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SAMplus: Adaptive Optics in optical wavelengths at SOAR

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Abstract. SAM is a laser-assisted AO module, designed to compensate ground-layer atmospheric turbulence at SOAR telescope. SAMplus is a project to upgrade SAM, focused on enhancing its performance at visible wavelengths. Such capabilities can be fully integrated with the latest SOAR instrumentation. This will open new research opportunities for various areas of Astronomy, both in spectroscopic as in imaging modes.

Resumo. SAM é um módulo AO assistido por laser, projetado para compensar a turbulência atmosférica da camada de solo no telescópio SOAR. O SAMplus é um projeto para atualizar o SAM focado em melhorar seu desempenho em comprimentos de onda visíveis. Tais recursos podem ser totalmente integrados com a última instrumentação SOAR. Isso abrirá novas oportunidades de pesquisa para várias áreas da Astronomia, tanto em modos espectroscópicos quanto em modos de imagem.

Keywords. Instrumentation: adaptive optics – Techniques: high angular resolution

1. Introduction

Adaptive Optics (AO) is an technique that substantially improve the optical performance of ground-based telescopes. So far, most of AO technologies were implemented for small on-sky Field of View (FoV) and/or to be applied over Infra-Red (IR) wavelengths.

Recently, a new access to AO came to the Brazilian community through SAM, the SOAR Adaptive Module (Tokovinin et al. 2016). SAM is a laser-assisted AO module, designed to compensate ground-layer atmospheric turbulence in near-IR and **visible wavelengths over a relative large FoV** (3×3 arcmin^2).

SAM was designed in early 2000's, based on the bimorph Deformable Mirrors (DM) technology that has considerable limitations (Madec 2012). SAM is in regular science operations since 2014. From the experience of these operations and theoretical considerations, it is clear that SAM's performance could be improved by an higher-order correction of the incoming wavefront.

SAMplus is a project addressed to the SOAR community to upgrade SAM focused on enhancing its performance at visible wavelengths. Science with AO in the visible offers a very broad perspective both in spectroscopic as in imaging modes (see Close 2016 for a review).

Some science cases of SAMplus: (i) LSST follow-up observations; (ii) Nuclei of galaxies; (iii) Young stars and star-forming regions; (iv) Compact nebulae; (v) Gravitational arcs and multiple lensed quasar systems; (vi) Globular clusters and multiple stars.

2. The SAMplus

The current AO technology allows to increase the turbulence correction order by using the same SAM's Nd:YAG laser flux more efficiently. The current version of SAM has a bimorph DM with 60 actuators. We propose for SAMplus a voice coil DM with 241 actuators and a corresponding new Wave-Front Sensor (WFS) and Real-Time Computer (RTC).

To illustrate SAMplus performance, a series of simulations were performed with the proposed 241 actuators DM and a 16x16 Shack-Hartman sensor. The typical seeing in SOAR site is 0.77 arcsec FWHM **at 500 nm** wavelength. Currently SAM improves the FWEHM resolution to 0.53 arcsec, and after the upgrade it is expected to deliver images with 0.39 arcsec – and up to 0.26 arcsec FWHM under good seeing conditions (Fig. 1).

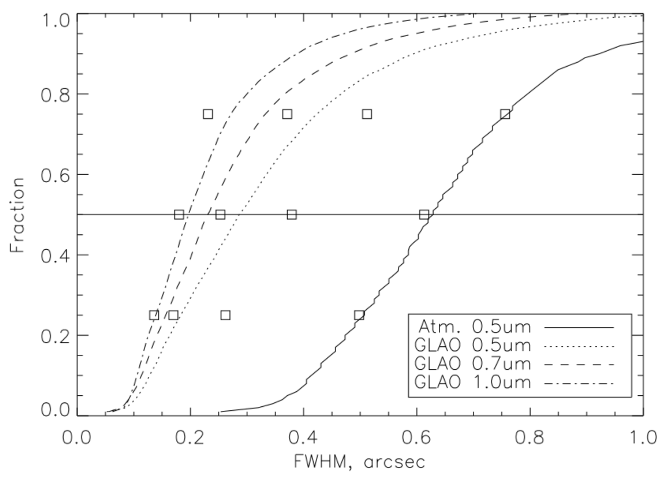

Figure 1. Cumulative distributions of FWHM resolution in the SAMplus. The squares depict performance for the good, median, and poor turbulence profiles computed previously for the current SAM parameters.

The most important aspect of the SAMplus project is the investigation of three critical AO components: (i) the specifications of the new DM (actuators settling time, pitch and stroke), within a physical size compatible with SAM optics; (ii) the definition of the detector camera for the WFS. A detector with substrate gating can eliminate the need of the current Pockels-cell shutter, simplifying the WFS subsystem and increasing the detected flux; and (iii) the WFS optical strategy, making the choice between Pyramid vs. Shack-Hartman configurations.

3. Project Management and tools

SAMplus has Dr. A. Tokovinin as PI, Dr. D. Faes as Co-PI. It is sponsored by FAPESP, IAG/USP and SOAR direction. Most of workforce, as well as the prototyping activities, will be under the responsibility of the group of Astronomical Instrumentation of IAG/USP.

The project is divided in four phases: (i) Conceptual Design; (ii) Preliminary Design; (iii) Laboratory integration; and (iv) Telescope integration. At the end of each phase it is planned a revision by an external committee.

A number of questions must be addressed in order to establish the best characteristic of the upgrade beyond the investigation of critical AO components. To assist this, some Systems Engineering (SE) processes are being applied in a customized way to the demands of the project. The main processes SE employed are: (i) interface configuration documentation, (ii) requirements management and (iii) risk management. The technical notes are written in a standardized way as *System Design Notes* and then properly classified.

The idea is to develop the upgrade in the IAG/USP laboratories, replicating the interfaced SAM components locally. Once the new system is ready, it will be transported to Chile and integrated with SAM with the minimum down-time as possible. The project is expected to be completed by the end of 2020.

4. Final remarks

SAMplus is a project to enhance SOAR AO performance at visible wavelengths. The project is based on a more efficient use of the UV laser system available in the SAM with the replacement of more modern adaptive optics components.

SAMplus operations can be fully integrated with the latest SOAR instrumentation. Beyond the obvious case of direct imaging, SAMplus will be integrated with SIFS (SOAR Integral Field Spectrograph), Fabry-Perot, and the future SAMOS (SOAR Multi-object Spectrograph).

Extending the possibility of doing AO to the *R*, *V* and *B* bands will allow investigations for multiple areas of Astronomy where angular resolution information is critical. In spectroscopy, important diagnostic lines lie at visible wavelengths, such as Hα/[NII] as well as Hβ/[OIII], that will be greatly impacted by SAMplus.

These new capabilities of optical AO over a large FoV puts SOAR in an unique position as observatory facility, opening new research opportunities for various areas of Astronomy.

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