Inverse problem approach for SPHERE+ adaptive optics control

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Abstract

The SPHERE+ project consists of an upgrade of the high-contrast SPHERE instrument at the VLT and in particular of an upgrade of its extreme Adaptive Optics (AO) system

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SAXO as SAXO+. The main goals of SAXO+ compared to SAXO are to improve the contrast at low angular separation and to push further the limiting magnitude to work on fainter near-infrared targets. SAXO currently uses a Shack-hartmann wavefront sensor, a 41x 41 deformable mirror (DM) and a tip-tilt mirror. SAXO+ will add a second stage equipped with a pyramid wavefront sensor and a second DM. In that respect, SAXO+ will also allow to demonstrate and compare advanced control methods in the perspective of the future PCS on the ELT.
We present here the control method studied at CRAL for SAXO+. The originality of this control relies on its inverse problem approach. It is an evolution of the AO control developed and installed by the CRAL on the THEMIS solar telescope, running at 1kHz in the visible, itself derived from the FrIM (Fractal Iterative Method) reconstructor and the FrIM-3D tomographic algorithms developed for the ELT.

We describe how our inverse problem approach can provide improved wavefront reconstruction even at low flux, and the effect it has on contrast performance. For SAXO+, we also introduce a novel regularized approach to distribute the commands on the high-order DMs and on the tip-tilt mirror.
We present the performance of the controller evaluated on SAXO end-to-end simulations using COMPASS. Comparison is made with performance of the existing SAXO system as a reference, using the same end-to-end COMPASS simulation framework.

Keywords: control, deformable mirrors, inverse problem, contrast