AO-COCKPYT: a semi-analytical model for Single Conjugate Adaptive Optics based on Fourier filtering Wave-Front Sensors

Christophe Verinaud*[1], Byron Engler , Miska Le Louarn† , Markus Kasper , and Henri Bonnet

[1]European Southern Observatory – Germany

Abstract

The future Single Conjugate Adaptive Optics (SCAO) systems on the ELT will be equipped with the Pyramid Wave-Front Sensor (WFS), considered now as the reference Wave-Front Sensor (WFS) for SCAO. Recent studies show that the non-linearities of the Pyramid sensor is a real challenge. The goal of the new Python code 'AO-COCKPYT', is to evaluate Fourier-Filtering WFS (FF-WFS) sensitivity in presence of residuals (aka Optical Gain) . The code is based on the Convolutional Model (Fauvarque, 2019) and yields a closed loop modal and/or Fourier-based error budget and residual Wave-Front (WF) statistics. In this presentation, we analyze the validity and limitations of the AO-COCKPYT model by comparison to OOPAO end-to-end results. We find that the agreement is very good for moderate residuals (typically $<$ 1 rad): in these cases, AO-COCKPYT makes accurate predictions and permits to compute optimum modal controller gains when used with a Least-Square WF reconstructor. For larger residuals, cross-talk in the WFS response to modes is the main limitation especially for the emblematic Petal modes. In this case, we propose a Minimum Variance (MV) approach to WF reconstruction using AO-COCKPYT sensitivity estimation to refine the WFS model. OOPAO simulations show that in cases when sensitivity to Petal modes is seriously hampered but not null, an MV-based correction of slow quasi-static Petal error is possible and can address partially issues linked to the Low wind effect. Finally, we show how AO-COCKPYT is applied to various ELT Pyramid-based system configurations, from K-band to R-band SCAO WFS. We also apply AO-COCKPYT to the new Bi-O-edge WFS in the frame of Planetary and Camera Spectrograph (PCS) simulations.

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*Speaker

†Corresponding author: nomail@eso.org