Disentangled cascade adaptive optics for the SPHERE instrument forthcoming upgrade

Nicolas Galland*[1], Caroline Kulcsar[2], Henri Francois Raynaud[2], Charles Goulas[3], Clémentine Béchet[4], Florian Ferreira[5], Michel Tallon[4], Fabrice Vidal[5], Maud Langlois[4], Anthony Boccaletti[5], Gael Chauvin[6], Emiliano Diolaiti[7], Raffaele Gratton[7], Magali Loupias[4], Julien Milli[8], and François Wildi[9]

[1]Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, 91127, Palaiseau, France. – Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, 91127, Palaiseau, France. – France

[2]Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, 91127, Palaiseau, France. – Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, 91127, Palaiseau, France. – France

[3]Laboratoire d'études spatiales et d'instrumentation en astrophysique – Institut National des Sciences de l'Univers, Observatoire de Paris, Sorbonne Universite, Centre National de la Recherche Scientifique, Université Paris Cité – France

[4]Centre de Recherche Astrophysique de Lyon – École Normale Supérieure - Lyon, Université Claude Bernard Lyon 1, Institut National des Sciences de l'Univers, Centre National de la Recherche Scientifique, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers – France

[5]Laboratoire d'études spatiales et d'instrumentation en astrophysique – Institut National des Sciences de l'Univers, Observatoire de Paris, Sorbonne Universite, Centre National de la Recherche Scientifique, Université Paris Cité – France

[6]Observatoire de la Côte d'Azur – Institut National des Sciences de l'Univers, Centre National de la Recherche Scientifique – France

[7]Istituto Nazionale di Astrofisica – Italy

[8]Institut de Planétologie et d'astrophysique de Grenoble – Centre National d´tudes Spatiales [Toulouse], observatoire des sciences de l'univers de Grenoble, Centre National d´tudes Spatiales [Toulouse], Centre National d´tudes Spatiales [Toulouse], Centre National d'Études Spatiales [Toulouse] – France

[9]University of Geneva, Dept. of Astronomy – Switzerland

Abstract

The Spectro-Polarimetric High-contrast Exoplanet REsearch instrument (SPHERE) is a European Southern Observatory exo-planet imaging instrument installed on the 8m Very

*Speaker

Large Telescope at Paranal (Chile). It has been operated for over 8 years since its commissioning in 2014 (1, 2). Exo-planets observations rely on the quality of the adaptive optics correction which should provide the best possible imaging contrast. Considering the already achieved results, it has been decided to define new science objectives through an upgrade of this instrument within the SPHERE+ project (3). In particular, the AO system main update will consist in the addition of a second stage (SAXO+) of correction that will take as input the residual phase of the current SPHERE AO system resulting in a Cascade AO (CAO) system. The second stage will use a pyramid wavefront sensor (WFS), taking advantage of the fact that the residual phase of the first stage will be already partially corrected allowing the use of a high sensitivity WFS. It should also run at a nominal frequency two to three times faster than the first stage. As a part of the design process for this new AO system, we propose to perform simulation regarding the specificities of CAO systems. We propose to explore especially the implementation of disantangled CAO (dCAO), see Figure 1. When the two AO stages operate at different rates, the residual phase entering the 2nd stage includes an oversampled version of the slower 1st stage correction. This oversampling generates a non-stationary high-frequency see-saw signal which cannot be efficiently compensated by a linear time-invariant 2nd stage controller (4). The proposed disentanglement procedure enables to compensate for this effect, with the control effort computed by the faster 2nd stage effectively split between the two DMs (5). This procedure has been shown to improve significantly the image raw contrast with respect to two loops managed separately. This dCAO structure will be here designed and evaluated in the context of SAXO+ and compared with CAO using the COMPASS (6) end-to-end simulator. Controlling both loops with different RTCs or with a single one that drives all the components will be discussed in the light of the results obtained.

Keywords: Adaptive Optics Control, Cascade Adaptive Optics, Adaptive Optics Simulation, Performance Assesment