ID de Contribution: **26** Type: **Oral contribution**

Precision emulation of high-contrast images using the low-order wave front sensor telemetry

mercredi 24 octobre 2018 15:10 (20 minutes)

Summary

High performance small inner working angle (IWA) coronagraphs equipped with ground-based extreme adaptive optics (ExAO) systems are capable of imaging exoplanets in the inner regions (< 10 AU) of extrasolar systems. However, the challenge is to gain access to the immediate neighbourhood of a star. Apart from improving coronagraphs design, an important factor that rules the system performance is the nature of wavefront control, especially the correction quality of the low-order wavefront aberrations. Low-order errors lead to starlight leak around the edge of a focal plane mask (FPM), thus further contributing to speckle noise in the science image. Such errors are capable of overwhelming a possible signal from a faint companion.

With a dedicated low-order wavefront sensor (LOWFS), the starlight leak can be measured and controlled, however, with an adjustable gain factor and after a processing delay. The non-zero low-order residuals per control loop iteration always leave some residual starlight in the final science image, especially at < 3 λ/D. This is the region where the current post-processing techniques such as Angular/Reference differential imaging cannot enhance the detection sensitivity. Addressing this issue, we propose an algorithm based on the Gaussian process modelling. Our model uses the telemetry of low-order residuals in closed-loop and calibrate the sub nanometric residuals in post-processing by emulating the given science images. A significant improvement in detection sensitivity at small angles is noticed in simulations. I will present the preliminary simulation and laboratory results of point spread function calibration using the Lyot-based LOWFS measurements (tip-tilt errors only) for a vector vortex coronagraph.

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Classification de Session: High Contrast Adaptive Optics