Exoplanet imaging with ExAO: exploring a second-stage AO approach with a Zernike wavefront sensor for high-contrast imaging with ELTs

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Abstract

We propose to explore a two-stage extreme Adaptive optics (ExAO) approach with a second stage based on a Zernike wavefront sensor (ZWFS) for exoplanet imaging and spectroscopy. Most exoplanet imagers currently use a single-stage ExAO to correct for the effects of atmospheric turbulence and produce high-Strehl images of observed stars in the near-infrared. While such systems enable the observation of warm gaseous companions around nearby stars, adding a second-stage AO enables to push the wavefront correction further and possibly observe colder or smaller planets. This approach is currently investigated in different exoplanet imagers (VLT/SPHERE, Mag-AOX, Subaru/SCExAO) by considering a PWFS in the second arm to measure the residual atmospheric turbulence left from the first stage. Since these aberrations are expected to be very small (a few tens of nm in the NIR), we propose to investigate an alternative approach based on the ZWFS. This sensor is a promising concept with a small capture range to measure residual wavefront errors thanks to its large sensitivity, simple phase reconstruction and easy implementation. In this contribution, we perform two-stage AO simulations to determine the best functioning points for the ZWFS-based second-stage AO in terms of image quality. Preliminary tests are then investigated on the GHOST testbed at ESO to validate this approach experimentally. Finally, we discuss a first comparison between PWFS-based and ZWFS-based second-stage AO to draw preliminary conclusions on the interests of both schemes for exoplanet imaging and spectroscopy with the upgrade of the current exoplanet imagers and the envisioned ExAO instruments for ELTs.

Keywords: extreme adaptive optics, second stage AO, Zernike wavefront sensor, exoplanet imaging and spectroscopy

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