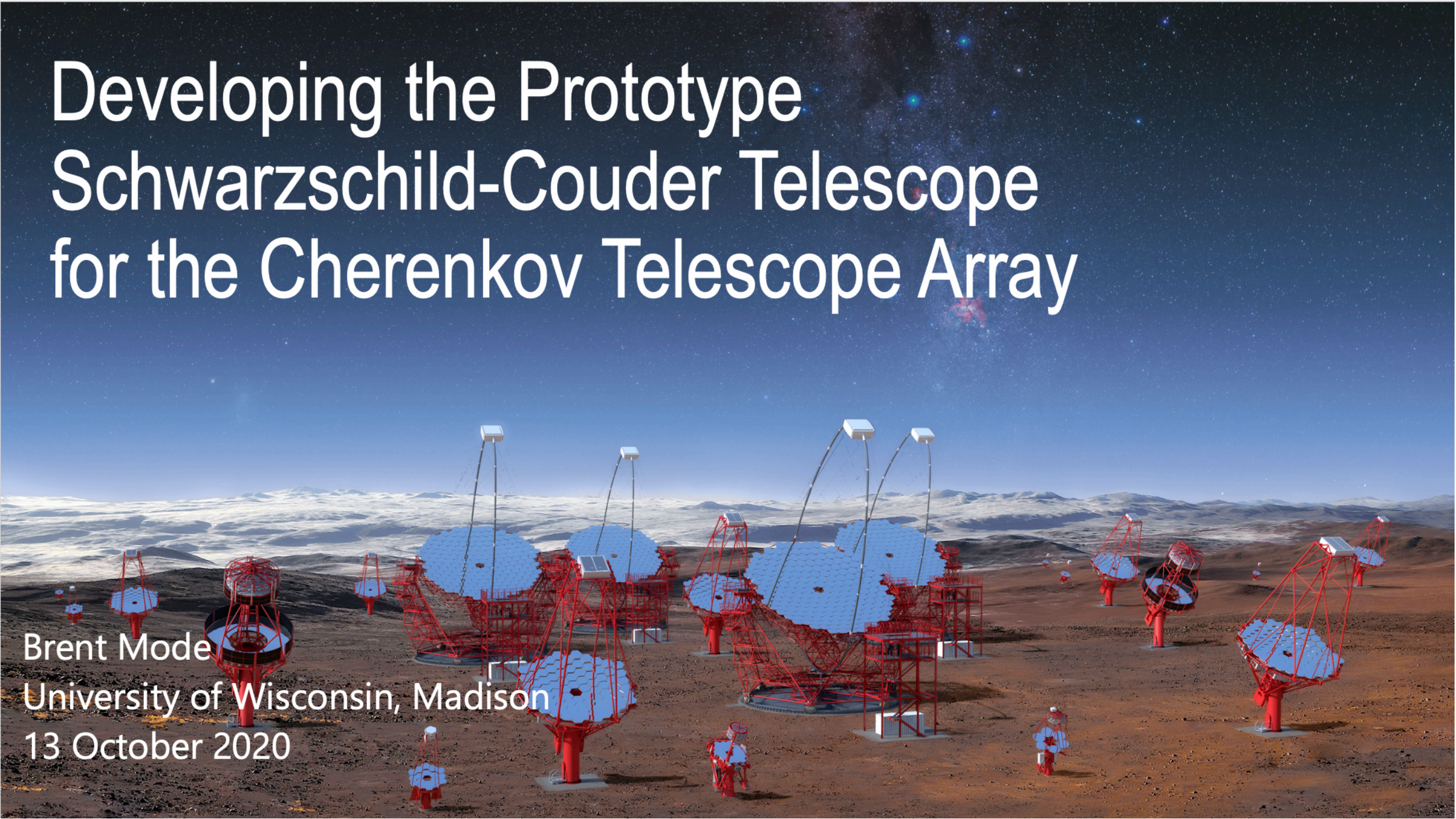
Developing the Prototype Schwarzschild-Couder Telescope for the Cherenkov Telescope Array



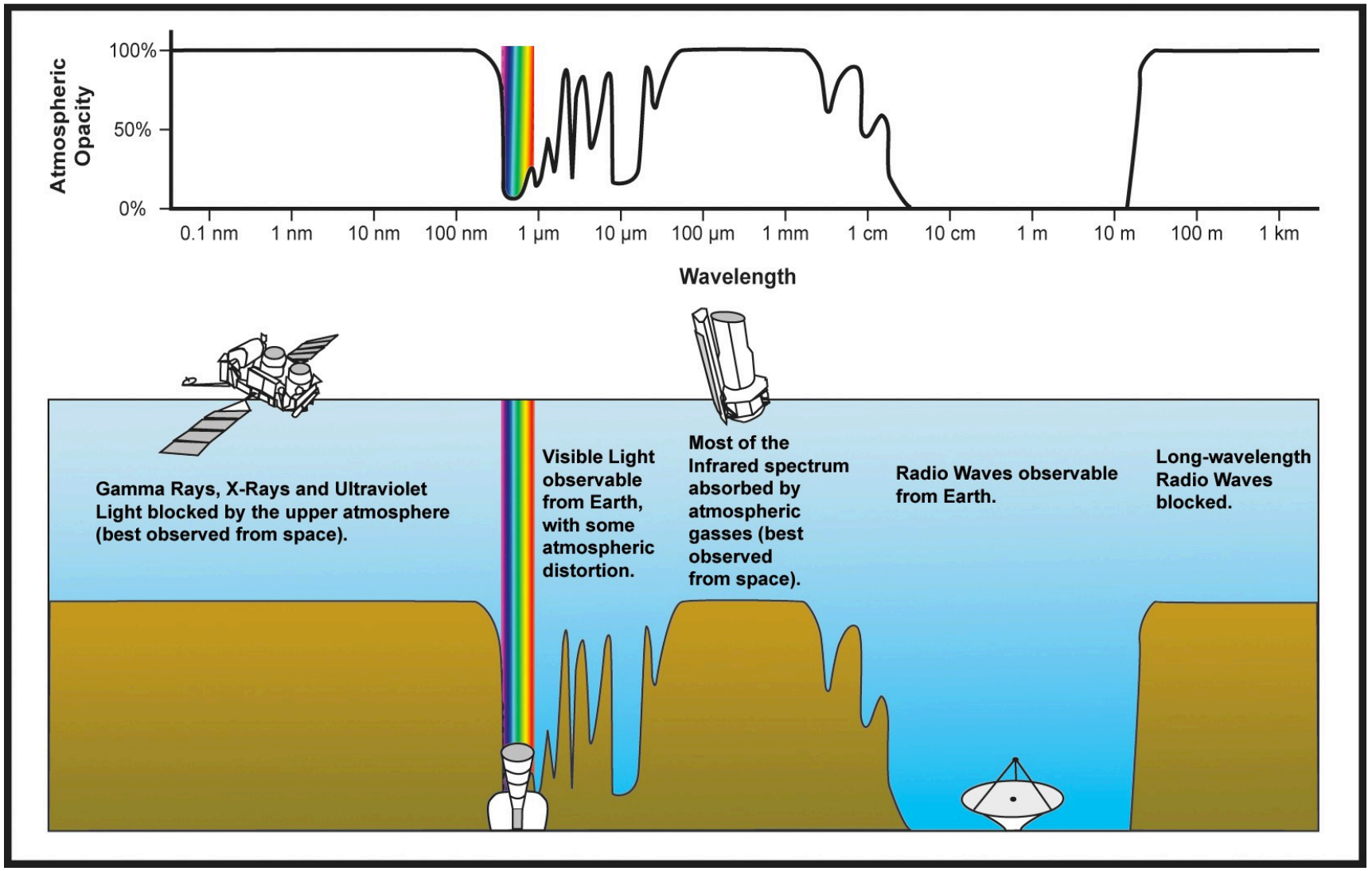
Brent Mode
University of Wisconsin, Madison
13 October 2020

Questions To Be Answered:

- What is a Cherenkov telescope?
- Why would we like to build one of those?
- How do we make the best one yet?

What is a Cherenkov Telescope?

The Atmosphere is Opaque to Gamma Rays

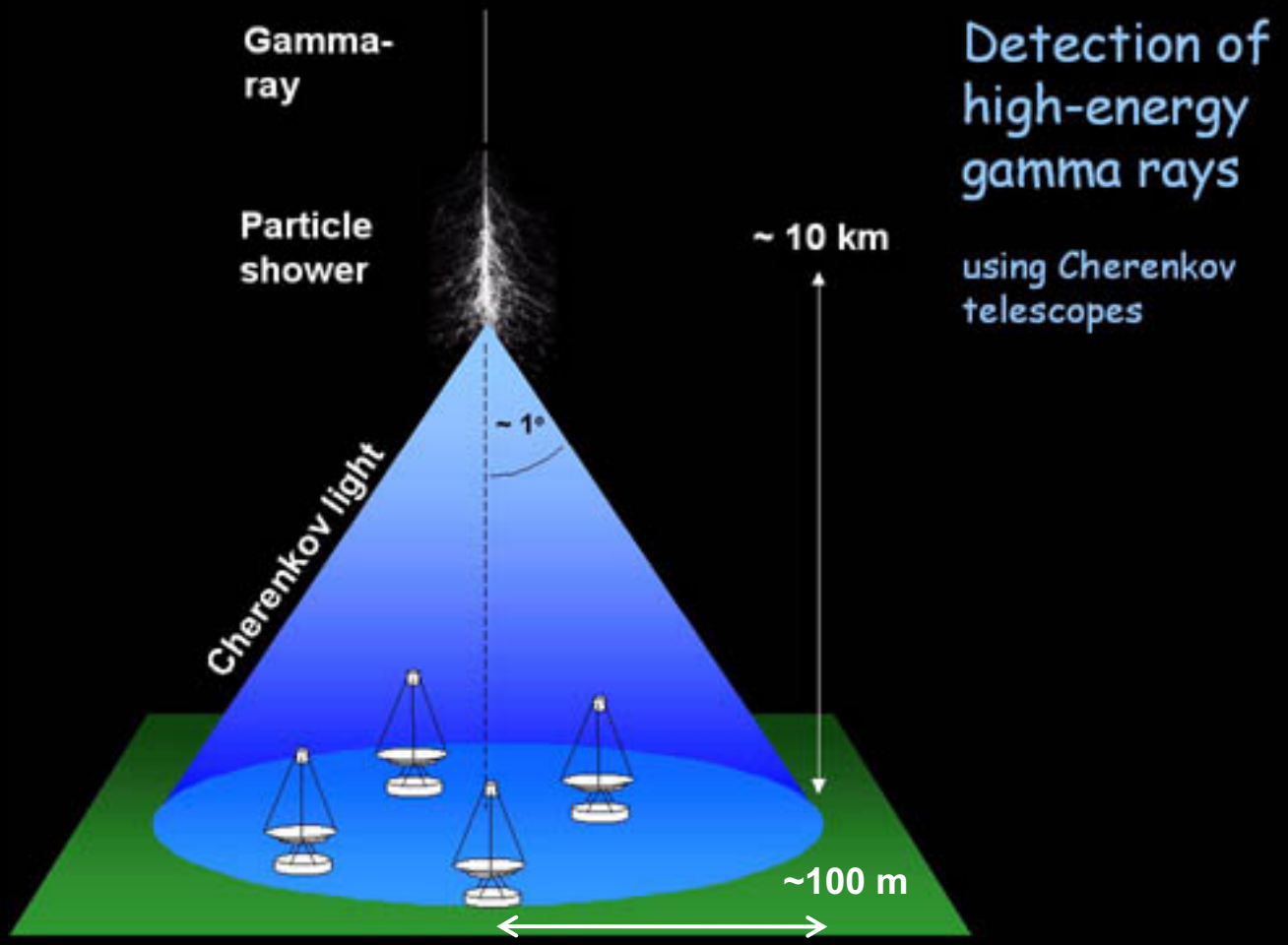


Atmospheric Cherenkov Radiation

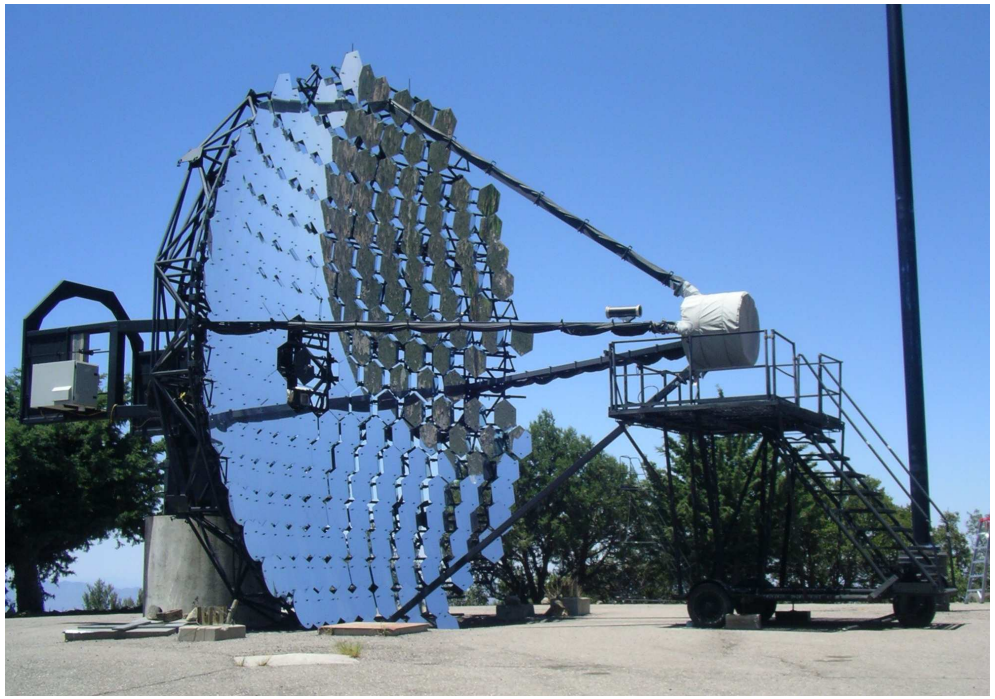
- Optical frequency (blue) light
- Very short (few ns) exposure to limit night sky background
- Cherenkov cone very narrow, ~1°:

- $\theta = \arccos \frac{1}{n\beta}$

- 1000-1500 hours per year (dark, good weather)



First IACT: Whipple 10 m Telescope at FLWO

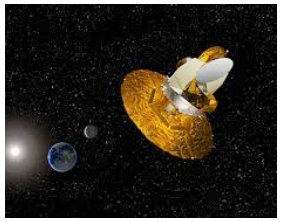


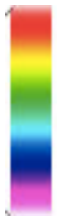
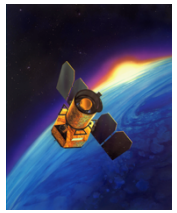
- Pioneer imaging atmospheric Cherenkov telescope
- Discovered the first very-high energy (TeV) astronomical sources
  - Crab Nebula: 1985 (Optical), 1989 (UV)
  - Markarian 421 (1992): a nearby blazar
  - Markarian 501 (1997): another nearby blazar

Current Generation of IACTs

Why Would We Like to Build One of These?

All the Different Colors of Light

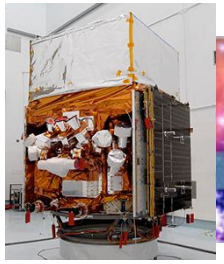




Astroparticle physics over 13 orders of magnitude

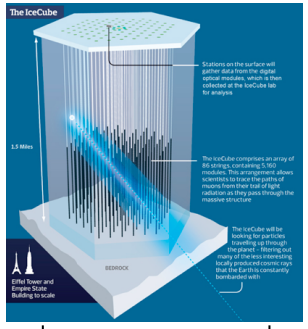
10^{3} 10^{1} 10^{-1} 10^{-3} 10^{-5} 10^{-7} 10^{-9} 10^{-11}

radio microwave infrared optical UV X-ray

Gamma rays over 9 orders of magnitude







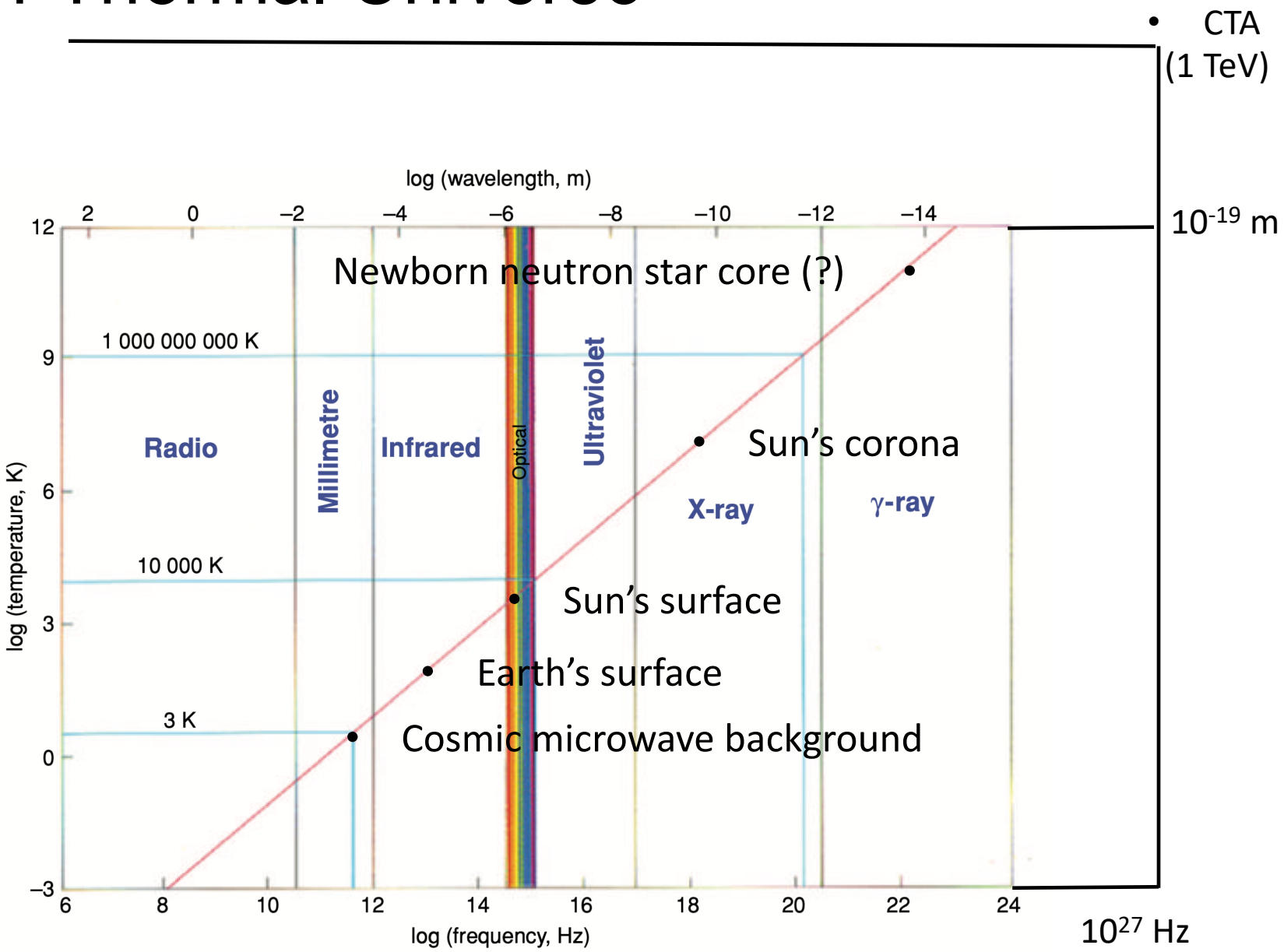
10^{-12} 10^{-14} 10^{-16} 10^{-18} 10^{-20} 10^{-22} 10^{-24} meters

Fermi CTA HAWC

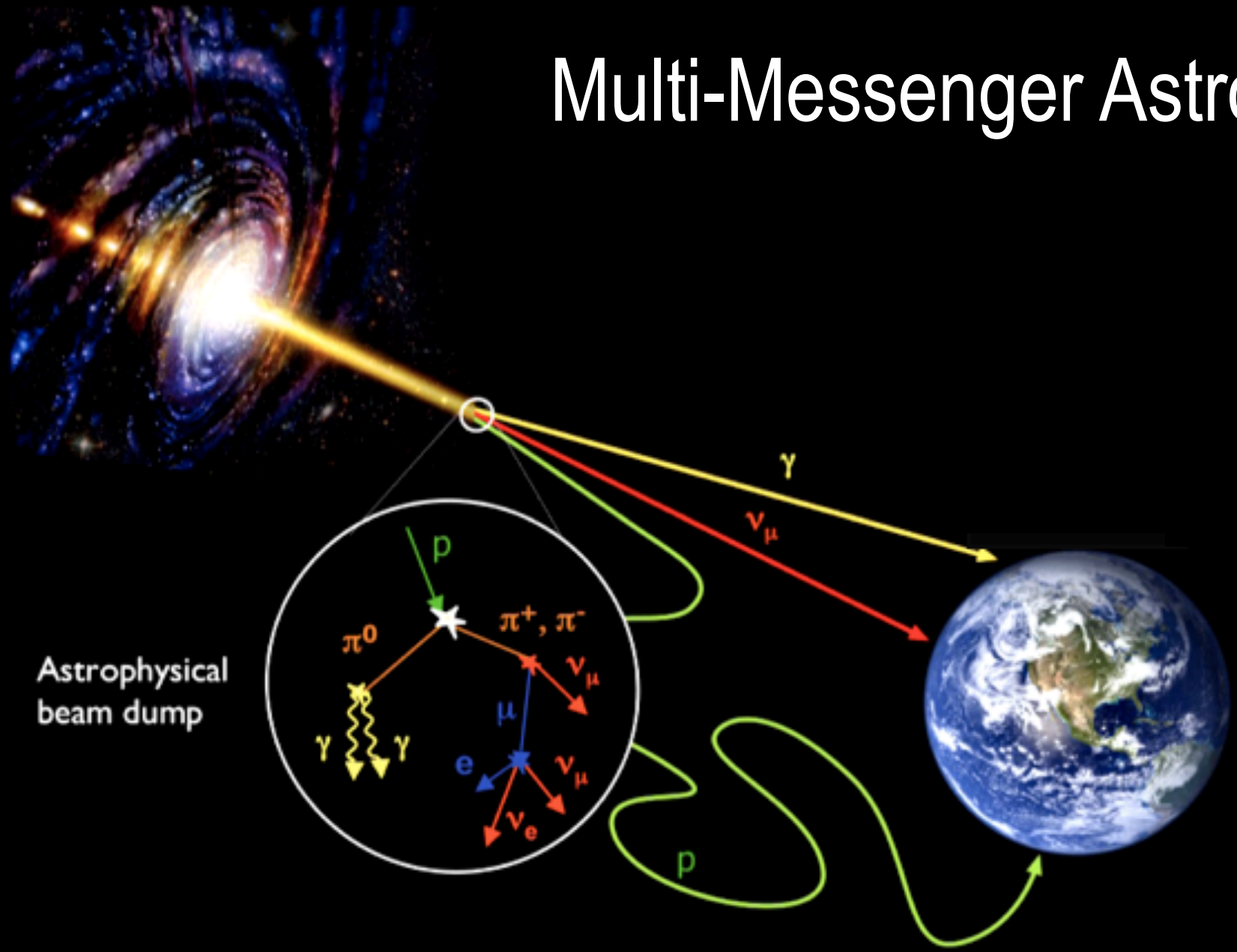
0.1 MeV 1 EeV

The Thermal v. Non-Thermal Universe

- Black body radiation is responsible for much of the low energy light in the universe
- Even some gamma rays can come from very high energy thermal events
- Most gamma rays will come from non-thermal processes, as the associated black body temperature peaked at 1 TeV is 10 quadrillion K

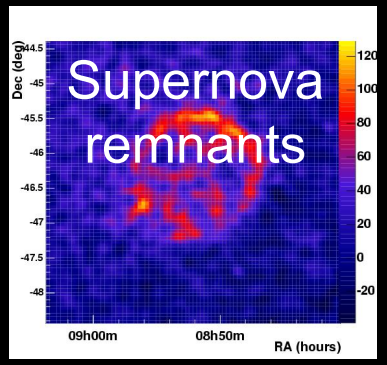


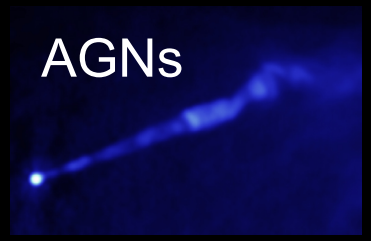
Multi-Messenger Astronomy

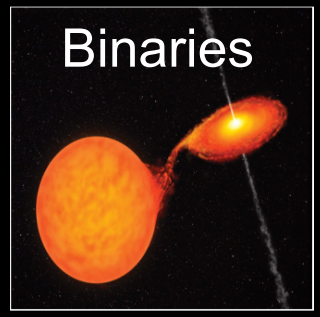


- Using photons, neutrinos, cosmic rays, and gravitational waves, we can study astrophysical sources and transient objects much more thoroughly than ever before
- Different astrophysical sources emit different particles and at different energies, allowing for multi-instrument, coordinated observations

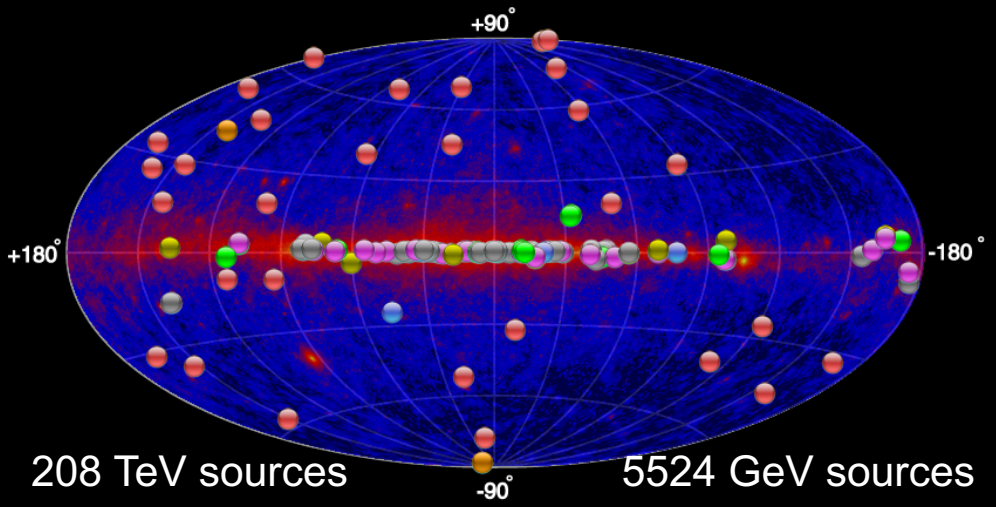
Physics with TeV Gamma Ray Telescopes





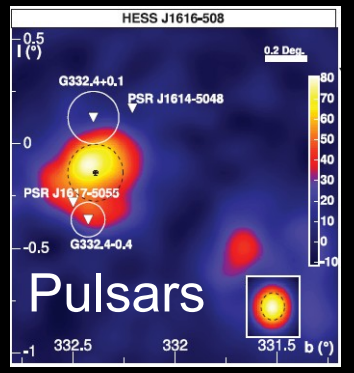


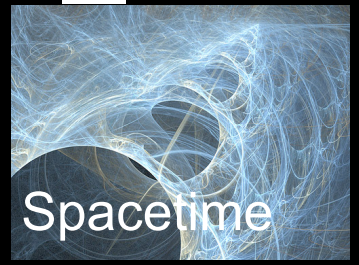
The gamma-ray sky

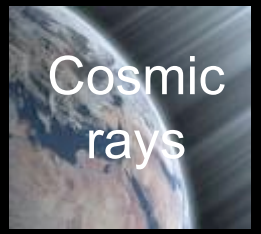


208 TeV sources

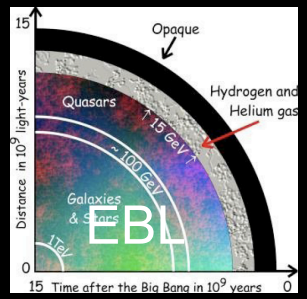
5524 GeV sources







Axions, …



How Do We Make the Best One Yet?

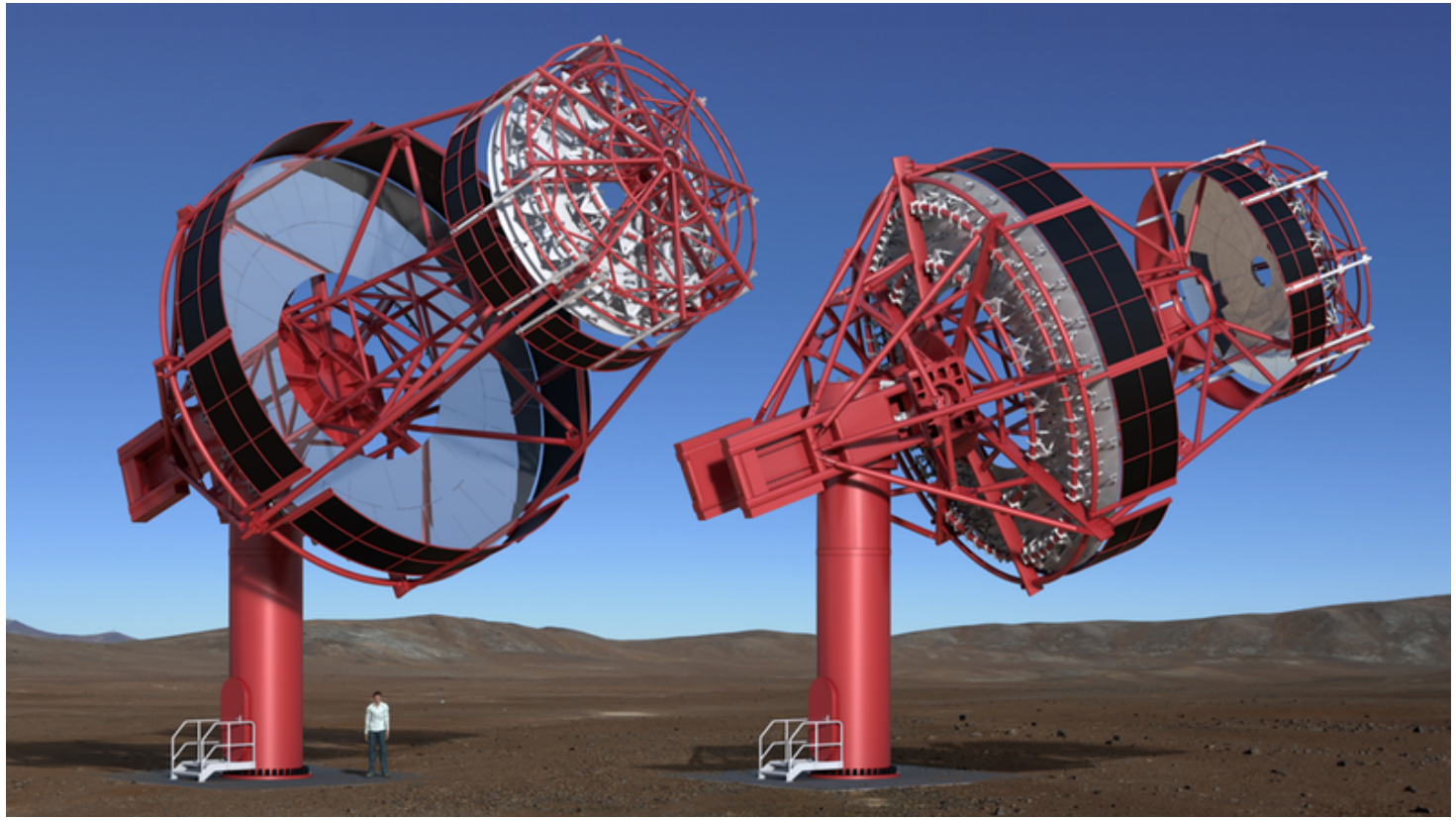
pSCT: Prototype Schwarzschild-Couder Telescope

Use two mirrors instead of one:

- Advantages:
  - Telescope can be more compact
  - Has wider field of view
  - Better resolution

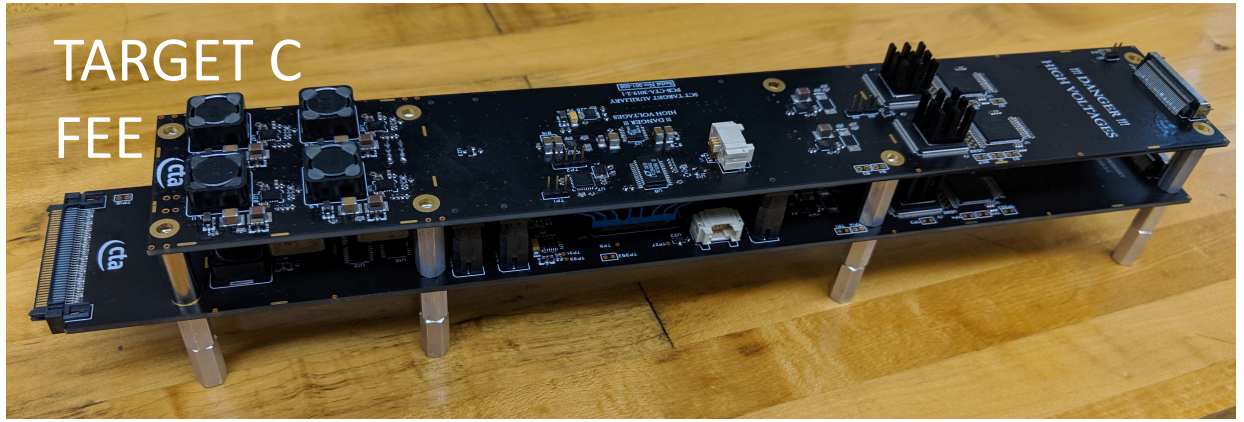
- Need special technique for a-spherical mirror shaping:
  - optimized for maximum resolution and field of view

- Need fast, high-resolution camera:
  - possible through new developments in SiPM and ASIC technology

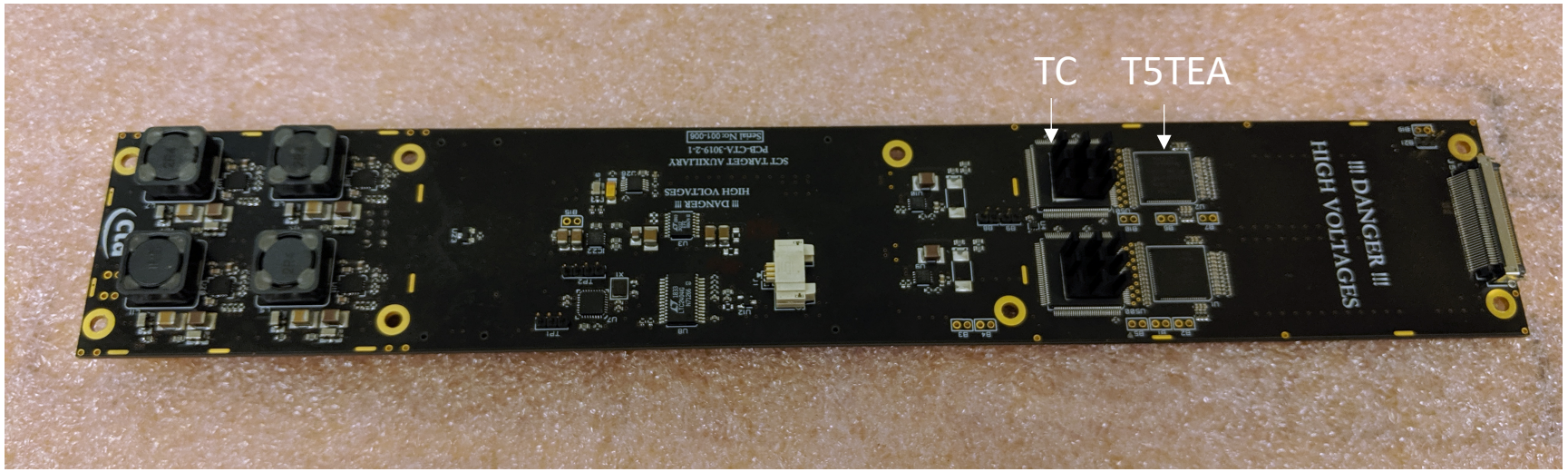


TARGET C and FPM

- TeV Array Readout with GSa/s sampling and Event Trigger – TARGET
- Light detected by SiPMs on the focal plane module
- Telescope can record 1,000,000,000 images per second
  - Needed to image an air shower accurately
- Holds 16 μs of images at once
  - Needed to give enough time to communicate with other telescopes
- UW group has been a strong contributor to the development of camera modules and commissioning of the pSCT camera

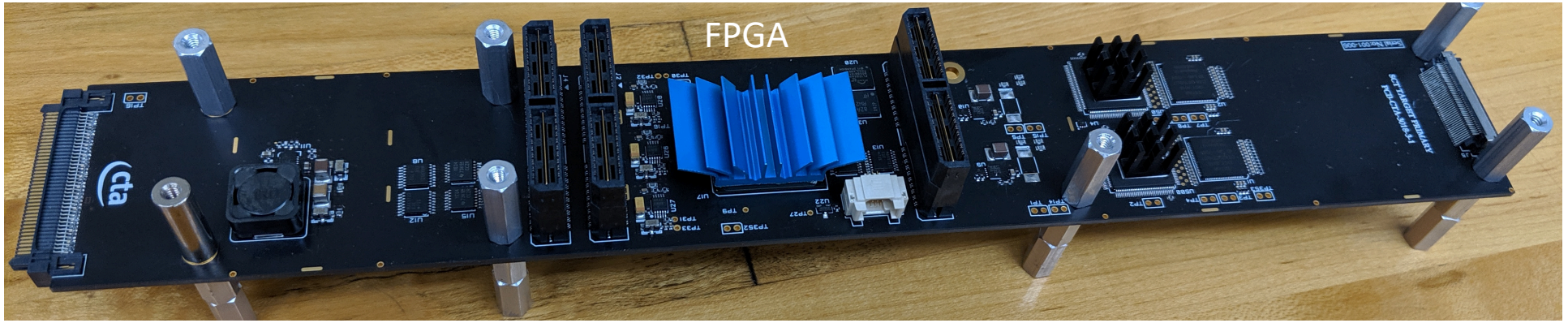


TARGET C Module



Signal Input

To Backplane



Analyzing Data from the pSCT

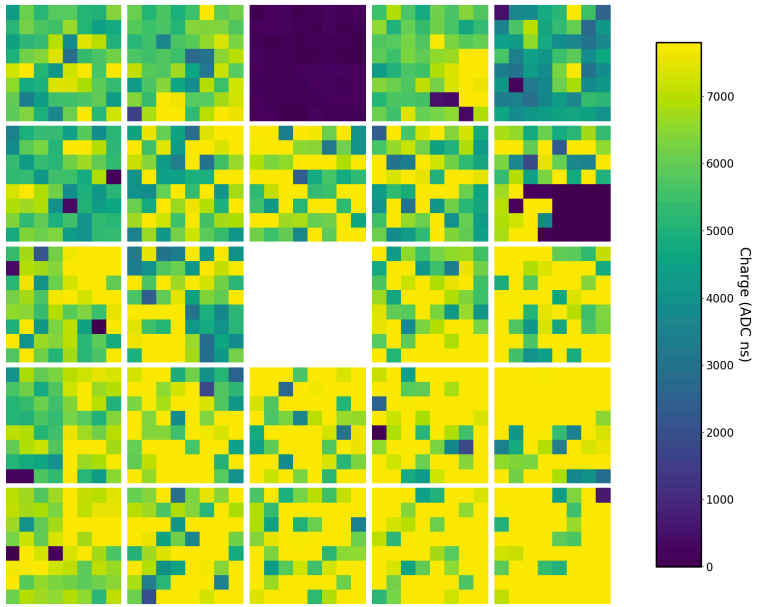
- New telescope, so we need to understand the kind of data that we are getting
- Need to do image classification to select the useful data
- Then need to clean up that data to do science
- Finally, need to do some science

Image Classification

Run 328555

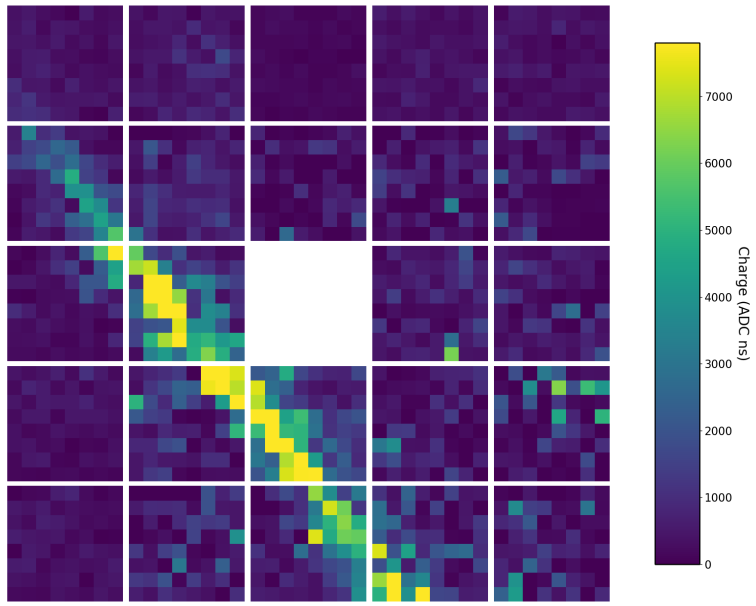
Flasher

Event 2709



Shower

Event 393



Noise

Event 112538

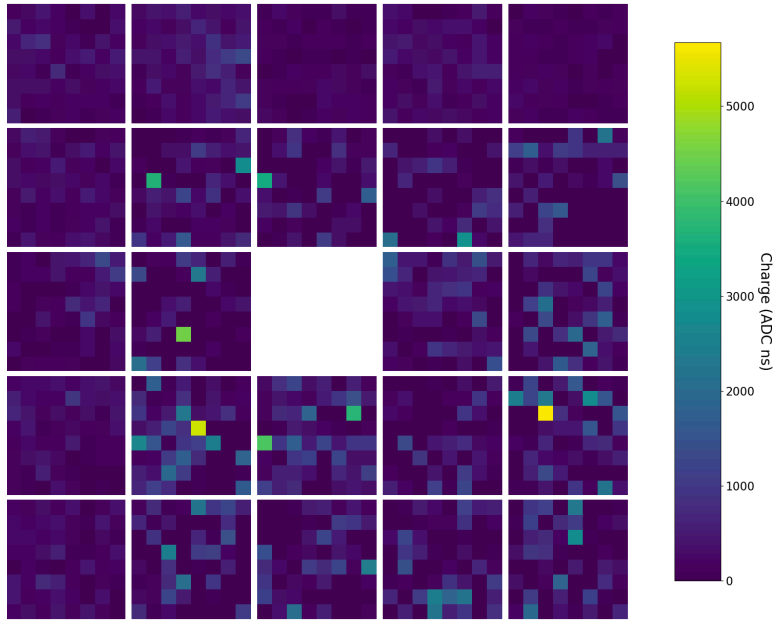
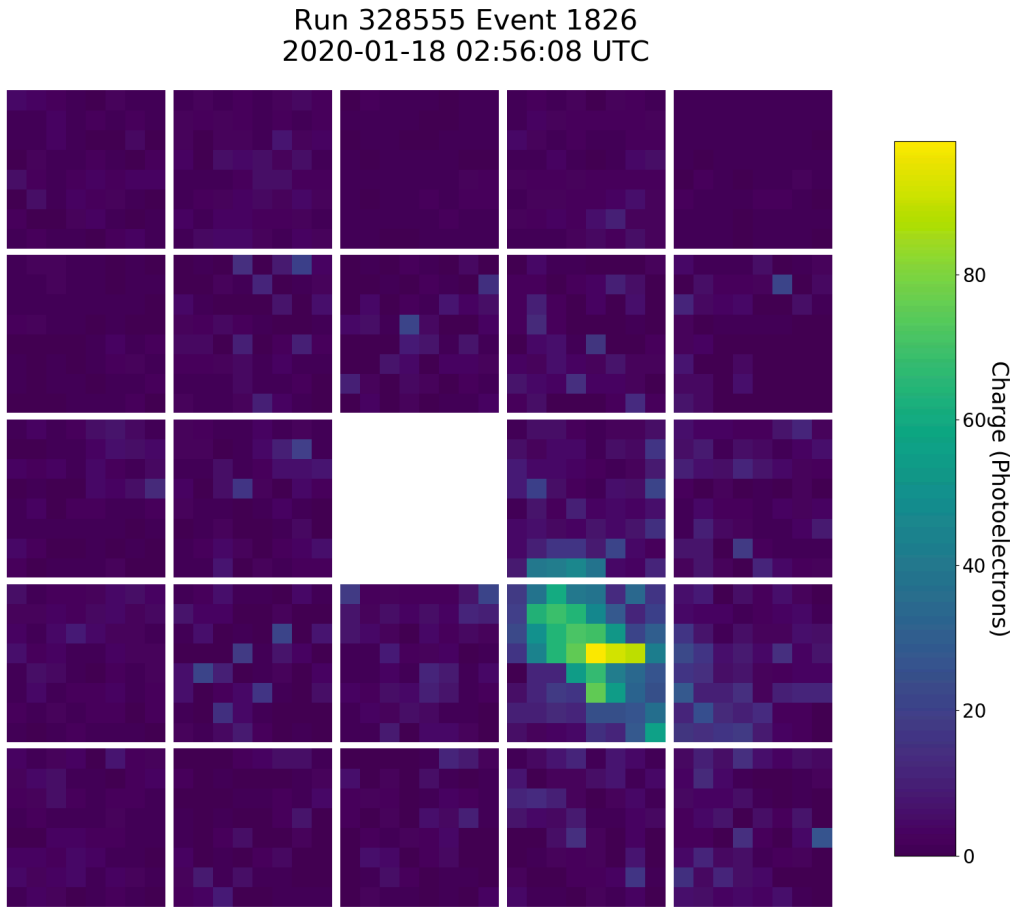
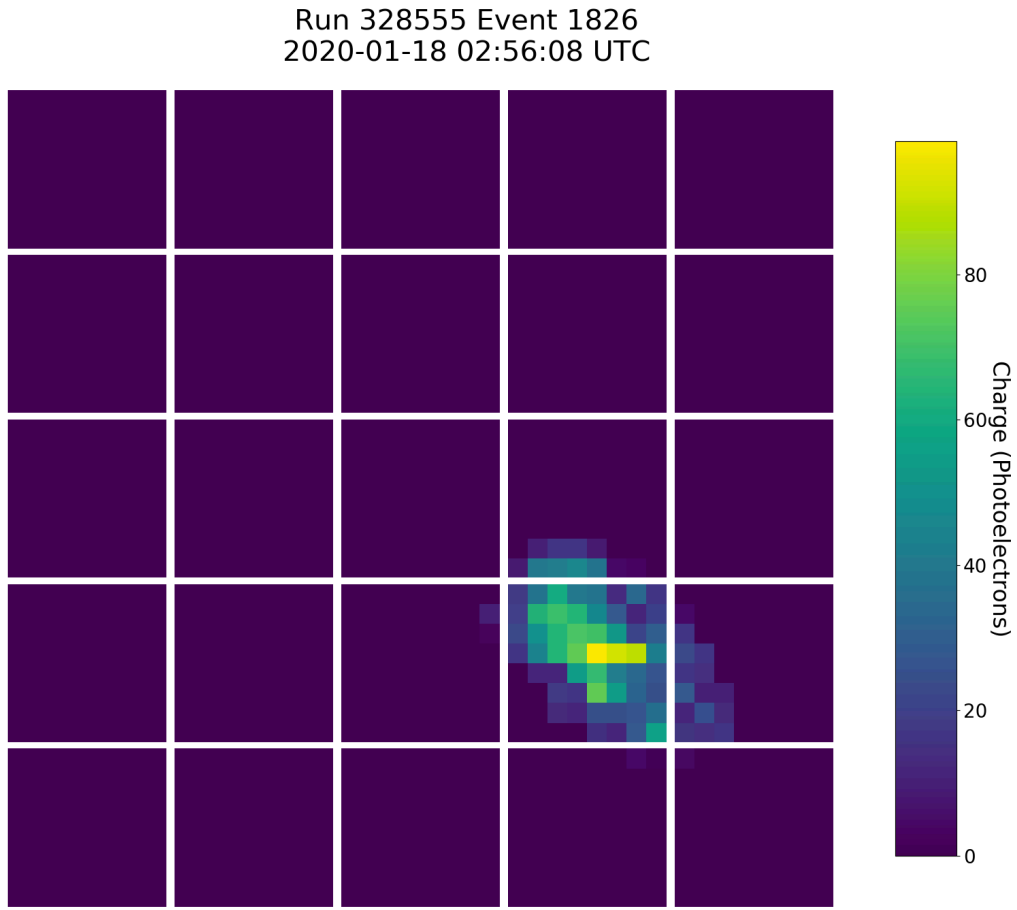


Image Cleaning





Detecting the Crab Nebula

- The Crab Nebula is the brightest constant gamma ray source in the sky
- pSCT observed the Crab Nebula from January to February 2020
- Resulted in this nice detection
- Paper in preparation