Simultaneous wavefront sensor and coronagraph dark hole calibration: real time optical gain tracking with incoherent focal plane speckles

Eden Mcewen*†[1], Jared Males‡ , Laird Close , Sebastiaan Haffert , Olivier Guyon , Joseph Long , Alex Hedglen , Maggie Kautz , Kyle Van Gorkom , Logan Pearce , Avalon Mcleod , Warren Foster , Jay Kueny , and Jialin Li

[1]Wyant College of Optical Sciences [University of Arizona] – United States

Abstract

Imaging exoplanets on next-generation extremely large telescopes requires adaptive optics (AO) fed coronagraphs that are exceptionally well calibrated with well-understood control loops. Current wavefront sensing (WFS) and control systems have become sensitive enough to expose an imperfect relationship between the applied corrections. This relationship, known as optical gain, is seen to drift throughout the night due to non linearities and signal loss due to low strehl. Unaddressed, optical gain is an additional unknown in the correction loop and degrades all possible WFS telemetry use-cases (e.g. real time correction speeds, NCPA offsetting capabilities, PSF reconstruction, telemetry based predictive control, and high performance correction at small working angles) due to lower controller gain or incomplete wavefront reconstruction.

We will report on a method for characterizing and tracking optical gain in coronagraphic ExAO systems non-destructively. Focal plane speckles can be produced by applying a high frequency sine wave in addition to Deformable Mirror (DM) commands. This reproduces copies of the central star's PSF unobstructed by the coronagraph at the focal plane. When the induced sine wave is given a 90 degree phase offset above the Nyquist sampling rate of the WFS, it no longer interferes with the atmospheric speckles resulting in clearer PSFs for astrometric and photometric calibrations in post processing. This procedure, which is common in high contrast imagers, leaves a consistent high spatial-frequency pattern on the WFS. This existing pattern is perfectly suited to track drifts in optical gain over time without degrading potential coronagraphic dark holes. We propose to use the WFS speckle signal to characterize and track discrepancies between sensed and applied modes. Here we show preliminary results of this optical gain tracking technique as used on the MagAO-X system and discuss how this will be applied to GMagAO-X, and other high-sensitivity AO systems of future telescopes. This work will enable extreme WFS systems of the next-generation to meet their full potential.

*Speaker

†Corresponding author: edenmcewen@arizona.edu

‡Corresponding author: jrmales@email.arizona.edu

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