Combining integral field spectroscopy and coronagraphy: new optical techniques to image habitable zone exoplanets with future space and ground-based instruments

Location: Paris Observatory - PSL, Meudon, France
Team: Exoplanet team at LIRA (*Laboratoire d'instrumentation et de recherche en astrophysique*)
Supervisors in Paris Observatory: Pierre Baudoz, Raphaël Galicher, Johan Mazoyer
Start Date: Fall 2026 **Duration:** 3 years

Deadline: Monday March 30th 2026 at 23h59 CET.

Direct imaging of exoplanets is one of the most exciting and rapidly evolving fields in modern astronomy. By capturing light directly from exoplanets, we can already study the atmospheres of large gas giants (Fig. 1), but the ultimate goal of this method is to access earth-like planets to measure compositions, and even search for bio-signatures. However, the extreme brightness of host stars compared to their planets makes this task extraordinarily challenging, akin to detecting a firefly next to a lighthouse from thousands of kilometers away. Coronagraphs are optical instruments designed specifically for this challenge: to suppress starlight, allowing us to detect the faint exoplanet signal.

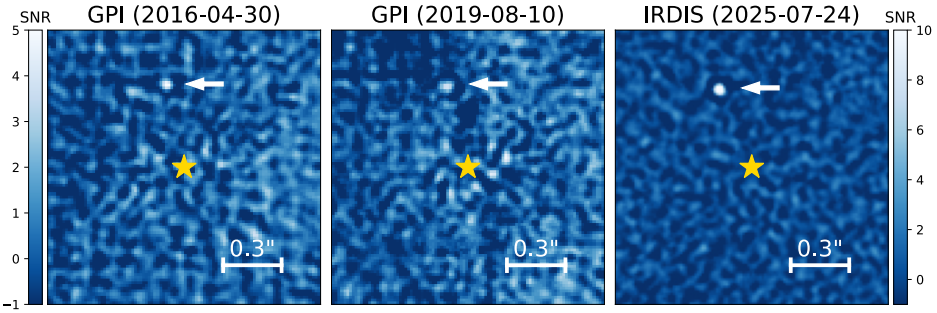

Fig 1: Ten years of observation of a circumbinary giant planet at 136 parsec (Squicciarini, Mazoyer + 2025).

The next generation of giant telescopes, such as the European **Extremely Large Telescope (ELT)** in Chile and NASA's **Habitable Worlds Observatory (HWO)**, will rely on these techniques to image Earth-like planets in the habitable zones of nearby stars. The **Planetary Camera and Spectrograph (PCS)**, a second-generation coronagraphic instrument for the ELT, is designed to probe the habitable zones of red dwarf stars, where rocky planets may reside. Meanwhile, HWO, NASA's next flagship mission, will target habitable-zone planets around Sun-like stars. Both missions require new coronagraphic techniques to achieve the extreme contrast necessary to detect these faint worlds.
The **ECHOES** project (PI: Mazoyer), funded by the European Research Council (ERC), aims to greatly advance exoplanet imaging by developing groundbreaking coronagraphic techniques for these missions. **As part of the ERC project ECHOES, this PhD is already funded.**

Objectives of the PhD

The main objective of this PhD is to combine coronagraphs with actively controllable optics (deformable mirrors) and multiwavelength technology (integral field spectroscopy or IFS), to create regions in the

image where starlight is actively suppressed, revealing hidden exoplanets. The primary objective of this PhD is to develop a novel active algorithm to achieve real-time starlight suppression at all wavelengths. The PhD candidate will develop in simulation the new algorithm, validate its performance under controlled laboratory conditions on an optical experimental platform at Paris Observatory and finally demonstrate it at the Very Large Telescope in Chile, for exoplanet detection and characterization.

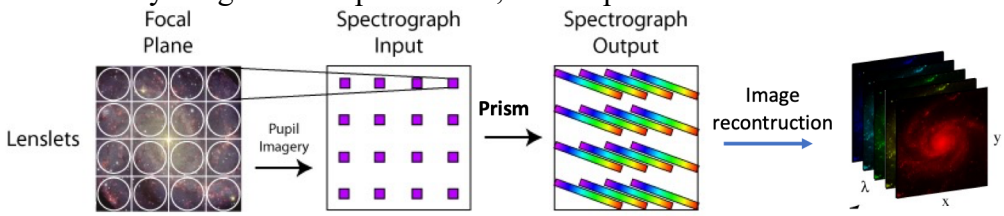

Fig 2: Principle of integral field spectroscopy (Ren & Allington-Smith 2002).

Methods

The PhD will employ a combination of simulation, optical engineering, and experimental validation:

- **Imaging processing and control algorithms**: Use and develop existing coronagraphic simulation tools in python to develop innovative algorithms.
- **Optical engineering**: Collaborate with an optical engineer to integrate an IFS prototype on the THD2 experimental testbed.
- **Experimental physics**: Conduct tests on the THD2 testbed to validate the algorithm's performance under realistic conditions.
- **On-Sky observations**: Participate in observing runs at the VLT in Chile to test the algorithm with the SPHERE+ instrument.

The results of this PhD will be published in high-impact journals (e.g., Astronomy & Astrophysics, Optics Express, Journal of Astronomical Telescopes, Instruments, and Systems) and presented at international conferences (e.g., SPIE, AO4ELT).

Profile of the candidate

ECHOES is an interdisciplinary project which values diverse expertise: we welcome applicants from a wide range of backgrounds, even if you never studied astrophysics previously! Candidates should hold a Master's degree in **Physics** or **Astrophysics**, **Optics**, or **computer science**, with an interest in instrumentation, experimental work or signal processing. Experience with programming (**Python**) is essential. The candidate will work in a collaborative, interdisciplinary and international environment: fluency in English, both written and spoken, is required for effective scientific communication.

Why Join Us?

The successful candidate will be part of **the exoplanet team at LIRA / Paris Observatory - PSL**. Our team, and Dr. Mazoyer in particular, is committed to fostering a diverse and dynamic work environment by actively recruiting individuals of all genders and nationalities. In Paris observatory, arguably the world oldest institution for astronomical research, our team is one of the largest and most dynamic exoplanet research groups in Europe, in particular for direct imaging. LIRA's researchers have been heavily involved in the building of most current and future direct imaging instruments providing a unique access to these instruments: at the Very Large Telescope (VLT / SPHERE) and its associated interferometer (VLTI /

GRAVITY), for the James Webb (MIRI coronagraph) but also in future instruments like the Roman Coronagraphic Instrument (NASA's upcoming high-contrast imaging mission) and MICADO (the first light instrument of the Extremely Large Telescope).

The project provides a collaborative network, engaging with leading experts in optics, astrophysics, and machine learning from institutions such as ESO, NASA, and ONERA. This PhD in astronomical instrumentation for future space missions sits at the intersection of engineering, and astrophysics, a uniquely interdisciplinary opportunity in a very promising field. It is a great opportunity for applicants interested in starting a high impact academic career but also open exciting job prospects in space agencies or industries, in optics, aerospace, or advanced high-tech instrumentation.

Benefits

PhD students in France receive a competitive salary, typically around €2,135 gross per month for 3 years, which covers living expenses in Paris area. This contract, equivalent to a PhD fellowship in the US, does not require the candidate to teach. They can choose to be teacher assistant up for up to 64 hours a year with additional annual remuneration calculated on the basis of the number of hours provided. Other benefits include full social security (health insurance, unemployment insurance, parental leaves) as well as reimbursement of 75% of public transportation fees.

References

- The ECHOES project: https://www.insu.cnrs.fr/fr/personne/johan-mazoyer-0
- Paris Observatory Exoplanet's team: https://lira.obspm.fr/-Pole-Systemes-Exoplanetaires-?lang=en (please contact our current and former PhDs to learn about our work environment!)
- The THD2 experimental testbed: https://thd-bench-lira.obspm.fr
- Professional pages :
    - Dr Johan Mazoyer: https://www.johanmazoyer.com/
    - Dr Raphaël Galicher: https://lira.obspm.fr/perso/raphael-galicher/
    - Dr Pierre Baudoz: https://www.linkedin.com/in/baudoz-pierre-b0b00a27/
- To dig deeper: *Imaging exoplanets with coronagraphic instruments* (Galicher & Mazoyer 2024) https://arxiv.org/abs/2302.10833

How to apply?

Send your application to johan.mazoyer@obspm.fr before Monday March 30th 2026 at 23h59 CET. Please clearly indicate the PhD name "**ECHOES: integral field spectroscopy and coronagraphy**" in your email:

- Resume
- Transcript for the last 2 academic years
- One letter of recommendation