

The Cherenkov Telescope Array Project

Halina Fest
Tel Aviv University
January 5, 2014

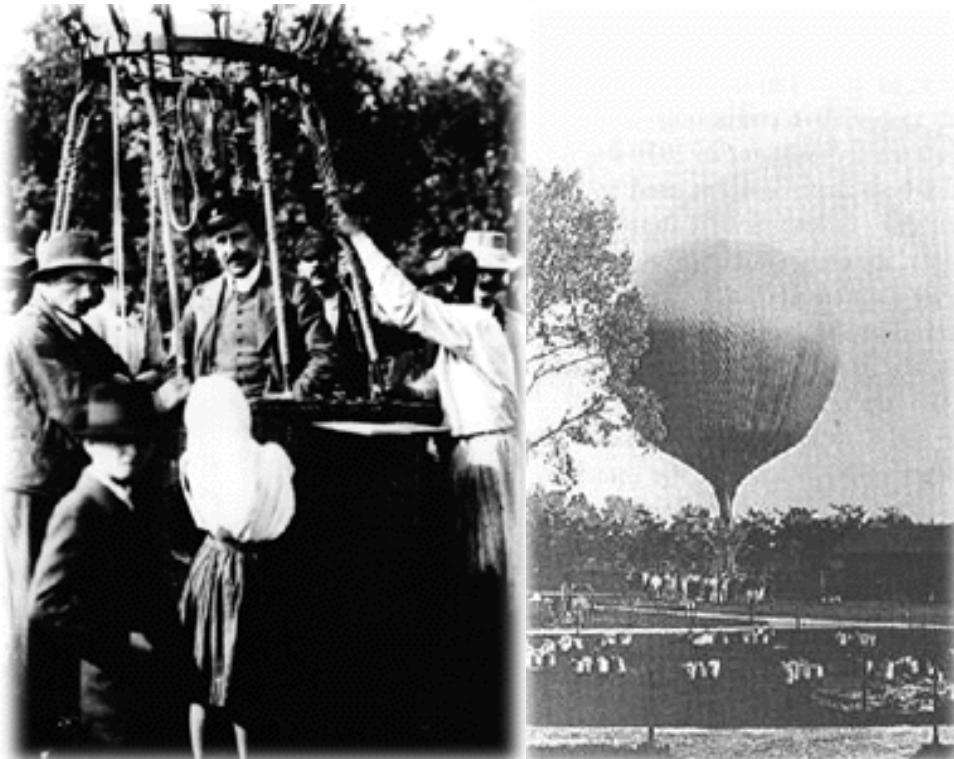
Stefan Schlenstedt

Principal Questions on The Physics of the Universe

New Century
Committee

- > How did the universe begin?
- > How do cosmic structures form and evolve?
- > What are the connections between dark and luminous matter?
- > What is dark matter?
- > What are the properties of dark energy, responsible for perplexing acceleration of present-day universe?
- > How do black holes work and influence their surroundings?
- > What are the progenitors of Type Ia supernovae and how do they explode?
- > What are the properties of the neutrinos?

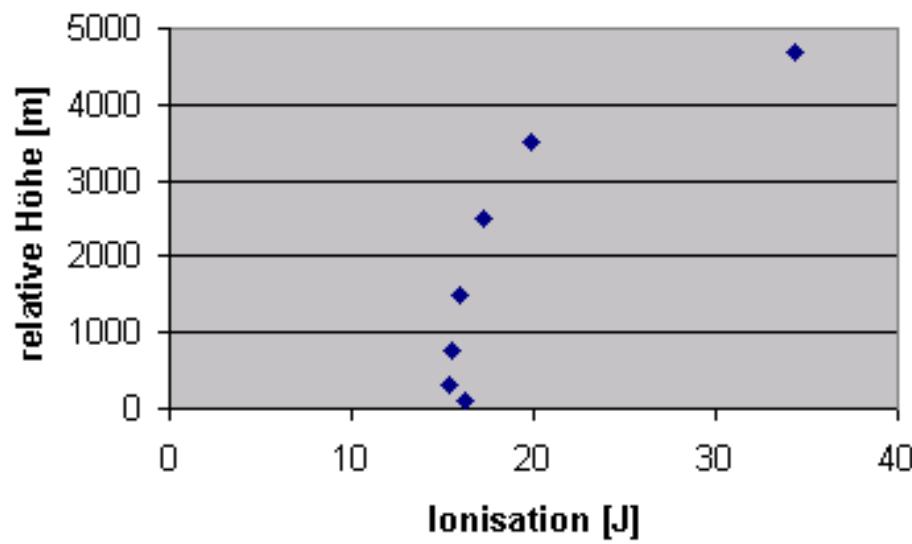
Höhenstrahlung = Cosmic Rays



Höhenstrahlung = Cosmic Rays



Strahlungsverlauf in der Atmosphäre



Höhenstrahlung = Cosmic Rays

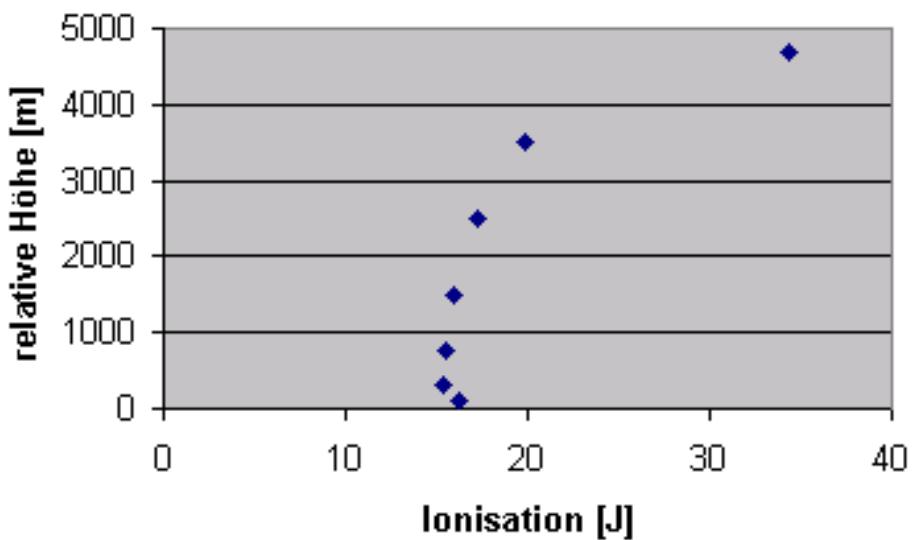


Physik. Zeitschr. XIII, 1912.

Viktor F. Hess (Wien), Über Beobachtungen der durchdringenden Strahlung bei sieben Freiballonfahrten.

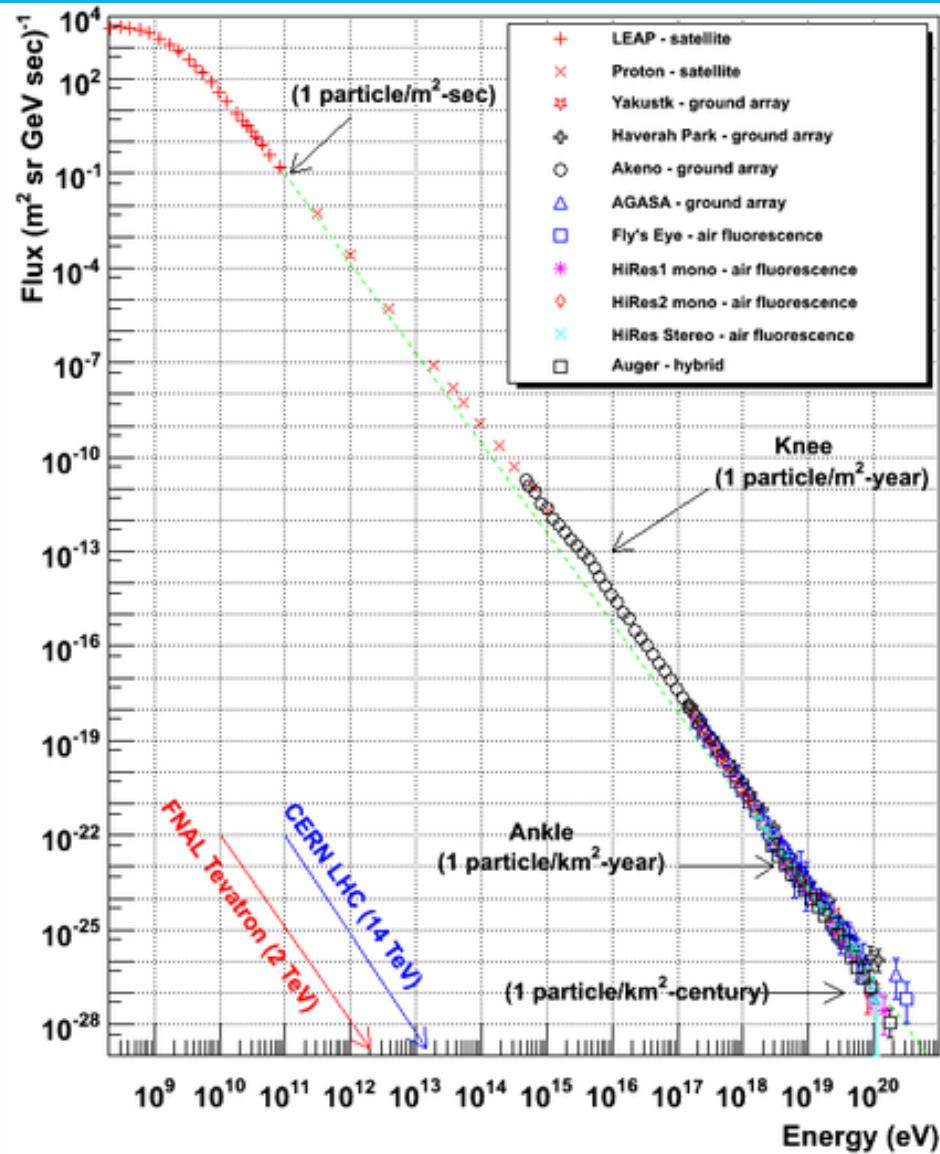
Im Vorjahr habe ich bereits Gelegenheit gehabt, zwei Ballonfahrten zur Erforschung der durchdringenden Strahlung zu unternehmen; über die erste Fahrt wurde schon auf der Naturforscherversammlung in Karlsruhe von mir berichtet¹⁾.

Strahlungsverlauf in der Atmosphäre



Meine Ballonbeobachtungen scheinen darauf hinzuweisen, daß noch eine dritte Komponente der Gesamtstrahlung existiert, welche in der Höhe zunimmt und auch am Boden merkwürdige Intensitätschwankungen aufweist. Die weitere Forschung wird insbesondere diesen die größte Aufmerksamkeit zu schenken haben.

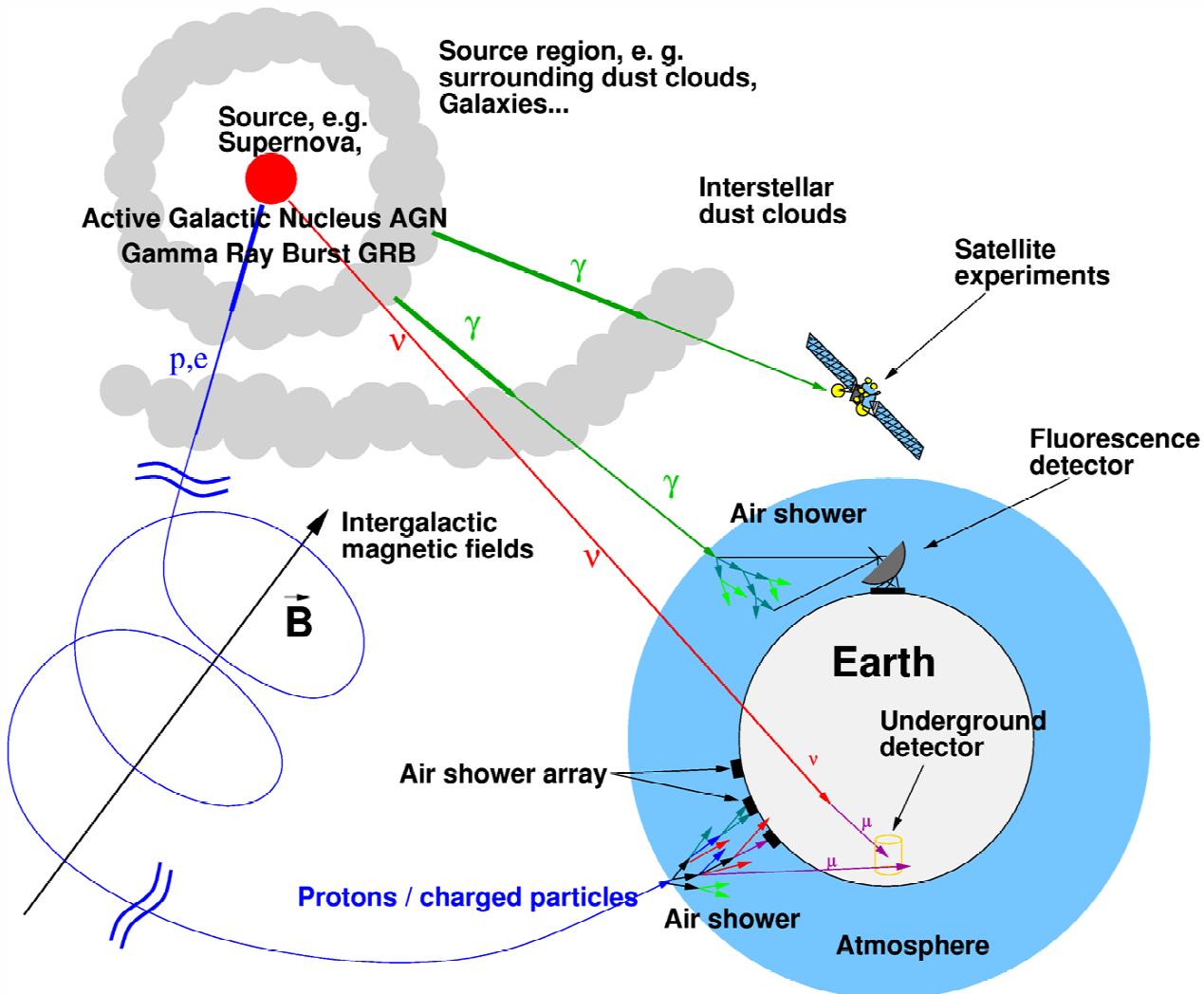
Charged Cosmic Rays



- > Power law
- > Knee
 - Transition from galactic to extragalactic sources
- > Protons and nuclei
- > At highest energies:
Greisen–Zatsepin–Kuzmin limit or no sources?

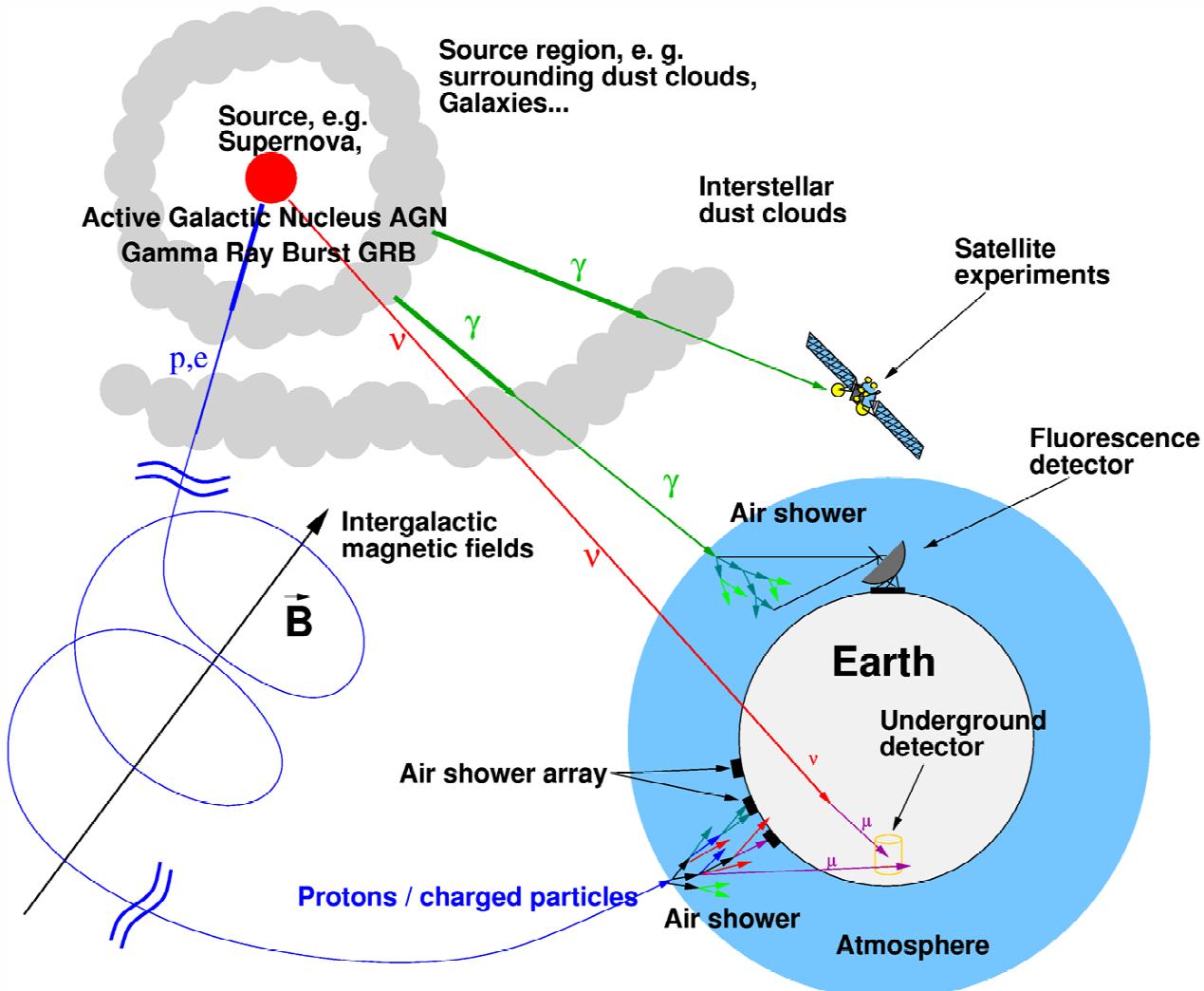
Messengers – Stable Particles

- > Protons and nuclei
- > Electrons



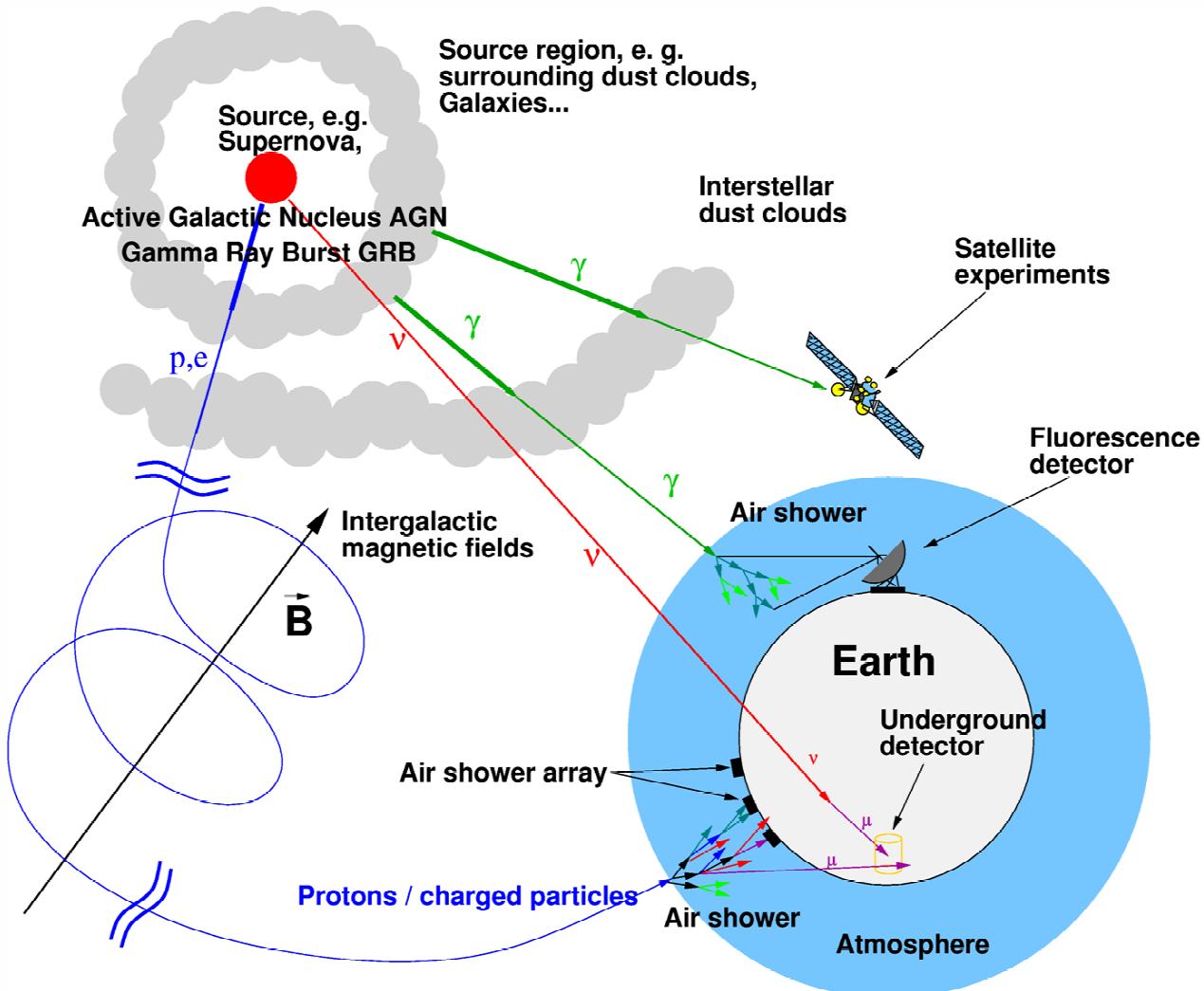
Messengers – Stable Particles

- > Protons and nuclei
- > Electrons
- > Neutrinos

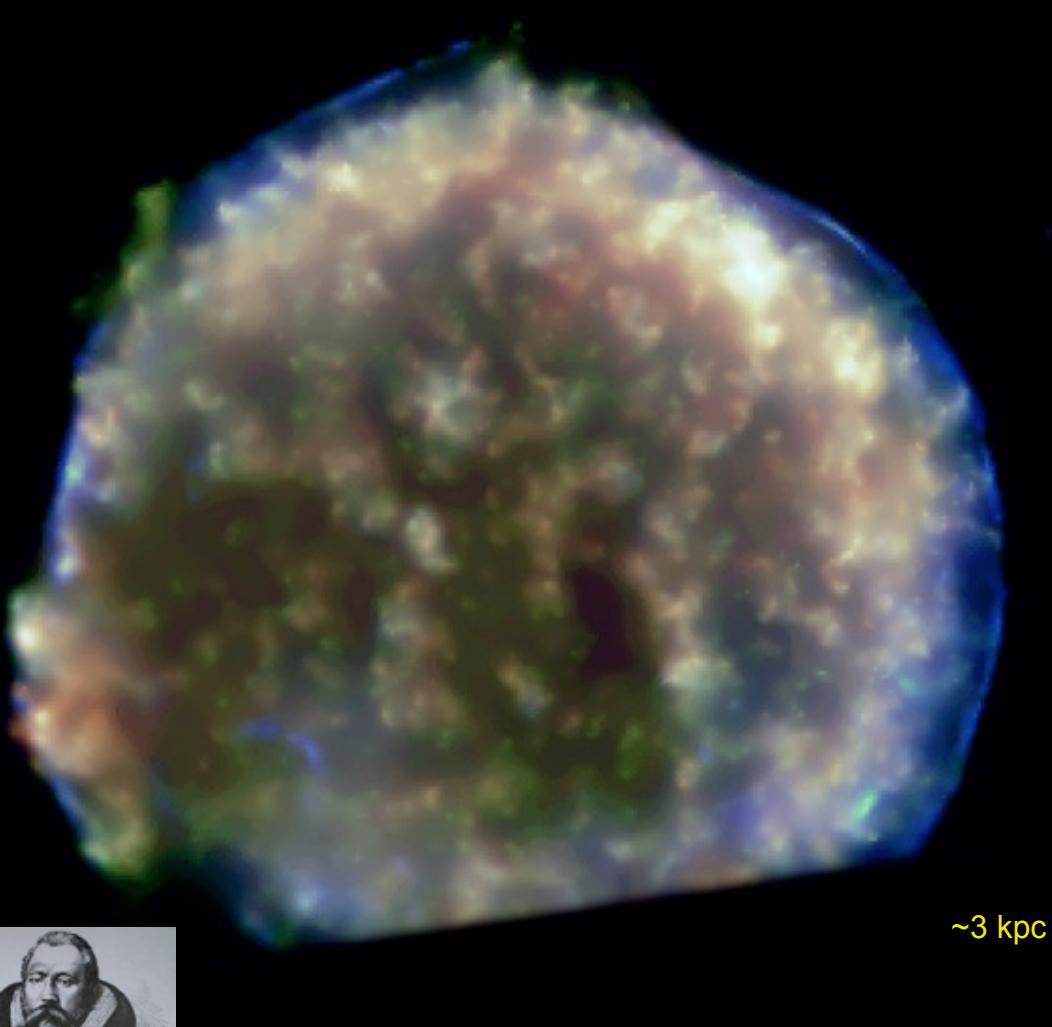


Messengers – Stable Particles

- > Protons and nuclei
- > Electrons
- > Neutrinos
- > Photons



Sources of Cosmic Rays

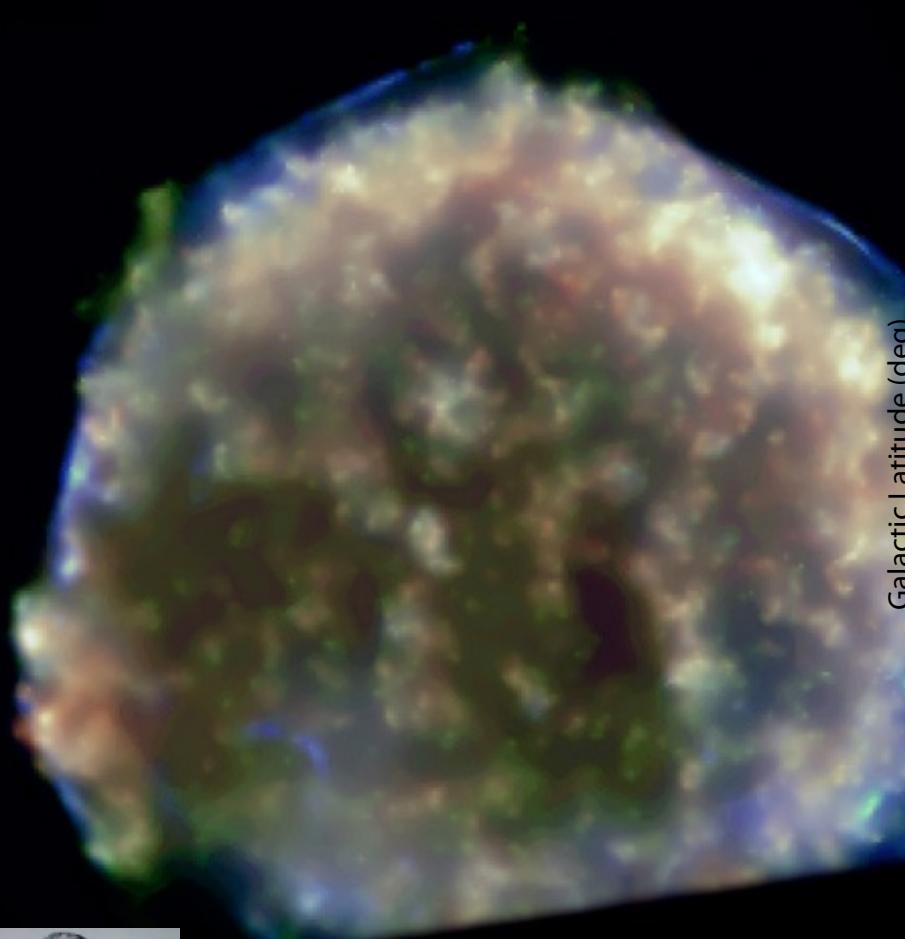


Optical

- > Supernovae
- > Supernova remnants



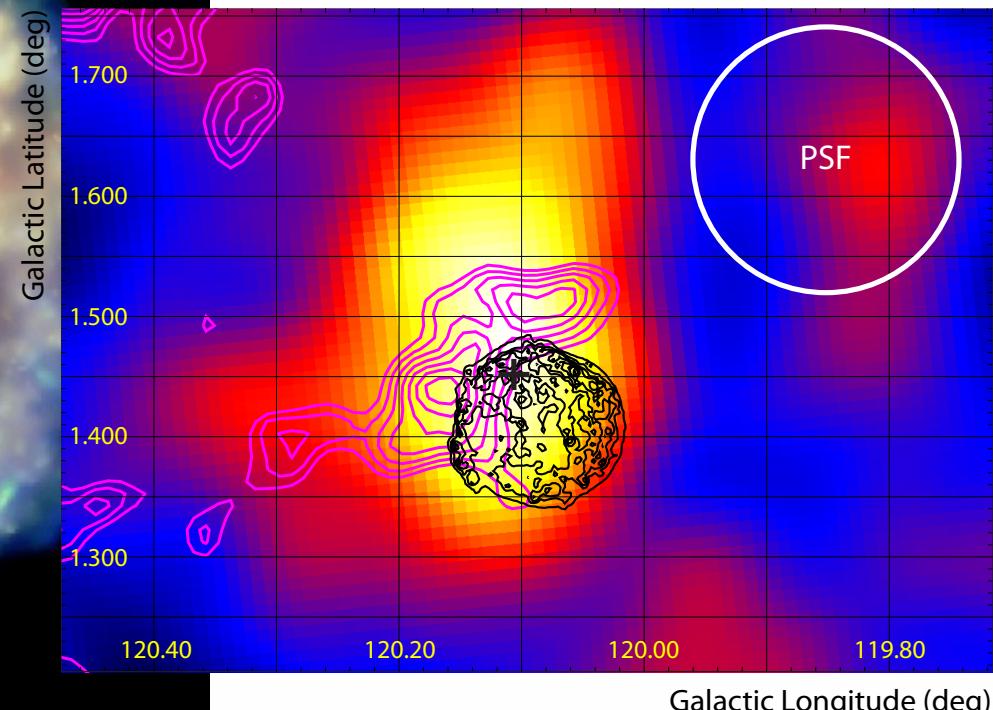
Sources of Cosmic Rays



Optical



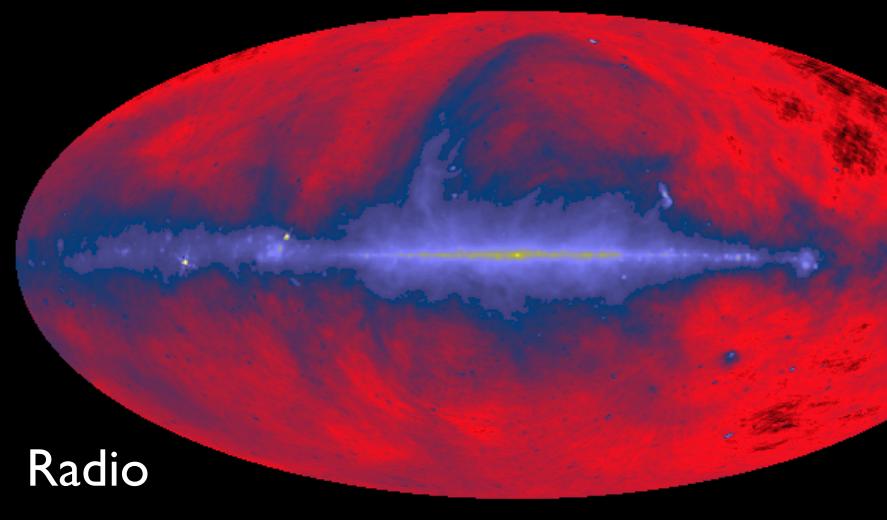
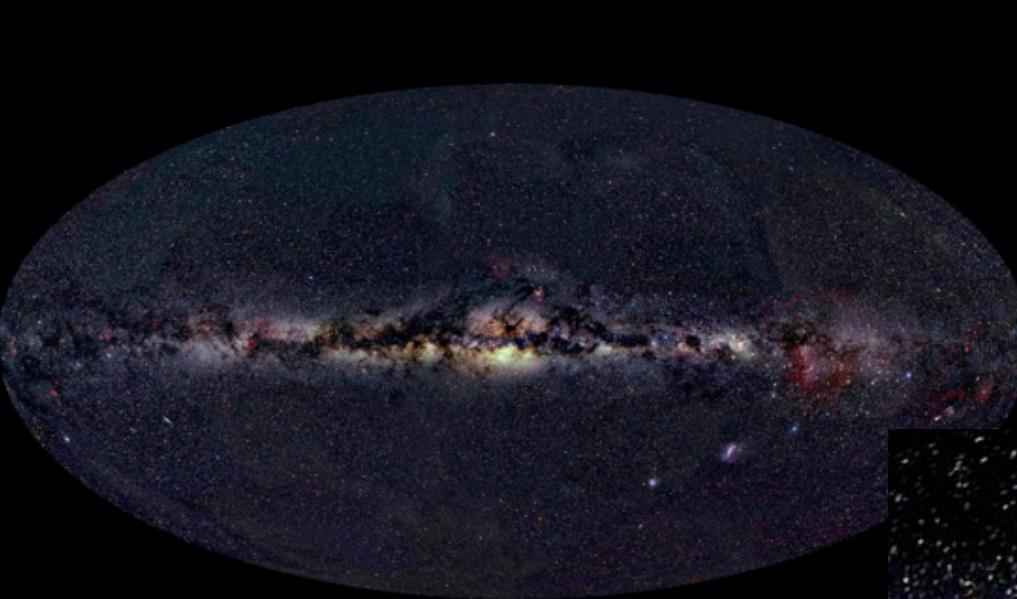
- > Supernovae
- > Supernova remnants



X-rays, radio and gamma-rays



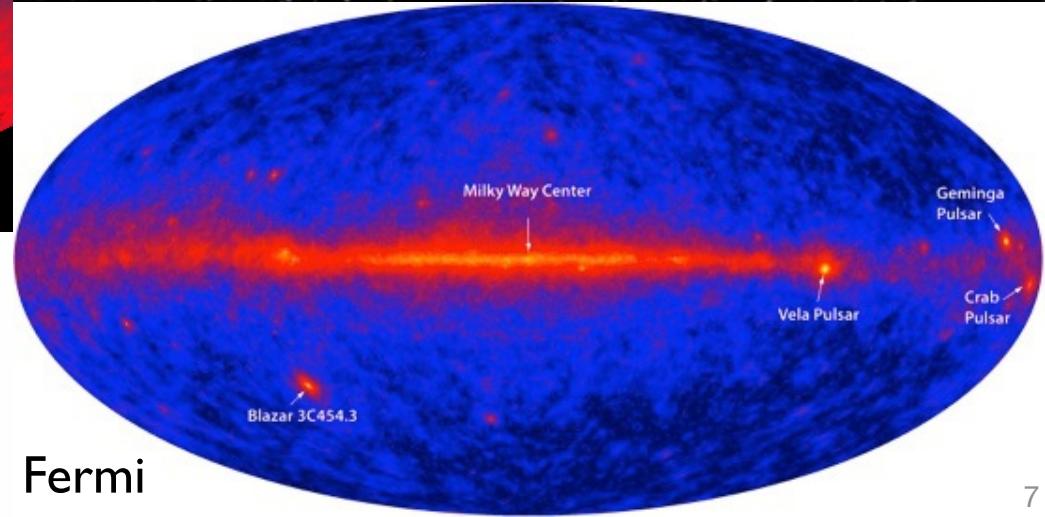
© 2000, Axel Mellinger



Radio



Microwave



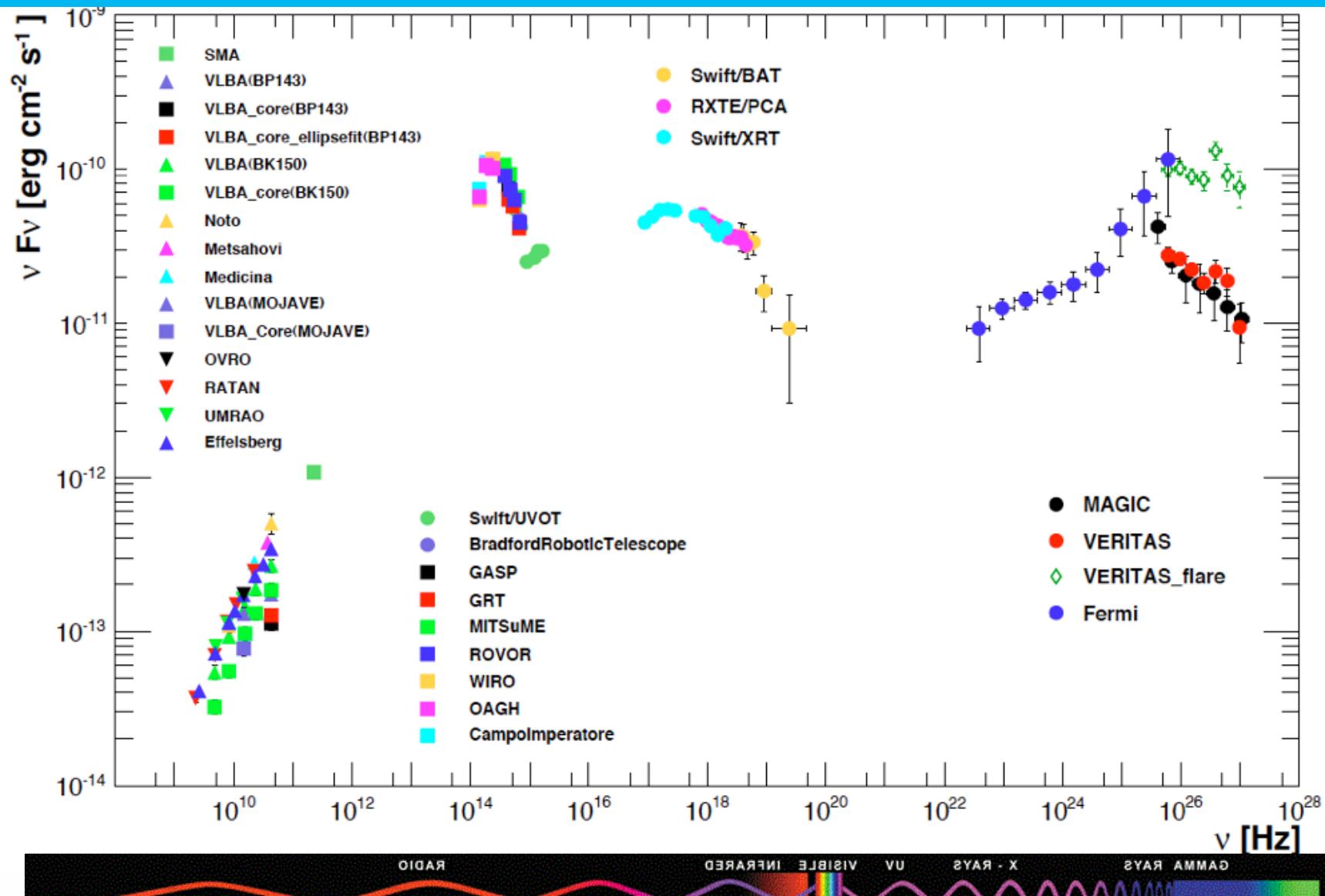
Fermi

Multi-Wavelength Observations

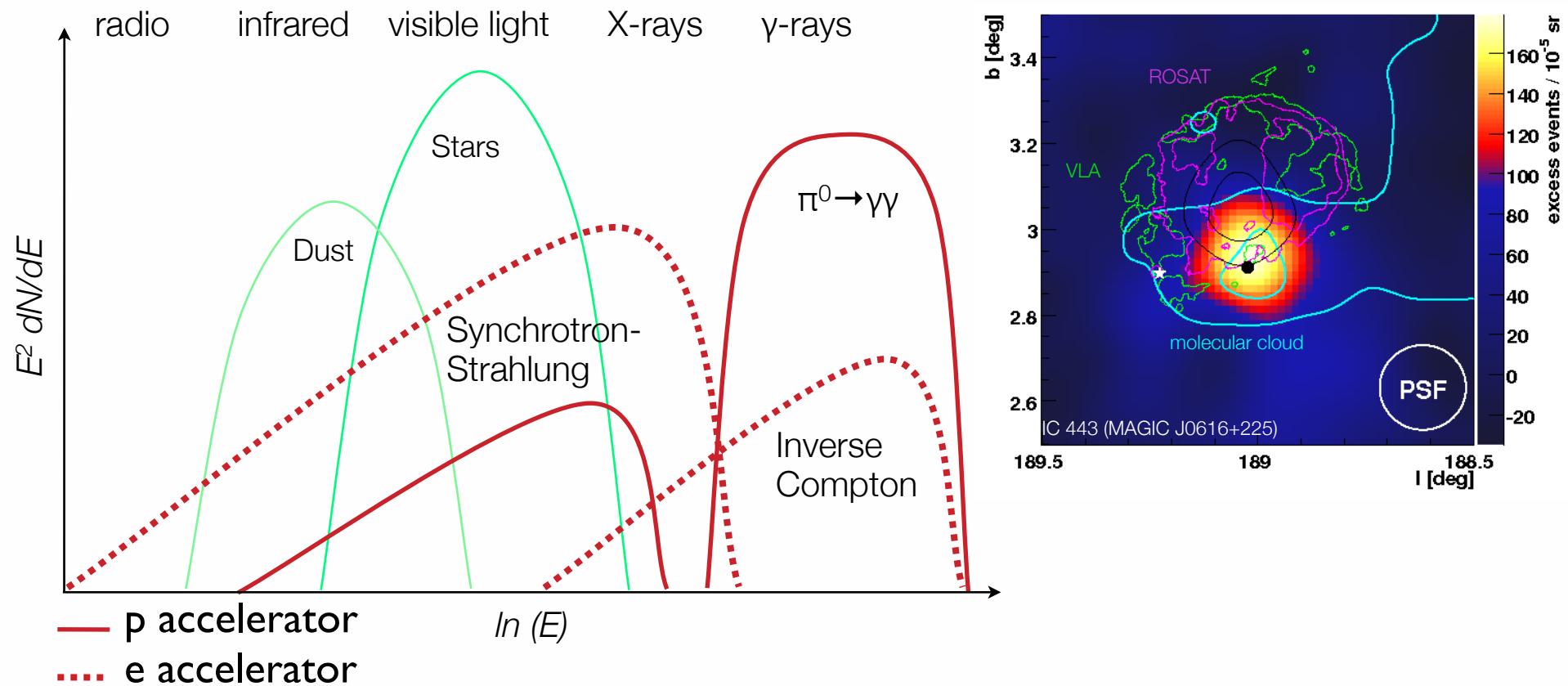
- > Optical
- > Radio started in the 30th
first signal Sagittarius A*
- > Infra-red measurements 1900
of Arcturus und Vega
- > Ultra-violet started in the 70th
- > X-ray first satellite in the 70th
first signal Scorpion
- > Gamma-ray astronomy
first signal Crab



Multi-Wavelength Measurements

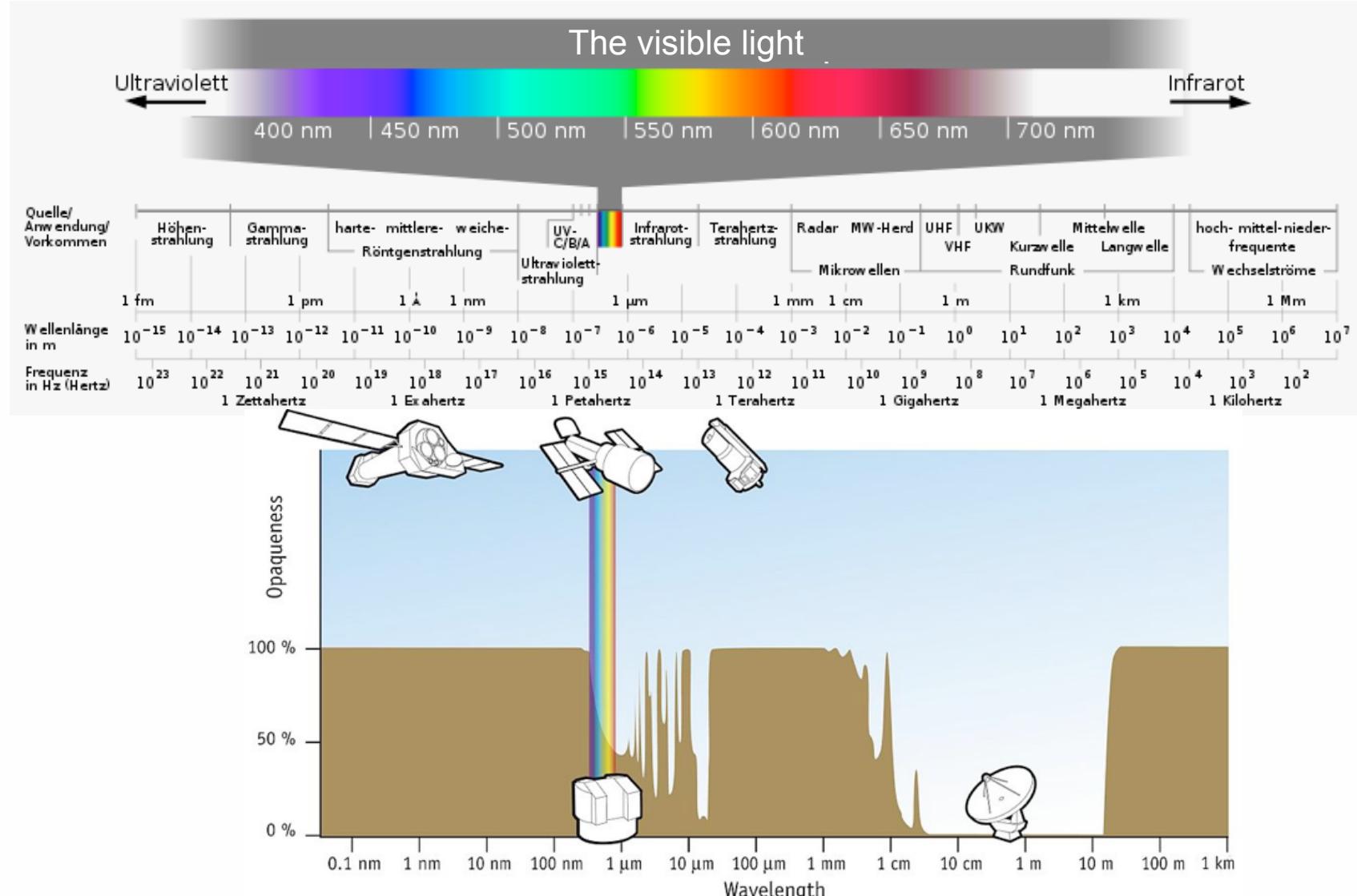


Multi-Wavelength Astronomy



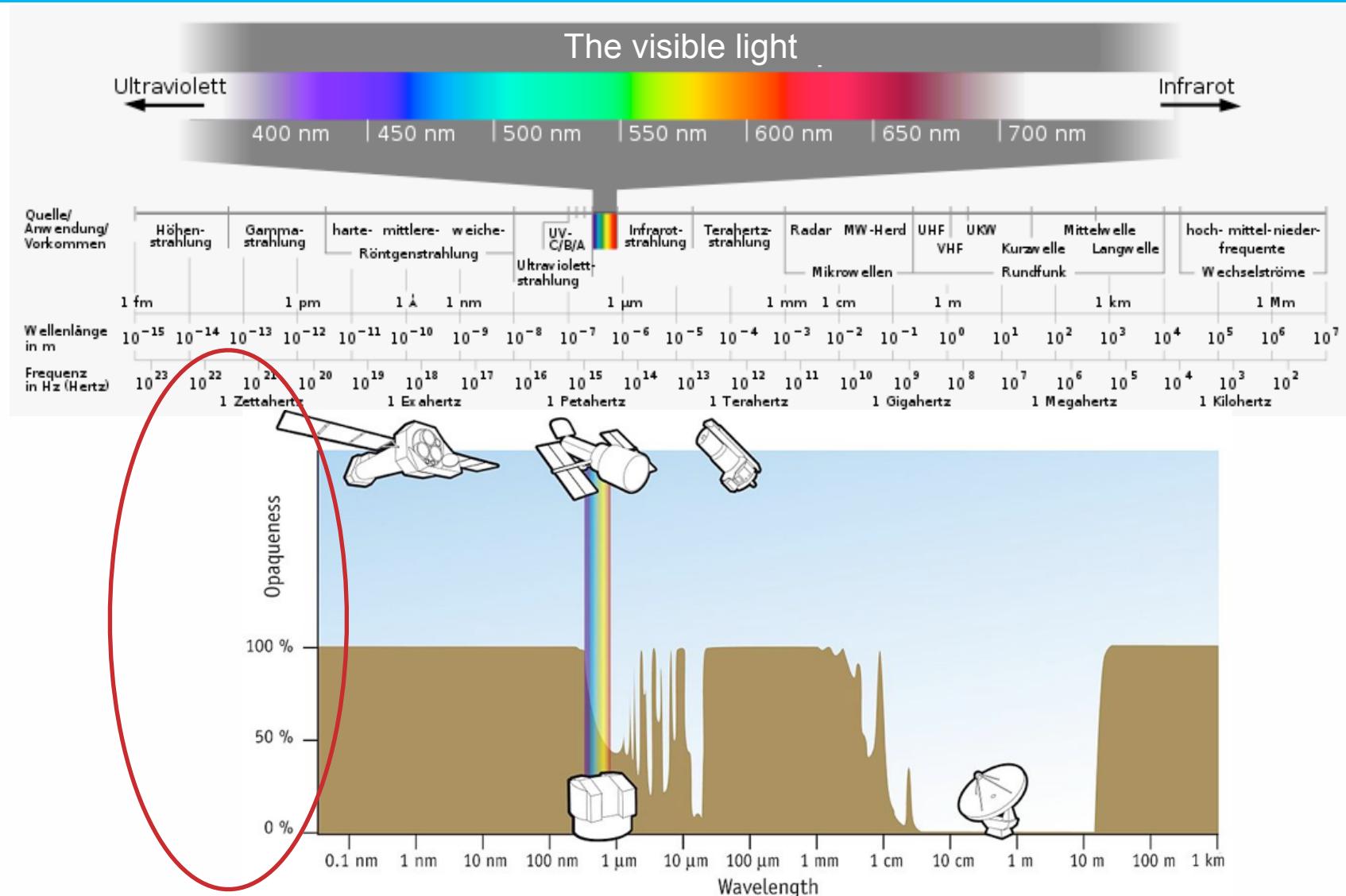
Maxima depend on primary spectra,
magnetic Fields and density of matter

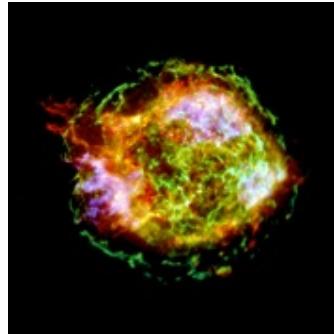
Huge Energy Spectrum



Huge Energy Spectrum

The visible light

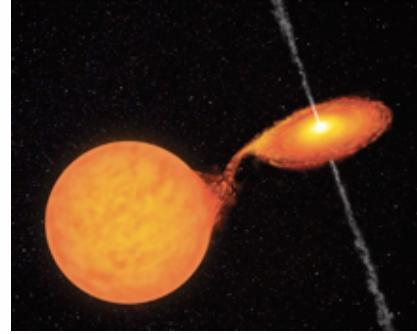




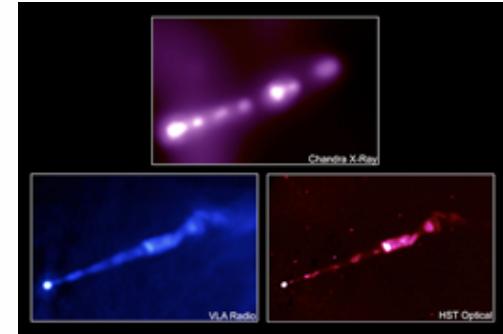
Super Nova
Remnants



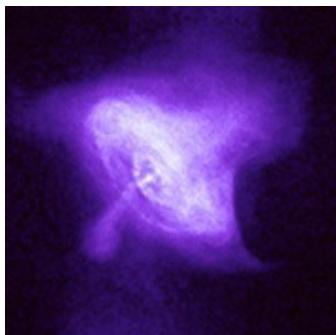
Gamma Ray
Bursts



Micro quasars



Active galactic
nuclei

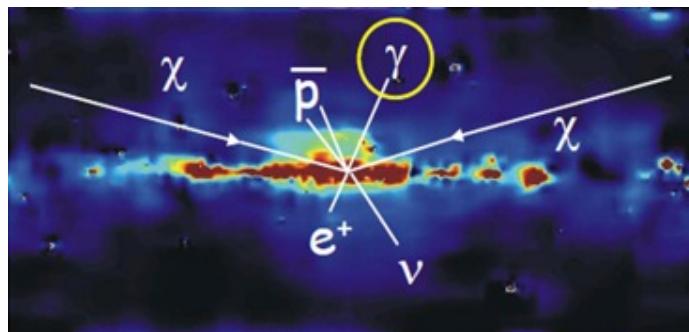


Pulsar
(Wind nebula)

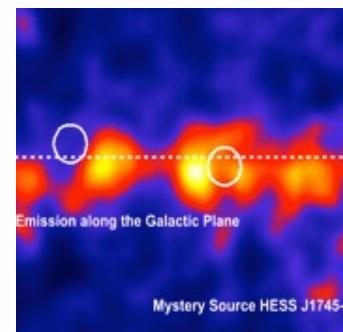
- > Sources of cosmic rays
- > Astrophysics of sources
- > Acceleration
- > Particle propagation



Starburst galaxies

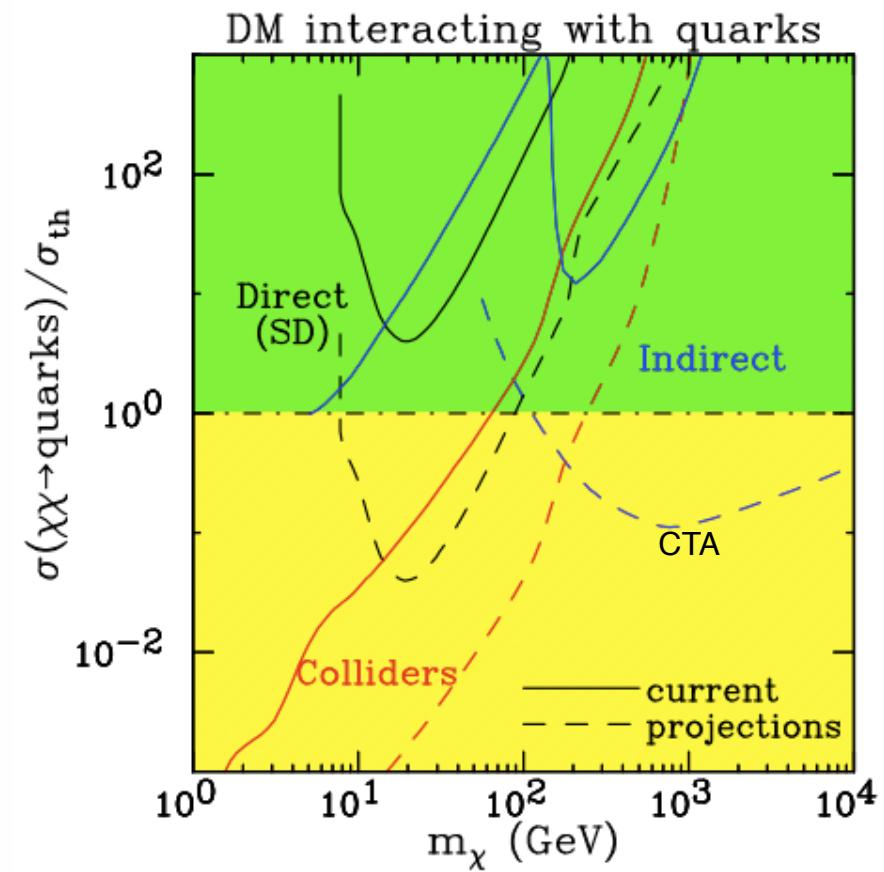
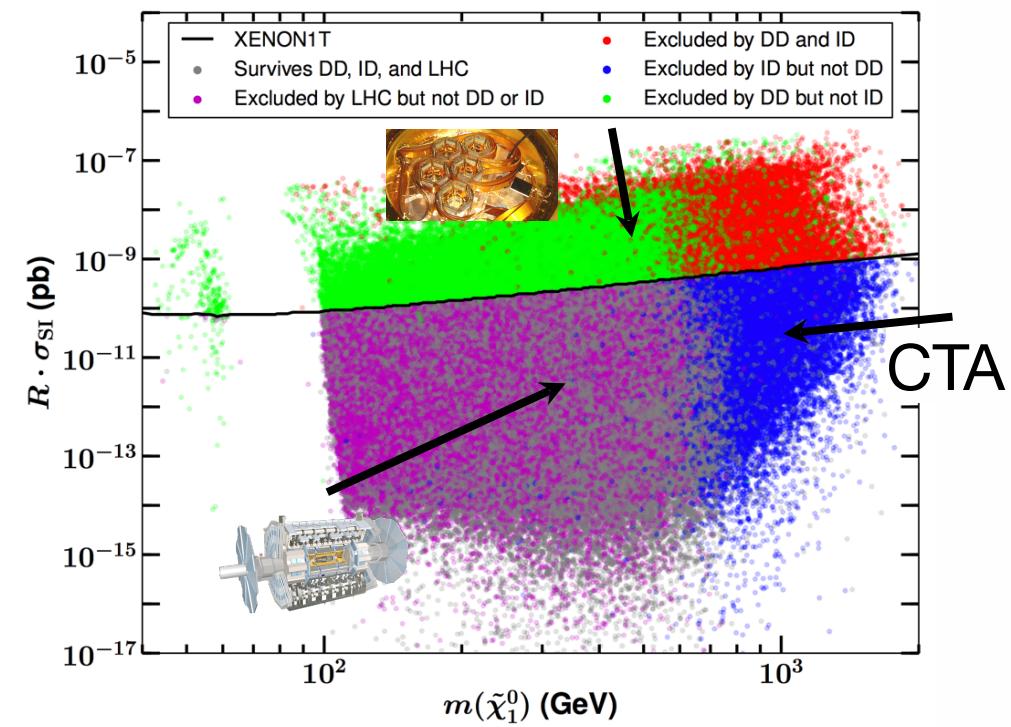


Dark matter



Unknown Sources

Unique Dark Matter Results with CTA



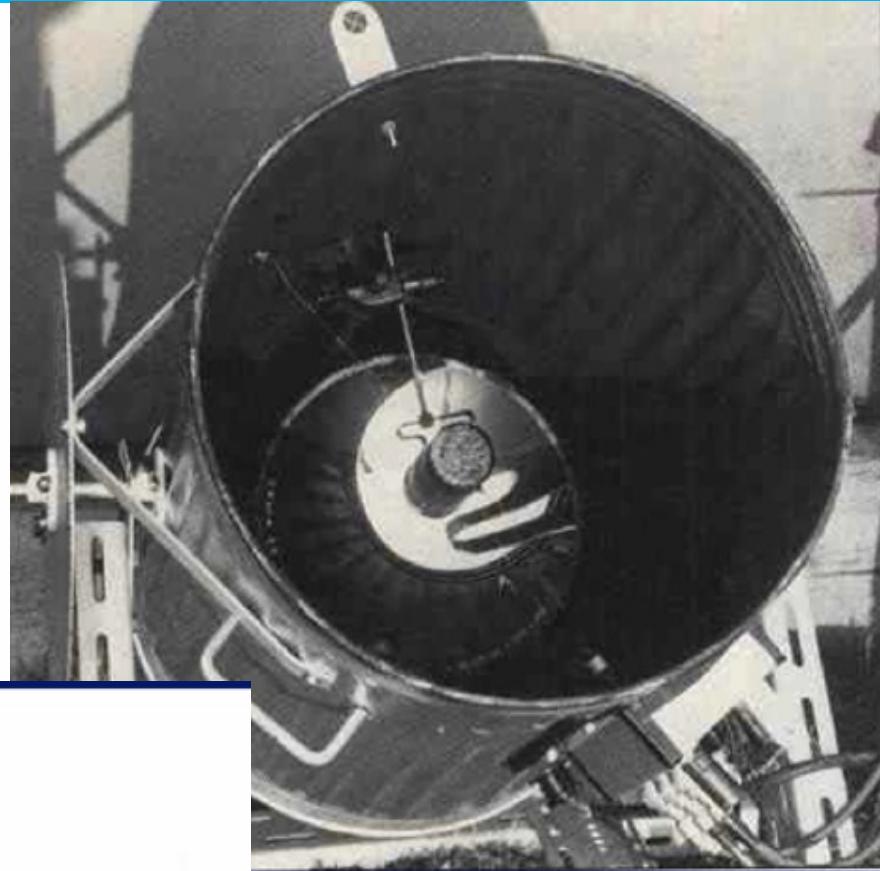
Constraints:

$\Omega_{\text{DM}} h^2 > 0.1$, XENON100 (2011),
CMS+ATLAS (2012)

Cherenkov Technique

First Steps

- > Galbraith und Jelly (1953) –
First measurements of
Cherenkov pulses from
extended air showers
- > Astronomy: Morrison (1958)
and Cocconi (1959)

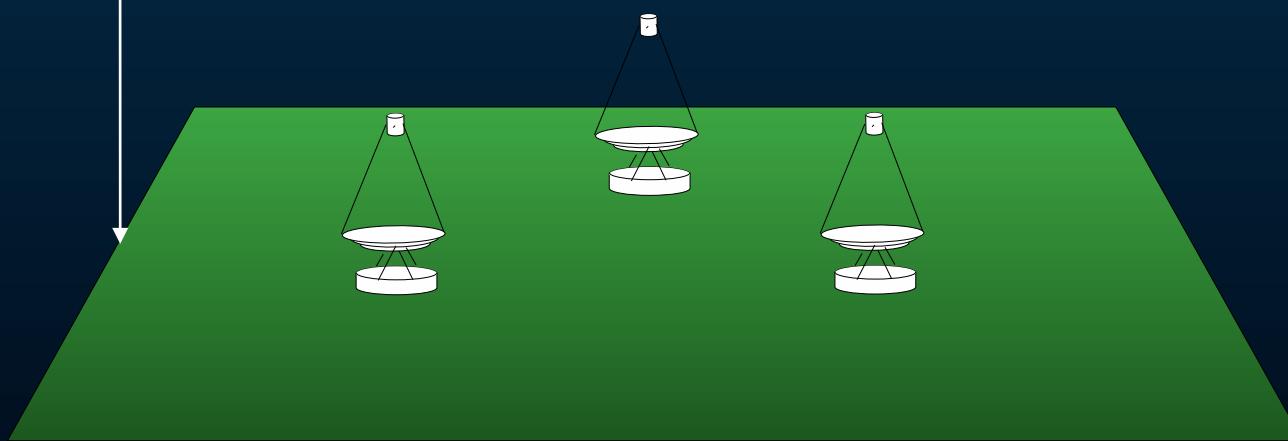


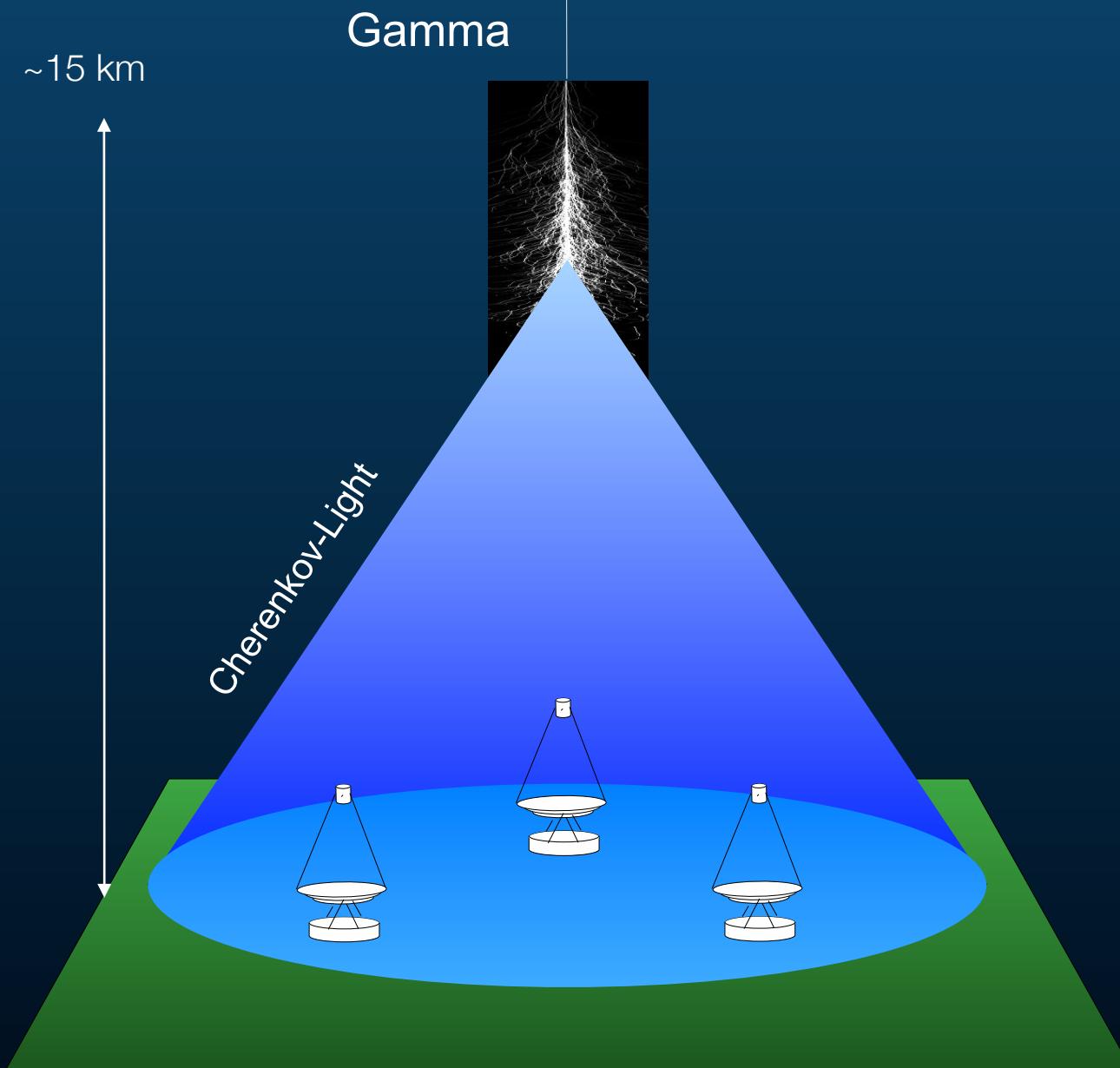
AN AIR SHOWER TELESCOPE
AND THE DETECTION OF 10^{12} eV PHOTON SOURCES
Giuseppe Cocconi
CERN - Geneva.

This paper discusses the possibility of detecting high energy photons produced by discrete astronomical objects. Sources of charged particles are not considered as the smearing produced by the magnetized plasmas filling the interstellar spaces probably obliterates the original directions of movement.

~15 km

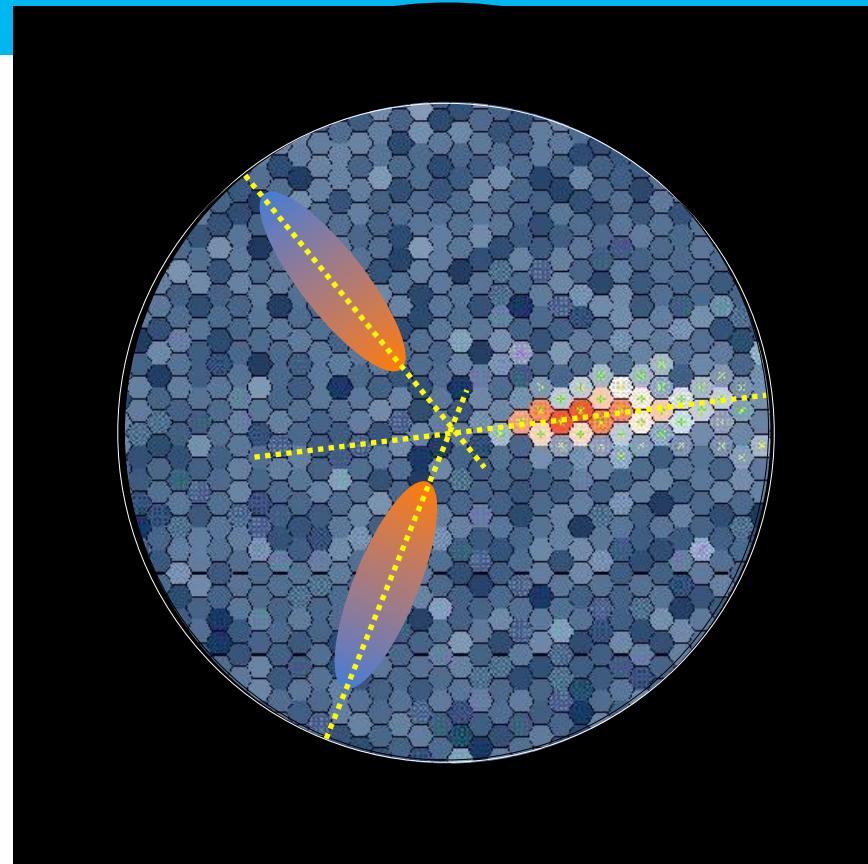
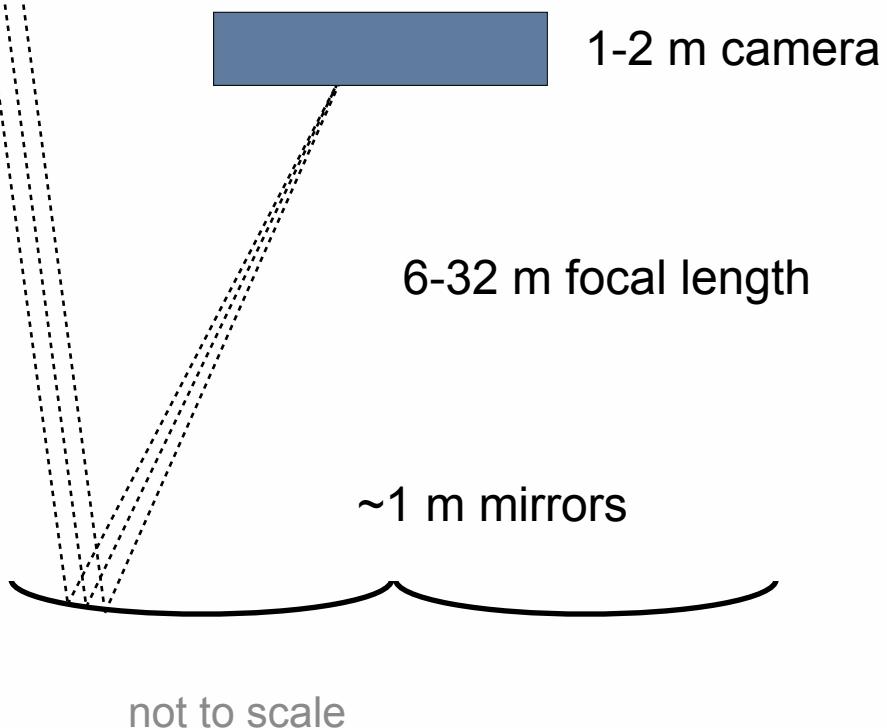
Gamma





Measurement Principle

Cherenkov light



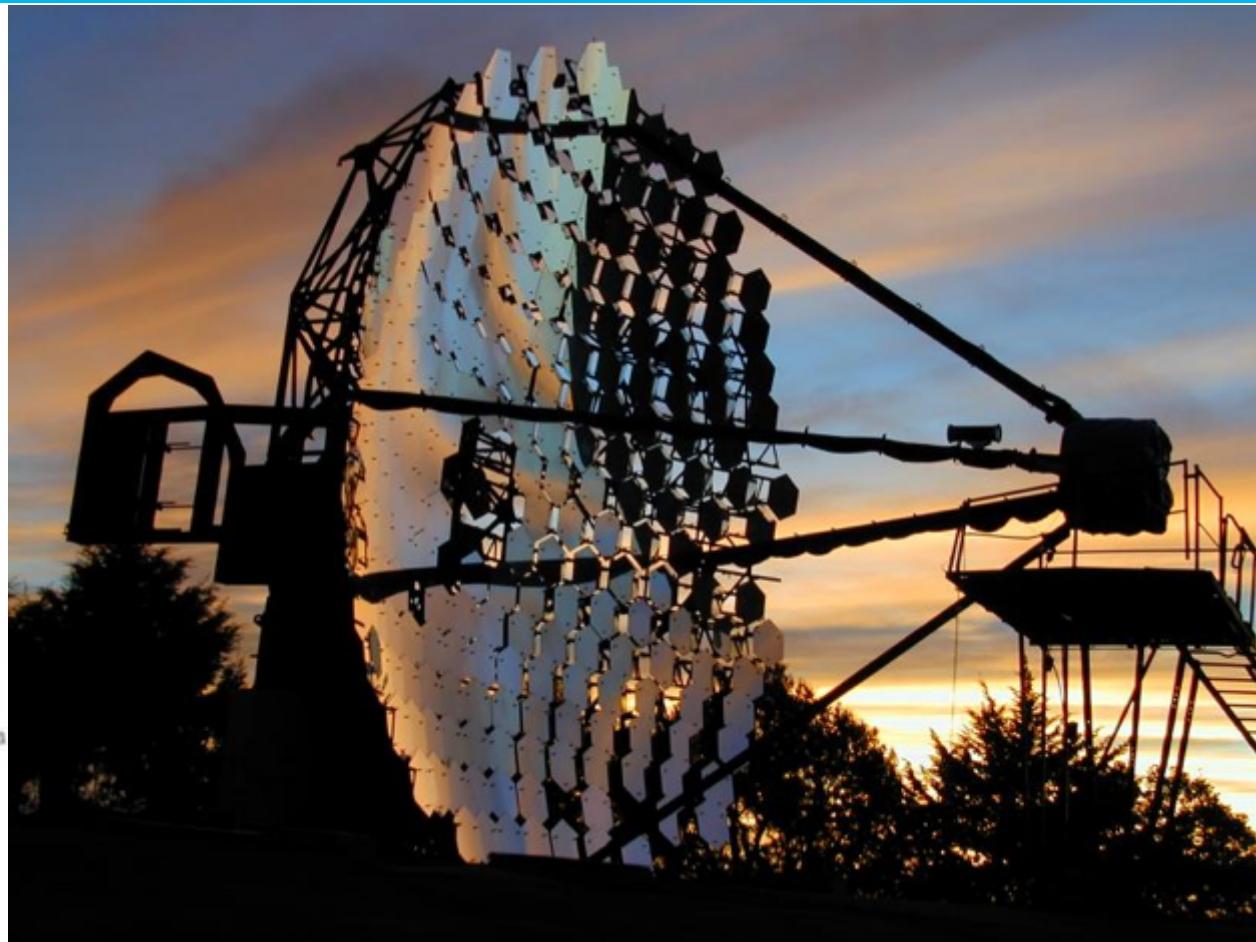
Intensity	→ energy
Orientation	→ direction
Shape	→ primary particle
Stereo	→ source position

WHIPPLE

The Pioneering Experiment

- > Start 1968
- > Crab in 1986
- > Stopped 2011

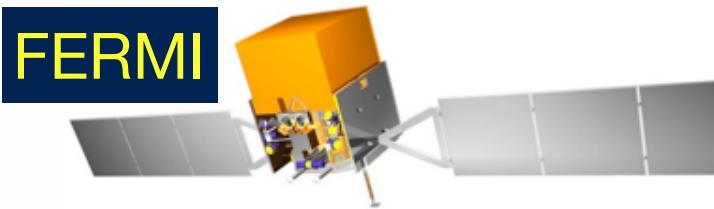
THE ASTROPHYSICAL JOURNAL, 342:379–395, 1989 July 1
© 1989. The American Astronomical Society. All rights reserved. Printed in



OBSERVATION OF TeV GAMMA RAYS FROM THE CRAB NEBULA USING THE
ATMOSPHERIC CERENKOV IMAGING TECHNIQUE

Modern Gamma-Ray Instruments

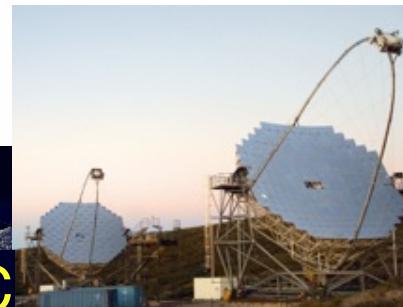
FERMI



VERITAS



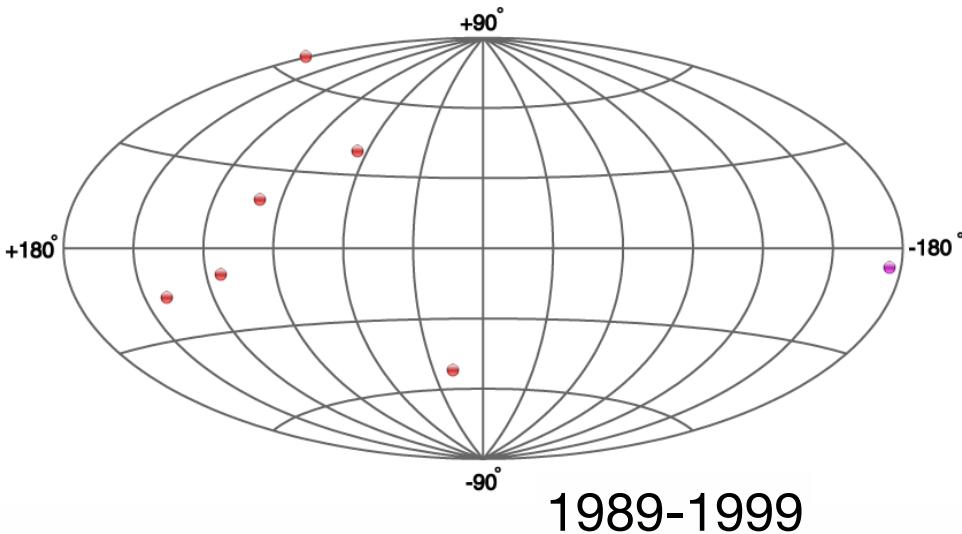
MAGIC



H.E.S.S.



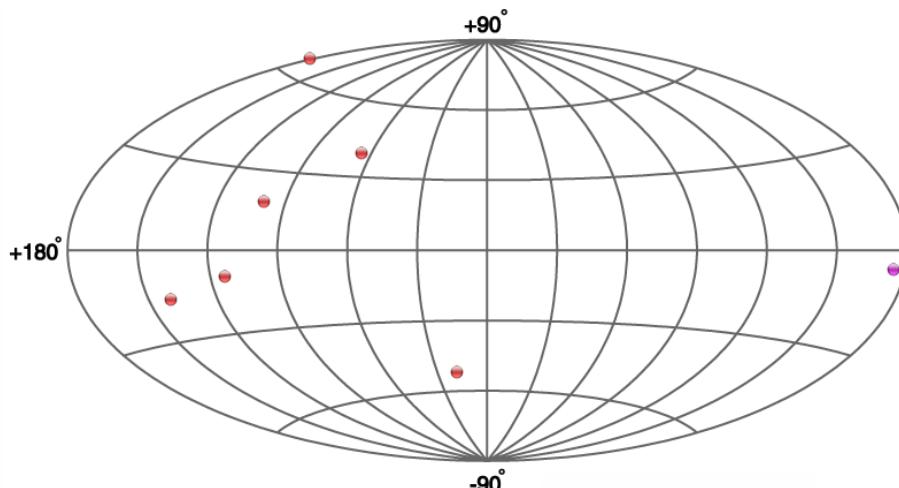
Gamma-Ray Sources



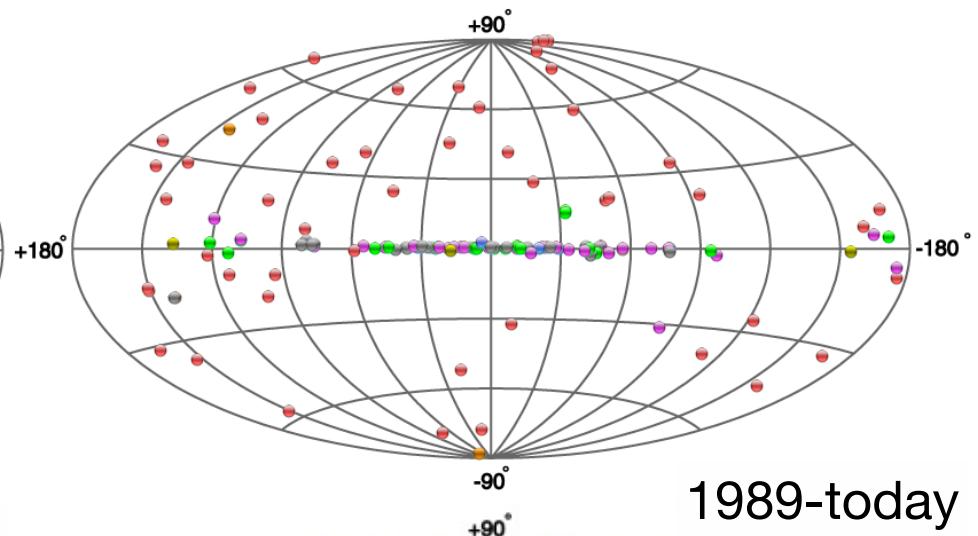
Source Types

- PWN
- XRB PSR Gamma BIN
- HBL IBL FRI FSRQ LBL
AGN (unknown type)
- Shell SNR/Molec. Cloud
- Starburst
- DARK UNID Other
- uQuasar Star Forming
Region Globular Cluster
Cat. Var. Massive Star
Cluster BIN WR

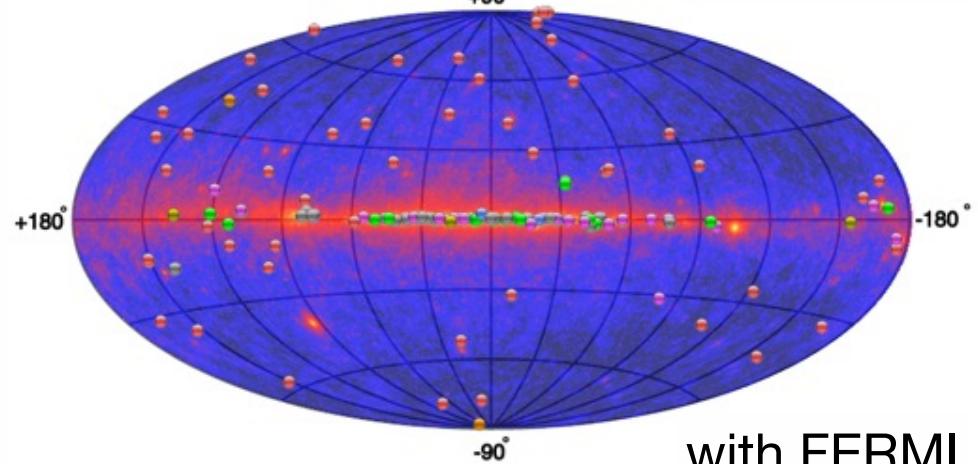
Gamma-Ray Sources



1989-1999



1989-today

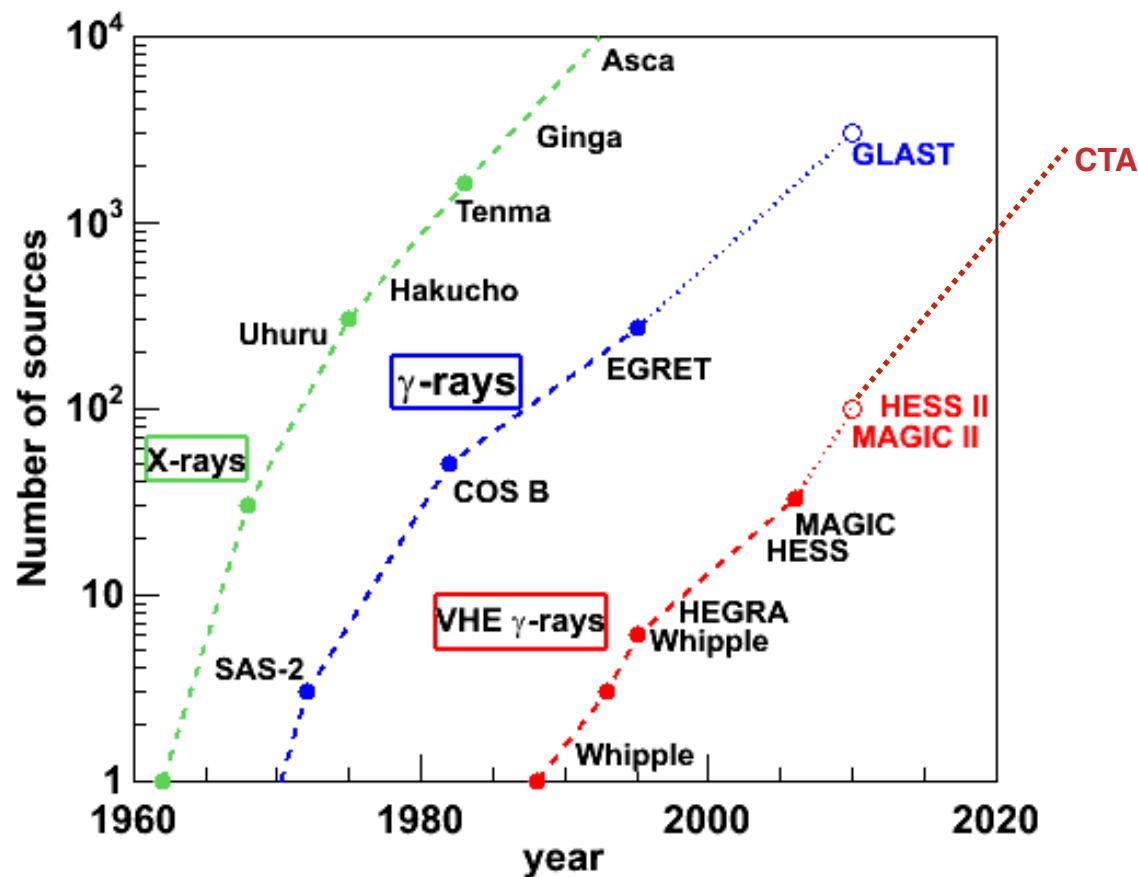


with FERMI

Source Types

- PWN
- XRB PSR Gamma BIN
- HBL IBL FRI FSRQ LBL AGN (unknown type)
- Shell SNR/Molec. Cloud
- Starburst
- DARK UNID Other
- uQuasar Star Forming Region Globular Cluster Cat. Var. Massive Star Cluster BIN WR

Kifune Plot

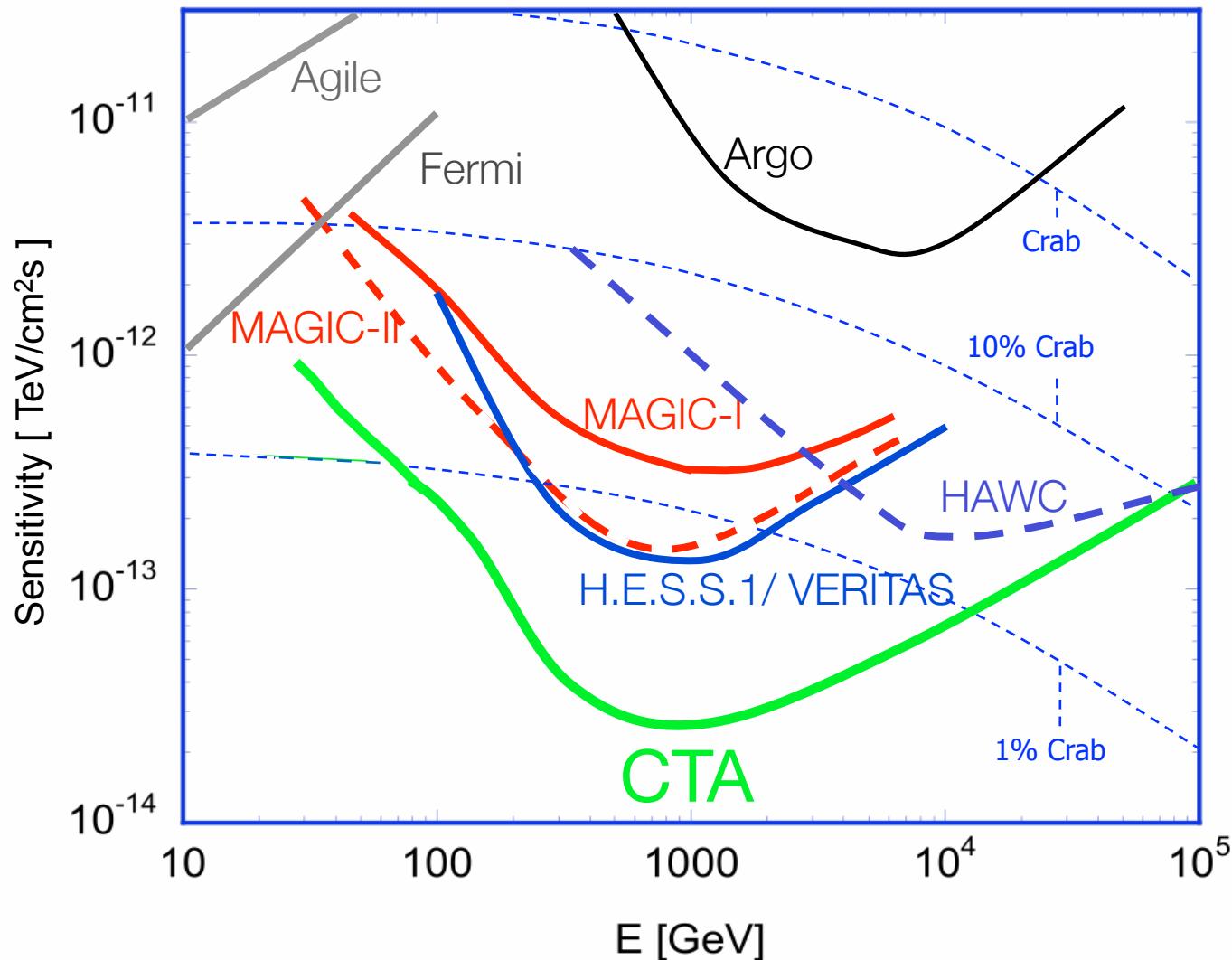


The Next Generation: Cherenkov Telescope Array

- > Ten times higher sensitivity
- > Extended energy range
- > Improved angular resolution
- > Observatory – on both hemispheres



Sensitivity and Energy Range

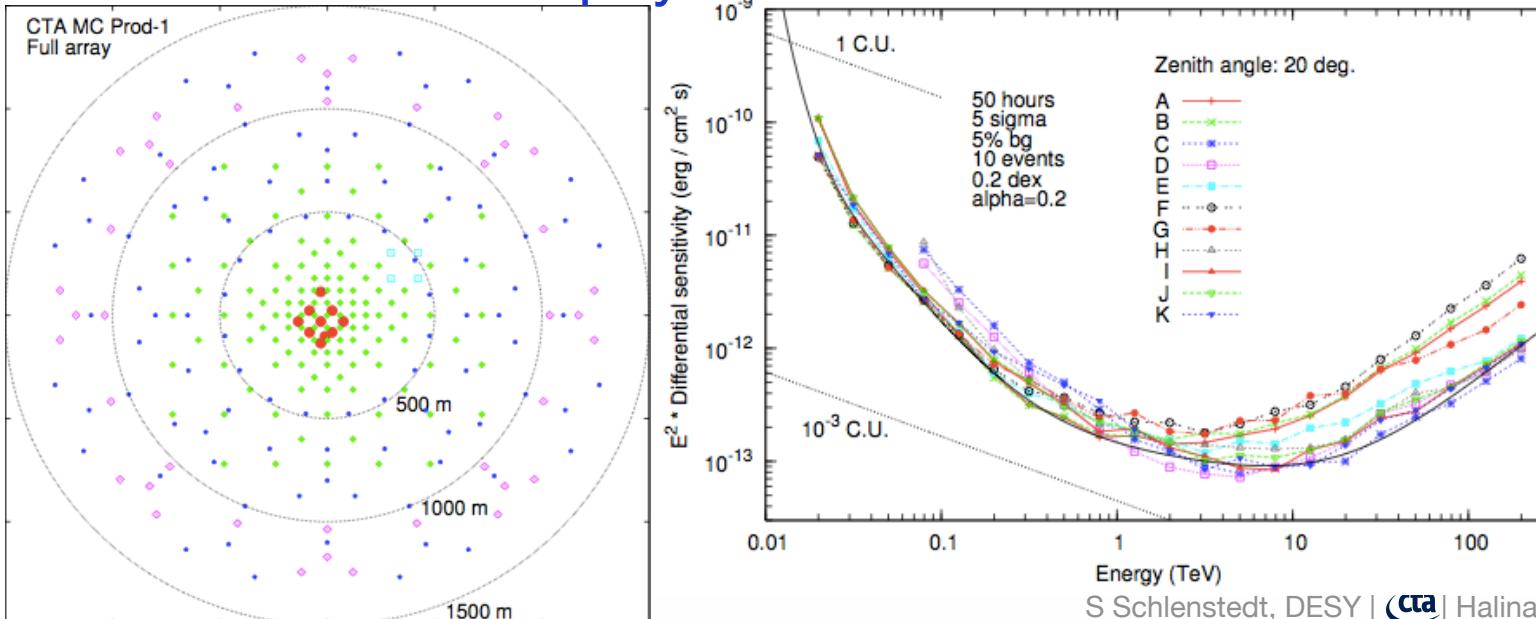


Physics Program Sensitivity Optimisation

- > Explore specific astrophysics & fundamental physics problems that profit from the capabilities of CTA
- > Study quantitatively CTA capabilities for galactic and extragalactic science and fundamental physics / dark matter

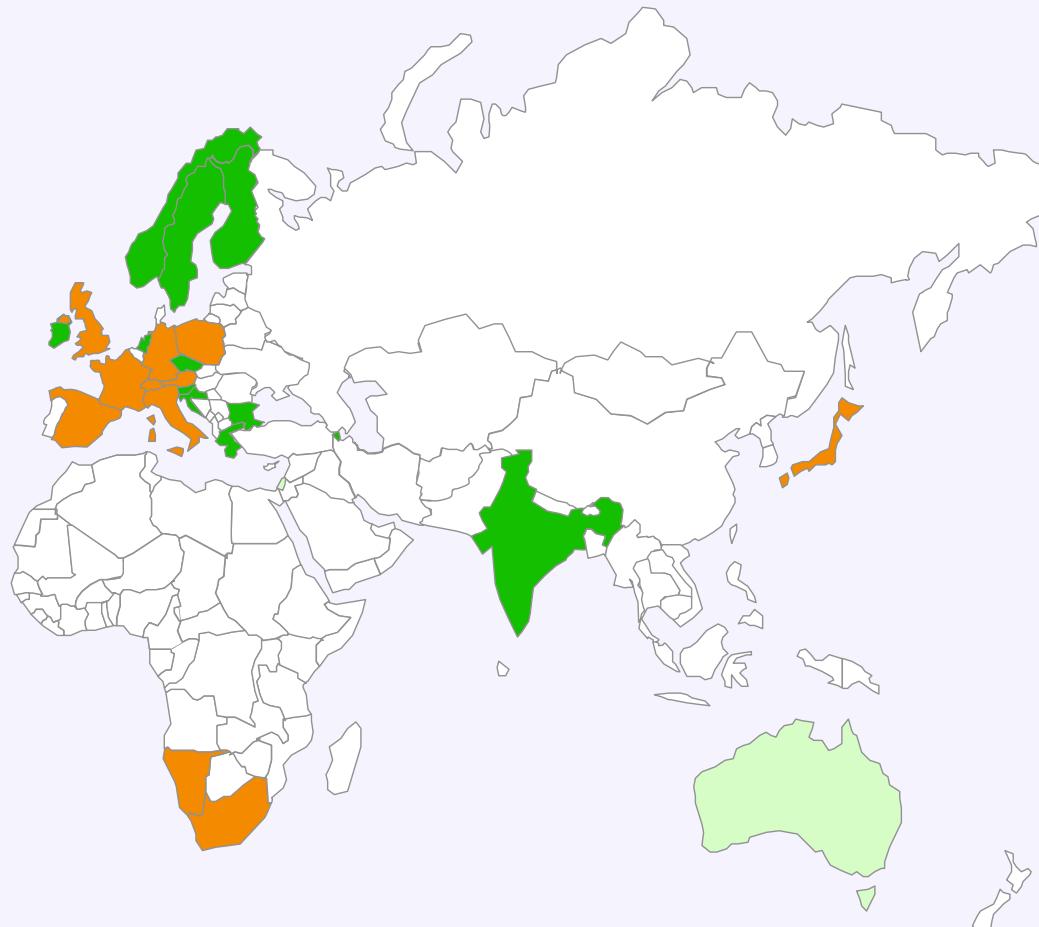
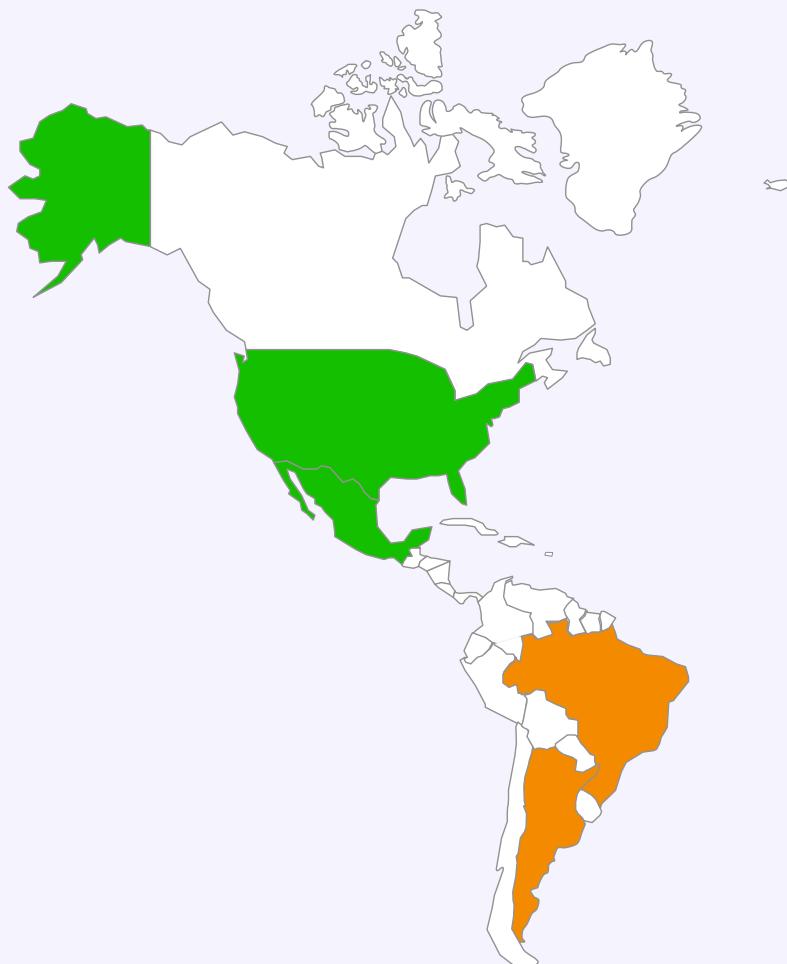
Physics Program Sensitivity Optimisation

- > Explore specific astrophysics & fundamental physics problems that profit from the capabilities of CTA
- > Study quantitatively CTA capabilities for galactic and extragalactic science and fundamental physics / dark matter
- > Study different array configurations and the impact of the site selection onto the physics cases of CTA



CTA-C Membership and RB membership

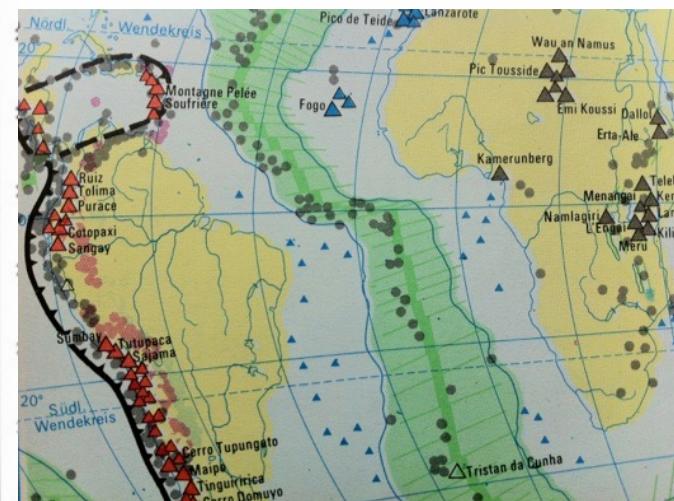
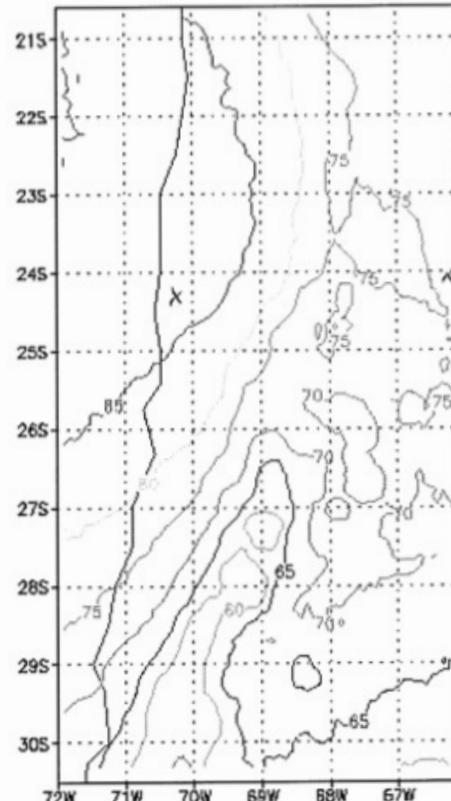
- Members (28 countries)
- interested to join
- DOI signed (13 countries)



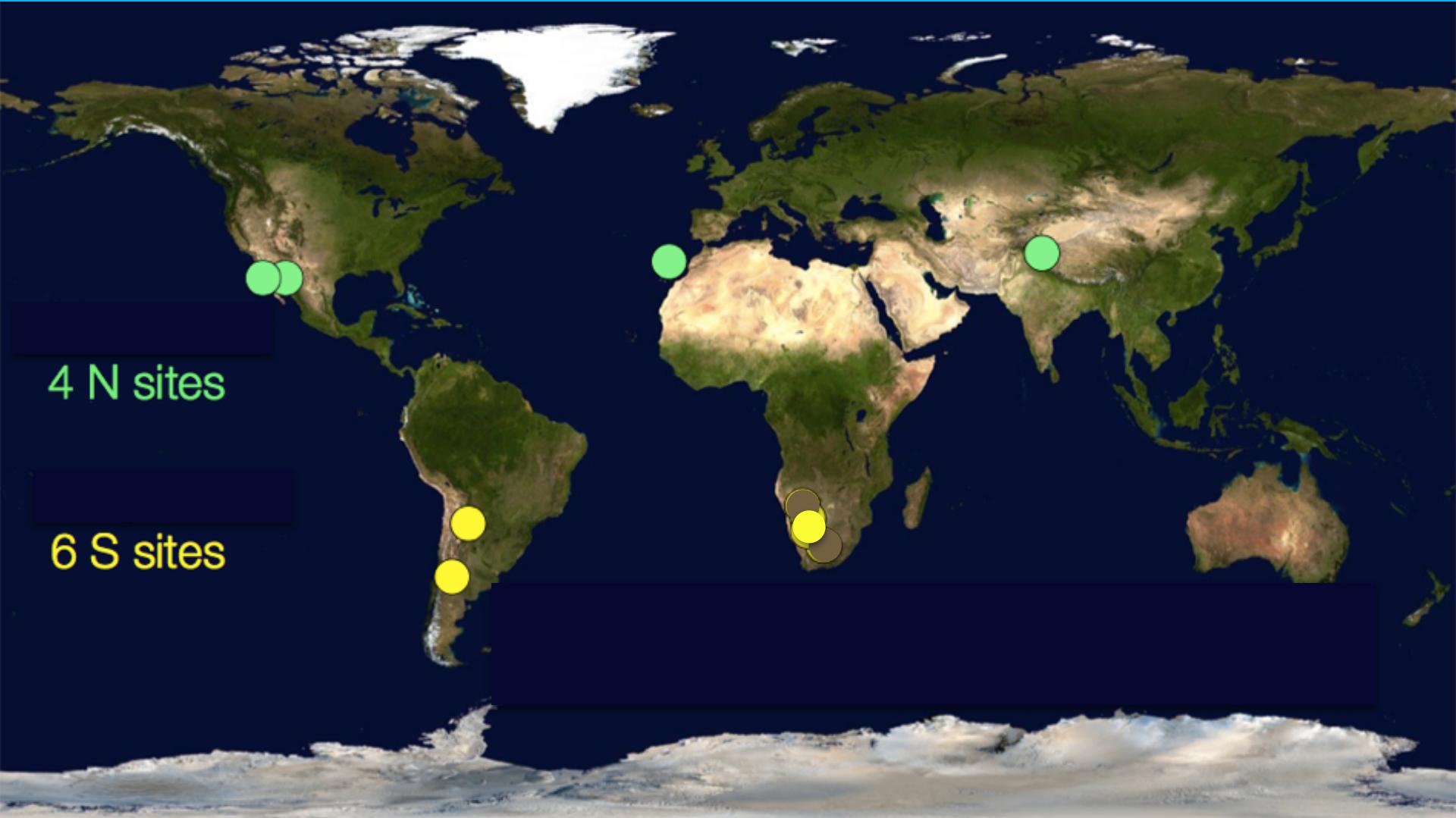
> 1138 authors (350 FTEs) from 173 institutes

CTA Site Selection

- > Clouds
- > Wind, rain, hail, snow
- > Earth quakes
- > Aerosole
- > Sensitivity simulation
 - Altitude
 - Magnetic field
- > Infrastructure
- > Host country support
- > CTA ground measurements
- > Satellites
- > Simulation/ extrapolation



CTA Site Candidates



CTA Site Candidates

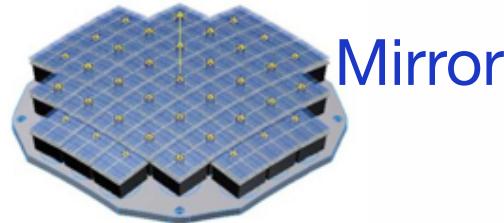
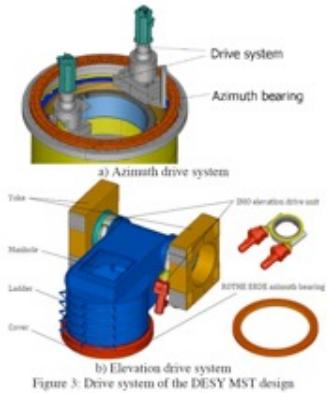
4 N sites

6 S sites



Telescope

Drives



Mirror

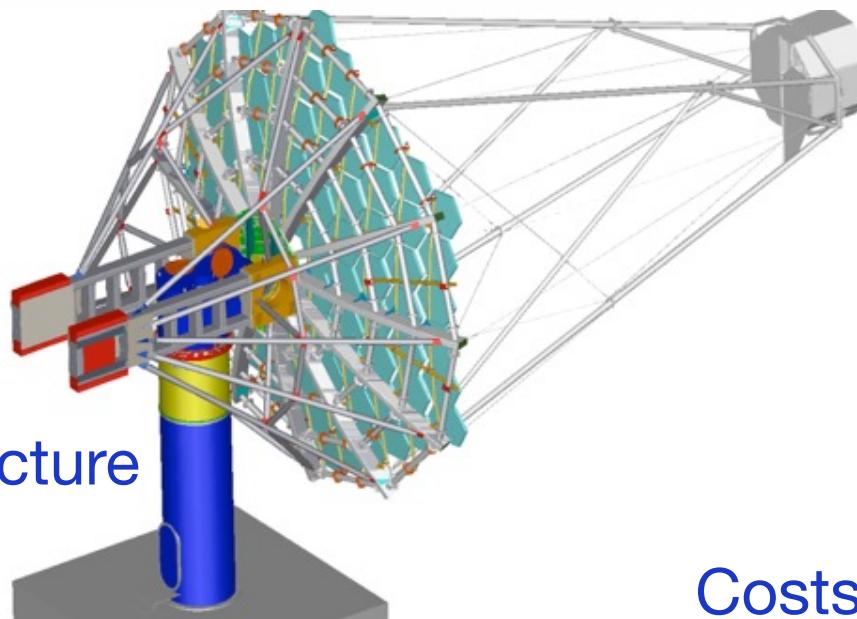
Camera



Array control



Structure



Costs



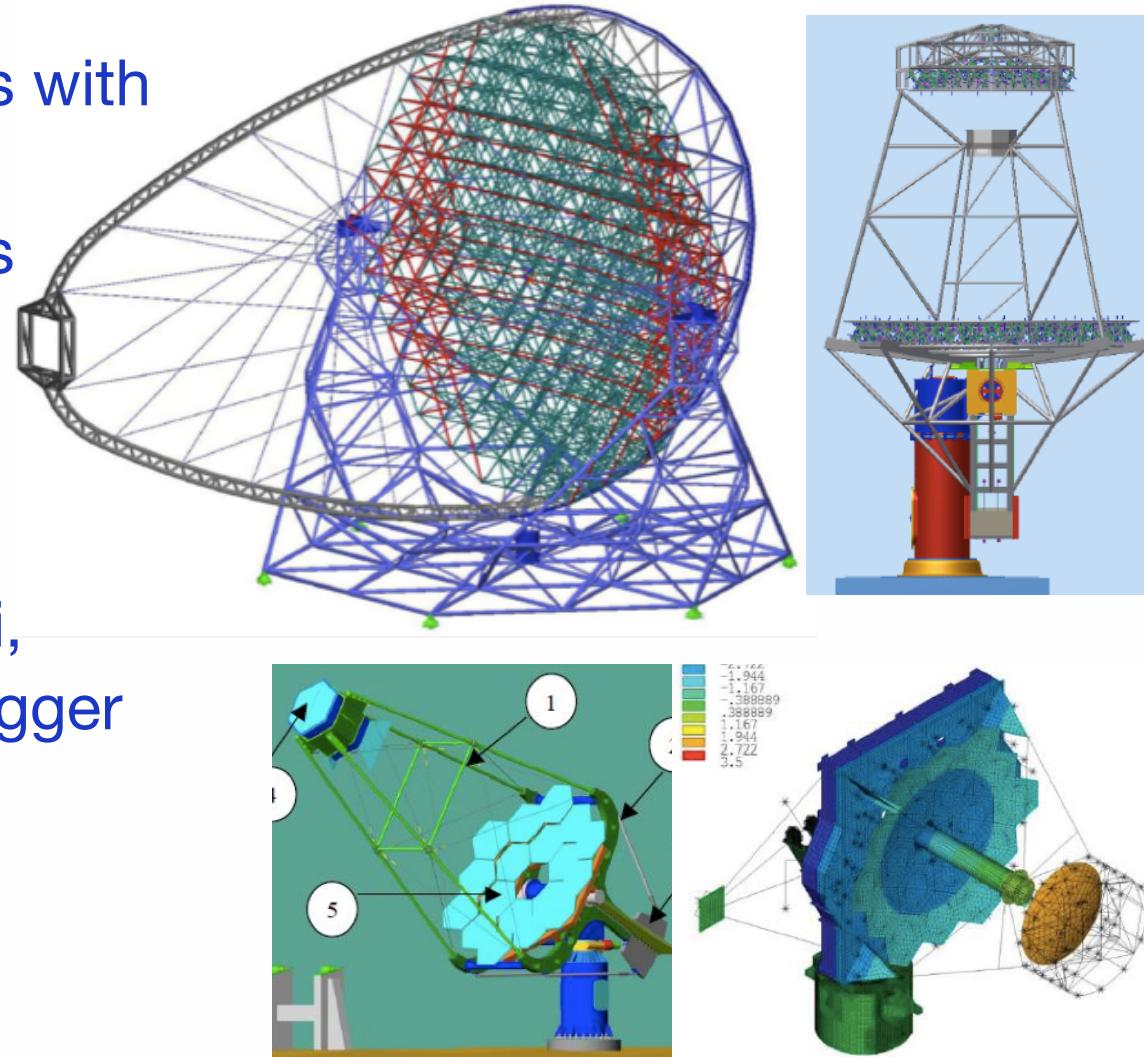
Infrastructure



- > Safety
- > Power management

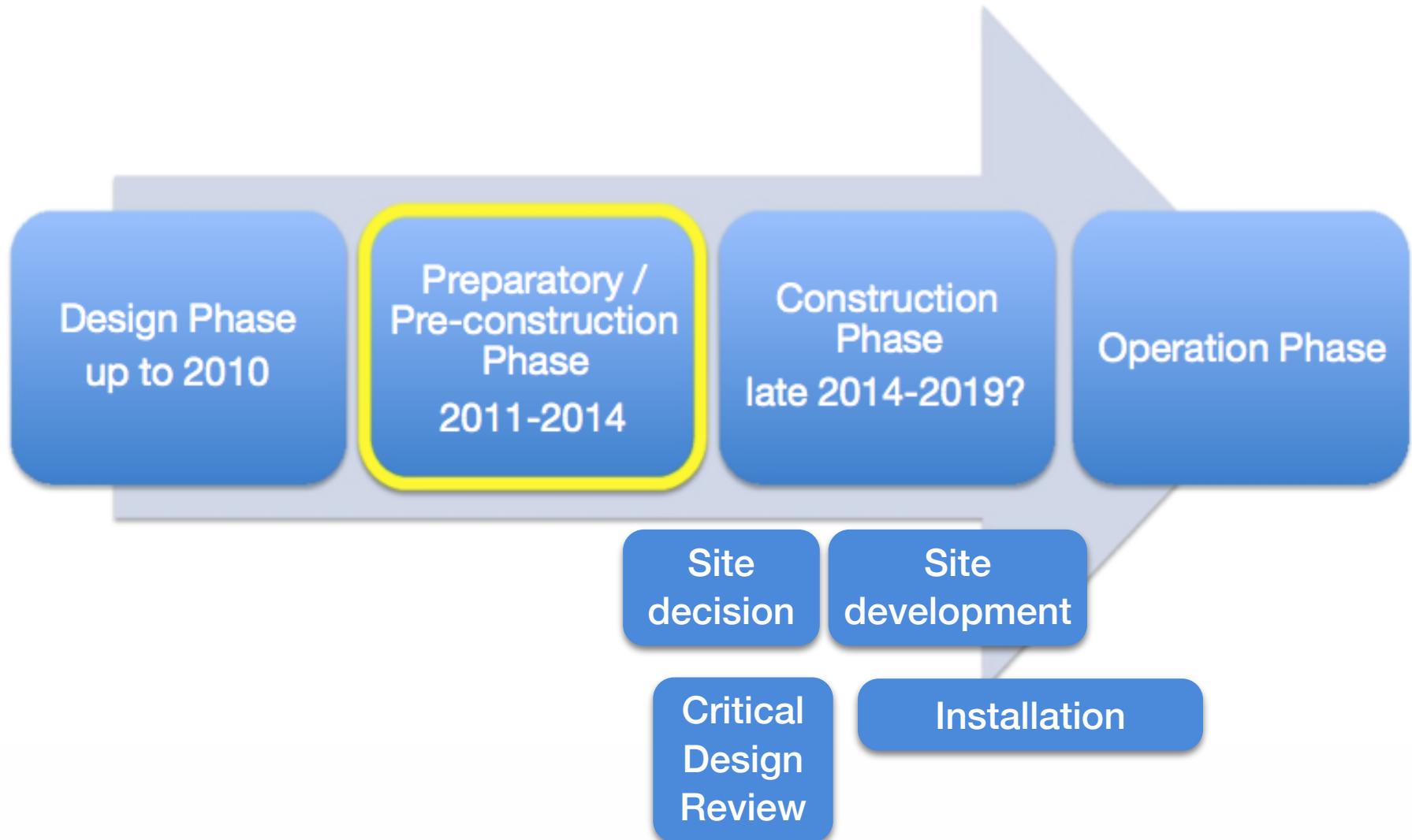
Many Technical Systems

- > Around 100 telescopes with 4, 10, 12, 23m dishes with one or two mirrors
- > Drive systems
- > Mirrors 0.4...1.5 m (a)spherical
- > Cameras: PMTs and Si, readout electronics, trigger
- > Calibration
- > Array control
- > Data centre
- > Observatory





CTA Timeline



Explore Extreme Cosmic Accelerators

- > Astronomy with gamma-rays (and neutrinos) – central research topic of high-energy astro-physics and astro particle physics
- > Investigate the high-energy universe
 - acceleration, propagation and radiation of ultra-relativistic protons/ nuclei and electrons
 - in extreme environments with huge fields, high temperatures, shock waves
 - associated with relativistic outbursts, in particle jets in the environments of black holes (AGN, micro quasars, GRB) and in cold ultra-relativistic pulsar winds

Cherenkov Telescope Array

- > A unique and versatile instrument for astronomy and astro-particle physics
- > CTA uses experience of H.E.S.S., MAGIC and VERITAS
- > First observatory in TeV band on both hemispheres – open for a world-wide community
- > Preparation
 - Design, prototypes, cost-model, quality control
 - Site selection and development
 - Establish project structure and observatory
- > Production and deployment
- > Science operation

