Proposition de stage M2 Instrumentation / Ingénieur

Control of the complex electric field in optical coronagraphy for the detection of extrasolar planets

Nom du proposant :

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Context :

Understanding the formation, evolution and surprising diversity of extrasolar planets is one of the major challenges facing modern astrophysics. Over the past two decades, numerous discoveries have already revealed the complex nature of these objects. In recent years, astronomers have obtained the first images of planetary systems in very special cases of gas giant planets bright enough to be detectable with today's instruments.
The large difference in brightness and the small angular separation between planets and stars make these observations difficult, and require the use of cutting-edge technologies (coronagraphy, deformable mirrors, complex algorithms) applied both on ground-based telescopes (VLT and future ELT) and on space missions (Roman Space Telescope, Habitable Worlds project).

To optimize the operation of actual instruments and prepare the future ones, we have set up a test bench (https://thd-bench.lesia.obspm.fr) to study the practical limits of these highly demanding observations in terms of optical wave quality.
Direct observation of extrasolar planets requires the use of a coronagraph, which theoretically makes it possible to reject starlight without affecting the planet. However, coronagraph performance is highly sensitive to beam phase and amplitude aberrations. In order to observe terrestrial-type exoplanets, the maximum level of phase aberrations upstream of the coronagraph must be less than a few tens of picometers RMS.
Such levels can be achieved using deformable mirrors but are very demanding in terms of stability, precision of the measurement and correction, etc. Uncertainties in our knowledge of the instrument slow down the actual correction speed and more optimized solutions are required for the Roman Space Telescope (to be launched in 2027) and for the future Habitable Worlds Observatory project.

Internship topic :

The aim of the internship is to implement and test new complex algorithms of wavefront measurement and correction on the THD2 test bench. The THD2 is currently being upgraded, and by 2025 will enable us to test more complex algorithmic solutions than currently. This work will be done in the framework of space coronagraphy, especially the Roman telescope, for which we have installed a copy of its main coronagraph. These tests could also be done on new type of coronagraphs (vector vortex coronagraph base on multi-layer liquid crystal polymers) that we are testing in collaboration with Leiden university in the context of an ESA research and development (R&D) project.

After familiarizing themselves with the subject (coronography, measurement and correction of optical aberrations), the student will implement new algorithmic solutions using either the currently available coronagraph that simulates the one installed on Roman, or the vector vortex developed in the context of ESA R&D.

The work will mainly involve implementing the algorithm in the THD2 control software (Python based), optimizing the parameters of the correction loop, collecting data, processing it and analyzing the results to compare them with the expected results.

Prerequisites :

The following notions would be useful:
- Wave optics, diffraction, Fourier optics,
- adaptive optics, deformable mirrors
- Python coding
- signal processing,

Bibliography :

See THD2 bench bibliography on the website:
https://thd-bench.lesia.obspm.fr/publications-16/