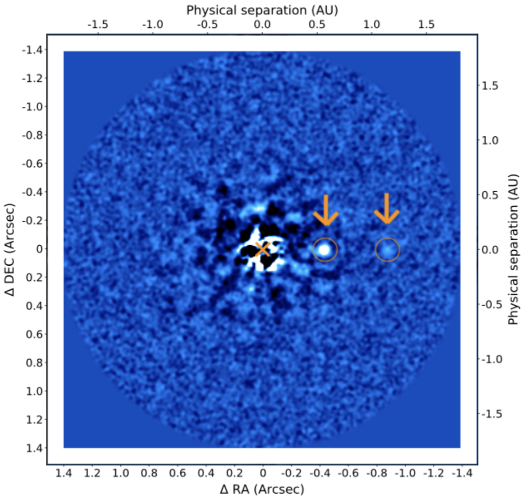
Imaging rocky planets with ELT/METIS



SUMMARY.

The Mid-infrared ELT Imager and Spectrograph (METIS) is one of the first-generation instruments for the Extremely Large Telescope, bound to see first light in 2030. With its dedicated high-contrast imaging capabilities, and exquisite angular resolution in the mid-infrared, METIS has the potential of providing the first direct detection of temperate rocky planets around nearby Sun-like stars. With the proposed project, we will use end-to-end simulations of the METIS high-contrast imaging modes to optimise our observing strategy, so as to maximise the expected yield of the instrument in terms of low-mass planets. The work will particularly focus on the alpha Centauri AB binary system, which offers the best chances of detecting temperate rocky planets.

OBJECTIVES

The main goal of this METEOR is for the students to become familiar with the field of high-contrast imaging with large ground-based telescopes. More specifically, the students will learn about the limitations to the performance of high-contrast imaging instruments due to atmospheric turbulence, internal aberrations, operational constraints, etc. They will learn how to simulate the behaviour of a ground-based high-contrast imager, and how these simulations can be used to optimise the design of the instrument, as well as its future observing programs. In the process, the students will also learn about the state of the art in the application of high-contrast imaging to the search for planetary systems. They will also learn about how constraints from other observing techniques can inform the search for exoplanets with high-contrast imaging.

INSTITUTE

- PSILab research team
- STAR Institute
- University of Liège
- 19C allée du Six Août, 4000 Liège, BELGIUM

THEORY

by Olivier Absil

The theoretical part will consist of a short series of informal lectures based on some of the material from the courses SPAT0063 (Introduction to exoplanetology) and SPAT0067 (Atmospheric and adaptive optics). More specifically, we will review the main pillars of high-contrast imaging, briefly introduce the basic concepts of Fourier optics, and how they are used to model the behaviour of diffraction-limited optical systems as well as the propagation of aberrations in such systems. We will also describe how water vapour affects mid-infrared observations. We will then introduce the students to the concept of signal-to-noise ratio and sensitivity limits. Finally, we will explain how the yield of a high-contrast imaging survey can be computed, based on the instrument performance and on planet population models.

by Gilles Orban de Xivry

The students will be introduced to modern Fourier optics propagation software, as well as to atmospheric and adaptive optics simulations in general.

by Valentin Christiaens

The students will be introduced to a python package for image processing in high-contrast imaging, including the computation of signal-to-noise ratio and sensitivity limits.

APPLICATIONS

by Olivier Absil

The students will use the knowledge and tools described in the Theory section to evaluate the sensitivity of METIS to low-mass planets in the alpha Cen system, and possibly a few more nearby Sun-like stars. In order to evaluate the potential yield of METIS, the students will also need to use publicly available resources to compute the probability of finding different types of planets around the considered stars, as well as their mid-infrared brightness. The end product of the project would be the definition of an optimised strategy in terms of integration time, number of visits, and observing mode.

MAIN PROGRESSION STEPS

- `Weeks 1-2`: theory, getting familiar with simulation tools
- `Weeks 3-4`: reproducing previously performed simulations
- `Weeks 5-6`: updating sensitivity limits around the target stars
- `Weeks 7-8`: evaluating the yield and optimising the observing strategy
- `Week 9`: wrapping up and presenting project

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

- Bowens et al. (2021)
- https://github.com/vortex-exoplanet/HEEPS
- https://github.com/vortex-exoplanet/VIP

CONTACT

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