



HAWC

the high energy gamma ray observatory

Presented at the CLAF meeting
April 20th 2023
Rio de Janeiro, Brazil

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High Altitude Water Cherenkov (HAWC) Observatory in Central Mexico at 4,100 m a.s.l.



Citlaltepetl
Pico de Orizaba
5160m a.s.l.

- 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



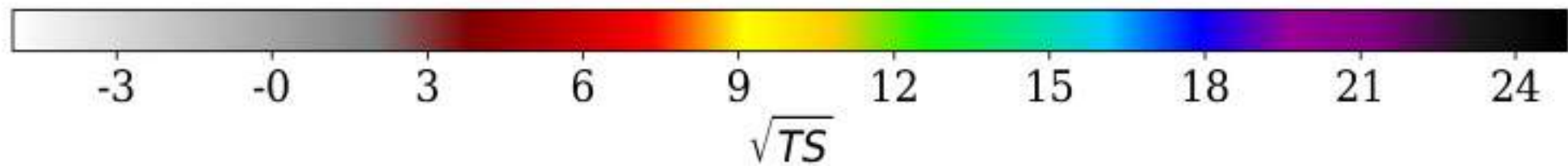
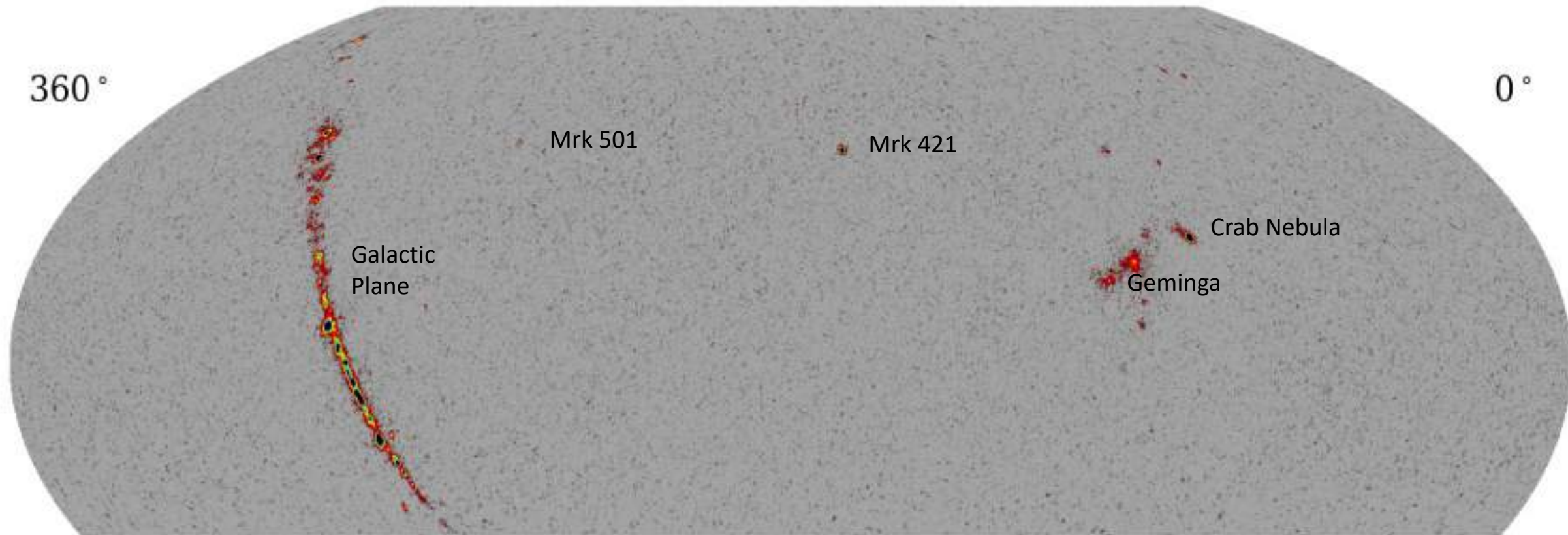
HAWC
4100 m a.s.l.

Tliltepetl
Sierra Negra
4582m a.s.l.

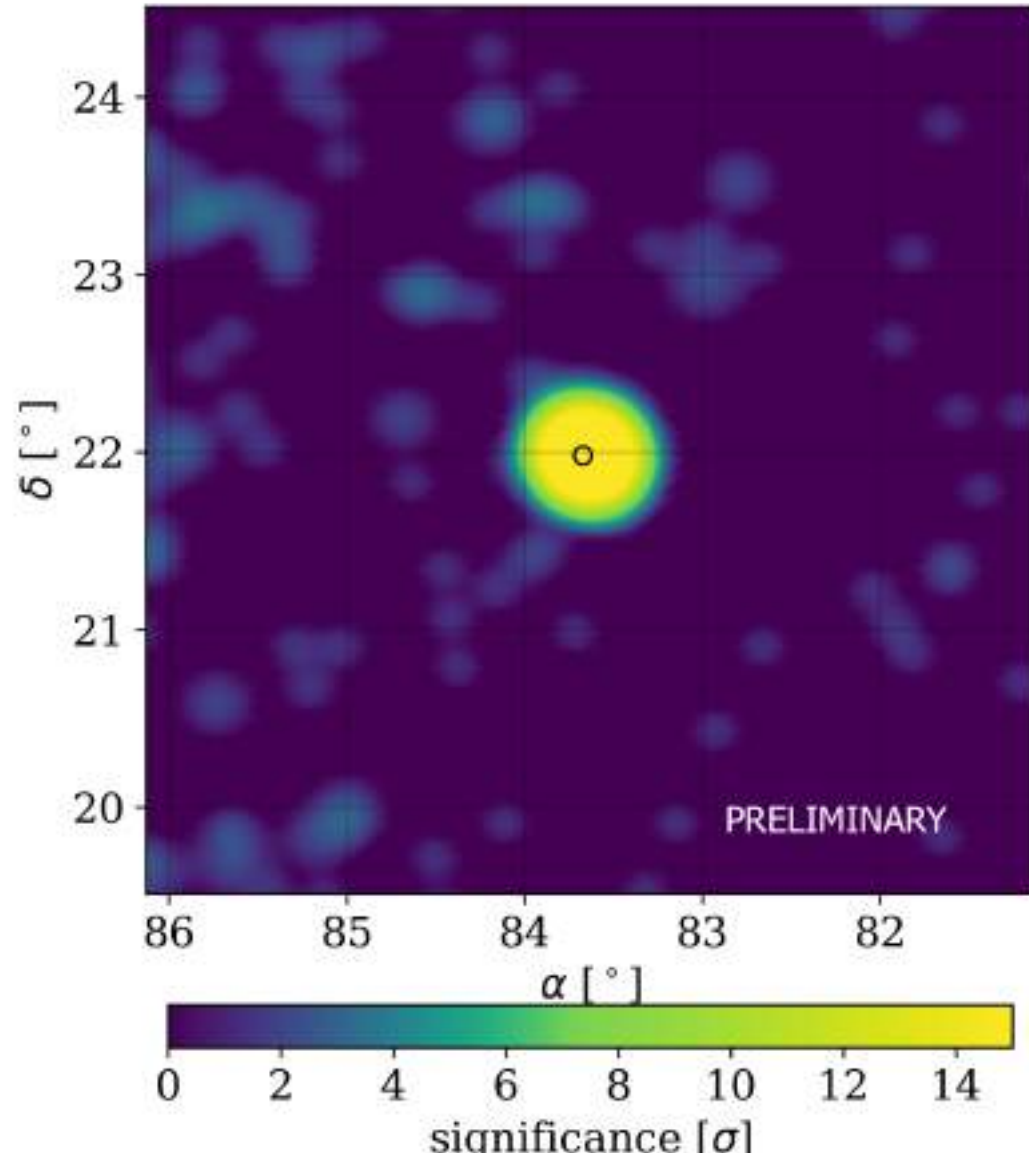
Showers of particles from primary gamma and cosmic rays hit the water tanks and give faint light flashes (Cherenkov radiation)



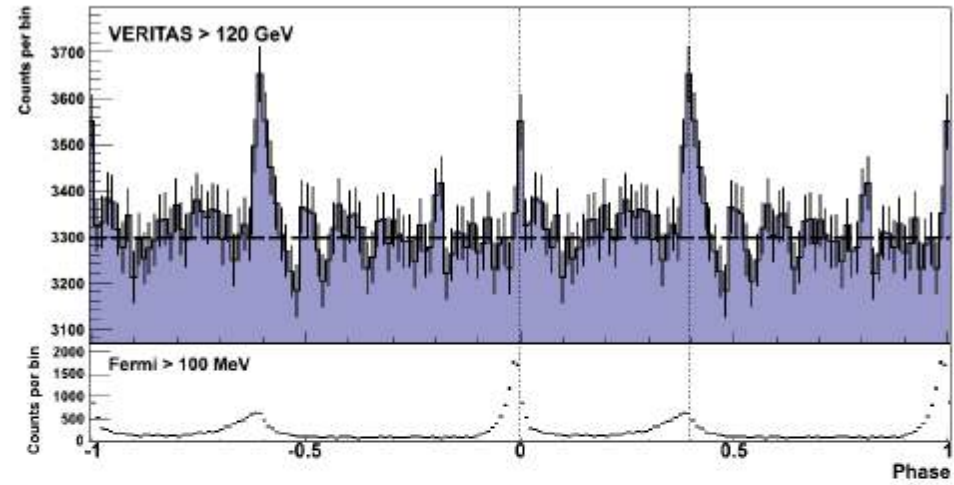
HAWC Sky Map 2090 Days of Data



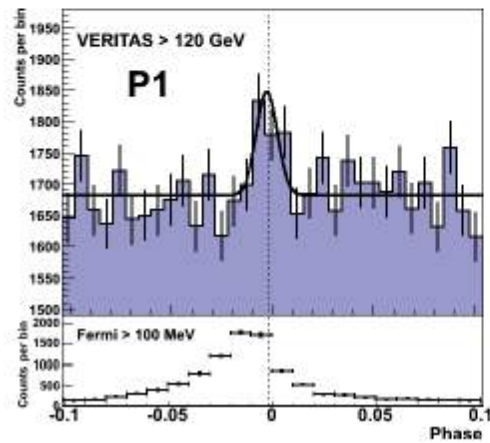
6500 light years rotates 30 x per second



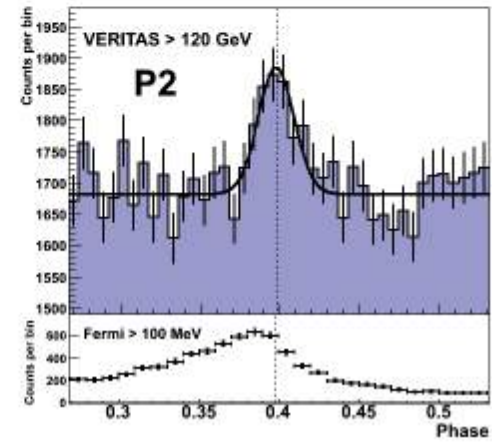
A



B



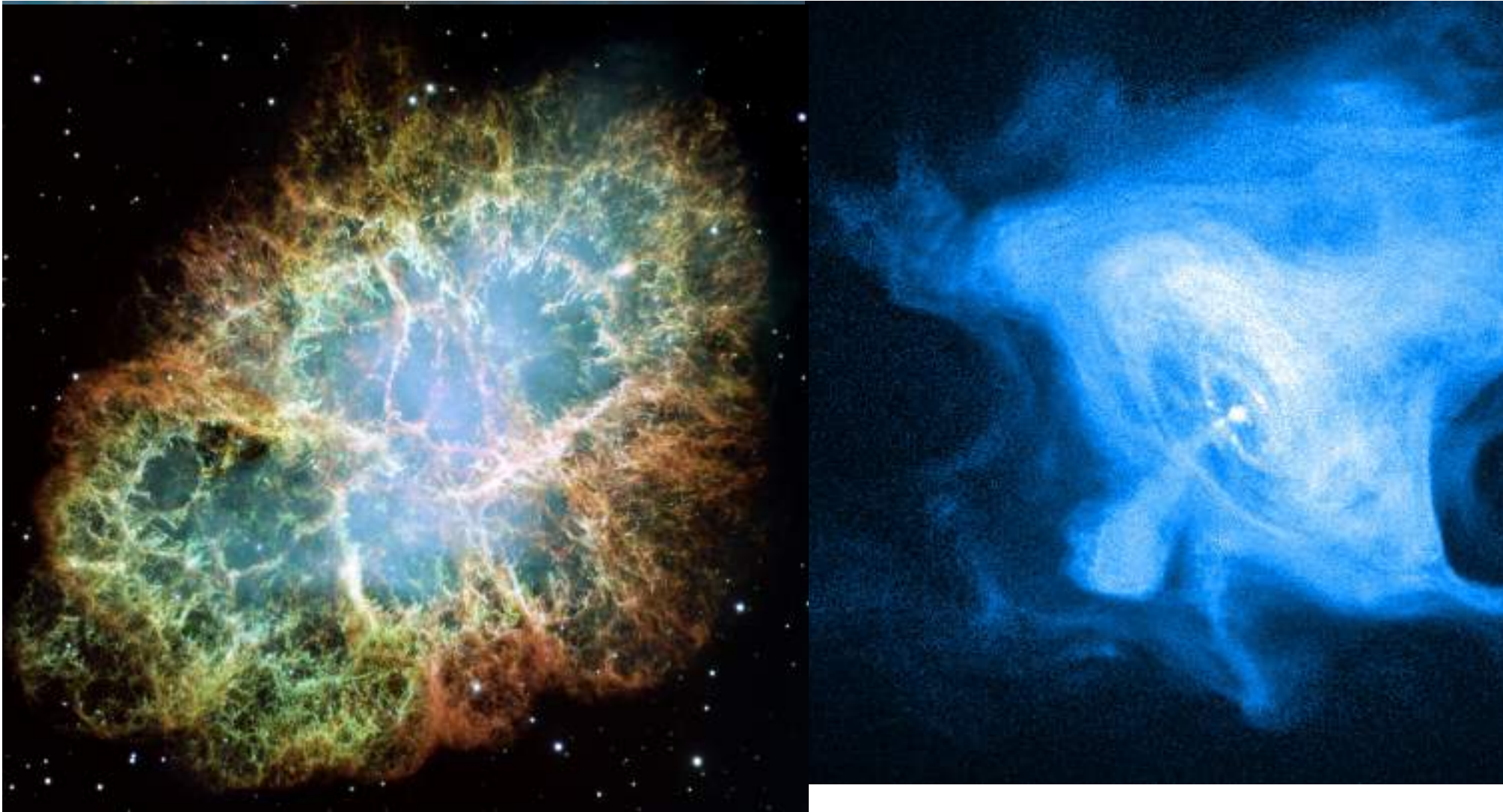
C





La Nebulosa del Cangrejo

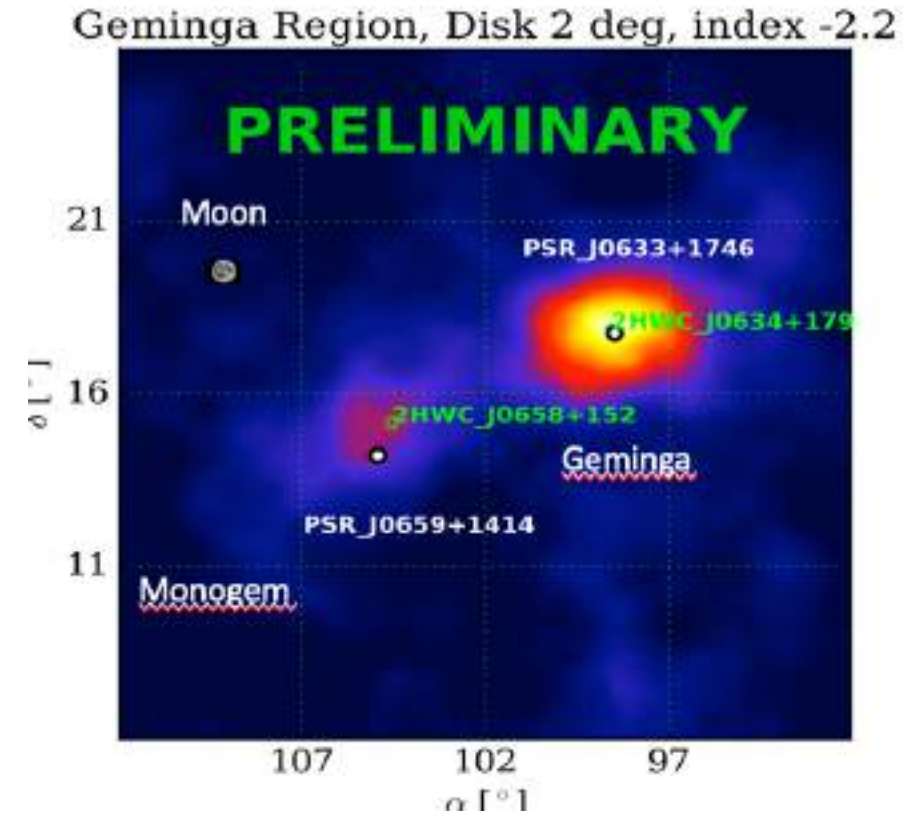
SN que vista en 1050 por los chinos





Geminga largest region in the sky emitting high energy gamma rays

- Pulsar 800 million light years away

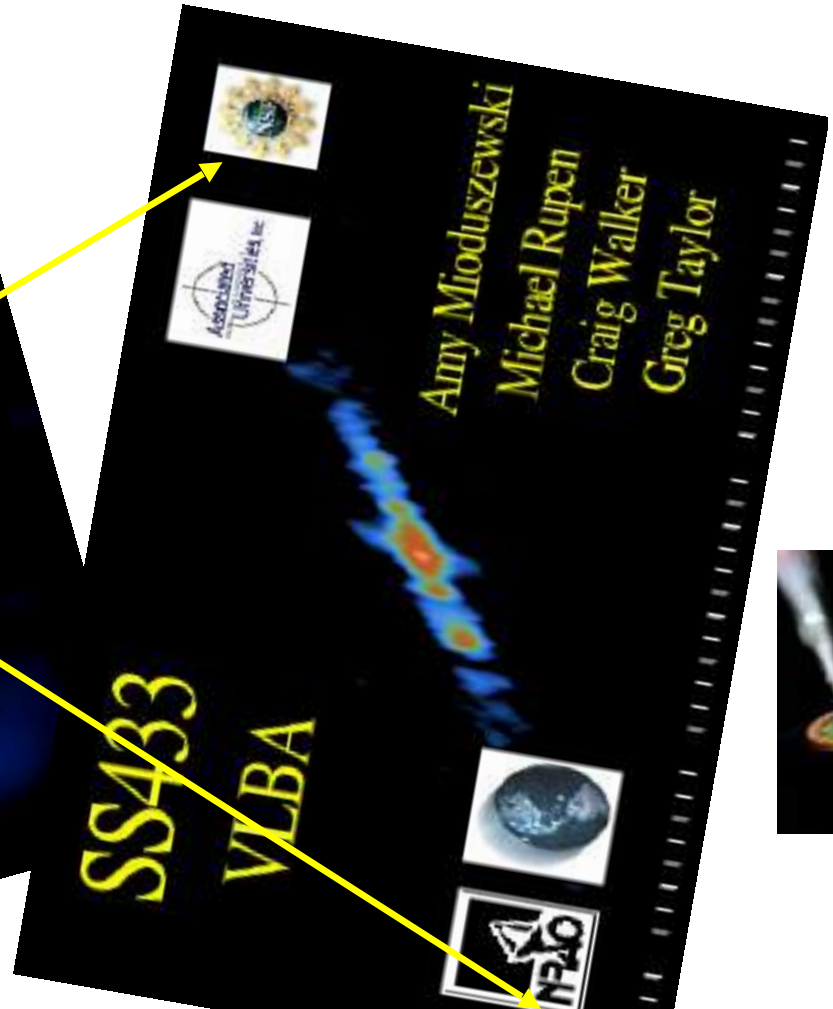
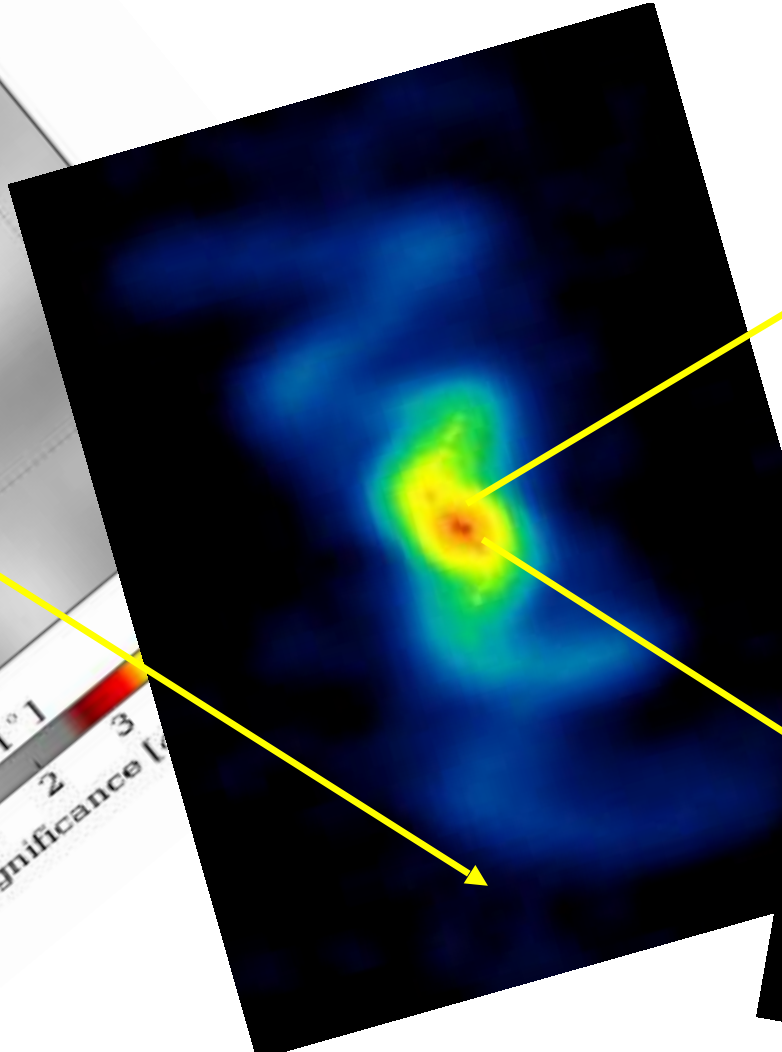
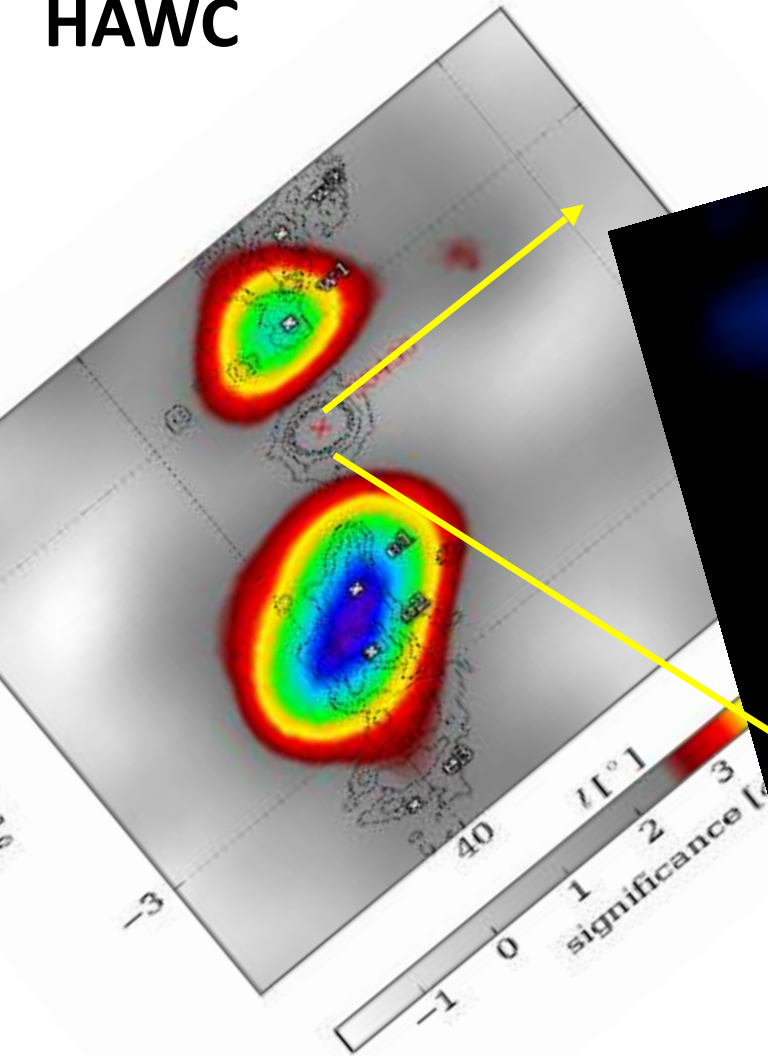




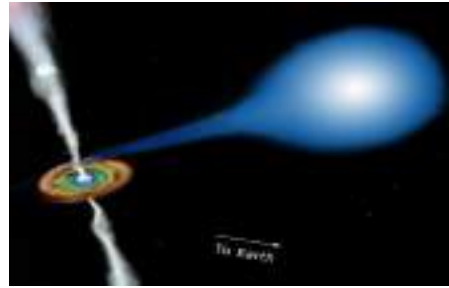
First detection of γ -rays from a binary system of a black hole and a 2 solar mass A type star

15,000 light years away

HAWC

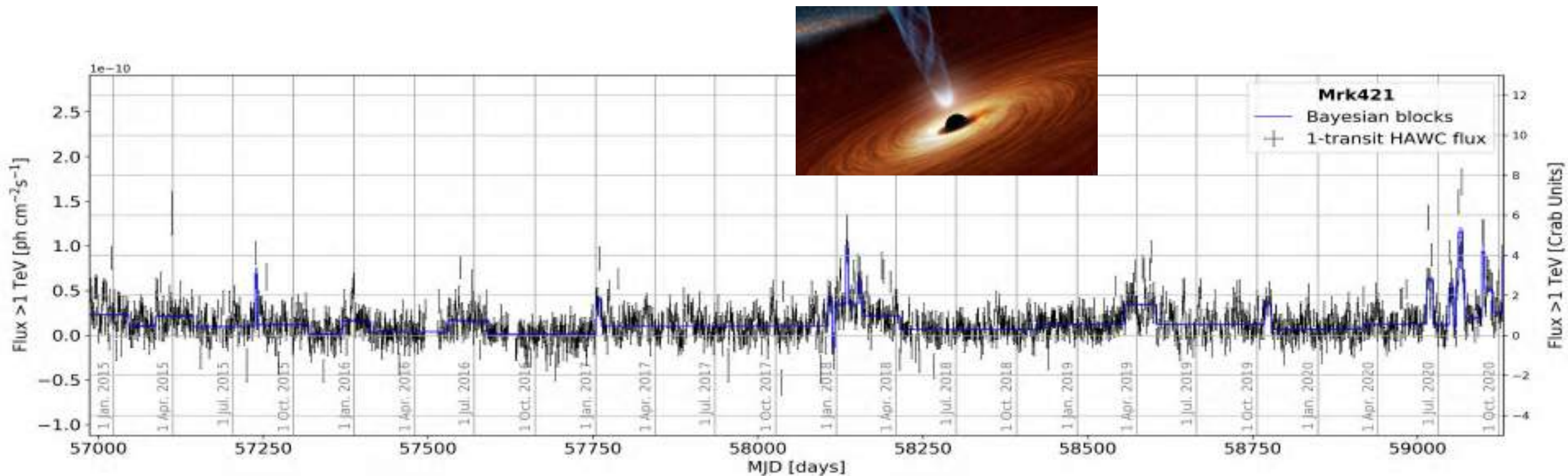


Nature



Daily monitoring of the active galaxy Mrk 421

400 million light years away



One Observatory



Two Nations



Three Funding Agencies



Four grant holders



A. Sandoval J. Goodman A. Carramiñana B. Dingus

Twenty seven Institutions



The HAWC Collaboration 2015



University of Maryland: Jordan Goodman, Andrew Smith, Greg Sullivan, Jim Braun

Los Alamos National Laboratory: Gus Sinnis, Brenda Dings, John Pretz

University of Wisconsin: Teresa Montaruli, Stefan Westerhoff

University of Utah: Dave Kieda, Wayne Springer

Univ. of California, Irvine: Gaurang Yodh, Scott DeLay

Univ. of California, Santa Cruz: Michael Schneider

Michigan State University: Jim Linnemann, Kirsten Tollefson

George Mason University: Robert Ellsworth

University of New Hampshire: James Ryan

Pennsylvania State University: Tyce DeYoung, Patrick Toale, Kathryn Sparks

University of New Mexico: John Matthews, William Miller

Michigan Technical University: Petra Hüntemeyer

NASA/Goddard Space Flight Center: Julie McEnery

Georgia Institute of Technology: Ignacio Taboada

Colorado State University: Miguel Mustafa

Instituto Nacional de Astrofísica Óptica y Electrónica (INAOE): Alberto Carramiñana, Eduardo Mendoza, Luis Carrasco, William Wall, Daniel Rosa, Guillermo Tenorio Tagle, Sergey Silich

Universidad Nacional Autónoma de México (UNAM): Instituto de Astronomía: Octavio Valenzuela, Vladimir Avila-Reese, Marco Martos, Maria Magdalena Gonzalez, Sergio Mendoza, Dany Page, William Lee, Hector Hernández, Deborah Dultzin, Erika Benitez
Instituto de Física: Arturo Menchaca, Rubén Alfaro, Varlen Grabski, Andres Sandoval, Ernesto Belmont. Arnulfo Matinez-Davalos
Instituto de Ciencias Nucleares: Lukas Nellen, Gustavo Medina-Tanco, Juan Carlos D'Olivo
Instituto de Geofísica: José Valdés Galicia, Alejandro Lara, Rogelio Caballero

Benemérita Universidad Autónoma de Puebla: Humberto Salazar, Arturo Fernández, Caupatitzio Ramirez, Oscar Martínez, Eduardo Moreno, Lorenzo Diaz, Alfonso Rosado,

Universidad Autónoma de Chiapas: Cesar Álvarez, Eli Santos Rodriguez, Omar Pedraza

Universidad de Guadalajara: Eduardo de la Fuente

Universidad Michoacana de San Nicolás de Hidalgo: Luis Villaseñor, Umberto Cotti, Ibrahim Torres, Juan Carlos Arteaga Velazquez

Centro de Investigación y de Estudios Avanzados: Arnulfo Zepeda

Universidad de Guanajuato: David Delepine, Gerardo Moreno, Edgar Casimiro Linares, Marco Reyes, Luis Ureña, Mauro Napsuciale, Victor Migenes



Mexico



The HAWC Collaboration



Formed in 2007 by Mexico and United States.
Now with participation of Europe, Latin America and Asia

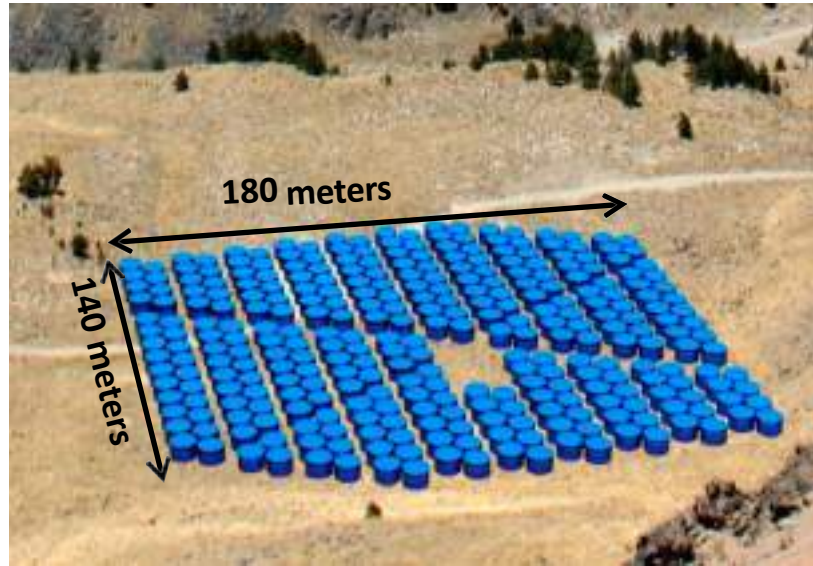


Time line

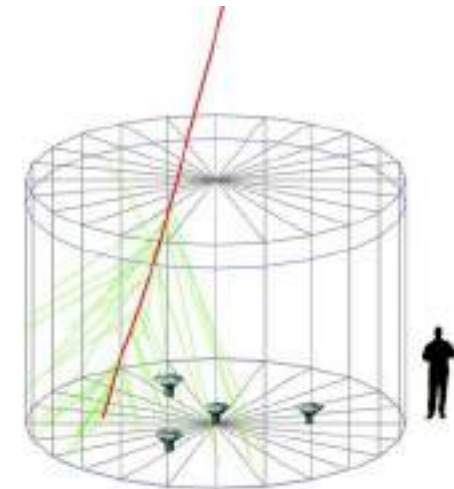
- In 2007 the site in Volcan Sierra Negra in central Mexico was chosen as the site for the HAWC observatory
 - In great part because 14 Mexican institution joined the largest Science project to be built in Mexico
- 2008-2010 we built prototype detectors, finalized design and created an Engineering array
- 2008 -2010 we submitted several proposals to NSF, DoE and CONACYT
- **2010 NSF, DoE and CONACYT agree to fund HAWC**
 - NSF and Conacyt funds arrive February 2011
 - DoE funds arrive January 2012



HAWC Design



- 300 water Cherenkov detectors of 200,000 liters and 4 photomultipliers each.
- 4th PMT financed by LANL and Mexico
- Modular design allows to start operations with a partial array



Components of a Water Cherenkov Detector WCD





HAWC Proposals 3

- PASAG review in Summer 2009, report in Oct. 2009
 - “Build under all funding scenarios”
- NSF DOE HAWC Review in Spring 2010 (Maryland)
 - Strong endorsement for funding
 - Recommendations for management
 - Recommend baseline of 250 tanks with last 50 from contingency
 - Recommendation for review at each major stage
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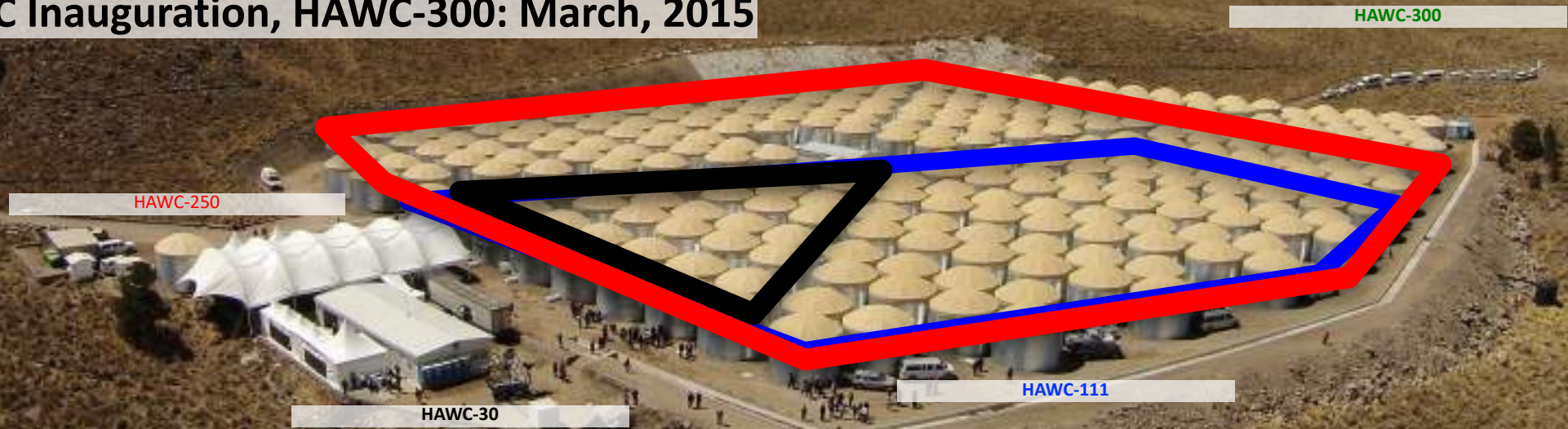
HAWC-30: Engineering Test of full detector

HAWC-111: Operations Begins: August 2013 (283 days)

HAWC-250: November, 2014 (~150Days)

HAWC-300: March 2015 – Present : >95% uptime

HAWC Inauguration, HAWC-300: March, 2015





HAWC inauguration 20 March 2015
Dr. France Cordoba director NSF
Dr. Enrique Cabrero director CONACYT



With 3 funding agencies: NSF, DoE and Conacyt

- we had to be very detailed in the project management
- in the budget, spending profiles, contingency, multi year funding
- from 2012 to 2019 we had a quarterly review by the JOG, Joint Oversight Group with the NSF and DoE project officers, the Conacyt adjunct director for Science and the UNAM Science coordinator
- The US embassy in Mexico was a great help during the construction
- also we had many other separate reviews
- we profited from knowledge, equipment, software from many sources: Milagro, Auger, FERMI, Veritas



HAWC production up to April 2023

- 68 papers published
- one in Nature
- two in Science
- cited 5,513 times
- 42 Ph. D. thesis
- It has brought Mexico to the forefront of High Energy Astrophysics
- It has shown that large, successful multi-year projects can be done in Mexico

HAWC main array construction begins February 2011 Completed March 2015
On Time, On Budget
Cost ~\$15M split evenly between Mexico (CONACYT and UNAM), NSF and DoE
Outrigger upgrade project completed August 2018
Cost ~\$1M (DOE, Mexico and MPIK)
Operating with >95% on-time
Operating Costs \$1M/yr (Mexico, NSF)





Outlook

- We will need your support to build a much larger and ambitious gamma ray observatory in South America.

The Southern Wide-field Gamma-ray Observatory (SWGGO)

