Exploring the Axicon for modulation-free Wavefront Sensing using deep learning

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Abstract

The core of an adaptive optics (AO) system lies in the use of wavefront sensors, traditionally the Shack Hartmann and later the Pyramid Wavefront Sensor. However, there are options, such as the Axicon Wavefront Sensor (AxWFS), that have been barely explored. The Axicon is a conical prism commonly used to extend the Depth of Field (DoF) in imaging systems as well as to create Bessel beams. Owing to its geometric equivalence to a pyramid with infinite faces, when the light focuses on its apex it creates overlap between all the possible sub-pupils emerging from its flat side, creating a continuous ring with homogeneous intensity in the absence of beam aberrations. On the other hand, intensity variations withing the doughnut shape can be associated to incoming wavefront aberrations. In this work, we use a modulation-free AxWFS assisted by deep learning to estimate the aberrations present in turbulent wavefronts for both open and closed-loop operations. The presented simulation results provide information regarding its capabilities and limitations as wavefront sensor. Furthermore, experimental results demonstrate the feasibility of its implementation in realistic AO situations. Since the Axicon is a cheaper and widely available optical element compared to the 4-sided pyramid, we believe the AxWFS could become an efficient alternative for low-cost, high performance AO solutions in small to mid-size telescopes.

Keywords: Axicon Wavefront Sensor, neural networks, nonmodulated wavefront sensor

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