A new visible wavefront sensor for AO3k

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MOTIVATION

- Subaru Telescope started the upgrade of the facility adaptive optics (AO) system few years ago.
- The main upgrade is replacing the 188-deformable mirror (DM) with a new 3k DM from ALPAO.
- However, the current visible wavefront (WFS) can only

NEW FEATURES

Conventional curvature WFS (CWFS) uses two defocused images for wavefront sensing.

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- However, our new visible WFS uses four defocused images to have a decent sensitivity for both lowand high-order aberrations.
- Two near pupil images are for high-order and two far pupil images are for low-order aberrations.
- We also deploy non-linear wavefront reconstruction methods for a extensive dynamic range. (aka.



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- measure 188 modes because it uses 188 elements lenslet array and APDs (Avalanche photodiodes).
- In order to overcome this limitation, we started developing a new visible WFS, which can measure ~16,000 modes (\gg DM 3k modes) and can utilize a full capability of thd 3k DM.



Current visible WFS \checkmark





Nonlinear CWFS, nICWFS)



Reconstructed WFS images **U-Net** pupil phase Convolution layer 🚺 BatchNorm + ReLu 🊺 Max Pooling ✓ Nonlinear reconstruction – Neural network







✓ New visible WFS



Nonlinear reconstruction – Phase diversity

✓ AO188 vs. AO3k (Simulated)

WFS DESIGN

The optical design of the nICWFS was inspired by a trombone shape. To generate four defocused pupil images, the nICWFS uses two beamsplitters/dichroic fileters.





- ✓ Optical design for the nICWFS
- ✓ Four different optical paths

AO ACTIVITIES @ KASI



LAB EXPERIMENT

- The right figure shows the hardware setup for experiments of the nICWFS in the lab.
- We used a spatial light modulator (SLM) to simulate atmospheric turbulence.
- The bottom left figure shows the software setup for the AO loop.
- We use the CACAO (compute and control for adaptive optics) package for the realtime control.
- We tested the linear and nonlinear reconstructors and confirmed the AO performance with different light levels.





✓ Hardware setup for experiments



AO testbed for GIRMOS (Gemini Infrared Multi-Object Spectrograph) @ UBC

✓ Software setup for experiments





✓ Installation @ Nasmyth IR

✓ Position of the nICWFS

AO performance evaluation testbed for multiple applications @ KASI

TESTBED IMAGE CONFIDENTIAL