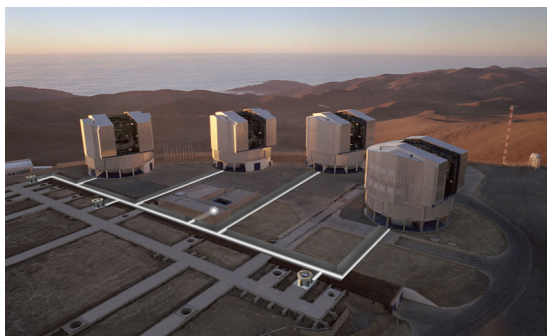




Exoplanet science with nulling interferometry



SUMMARY.

This METEOR project introduces students to the field of high-contrast interferometry, with a particular focus on nulling techniques for the detection and characterization of exoplanets. Students will explore the physical and instrumental limitations affecting ground-based observations, including atmospheric turbulence, optical aberrations, and operational constraints. The project combines theoretical concepts, numerical simulations, and data analysis using state-of-the-art tools such as SCIFYSim and the GRIP nulling pipeline. Students will gain hands-on experience in modelling interferometric instruments, reducing realistic datasets, and linking instrumental performance to scientific outcomes.

— SCIENTIFIC CONTEXT —

This project is directly relevant to current challenges in exoplanet detection and characterization. High-contrast interferometry is a key technique for detecting faint companions and studying circumstellar environments. The methods explored in this project are applicable to current and future facilities, including VLTI instruments and concepts for future space missions. Students will gain insight into how instrumental design choices translate into scientific performance and discovery potential.

— OBJECTIVES —

The main goal of this METEOR is for students to become familiar with the field of high-contrast interferometry and its application to exoplanet science. More specifically, students will:

- Understand the principles of high-contrast imaging and interferometry, including nulling techniques
- Identify the main limitations to performance, such as atmospheric turbulence, wavefront errors, and instrumental constraints
- Learn how to simulate the behaviour of a ground-based high-contrast interferometer
- Use simulations to optimise instrument design and observing strategies
- Become familiar with nulling data reduction using dedicated pipelines (e.g. GRIP)
- Develop skills in scientific programming, data analysis, and interpretation

— INSTITUTE —

- Institute of Astronomy (KU Leuven)

- Celestijnenlaan 200D, 3001 Leuven

— THEORY —

by DENIS DEFRÈRE

Students will be introduced to the fundamental concepts of high-contrast interferometry. This includes the basics of optical interferometry, the principles of nulling interferometry, and the challenges associated with the star-planet contrast problem. The course will cover the impact of atmospheric turbulence (phase noise, piston errors), optical aberrations, and instrumental limitations on performance. Students will also be introduced to current and future interferometric instruments, and to the role of simulations in instrument design and science preparation.

by THOMAS MATTHEUSSEN

Students will be introduced to interferometric observations and to nulling data reduction techniques. They will learn how to use dedicated software such as the GRIP pipeline, including calibration strategies, bias correction, and the extraction of astrophysical signals from noisy data.

— APPLICATIONS —

by DENIS DEFRÈRE

The practical work will consist of a hands-on project combining simulation and data analysis. Students will first use simulation tools (e.g. SCIFYSim) to model the behaviour of a ground-based interferometric instrument, including the impact of instrumental parameters and noise sources (e.g. phase errors, transmission maps, atmospheric perturbations). They will then apply the GRIP nulling data reduction pipeline to simulated (and optionally real) datasets. This will include calibration, estimation of null depths, and error analysis. Students

will develop diagnostic tools to evaluate instrument performance, compare simulated and reduced data, and investigate detection limits. Finally, they will interpret their results in a scientific context, assessing the detectability of exoplanets or circumstellar material and proposing possible optimisations of the instrument or observing strategy.

— MAIN PROGRESSION STEPS —

- Weeks 1-2: theory, getting familiar with simulation tools
- Weeks 3-4: first data reduction and results
- Weeks 5-6: development of diagnostic tools and analysis of results
- Weeks 7-8: data reduction optimization
- Week 9: project presentation

— EVALUATION —

- Theory grade [30%] The theory part will be evaluated based on the written report.
- Practice grade [30%] The practical grade will be based on the output of the project, i.e., through the written report.
- Defense grade [40%]
 - Oral and slides quality
 - Context
 - Project / Personal work
 - Answers to questions

— BIBLIOGRAPHY & RESOURCES —

- Laugier et al. 2023
- SCIFYSim
- GRIP

— CONTACT —

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