Mapping Highly-Energetic Messengers throughout the Universe

Our team pursues cutting-edge research in the multi-messenger astrophysics field. We exploit state of the art, space- and ground-based observatories, among which the NASA Fermi Large Area Telescope (LAT) and the IceCube observatory. These facilities enable the researchers to explore cosmic-ray accelerators and investigate the origins of astrophysical neutrinos.

Contact : **Prof. Sara Buson**

sara.buson@uni-wuerzburg.de

www.sarabuson.com

Institut für Theoretische Physik und Astrophysik,
office n° 01.011, Building 31

The MessMapp Project

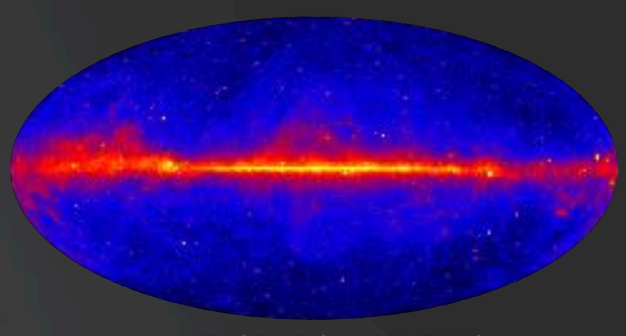
focuses on the physics of the most massive, powerful **black holes** in the Universe, i.e. active galactic nuclei (**AGN**). Some can power **relativistic jets** whose physical processes remain a mystery. MessMapp aims shedding light into their link with **cosmic rays** and **astrophysical neutrinos**.

Methodologies, Techniques, Goals

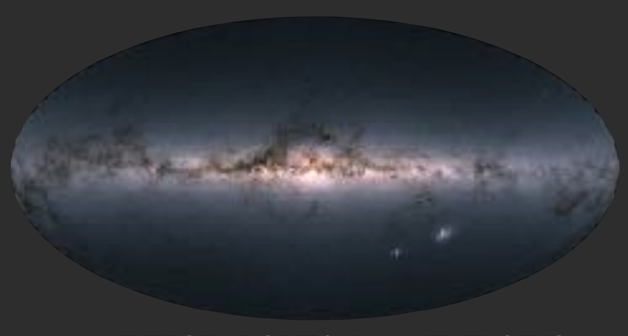
- Exploiting observations from space- and ground-based facilities.
- Developing analysis tools and theoretical models to interpret multi-messenger observations.
- Understanding the processes at work in cosmic-ray accelerators.
- Identifying electromagnetic counterparts of cosmic neutrinos.

Multi-Messenger Black Hole Astrophysics

At the center of most galaxies there is a supermassive black hole, which in some cases can accrete gas through a disk and become active. In active galactic nuclei (AGN), relativistic jets are formed when the black hole spins and the accretion disk is strongly magnetized. Jetted AGN of the **blazar** class are the most powerful persistent sources of electromagnetic radiation. They are the overwhelming population of sources detected at γ rays, as observed by the NASA *Fermi*-Large Area Telescope.



UNIVERSE AT GAMMA RAYS
(*FERMI*-LARGE AREA TELESCOPE)



UNIVERSE AT OPTICAL WAVELENGTHS
(GAIA; CREDIT: ESA/GAIA/DPAC)

Theoretical Modelling of Extragalactic Jets

Blazars are powered by mass accretion onto the central supermassive black hole of their host galaxies. Their jets are collimated beams of relativistic plasma, so powerful to out-shine the cumulative emission from all the stars of the host galaxy. The jet non-thermal radiation spans across the whole electromagnetic spectrum (from radio wavelengths to TeV γ-rays), as observed from their spectral energy distributions (SED).

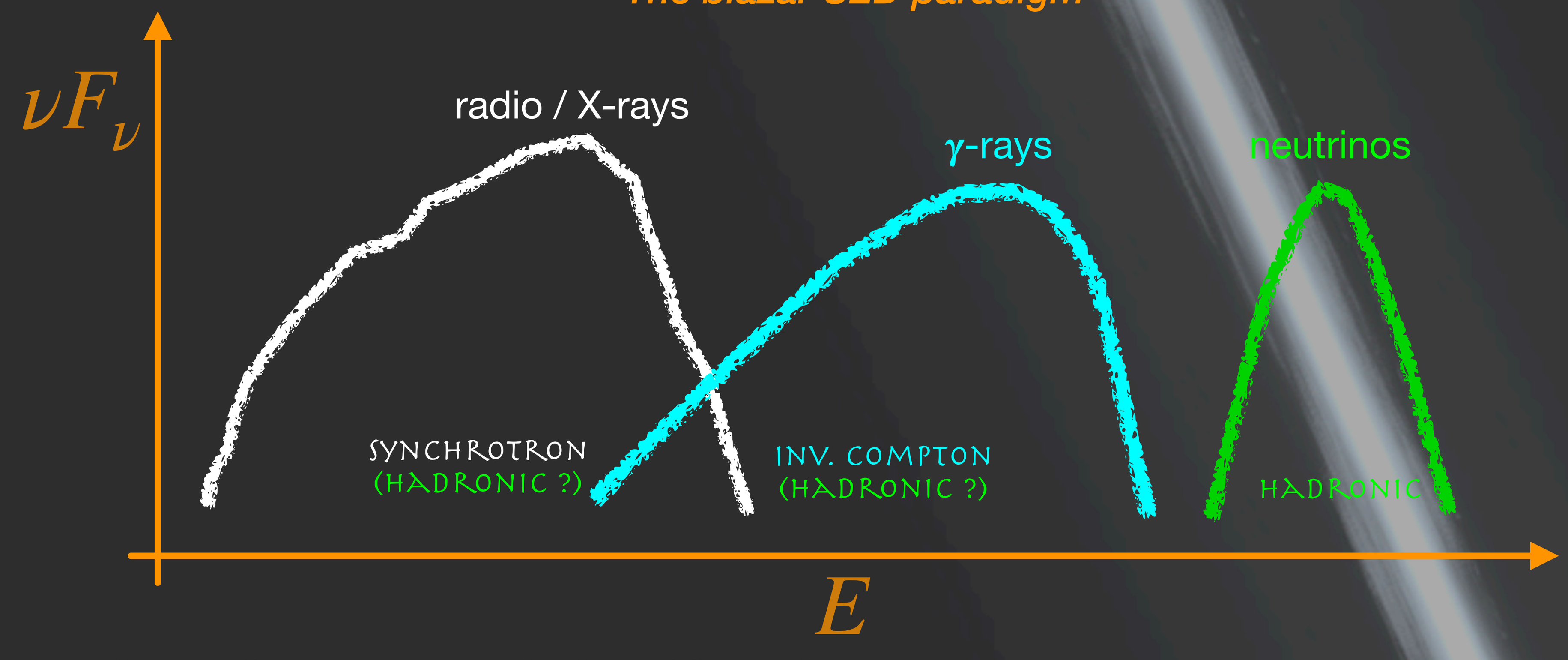
When interpreting blazars' multi-messenger observations many fundamentals physical processes are at play, from the acceleration of particles to the emission processes. A longstanding question is whether the blazar's engine is capable of accelerating hadrons, along with electrons. In this scenario, neutrinos are produced as a byproduct.

- What are the physical processes at work near supermassive black holes in AGN?
- What is the particle content of their jets?
- What fraction of cosmic rays may be ultimately linked to AGN?

Our team employs photons across the entire electromagnetic spectrum, along with neutrinos of the highest energies (≳TeV) to address these questions, among many others.

The ''smoking gun" for hadronic acceleration is the detection of astrophysical neutrinos: unlike photons, high-energy neutrinos can only be produced by hadronic interactions. Amongst the most crucial challenges of multi-messenger astrophysics is proving - both from the observational and physical point of view - an incontrovertible causality connection between these diverse population of particles. To this aim, our team develops state-of-the-art models and applies them to the multi-messenger SED of blazars.

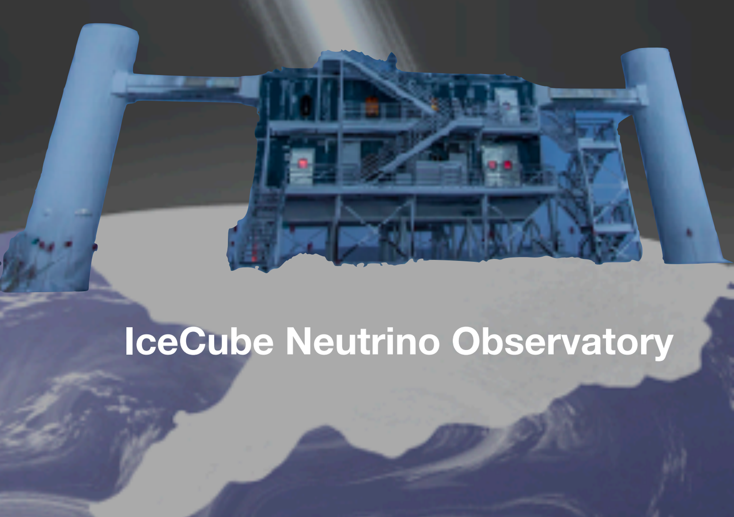
The blazar SED paradigm



Neutrino Astroparticle Physics

Neutrinos are nearly massless, ghostly particles that rarely interact with matter. As such, they are very challenging to detect and are hardly observed by experiments. Immense detectors are required to collect astrophysical neutrinos in statistically significant number. Located at the South Pole, the **IceCube observatory** is the world's largest neutrino detector. It consists of a cubic-km array of thousands of sensors buried in the antarctic ice. Despite its gigaton mass and continuous all-sky observations, IceCube allows us to pinpoint only a few high-energy cosmic neutrino interactions per year.

The recent detection by IceCube of an astrophysical neutrino flux in the 10 TeV to 10 PeV energy range opened a new window to the high-energy Universe. Despite the notable step forward the origin of these neutrinos remains largely a mystery.



IceCube Neutrino Observatory

Credits: Leonard Pfeiffer, MessMapp team