On-Sky Adaptive Secondary Interaction Matrix Calibration on the MMT

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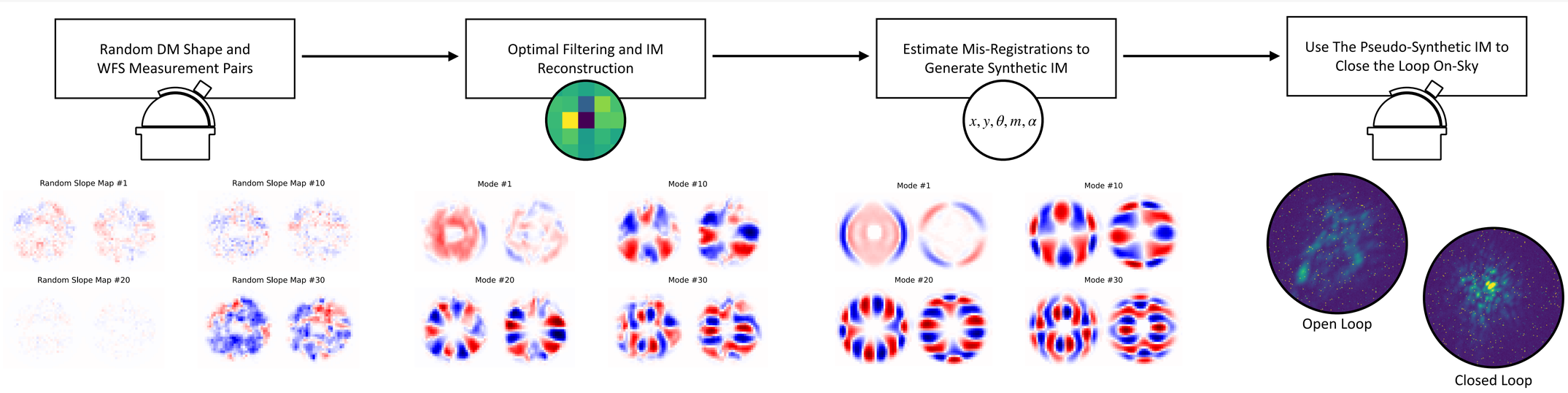
With the commissioning of the refurbished adaptive secondary mirror (ASM) and (visible and infrared) pyramid wavefront sensors (WFS) for the 6.5-meter MMT Observatory under way, special consideration had to be made to properly calibrate the mirror response functions to generate an interaction matrix (IM). Like many upcoming extremely large aperture telescopes (ELTs), the MMT lacks a point in the optical path to place a calibration source to accurately sample the ASM's actuator response functions. We show how the DO-CRIME[1] and SPRINT[2] algorithms were successfully implemented at the MMT to extract an IM from on sky data and match them to a mis-registration accurate synthetic IM. We also present improvements to their base algorithms, greatly improving robustness to noise as well as errant actuators. Our ultimate goal is to provide a 100 mode pseudo-synthetic calibration with under 10 minutes of on-sky time.These methods have been validated both on an optical bench AO system as well as preliminary on-sky results from the MAPS (MMTO Adaptive optics exoPlanet characterization System) project on the MMT.

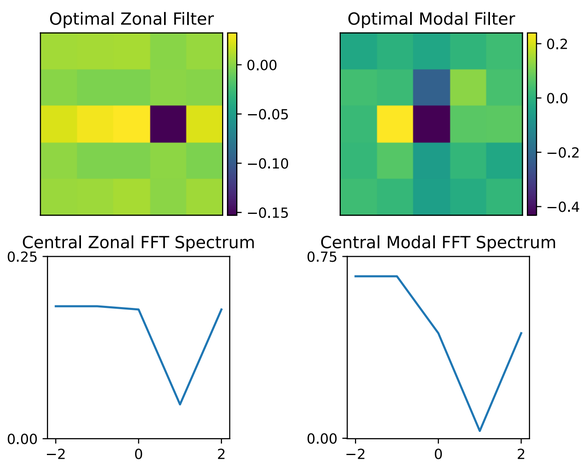


Step 1: Slope measurements created by randomly poking the ASM during on-sky open-loop operation

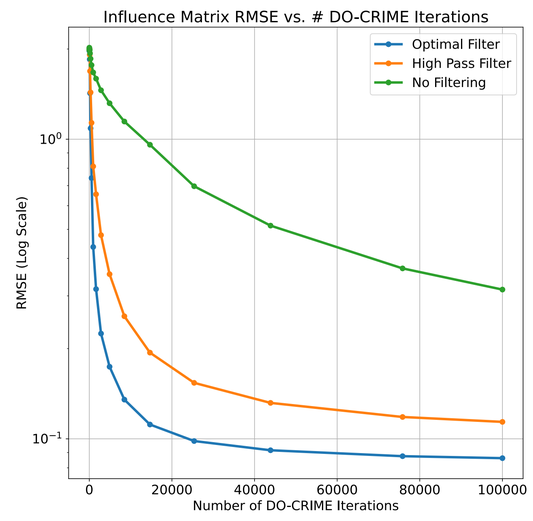
Step 2: Our optimal filter applied to the DO-CRIME method recovers an initial noisy IM

Step 3: SPRINT aligns our noisy IM with simulation to estimate mis-registrations and create a synthetic IM

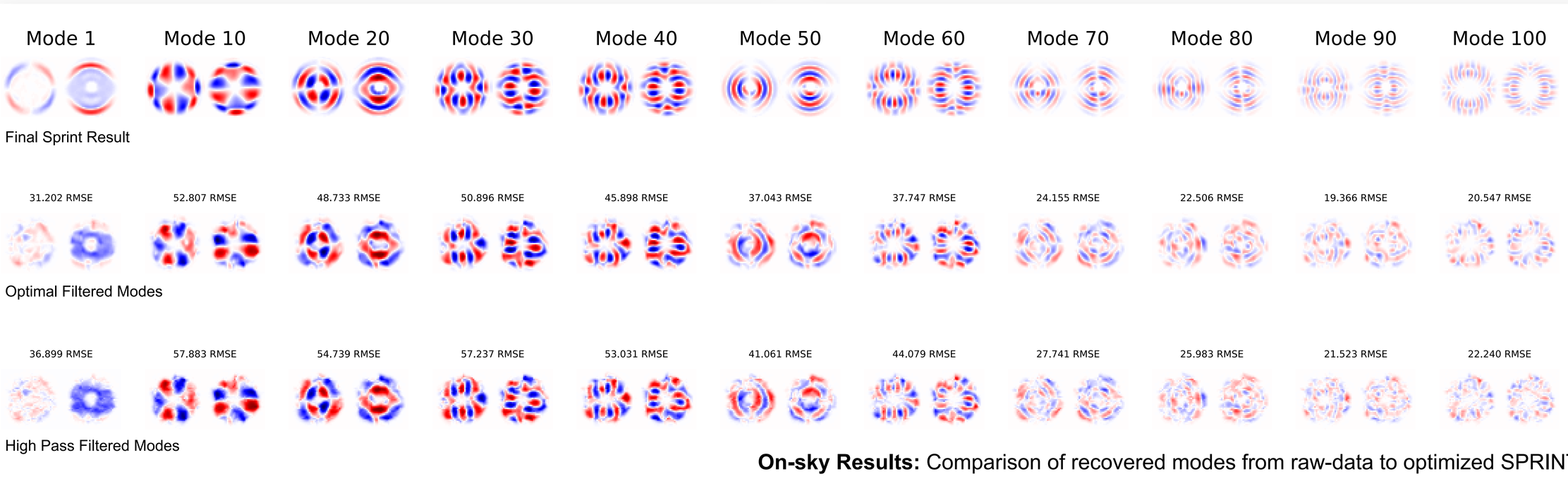
Early Results: First light results from closing the loop on MMT with our synthetic IM on MIRAC-5. More results soon to come



Optimal Filtering: The optimal filter for our DO-CRIME data was generated by carefully creating a “ground truth” IM on our bench and optimizing the filtering method used on our raw slope data. Dubbed the **Crime Wave**, our filter works equally well on optical bench and on-sky MMT data



Data efficient: Due to our improved filtering and optimization methods, we require fewer measurements of random slopes during on-sky operation to identify the mis-registrations required to generate the synthetic IM with the SPRINT method



On-sky Results: Comparison of recovered modes from raw-data to optimized SPRINT

Citations:
[1] DO-CRIME: Dynamic On-sky Covariance Random Interaction Matrix Evaluation, a novel method for calibrating adaptive optics systems — O. Lai (2020)
[2] SPRINT, system parameters recurrent invasive tracking: a fast and least-cost online calibration strategy for adaptive optics — CT. Heritier (2021)

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MMT Adaptive Optics ExoPlanet Characterization System — MAPS — MMTO and Steward Observatory