– Internship Position at LAM –

# Simulating the characterization of exoplanets at high contrast & high spectral resolution

**Location:** Laboratoire d'Astrophysique de Marseille (https://www.lam.fr/)
**Duration:** 3 to 4 months
**Starting data:** March or April 2019 (flexible)
**Level:** Master 2
**Supervisor:** Gilles Otten (gilles.otten@lam.fr)
**Co-supervisor:** Arthur Vigan (arthur.vigan@lam.fr)

## Background

Since the first detection of a directly imaged exoplanet in 2004, over a dozen of such planets have been detected. In recent years, dedicated high-contrast direct imagers and spectrographs such as SPHERE and GPI have detected many more disks and several new companions around young nearby stars. Using extreme adaptive optics and coronagraphy, these instruments are able to detected planets that are $10^5$ to $10^6$ times fainter than their star. And thanks to their integral field spectrographs we are able to analyse the light of these exoplanets to assess the presence of molecules such as water, methane, carbon monoxide or ammonia in their atmospheres. However, these spectrographs have only limited capability for characterization, as both their wavelength range and their spectral resolution are restricted.

New or upgraded high-spectral resolution spectrometers (such as SPIRou or CRIRES+) will soon come into service and will hopefully enable new advances in exoplanetary science for the characterization of the brightest directly imaged planets and brown dwarfs. However, these high resolution spectrometers do not benefit from the developments in the suppression of starlight (extreme adaptive optics and coronagraphs): they are usually seeing-limited or with only partial atmospheric correction. For major advances in the understanding of directly imaged exoplanets, the properties of high-contrast imagers and high-resolution spectrographs need to be combined to benefit from the starlight suppression and enhanced spectral capabilities.

At LAM we are currently developing the HiRISE instrument, designed to couple the direct imager SPHERE with the high resolution spectrograph CRIRES+ at the Very Large Telescope in Chile, thereby combining the quality of both instruments and allowing the characterization of targets at high contrast and high spectral resolution.

## Project outline

To predict the performance of HiRISE we have developed an end-to-end simulation tool that takes the model spectra of a star and planet, and adds in all the noise contributions such as the

Erth's atmosphere, the telescope, the instrument, the detector and the coupling system. From this noisy spectrum we retrieve an atmospheric signal from the extrasolar planet and analyze how changes in the instrument configuration improve the detection sensitivity.

In this internship project, we invite Master students to work with us to extend the HiRISE simulation framework. The goal will be to add key new functionalities to explore potential science cases related to the characterization of extrasolar planets using HiRISE and other high resolution spectrometers.

The outline of the internship will be the following:

- Study relevant papers on high contrast imaging and high dispersion spectroscopy.
- Extend the simulation framework (written in Python 3) to include parameters and observables such as time variability, orbital motion, winds and rotation of the planet.
- Explore new science cases: testing the feasibility of detecting atmospheric species, winds and rotation of known transiting, directly imaged or radial velocity planets / brown dwarfs

These science case studies will act as a guide for the HiRISE project, and can potentially lead to a future proposal for telescope time.

## Required skills

This internship is intended for second year Master's students (Master 2), if possible specialized in astronomy, physics or a related field. Affinity with programming in Python or a similar data language is expected.

## Applying

Applicants who are interested in this project are invited to send an email with a one page letter of motivation and a curriculum vitae to Gilles Otten (gilles.otten@lam.fr) and Arthur Vigan (arthur.vigan@lam.fr).

## Duration and allowance

The internship will last from 3 to 4 months, depending on the availability of the student. The student will receive a monthly allowance of 550.

## Bibliography


- Snellen et al. 2010, *Nature*, Volume 465, 1049: https://arxiv.org/abs/1006.4364
- Brogi et al. 2012, *Nature*, Volume 486, 502: https://arxiv.org/abs/1206.6109
- Snellen et al. 2014, *Nature*, Volume 509, 63: https://arxiv.org/abs/1404.7506
- Hoeijmakers et al. 2018, *A&A*, 617, A144, https://arxiv.org/abs/1802.09721
- Vigan et al. 2018, *SPIE* Proceedings: https://arxiv.org/abs/1806.10618
- HiRISE project website: http://astro.vigan.fr/hirise.html