Demonstration of real-time linear closed-loop control with a photonic lantern focal-plane wavefront sensor

Jonathan Lin*†[1], Olivier Guyon[2], Fitzgerald Michael[1], Barnaby Norris[3], Yinzi Xin[4], Yoo Jung Kim[1], Sebastien Vievard[2], Julien Lozi[2], Sergio Leon-Saval[5], Christopher Betters[5], Steph Sallum[6], Pradip Gatkine[4], Dimitri Mawet[4], and Nemanja Jovanovic[4]

[1]University of California, Los Angeles – United States
[2]Subaru Telescope – United States
[3]Sydney Institute for Astronomy – Australia
[4]California Institute of Technology – United States
[5]Sydney Astrophotonic Instrumentation Laboratory – Australia
[6]University of California [Irvine] – United States

Abstract

Current pupil-plane adaptive optics (AO) faces two major challenges. The first are non-common-path aberrations (NCPAs), quasistatic aberrations which appear along the optical path due to differences between the sensing and science arms of the instrument. The second challenge, especially relevant for telescopes with large apertures subdivided by spiders and/or mirror segmentation, is petaling: aberrations which, in the pupil, form phase discontinuities at subaperture boundaries. These aberrations drastically impact the capabilities of high-contrast instruments even when correction is good; to date, petaling modes remain difficult to correct with conventional pupil-plane AO. One solution is to add a dedicated wavefront sensor stage which senses aberrations in the final focal plane. In this work, we consider how the photonic lantern (PL), a waveguide that efficiently couples aberrated light into single-mode fibers, may be used in such a way to correct low-order NCPAs. Since we envision the PL operating downstream a conventional pupil-plane AO, our analysis is centered in the linear (i.e. small wavefront error) regime. We also consider sensitivity to petaling modes, and potentials for spectrally dispersed wavefront sensing. Finally, we present a first experimental verification of real-time closed-loop control with the photonic lantern wavefront sensor (PLWFS), using a linear phase-retrieval algorithm, as well as first demonstrations of on-sky performance. We find that our prototype PLWFS can effectively correct _˜100nm RMS of low-order Zernike wavefront error, with potential to push further; and even more gains are possible with nonlinear neural-net phase retrieval (see abstract from Barnaby Norris). In the future, novel sensor architectures like the PLWFS may prove to be critical in resolving challenges in NCPA correction, petaling, and cophasing posed by upcoming ELTs.

Keywords: Photonics, Adaptive Optics, Wavefront Sensing

*Speaker
†Corresponding author: jon880@astro.ucla.edu