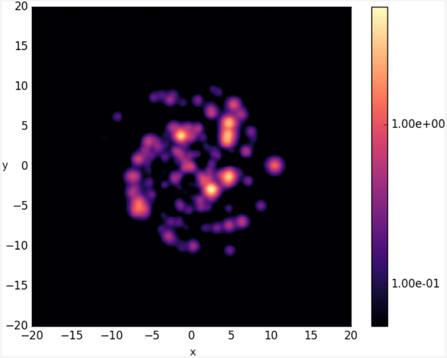
Simulation of Galactic CR Transport

CR Distribution



(Thaler (2019))

Simulation of Galactic CR Transport

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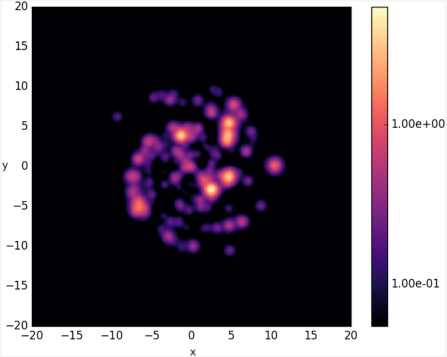
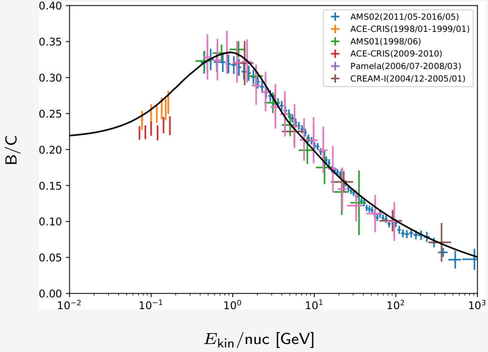


(Thaler (2019))

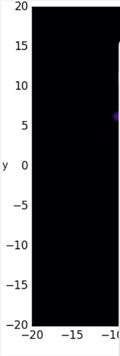
Simulated CR Spectra



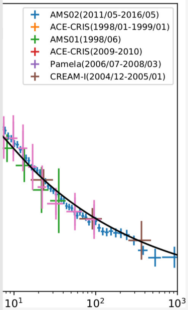
(Picard (2018))

Simulation of Galactic CR Transport

CR Distribution

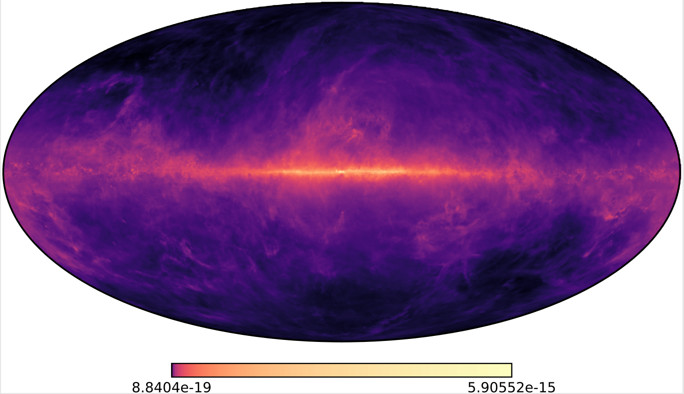


Simulated CR Spectra



(Picard (2018))

Predicted Diffuse Gamma-Ray Emission

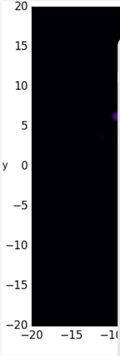


(Thaler (2019))

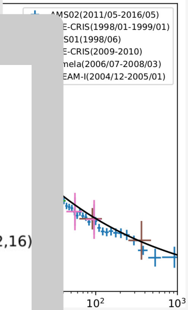
Simulation of Galactic CR Transport

Computational Astroparticle Physics

CR Distribution

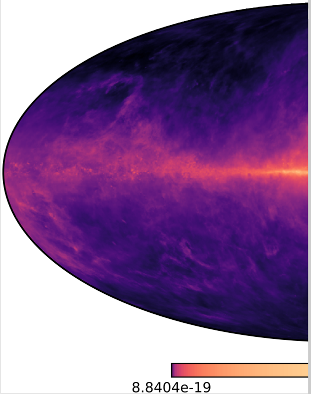


Simulated CR Spectra



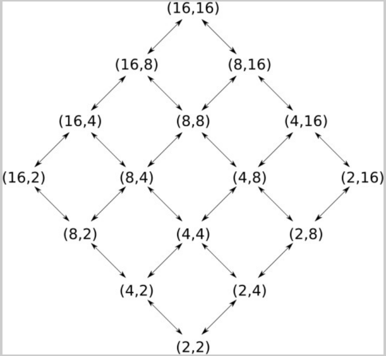
(Picard (2018))

Predicted Diffuse Gamma-Ray Emission



(Thaler (2019))

Numerics: Multigrid



(Steinlechner (2021))

Simulation of Galactic CR Transport

Computational Astroparticle Physics

CR Distribution

Quantifying Dependencies in Cosmic-Ray Transport

Context: Numerical Simulations; Cosmic-Ray Transport;

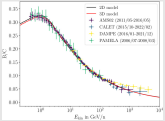
Supervisor: Ralf Kissmann

Abstract

Cosmic rays in our Galaxy are subject to diffusive transport, advection with Galactic gas, energy losses, etc. These effects are combined in the cosmic-ray transport equation, where they are described via different physical parameters like, e.g., the strength of spatial diffusion, the speed of advection, and others. Correspondingly, searching for a fit to observations of cosmic-ray spectra means to adapt different of these parameters, so the simulated spectra correspond to the observed ones. This bachelor topic aims to make this fitting procedure more systematic. For this, the student will analyse the numerical results for different simulation, to determine the gradient in the solution with respect to different of these transport parameters. This will quantify how the cosmic-ray spectra depend on different parameters, thus making finding a good fit easier than before.

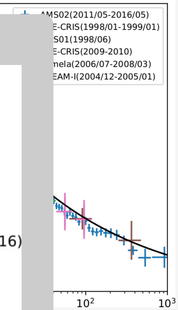
Helpful Skills

- Interest in statistical analysis
- Interest in numerical modelling (C++ and Python)



Comparison of data and simulation result for B/C ratio in Galactic cosmic-rays.

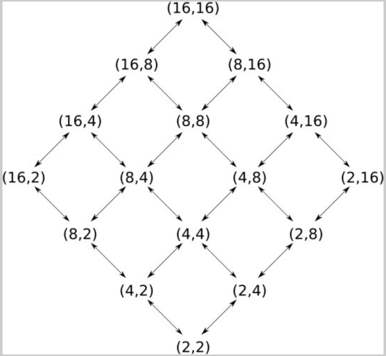
Simulated CR Spectra



(Picard (2018))

-Ray Emission

Numerics: Multigrid



(Steinlechner (2021))

Simulation of Galactic CR Transport

Computational Astroparticle Physics

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Quantifying Dependencies in Cosmic-Ray Transport

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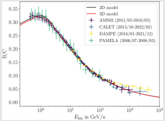
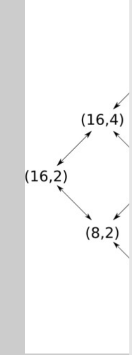


Comparison of data and simulation result for B/C ratio in Galactic cosmic-rays.

Numerics:



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Evaluation of Multigrid Efficiency

Context: Numerical Simulations; Cosmic-Ray Transport; Multigrid

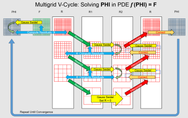
Supervisor: Ralf Kissmann

Abstract

Cosmic-ray transport can be described via a linear, four-dimensional transport equation, with diffusion and advection both in configuration space and in momentum. Such linear partial differential equations can be handled numerically by first discretising the equation using finite differences and then solving the corresponding linear system of equations. In the computational astroparticle physics group, we often employ a multigrid method to solve this system of equations. However, there is a broad range of different aspects of a multigrid scheme that can be adapted to optimise the solution speed. The focus of this bachelor topic is to analyse the different possible choices in setting up a multigrid scheme via a local Fourier analysis. The resulting estimates will then be compared with the performance of an already implemented multigrid scheme.

Helpful Skills

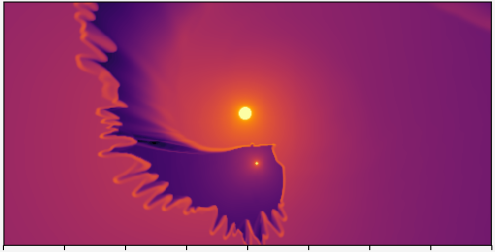
- Interest in mathematical analysis
- Interest in numerical modelling



Schematics of a multigrid scheme (Adilnisar on Wikipedia)

Simulation of Cosmic-Ray Sources

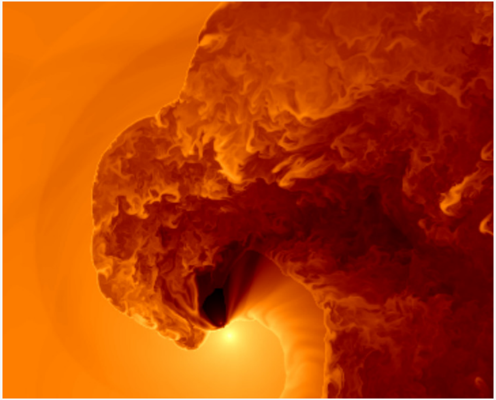
A Collinding-Wind Binary



(Kissmann (2019))

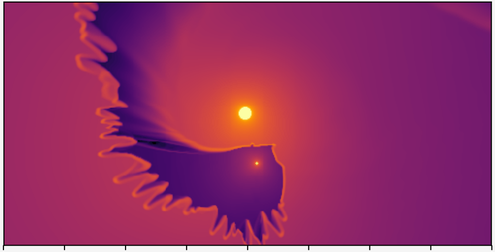
Simulation of Cosmic-Ray Sources

Simulated Gamma-Ray Binary



(Huber & Kissmann (2021))

A Collinding-Wind Binary



(Kissmann (2019))

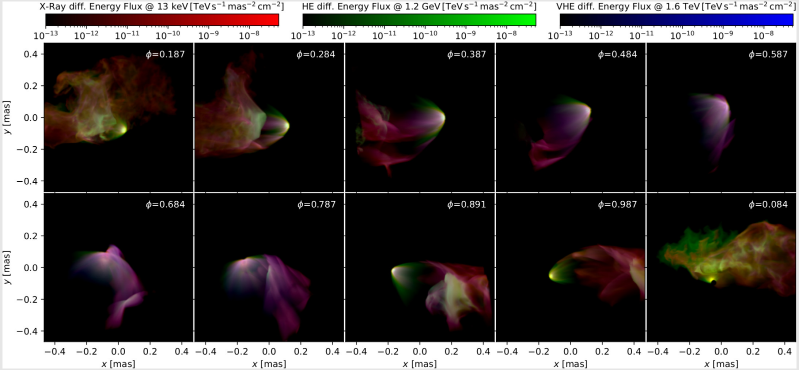
Simulation of Cosmic-Ray Sources

Simulated Gamma-Ray Binary

A Collinding-Wind Binary

(Kissmann (2019))

Related High-Energy Emission



(Huber, Kissmann & Reimer (2021))

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Simulation of Cosmic-Ray Sources

Computational Astroparticle Physics

Simulated Gamma-Ray Binary

A Collinding-Wind Binary

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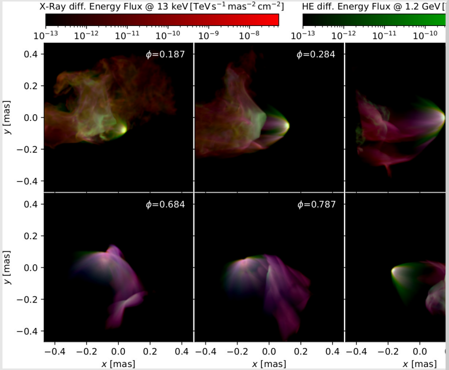
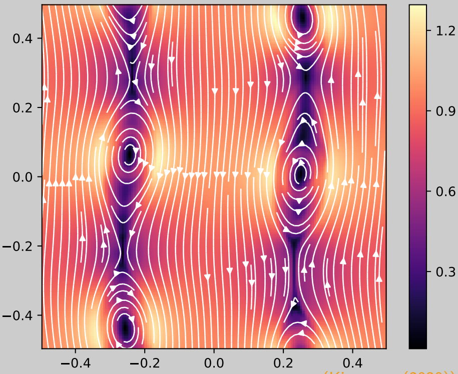
Related High-Energy Emission



Numerics: MHD / Relativistic HD



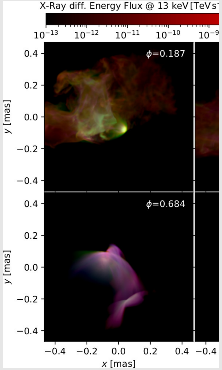
(Kissmann (2020))

Simulation of Cosmic-Ray Sources

Computational Astroparticle Physics

Simulated Gamma-Ray

Related High-Ener



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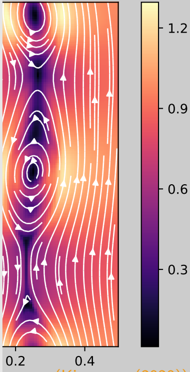
lativistic HD



(Kissmann (2020))

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Connecting Data and Simulations of the Gamma-Ray Binary LS 5039

Bachelorarbeit - Sommersemester 2025

Context/Keywords: Astroparticle Physics; Ground-Based Gamma-Ray Astronomy; Analysis Methods

Supervisors: Markus Holler, Ralf Kissmann

Abstract

During the last two decades, the field of ground-based gamma-ray astronomy with Imaging Atmospheric Cherenkov Telescopes (IACTs) has matured into an important part of Astroparticle Physics, expanding our knowledge about the universe on the high-energy end. Among the different source classes detected with IACTs are binary systems such as LS 5039. It consists of an O-type star and a massive companion, which is typically assumed to be a pulsar. The interaction of the stellar and the pulsar wind are assumed to form a shock region, which in turn results in particle acceleration and subsequently gamma-ray emission. In this BSc thesis you are going to analyse LS 5039 data from the H.E.S.S. array of IACTs and compare the resulting energy spectrum to corresponding simulations.

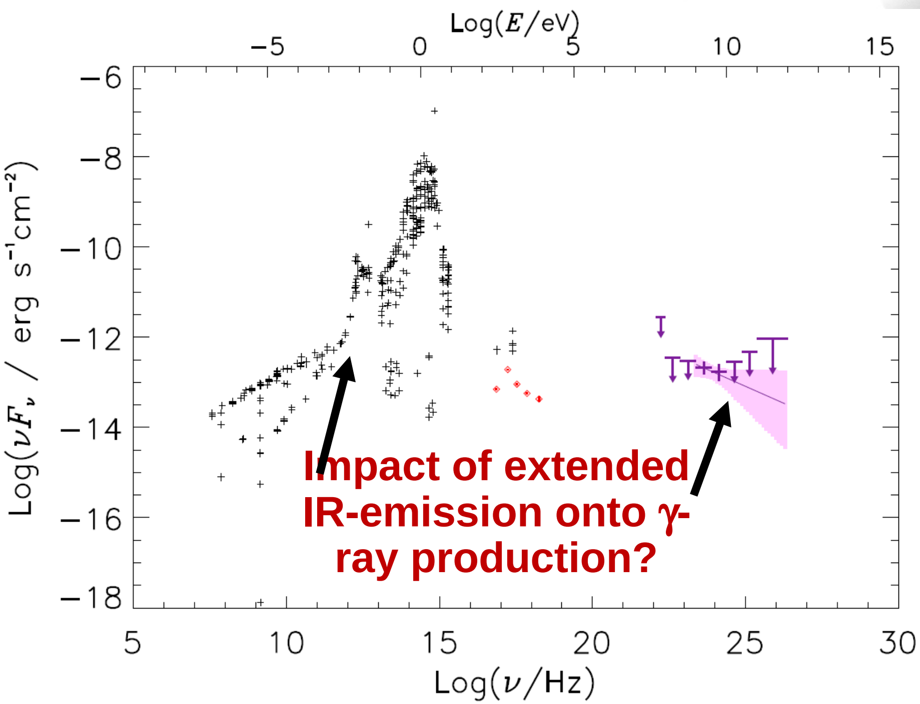
Helpful Skills

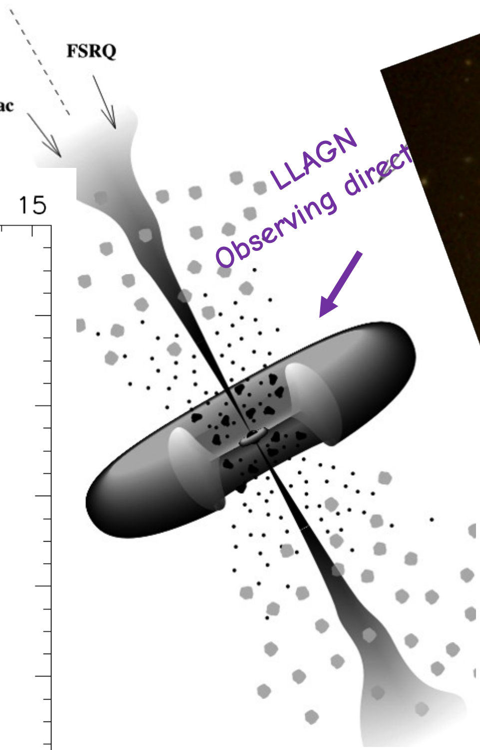
- Basic knowledge of *python* or programming in general
- Interest in analysis methods as well as ground-based gamma-ray astronomy

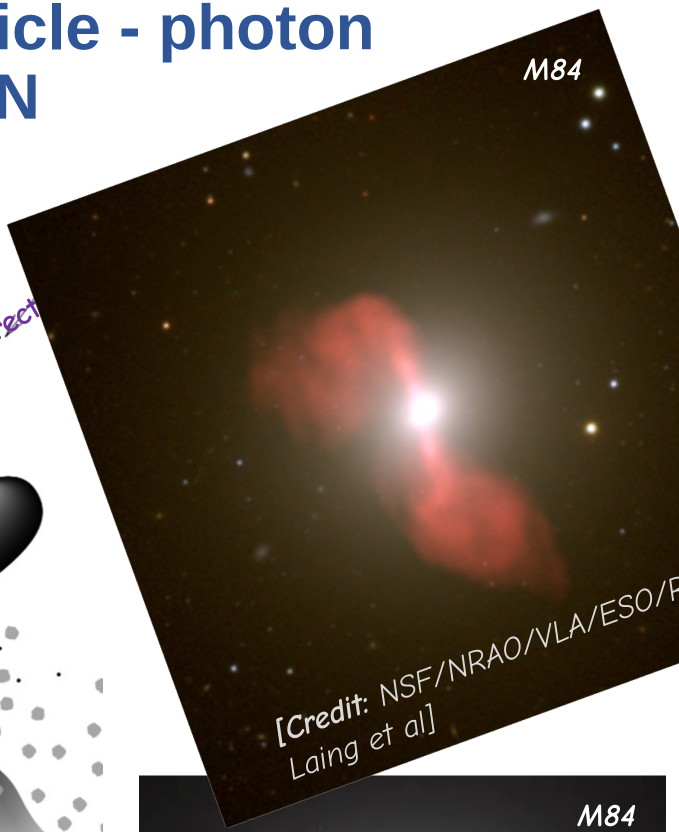
Left: The H.E.S.S. array of IACTs in Namibia. Picture credit: Vikas Chander.
Middle: Simulation of the mass density in the LS 5039 system. Credit: R. Kissmann et al. (2023)
Right: H.E.S.S. sky map of the field of view containing LS 5039. Credit: H.E.S.S. collaboration

Bachelor thesis topic:

- # Gamma rays from relativistic particle - photon interactions in low-luminosity AGN







Supervisor: A. Reimer (anita.reimer(at)uibk.ac.at)

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