Strategy for sensing petal mode in presence of AO residual turbulence with a pyramid wavefront sensor

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Abstract

The next generation of Extremely Large Telescope (24 to 39m diameter) will suffer from the so-called "pupil fragmentation" problem. Due to their large spiders, differential pistons will appear in the wavefront between the part of the pupil separated by these spiders during observations.

The Adaptive Optics (AO) system necessary to compensate atmospheric turbulence appears unable to sense this differential piston leading to bad control by the loop. Hence, such differential pistons, a.k.a petal modes, will prevent the AO system from reaching the diffraction limit of the telescope and ultimately will represent the main limitation of AO-assisted observation with an ELT. All the future single conjugated AO systems for the ELT have a PyWFS that is sensible to differential piston unlike the Shack-Hartmann, but it is not trivial to get a good enough sensitivity. This is particularly true for high contrast observing modes. These differential pistons can evolve quickly, so we are looking for an AO loop scheme able to measure both the atmospheric turbulence and the petal modes.
Solutions have been proposed such as the Holographic Dispersed Fringe Sensor (HDFS) for the Giant Magellan Telescope but they are not fast enough to be implemented as WFS of the AO loop and require longer AO sensing wavelength.

In this talk we want to study how to make the Pyramid Wavefront Sensor (PyWFS) sensitive to petal mode with visible light. We show that a small modulation radius makes the PyWFS sensitive to petal but unable to measure atmospheric turbulence due to the PyWFS non-linearities. We therefore propose to add dedicated petal sensor as a 2nd path and we study the unmodulated PyWFS as a candidate for this role. We study the reconstruction of the petal mode present in the residuals by this petalometer. We show that the petal mode due to its spatial frequency distribution beeing infinite can be confused with other high spatial frequency modes present in the residual turbulence. We propose a focal plane spatial filter to reduce high frequency residuals. The spatial filter helps in reducing this confusion, improving the petal measurement. In this talk we perform E2E simulations and laboratory

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tests to demonstrate the validity and performance of this new concept.

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