Toward the next generation of tomographic AO assisted instruments: Self-Learning techniques for system optimization & science exploitation

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Adaptive Optics (AO) aims at compensating the quickly varying aberrations induced by the earth's atmosphere, and restoring images at the diffraction limit of current large ground-based telescopes. Very recently, such capability has been brought to its apogee by coupling the ESO Adaptive Optics Facility (AOF) with the cutting-edge instrumentation of the MUSE integral-field (3D) spectrograph at the VLT. This achievement only represents a first step and within less than a decade the world will see a new generation of telescopes with diameters up to 39m. Called the Extremely Large Telescopes (ELTs), the scientific potential of these giants relies on integrated WFAO capabilities, fully operating from first light.

This change of paradigm comes with a cost : it becomes harder and harder to have a comprehensive view of the performance of the AO system and its impact on the final performance of the instruments. Classical laws, models and rules no longer apply to the new generation of ground-based instrumentation. Indeed, on top of well-known phenomena (classical turbulence effects), the dramatic increase of the telescope size (up to 39m diameter) induces new deleterious effects that have not yet been fully characterized nor modeled (due to telescope spiders, segmentations, windshake residual, cophasing errors etc …) .

On the other hand, AO systems are producing a tremendous amount of data - called telemetry data - with all the wave-front sensors engaged, which could be used to improve our understanding and prediction of the AO performance. All this data is not currently used, and this Ph.D. will explore how Machine learning could be exploited for that.

The primary goal of the thesis will be to develop new concepts and methods to break the current barrier of the system and atmospheric parameter estimation using AO telemetry combined with exogenous information provided by the telescope and the instrument auxiliary sensors.

Indeed, the relations between the inputs (hundreds of Gb of telemetry) and the outputs (few parameters) can be non-linear, and algorithms like multivariate regression are appropriate to manage such a huge parameter space. A strong collaboration with data processing experts has been initiated to that end. Furthermore access to dedicated Hardware such as powerful GPUs should be possible. More importantly, the PhD student will have access to several years of data recorded on the VLT AOF+MUSE instrument, as a benchmark for testing, demonstrating and validating the proposed approaches. These real field datasets will allow exploring innovative methods based on machine learning algorithms and compare their performance with classical methods like PCA and simple correlations.

The application of these novel approaches is to retrieve system and environment real time characteristics. Indeed, system identification will allow an online optimization of the AO loop parameters, provide diagnostic tools and key information to improve post-processing of the telemetry and science data. Such developments would represent a key step in the direction of future self-learning and self-calibrating systems.

The student will eventually expand her/his approach to future ESO instrumentation, such as the Multi Conjugate AO system MAVIS, being developed for the VLT. In the framework of the European Extremely Large Telescope (ELT), the successful candidate will focus on the specificities of the two first Laser Assisted tomographic AO instruments, namely HARMONI and MICADO-MAORY. This last part of the work is carried out in close collaboration with the on-going ESO ELT Working groups - https://eso.org/wiki/bin/view/ELTScience/WebHome.

Context of the PhD

The student will share her/his time between Laboratoire d'Astrophysique de Marseille (LAM – Marseille – France) and the ESO headquarters (ESO – Garching – Germany).
The collaboration between LAM, ONERA and ESO is an ideal framework for the PhD with unique access to high quality data, infrastructure, qualified personnel and possibly telescope time. LAM, ONERA and ESO have long been collaborating in the area of system design, science exploitation, development of instruments and innovative R&D.
Previous successful PhDs in a similar context have strongly benefited from this collaboration.

Funding:

The PhD is equally funded by ONERA, ESO and LAM.
The employers will provide assistance with the logistics and extra costs of the relocation, traveling and accommodation in France or Germany.

Duration: 3 years
Starting date: Fall 2021
Deadline for applications: 31 March 2021

Skills and Know-How

Excellent candidates with astronomy, applied physics, mathematics, engineering backgrounds with strong signal processing and programming skills are encouraged to apply.

ESO , ONERA and LAM are Equal Opportunity Employers