

Bachelor / Master theses

2025

Stars are light sources that appear point-like and it is very hard to resolve their spatial extent. The world's largest telescopes are employed to reach the required angular resolution and many technical challenges have to be overcome in the design and operation of such systems. An alternative approach for high angular resolution astronomy is offered by intensity interferometry (II). Intensity Interferometry is a method based on the quantum optical correlation of photons. While standard amplitude interferometry measures the first order correlation - each photon interferes with itself - intensity interferometry measures a second order correlation where two photons correlate such that enhanced intensity is observed as a function of time difference and position distance at which these photons are detected. The resulting coincidence rate between two telescopes as function of the distance between the telescopes is proportional to the diffraction pattern of the light source. The spatial extent of a star is then given by the Fourier transform of this pattern. Intensity interferometry enables angular resolution down to the sub-milliarcsecond scale. It may even be able to reach better resolution than the largest telescopes. Arrays of Imaging Atmospheric Cherenkov Telescopes (IACTs), such as H.E.S.S. or the future CTA, are suitable for the application of the method. The ECAP team designed and built an intensity interferometer for the H.E.S.S. telescopes and has already performed measurements of star diameters. We are now looking to improve this experimental setup, our data analysis and modelling of II targets.

Master's theses

- Simulation of binary star systems for Intensity Interferometry measurements
- Off-axis response of Fresnel lens telescopes and suitability for air shower observations
- Analysis of intensity interferometry data taken with H.E.S.S.
- Automated focus adjustment of the H.E.S.S. Intensity Interferometry Setup
- Stellar diameter measurement with the ECAP Intensity Interferometer

Bachelor's theses

- Stellar diameter measurement with the ECAP Intensity Interferometer

Possible supervisors for projects in this group:

- Stefan Funk, s.funk@fau.de, office 02.036
- Alison Mitchell, alison.mw.mitchell@fau.de, office 02.038

Master Thesis

Simulation of binary star systems for Intensity Interferometry measurements

The spatial coherence curve of a singular thermal light source of finite size - a single star - is very well understood and explained by intensity interferometry. However, if additional structure (or additional objects in the direct vicinity) is introduced, the picture becomes unclear quite quickly. What is the shape of a binary star system's spatial coherence curve? Which part of it does an intensity interferometer measure? What about $n > 2$ multiple star systems, occultations or stellar surface inhomogeneities? This masters project will develop simulations to interpret intensity interferometry data of multiple star systems and address challenges related to binaries arising from intensity interferometer design. In particular, this will include theoretical predictions for the performance capabilities of different telescope systems, investigating the necessary properties to address more complex stellar structures.

Physics topics related to this work:

- Intensity Interferometry in astronomy
- Multiple star system dynamics

Skills acquired during this work:

- Programming in Python
- Star system modeling
- Telescope system response simulations

Interested? Please get in touch:

- Alison Mitchell, alison.mw.mitchell@fau.de, office 02.038
- Stefan Funk, s.funk@fau.de, office 02.036

Master Thesis

Off-axis response of Fresnel lens telescopes and suitability for air shower observations

While IACT arrays are suitable for Intensity Interferometry (II), their primary application is gamma-ray astronomy, taking up the time with the best observation conditions. Dedicated instruments for II are very scarce and due to the nature of being a niche field, often are implemented in other telescopes/telescope arrays without impairing their primary function. The ECAP team has assembled two Fresnel lens telescopes for use in II measurements. While the larger optical aberrations of a Fresnel lens have little impact on II measurements, are they still of good enough quality to be used in air shower observations? What is the off-axis response of Fresnel lenses? This project will characterize two different types in two different sizes of Fresnel lenses with respect to their point spread function and off-axis response to evaluate them for use in II and gamma-ray astronomy.

Physics topics related to this work:

- Fresnel lenses, lens aberrations
- Gamma-ray astronomy

Skills acquired during this work:

- Statistical analysis of data
- Test bench setup for large optical elements, hardware design
- Systematic experimental work

Interested? Please get in touch:

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Master Thesis

Analysis of intensity interferometry data taken with H.E.S.S.

In 2022 and 2023 the ECAP team took intensity interferometry data using up to three of the H.E.S.S. telescopes simultaneously. These data, in particular, the squared visibility vs. the projected baseline between the telescopes, can be used to determine geometric parameters of the observed stars, such as their angular diameters. Although a straightforward one-dimensional analysis has already been performed and stellar diameters have been extracted, there are a lot of missing analyses that might yield a better understanding of the observations. One particularly interesting question is: do we see indications of non-spherical stars when we analyze interferometric data of fast rotators? This requires an extension of the data analysis into two dimensions, replacing one-dimensional telescope baselines by the uv-plane.

Physics topics related to this work:

- Intensity Interferometry in astronomy
- Stellar physics

Skills acquired during this work:

- Statistical analysis of data
- Programming in python
- Modeling and simulating

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Master Thesis

Automated focus adjustment of the H.E.S.S. Intensity Interferometry Setup

For intensity interferometry observations at H.E.S.S. an optical setup is mounted onto the lid of the telescopes, redirecting the light into the interferometer. The setups, located at ECAP and brought to H.E.S.S. during the campaigns consist of optical elements which are supplied with stepper motors, allowing for their remote alignment while the telescopes are tracking a target. As the tracking of the telescopes is susceptible to slight mispointings over time, the observed star moves out of focus of the interferometer, and by now manual re-adjustments of the optics in the setup are necessary every couple of minutes. The task of this work is to automate this re-focusing routine. This can be done by integrating an algorithm that continuously optimizes the measured photon rates by slight adjustments of the positions of the optical elements. This routine can be developed at ECAP in the lab using light sources shining on the setup (simulating the star), and purposely moving them out of position to simulate telescope mispointing.

Physics topics related to this work:

- Intensity Interferometry
- Optical devices and photo-detection

Skills acquired during this work:

- Operation of photo-multipliers
- Hands-on programming of devices at the interface between different machines
- Systematic experimental work
- Programming in python

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Bachelor/Master Thesis

Stellar diameter measurement with the ECAP Intensity Interferometer

Since 2024, ECAP has successfully performed intensity interferometry observations on the roof. The two self-made telescopes each consist of a light-weight 1m diameter plastic ('Fresnel') lens, which enables interferometric measurements of the brightest targets in the northern sky. A suitable work for a Bachelor student would be the measurement of the angular diameter of a bright single star (such as Vega), while a Master student could focus on a binary system (e.g. Capella), requiring more measurement time and advanced data analysis.

Physics topics related to this work:

- Intensity Interferometry in astronomy
- Stellar physics
- Fresnel lenses

Skills acquired during this work:

- Hands-on work with Photo-multipliers, telescopes and their operation
- Statistical analysis of data

Interested? Please get in touch:

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