– Internship Position at LAM –

Wavefront control for direct detection and characterization of exoplanets

Location: Laboratoire d'Astrophysique de Marseille (LAM; https://www.lam.fr/)
Duration: 4 to 6 months
Starting date: March-April 2018 (flexible)
Level: Master, 2nd year
Supervisor: Arthur Vigan (CNRS/LAM)
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Context

The direct detection of exoplanets, which means *taking actual pictures of distant worlds*, requires combining powerful optical instruments and advanced data analysis methods. The new generation of exoplanet imagers installed on 8-meter telescopes, like SPHERE at the Very Large Telescope in Chile, has been designed from the start to detect giant exoplanets at angular separations of a few hundreds of milli-arcseconds from stars that are 10^5 to 10^7 times brighter. To face such a challenge, these instruments are equipped with extreme adaptive optics (AO) systems to correct for the atmospheric turbulence and with coronagraphs to remove the diffraction and reduce the piercing glare of the star.

The coronagraphic images provided by SPHERE are still limited by the optical aberrations inside the instrument, which create *speckles* in the focal plane. To decrease their amount and brightness, we can use the deformable mirror of the AO system to shape the wavefront and compensate for the instrumental aberrations. In 2013, we proposed the ZELDA wavefront sensor to measure the aberrations in SPHERE, and in 2016 we demonstrated that it can be used to significantly improve the performance for exoplanet detection.

The next step is to use the information provided by ZELDA for more advanced wavefront control, like reducing the speckles in small specific area of the focal plane, where we know a planet is located. This will open new possibilities for their detailed characterization.

Internship work

The MITHIC high-contrast imaging testbed at LAM has been developed to study wavefront control techniques and new coronagraphic concepts. During the internship, the student will work on MITHIC with the goal of using ZELDA to compensate the aberrations of the bench and move towards advanced wavefront control to create a *dark hole* region, i.e. to clean a specific area in the focal plane to reach higher contrast in this region.

The internship will take place in several steps:

1) Bibliography on coronagraphy and wavefront control
2) Familiarization with the MITHIC testbed and how to operate it

3) Improvement of existing tools to measure and compensate the aberrations of the bench. Preliminary tools and procedures exist, but they need to be improved to reach the maximum performance
4) Comparison of aberration compensation with a direct approach and with an approach based on an interaction matrix
5) Estimation of the ultimate contrast performance on coronagraphic images, without and with compensation of the aberrations

Depending on the progress on these points during the internship, the student will then gradually move towards more advanced wavefront control algorithms to try to create a *dark hole* in the coronagraphic images.

Over the course of the internship, the student will probably have the opportunity for a short duration stay (6-10 days) at one of LAM collaborating institutes in the USA (Caltech in Pasadena or STScI in Baltimore) who are actively working on coronagraphic concepts and wavefront control techniques with top-level high-contrast imaging testbeds.

Required level and skills

This internship is intended for second year Master's students (Master 2), preferably specialized in physics, optics, astronomical instrumentation or a related field.

Practical experience in optics (test bench alignment, optical measurements, etc) is preferable but not mandatory. Some experience with Python or a similar data analysis language is preferable.

Continuation in PhD

This internship will prepare for a fully-funded PhD project proposed in the context of the HiRISE project led by LAM. A full description of the PhD project is available here:

http://astro.vigan.fr/docs/PhD1-LAM-ERC-HiRISE.pdf

Students interested by the PhD project are strongly encouraged to apply for the internship.

Duration and allowance

The internship can last from 4 to 6 months, depending on the availability of the student. The student will receive a monthly allowance of ~550€.

Application

Applicants are invited to send by e-mail a one page letter of motivation and a curriculum vitae to Arthur Vigan (arthur.vigan@lam.fr).

Bibliography

- Oppenheimer & Hinkley, ARA&A, 47, 253: https://arxiv.org/abs/0903.4466
- N'Diaye et al., 2013, A&A, 555, A94: https://arxiv.org/abs/1305.5143
- N'Diaye et al., 2016, A&A, 592, A79: https://arxiv.org/abs/1606.01895
- Mawet et al., 2017, ApJ, 838, 92: https://arxiv.org/abs/1703.00583
- http://astro.vigan.fr/zelda.html