# Advancing multi-chromatic wavefront sensors based on colored-filtered arrays for exoplanet observations with future large observatories

**Location:**

- Laboratoire Lagrange, Observatoire de la Côte d'Azur (OCA), Nice, France
- Laboratoire d'Astrophysique de Marseille (LAM), Marseille, France

**Funding:**

- AMINO (Advanced Multi-spectral Imaging using Novel wavefront sensors with Optical photon-counting detectors), a target project from the PEPR Origins under France 2030 fundings managed by ANR - **This PhD scholarship is already fully funded.**

**Starting date:** November 1st, 2026
**Ending date:** October 31st, 2029

**Supervisors:**

- Mamadou N'Diaye, Olivier Lai (Laboratoire Lagrange/OCA)
- Arthur Vigan (Laboratoire d'Astrophysique de Marseille)

**Collaborators:**
Johan Mazoyer, Pierre Baudoz, Moustapha Dekkali, Raphaël Galicher, Axel Potier (LIRA/Observatoire de Paris), Faouzi Boussaha, Christine Chaumont (LUX/Observatoire de Paris), Vincent Chambouleyron, Kjetil Dohlen (LAM), Iva Laginja (Lagrange/OCA)

**Context:**
Over the past three decades, the discovery of nearly 6000 exoplanets has revealed an extraordinary diversity in planetary systems. Direct imaging —particularly coronagraphy—has emerged as one of the most promising methods for detecting and characterizing exoplanets in the habitable zone (HZ) of their host star. Such an approach is envisioned in future large facilities, e.g., NASA's **Habitable Worlds Observatory (HWO) in space** and ESO's **Extremely Large Telescope (ELT)** with the Planetary Camera and Spectrograph (PCS) **on the ground**.

The AMINO project (co-PIs: J. Mazoyer and V. Chambouleyron) aims to address the formidable challenges associated with direct imaging, particularly for observing exo-Earths with planet/star flux ratios down to $10^{-10}$. One of them is the precise control of the incoming light aberrations with deformable optics, producing high-contrast regions in the image of an observed star called 'dark-hole' to reveal faint exoplanets. A major difficulty lies in maintaining these dark-holes over large spectral bands, which is critical for spectroscopy of exo-Earth atmospheres and detection of biosignatures, see Figure below.

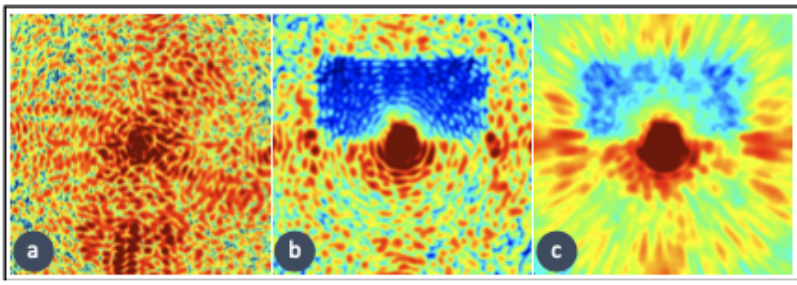


**Fig 2:** *Experimental DH results on LIRA's coronagraphic testbed [Mazoyer+ 2014]. Blue color correspond to higher contrast. (a) field of uncorrected speckles, masking the planet; (b,c) DH in narrow, and wide (Δλ/λ =39%) spectral band*

The AMINO project focuses on advancing **Focal Plane Wavefront Sensing (FPWFS)** techniques, to estimate aberrations and create or maintain dark-holes. Our team has pioneered some of these techniques, and is currently involved in their integration in both space and ground-based technological demonstrators: **Coronagraph Instrument (CGI) on** NASA's **Roman Space Telescope** and **SPHERE+** on ESO's Very Large Telescope (VLT). But the efficiency of these FPWFS drops quickly in large spectral broadband: current instruments must rely on slow, sequential measurements in several narrow bands, which limit their performance.

**Proposed work:**
In the context of a collaboration between LAM and Laboratoire Lagrange, we propose a project that is defined by two different but related lines of research:

**1/ Investigate wavefront sensing measurements with Color-filter arrays (CFA) detectors.**
The PhD student will perform python simulations based on Fourier optics to combine wavefront sensing approaches (Pair-Wise Probing, Self-Coherent Camera, Zernike Sensor) and CFA detectors. This research work will aim to find the most suitable configurations for simultaneous wavefront error measurements in several narrow bands.

**2/ Implement the CFA-based approach with a Zernike wavefront sensor (ZWFS).**
The PhD student will carry out experimental work to demonstrate the combination of the ZWFS with CFA. Laboratoire Lagrange has recently initiated an optical bench to assess novel approaches with the ZWFS. The PhD student will pursue the development of the testbed and enable the validation of ZWFS+CFA combination.

**Team & environment:**
We value diversity of backgrounds and perspectives as essential drivers for innovation and collective success. We are committed to fostering an inclusive environment where everyone feels valued and supported in their professional development.

The PhD student will work at the Laboratoire Lagrange with M. N'Diaye and O. Lai as a member of the Physics Method for Observation (MPO) group and at the Laboratoire d'Astrophysique de

Marseille (LAM) with A. Vigan as a member of the Research and Development (GRD) group.

The selected candidate will be a member of the AMINO project, and will collaborate with experts in the field of brown dwarfs and exoplanets, adaptive optics, coronagraphy, wavefront sensors, and detectors at LIRA (Paris), LUX (Paris), LAM (Marseille) and Lagrange (Nice). Additional collaborations include the Makidon Lab at the Space Telescope Science Institute (Baltimore, USA) for space applications towards HWO.

The PhD student will in addition develop skills in programming (python), optics (simulations, testbeds, experiments), will benefit from a rich national and international scientific environment, and will have the opportunity to share their work with the community through international schools and conferences.

**Keywords:** instrumentation, adaptive optics, high-contrast imaging and spectroscopy, coronagraphy, wavefront sensing and control, detectors, exoplanets, brown dwarfs.

**Applicant's profile:**
The applicant will have a Master 2 degree level or equivalent (Engineering school or research master's degree) in astronomy, physics, optics, or other related fields.
Skills in Astrophysics, Fourier optics, python programming and associated scientific libraries, in-lab practice (laser handling, opto-mechanical components, detectors, optics alignment), or in data processing will be assets for this research work.
The applicant is expected to be enthusiastic, dynamic, autonomous while having teamwork abilities. A strong interest in astronomy and interdisciplinary work will be a plus.
The applicant should have a very good level in English.

**Application**
Please send your application by including a curriculum, a cover letter and a transcript of grades/marks to Mamadou N'Diaye (mamadou.ndiaye@oca.eu), Arthur Vigan (arthur.vigan@lam.fr ) and Olivier Lai (olivier.lai@oca.eu ).
All applications sent by March 30th, 2026 will receive full consideration.