Post doc opportunity: innovative WFS for AO

Full funding for 18months with a possible extension (at least 1 year)

Starting date: as soon as possible

Europe is currently preparing the largest telescope of the world: the ELT [European Extremely Large Telescope] (https://www.eso.org/public/france/videos/elttrailer/). Planned by the end of 2025, this giant of 39 m diameter will allow answering fundamental questions of contemporary astrophysics by imaging exoplanets or studying large scales of the universe. However, images of astrophysical objects done by ground-based telescopes suffer from the distortion caused by the atmospheric turbulence which reduces the capacity of instruments to distinguish objects too close to each other. Adaptive Optics [AO] is a technique which allows restoring this loss of angular resolution by correcting the effects of atmospheric turbulence. In operation, on several astronomical observatories for almost 25 years, This technology is based on a deformable mirror which corrects in real time the incoming wave front by using information coming from a sensor which measures the turbulent phase called «Wave Front Sensor » [WFS]. WFS is the heart of any AO system. Ultimately it drives the final performance of the AO and thus of the associated astrophysical instrumentation.

For direct imaging of exoplanet applications, the state of the art AO instruments – SPHERE@ and GPI@GEMINI – are both using classical Shack-Hartman WFS [SHWFS]. Those instruments have been designed for an extreme Wave-Front control, hence a very high sub-aperture density. They typically provide 40x40 phase measurement points across the 8meter telescope pupil. It has been shown that one of the main performance limitations of these instruments comes from the fastest atmospheric residuals, which are not properly compensated by the AO correction. Figure1 illustrates this case on real SPHERE data: when the atmospheric conditions are evolving faster than the AO correction rate, significant residuals from uncorrected star light pollute the images in the region where exoplanets could be discovered. The exoplanet detectability is therefore reduced by factors 2 to 10. To tackle this issue, the AO corrections must be applied at a faster rate, typically 2 to 3 times faster than the 1 kHz which is the current standard for both SPHERE and GPI. Using the same SHWFS, this would mean dramatically reducing the limiting magnitude, and hence the number of suitable targets. This also means having access to a noiseless detector running at > 3kHz, which may be at the limit of what current technologies can do, but out of the scope of future ELT requirements. Indeed, scaling a SPHERE-like instrument for the ELT would require more than 200x200 phase measurement points across the pupil, and the need for noiseless, large format (>1 million pixels) detectors. Hence **Exoplanet detectability will be improved (x10) with faster (x2-3), more sensitive (1-2mag) and optimized Wave-Front Sensors.**

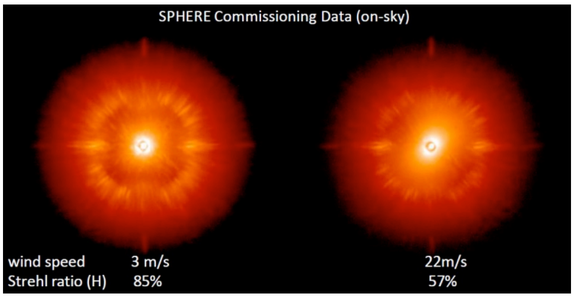

Figure1 ; Impact of wind speed on SPHERE data. Temporal error is the main limitation for the system. Faster and more sensitive WFS are required to improve the performance

Optimizing a wave-front sensor means maximizing the Signal to Noise Ratio of each phase measurements. That is nothing but (1) Finding the most efficient transformation procedure of phase into photons, (2) Minimizing the number of useful pixels on which the signal is coded; (3) Developing new signal processing approaches to deal with the various noises inherent to photon detection: photons, detector read-out, background. In that context, several innovative sensors have been proposed in the past decades to overcome the historical SHWFS. The most impressive example is certainly the introduction of the Pyramid WFS, proposed by R. Ragazzoni in 1996, which provides AO-corrected images with an astonishing quality at the Large Binocular Telescope. Very recently, **LAM** and **ONERA** have proposed an unified and rigorous analytical description of a new particular class of WFS which includes the Pyramid WFS: the Fourier Filtered WFS [FF-WFS] (see https://anr-wolf.com/index.php/wolf-the-project/). It has allowed to identify the three clear stages (beam shaping, spatial Fourier filtering, pupil plane detection and its associated signal processing) required for an efficient wave front measurement and how each stage affects the WFS performance.

In this general frame work the objectives of the post-doctorate project are threefold:

1. to develop new agile and multi-stage WFS schemes that will ensure both ultimate performance and good robustness to variable observing conditions in the frame of High Contrast Imaging applications;
2. to propose innovative on-sky identification and calibration processes to ensure the ultimate performance of the full AO loop on a very wide range of observational and environmental conditions
3. to lead the final design and implementation in the laboratory and on-sky of these new concepts with existing and in-development facilities. In laboratory, it will consist in modifying the LOOPS bench @ LAM in order to include the new proposed WFS schemes. For the on-sky validations, two AO benches (currently under development) could be considered: the PAPYRUS bench on the 1m52 telescope of the Observatoire de Haute Provence (nearby Marseille) and the CANARDO bench on the William Herschel Telescope (4.2m) located in the Canary Islands.

The postdoctoral researcher will be at the heart of the AO developments for the next generation of high contrast instrumentation both for the VLT (SPHERE+, MAVIS) and the ELT (HARMONI, PCS).

The postdoctoral researcher will work in the premise of the Laboratoire d'Astrophysique de Marseille within the R&D team (https://www.lam.fr/recherche-14/r-d-optics-group/?lang=en). He/She will benefit from all the expertise and the resources (simulation, benches, access to on-sky instrumentations) of the team.

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