Estimating the ELT's Differential Pistons with Deep Learning

Charleston Chauvet*†[1,2], Morgan Gray[1], Benoit Neichel[1], Maxime Dumont[1,3], Lisa Bardou[4], Jean-François Sauvage[1,3], and Olivier Beltramo-Martin[2]

[1]Aix Marseille Université, CNRS, CNES, LAM – Aix Marseille Univ, CNRS, LAM, Laboratoire d'Astrophysique de Marseille, Marseille, France – Laboratoire d'Astrophysique de Marseille Pôle de l'Étoile Site de Château-Gombert 38, rue Frédéric Joliot-Curie 13388 Marseille cedex 13 FRANCE, France

[2]SpaceAble – SpaceAble – 13-15 rue Taitbout 75009 Paris. France, France

[3]DOTA, ONERA, Université Paris Saclay [Palaiseau] – ONERA, Université Paris-Saclay – F-91123 Palaiseau, France

[4]Department of Physics [Durham University] – South Road, Durham DH1 3LE, United Kingdom, United Kingdom

Abstract

High angular resolution requires large telescope apertures, which in turn often require segmented pupils. This is particularly true for large optical and infrared ground-based telescopes such as the Extremely Large Telescope (ELT). Due to its six large spiders and the segmented surface of its main mirror, the ELT's angular resolution is affected by the presence of pistons which cause phasing errors, thus the importance of measuring and correcting them. In addition to the pistons, the implementation of a fixed two-by-two Shack-Hartmann Wave Front Sensor (SHWFS), optical effects such as Turbulence Residuals (TR), Adaptive Optics RESiduals (AORES) and the main pupil's constant rotation also affect the ELT's Point Spread Function (PSF). Assuming in our study that each of the ELT's main pupil's six differential pistons follows a ($-\pi/2$, $\pi/2$) uniform distribution (units in rad) and that the wavelength is set to 2.2 μm, we show that convolutional Neural Networks (NN) offer a promising technique for accurately estimating each of the ELT's six differential pistons in the presence of TR. Indeed, each of the Root Mean Square Error (RMSE) values associated to these differential pistons are much lower than 0.1 rad, or equivalently about 35 nm, regardless of the pupil's rotation angle, except for configurations when a spider is close to a SHWFS axis by less than 3○ of pupil rotation.

Keywords: Differential Pistons, Deep Learning, Point Spread Function, Extremely Large Telescope, Shack, Hartmann Wave Front Sensor, Turbulence Residuals, Adaptive Optics

*Speaker

†Corresponding author: charleston.chauvet@lam.fr