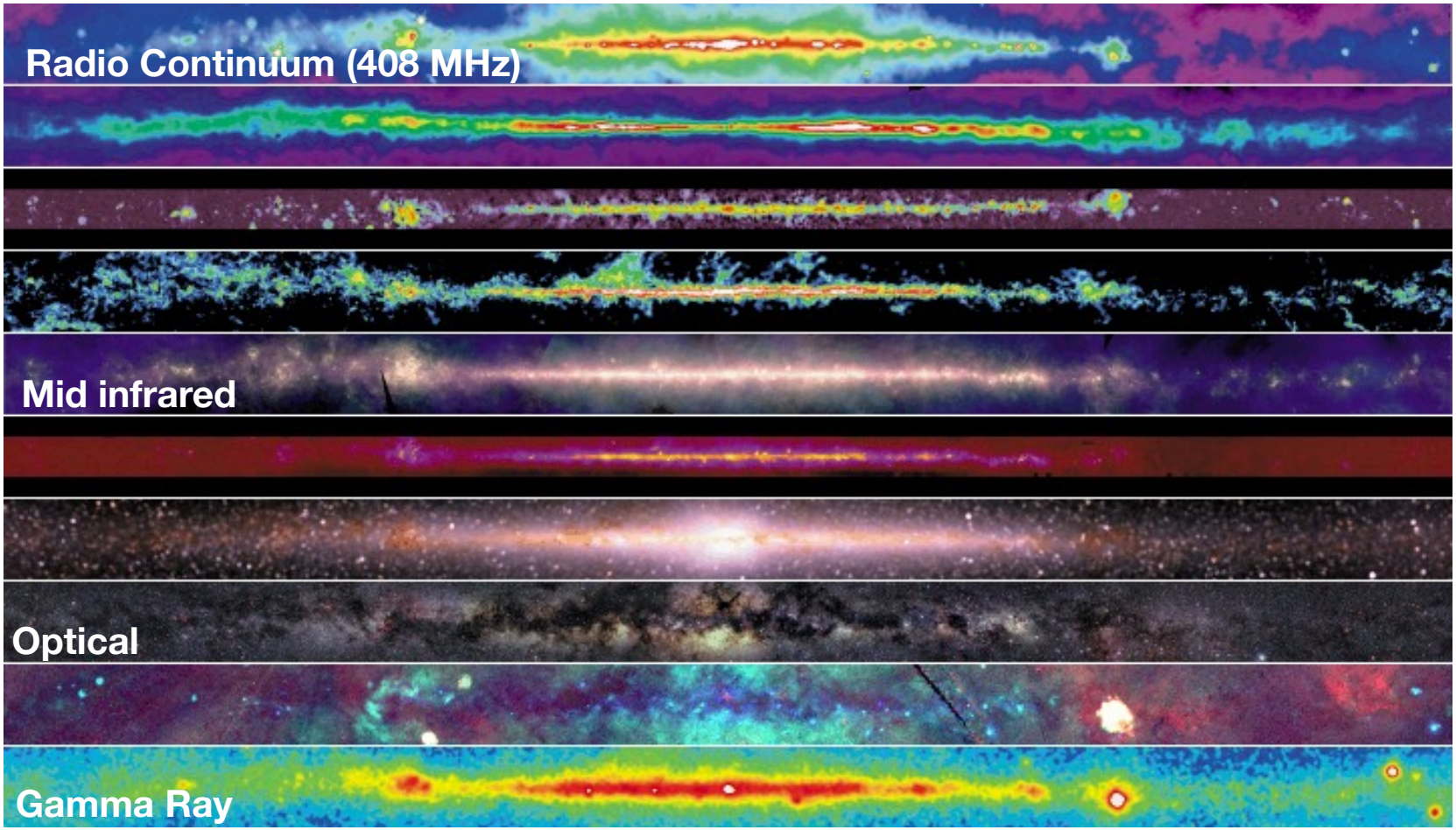
High energy experimental (multi-messenger) astrophysics

Speaker: Elisa Bernardini

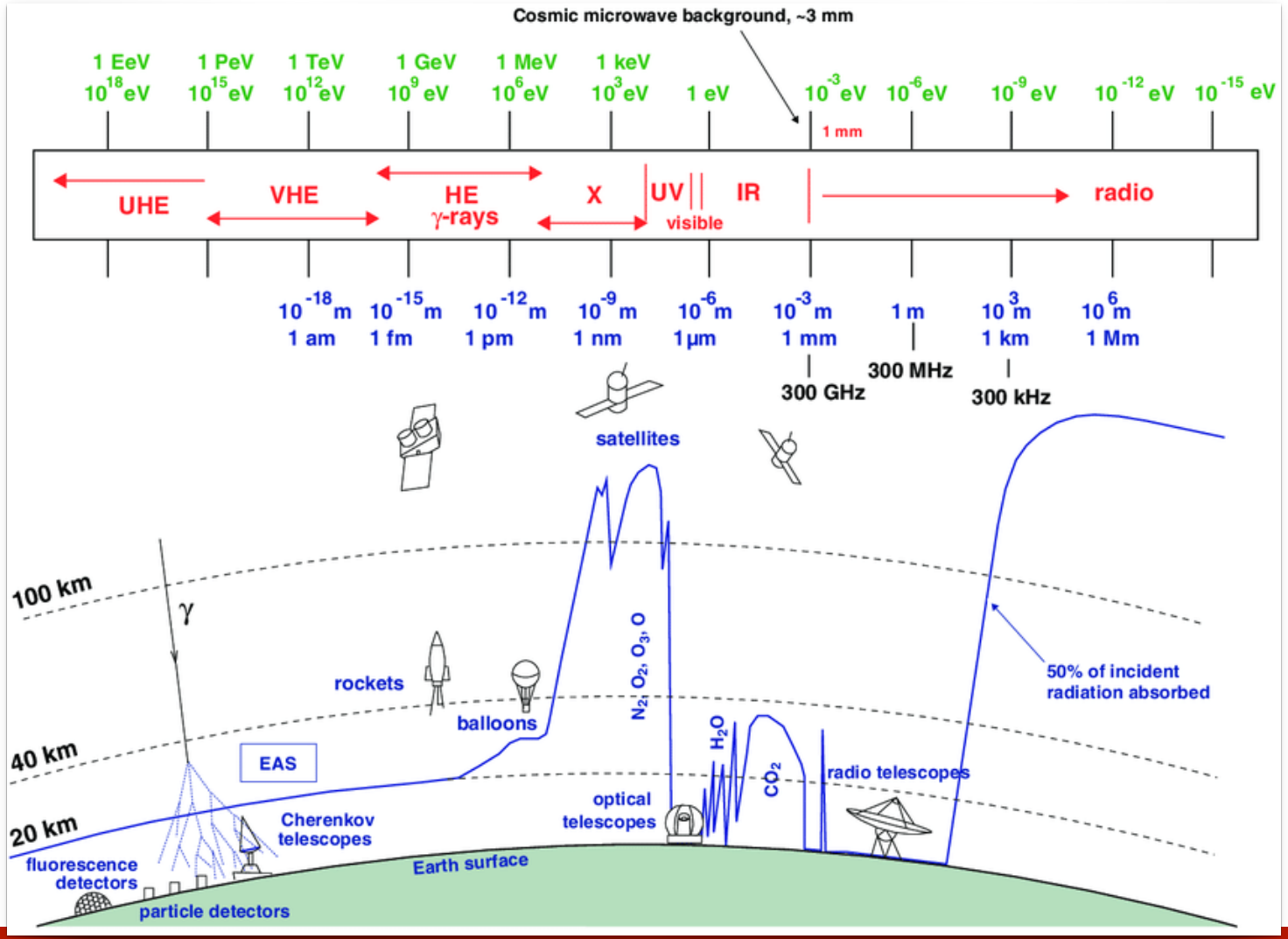
Group: High Energy Astroparticle Physics

Web site:
IT: "Astrofisica multi-messenger delle Alte Energie"
EN: "High Energy Astrophysics from Ground and Space"

The Multi-wavelength picture of the Milky Way

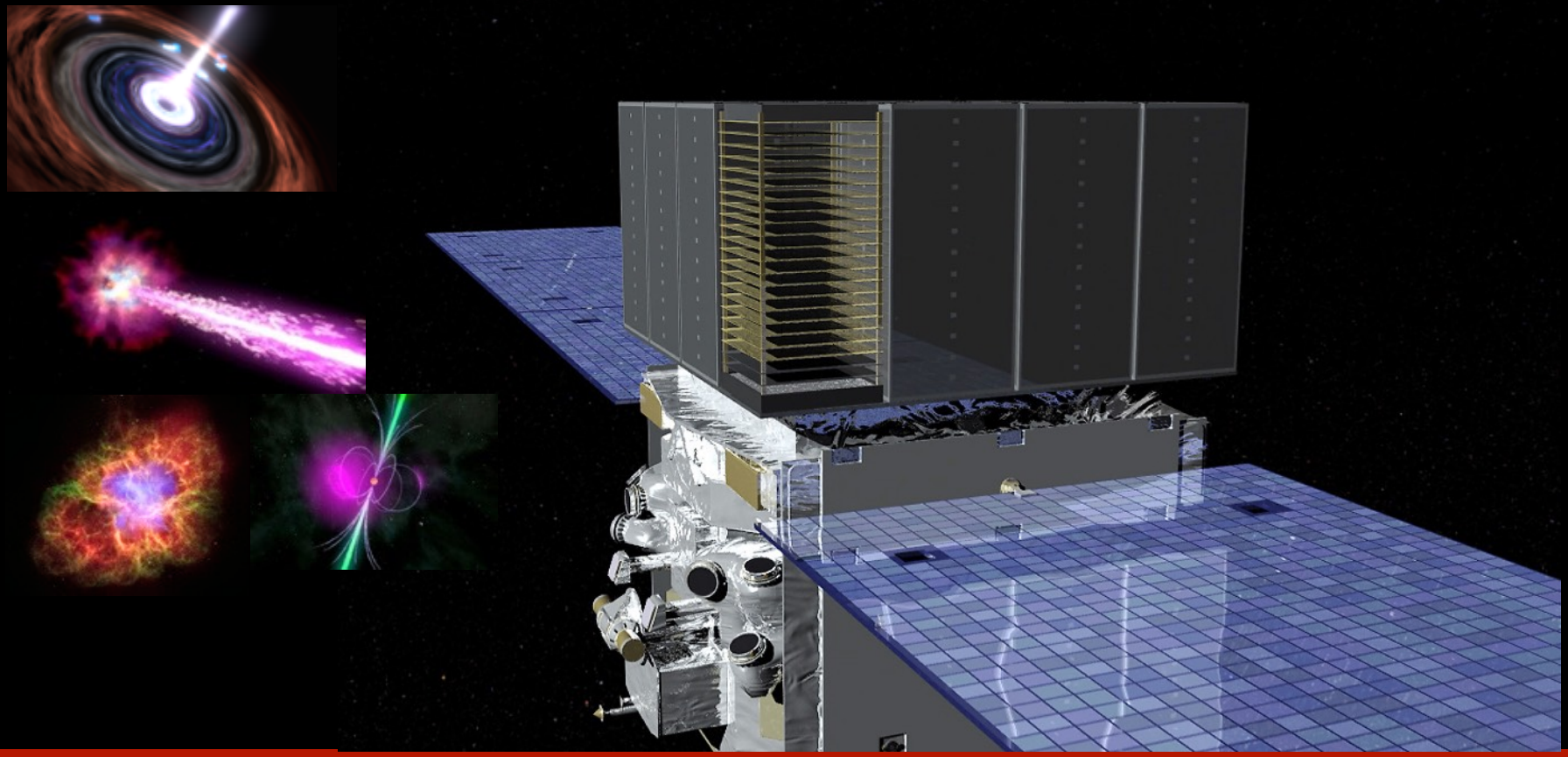


Many wavelengths = many techniques



Fermi-LAT

Gamma ray detector: a High-Energy Physics tracker+calorimeter, in space
Images the most energetic phenomena in the Universe: pulsars, supernova remnants, active galaxies, gamma-ray bursts, …

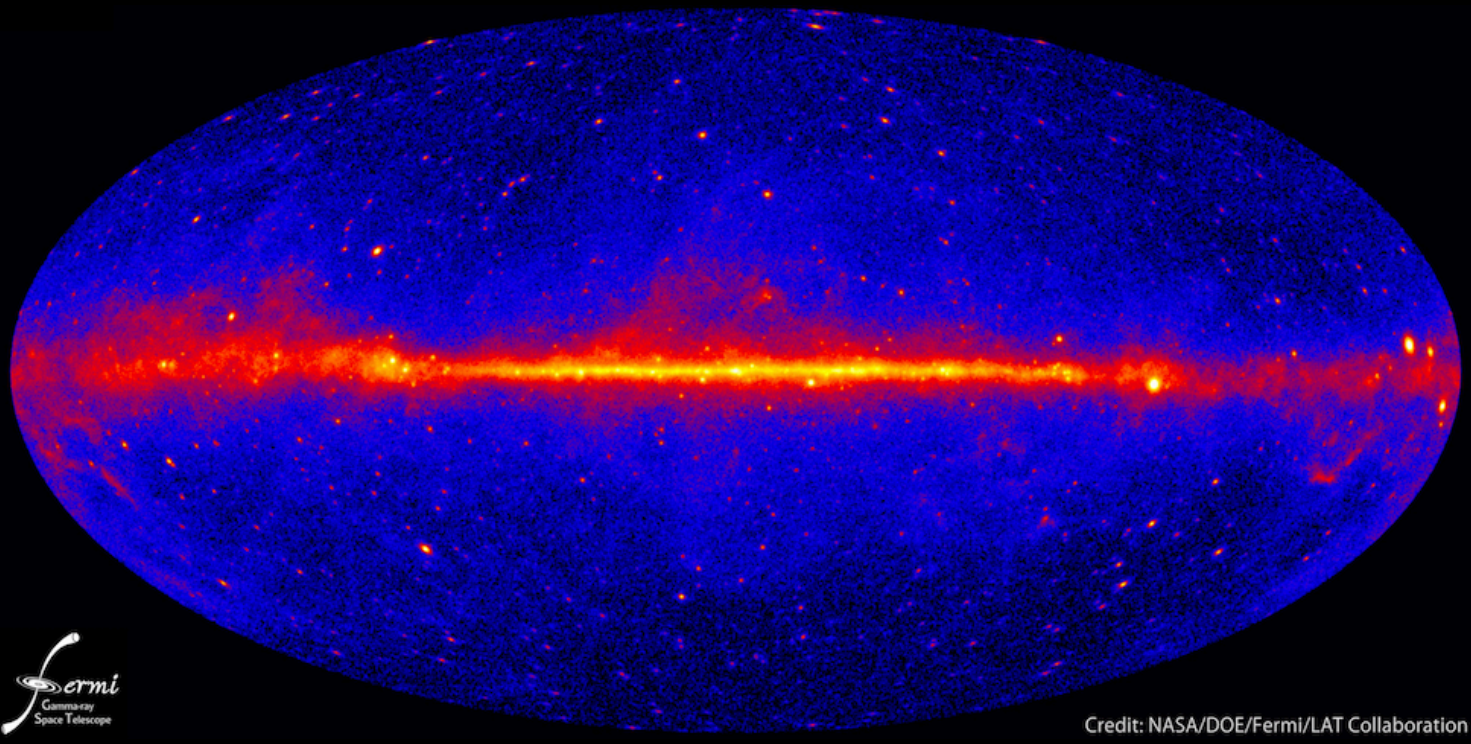


Fermi-LAT

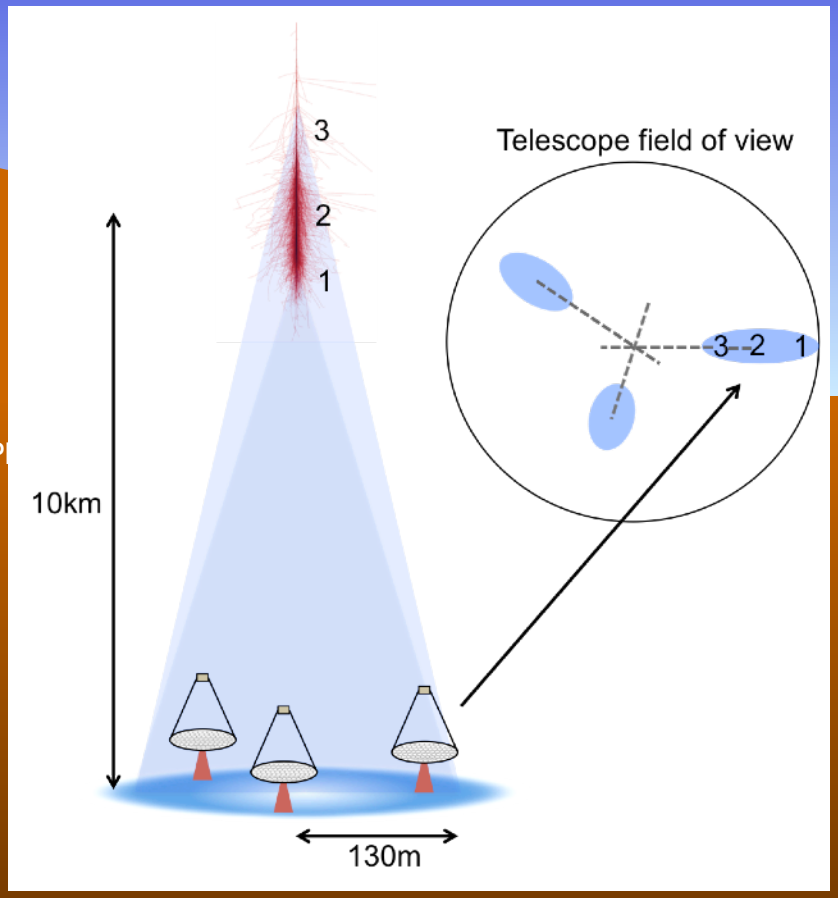
The most complete census of high-energy astrophysical objects: more than 7000 sources.

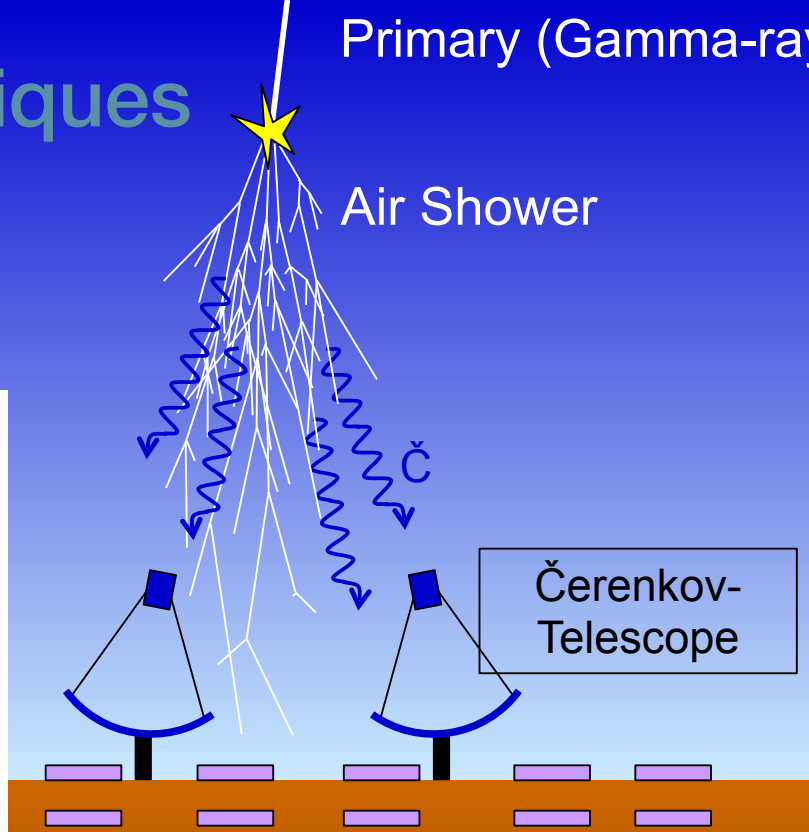
@ Padova: multifrequency studies of blazars; identification of unknown astrophysical objects of the Milky Way; study of neutron stars, high-mass binaries, cataclysmic variable stars.

eugenio.bottacini@unipd.it, **riccardo.rando@unipd.it**



Experimental Techniques at Energy > 10 GeV





MAGIC & CTA: instruments

The most sensitive instruments to detect gamma-rays at energies greater than few hundred GeV: several hundred sources, greatly resolved in time.

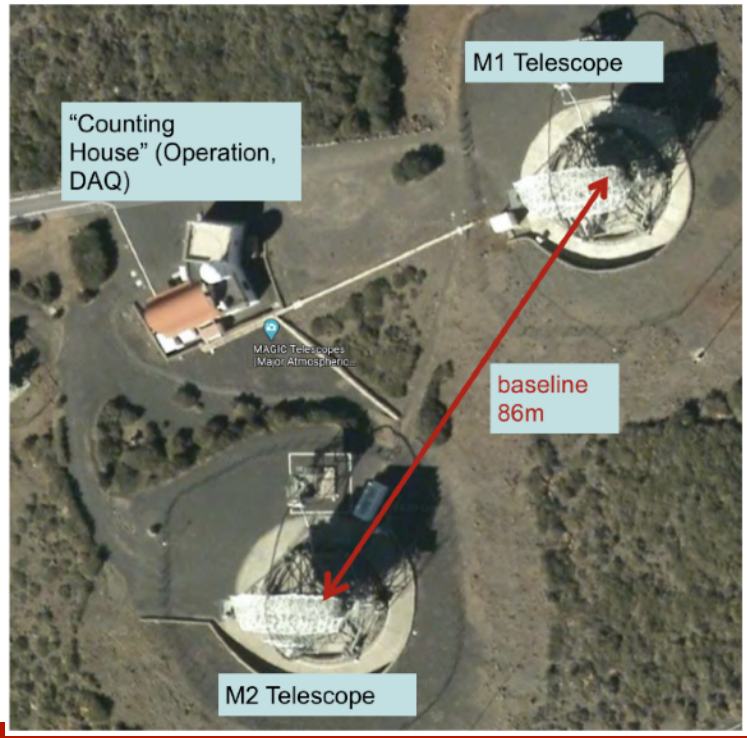
@ Padova: multifrequency studies of blazars; study of particle acceleration in the jets, optimisation of the science program of future installations.

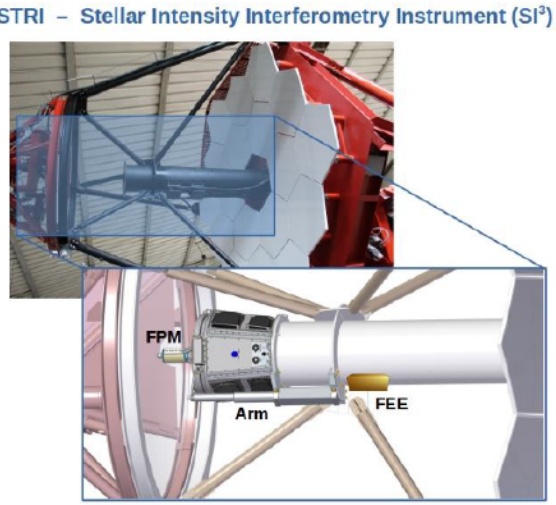
cornelia.arcaro@pd.infn.it, elisa.bernardini@unipd.it, michele.doro@unipd.it, elisa.prandini@unipd.it, davide.miceli@pd.infn.it

Intensity Interferometry @ MAGIC

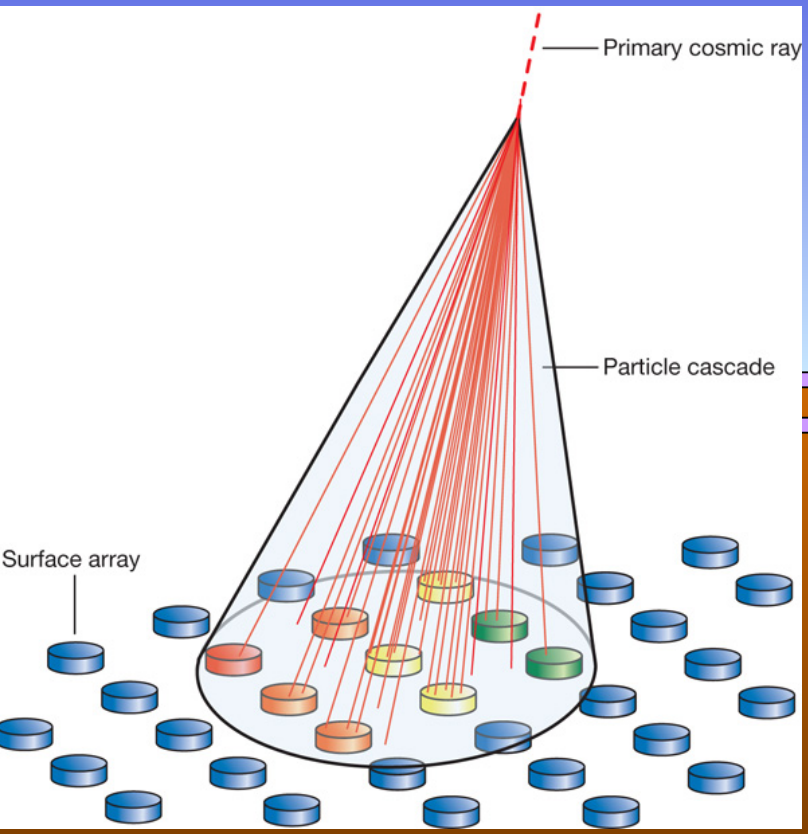
A different use of MAGIC (& LST) telescopes: the Intensity Interferometry instrument, for star imaging applications, available for the first time thanks to many instruments at large distances. Under development also for the ASTRI mini-array.

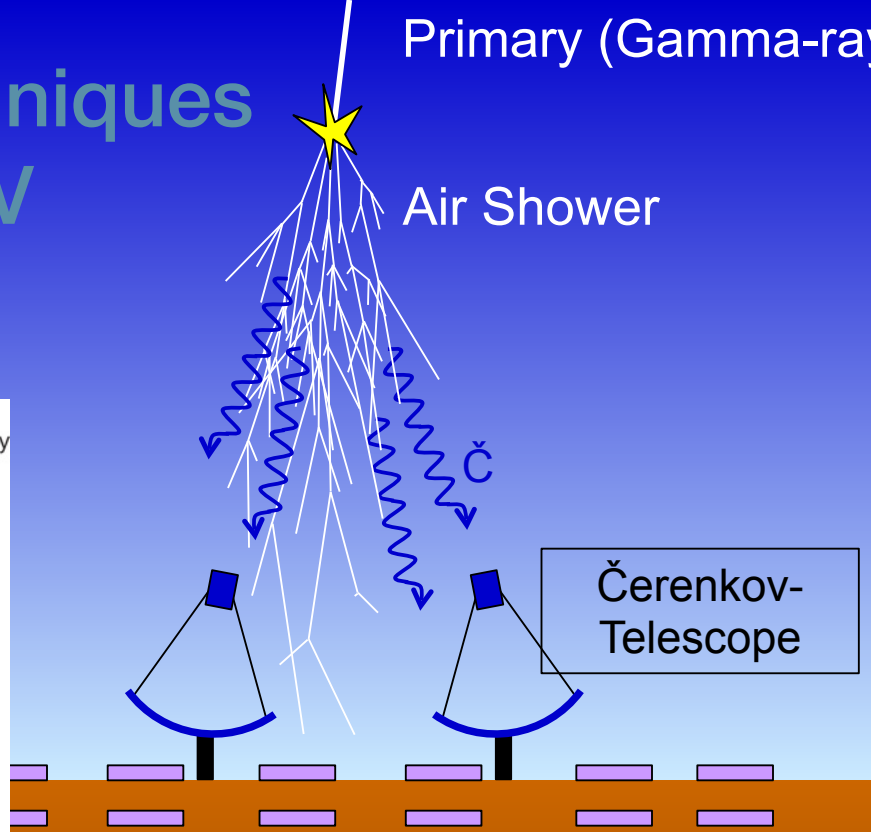
giampiero.naletto@unipd.it, luca.zampieri@oapd.inaf.it





Experimental Techniques at Energy > 10 GeV



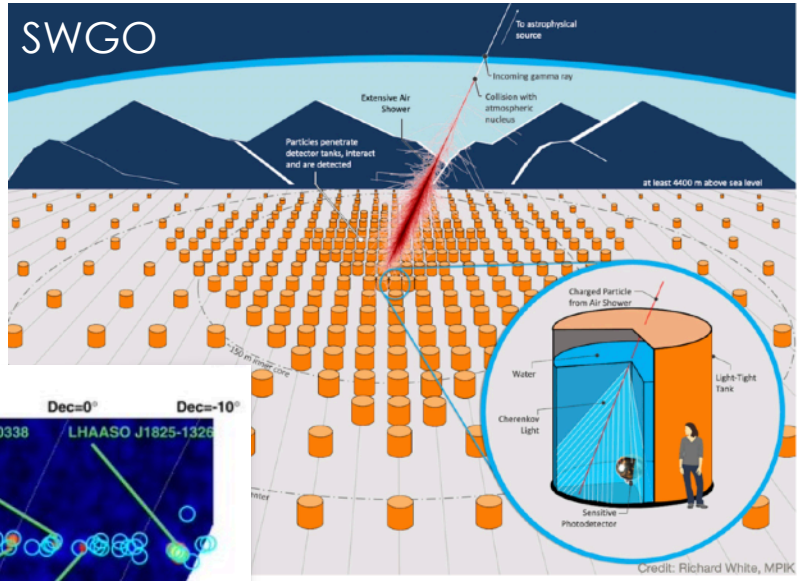


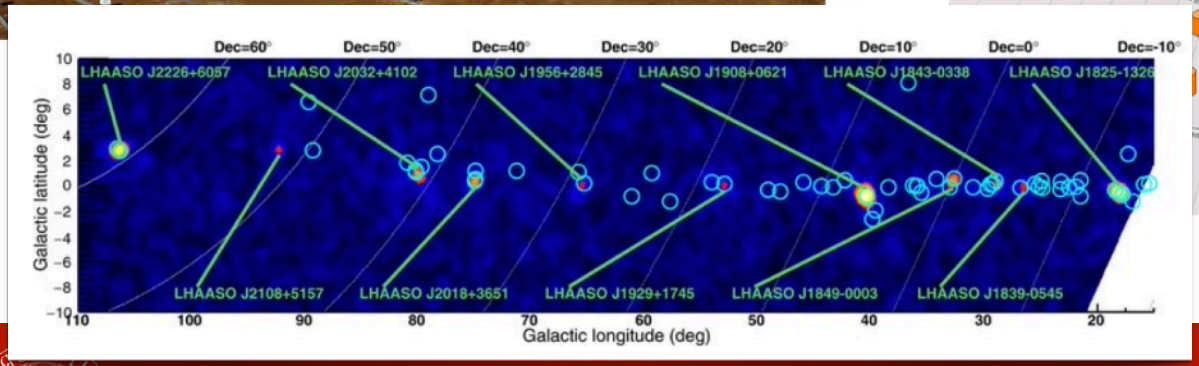
The air shower array SWGO

An air shower array to be installed in the Souther hemisphere to unveil the Milky Way at the uppermost gamma-ray energies of the electromagnetic spectrum.

@ Padova: optimisation of the design of SWGO (e.g. type of detectors, array configuration)

cornelia.arcaro@pd.infn.it, tommaso.dorigo@gmail.com, michele.doro@unipd.it, elisa.prandini@unipd.it





Messengers of the Universe: Cosmic Rays

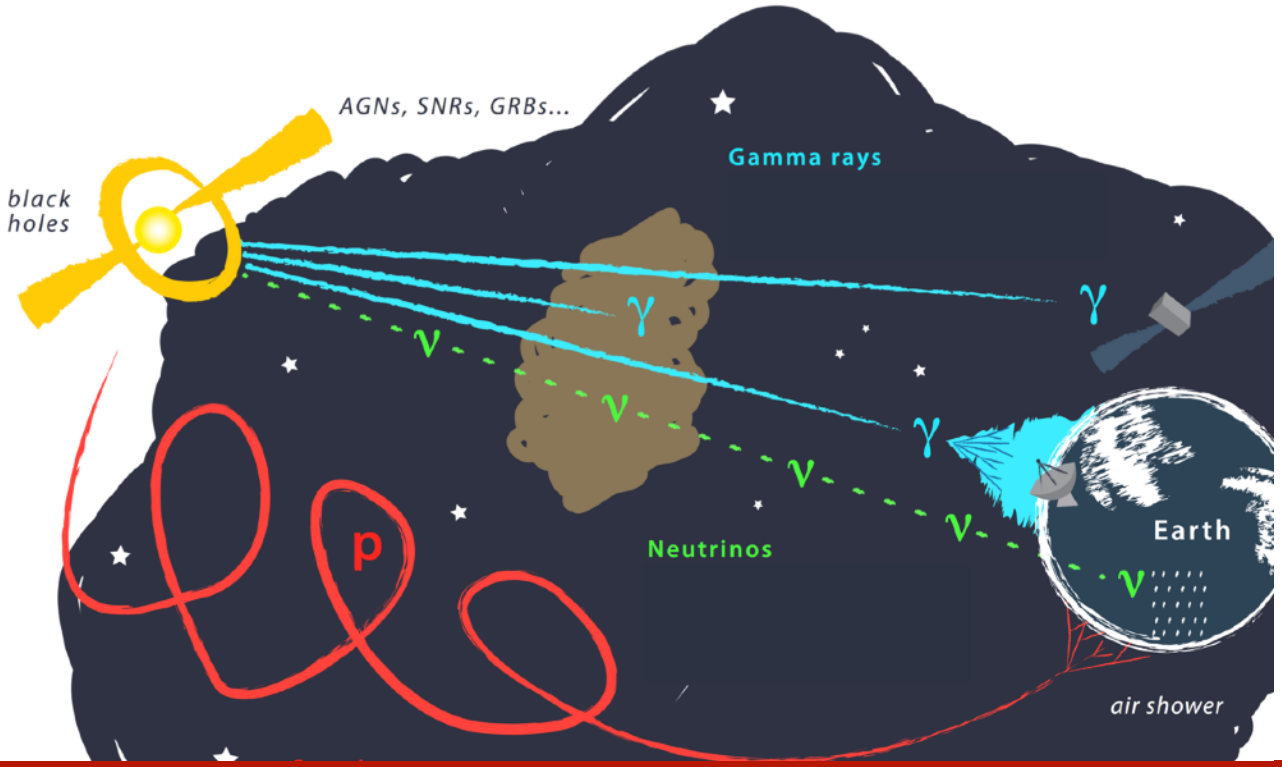
Discovered more than 100 years ago, **Cosmic Rays** are another form of "**messages of the Universe**", whose origin we cannot decipher yet. They are mostly made of protons and heavier nuclei.

Cosmic Rays reach extremely high energies, up to about 10^{21} eV, i.e., 1000 times the kinetic energy of a tennis ball at a speed of 100 km/h

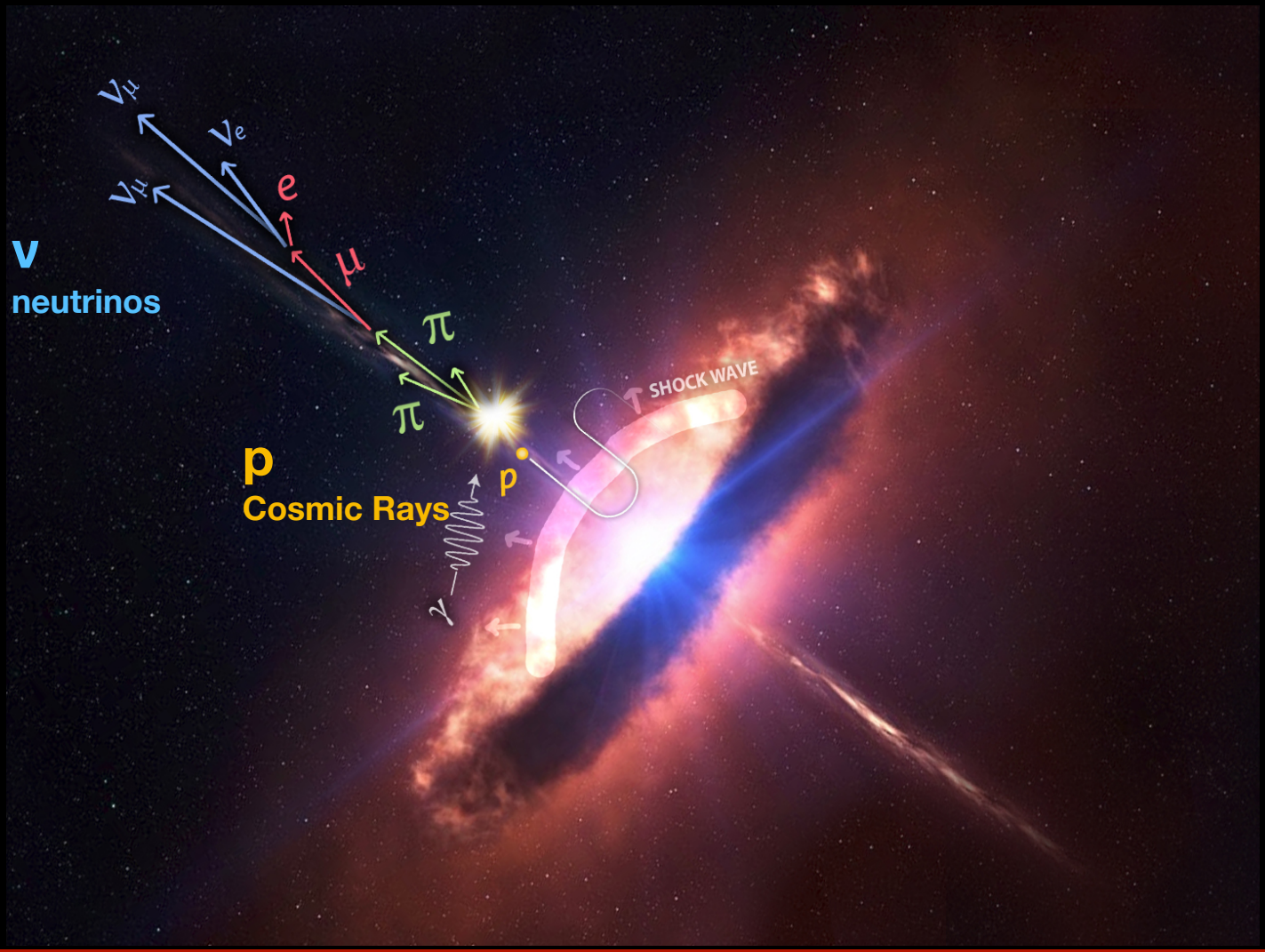
Cosmic Mysteries

It is not possible to unveil the origin of Cosmic Rays by studying the arrival directions of particles, because during their journey to Earth, Cosmic Rays gets deflected by magnetic fields and loose memory of their origin. It is necessary to use indirect methods, i.e., studying neutral particles produced after interactions of Cosmic Rays with the environments of their sources.

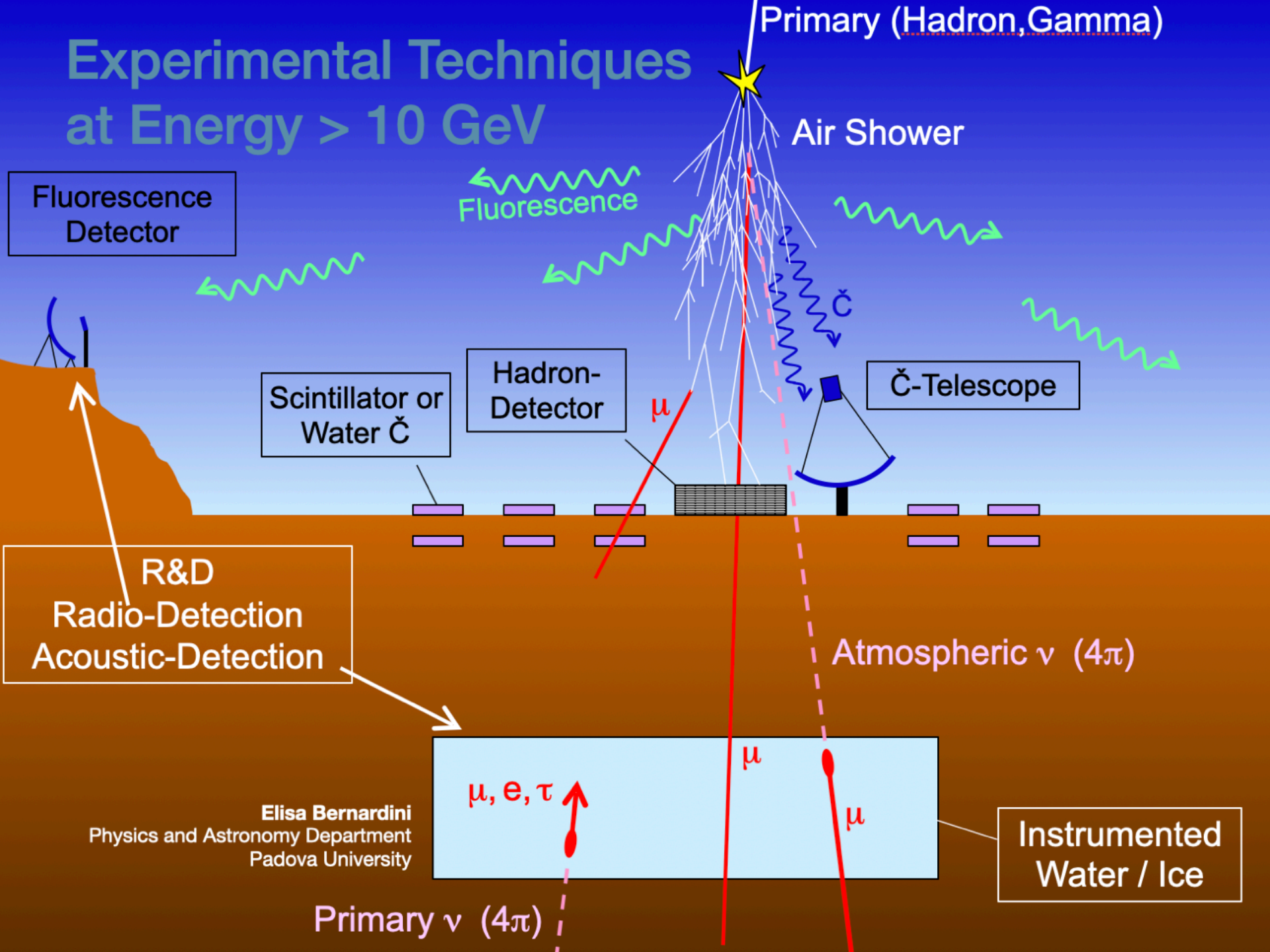
Cosmic Rays are charged particles and as such they are deflected by the magnetic fields in the Universe, while neutrinos and photons propagate along straight trajectories



A Cosmic Laboratory at extreme energies



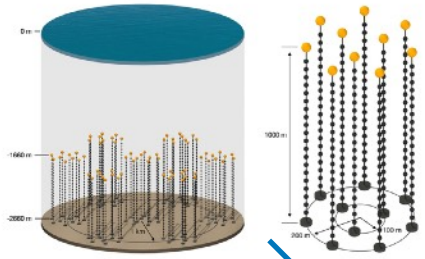
Experimental Techniques at Energy > 10 GeV



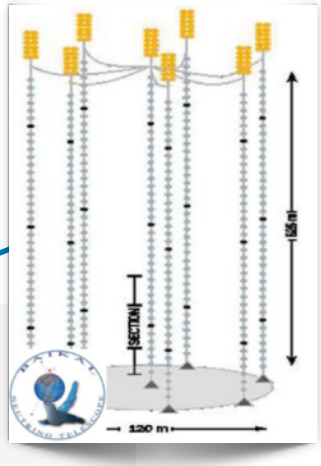
Elisa Bernardini
Physics and Astronomy Department
Padova University

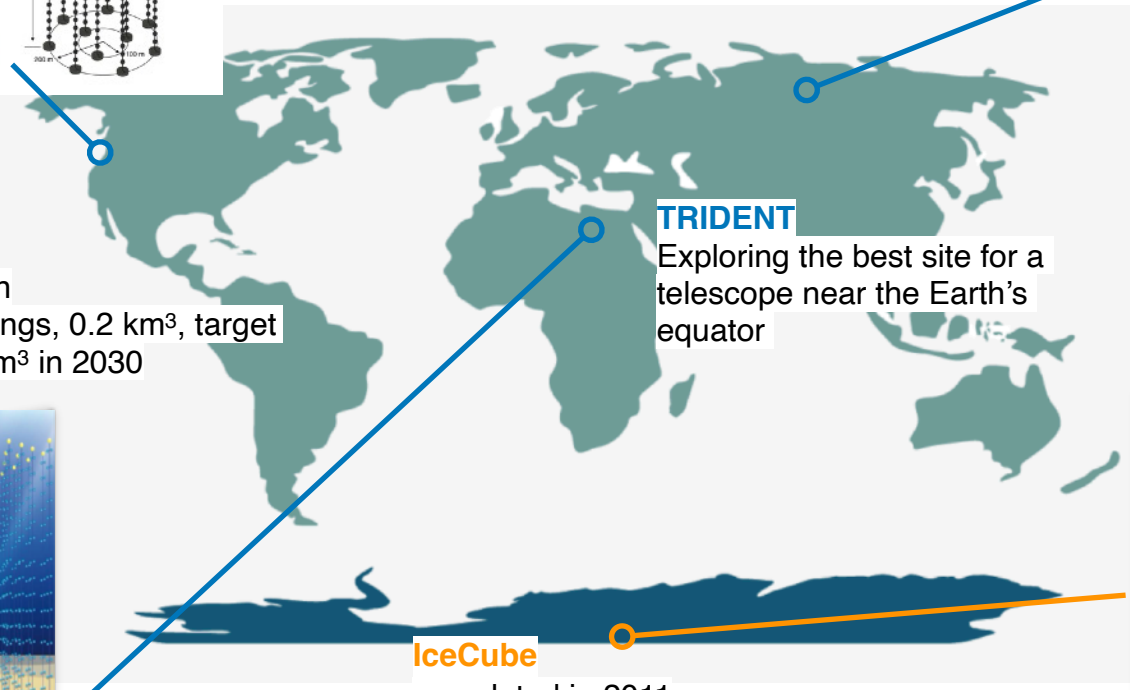
Neutrino telescopes around the World

P-ONE
Canada
R&D / design

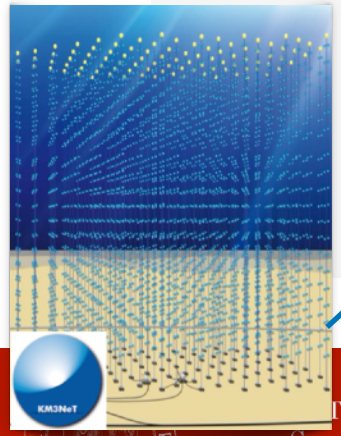


Baikal/GVD
Russia
3 out of 8 clusters, 0.4 km^3,
target 2304 OMs & 1 km^3

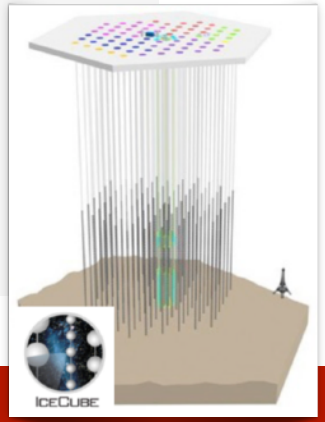




KM3NeT
Under construction
19 out of ~200 strings, 0.2 km^3, target
~4100 OMs & 1 km^3 in 2030



TRIDENT
Exploring the best site for a telescope near the Earth's equator

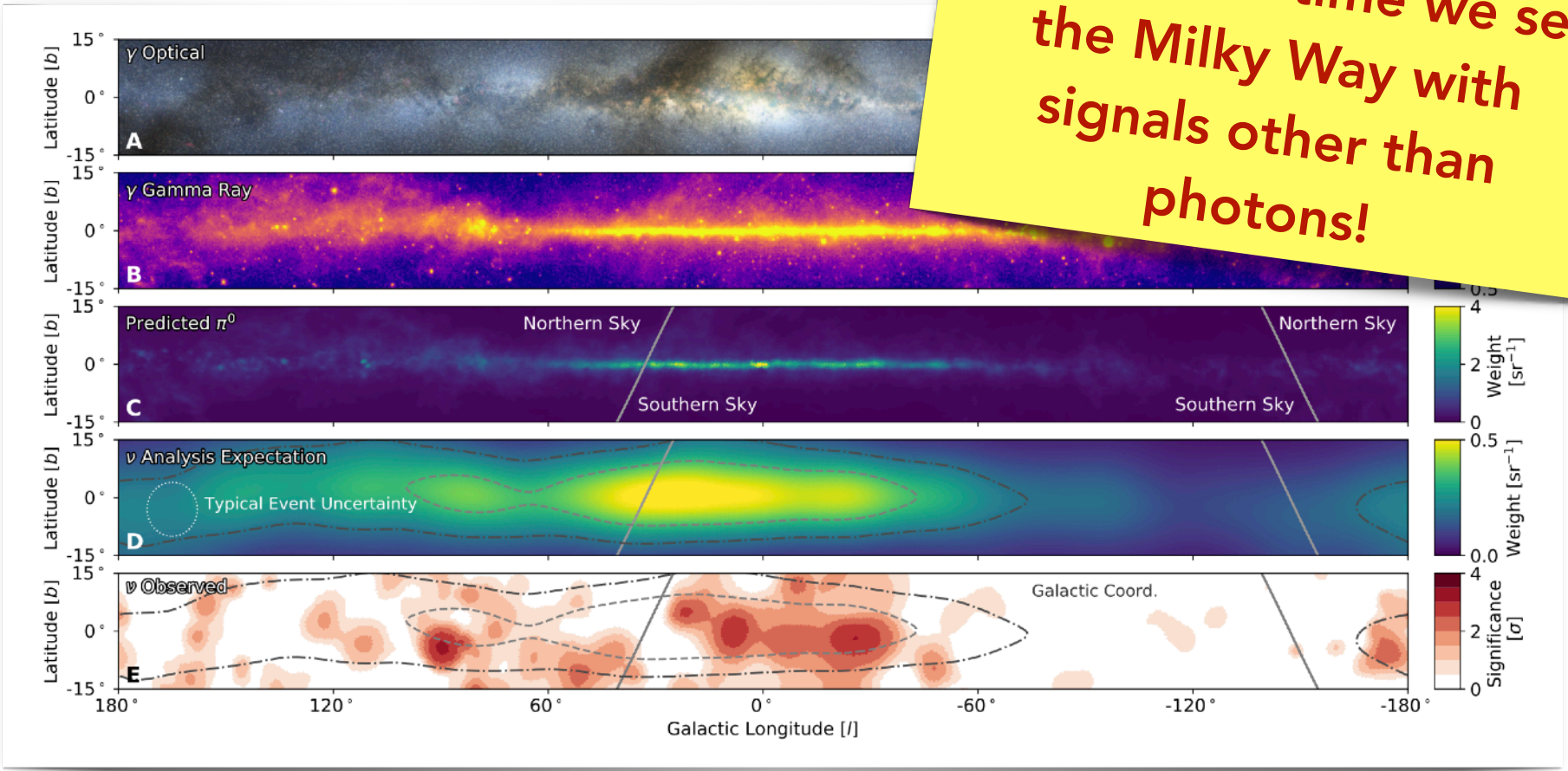


IceCube
completed in 2011
5160 OMs, ~ 1km^3
Planned 10 times extension: IceCube-Gen2 with present and new technologies

Neutrinos from the galactic plane

Machine learning techniques applied to ten years of IceCube data enabled discovering neutrino emission from the Galactic plane

For the first time we see the Milky Way with signals other than photons!

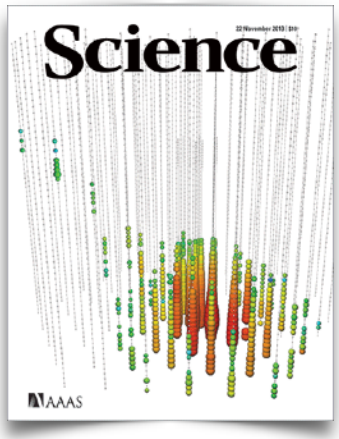


The dawn of Neutrino Astronomy

1988	2000	2001	2011	2013	2018	2021	2022	2023
Telescope in the Ice Envisioned	AMANDA Completed	Atmospheric Neutrinos Detected	IceCube Completed	Astrophysical Neutrinos Discovered	First Source TXS 0506+056 Identified	Glashow Resonance Neutrino Identified	Second Source NGC 1068 Identified	Third Source Milky Way Identified

2007

2019



2018

2019

2022

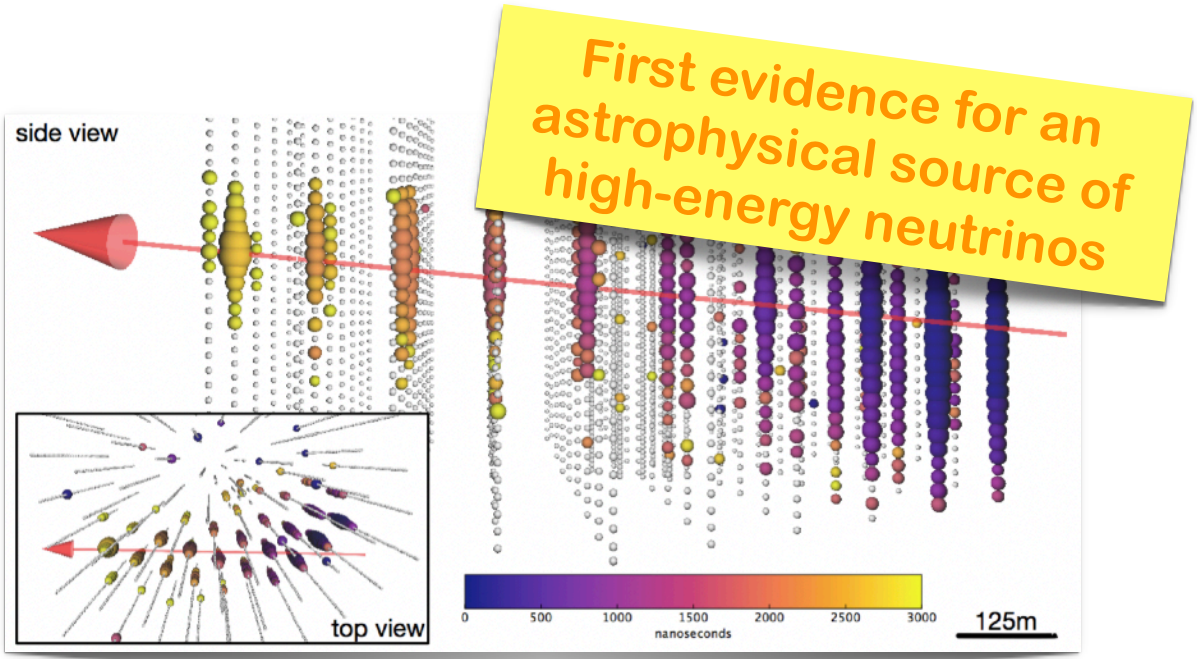
17

Some examples of the activities at DFA

A planetary effort involving more than 1000 astronomers and 18 instruments led in 2017 to the discovery of the first source of high-energy neutrinos.

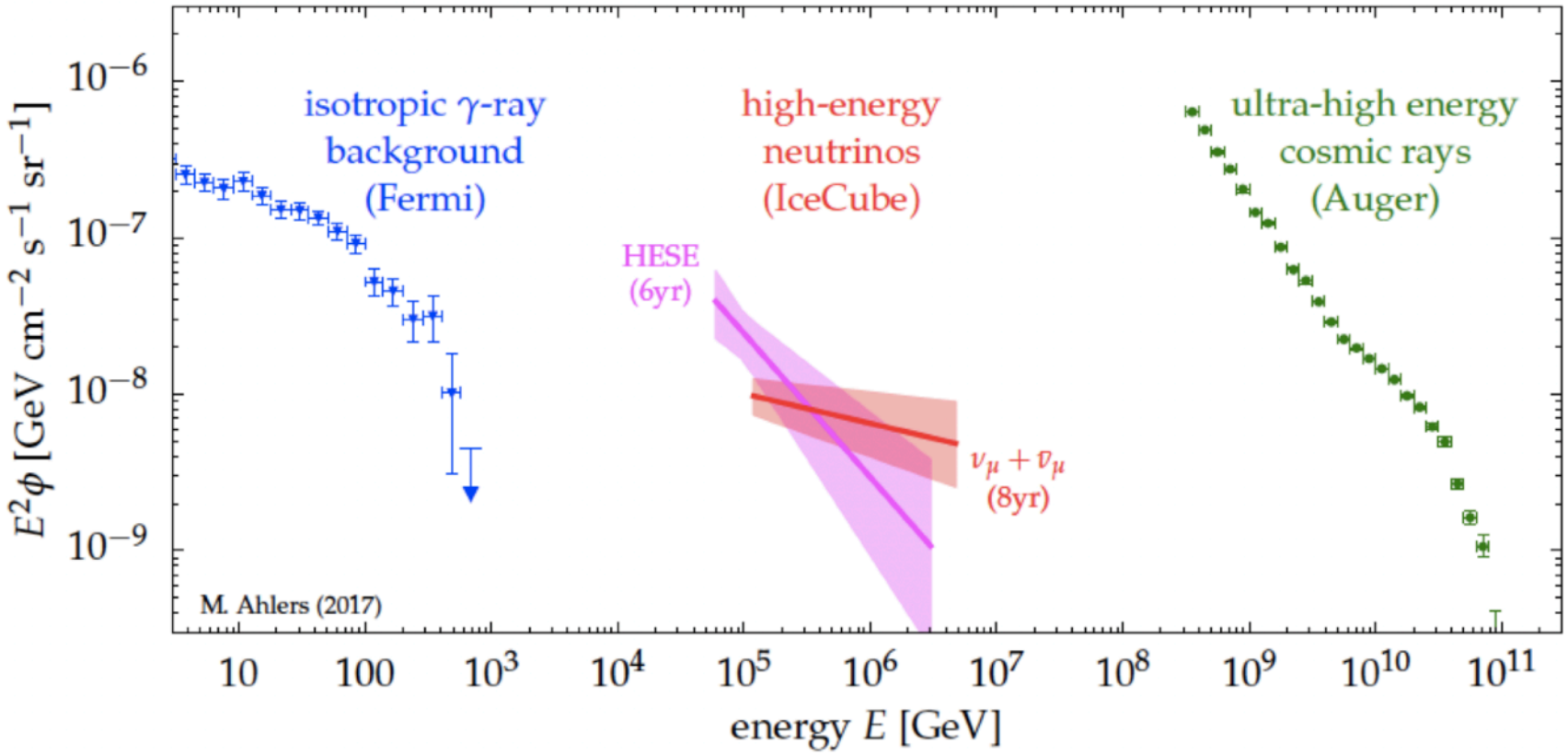
@ Padova Improving the IceCube realtime alerts for the discovery of sources of high-energy neutrinos; developing joint analyses IceCube+KM3NeT.

elisa.bernardini@unipd.it



Multi-Messenger connection

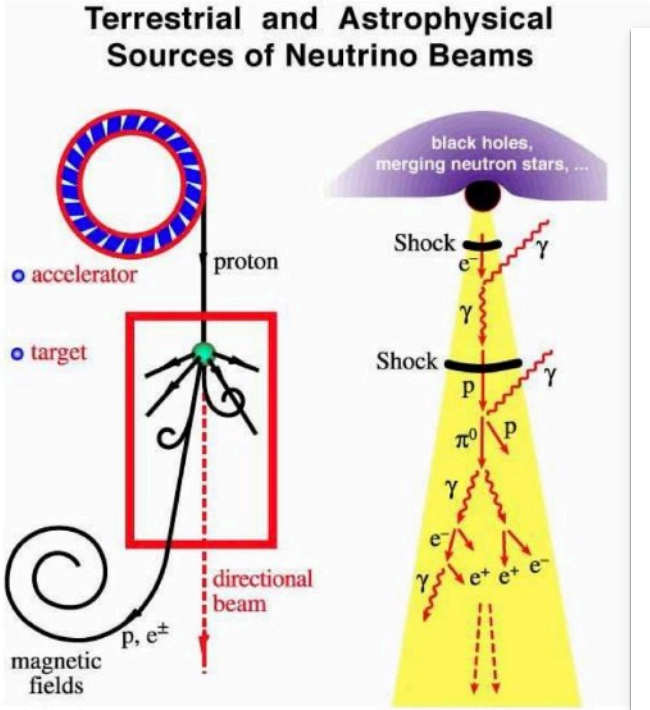
Diffuse cosmic ray, γ-ray, and neutrino fluxes show similar energy content despite their different energy regimes. This correspondence suggests an intriguing multi-messenger relationship.

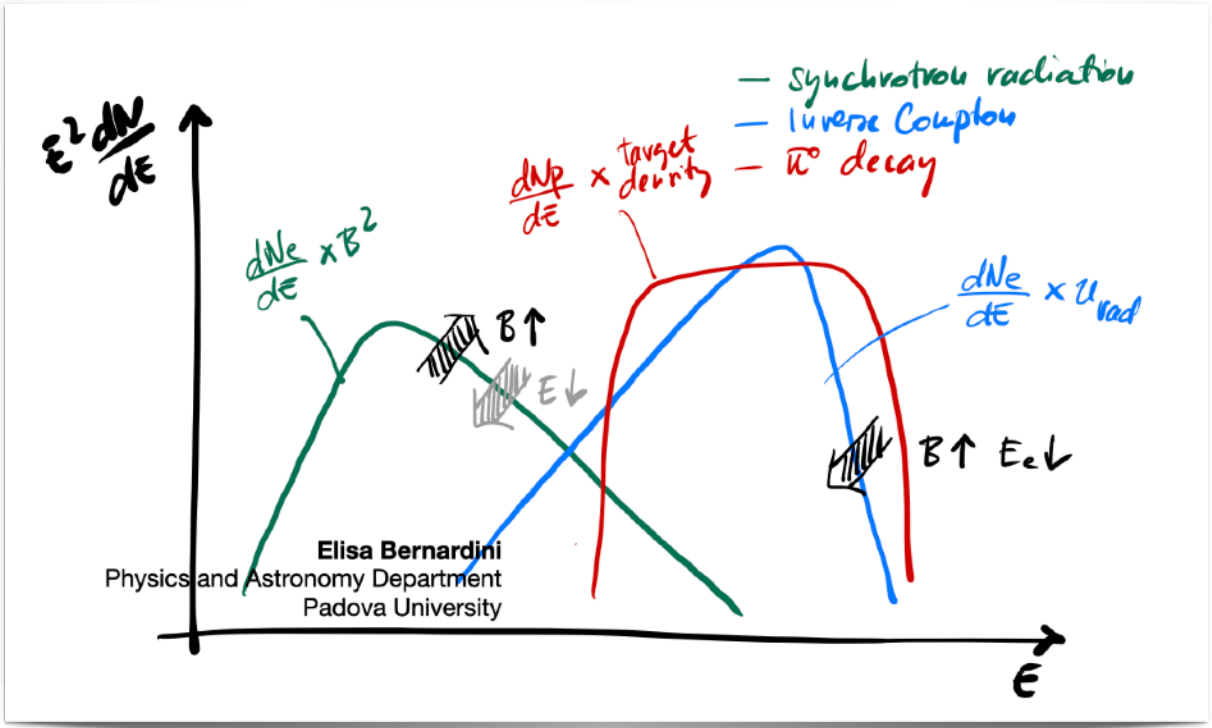


Modelling the high energy emission

Unveiling the origin of cosmic rays requires intersecting many different research areas. Among those modelling astrophysical sources with particle physics tools to explain the origin of the high energy emission

elisa.bernardini@unipd.it





Contacts

Speaker: Office n. 320, Paolotti Building
elisa.bernardini@unipd.it

Group:

- Instrumentation (photosensors): Mosè Mariotti & Riccardo Rando
- Black holes and relativistic jets in AGN: Elisa Bernardini & Elisa Prandini
- Radiative mechanisms in galactic objects: Luca Zampieri
- High energy neutrino astrophysics: Elisa Bernardini
- Fundamental (astroparticle) physics: Michele Doro & Alessandro de Angelis
- High energy surveys: Eugenio Bottacini & Riccardo Rando
- Intensity Interferometry: G. Naletto & L. Zampieri