Bachelor / Master thesis

CTA, H.E.S.S., Fermi LAT, SWGO

2021 / 2022

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

1. **High level data analysis**
   - Searching for Dark Matter using gamma rays
   - Using gamma-ray simulations to model cosmic-ray background
   - Investigation of Crab Nebula and PKS 2155–304 data from the H.E.S.S. Telescopes
   - The H.E.S.S. real-time analysis for the detection of gamma flares
   - Fermi bubbles: sensitivity study for CTA and a search in H.E.S.S. data
2. **Instrument development and low level data analysis**
   - Calibration of an advanced mirror measurement facility
   - Design and construction of a mirror testing facility
   - Simulating the orientation of CTA telescopes
   - Obtaining the orientation of CTA telescopes through sky images
   - Testing and optimization of ASICs for CTA cameras
   - Analysis of moonlight data of H.E.S.S.
   - Gamma-hadron separation with neural networks

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Master's Thesis
Spring 2021

The **High Energy Stereoscopic System (H.E.S.S.)** is the most successful telescope to detect highly energetic gamma radiation with energies above 100 GeV. At its location in Namibia, it has an optimum view onto the Milky Way, and has detected more than 100 galactic gamma-ray sources.

Searching for Dark Matter using gamma rays

The inner Galactic Halo is a perfect region to search for dark matter annihilations: In most annihilation scenarios, gamma rays are produced which may be detected by telescopes such as H.E.S.S. In this thesis, a search for TeV-mass dark matter is carried out, using advanced analysis techniques and data from the H.E.S.S. telescopes.

Physics topics related to this work:

- Analysis techniques in very-high-energy gamma-ray astronomy
- Indirect dark matter searches

Skills acquired during this work:

- Large-scale data analysis in gamma-ray astronomy
- Using Python for data analysis
- Working together in a motivated team

Interested? Please get in touch!

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Bachelor's/Master's Thesis

Spring 2021

The **High Energy Stereoscopic System (H.E.S.S.)** is the most successful telescope to detect highly energetic gamma radiation with energies above 100 GeV. At its location in Namibia, it has an optimum view onto the Milky Way, and has detected more than 100 galactic gamma-ray sources.

Using gamma-ray simulations to model cosmic-ray background

The detection of highest-energy photons from the Universe is complicated by cosmic-ray air showers in the atmosphere. In this thesis, a novel approach is followed-up, by which this cosmic-ray background is modelled using gamma-ray simulations. The validity of this approach is tested on various well-known gamma-ray sources detected by H.E.S.S.

Physics topics related to this work:

- Analysis techniques in very-high-energy gamma-ray astronomy
- High-energy astrophysics using gamma rays

Skills acquired during this work:

- Large-scale simulation studies
- Using Python for data analysis
- Working together in a motivated team

Interested? Please get in touch!

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master thesis

Spring 2021

H.E.S.S. is a system of Imaging Atmospheric Cherenkov Telescopes that investigates cosmic gamma rays in the energy range from 10s of GeV to 10s of TeV. In Phase I of the H.E.S.S. project since 2004, this array consisted of four telescopes. In 2012, a much larger fifth telescope was added, extending the energy coverage towards lower energies and further improving sensitivity. Further major upgrades of the system were completed in 2017 and 2019 by exchanging the cameras of the small and the large telescopes.

Investigation of Crab Nebula and PKS 2155−304 data from the H.E.S.S. Telescopes

The goal of this project is to analyse data sets from two exciting key objects for TeV gamma-ray astronomy. The first one is the Crab Nebular, a pulsar wind nebula, and the second is an active galactic nucleus, PKS 2155−304, which showed extremely fast brightness changes in the past. Besides the astrophysical investigation of these data, the analysis will help to study the performance of the instrument and to see how the sensitivity changed over the time during different instrument configurations.

Physics topics related to this work:

- Understanding of air showers
- Study of the Crab Nebula
- Understanding active galactic nuclei

Skills acquired during this work:

- Analysis of Imaging Air Cherenkov Telescope data from H.E.S.S.

Interested? Please get in touch:

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Bachelor & Master thesis

Starting 2021

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.

The H.E.S.S. real-time analysis for the detection of gamma flares

While surveying the night sky, the H.E.S.S. telescopes may detect a gamma flare within their field of view, i.e. an extremely energetic explosion of an astrophysical source such as a gamma-ray burst (GRB). As those can be very short-lived, it is critical that we be able to identify them in real-time and initiate appropriate actions to maximize the physics potential of H.E.S.S. Your task within this project will be to develop efficient algorithms for the real-time detection of gamma flares with the H.E.S.S. telescopes. If you are Master's student and interested in deep learning, you could try to tackle the challenge with LSTMs (long short-term memory networks), which are great for anomaly detection.

Physics topics related to this work:

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

Skills acquired during this work:

- Development of algorithms for real-time data analysis
- Programming in Python or C++
- Using deep learning (LSTMs) for anomaly detection (if you are a Master's student)
- Experience working in a large, international experimental collaboration

Interested? Please get in touch:

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master thesis

2020/2021

The High Energy Stereoscopic System (H.E.S.S.) is a system of Imaging Atmospheric Cherenkov Telescopes (IACT) for the investigation of cosmic gamma rays in the photon energy range of 30 GeV to 100 TeV. The Cherenkov Telescope Array (CTA) is the next generation IACT observatory. 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.

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 more than eight 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 the future CTA instrument. H.E.S.S. instrument has a much smaller effective area than CTA, but in some models of the Fermi bubbles it may be possible to detect them already with existing H.E.S.S. data. 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 and a search in H.E.S.S. data

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. Depending on the available time, we will also search for the Fermi bubbles in the existing H.E.S.S. data.

Physics topics related to this work:

- High-energy astrophysics
- Ground-based gamma-ray astronomy

Skills acquired during this work:

- Modern analysis of gamma-ray data
- Monte Carlo Simulations
- Programming in Python

Interested? Please get in touch:

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master's Thesis

Spring 2021

The **Cherenkov Telescope Array (CTA)** is the next-generation instrument for very-high-energy gamma-ray astronomy. It will consist of about 70 mirror telescopes of up to 20 m diameter, and will observe the sky at photon energies of about 30 GeV to 300 TeV.

Calibration of an advanced mirror measurement facility

In our group, several optical setups are developed and operated to precisely measure the surfaces of various CTA mirrors. In this thesis, a robust calibration procedure for the cameras of these setups will be developed.

Physics topics related to this work:

- Introduction to optical metrology
- Precision measurement of specular surfaces

Skills acquired during this work:

- Calibration techniques for phase-measuring deflectometry
- Programming in Python
- Working together in a motivated team

Interested? Please get in touch!

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Bachelor's/Master's Thesis

Spring 2021

The **Cherenkov Telescope Array (CTA)** is the next-generation instrument for very-high-energy gamma-ray astronomy. It will consist of about 70 mirror telescopes of up to 20 m diameter. It will observe the sky at photon energies of about 30 GeV to 300 TeV.

Design and construction of a mirror testing facility

In our group, several optical setups are developed and operated to precisely measure the surfaces of various CTA mirrors. In this thesis, a "long-working distance" setup will be designed and simulated.

Physics topics related to this work:

- Introduction to optical metrology
- Precision measurement of specular surfaces

Skills acquired during this work:

- Simulation techniques for phase-measuring deflectometry
- Data analysis in Python
- Working together in a motivated team

Interested? Please get in touch!

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ERLANGEN CENTRE
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PHYSICS

Bachelor's/Master's Thesis

Spring 2021

The **Cherenkov Telescope Array (CTA)** is the next-generation instrument for very-high-energy gamma-ray astronomy. It will consist of about 70 mirror telescopes of up to 20 m diameter, and will observe the sky at photon energies of about 30 GeV to 300 TeV.

Simulating the orientation of CTA telescopes

The alignment of a telescope to the sky is never perfect. Therefore, the sky orientation of the CTA telescopes is measured with CCD cameras monitoring stars during science observations.

In this thesis, the effect of several well-known imperfections of the CTA telescopes will be incorporated into an existing CCD image simulation, and the effect of these imperfections on the precision of the telescope orientation be determined.

Physics topics related to this work:

- Simulation techniques in gamma-ray astronomy
- Astrometry with CCD cameras

Skills acquired during this work:

- Simulation of sky images, modelling and analysis of large amounts of data
- Programming in Python
- Working together in a motivated team

Interested? Please get in touch!

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Bachelor's/Master's Thesis

Spring 2021

The **Cherenkov Telescope Array (CTA)** is the next-generation instrument for very-high-energy gamma-ray astronomy. It will consist of about 70 mirror telescopes of up to 20 m diameter, and will observe the sky at photon energies of about 30 GeV to 300 TeV.

Obtaining the orientation of CTA telescopes through sky images

The alignment of a telescope to the sky is never perfect. Therefore, the sky orientation of the CTA telescopes is measured with CCD cameras monitoring stars during science observations.

In this thesis, simulated CCD images of a few camera optics will be characterised, the aim being to optimize the precision with which the telescope orientation can be determined.

Physics topics related to this work:

- Simulation techniques in gamma-ray astronomy
- Astrometry with CCD cameras

Skills acquired during this work:

- Simulation of sky images, modelling and analysis of large amounts of data
- Programming in Python
- Working together in a motivated team

Interested? Please get in touch!

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ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

Bachelor / Master's thesis

Winter/Spring 2020/2021

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 and trigger 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

- Measurement of the TARGET's analog bandwidth
- Characterisation of trigger and read-out chain of the newest TARGET ASIC generation

Master's thesis

- Optimisation of the CTARGET C timing parameters
- Understanding the temperature influence on the SSTCam on-sky data

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!

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ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

Bachelor & Master thesis

Starting 2021

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 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 are extending the observations into the moonlight time. Your task within this project will be to contribute to getting H.E.S.S. up and running during moonlight by analyzing the first data, which is currently coming in.

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:

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Master thesis

Spring 2020

The Southern Wide-field Gamma-ray Observatory (SWGO) will be a next-generation wide field-of-view gamma-ray survey instrument, sensitive to gamma-rays in the energy range from 100 GeV to hundreds of TeV. SWGO will consist of an air shower detector array, located in South America. Due to its location and large field of view, SWGO will be complementary to other current and planned gamma-ray observatories such as HAWC, LHAASO, and CTA. To enhance the capabilities of SWGO and in general of air shower arrays, improving the gamma-hadron separation is one of the key aspects.

Gamma-hadron separation with neural networks

Hadronic cosmic rays are the most abundant particles producing air showers and constitute the chief background to high-energy gamma-ray observation. The air showers produced by high-energy cosmic rays and gamma rays differ: gamma-ray showers are pure electromagnetic showers with few muons or pions. This results in difference in shape features of the detected hadron-induced showers compared to gamma-ray induced ones. In this work, we plan to explore the application of neural network techniques such as graph neural networks (GNNs) to test its viability and performance to hadron rejection for SWGO.

Physics topics related to this work:

- Ground-based gamma-ray astronomy
- Air shower physics
- Water Cherenkov detectors

Skills acquired during this work:

- Programming in Python
- Using neural networks for data analysis

Interested? Please get in touch:

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