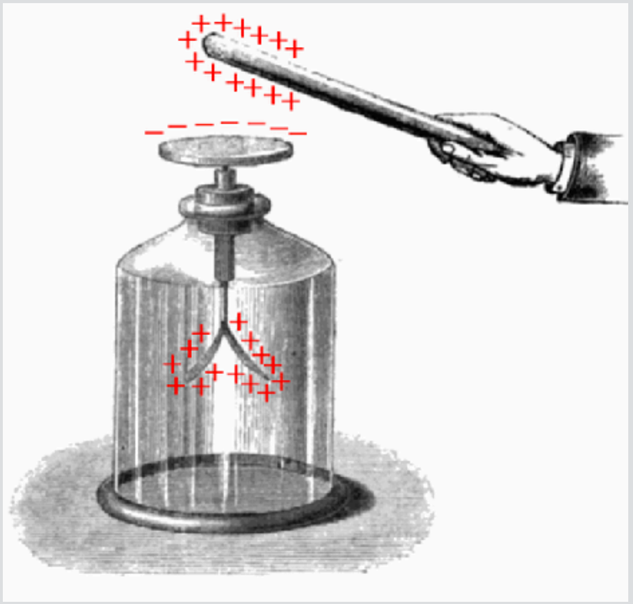
Surveying the TeV Gamma-ray Sky with the High Altitude Water Cherenkov Gamma-ray Observatory

Chad Brisbois
For the HAWC Collaboration
New Mexico Symposium
Nov 3rd 2017

Cosmic-rays Discovered in 1912 by Victor Hess

Electroscopes discharge faster higher in the atmosphere

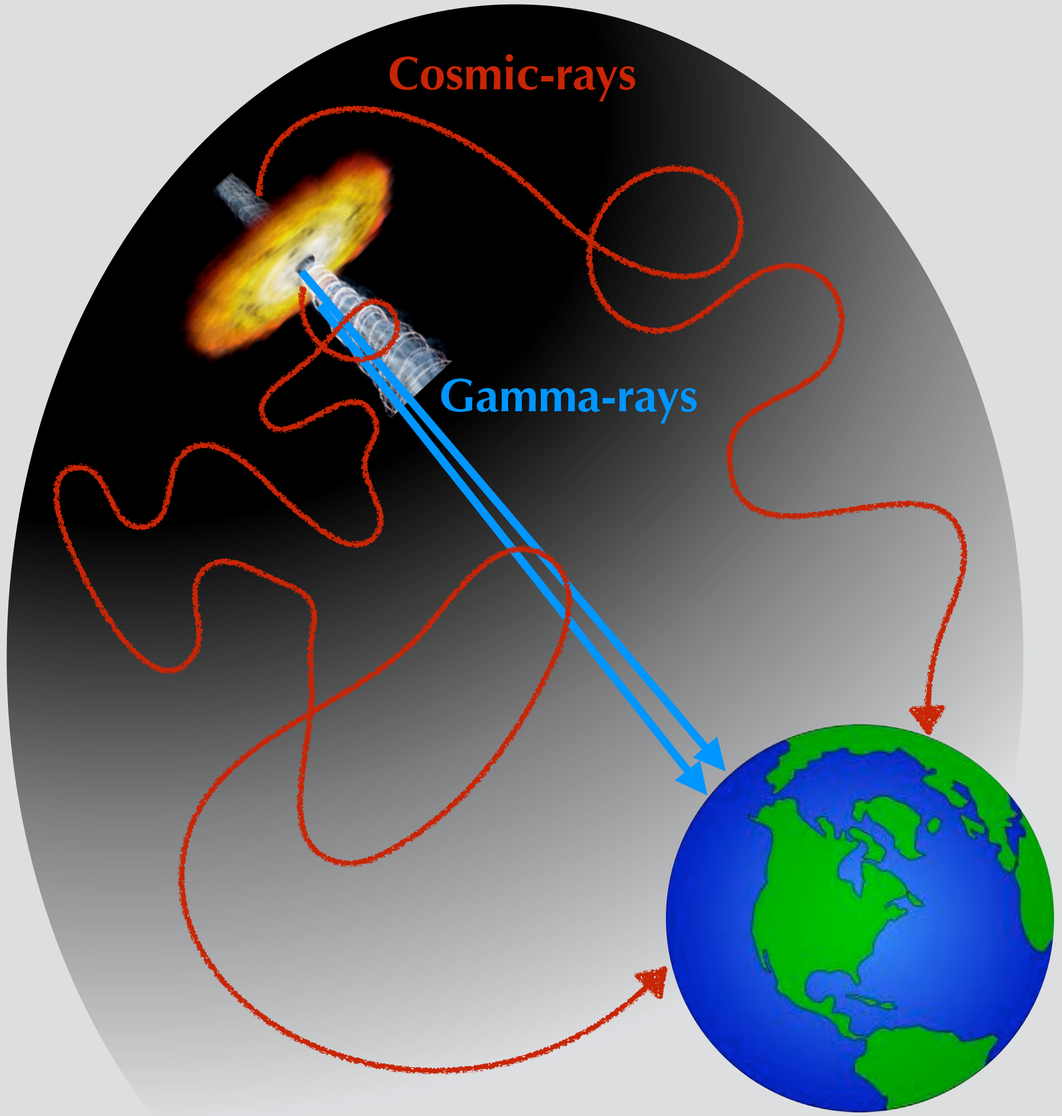
Ionizing radiation comes from space!



Cosmic-rays vs Gamma-rays

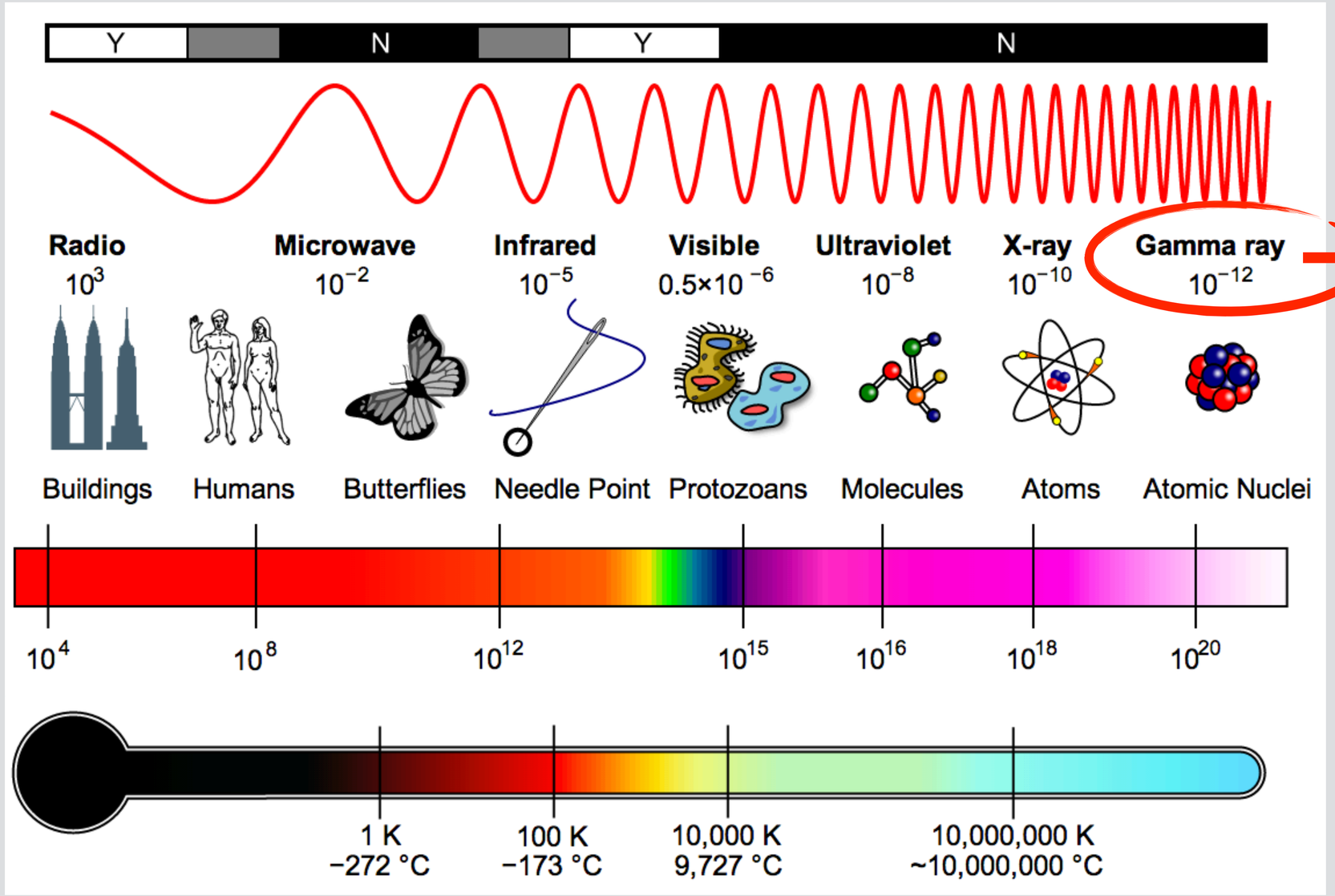
Cosmic-rays are charged particles, direction determined by **B** fields

Gamma-rays point back to the source



Gamma-rays are the highest energy light

Waves



Particles

~10^{-18} - 10^{-20} m

~1 - 100 TeV

~10^{26} - 10^{28} Hz

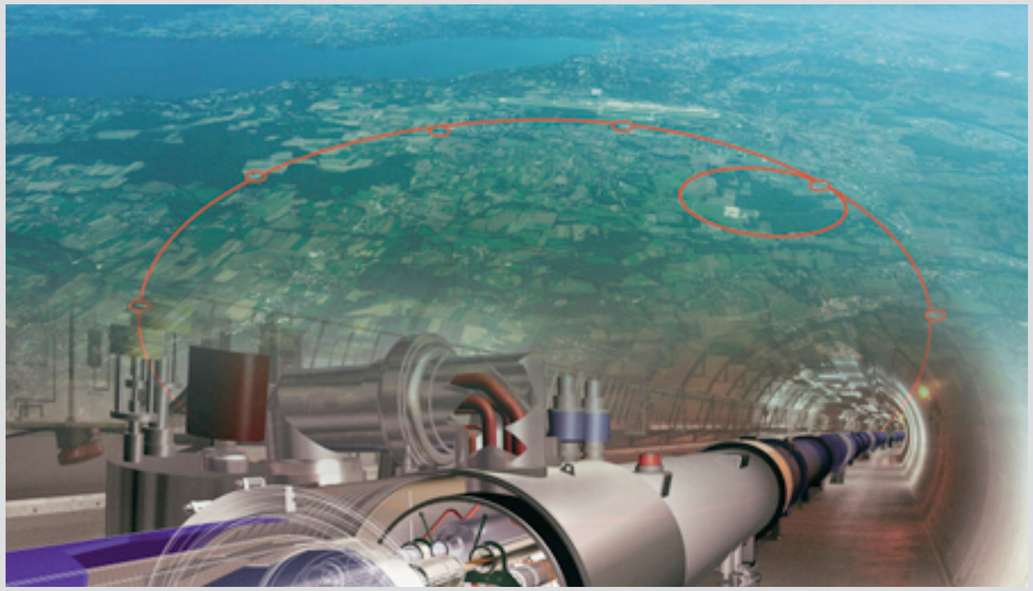
~10^{25} - 10^{27} K

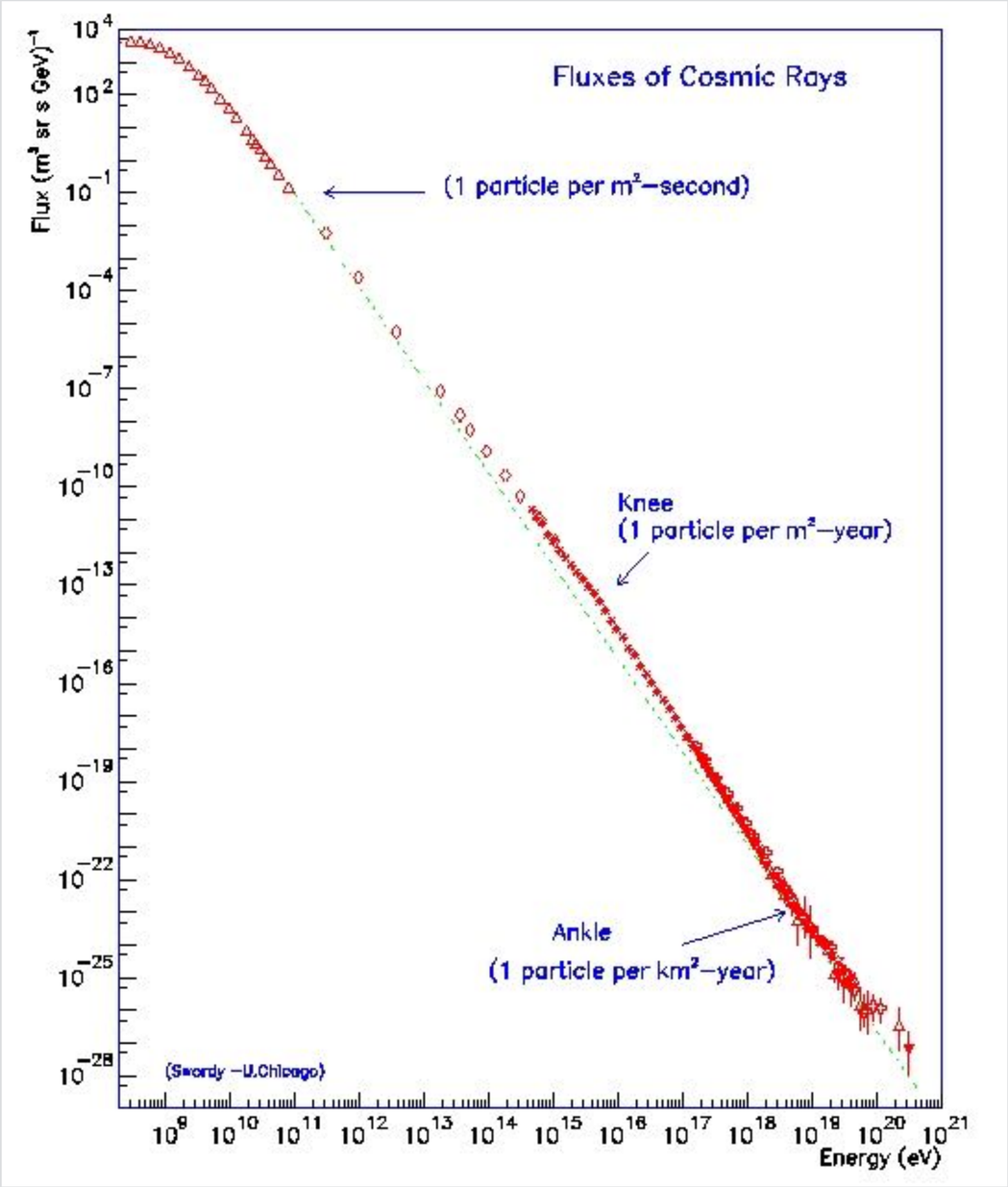
Particle Accelerators make Gamma-rays

Nature's accelerators bring cosmic-rays to kinetic energies up to $3(10^{20})$ eV!

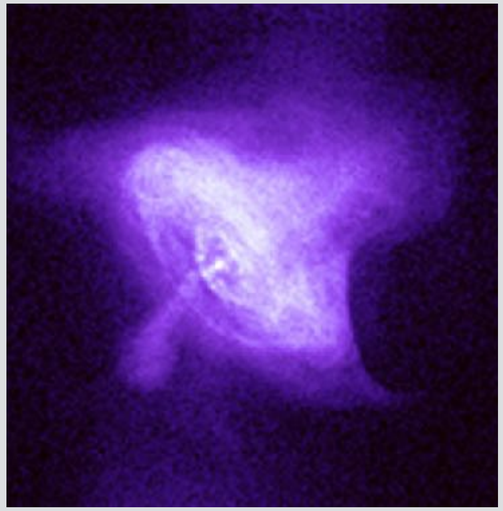
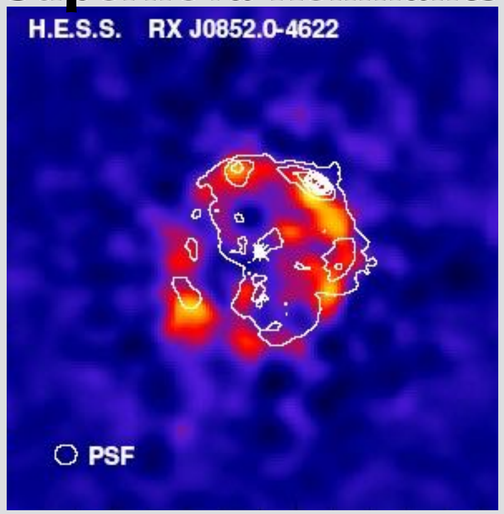
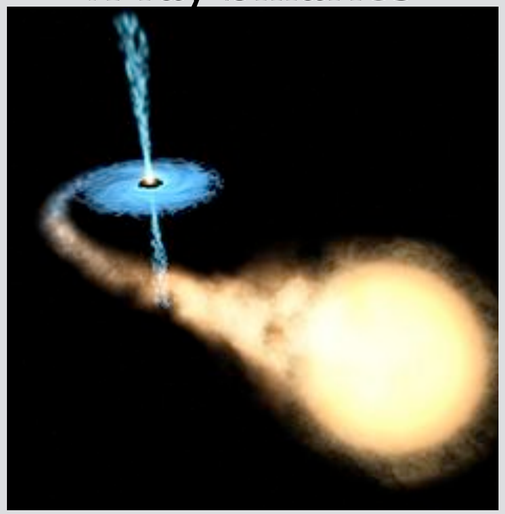
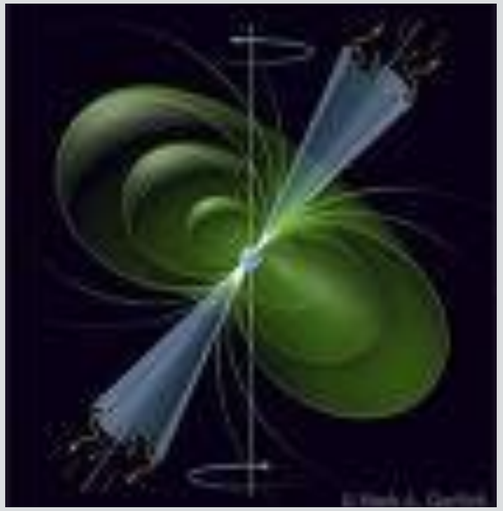
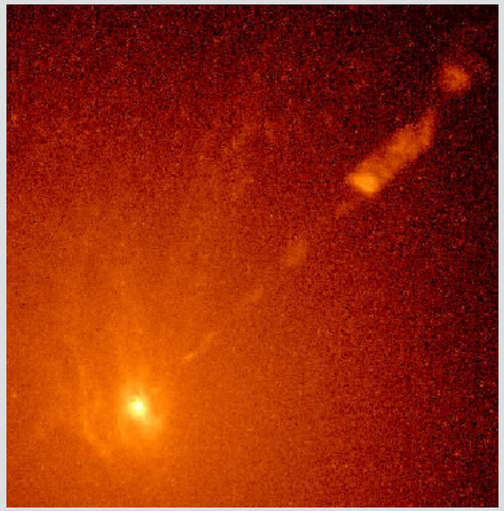
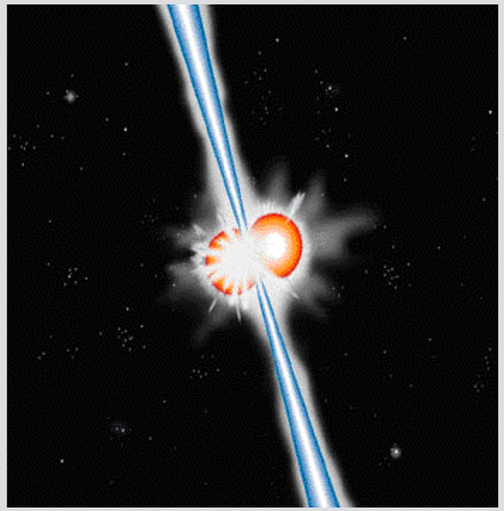
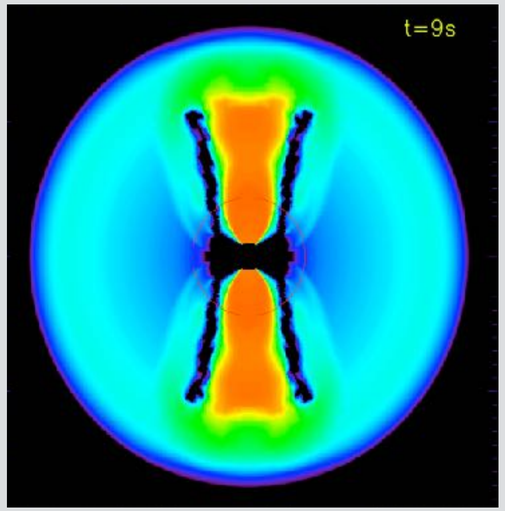
~50 Joules

LHC ~$7(10^{12})$ eV

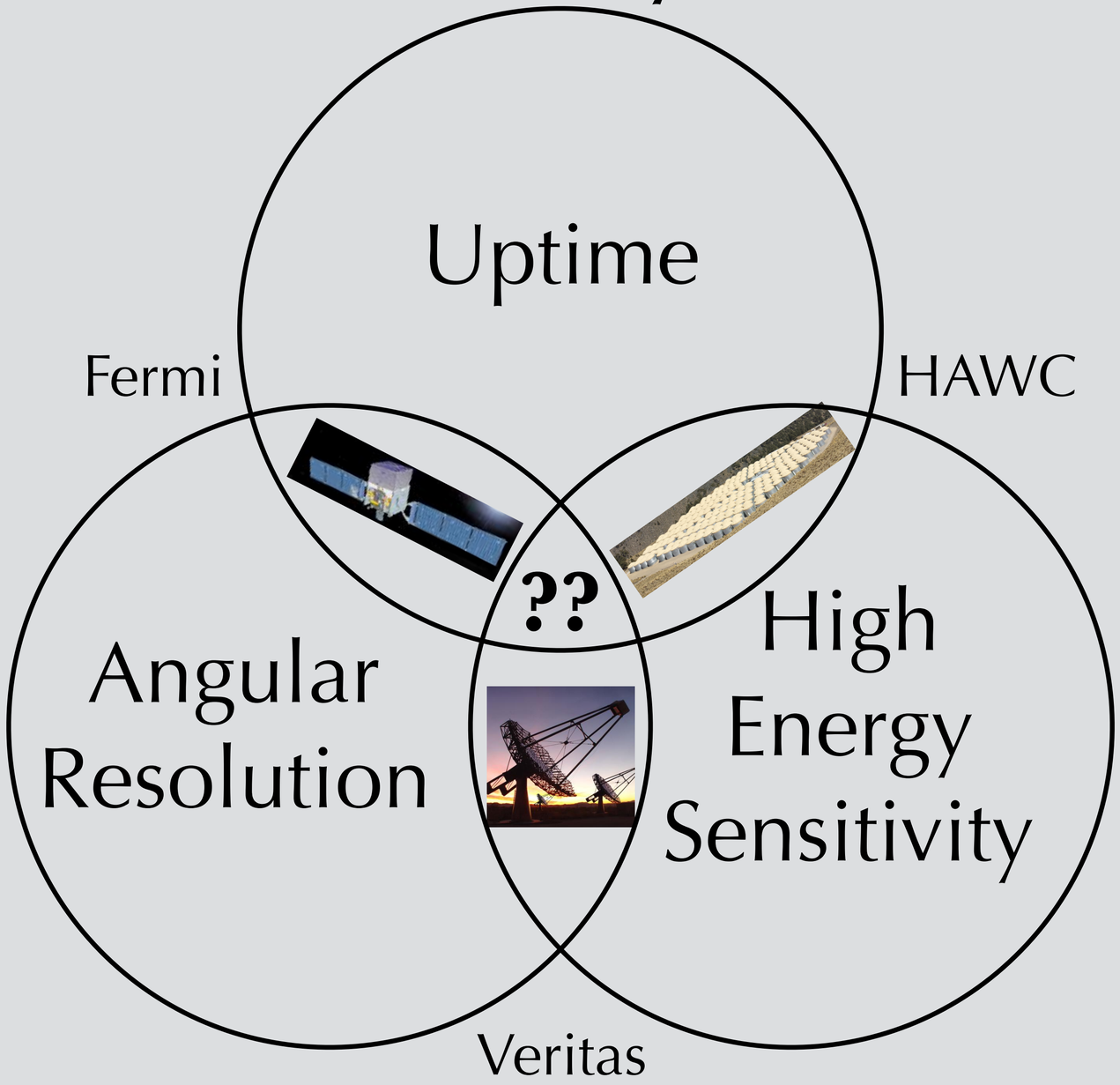




Particle Accelerators in Nature

	Pulsar Wind Nebulae	Supernova Remnants	X-ray binaries	Pulsars
Galactic				
Extragalactic				
	Active Galaxies	Short γ-ray Bursts	Long γ-ray Bursts	Starburst Galaxies

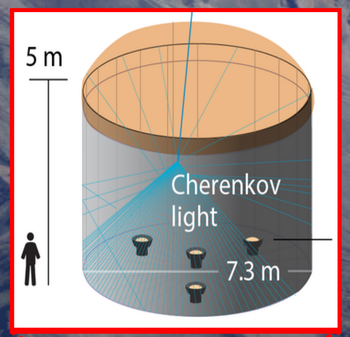
Different ways to see



HAWC

Pico de Orizaba
5600 m

22,000 m² air shower array
300 Water Cherenkov detectors (WCD)
200,000 liters of purified water per WCD
4 sensors (Photo-Multiplier Tubes) per WCD
Completed March 2015

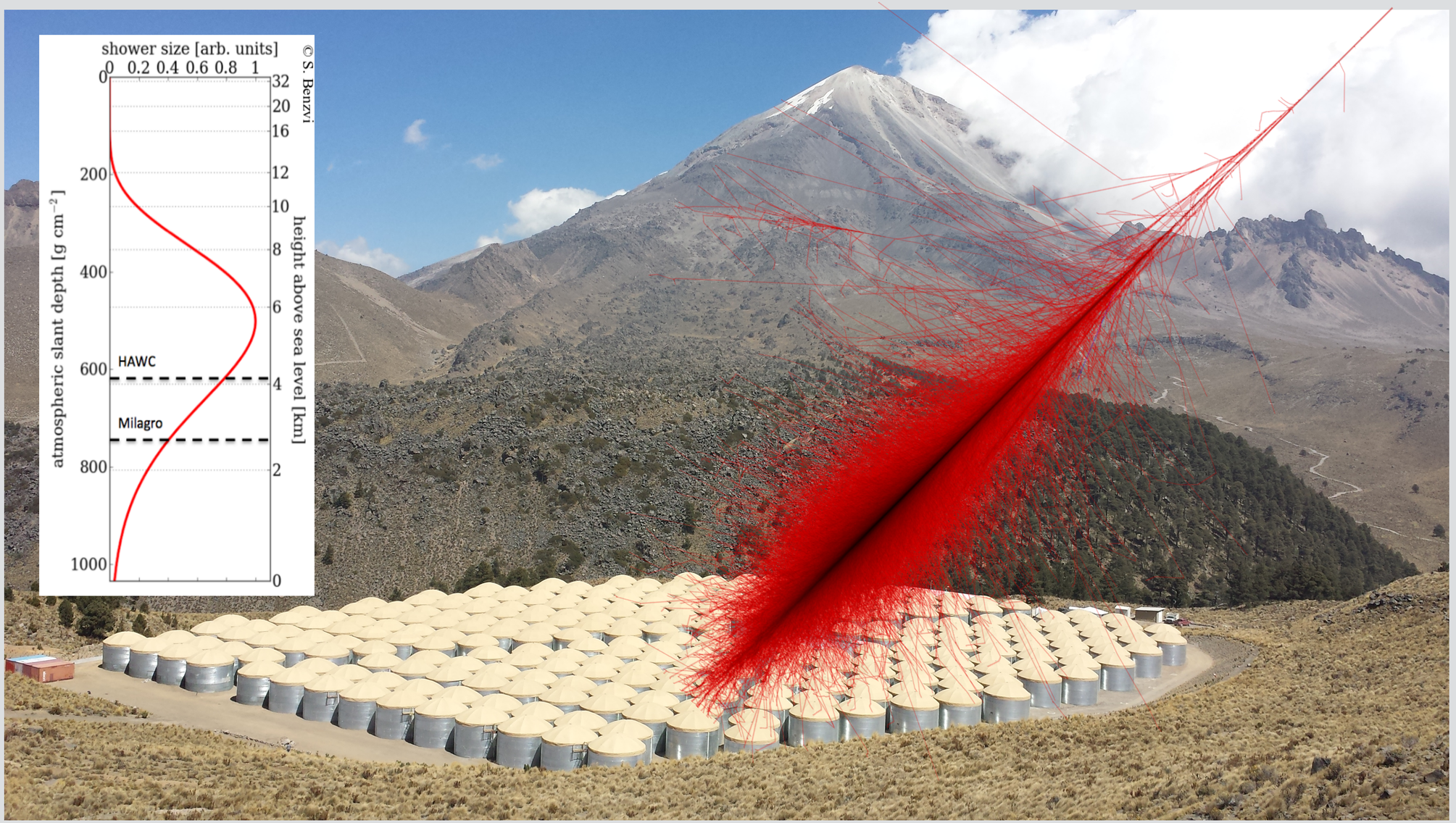


Large Millimeter
Telescope

HAWC
4100 m

Sierra Negra
4800 m

Extensive Air Showers



Interview with an Air Shower…

Q

Where did the air shower land?
Which direction did it come from?
What is its energy?
Is it a gamma-ray?

Interview with an Air Shower…

Q

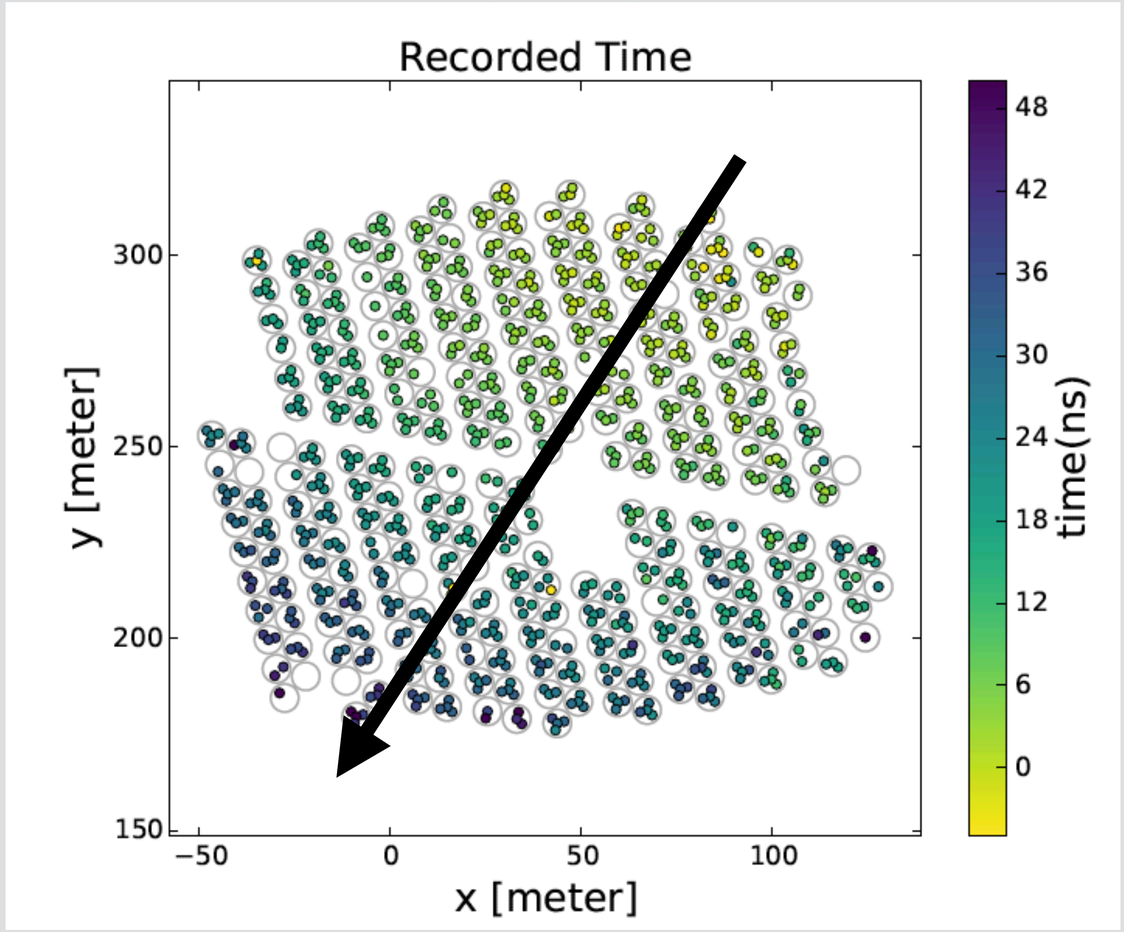
Where did the air shower land?
Which direction did it come from?
What is its energy?
Is it a gamma-ray?

A

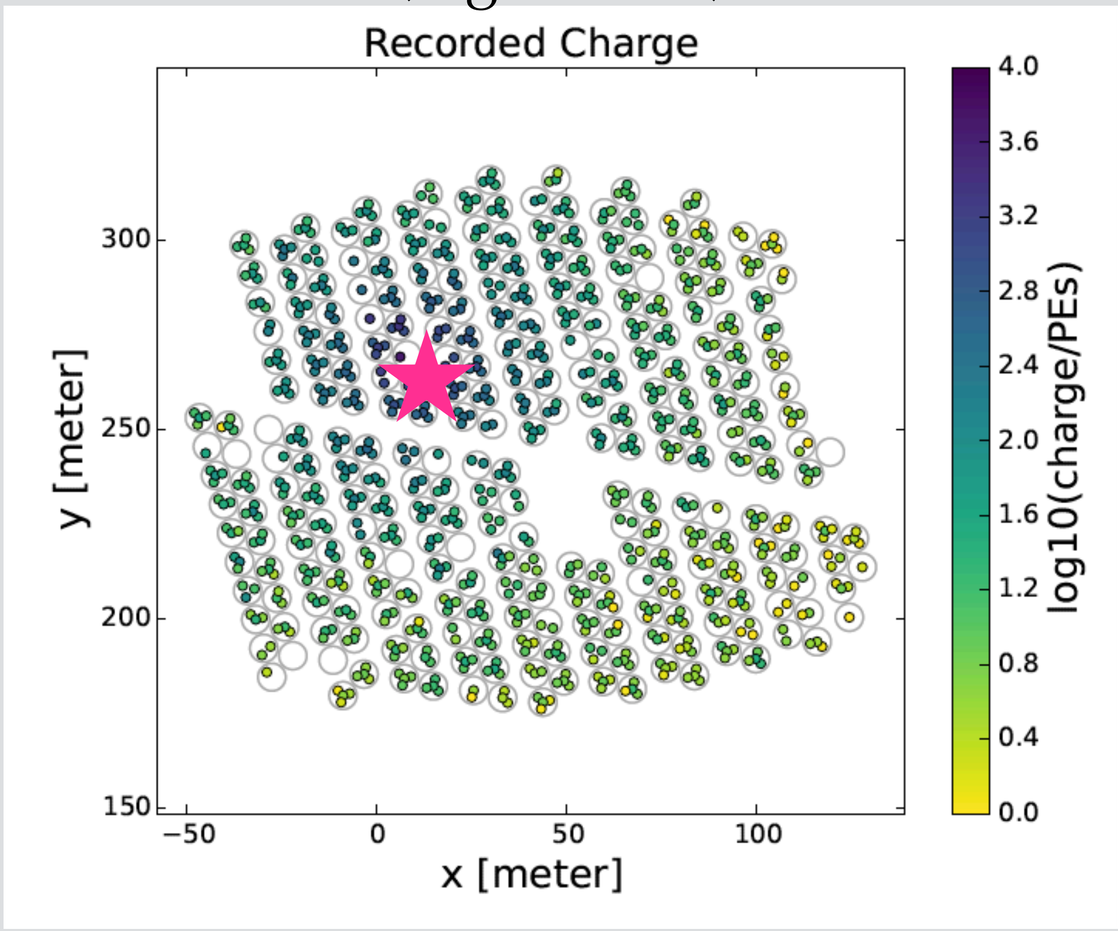
Event Reconstruction
Gamma/Hadron Separation

Event Reconstruction

Angle Information
(Time)



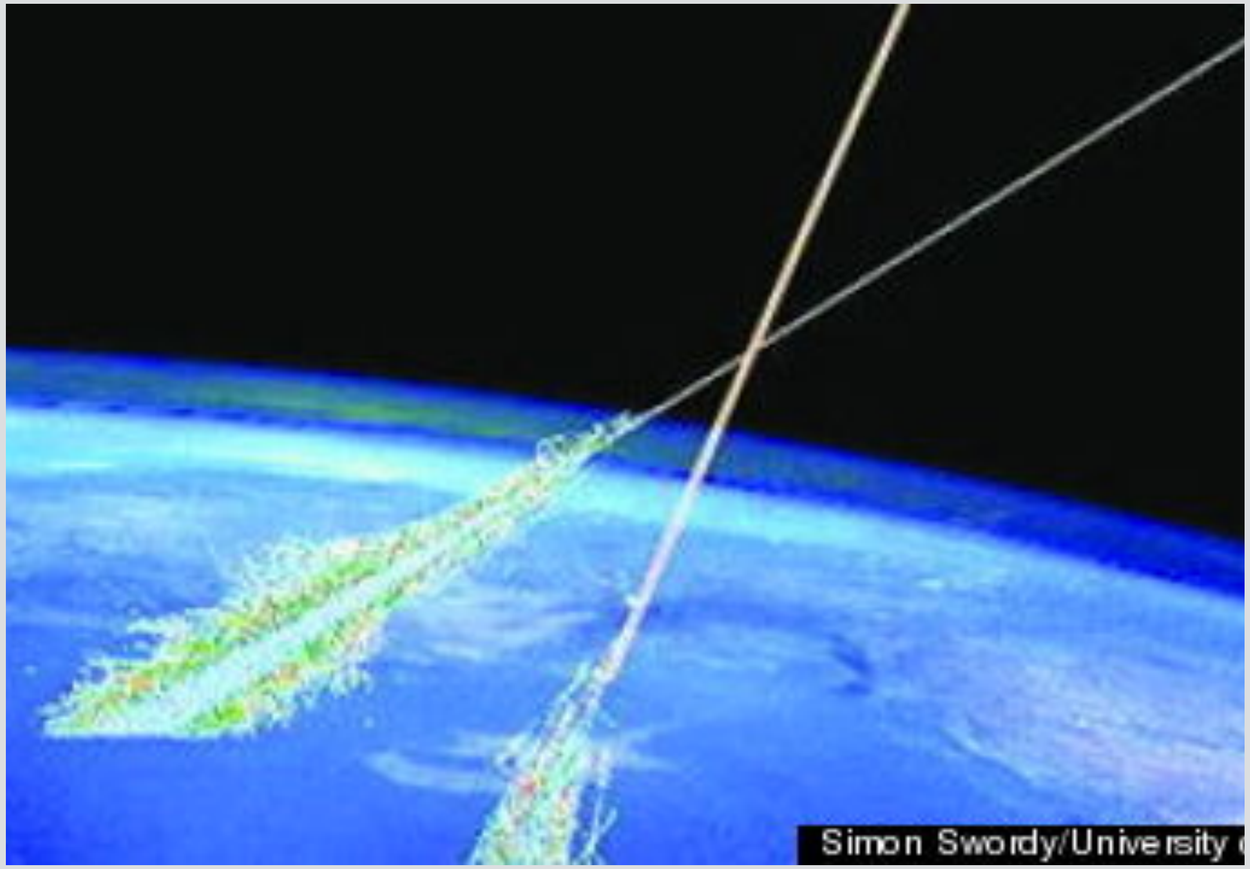
Location Information
(Light level)



Extensive Air Shower Facts:

Collect 20,000 air showers /second
~3 TB /day

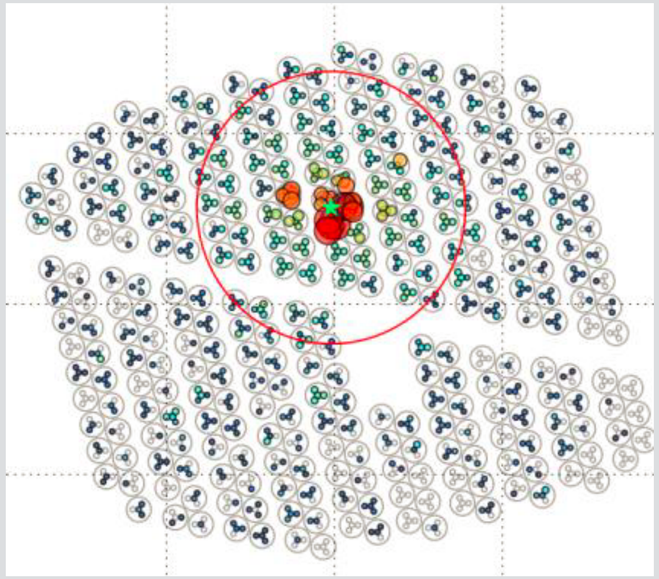
Rule of Thumb:
10^3 - 10^4 air showers per gamma-ray

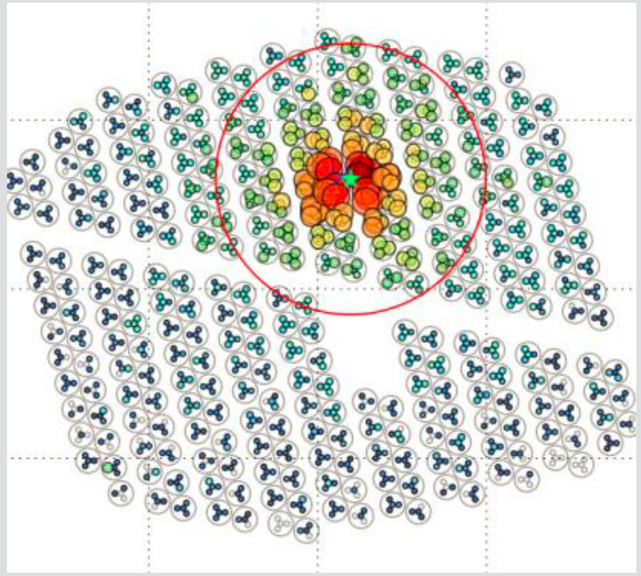


Need to get Gamma/Hadron separation right!

Gamma/Hadron Separation

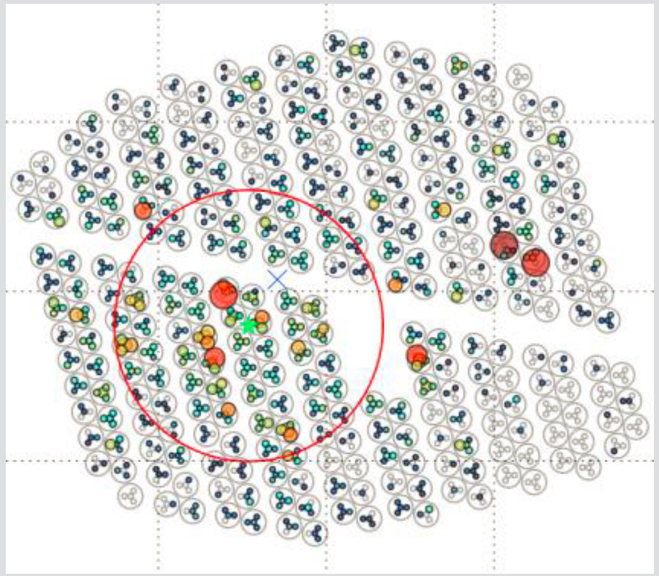
Gamma-ray event

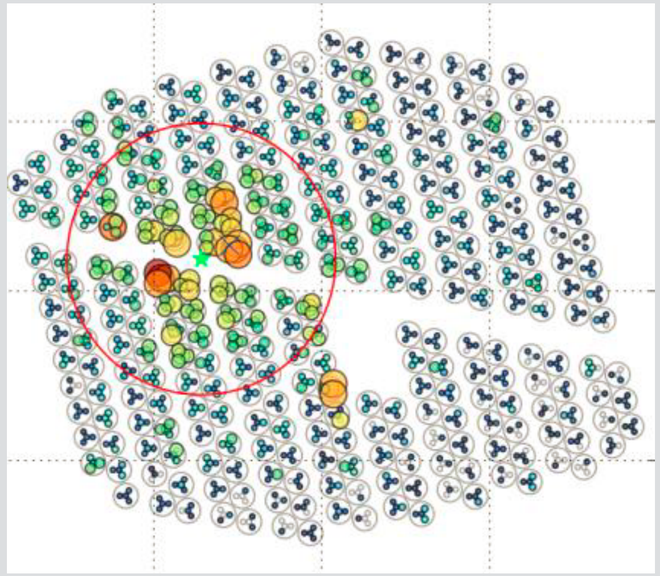




Axial symmetry

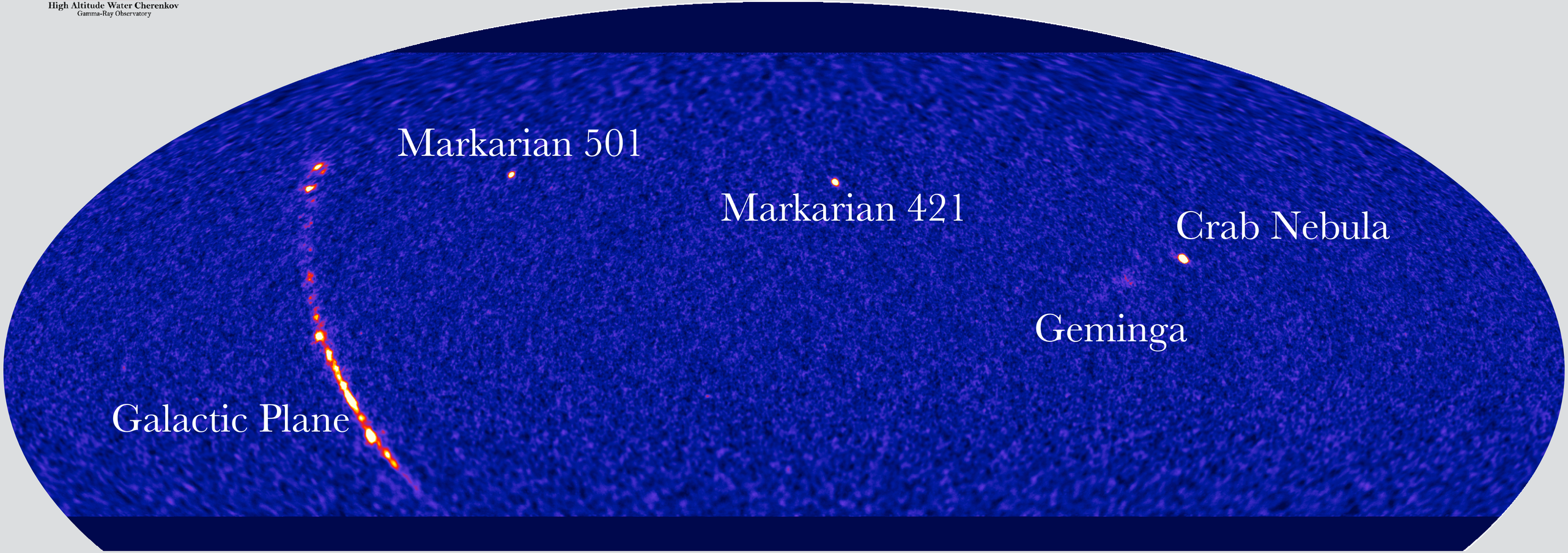
High charge hits
far from core



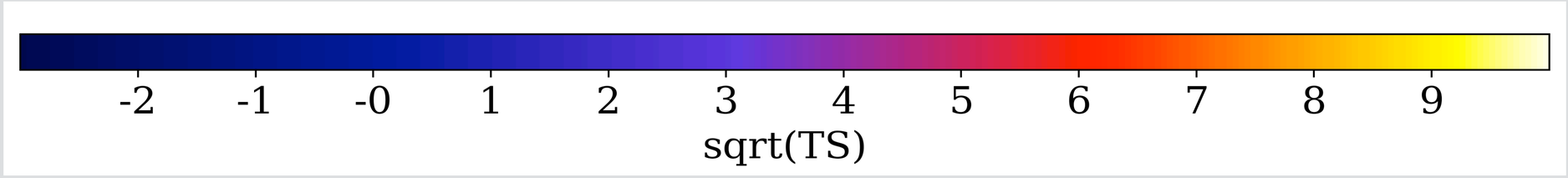


Cosmic-ray event

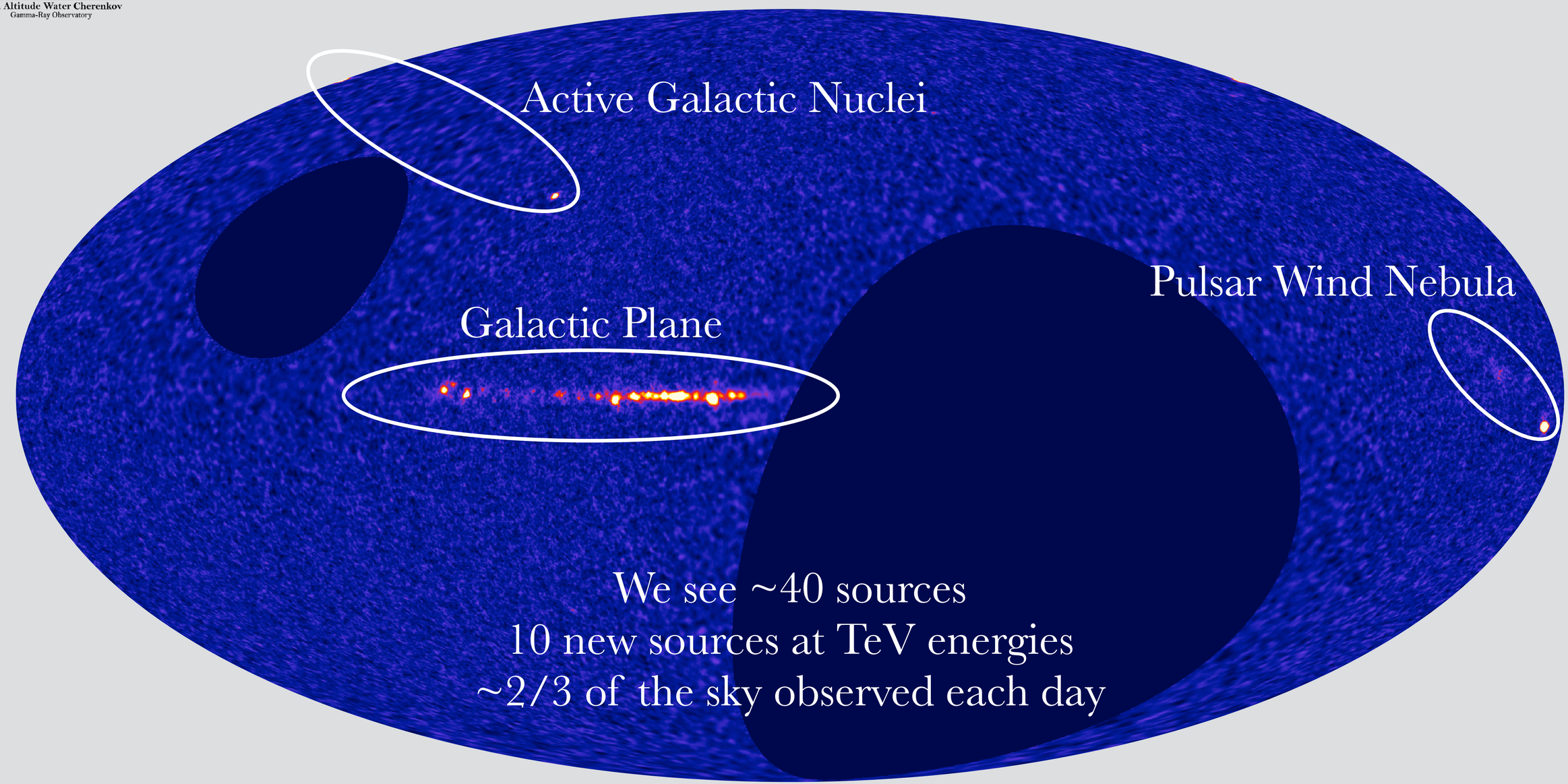
17 Month Skymap



Abeysekara, ApJ 843, 40 (2017)

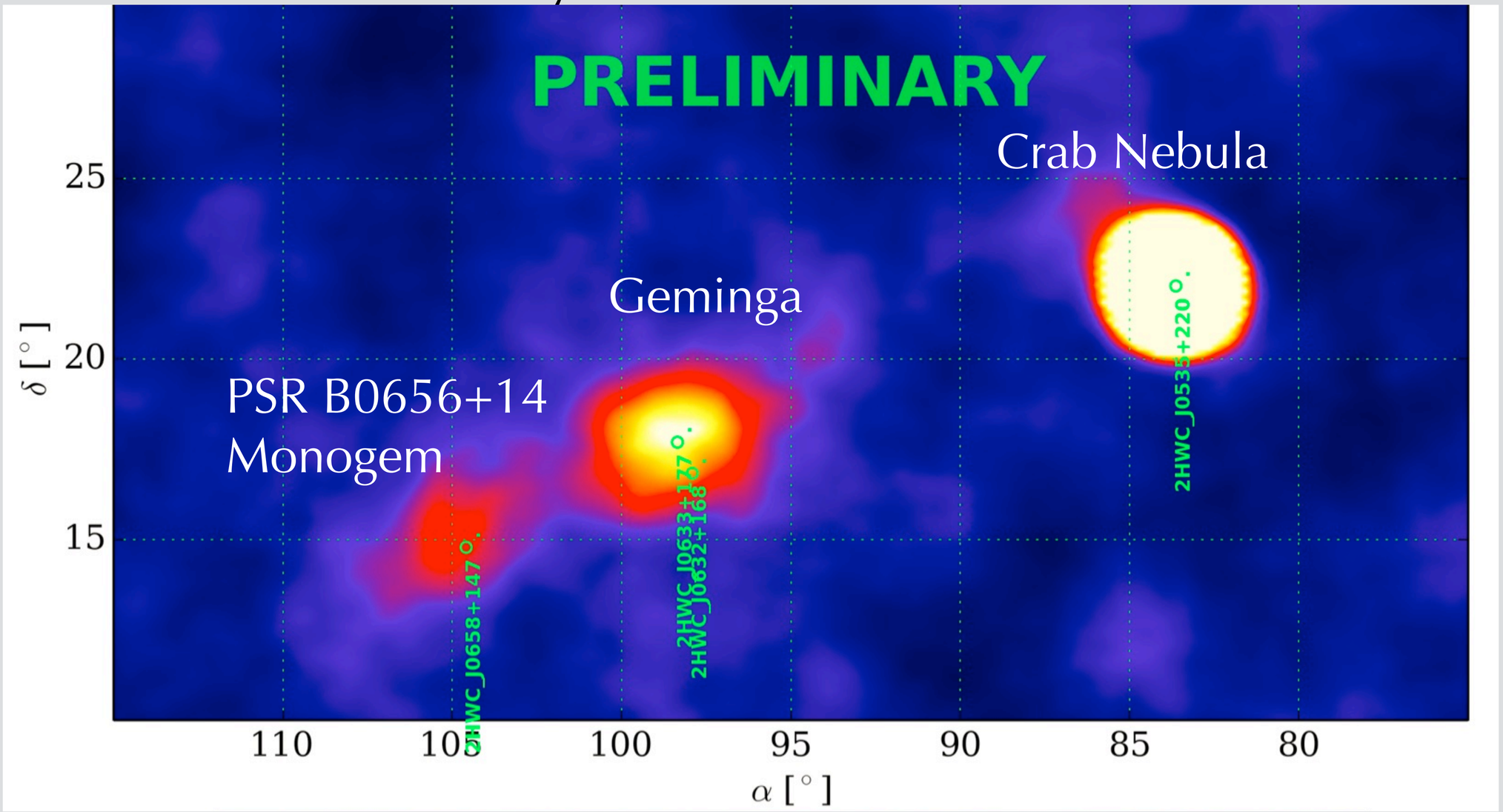


In Galactic Coordinates…

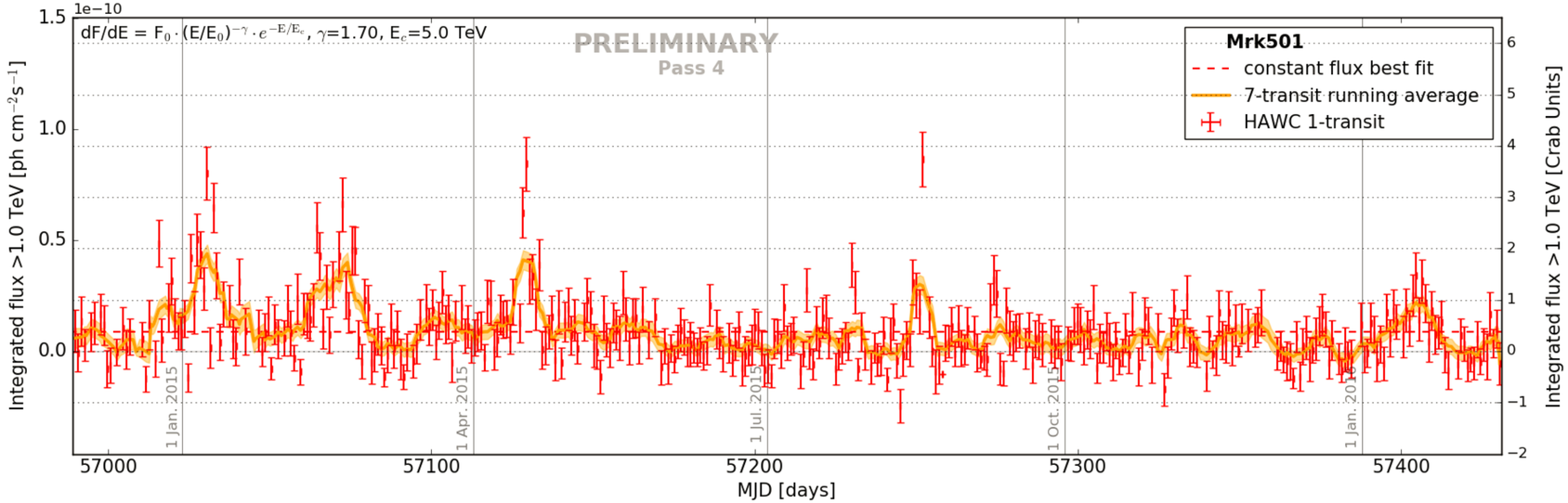


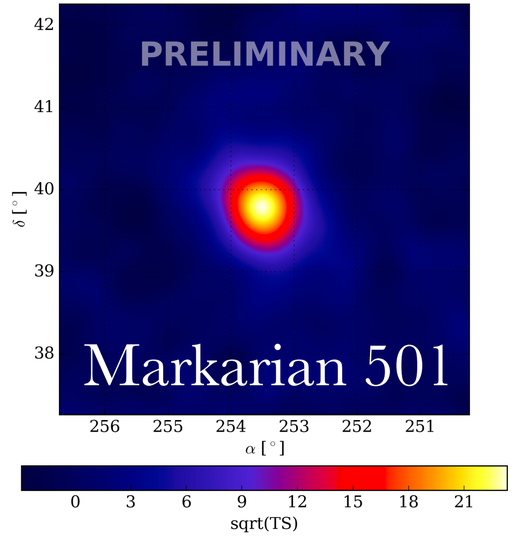
Extended PWN Observations

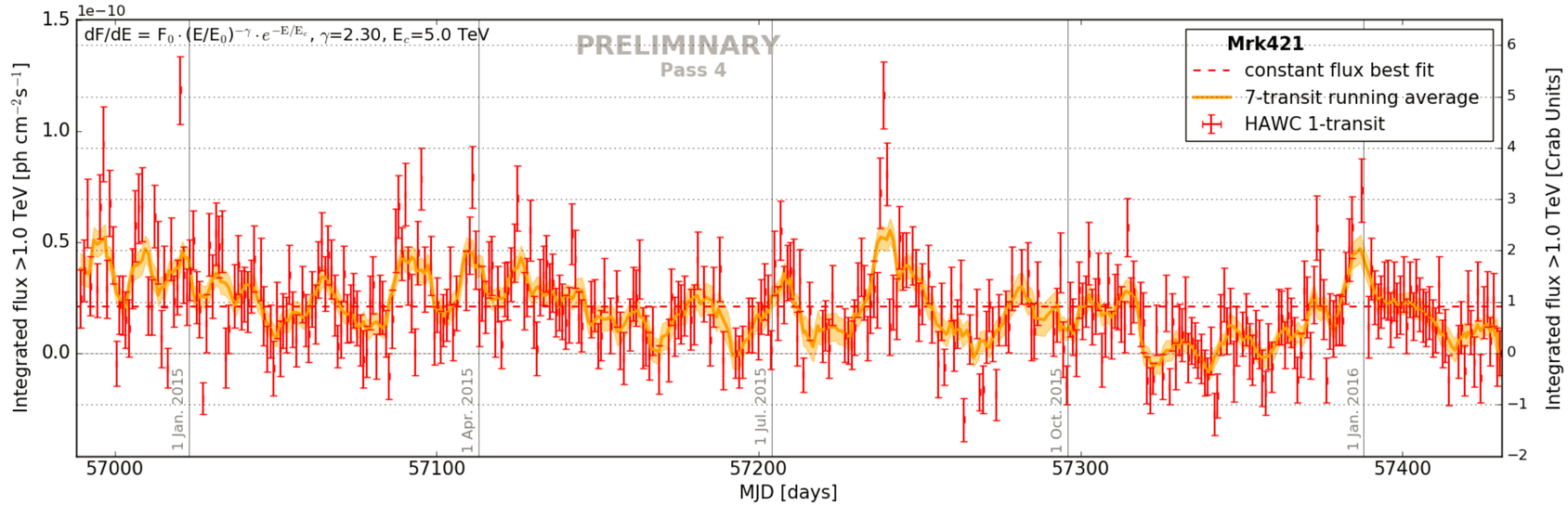
Enabled by Wide FoV of HAWC

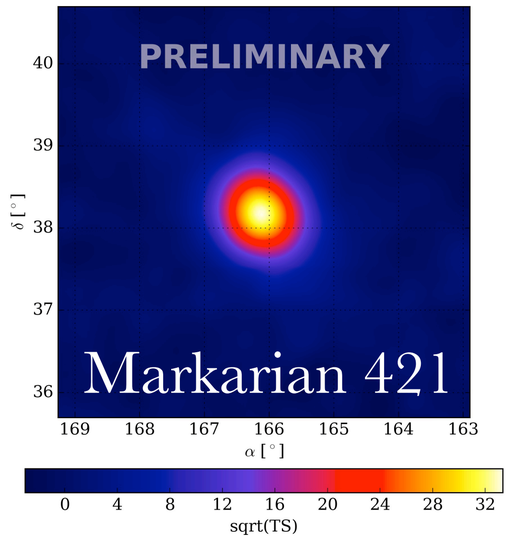


High Uptime enables continuous monitoring

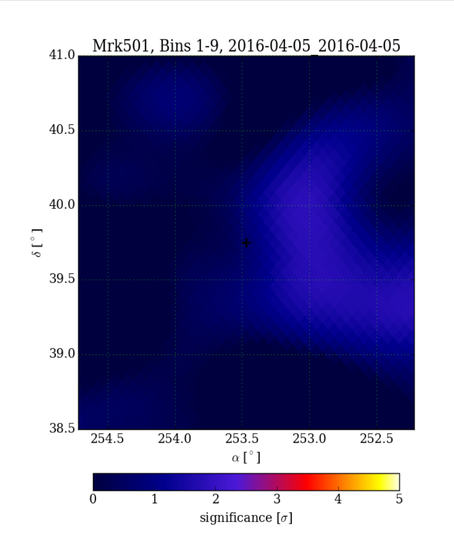




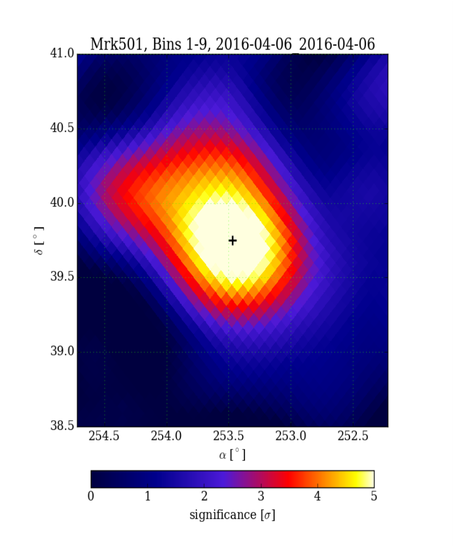




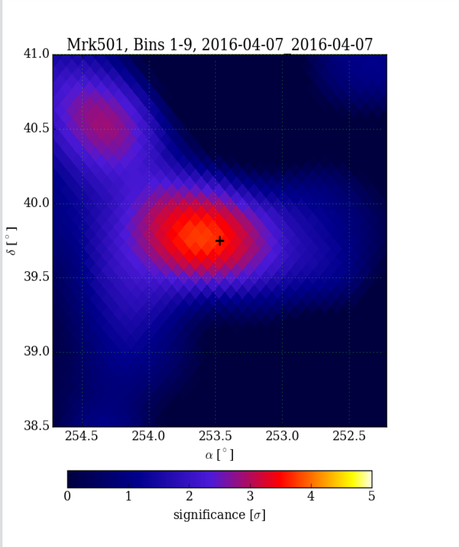
Observations of Flaring Sources



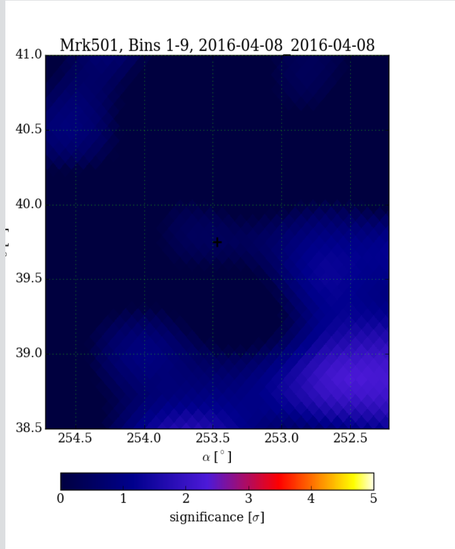
April 5th, 2016



April 6th, 2016



April 7th, 2016



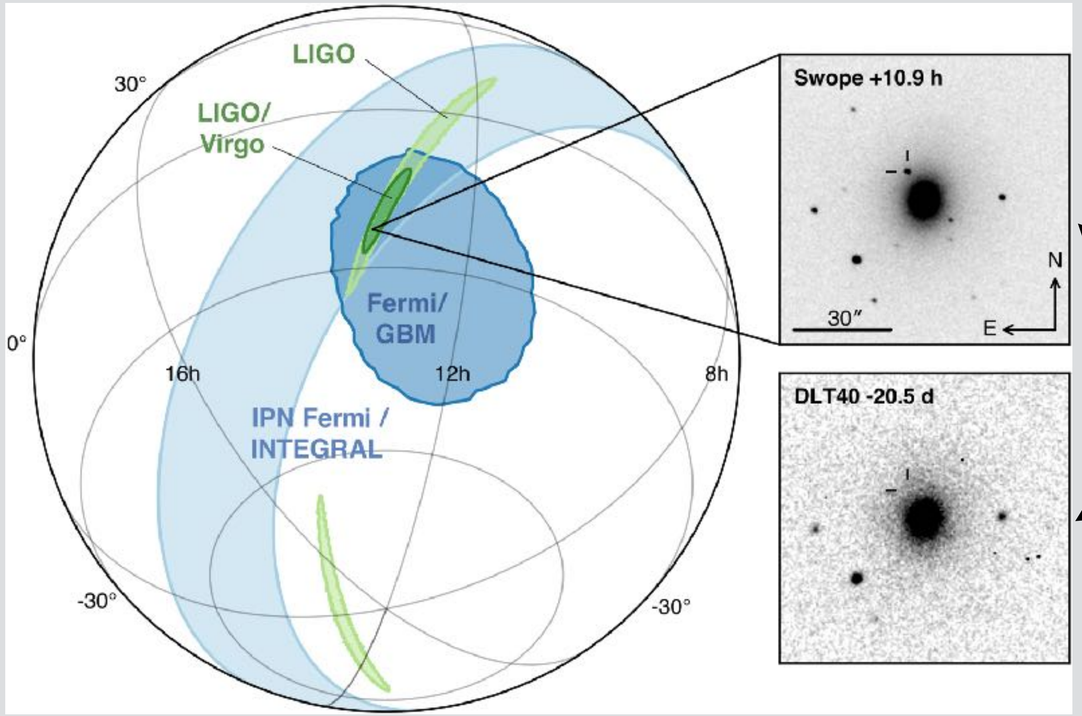
April 8th, 2016

HAWC detection of increased TeV flux state for Markarian 501 ATel #8922

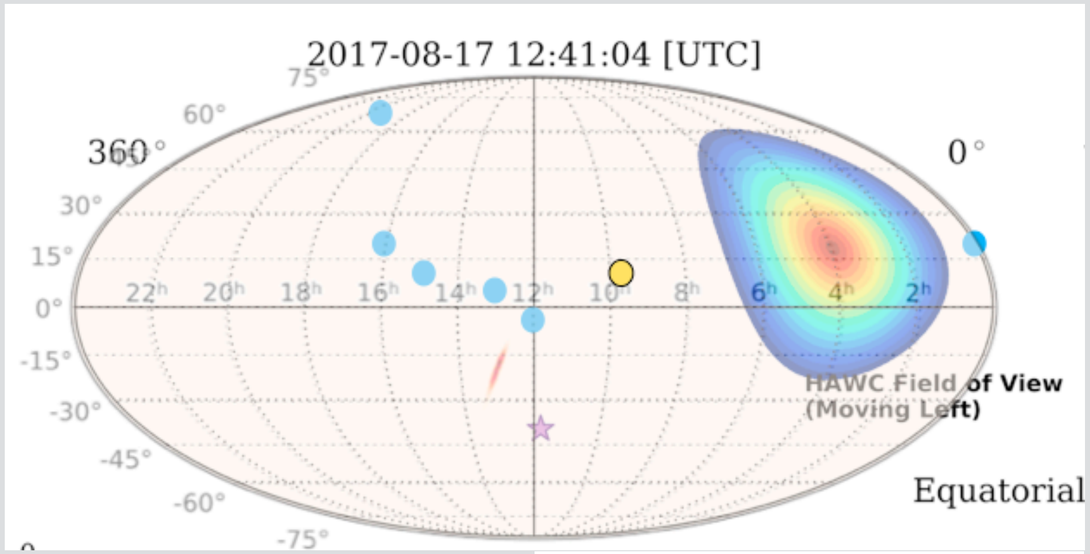
HAWC monitors entire sky for flaring sources

LIGO/VIRGO Neutron Star Merger GW 17082017

~9 hours after event
GW location was in HAWCs field of view



Optical Observations Before & After



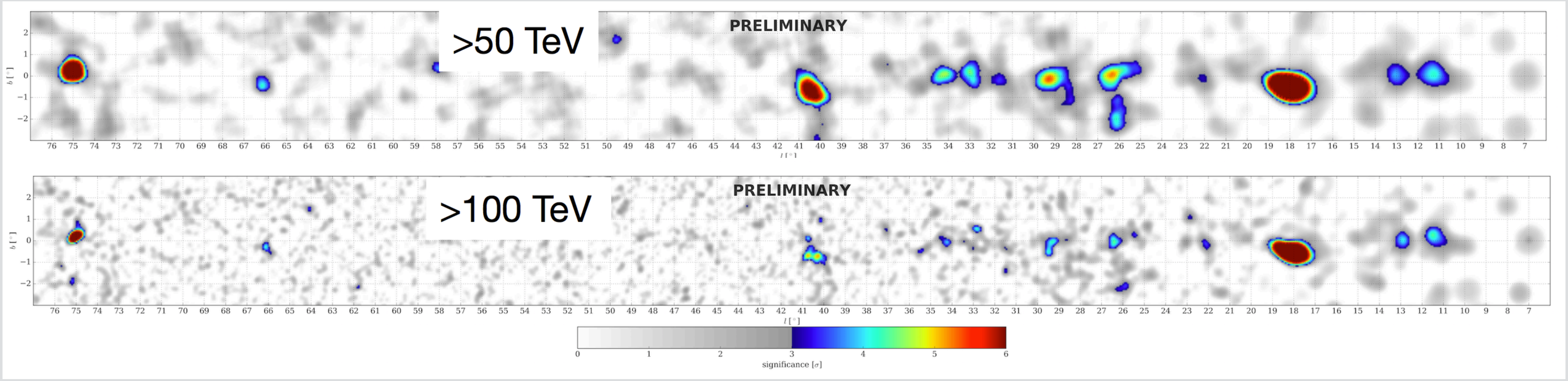
Star is at the GBM position with GBM error of 11 deg (68% containment)

I3 Neutrinos

Sun

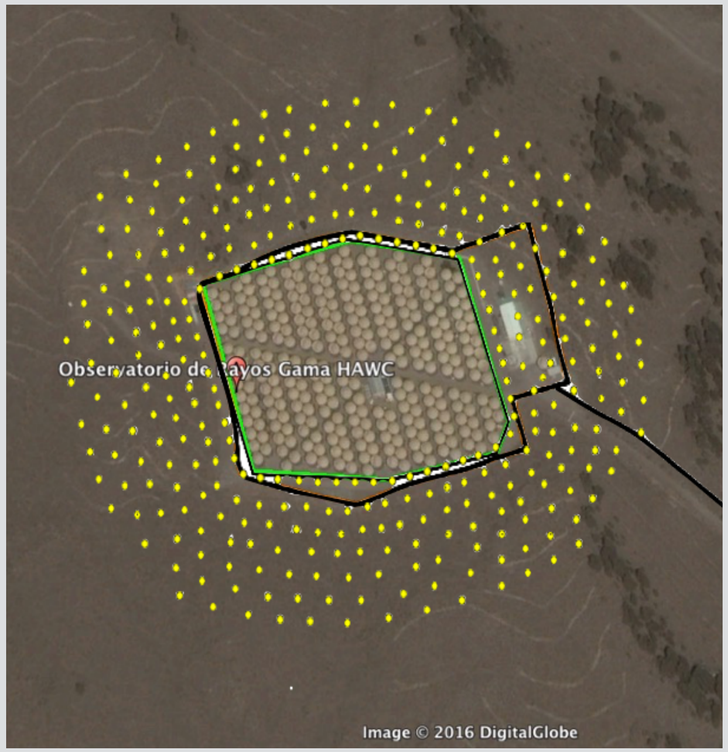
B. P. Abbott *et al* 2017 *ApJL* **848** L12

Highest Energy Sky



We see sources >50, >100 TeV
0.5 degree smoothing applied

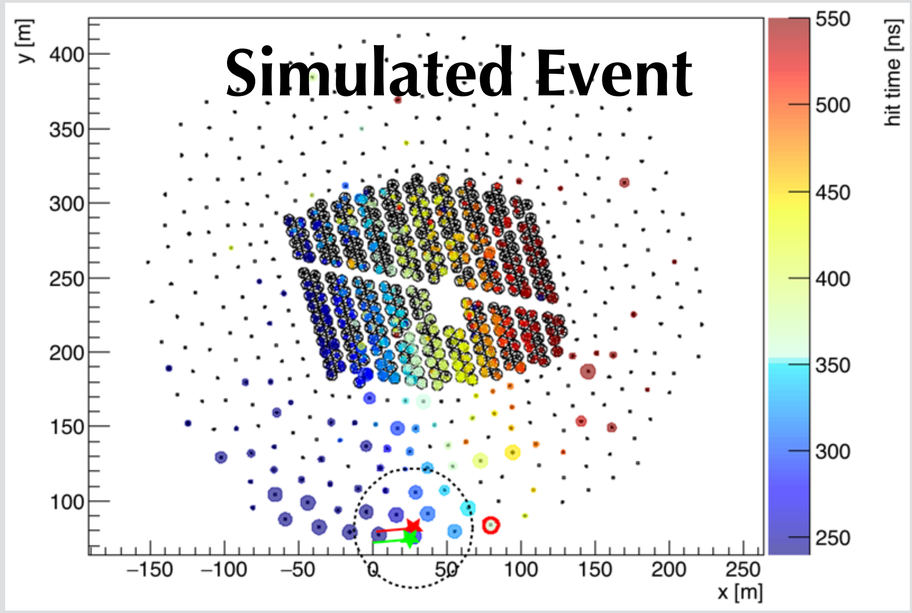
Outrigger Extension Array



Projected Completion
by March 2018

Will increase HAWC sensitivity above 50 TeV by factor of ~4

Improvement primarily due to better core location determination



Permit approved in Late August
~1/6 deployed as of this week

The HAWC Collaboration

Halloween 2017

Cocoyoc, Mexico

Thanks!