As the Extremely Large Telescope (ELT) approaches operational status, optimising its imaging performance is critical. A differential piston, arising from either the adaptive optics (AO) control loop, thermomechanical effects, or other sources, significantly degrades the image quality and is detrimental to the telescope's overall performance.

In a numerical simulation set-up, we propose a method for estimating the differential piston between the petals of the ELT's M4 mirror using images from a 2 × 2 Shack-Hartmann wavefront sensor (SH-WFS), commonly used in the ELT's tomographic AO mode. We aim to identify the limitations of this approach by evaluating its sensitivity to various observing conditions and sources of noise.

Using a deep learning model based on a ResNet architecture, we trained a neural network (NN) on simulated datasets to estimate the differential piston. We assessed the robustness of the method under various conditions, including variations in Strehl ratio, polychromaticity, and detector noise. The performance was quantified using the root mean square error (RMSE) of the estimated differential piston aberration.

This method demonstrates the ability to extract differential piston information from 2 × 2 SH-WFS images. Temporal averaging of frames makes the differential piston signal emerge from the turbulence-induced speckle field and leads to a significant improvement in the RMSE calculation. As expected, better seeing conditions result in improved accuracy. Polychromaticity only degrades the performance by less than 5%, compared to the monochromatic case. In a realistic scenario, detector noise is not a limiting factor, as the primary limitation rather arises from the need for sufficient speckle averaging. The network was also shown to be applicable to input images other than the 2 × 2 SH-WFS data.

Furthermore, we are currently exploiting multi-wavelength measurements and show that feeding multiple wavelengths simultaneously to the network enhances the capture range with minimal modifications to the baseline architecture.