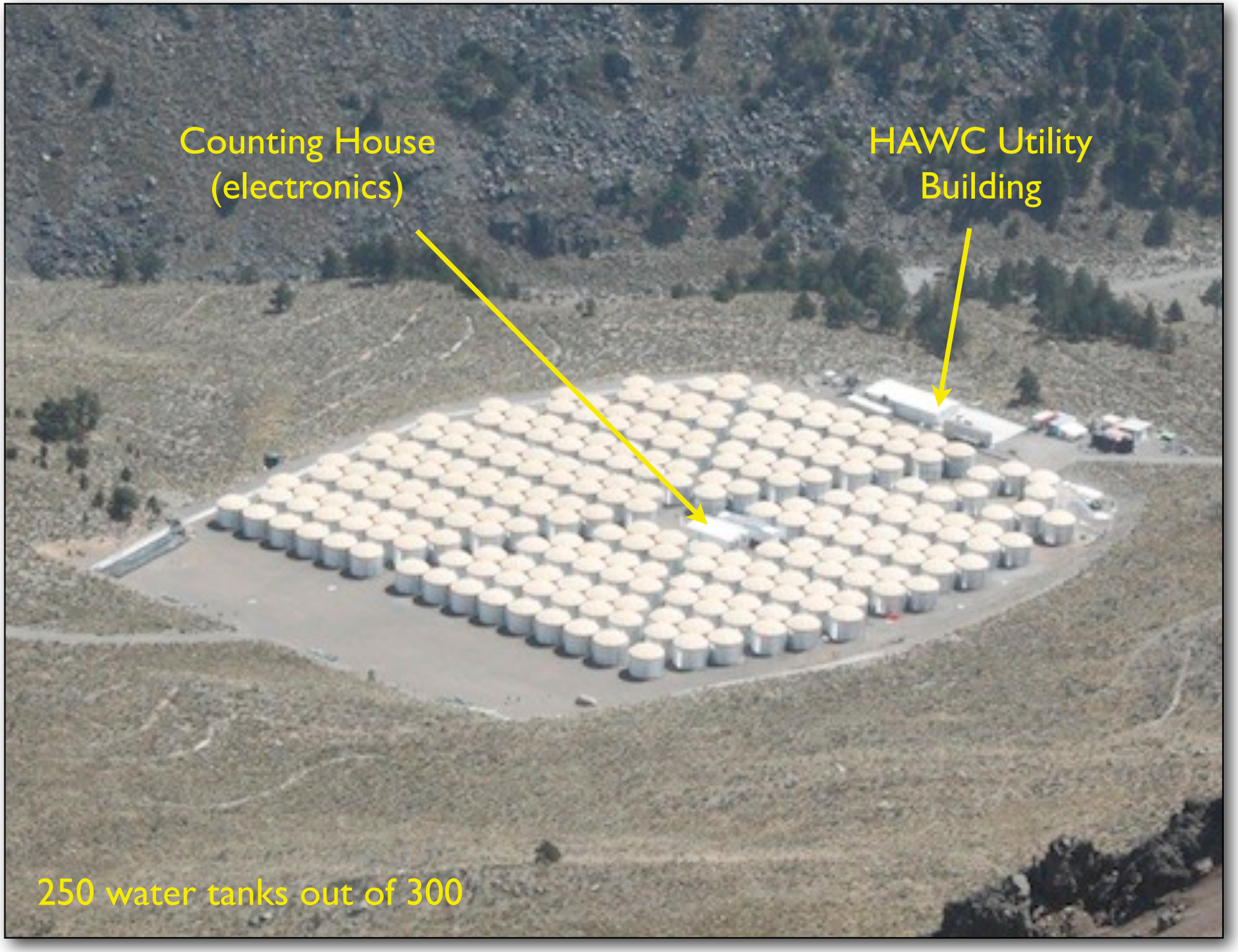

HAWC Site

NASA Earth Observatory

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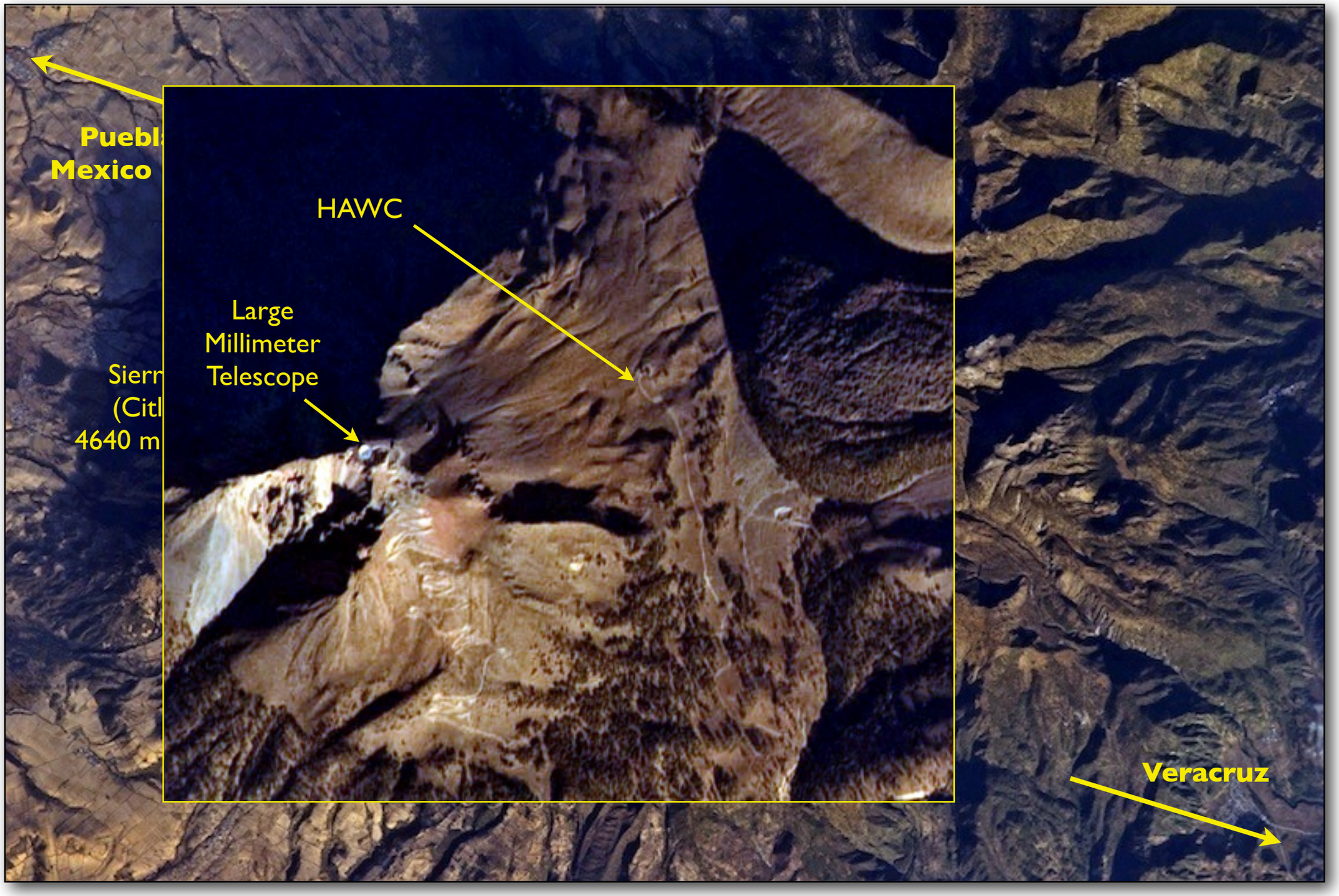
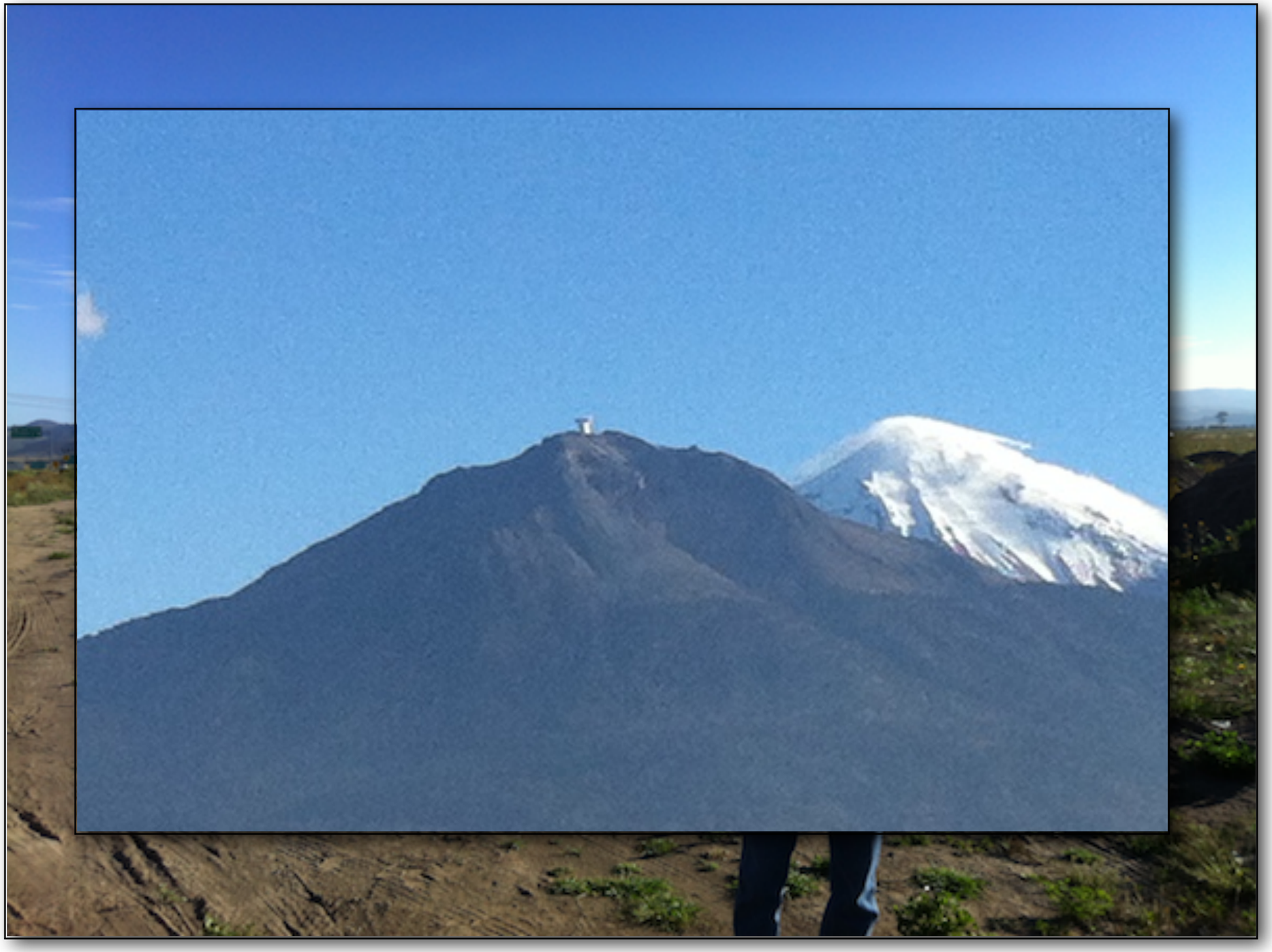


Going Up the Mountain

Going Up the Mountain



Going Up the Mountain

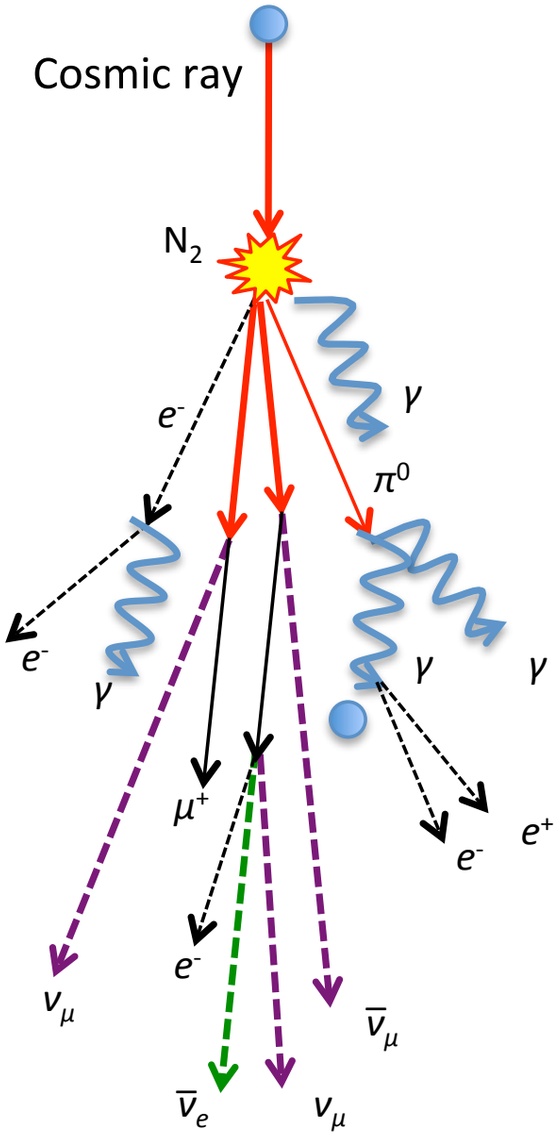
Going Up the Mountain

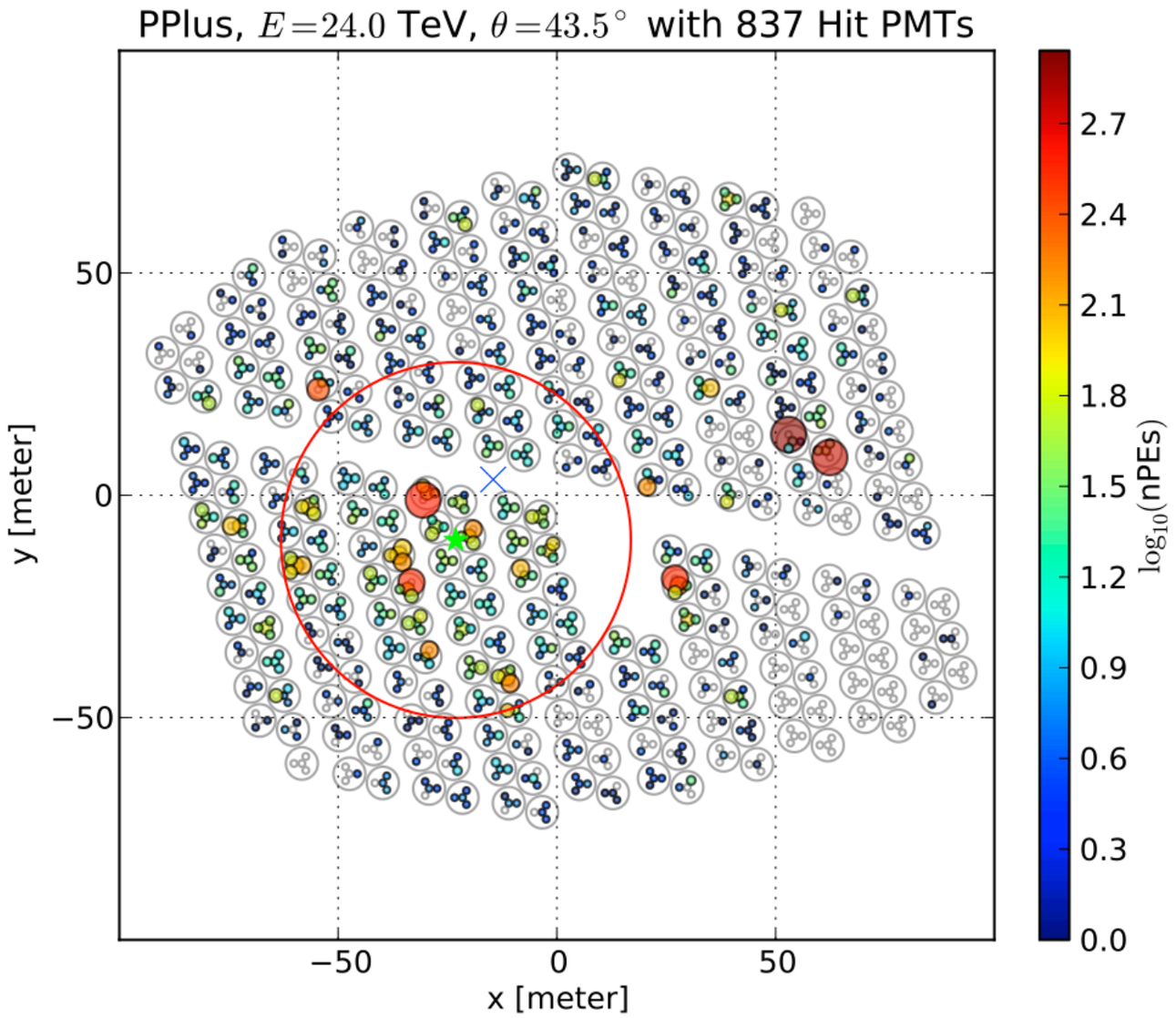
Life Near the Site

Life Near the Site

Background Rejection: Proton Tagging

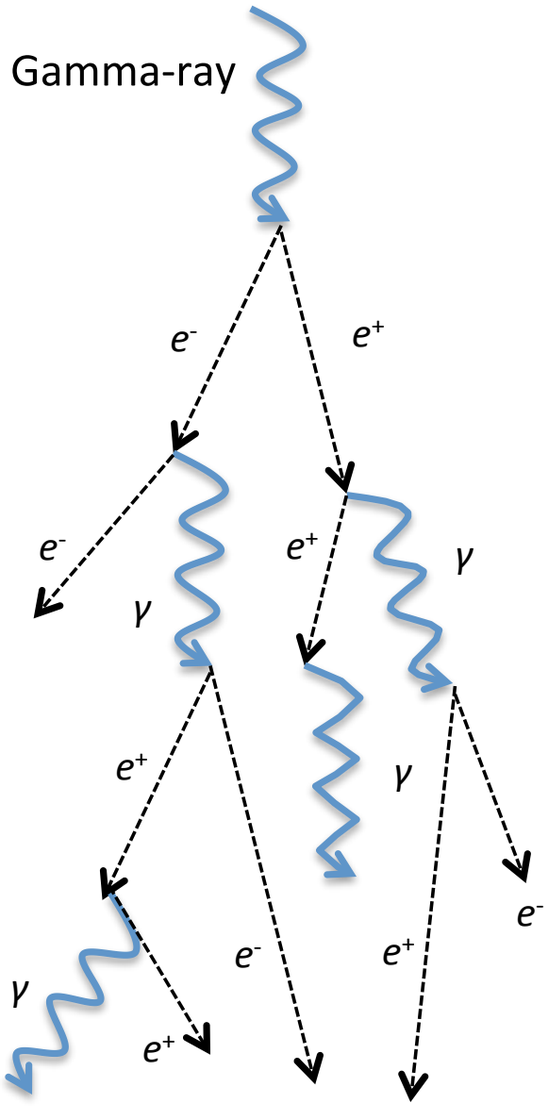
- Look for large hits far from shower core (99% rejection at 10 TeV)

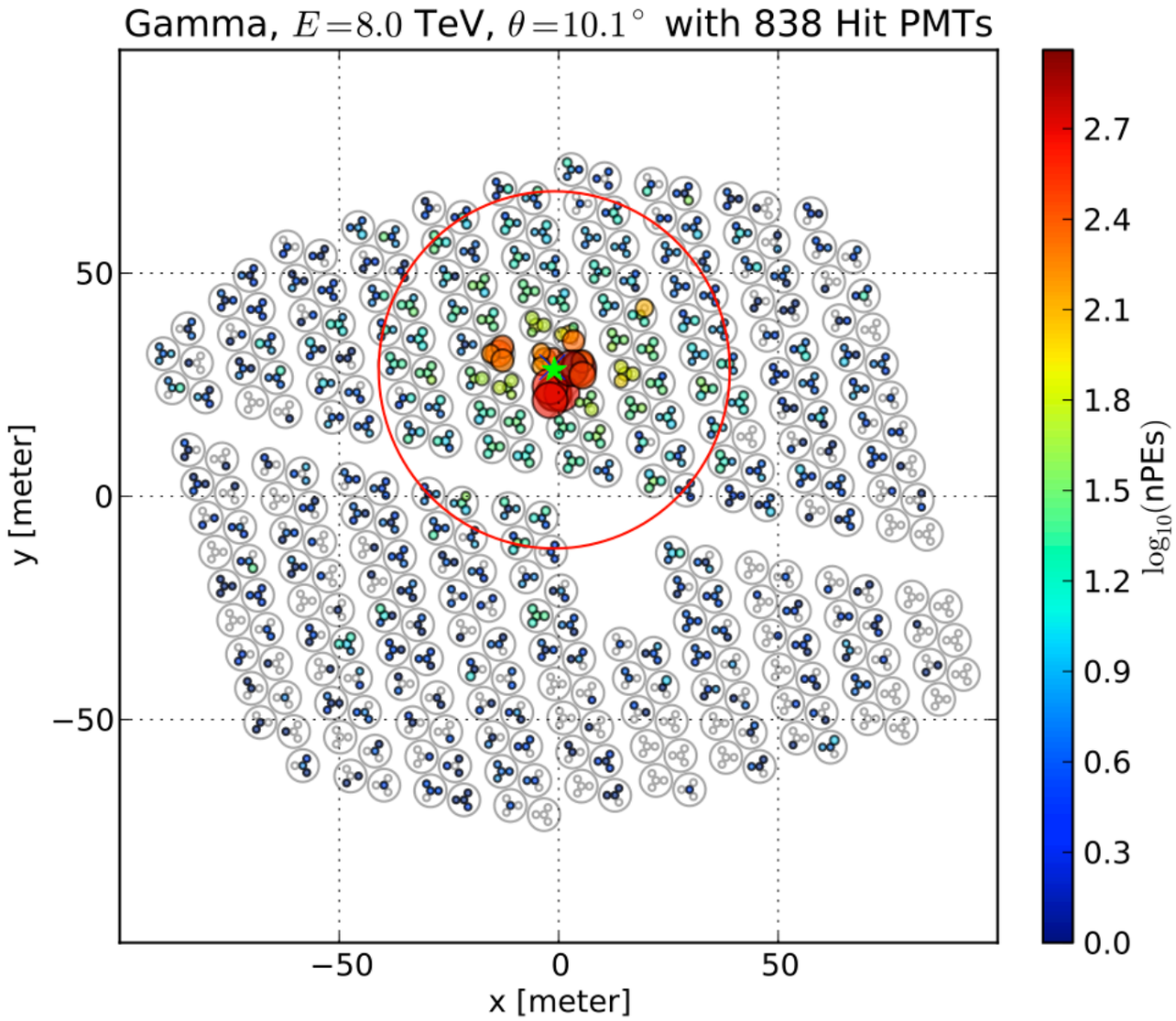




Signal: Gamma-Ray Tagging

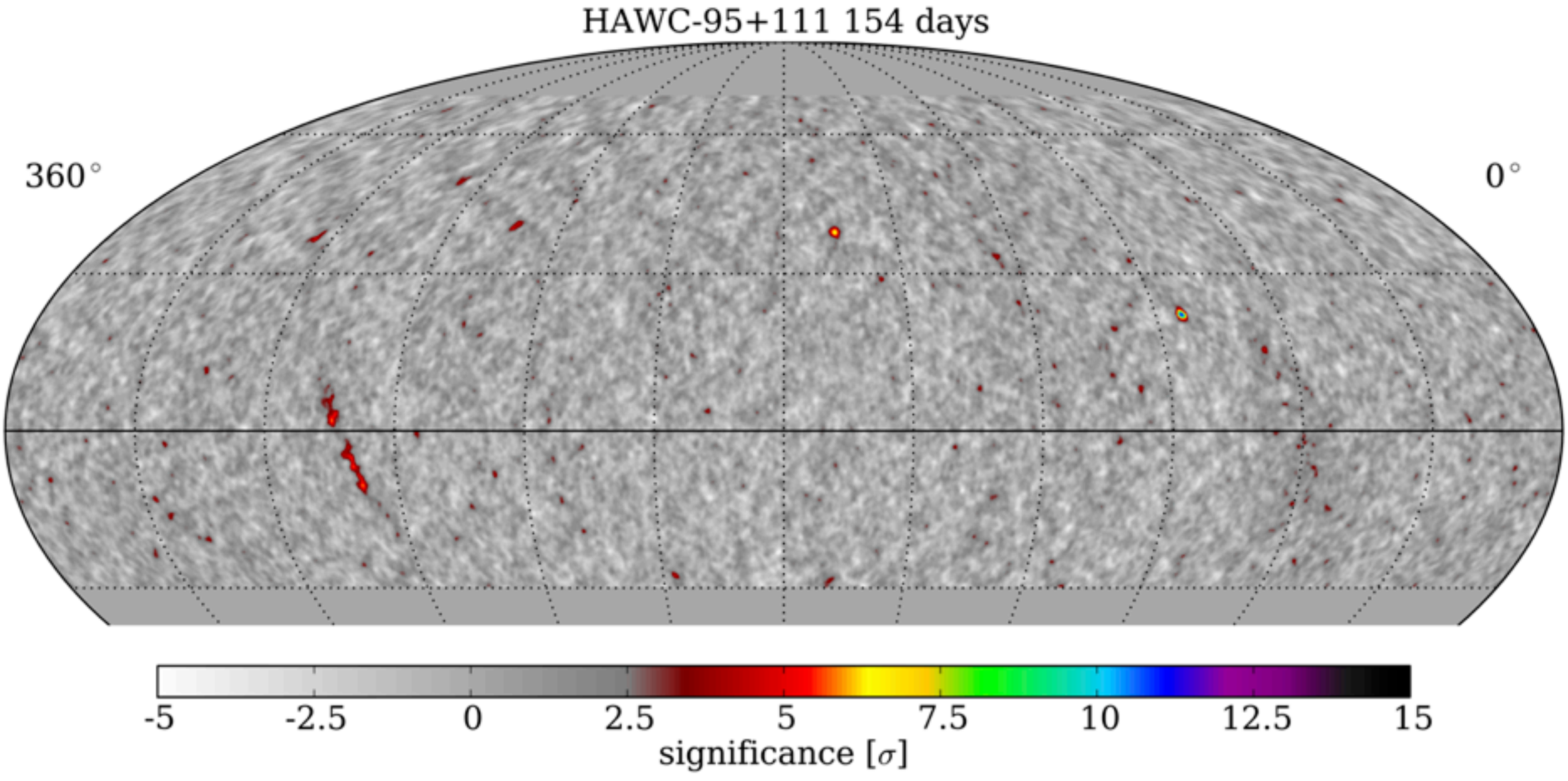
- No large hits far from core: probably a gamma-ray





Data: Galactic Survey

- 12 weeks of HAWC-95+111 data (June - September)



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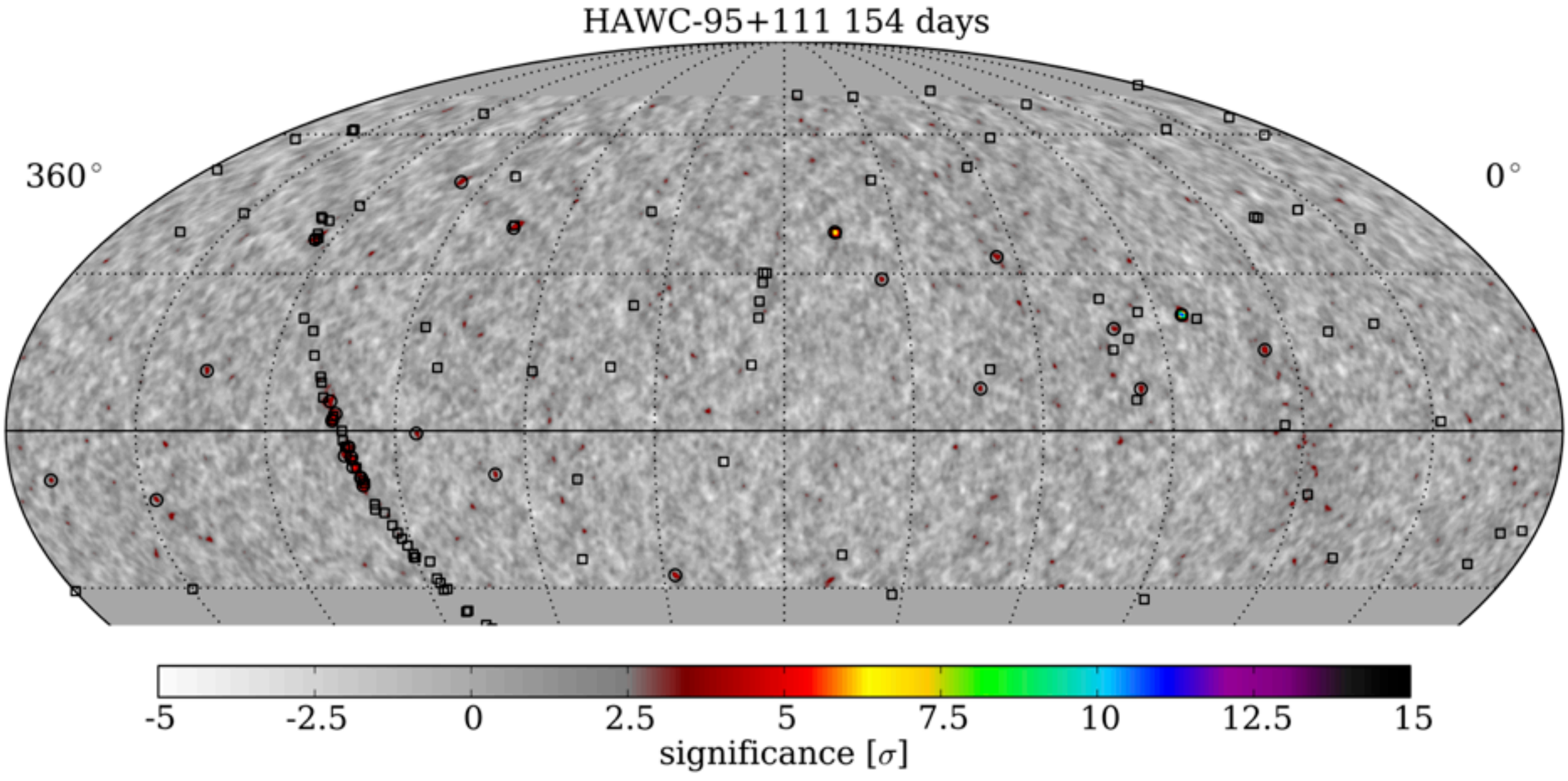

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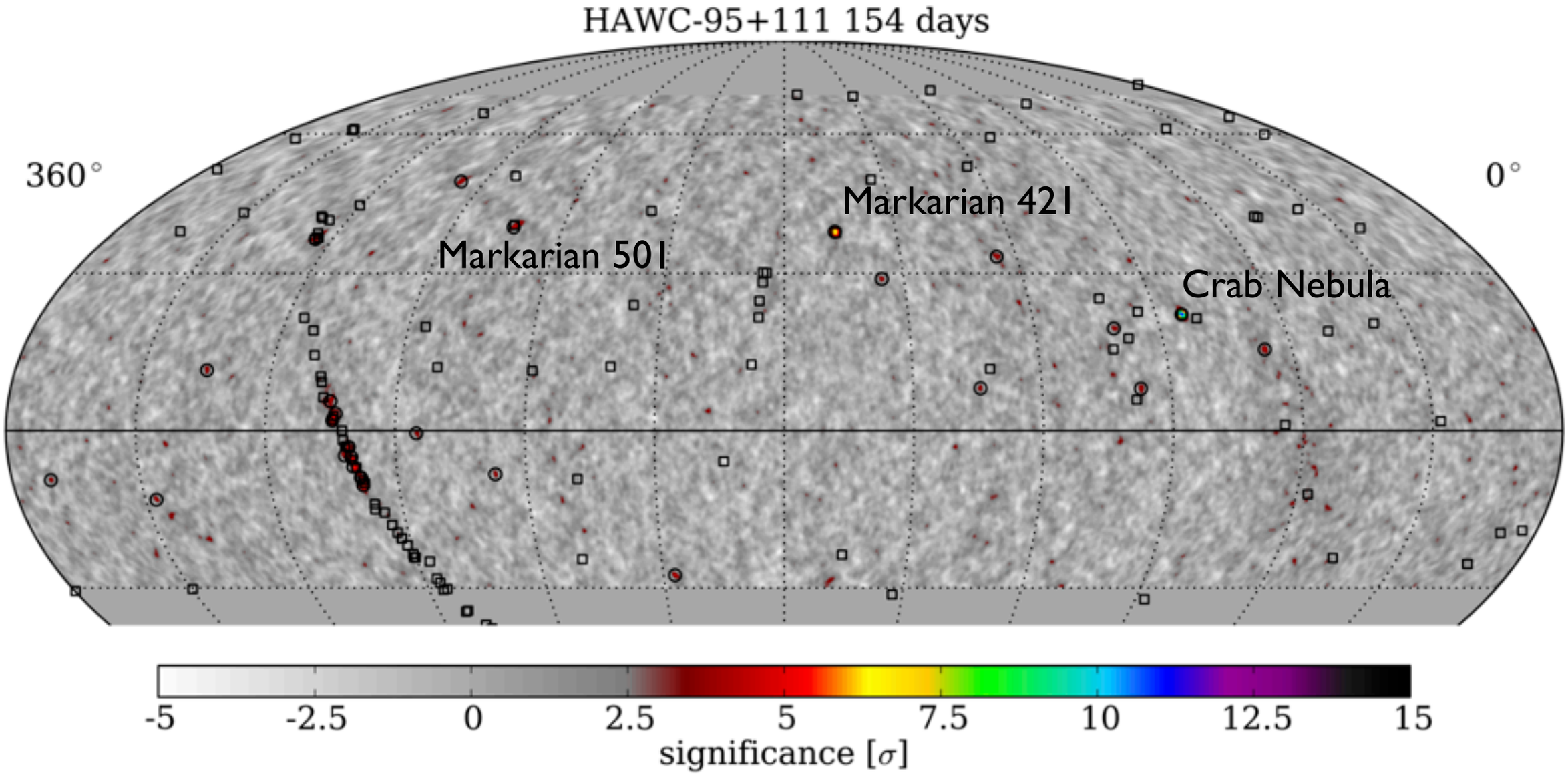
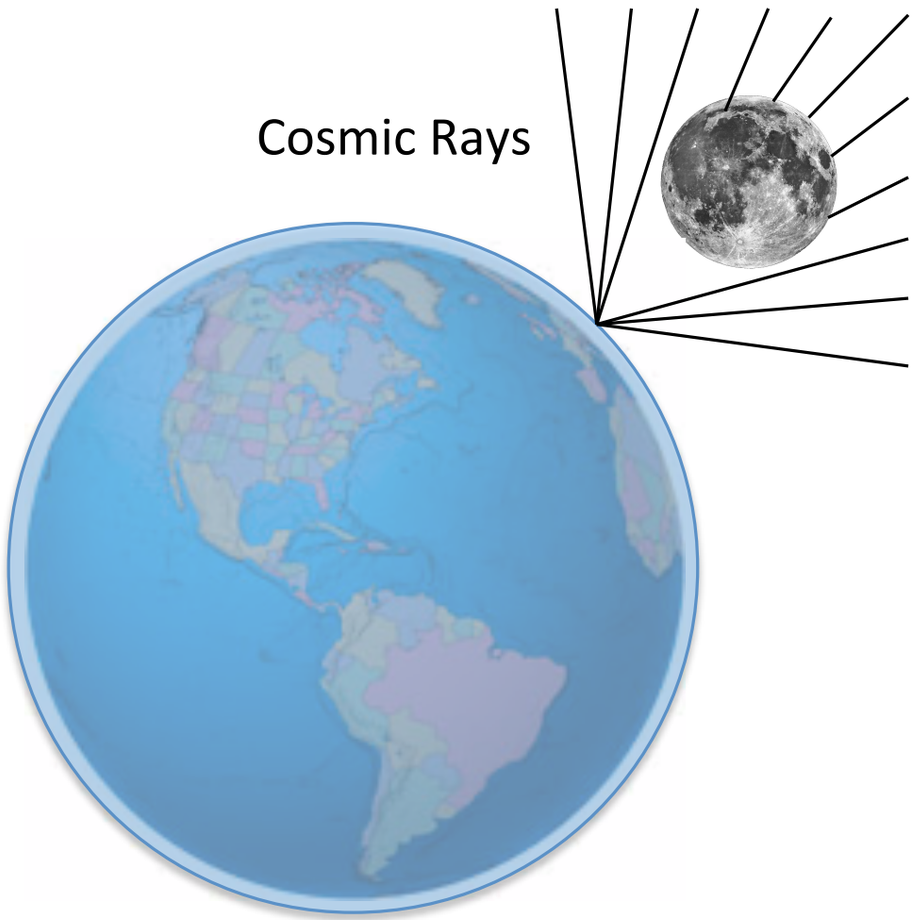
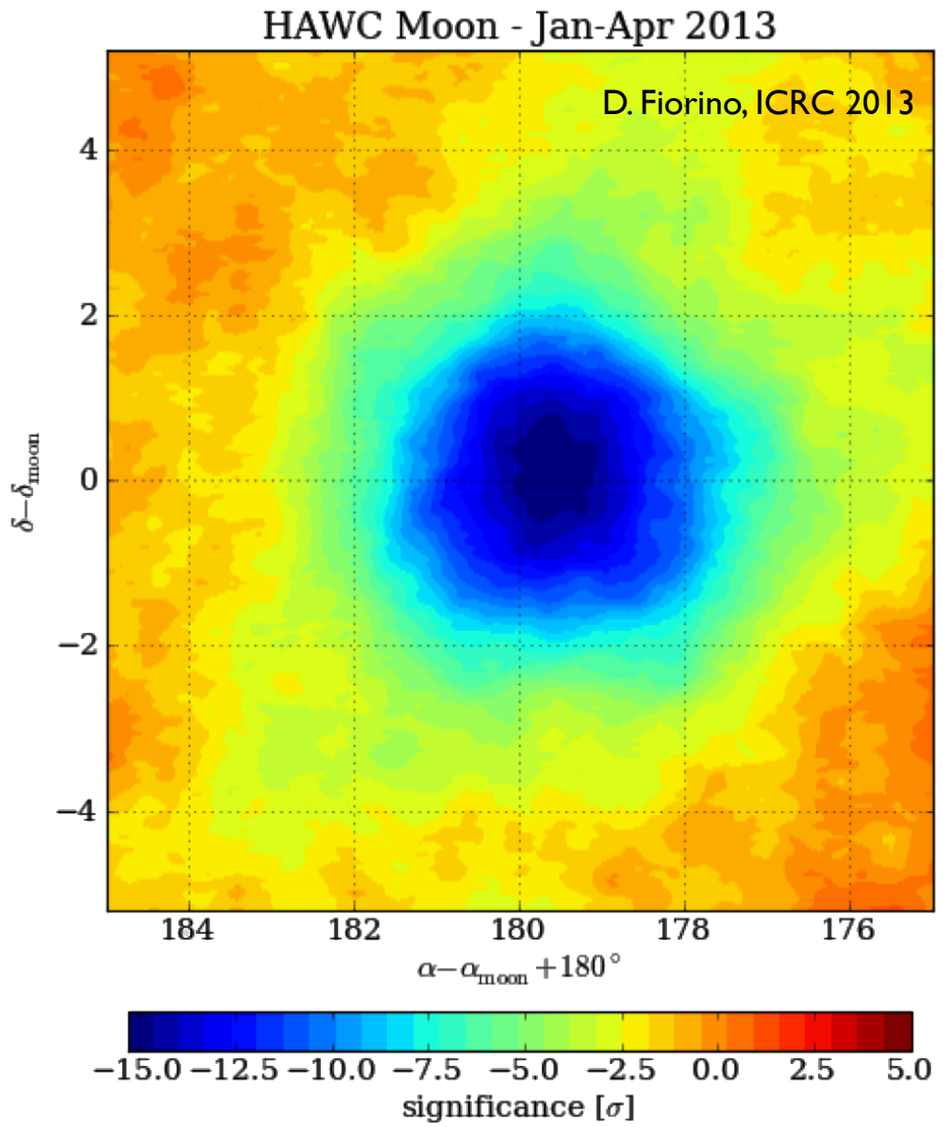


Other Weird Things We Can Do with HAWC

Data: Moon Shadow

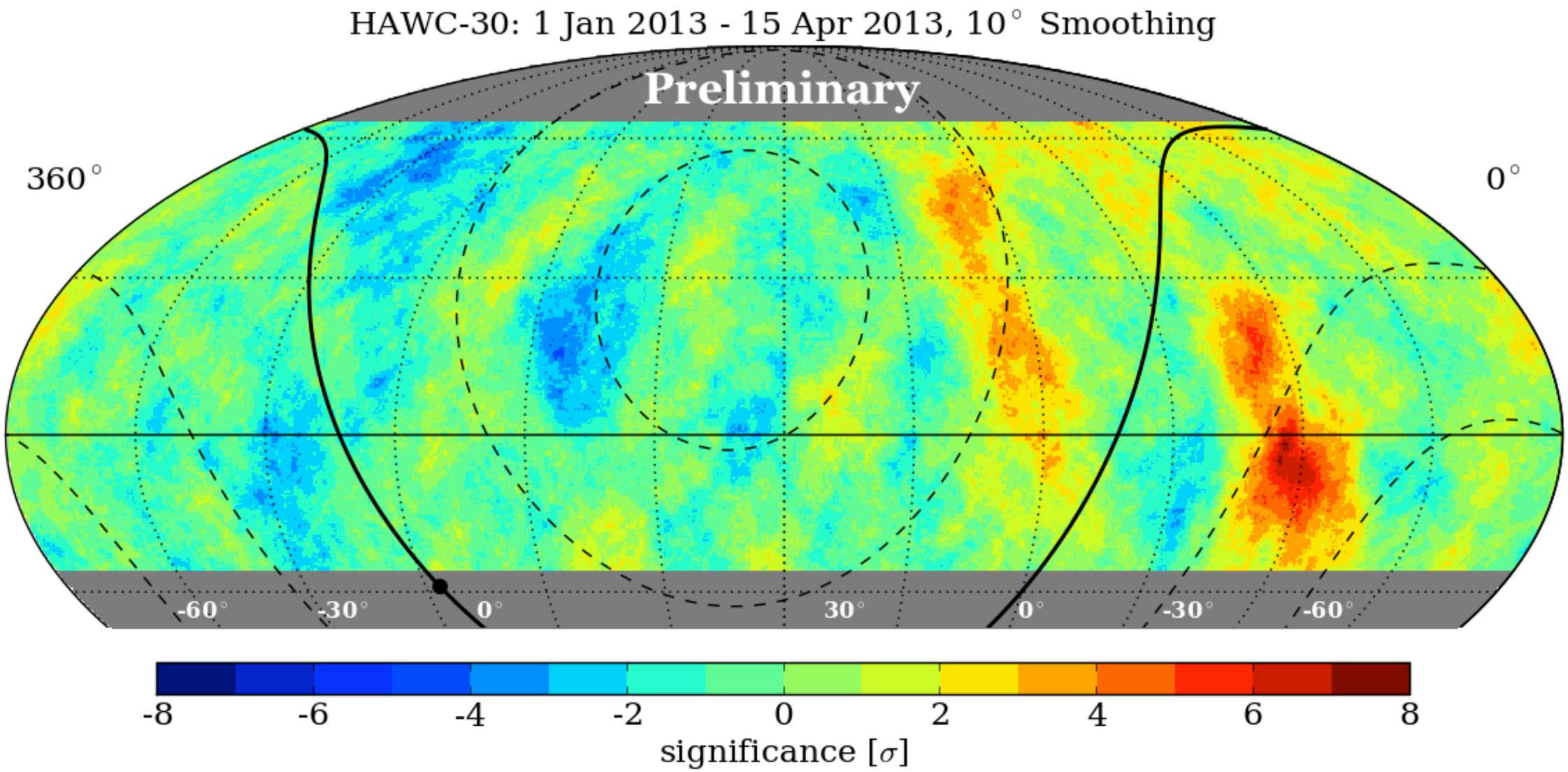
- Cosmic rays are blocked by the moon
- We can see a “shadow” in direction of moon; use this to calibrate detector





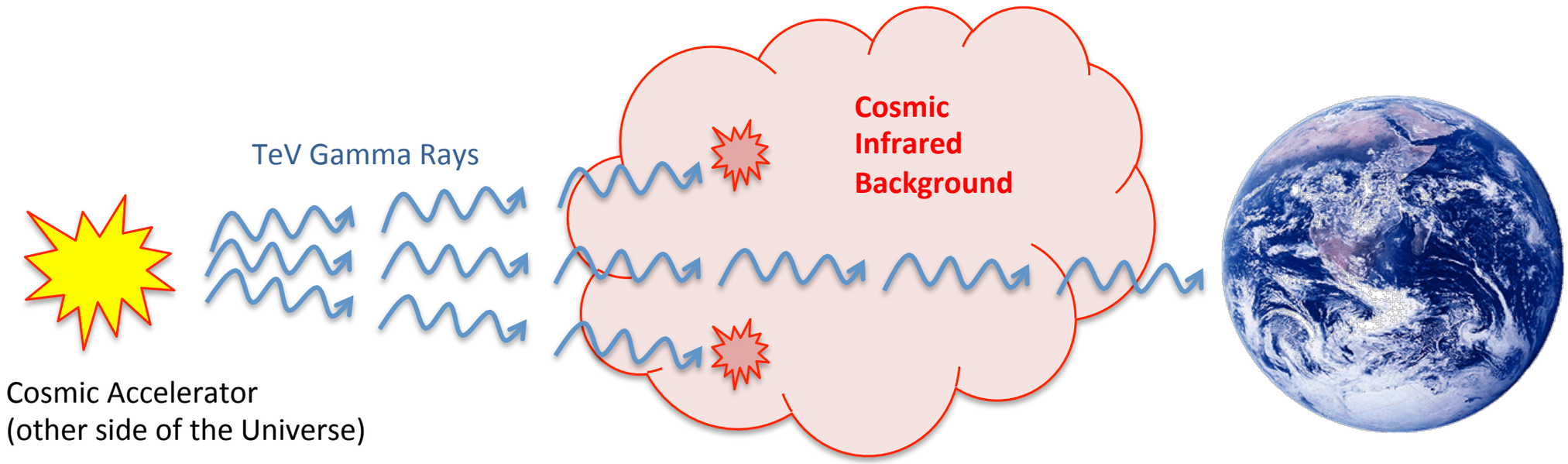
Cosmic Ray Anisotropy

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



Cosmology: IR Background

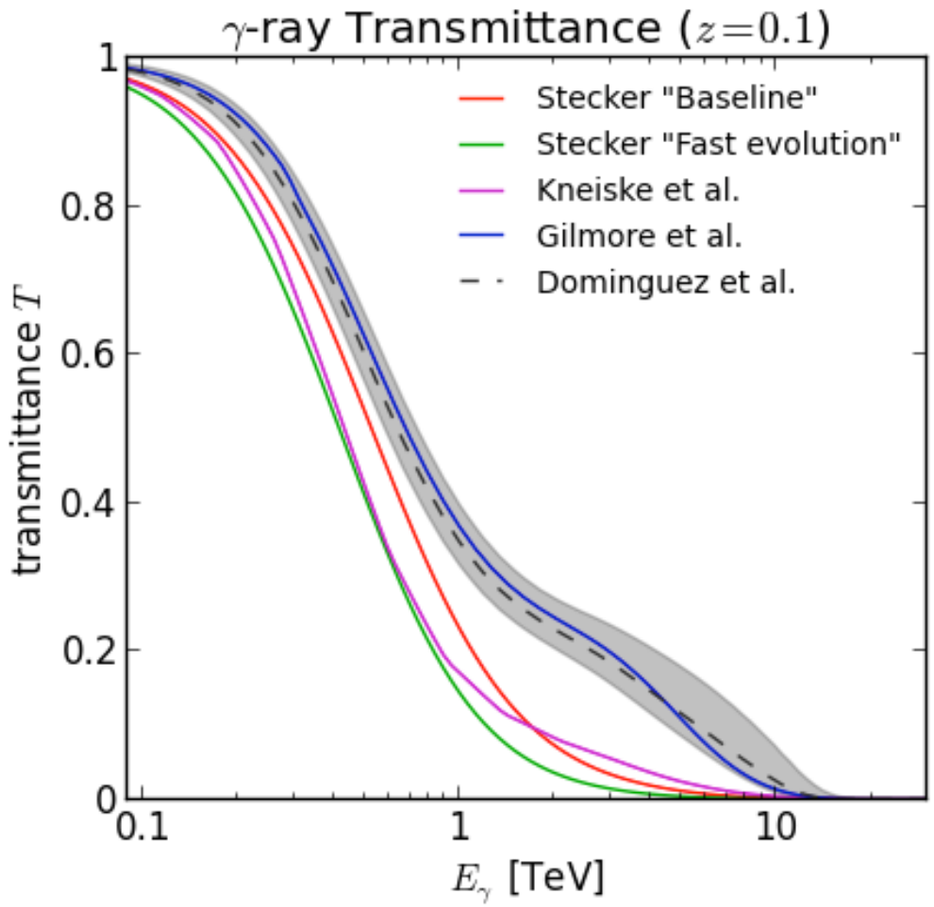
- TeV gamma rays are absorbed by the cosmic infrared background

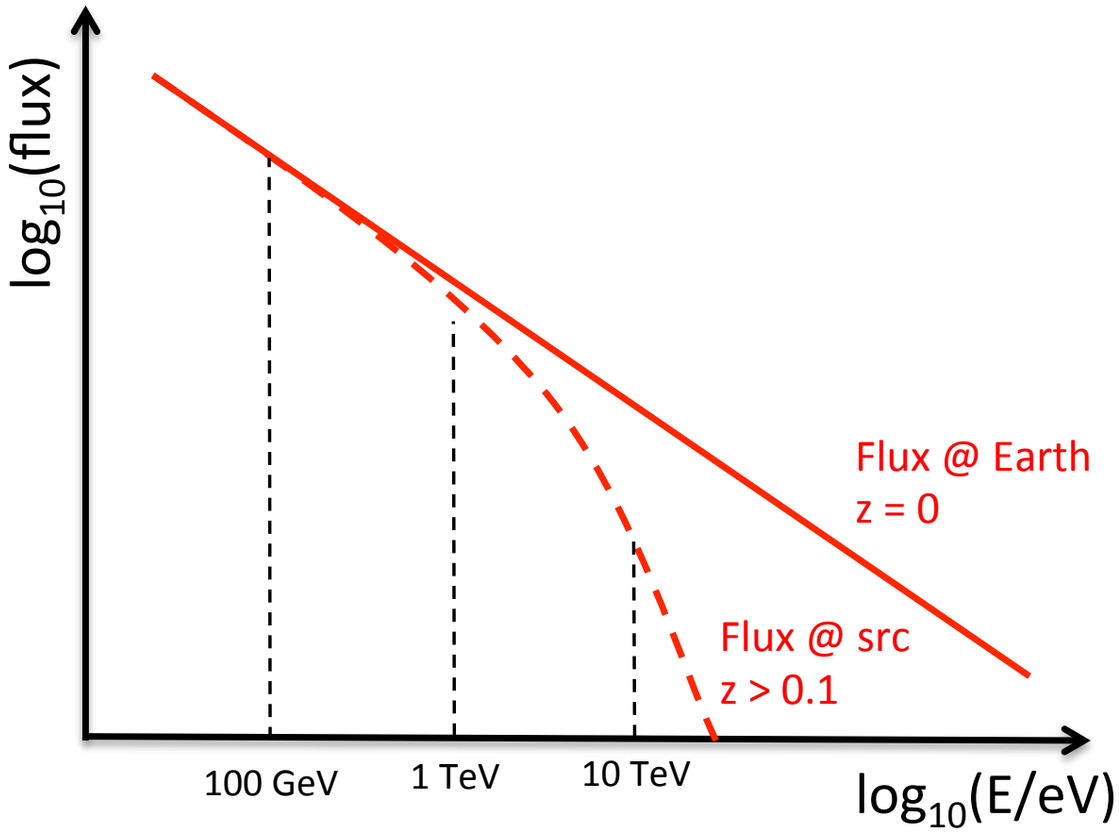


- This is redshifted light from the first stars; very important for models of evolution of universe

Detecting the IR Background

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

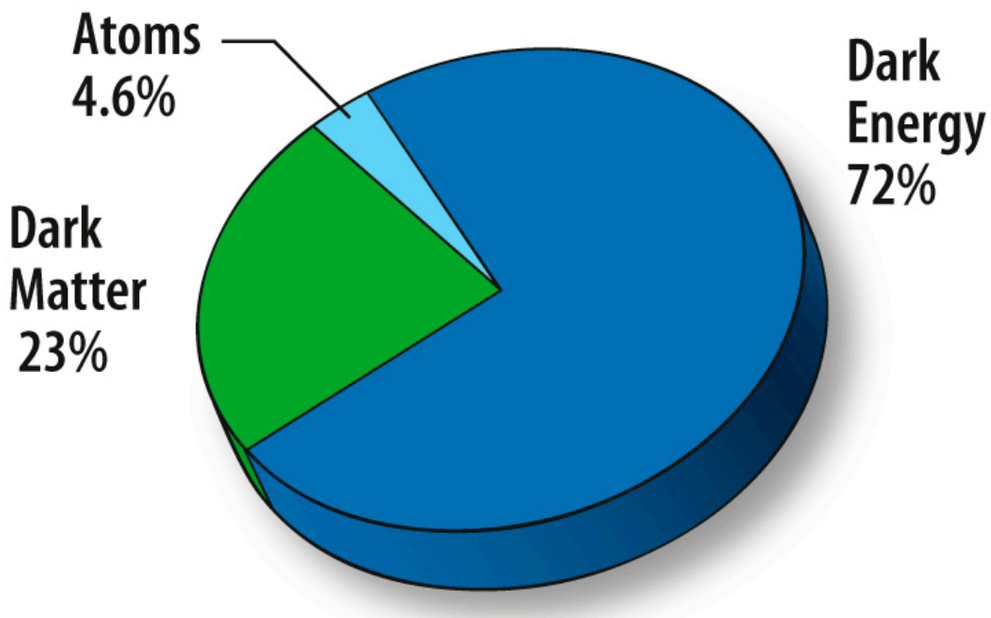




- Try to "de-absorb" spectra and estimate IR flux

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