Bachelor / Master Thesis

Gamma-ray astronomy searches for evidence of astrophysical particle accelerators - sources of energetic Cosmic Rays. Within our Galaxy, there are several different types of accelerators present, including supernova remnants, pulsar wind nebulae and binary systems. However, many sources remain unidentified or are in close proximity to each other, such that their gamma-ray emission can become confused. In this project, we aim to tackle the identification of enigmatic gamma-ray sources, attributing quantitatively the confused gamma-ray emission to the different potential origins.

Disentangling Enigmatic Gamma-ray Sources

This project will use public data available from several gamma-ray facilities, with different sensitivity and resolution. The aim is to cross-identify emission in a specific sky region, characterise the properties and determine its origin. Can the gamma-ray emission detected at energies $> 10^{14}$ eV be attributed to specific accelerator types? Which source classes dominate the origin of Cosmic Rays?

You will develop programming and data analysis skills, whilst gaining a deeper knowledge of the physics of various astrophysical particle accelerators.

Physics topics related to this work:

- High Energy Astrophysics
- Gamma-ray Astronomy
- Imaging Atmospheric Cherenkov Telescopes

Skills acquired during this work:

- Python programming
- Gamma-ray data analysis
- Astrophysical source modelling

Interested? Please get in touch:

- Dr. Alison Mitchell
  alison.mw.mitchell@fau.de
  Büro 02.038, Nikolaus-Fiebiger-Str. 2

Composite multi-wavelength image of the Crab pulsar wind nebula.

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Bachelor / Master's thesis

Gamma-ray astronomy is concerned with some of the highest energy signals from the universe. Ground-based instruments detect gamma-ray photons via the Extensive Air Showers that they generate in the Earth's atmosphere. A cascade of highly energetic particles produces Cherenkov emission as they pass through water tanks located at high altitudes. By reconstructing these Cherenkov light signals, the energy and direction of the original gamma-ray photon can be determined.

The Southern Wide-field Gamma-ray Observatory (SWGO), is a Water Cherenkov Detector facility being planned to observe the Southern sky. This project will develop new techniques for calibrating the efficiency with which water Cherenkov facilities - such as SWGO - measure Cherenkov radiation.

Light Efficiency Calibration of SWGO using Muons

This project will use simulations of muons within SWGO to develop a method of calibrating the light collection efficiency. The aim is to recover how well the expected light signal from muons can be characterised, and how sensitive this measurement is to degradations in efficiency. (For example via degradation of the photomultiplier tube or of the water quality.) Furthermore, inter-calibration of individual water tanks within the array may be explored.

You will develop programming and data analysis skills, whilst gaining a deeper knowledge of the physics of extensive air showers and the detector.

Physics topics related to this work:

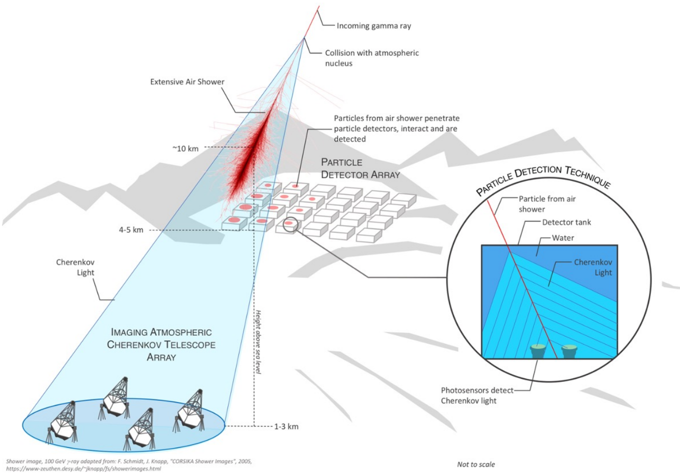
- Extensive Air Showers
- Water Cherenkov Detectors

Skills acquired during this work:

- Python and/or C++ programming
- Data analysis
- Calibration

Interested? Please get in touch:

- Dr. Alison Mitchell
  alison.mw.mitchell@fau.de



Schematic showing the detection of Cherenkov radiation from an Extensive Air Shower.

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master Thesis Project

Novae are explosive astrophysical events occurring in binary star systems, comprised of a compact White Dwarf and a massive companion star (Main sequence or Red Giant). The compact star accretes material from the massive star - until enough material accumulates to ignite a thermonuclear explosion on the surface of the White Dwarf. The resulting outburst can sometimes be bright enough to see with the naked eye. Expanding shocks from the explosion accelerate particles to high energies – producing detectable gamma-ray emission.

To date, gamma-ray emission has been detected by the Fermi gamma-ray satellite from around 17 novae in our Milky Way. However, many open questions remain, such as: what is the maximum energy reached by particles accelerated in nova shocks? How diverse are the nova environments that produce gamma-ray emission? What is the connection between the multiwavelength (MWL) components of a nova outburst?

Gamma-ray emission from novae with Fermi-LAT

This project will perform detailed analysis and modelling of gamma-ray emission from novae using Fermi-LAT. Data corresponding to known nova outbursts will be analysed to investigate the decay of emission and light curve variability. Spectral analysis and combined MWL information will be used to constrain the maximum energy and investigate the links between different components to the system. As well as novae with known gamma-ray emission, upper limits corresponding to other novae could also be useful in constraining model parameters. Source modelling will be used to explain the MWL emission and predict the expected gamma-ray emission from novae.

You will develop programming and data analysis skills, whilst studying the physics of novae and gamma-ray astronomy.

Physics topics related to this work:

- Gamma-ray Astronomy
- Astrophysics of novae

Skills acquired during this work:

- Python / C++ programming
- Gamma-ray data analysis
- Astrophysical Source Modelling

Artist's impression of a nova binary system

Interested? Please get in touch:

- Dr. Alison Mitchell, alison.mw.mitchell@fau.de

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Bachelor / Master thesis

The High Energy Stereoscopic System (H.E.S.S.) is a system of imaging atmospheric Cherenkov telescopes situated in the Khomas Highlands in Namibia. The H.E.S.S. telescopes observe the night sky in the high-energy gamma regime (from 0.03 to 100 TeV), studying fascinating objects such as pulsars, binary stars and supernovae within our Galaxy and powerful sources such as active galactic nuclei, blazars or radio galaxies outside of our Galaxy.

Analysis of moonlight & twilight data of H.E.S.S.

The Cherenkov light flashes detected by the H.E.S.S. telescopes are extremely faint, therefore the telescopes are normally operated only during complete dark time, i. e. when both the Sun and the Moon are below the horizon. In order to grant more observation time and more importantly increased flexibility for observations of transient objects such as gamma-ray bursts, we have extended the observations into twilight and moonlight time. Your task within this project will be to analyze data taken during those times of higher sky brightness and to understand how they behave compared to data taken during traditional dark time.

Physics topics related to this work:

- High-energy astrophysics
- Gamma-ray astronomy with imaging air Cherenkov telescopes

Skills acquired during this work:

- (Statistical) Analysis of astronomical data
- Programming in Python or a language of your choice
- Experience working in a large, international experimental collaboration

Interested? Please get in touch:

- Dr. Alison Mitchell, alison.mw.mitchell@fau.de

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master Thesis Project

Gamma-ray astronomy searches for evidence of astrophysical particle accelerators - sources of energetic Cosmic Rays. Gamma-rays are detected via Extensive Air Showers (EAS) that develop in the Earth's atmosphere, cascades of particles producing Cherenkov light. The size of the EAS relates to the energy of the gamma-ray, such that atmosphere acts as a calorimeter for gamma-ray detection. The light from these Extensive Air Showers is detected by Imaging Atmospheric Cherenkov Telescopes (IACTs) such as the H.E.S.S. telescope array located in Namibia.

Variation of atmospheric conditions, e.g. by the presence of aerosols of cirrus clouds, can affect the amount of Cherenkov light detected. To correctly account for these effects, Lidar measurements are used, where a laser beam is fired into the atmosphere and the amount of light reflected from different altitudes is measured.

Correcting for Atmospheric Effects using a Lidar

This project will use Lidar measurements from the H.E.S.S. site to construct an altitude dependent transmission profile for the atmosphere under varying conditions. The level of natural variations and optimum correction methods will be investigated. Different approaches will be compared, in particular their result on the final gamma-ray performance metrics. Evaluation of the methods may use both on data from the H.E.S.S. telescopes and preliminary data for the forthcoming Cherenkov Telescope Array.

You will develop programming and data analysis skills, whilst studying the physics of particle interactions and the Earth's atmosphere.

Photo of a Lidar at the VLT ESO site, Paranal. Image credit: ESO/Y. Beletsky

Physics topics related to this work:

- Atmospheric Physics
- Gamma-ray Astronomy
- Imaging Atmospheric Cherenkov Telescopes

Skills acquired during this work:

- Python / C++ programming
- Gamma-ray data analysis
- Lidar instrument data analysis

Interested? Please get in touch:

Dr. Alison Mitchell, alison.mw.mitchell@fau.de
Dr. Rodrigo Guedes Lang, rodrigo.lang@fau.de

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Bachelor / Master's thesis

Gamma-ray astronomy searches for evidence of astrophysical particle accelerators - sources of energetic Cosmic Rays. Within our own Milky Way Galaxy, a wide variety of natural particle accelerators are known, including supernovae, pulsars and their environments, stellar clusters and binary star systems. To identify the origins of the most energetic Cosmic Rays in our Galaxy, a new facility, the Southern Wide-field Gamma-ray Observatory (SWGO), is being planned to observe the Southern sky. This project will investigate the potential SWGO has for studying different phenomena in the very-high-energy gamma-ray sky. Recent results from both the HAWC and LHAASO facilities have revealed exciting discoveries in the Northern sky - what could we see in the South?

Galactic Sources with SWGO

This project will simulate different source classes that we expect to encounter with SWGO in the Southern sky. The aim is to identify which areas SWGO will outperform other experimental facilities and consolidate the open questions where SWGO will excel. Possible projects may focus on simulating pulsar environments in various evolutionary stages, on stellar clusters, or on time-varying sources such as binary systems comprised of a massive star and a compact companion (White Dwarf, Neutron Star or Black Hole).

You will develop programming and data analysis skills, whilst gaining a deeper knowledge of the physics of various Galactic sources of cosmic rays.

Physics topics related to this work:

- High Energy Astrophysics
- Gamma-ray Astronomy
- Imaging Atmospheric Cherenkov Telescopes

Skills acquired during this work:

- Python programming
- Gamma-ray data analysis
- Astrophysical source modelling

Composite multi-wavelength image of the Crab pulsar wind nebula.

Interested? Please get in touch:

- Dr. Alison Mitchell
  alison.mw.mitchell@fau.de

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master's Thesis

Analysis of Low-Level H.E.S.S. Data Using New Open-Source Tools

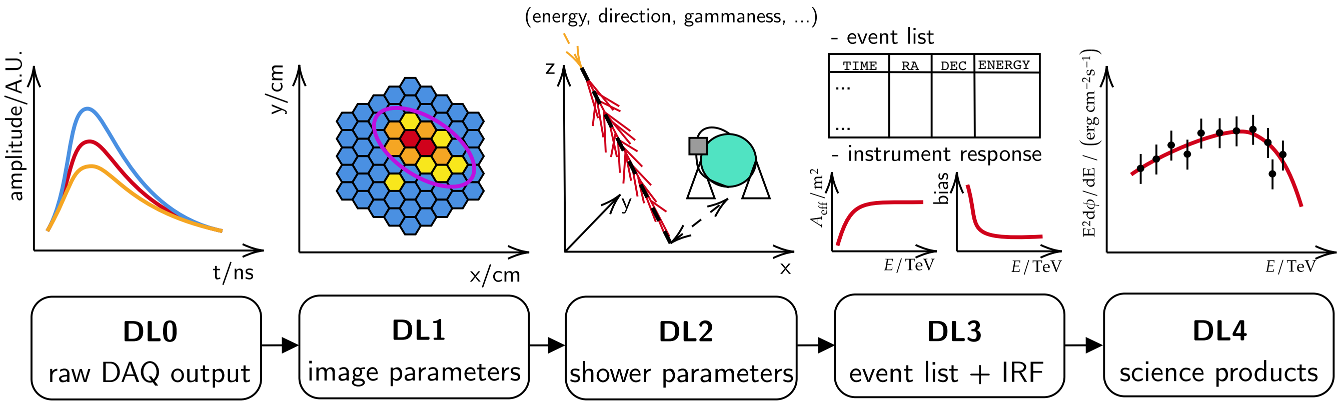


Abbildung 1: The standard IACT data processing framework, figure from Nigro et al. 2021 (arXiv:2109.14661).

High Energy Stereoscopic System (H.E.S.S.) is an array of Imaging Atmospheric Cherenkov Telescopes (IACTs) located in Namibia, that has been operated since 2004. It is designed to observe the γ-ray sky from 0.03 – 100 TeV, and does so by observing Extensive Air Showers (EAS) created when such photons interact in Earth's atmosphere. H.E.S.S. observations have historically relied on closed-source *ROOT*-based pipelines to process the data from the telescopes. However, these pipelines are difficult to interface with state-of-the-art machine learning analyses based on *Python*. Valuable low-level H.E.S.S. data (such as event images) processed with these proprietary pipelines will be difficult to maintain.

The aim of the project will be to develop a plugin for the *ctapipe* package, developed for the next-generation Cherenkov Telescope Array (CTA), to allow for the processing of H.E.S.S. data. Potential extensions include in-depth comparisons of the performance or replication of recent deep multi-task learning results from the CTA Large Size Telescope prototype on La Palma.

Skills acquired during this work:

- Open-Source Software Development Using *Python* and *PyROOT*
- IACT Data Analysis
- Machine Learning

Interested? Please get in touch:

- Dr. Samuel Spencer, samuel.spencer@fau.de
  Büro 02.042, Nikolaus-Fiebiger-Str. 2

- Dr. Alison Mitchell, alison.mw.mitchell@fau.de
  Büro 02.038, Nikolaus-Fiebiger-Str. 2

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Bachelor / Master's thesis

in Hardware Development

The Cherenkov Telescope Array (CTA) is the next generation of telescope systems to observe high-energy gamma rays. In line with CTA, the ECAP/work group of Stefan Funk takes an active part in the development of a front-end electronics, based on the sampling (CTC) and trigger (CT5TEA) ASIC (application-specific integrated circuit) TARGET (TeV array readout and Event Trigger). This is to take over the digitization of silicon photomultiplier signals in the Small Size Telescope Cameras (SSTCam).

Bachelor thesis

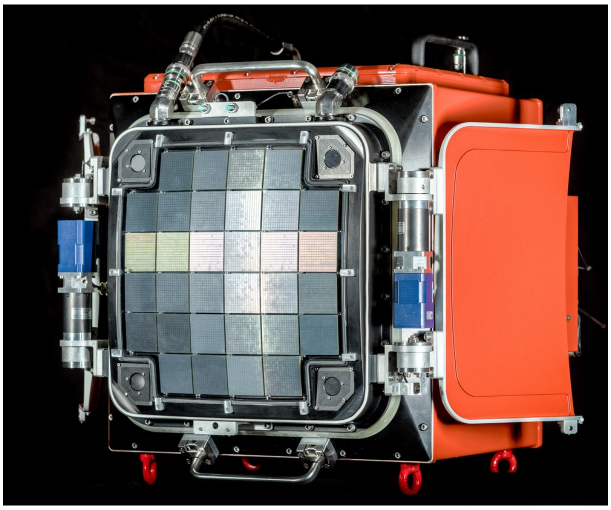
- Characterisation of trigger and read-out chain of the latest TARGET ASIC generation
- Optimization of the trigger threshold lookup generation for the SSTCam TARGET modules
- Developing a robust peak extraction algorithm for CTC
- In-depth study of the CTC's "cell 32 anomaly"

Master's thesis

- Optimization of the CTC timing parameters and time-base calibration
- Online CTC ramp tuning for temperature variation compensation

Physics topics related to this work

- Ground based gamma ray telescopes
- State-of-the-art electronics



Skills acquired during this work

- Statistical analysis of data
- Programming in Python
- Understanding of electronics instruments

Interested? Please get in touch!

Prof. Stefan Funk, s.funk@fau.de
Room 02.036, ECAP laboratory

Bachelor thesis

in Hardware Development

Characterisation of trigger and read-out chain of the latest TARGET ASIC generation

The goal of this thesis is to understand the performance of the latest TARGET Trigger ASIC (CT5TEA). Several parameters can be tuned to achieve low noise and low trigger thresholds, which enables the detection of single photon pulses or a large dynamic range for multi-photon signals with high precision. The knowledge from previous versions can be used as a good starting point.

Optimization of the trigger threshold lookup generation for the SSTCam TARGET modules

For CTA, the ECAP will produce, commission and calibrate in the order of 1,000 TARGET modules for a large fraction of the envisaged 37 SSTCams. One of the main calibration topics is the generation of a trigger threshold lookup. Clever routines and/or new methods need to improve the time needed for this step.

Developing a robust peak extraction algorithm for CTC

For the energy reconstruction of a gamma ray event, it is important to accurately determine the number of detected Cherenkov photons. This number is proportional to the amplitude and intergral of the voltage pulse measured in the Silicon Photomultiplier. Extracting these is crucial to the success of CTA. To archive the best possible signal to noise ratio, a matched filter shall be implemented for the peak extraction. As there will be 37 SSTCams build with 32 TARGET modules each, it is important to know how sensitive the algorithm is to variations and environmental factors.

In-depth study of the CTC's "cell 32 anomaly"

To avoid uncontrollable amounts of data, the CTC ASIC uses a ring buffer to temporally store the data before it is digitized (if a trigger hits). One issue of this ring buffer is, that the 31st sample modulo 32 shows a different behaviour, limiting the resolution of the Analog to Digital Converter and therefore the resolution of the SST Cam. The task would be to localise the cause of this behaviour in the ASIC and to fix it.

Interested? Please get in touch!

Prof. Stefan Funk, s.funk@fau.de
Room 02.036, ECAP laboratory

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master’s thesis
in Hardware Development

Optimization of the CTC timing parameters and time-base calibration

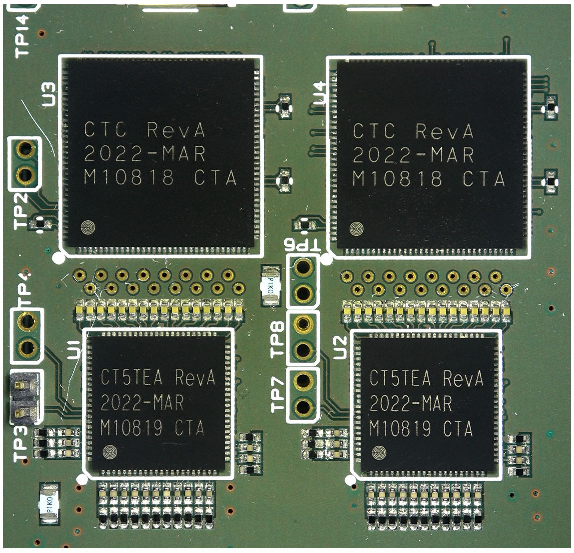
The main advantages of the CTC ASIC over a classic flash ADC are the cost and compactness. They come at the cost of an switched capacitor array, where the sampling and digitizing process is separated, sampling on ns scale, digitizing on µs scale. Due to the manufacturing process the time-base of the switched capacitor array is not homogeneous, leading to variations in the time width of the individual samples. In this work you will develop a method to take this variation into account in data analysis. Another part will be the optimization of the ASIC’s internal timing parameter, that will have an impact on these variations.

Online CTC ramp tuning for temperature variation compensation

The CTC has shown a great temperature dependency, which could be localised in the Analog to Digital Converter, where the sample gets compared to a rising voltage ramp, while a clock counts the time until the ramp crosses the sampled value. The slope of the ramp changes with temperature, leading to higher or lower values of the clock. Additional to that, the slope of the ramp voltage changes with the voltage of the sampled value. Past approaches calibrated the whole ASIC including the ring buffer, which is computationally and data intensive. For the data out of CTA, the calibration needs to be as accurate as simple to run on a server which host over 37 SSTs.

Interested? Please get in touch!

Prof. Stefan Funk, s.funk@fau.de
Room 02.036, ECAP laboratory



ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

Master's Thesis

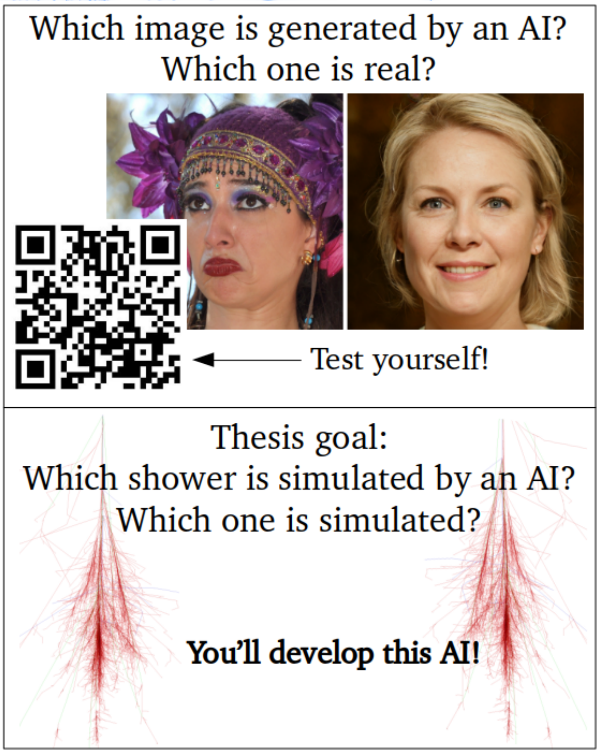
Artificial intelligence (AI) has become an integral part of our daily lives, revolutionizing industries and enhancing our capabilities in countless domains. With recent breakthroughs in deep learning, AI has demonstrated its immense potential to tackle complex challenges. We are now at an exciting juncture where we can harness the power of AI to accelerate knowledge discovery in fundamental science using novel algorithms with unprecedented performance.
Modern experiments and observatories detect an enormous amount of data, requiring large amounts of simulations which are time-consuming and computationally expensive. With the recent progress in deep learning, we can accelerate such simulations using generative models.

Accelerating Air Shower Simulations using Deep Neural Networks

In this master's thesis, we aim to develop an algorithm that accelerates the generation of air shower simulations, simulated using CORSIKA, through the use of state-of-the-art network architectures like generative adversarial networks or diffusion models. Air showers are cascades of particles generated when high-energy cosmic rays interact with the Earth's atmosphere. Since, in theory, each particle interaction has to be simulated, the generation of air showers is time-consuming.

By leveraging deep neural networks, we can generate these simulations much faster and more efficiently than traditional methods, paving the way for cost-efficient algorithms that not only accelerate the generation of air shower simulations but also enables to enhances their accuracy by increasing their details without an increase in computational costs.

As a member of our research group, you will work alongside passionate physicists and machine learning enthusiasts, and we offer you access to a powerful GPU computing cluster. Take advantage of this opportunity to combine your passion for physics and AI while contributing to the scientific community!



Top: www.whichfaceisreal.com, photographs from the FFHQ dataset, generated image from www.thispersondoesnotexist.com. Bottom: Fabian Schmidt

Physics topics related to this work:

- Development of deep learning algorithms
- Simulation of particle cascades

Skills acquired during this work:

- Python coding skills
- Expertise in machine learning, deep learning, and data science

Interested? Please get in touch:

- Dr. Jonas Glombitza, jonas.glombitza@fau.de
- Prof. Dr. Stefan Funk, s.funk@fau.de

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master's Thesis

Are you fascinated by the ever-expanding possibilities of Artificial Intelligence (AI) and its impact on our daily lives? Are you passionate about unraveling the mysteries of physics?
We invite you to embark on a cutting-edge journey as we explore the application of AI in the context of physics challenges. With recent breakthroughs in deep neural networks, AI has reached new heights, demonstrating its immense potential to tackle complex challenges. Modern experiments and observatories produce an enormous amount of data, often too vast and complex for traditional analysis methods to fully comprehend. With AI, we can analyze this vast trove of information with unprecedented efficiency and accuracy.

Improved reconstruction algorithms using Deep Neural Networks

This thesis work focuses on the improved reconstruction of Air Showers detected by Imaging Atmospheric Cherenkov Telescopes (IACTs), like the Cherenkov Telescope Array. Air Showers are cascades of particles generated when high-energy cosmic rays collide with the Earth's atmosphere. The accurate reconstruction of these events is crucial for understanding the nature and origins of cosmic rays. By leveraging state-of-the-art network architectures and advanced machine learning techniques, you will be at the forefront of developing innovative approaches for the precise reconstruction of Air Showers.

As part of our research group, you will work with passionate physicists with a strong background in machine learning, gaining expertise in data science and event reconstruction. Moreover, you will have access to powerful computing resources, including NVIDIA A100 and NVIDIA A40 GPUs, ensuring that you have the necessary tools to execute your research fast and efficiently.

Physics topics related to this work:

- Development of deep learning algorithms
- Experimental detection of astroparticles

Skills acquired during this work:

- Python coding skills
- Expertise in machine learning, deep learning, and data science

Interested? Please get in touch:

- Dr. Jonas Glombitza, jonas.glombitza@fau.de
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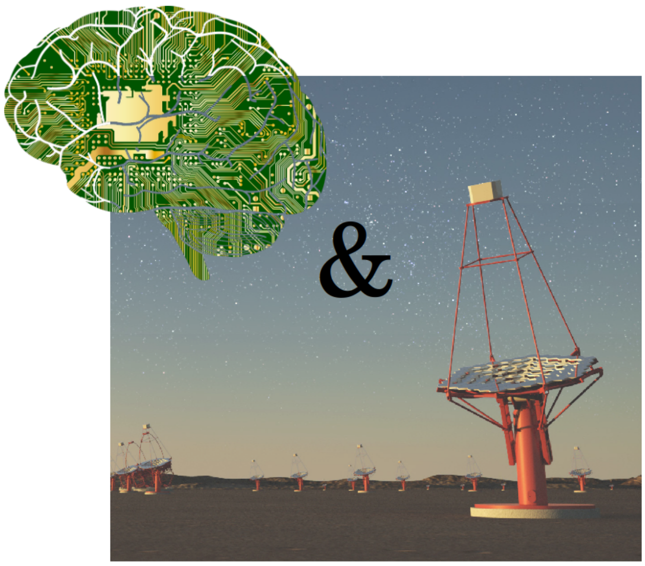
- Prof. Dr. Stefan Funk, s.funk@fau.de
  Nikolaus-Fiebiger-Strasse 2



Modification of private work by G. Perez, IAC
and https://www.pngwing.com/en/free-png-bppox

ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

Master’s Thesis

Relativity has been one of the most widely tested theories ever and yet it has survived every experimental test so far. Nevertheless, several novel high-energy models either accommodate or assume some deviation of relativity via Lorentz invariance violation (LIV). This effect is expected to become significant only at the highest energies and, thus, astroparticles play a crucial role in searching for signals of LIV.

Estimating the potential of SWGO to study Lorentz invariance violation

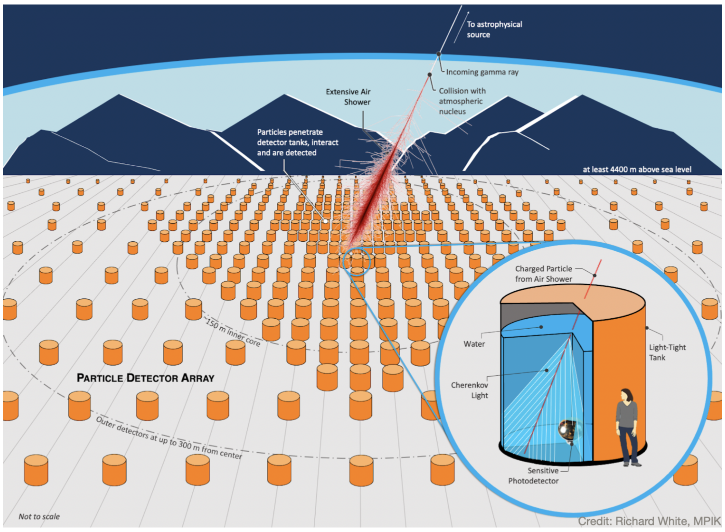
Over the last years, the potentiality of using astroparticles as a probe for LIV has been extensively proved. In particular, very-high-energy (VHE) gamma rays play an important role in this search due to their high energy, long travel distance (which leads to accumulation of the effects), and exceptional experimental precision. Several phenomenological tests of LIV using data from the current generation of experiments have been performed. No signal of LIV has been detected, leading to the most restrictive limits on the energy range of validity of relativity imposed up to date. The Southern Wide-field Gamma-ray Observatory (SWGO) is a planned future ground-particle-based experiment to be built high in the Andes currently in the research and development phase. The aim of this thesis is to estimate the potential of SWGO to study LIV, in particular by calculating the expected level of imprint in data coming from a modified interaction of gamma rays with the extra-galactic background light (EBL) and/or from photons of different energy having a different “speed of light” due to LIV.

Physics topics related to this work:

- Lorentz invariance violation
- Propagation of gamma rays and the EBL
- Ground-based gamma-ray observatories

Skills acquired during this work:

- Phenomenological interplay between theoretical and experimental physics
- Data analysis techniques



Scheme of SWGO
Credits: Richard White, MPIK.

Interested? Please get in touch:

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- Prof. Dr. Stefan Funk, s.funk@fau.de
  Büro 219, Erwin-Rommel-Str. 1

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master thesis

The Cherenkov Telescope Array (CTA) is the next generation Imaging Atmospheric Cherenkov Telescope (IACT). With more than 100 telescopes located in the northern and southern hemispheres, CTA will be the world's largest and most sensitive high-energy gamma-ray observatory in the 20 GeV to 300 TeV band. Construction of CTA has started and will last for several years.

Fermi bubbles are two large lobes above and below the center of our Galaxy which are visible in gamma-rays. Possible mechanisms of creation of these bubbles are either an activity of the supermassive black hole at the center of the Galaxy or a period of intensive star formation in the vicinity of the Galactic center. Although the bubbles were discovered about 13 years ago, the question of their origin is still unresolved. Analysis of the Fermi LAT data between 1 GeV and 1 TeV shows that the bubbles have a larger intensity of emission and a hard energy spectrum near the Galactic center, which opens up a possibility of a detection with IACTs. A study of the Fermi bubbles at energies above 100 GeV near the Galactic center will help to resolve the puzzle of their origin.

Fermi bubbles: sensitivity study for CTA

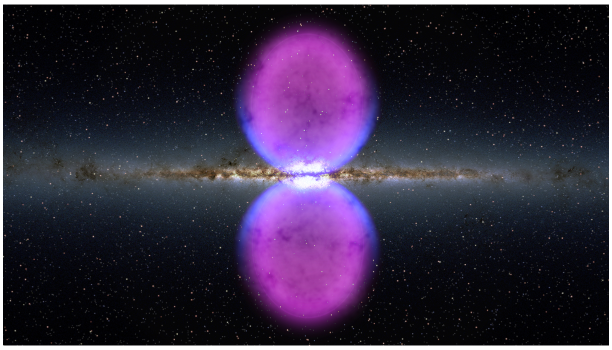
In the master thesis, we will use Monte Carlo simulations of CTA data to study the sensitivity of CTA to detect the Fermi bubbles near the Galactic center. The main goal is to separate the Fermi bubbles from the residual background of hadronic cosmic rays as well as from other sources of very high energy gamma-ray emission in the area. The project will pave the way for the future analysis of the Fermi bubbles with CTA data, when the construction of CTA will be finished.

Physics topics related to this work:

- High-energy astrophysics
- Observation of very high energy gamma rays with IACTs

Skills acquired during this work:

- Programming in Python
- Analysis of gamma-ray data
- Maximum likelihood methods



Artist's view of the Fermi bubbles.
Credit: Fermi-LAT, NASA

Interested? Please get in touch:

- Dr. Dmitry Malyshev, dmitry.malyshev@fau.de
  Room 02.050, Nikolaus-Fiebiger-Str. 2
- Prof. Dr. Stefan Funk, s.funk@fau.de
  Room 02.036, Nikolaus-Fiebiger-Str. 2

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master thesis

Fermi Large Area Telescope (LAT) is a gamma-ray space telescope. It measures gamma-ray emission from the whole sky in energies from 30 MeV to above 1 TeV. The gamma-ray emission consists of extended diffuse emission components and emission from individual sources, such as supernova remnants, supermassive black holes, neutron stars. The latest catalog of sources consists of about 6700 sources. About one third of the sources do not have known associations with multi-wavelength counterparts. Machine learning (ML) methods have been used to predict the classes of unknown sources by training the ML algorithms using associated sources. Recently, the procedure for multi-class classification of Fermi LAT sources has been developed.

Multi-class classification of gamma-ray sources using machine learning

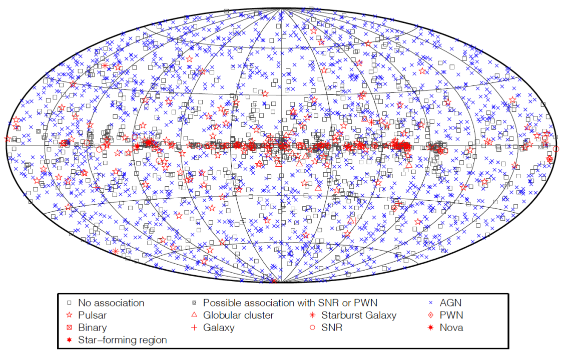
The goal of the master thesis will be to further develop the multi-class classification of Fermi LAT sources using ML algorithms (such as random forest and neural networks) and to work on applications of the multi-class classification for the characterization of the Fermi LAT sources, e.g., classification of the unassociated sources. There are also several classes with uncertain associations, such as blazars of unknown type and sources where both a supernova remnant and a pulsar wind nebular are present. The ML algorithms can be also used to determine the physical type of these sources.

Physics topics related to this work:

- Study different sources of gamma rays
- Measurements of gamma-rays with a space-based telescope

Skills acquired during this work:

- Multi-class classification using machine learning algorithms with python
- Application of machine learning for population studies of Fermi LAT sources



Associated and unassociated Fermi-LAT sources in the third Fermi-LAT catalog.

Interested? Please get in touch:

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  Room 02.050, Nikolaus-Fiebiger-Str. 2
- Prof. Dr. Stefan Funk, s.funk@fau.de
  Room 02.036, Nikolaus-Fiebiger-Str. 2

Master thesis

The High Energy Stereoscopic System (H.E.S.S.) is an Imaging Atmospheric Cherenkov Telescope (IACT) that measures gamma rays with energies above about 100 GeV. H.E.S.S. consists of four medium-size and one large-size telescopes. H.E.S.S. has detected numerous point-like and slightly extended sources. However, detection of sources with extension exceeding a few degrees is challenging due to small field of view (less than 5 degrees diameter) and large residual background from cosmic ray showers. In order to study such sources one needs a background model that covers the full H.E.S.S. field of view rather than to use the on-off analysis method, which is used for small-size sources.

Development of H.E.S.S. background model with deep learning

A method for data-driven background determination from high-latitude observations has been developed: background model is derived by averaging the data outside of the known sources of high-energy gamma rays. This method however requires a choice of binning in several variables, such as energy and zenith angle, which leads to high systematic uncertainties at small and high energies. The project is to determine the background model using deep learning methods, more specifically a decoder that takes some input parameters, e.g., energy and zenith angle, and outputs a map representing the expected background.

Physics topics related to this work:

- High-energy astrophysics
- Observation of very high energy gamma rays with IACTs

Skills acquired during this work:

- Programming in Python
- Deep learning methods

Interested? Please get in touch:

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