First AO3k On-sky Result with the Non-linear Curvature Wavefront Sensor

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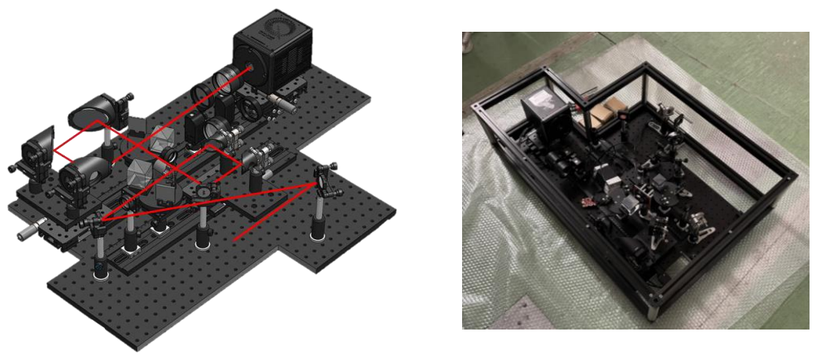
INTRODUCTION

- The upgrade of facility adaptive optics AO188 is one of the crucial ongoing projects of the Subaru Telescope.
- The non-linear curvature wavefront sensor (nlCWFS) is planned to replace the current visible WFS for the AO3k system, which is the upgraded version of the AO188.
- We successfully finished the AO performance evaluations in the lab and commissioned the nlCWFS inside of the AO188 box in November 2023.
- In this poster, we present the first on-sky results of the AO3k with the nlCWFS.

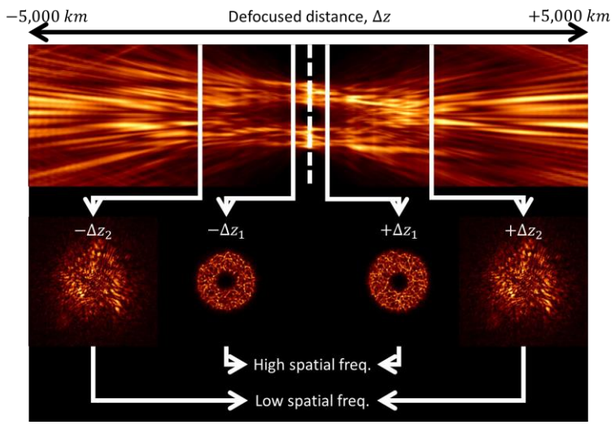


✓ A 3D model (left) and actual implementation (right) of the nlCWFS

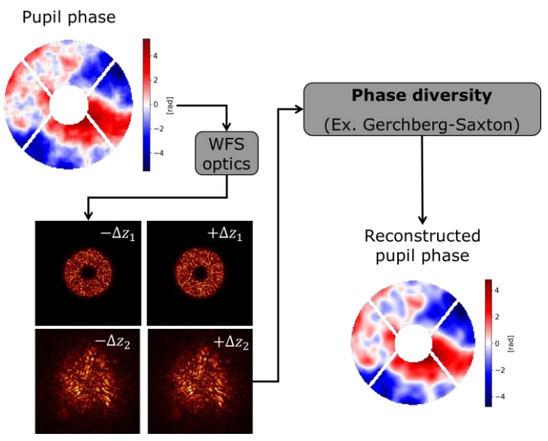
✓ Location of the nlCWFS (@ Nasmyth IR)

VISIBLE WAVEFRONT SENSOR UPGRADE

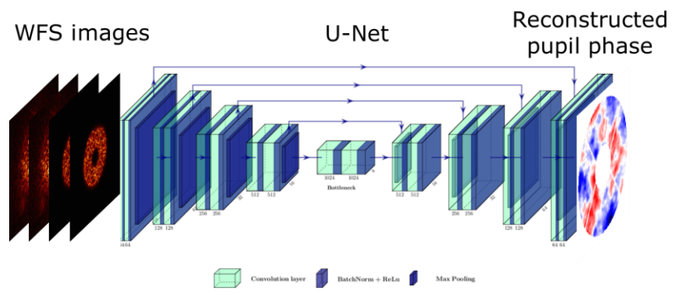
- The current visible WFS uses two defocused pupil images for WFSing.
- However, the nlCWFS utilizes four defocused pupil images to have a decent sensitivity for both low-order and high-order aberrations.
- Two near-pupil images are for high-order aberrations, and two far-pupil images are for low-order aberrations.
- We also plan to deploy non-linear wavefront reconstruction methods for an extensive dynamic range.



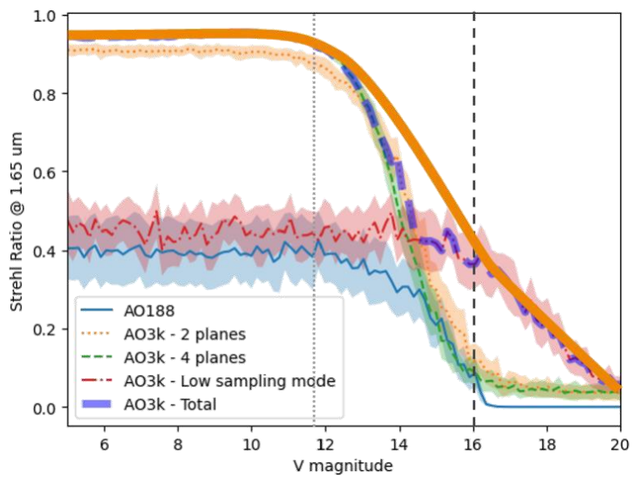
✓ Four defocused pupil images of the nlCWFS



✓ Nonlinear reconstruction – Phase diversity



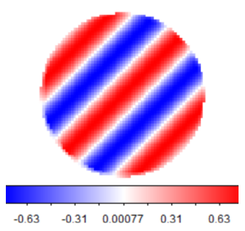
✓ Nonlinear reconstruction – Neural network



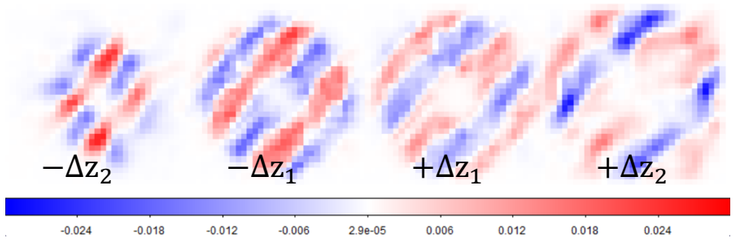
✓ AO188 vs. AO3k (Simulated)

ENGINEERING RESULTS #1

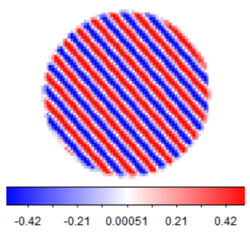
- To close the AO loop, we first took an on-sky response matrix (RM) while the nirPyWFS (near infrared Pyramid Wavefront Sensor) loop was closed.
- Even with on-sky RM measurement, we could get clear responses of the control modes at the deformable mirror (DM) thanks to the nirPyWFS loop.
- The images below show the injected DM phase and response image of the nlCWFS.



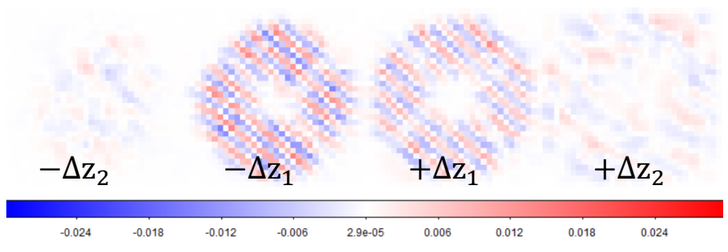
✓ Phase @ DM



✓ Response image of the nlCWFS



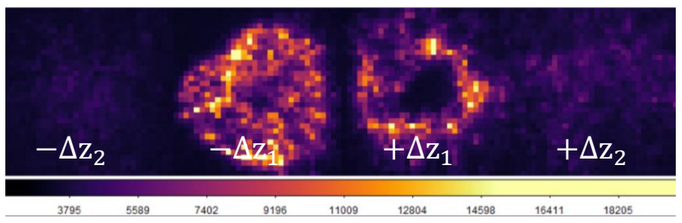
✓ Phase @ DM



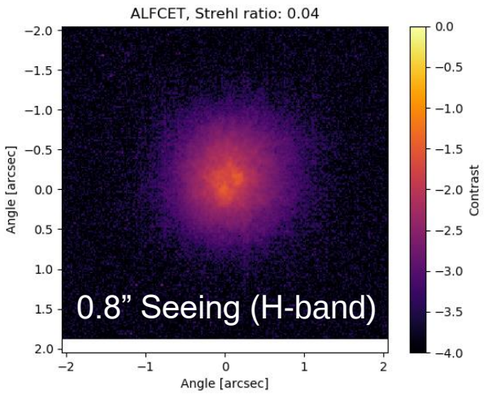
✓ Response image of the nlCWFS

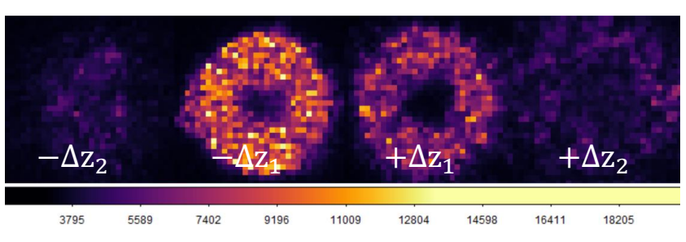
ENGINEERING RESULTS #2

- After taking the on-sky RM, we tried to close the AO loop with the nlCWFS.
- 2024-08-18_15:30 ~ 15:40, Target: *Alpha Cet*, Seeing: 0.8” ~ 1”

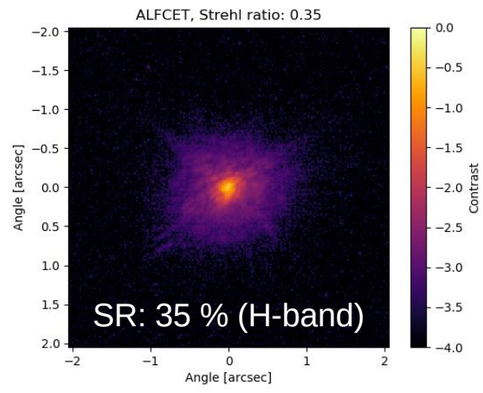


✓ **Loop open** – WFS image (left), H-band PSF image (right)





✓ **Loop closed** – WFS image (left), H-band PSF image (right)



SUMMARY

- We conducted the AO3k on-sky tests with the nlCWFS during Aug. 15th, 2024. ~ Aug. 18th, 2024. along with other AO3k tasks. (1 Full night, 3 half nights)
- Due to the bed weather, we couldn’t conduct any tasks on Aug. 19th 2024.
- We confirmed the closed-loop AO3k performance with the nlCWFS.
- **The highest Strehl ratio was 35% at 0.8” seeing condition.**
- **We anticipate the nlCWFS will provide a full AO3k capability with the new 3k DM after optimizing the closed-loop performance.**

FUTURE WORKS

- Optimizing AO performance for various conditions.
- Quantitative comparison of the AO performance between the current visible WFS and the nlCWFS.
- Upgrading the mechanical design to provide different modes, such as Natural Guide Star mode, Laser Guide Star mode, and Focal Plane Wavefront Sensing mode.
- Preparing the nlCWFS as the PI-type instrument.
- Deploying the non-linear wavefront reconstruction algorithms.