LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Astroparticle Physics

LIP Summer Internships
July 5, 2023

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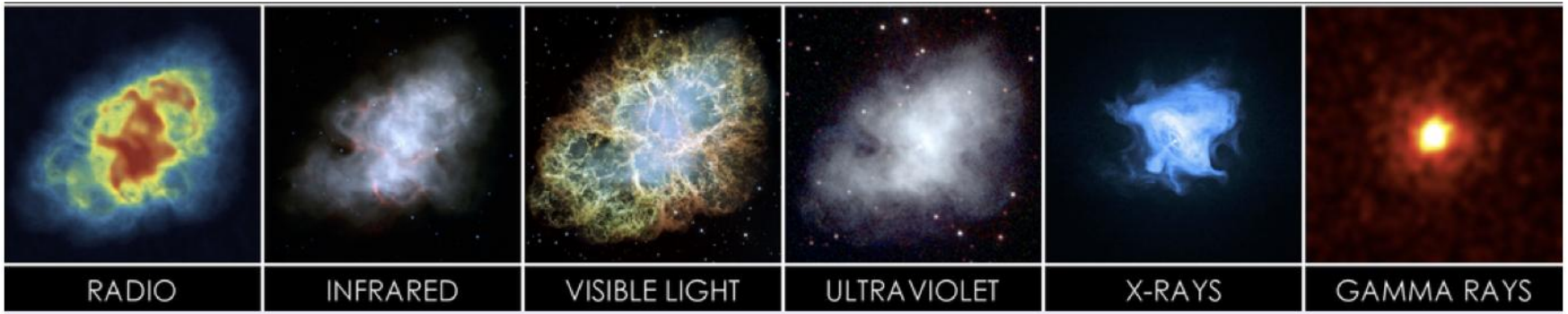
Summary

- What is astroparticle physics and why is it important?
- How do we observe astroparticles?
- Selected research topics

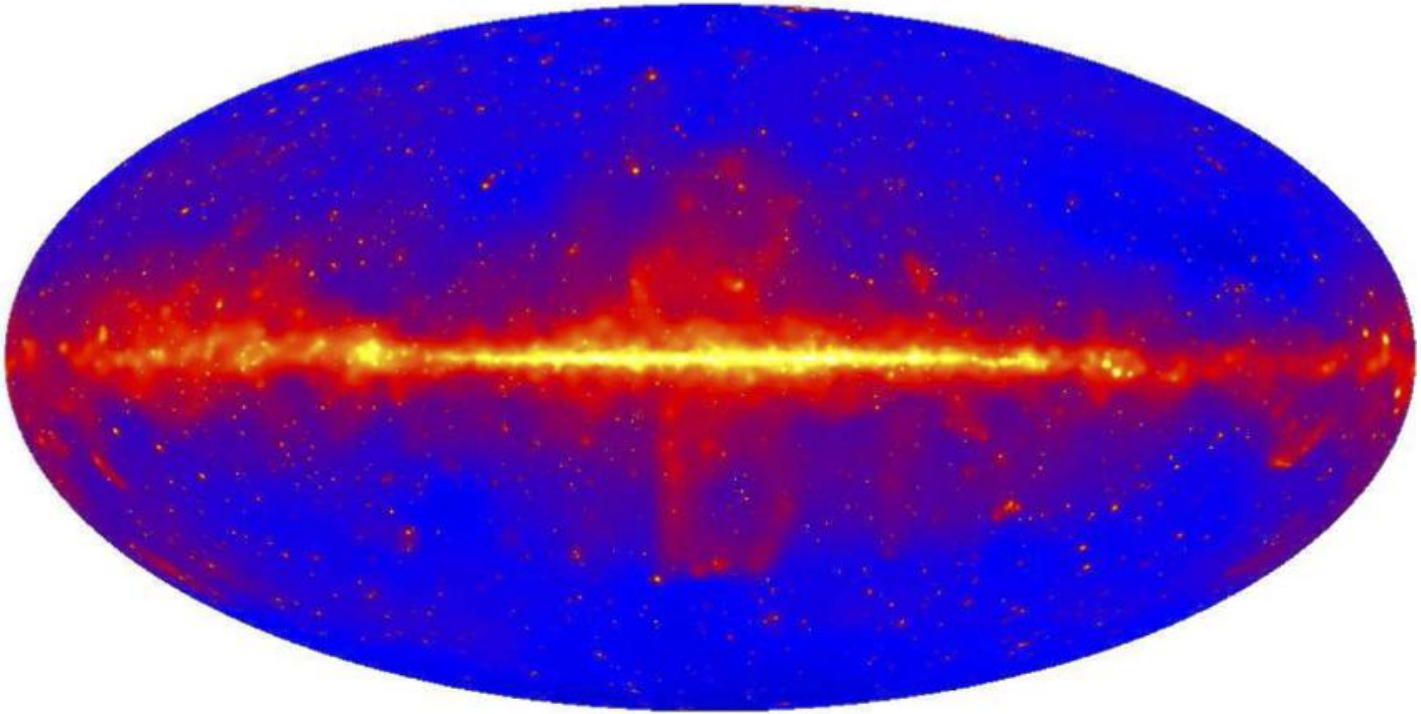
What is astroparticle physics and why is it important?

Observing the Universe

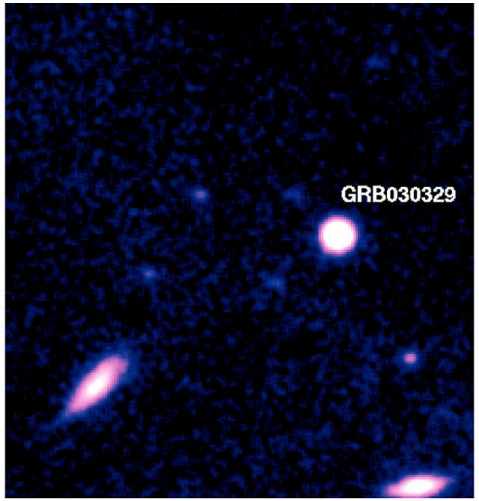
crab nebula

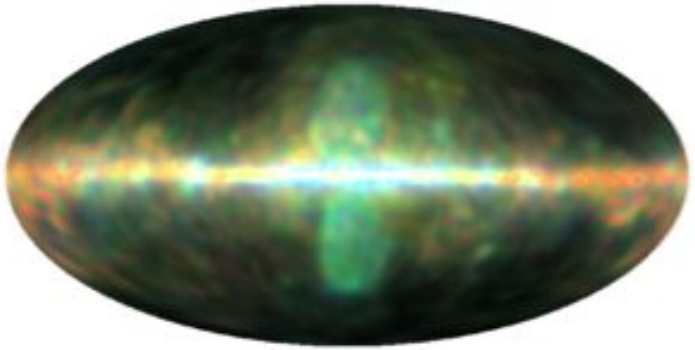


A map of the Universe
in gamma rays



The high-energy Universe
AGN, GRB, Fermi bubbles

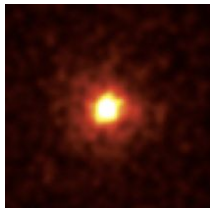




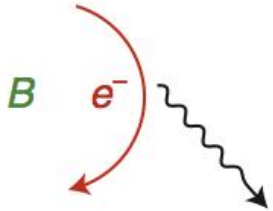
Energy scales
photons

3 eV

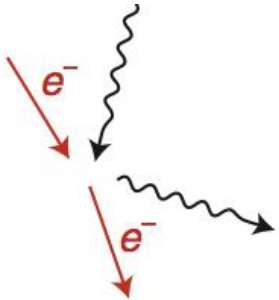
300 GeV = 3×10^{11} eV



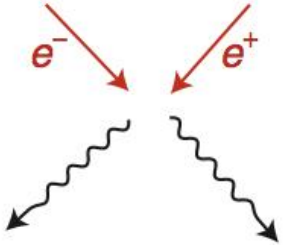
Photon production
examples



Electron synchrotron



Inverse Compton scattering



Electron–positron annihilation

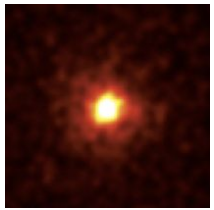
Energy scales
charged particles

1.5 eV

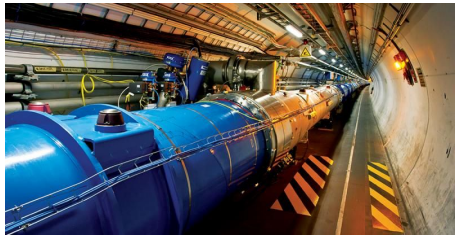
3 eV

10 keV = 10^4 eV

300 GeV = $3x10^{11}$ eV



7 TeV = $7x10^{12}$ eV



Energy scales
cosmic accelerators

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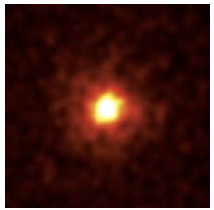
3 eV

10 keV = 10^4 eV

300 GeV = $3x10^{11}$ eV



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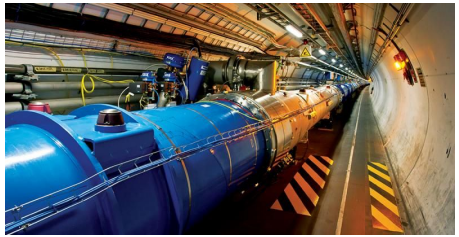

1 PeV = 10^{15} eV

Energy scales
cosmic accelerators

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3 eV

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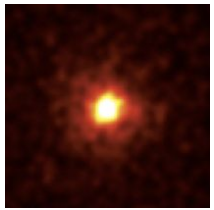

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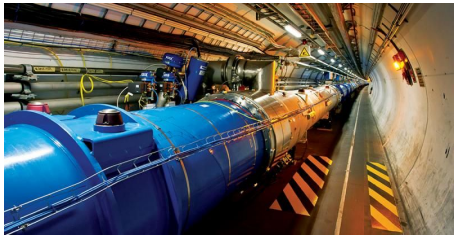
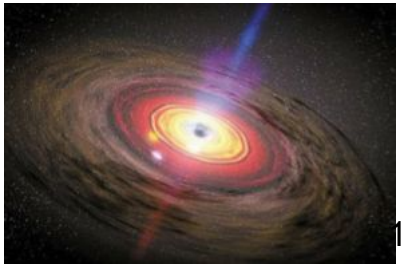


1 PeV = 10^{15} eV

ultra-high energy cosmic rays

100 EeV = 10^{20} eV



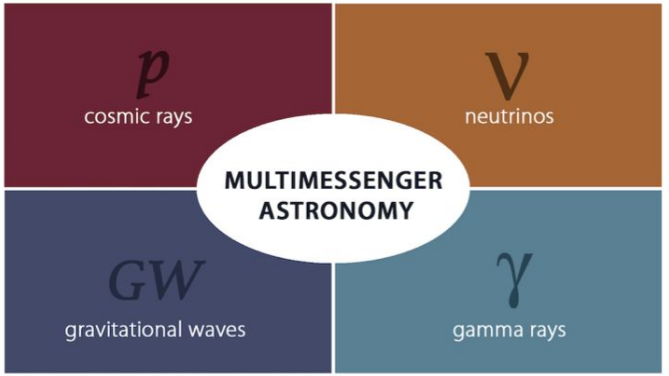
Astroparticle physics
what it is

$$\hookrightarrow \mu + \nu$$
$$p + p \longrightarrow p + n + \pi^0 + \pi^{\pm} + \ldots$$
$$\hookrightarrow \gamma + \gamma$$

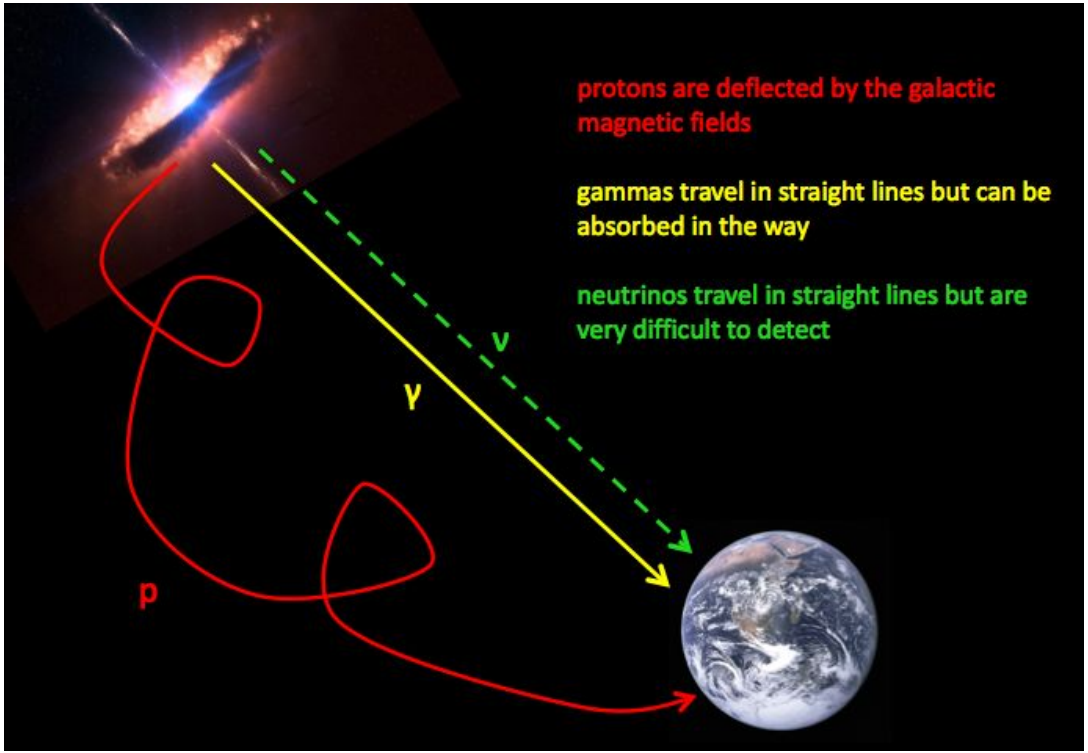
Study of particles with cosmic origin:

- charged particles (cosmic rays)
- gamma rays
- neutrinos

\+ gravitational waves



Astroparticle physics
no ideal messengers

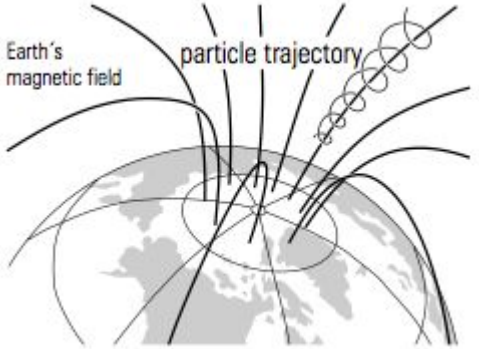


Astroparticle physics
scientific relevance

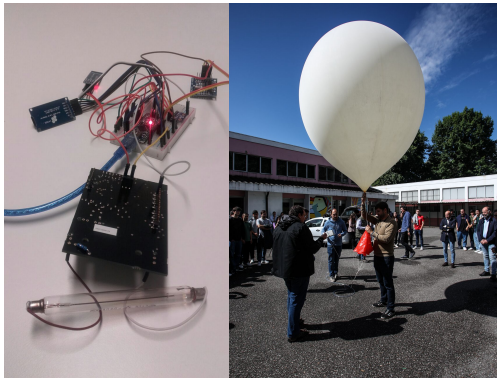
- Fundamental particle physics (e.g. neutrino oscillations, cross sections)
- Searches for new physics phenomena (e.g. dark matter, magnetic monopoles)
- Production mechanisms of highest energy particles
- Modelling of astrophysical sources
- Others

How do we observe astroparticles?

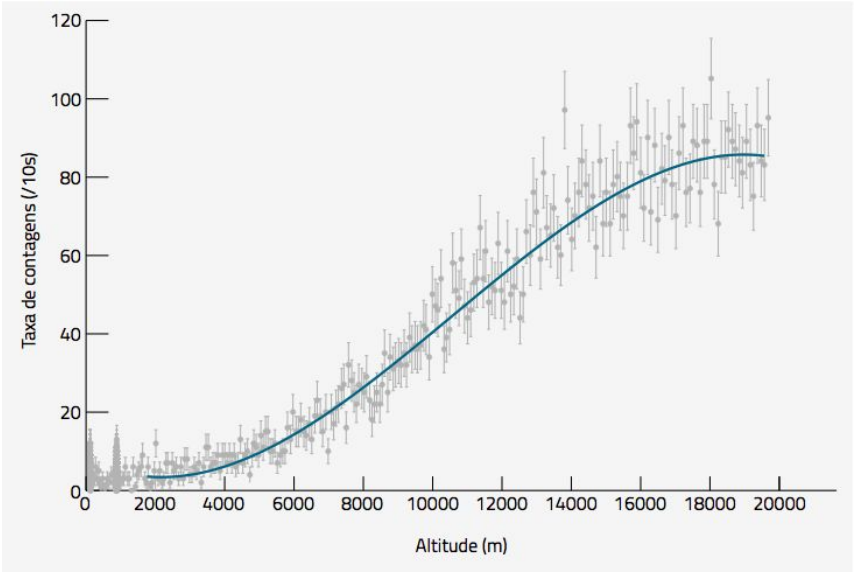
Cosmic rays
northern lights?



Cosmic rays
an accidental discovery

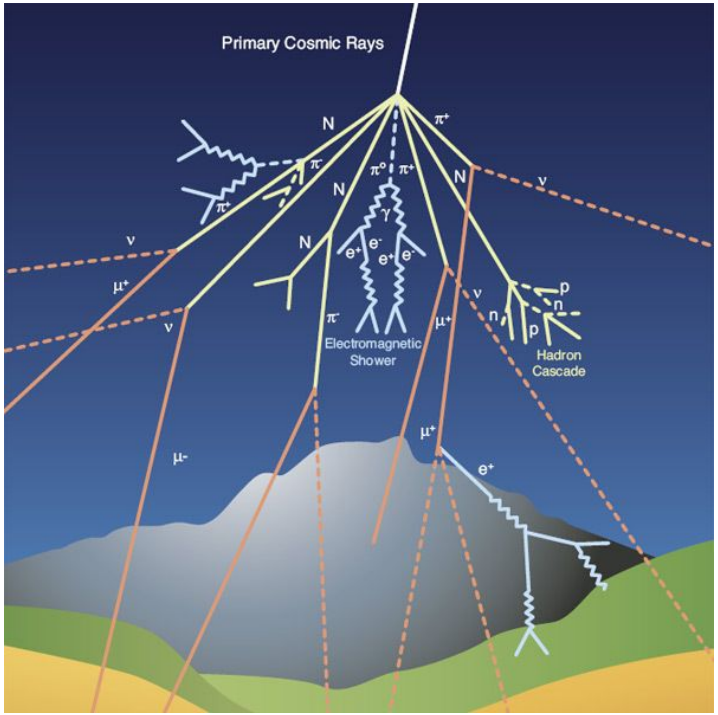


2022



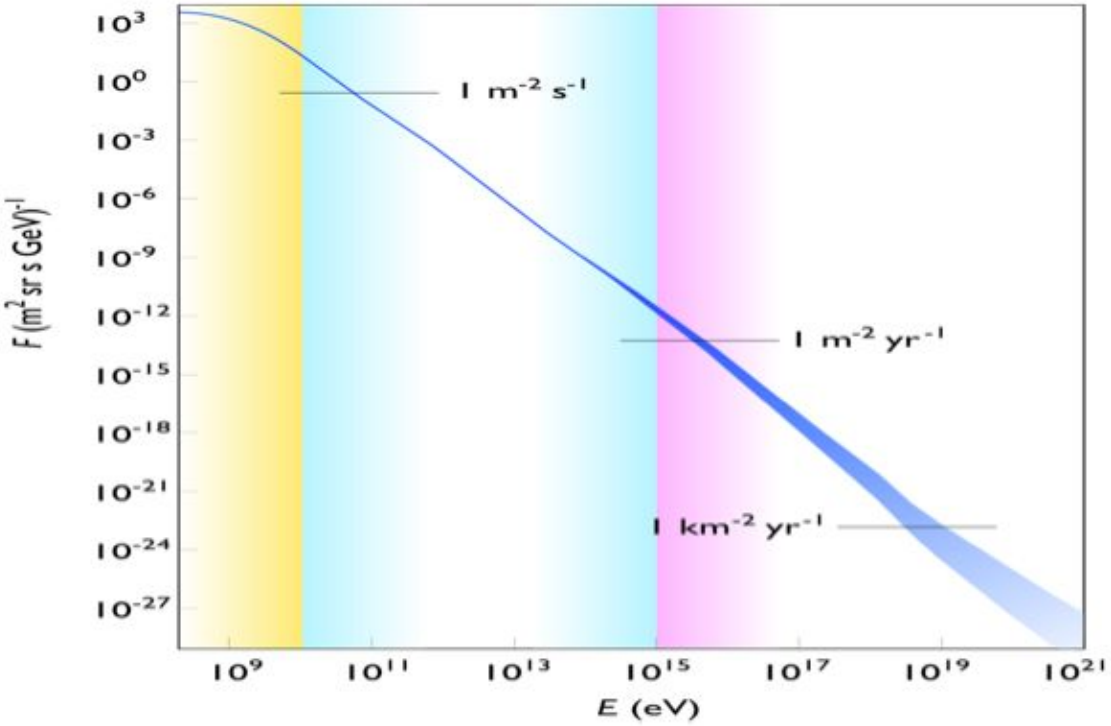
Cosmic rays
atmospheric particle showers

it's raining muons

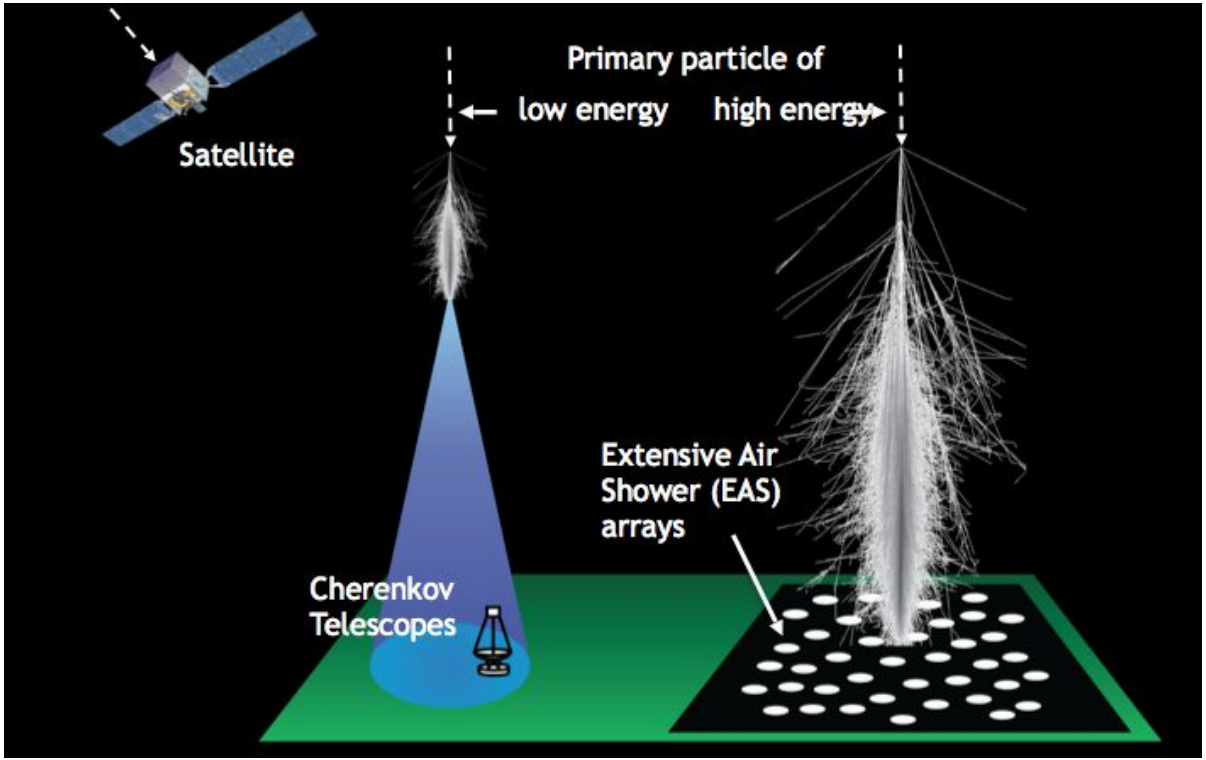


Cosmic rays

more energetic, more rare

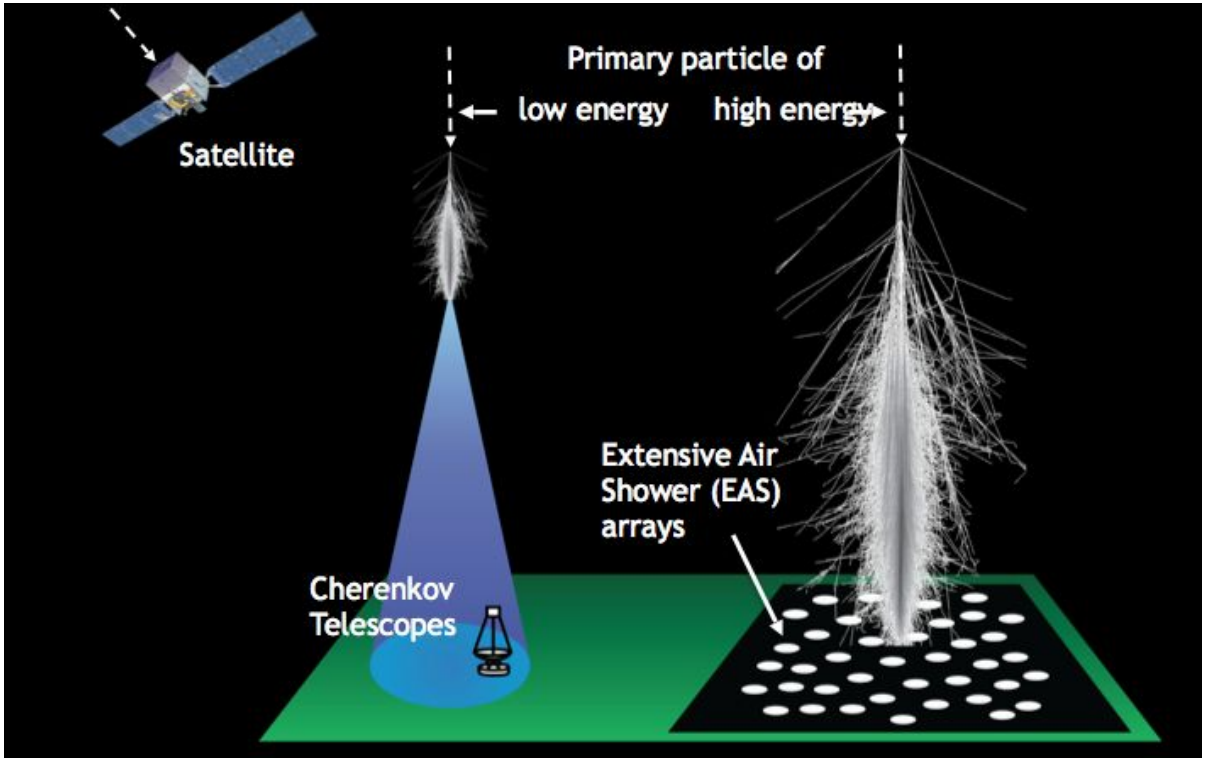


Cosmic rays
how to observe them?



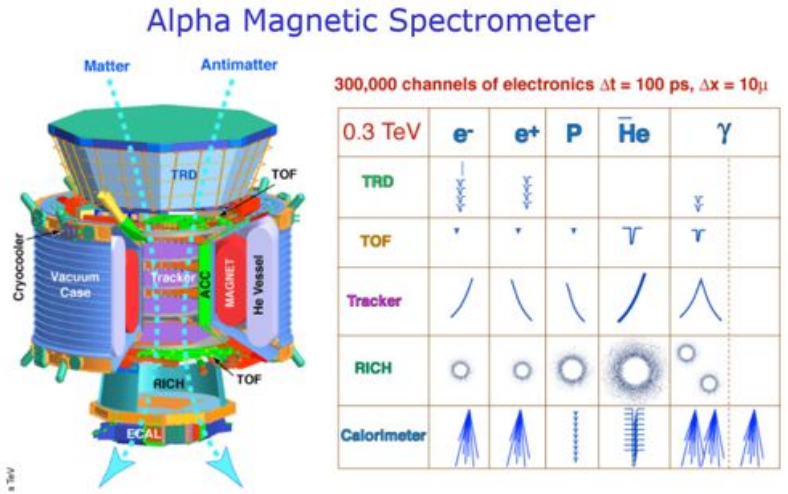
Cosmic rays
how to observe them?

AMS



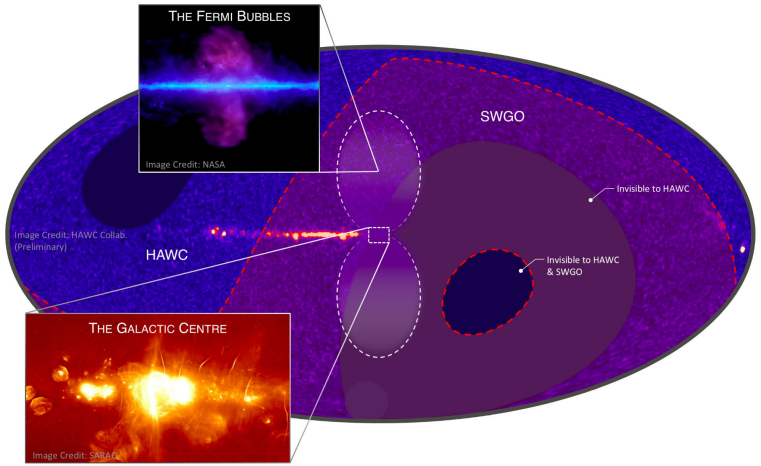
SWGO
Auger

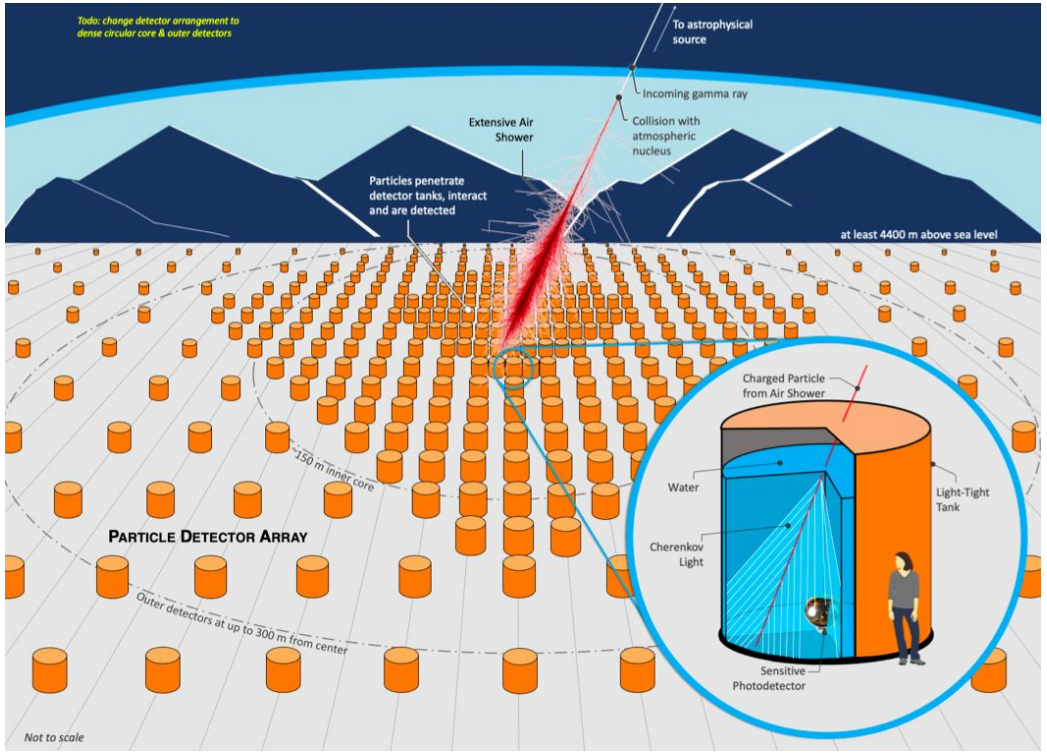
Low-energy cosmic rays
AMS



Very-high energy gamma rays
SWGO

in the phase of design





Ultra-high energy cosmic rays
Pierre Auger Observatory

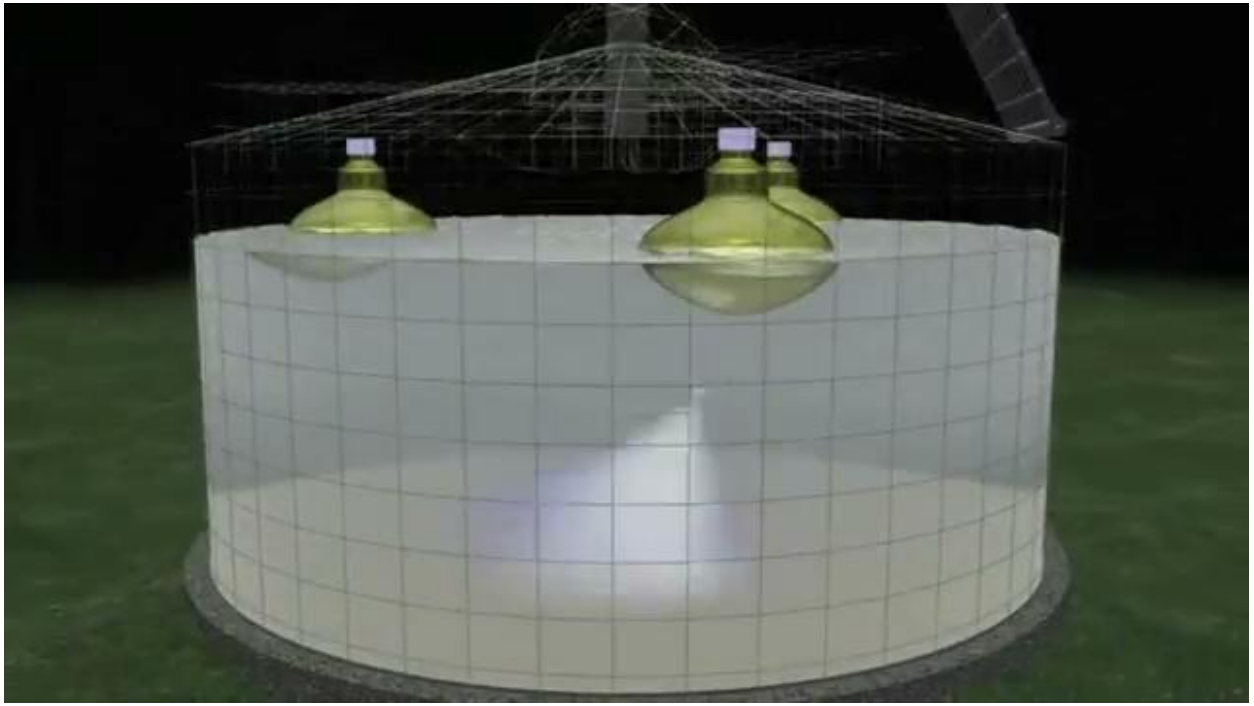
PIERRE AUGER OBSERVATORY

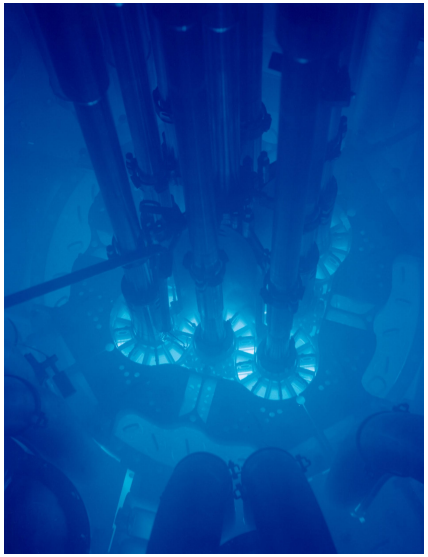
Pierre Auger Observatory
with the size of Minho

1661 tanks

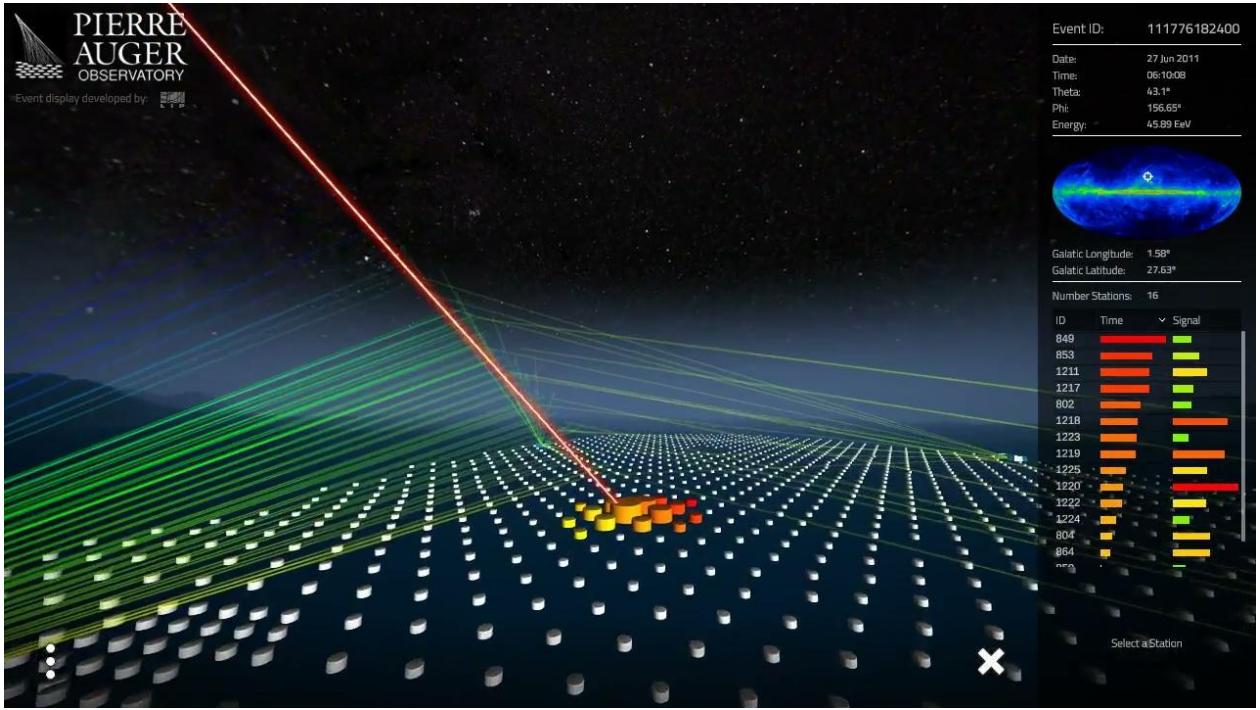
3000 km²

Pierre Auger Observatory
water-Cherenkov tanks



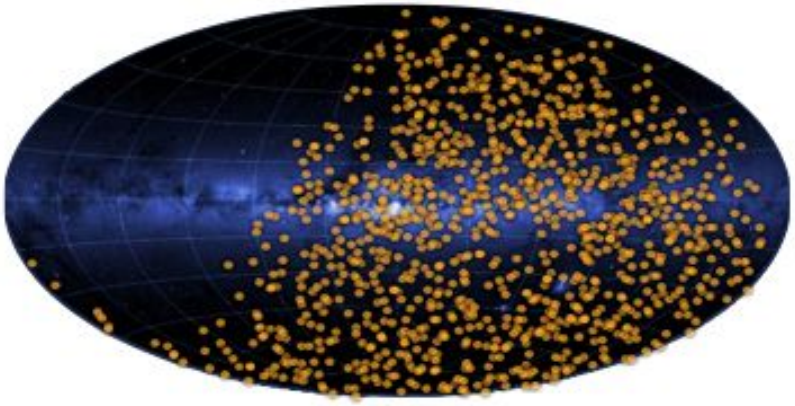


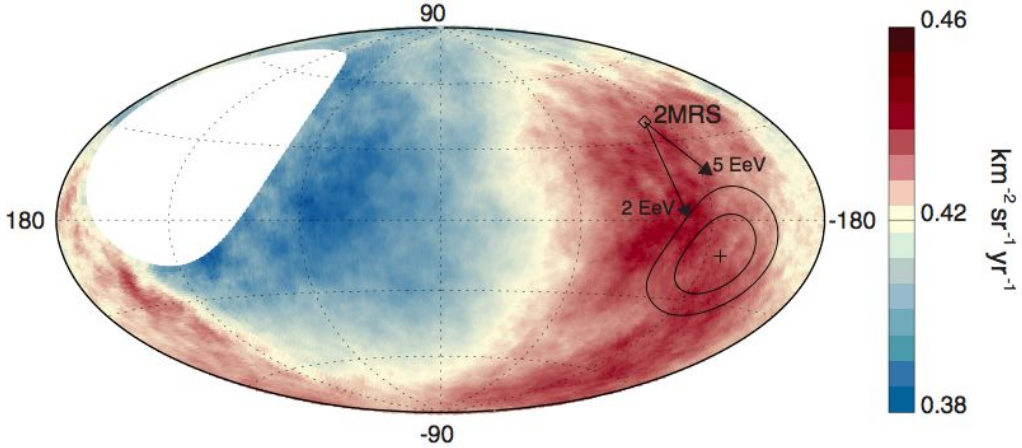
Pierre Auger Observatory
visualizing events



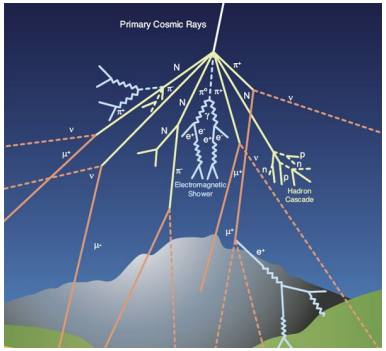
Selected research topics

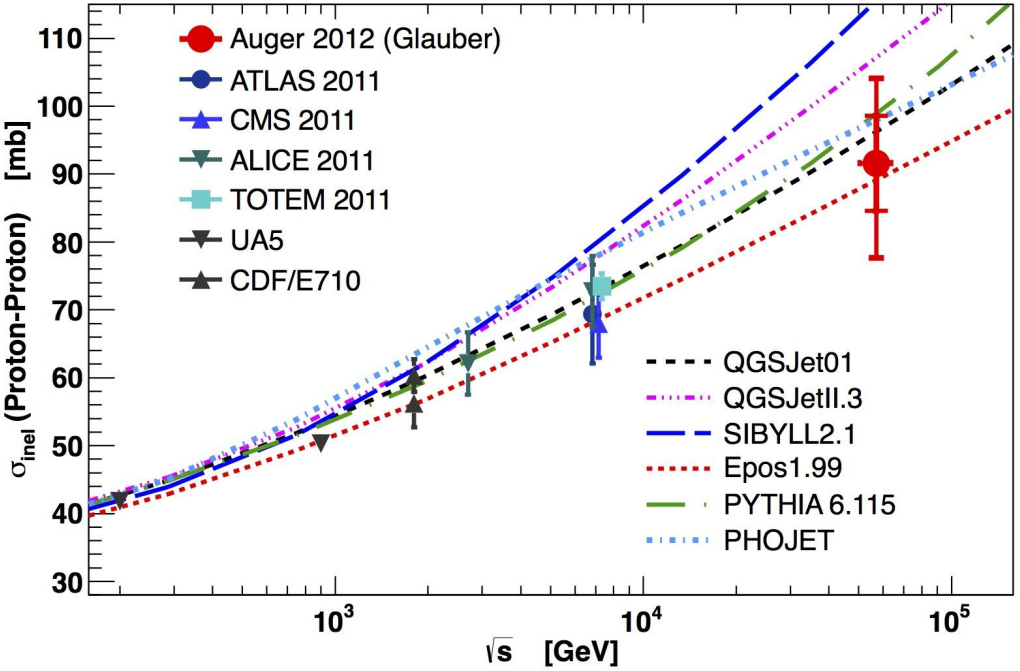
Sources of the highest energies
extragalactic origin

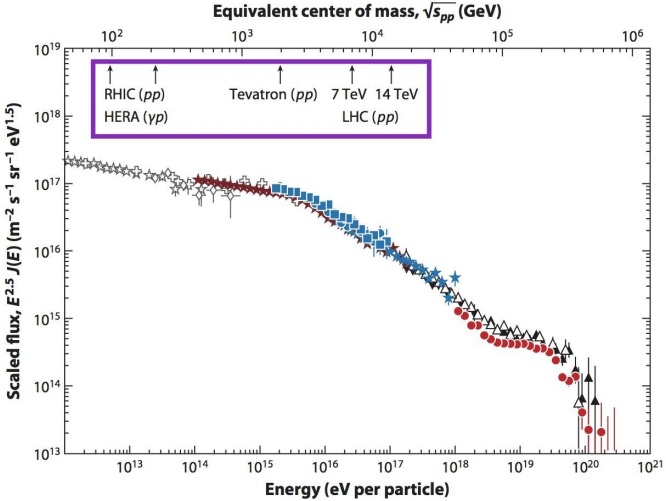




Interaction cross sections
fundamental physics in the sky

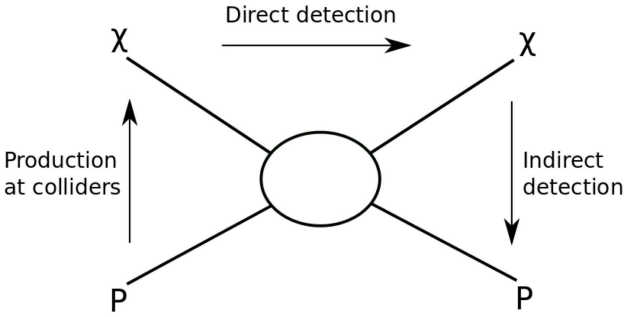


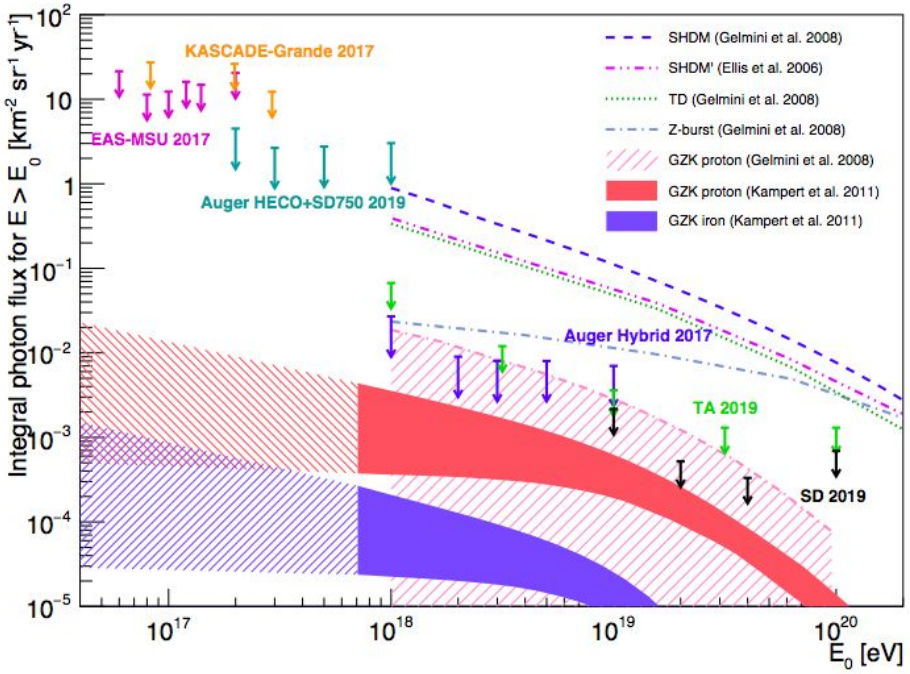




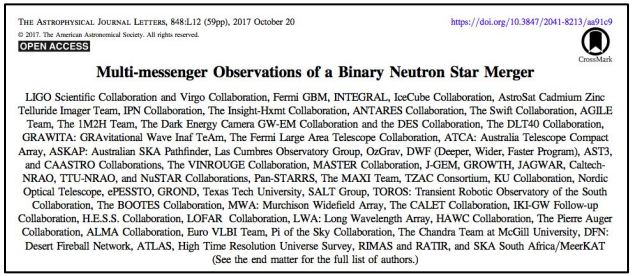
Dark matter searches

SHDM models predicted decays





Multi-messenger astrophysics
GW follow-up observations


The Astrophysical Journal Letters, 848:L12 (59pp), 2017 October 20 https://doi.org/10.3847/2041-8213/aa91c9
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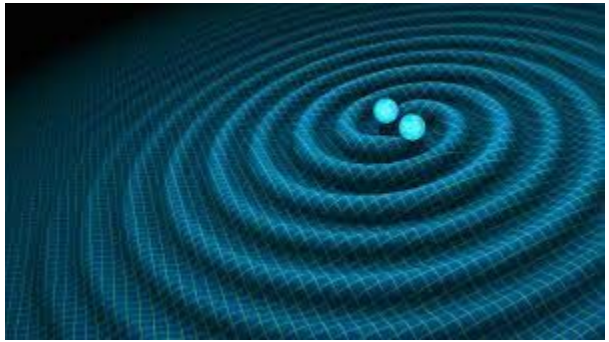
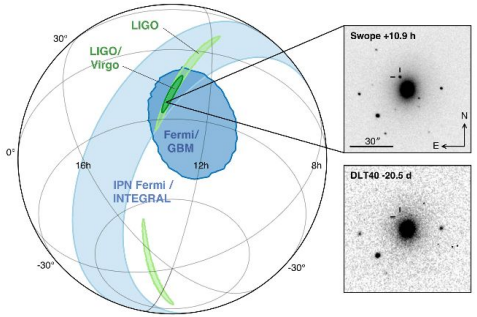
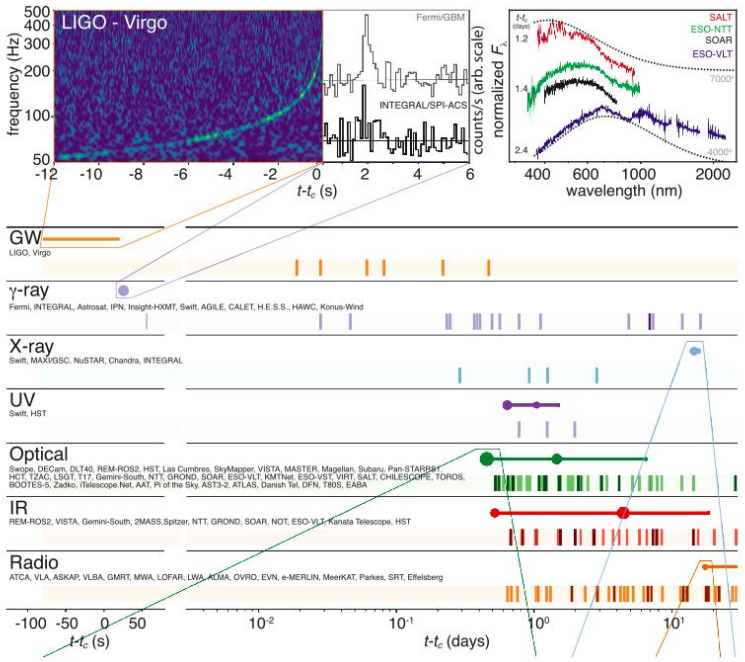
Multi-messenger Observations of a Binary Neutron Star Merger

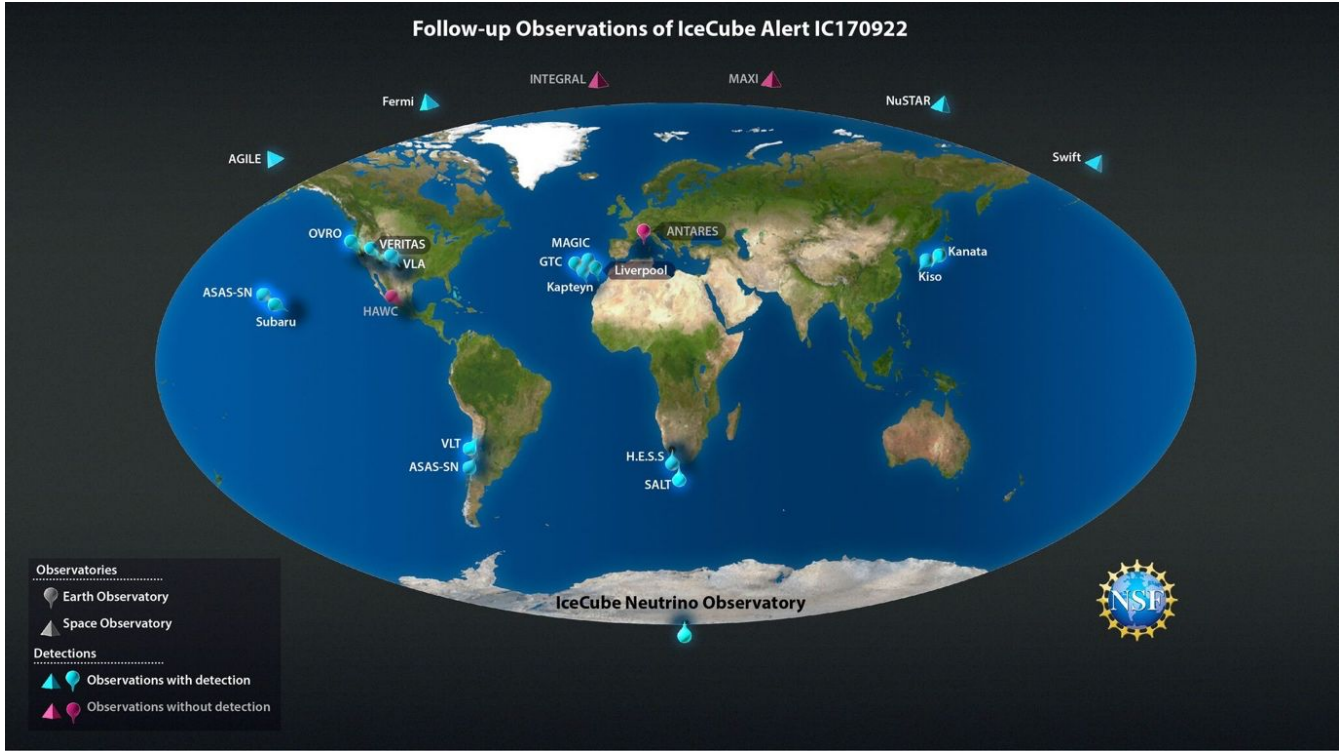
LIGO Scientific Collaboration and Virgo Collaboration, Fermi GBM, INTEGRAL, IceCube Collaboration, AstroSat Cadmium Zinc Telluride Imager Team, IPN Collaboration, The Insight-Hxmt Collaboration, ANTARES Collaboration, The Swift Collaboration, AGILE Team, The 1M2H Team, The Dark Energy Camera GW-EM Collaboration and the DES Collaboration, The DLT40 Collaboration, GRAWITA: GRAvitational Wave Inaf TeAm, The Fermi Large Area Telescope Collaboration, ATCA: Australia Telescope Compact Array, ASKAP: Australian SKA Pathfinder, Las Cumbres Observatory Group, OzGrav, DWF (Deeper, Wider, Faster Program), AST3, and CAASTRO Collaborations, The VINROUGE Collaboration, MASTER Collaboration, J-GEM, GROWTH, JAGWAR, Caltech-NRAO, TTU-NRAO, and NuSTAR Collaborations, Pan-STARRS, The MAXI Team, TZAC Consortium, KU Collaboration, Nordic Optical Telescope, ePESSTO, GROND, Texas Tech University, SALT Group, TOROS: Transient Robotic Observatory of the South Collaboration, The BOOTES Collaboration, MWA: Murchison Widefield Array, The CALET Collaboration, IKI-GW Follow-up Collaboration, H.E.S.S. Collaboration, LOFAR Collaboration, LWA: Long Wavelength Array, HAWC Collaboration, The Pierre Auger Collaboration, ALMA Collaboration, Euro VLBI Team, Pi of the Sky Collaboration, The Chandra Team at McGill University, DFN: Desert Fireball Network, ATLAS, High Time Resolution Universe Survey, RIMAS and RATIR, and SKA South Africa/MeerKAT
(See the end matter for the full list of authors.)



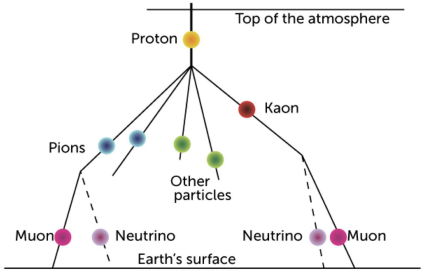


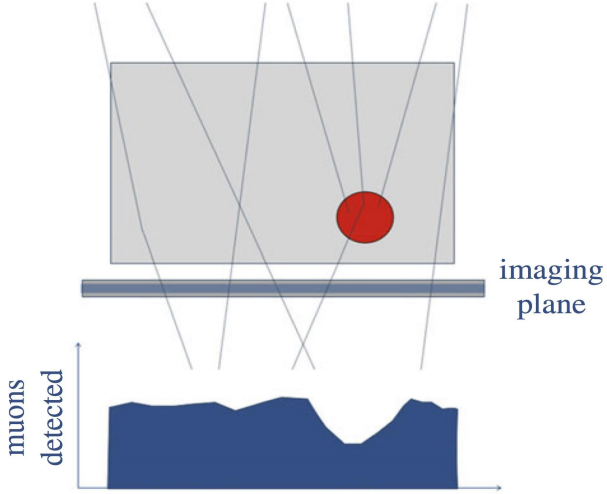


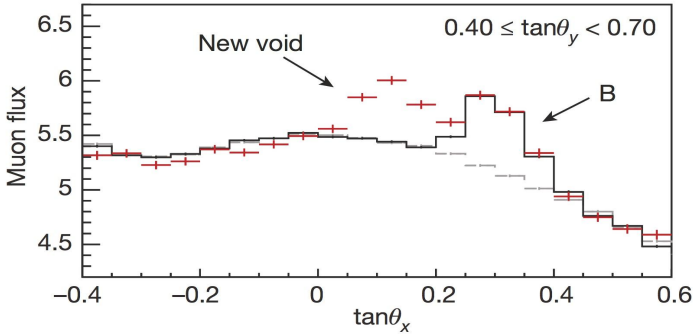
Multi-messenger astrophysics
a planetary observatory



Applied cosmic-ray physics
muon tomography







Thanks for the attention!

Questions?

You may contact me at:

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