

Title: High Order Dithering experimental validation: extending JWST small grid dithering strategies on Roman CGI

Abstract:

The Roman Space Telescope Coronagraphic Instrument (Roman CGI) is a pathfinder mission designed to demonstrate high-contrast imaging technologies for the characterization of exoplanets in reflected light. With active wavefront control, CGI aims to achieve contrasts of  $10^{-7}$  or better at separations of  $3\text{--}9 \lambda/D$ , marking the first demonstration of this regime in space. In practice, however, temporal wavefront variations between science and reference observations set the detection floor. When the reference library does not adequately span the science speckle field, post-processing can leave residual speckles or over-subtract the signal, biasing and attenuating planetary detections.

We investigate strategies to mitigate this mismatch by introducing high-order dithering beyond tip-tilt during reference star observations, extending the small-grid dithering approach used on JWST. Experiments are conducted on the High-Contrast Imager for Complex Aperture Telescopes (HiCAT) testbed, where controlled aberrations are applied to evaluate their impact on achievable contrast.

We present the first demonstration of this approach on a functional high-contrast imaging testbed, showing consistent performance gains across Zernike modes Z5–Z24. Mixing linear combinations of these modes with their constituent single modes yields the most robust improvements, with repeatable gains of  $1.5\text{--}3\times$  in throughput-corrected  $5\sigma$  post-processed contrast at separations of  $5\text{--}8 \lambda/D$ . This corresponds to  $0.44\text{--}1.19$  mag deeper detection limits, improving the detectability of nearby Jupiter analogs from marginal to probable. At smaller separations of  $4\text{--}5 \lambda/D$ , certain modes and dithering strategies provide gains of up to  $2\times$  (approximately  $0.75$  mag). Small-amplitude probes tend to underdrive the improvement, while very large probes show reduced performance near the outer working angle.

These results demonstrate that high-order dithering can significantly enhance reference-based post-processing, providing a pathway to improved exoplanet detection limits for Roman CGI and future missions. Ongoing work is extending this framework to an additional dithering basis, with the goal of further broadening the design space for robust reference library construction.