



**Centro UC**  
Astro - Ingeniería

# The telescope interface for the Tao-Aiuc high Resolution Y-band Spectrograph (TARdYS)

Matías Marambio-Jiménez

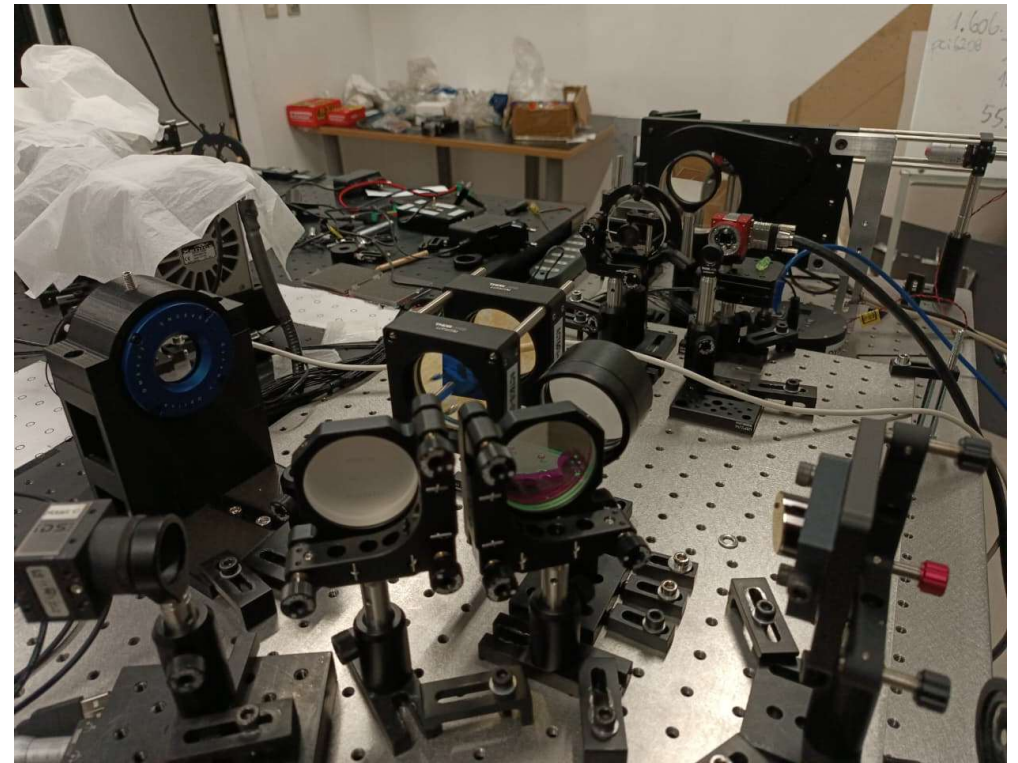
November 10th, 2025

Kyoto, Japan

Optical & Infrared Astronomical Instrumentation Workshop

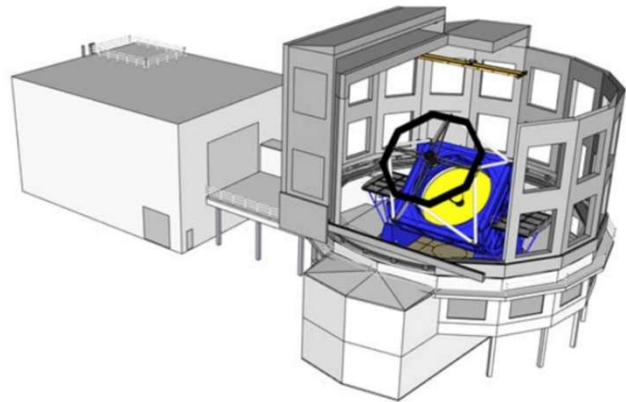
# Outline

- Introduction and Problem
- Theory and Background
- Methods
- Results
- Summary



# Introduction and Problem

## The Tokyo Atacama Observatory



The University of Tokyo Atacama Observatory  
6.5m telescope project. (Yoshii et al., 2010).

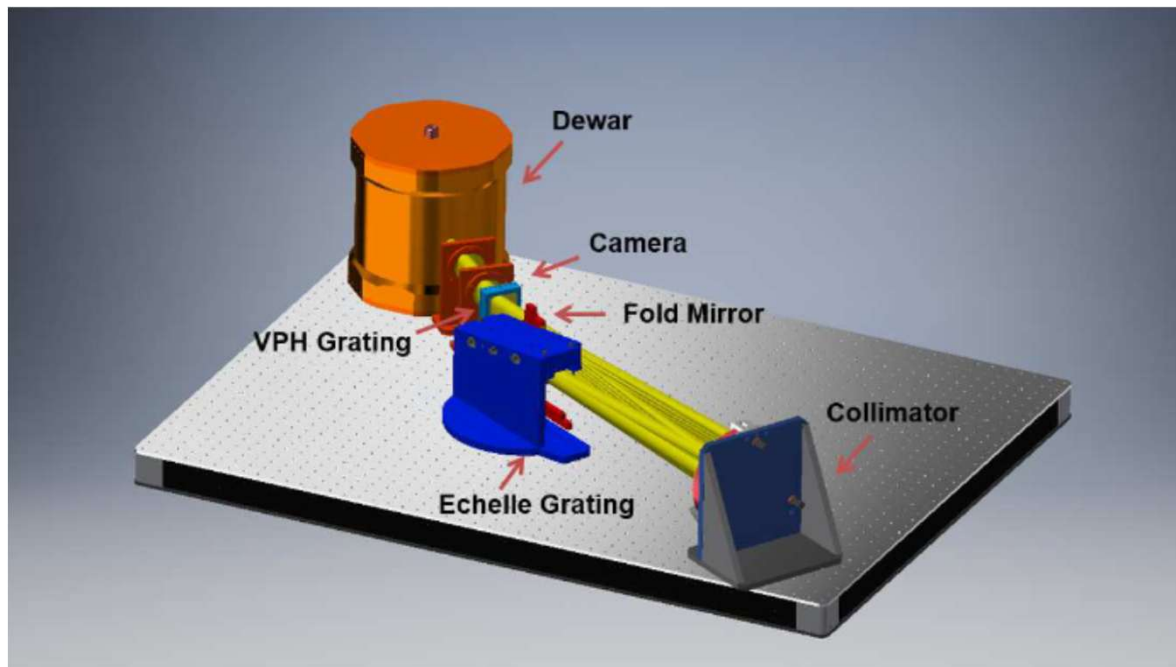
Optimized for optical-infrared observations,  
complement of the Subaru Telescope in Hawaii.



The University of Tokyo Atacama Observatory  
6.5m telescope: project status 2024. (Miyata et  
al., 2024).

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# The Tao Aiuc high-Resolution (d) Y-band Spectrograph



TARdYS: Design and prototype of an exoplanet hunter for TAO using a R6 Echelle grating (Rukdee et al., 2019)

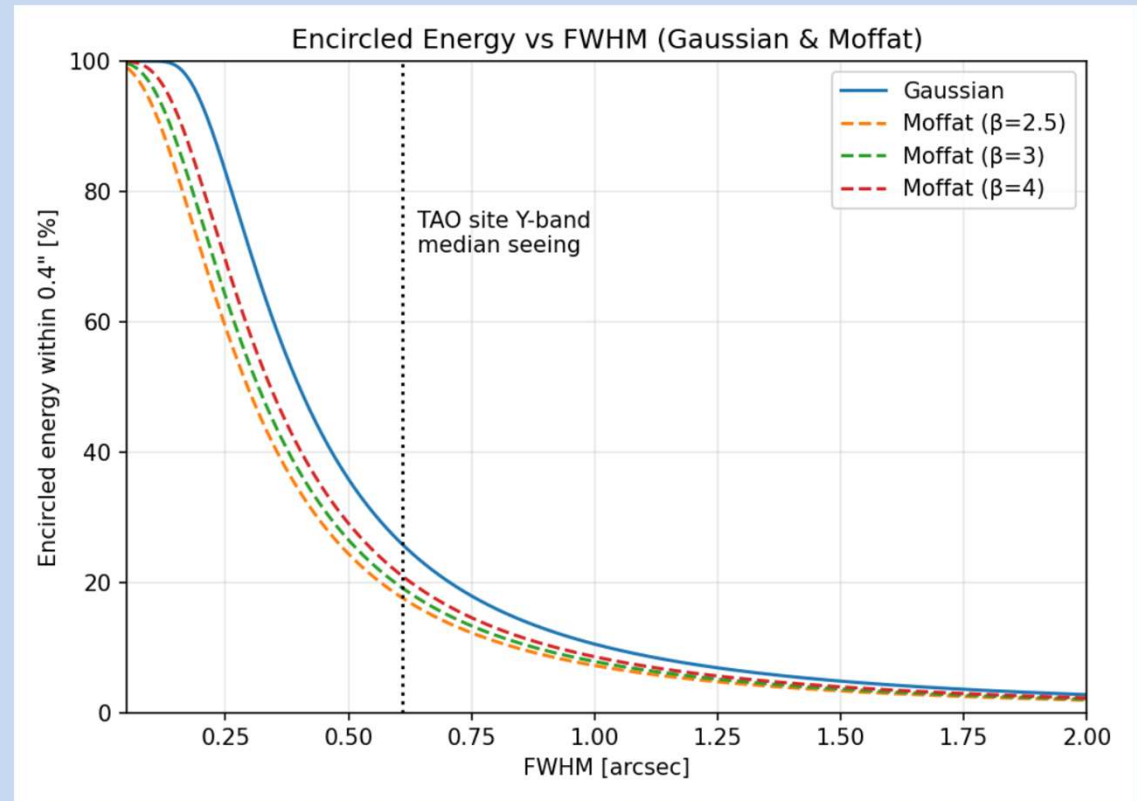


- Wavelength band: 0.843 – 1.117  $\mu\text{m}$
- R6 echelle,  $R \sim 66000$
- 50  $\mu\text{m}$  multi-mode optical fiber core
  - 0.4" projected on sky @ F/4
- Semi-cryogenic setup

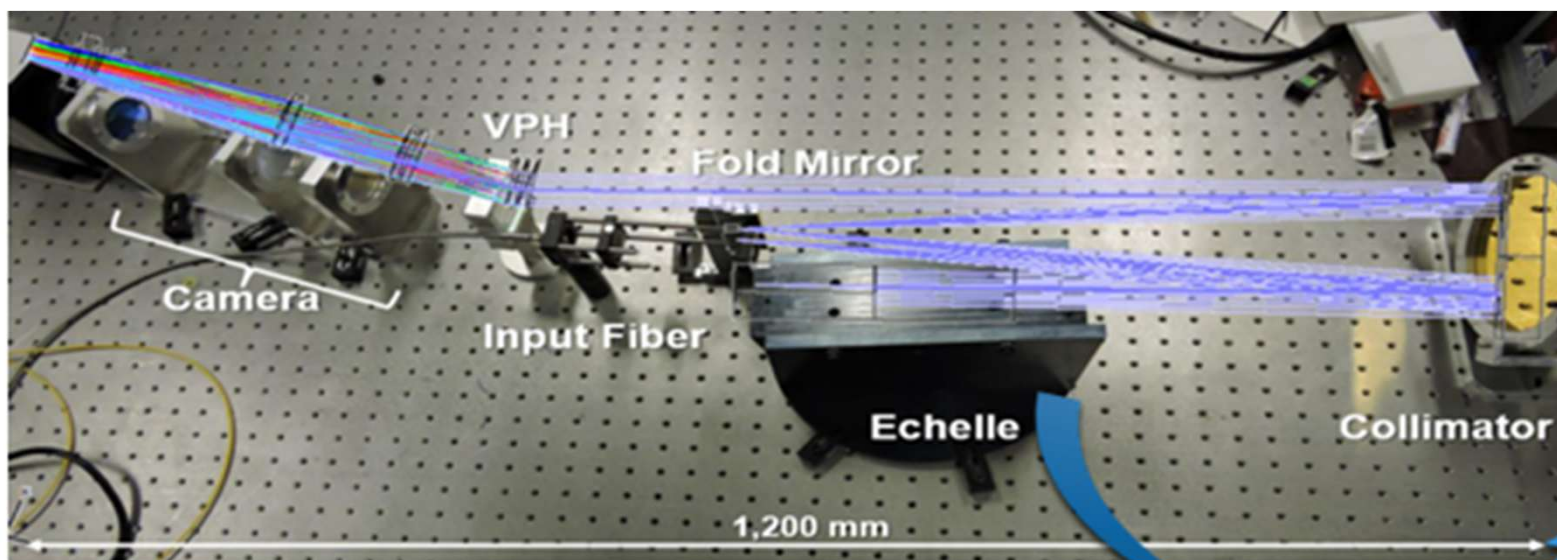
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# The problem I try to solve

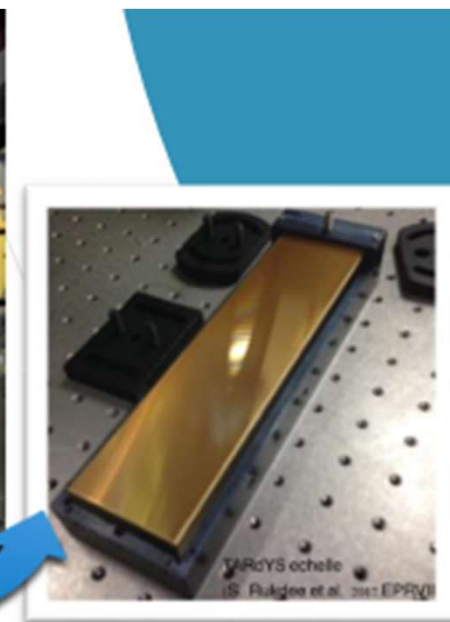
- Atmospheric turbulence effect degrades the telescope's theoretical performance, transforming the ideal, diffraction-limited image of just  $\sim 33$  milli-arcseconds into a seeing-limited disk of 0.6 arcseconds in the TARdYS Y-band (0.843 - 1.117  $\mu\text{m}$ ).
- Consequently, a large fraction of the star's photons misses the fiber core (0.4", 50  $\mu\text{m}$ ), drastically reducing the spectrograph's overall efficiency, to a throughput of  $\sim 18\%$ .



# The Tao Aiuc high-Resolution (d) Y-band Spectrograph



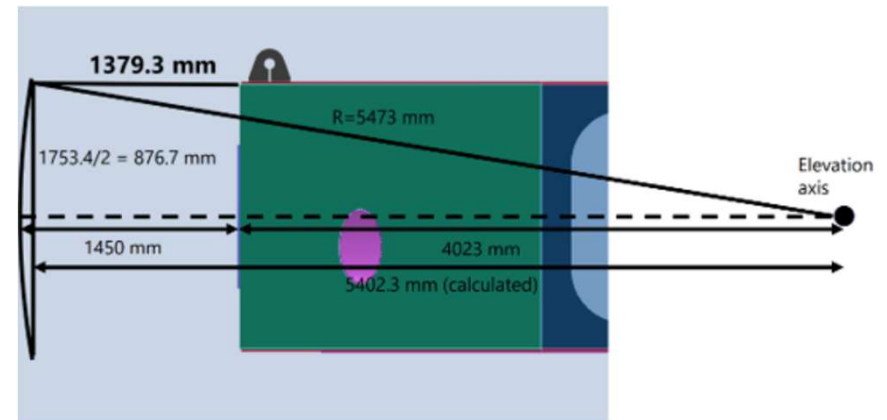
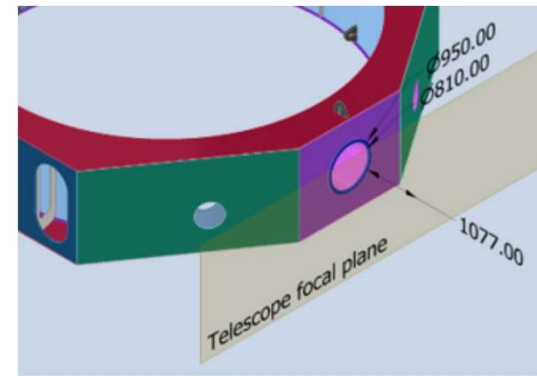
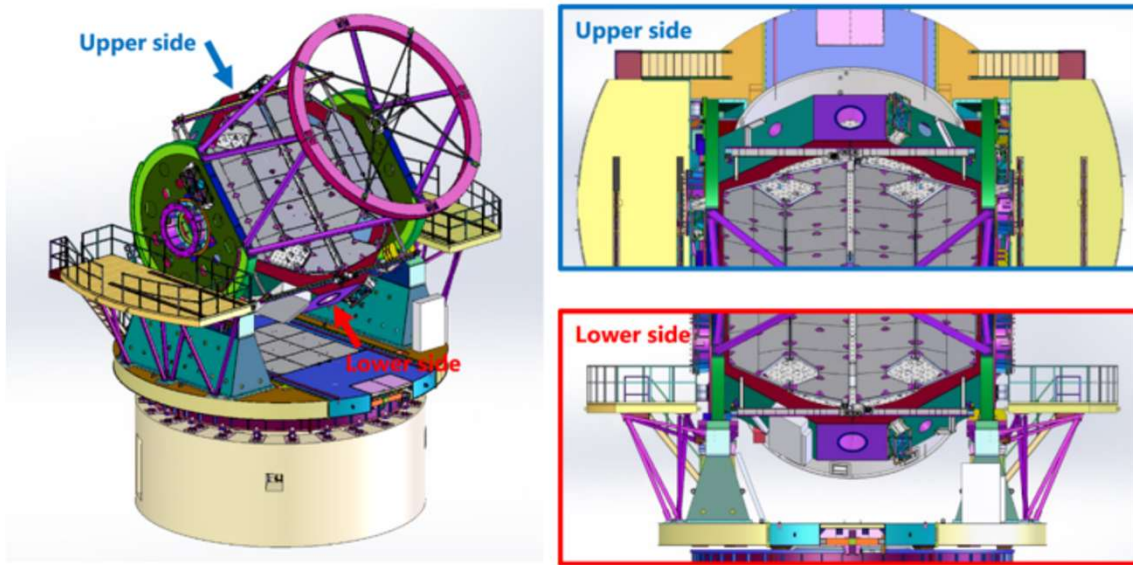
Rukdee et al. 2019



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# Theory and Background

## Limitations



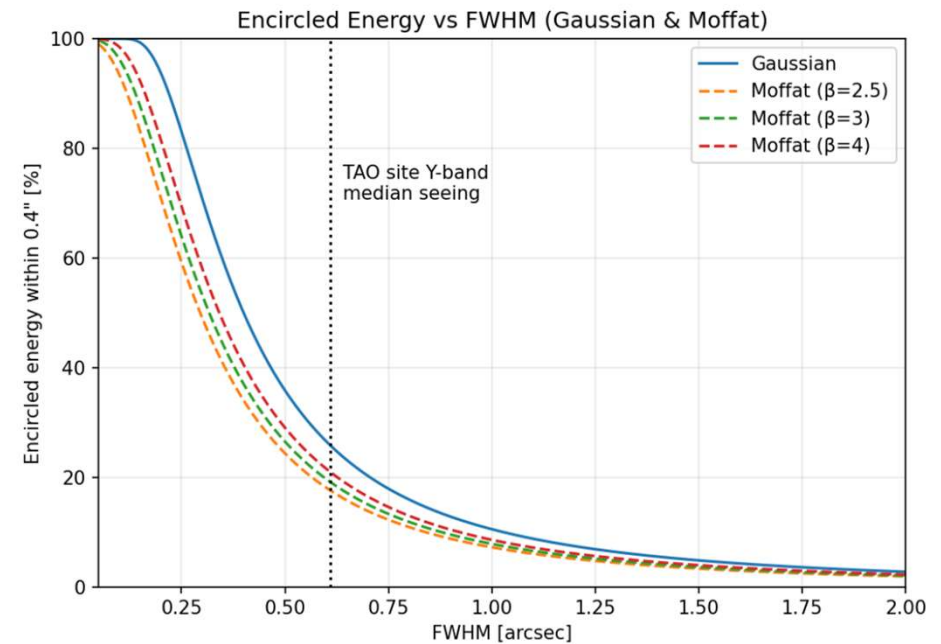
Via: Kushibiki Kosuke (2024)

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# Theory and Background

## Limitations

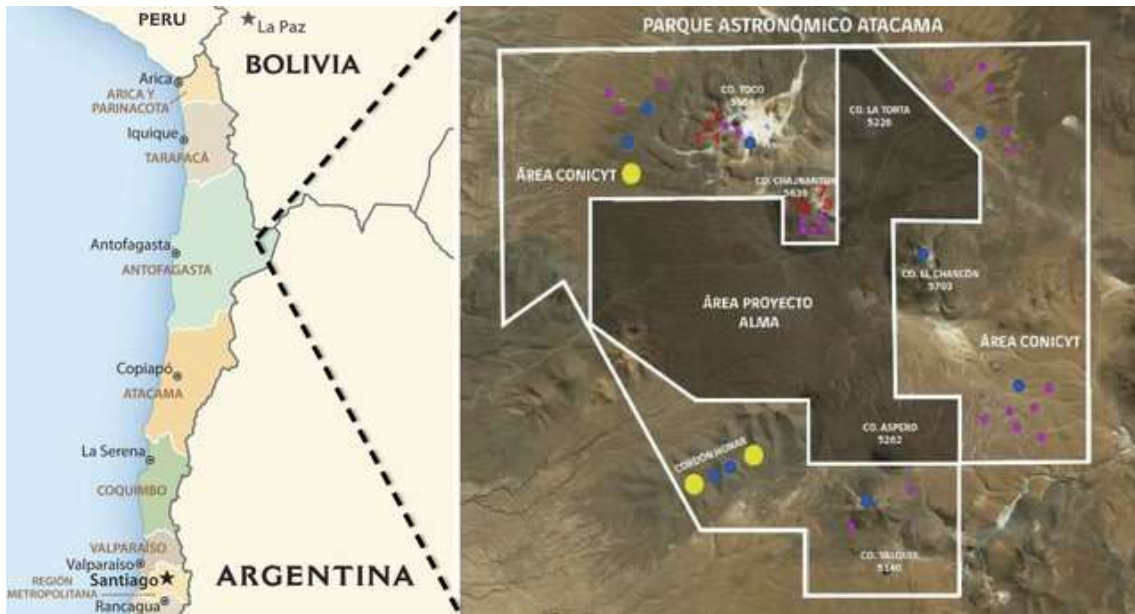
- Reduced clearing against Cassegrain floor.
- > 45% fiber coupling efficiency.
- COTS components.
- 600 x 450 mm optical bench.



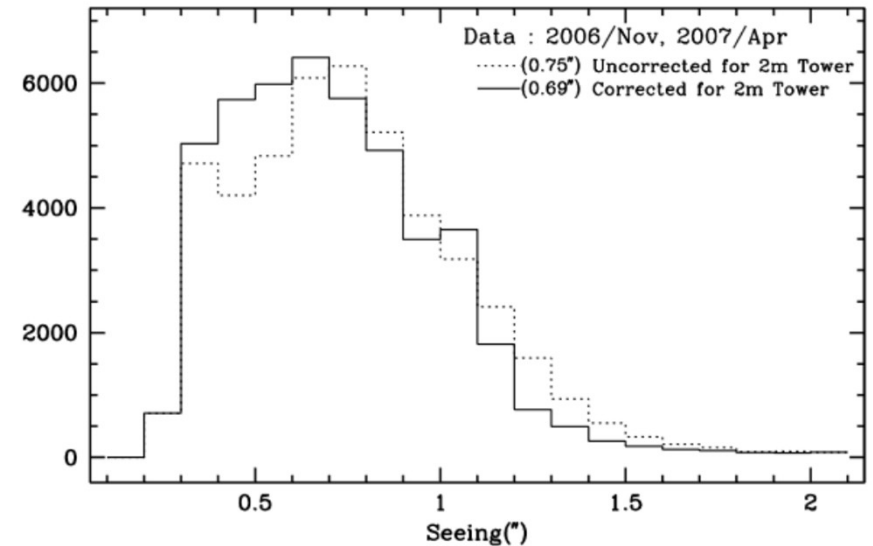
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# Theory and Background

## The TAO site



Parque Astronómico de Atacama: An Ideal Site for Millimeter, Submillimeter, and Mid-Infrared Astronomy (R. Bustos *et al.*, 2014)



Seeing environment at a 5640m altitude of Co. Chajnantor in northern Chile. (Motohara *et al.*, 2008)

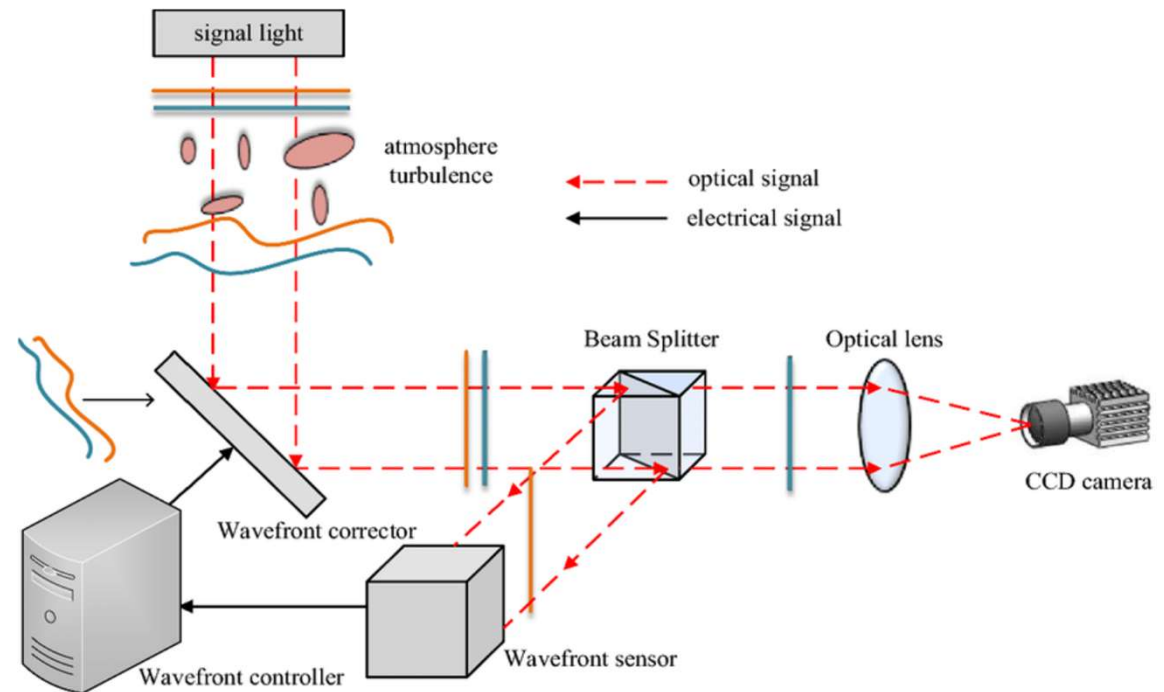
- 5640 m.a.s.l.
- Median Temp. =  $-5.8^{\circ}\text{C}$
- Median WindSp. = 5.3 m/s
- Median Seeing = 0.69" (@500nm)

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# Theory and Background

## Adaptive Optics

- Use the information from the medium of propagation.
- Corrects turbulence in closed-loop.
- Technique mostly used in big telescopes.



Distorted wavefront reconstruction based on compressed sensing. (Ke et al., 2022)

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# Methods

## OOMA end-to-end AO simulation

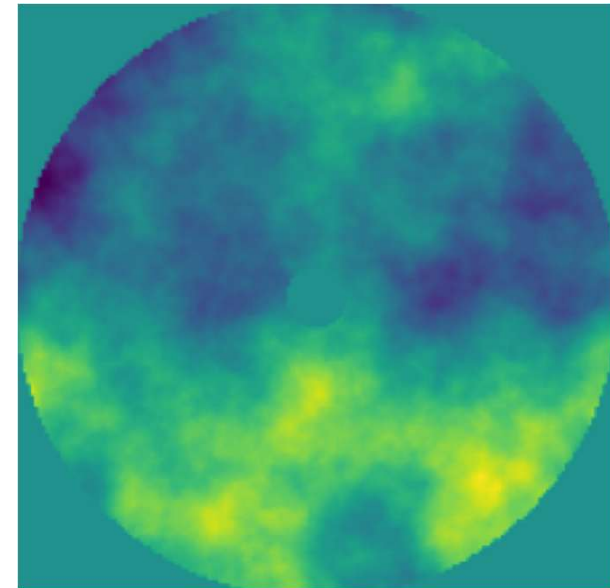
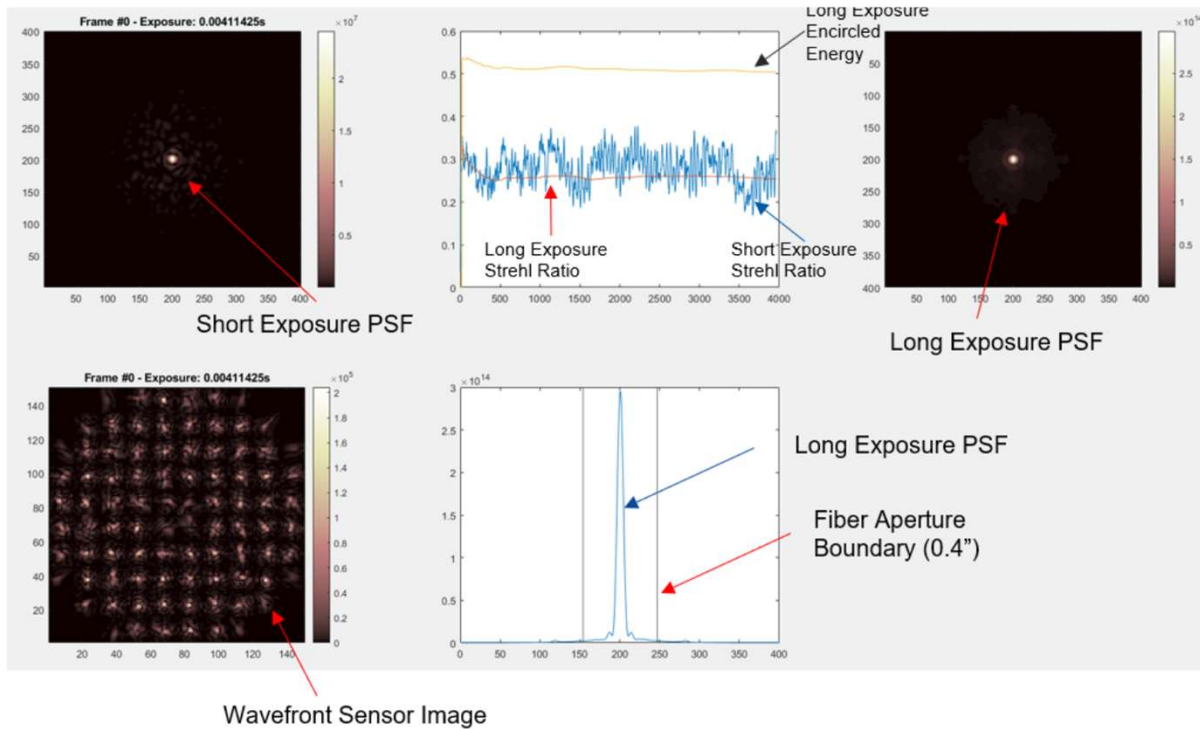
Camera	Size (pix)	#spots	fps	RON (e- RMS)	Price
ALPAO SH-CMOS	–	8 × 8	>400	2.1	9595.90 USD
ALPAO SH-EMCCD	–	8 × 8	>1k	0.1	10832 USD
Baumer VLXT-06M.I	800 × 620	11 × 11	1612	2.5	2600 USD
AV Alvium 1800 U-052m	816 × 620	11 × 11	619	2.5	520 USD
Thorlabs WFS20-14AR	1440 × 1080	-	>400	–	7034.36 USD

- 11 microlenses across the diameter of the detector.
- pitch = 500 microns.
- EFL = 13.8mm;  $s = 0.24''/\text{pix}$ ; FoV=6.72";  $\frac{\lambda}{D} = 0.28''$

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# Methods

## OOMA end-to-end AO simulation



$$\mathbf{X} = \mathbf{AZ} + \mathbf{B}\beta$$

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# Methods

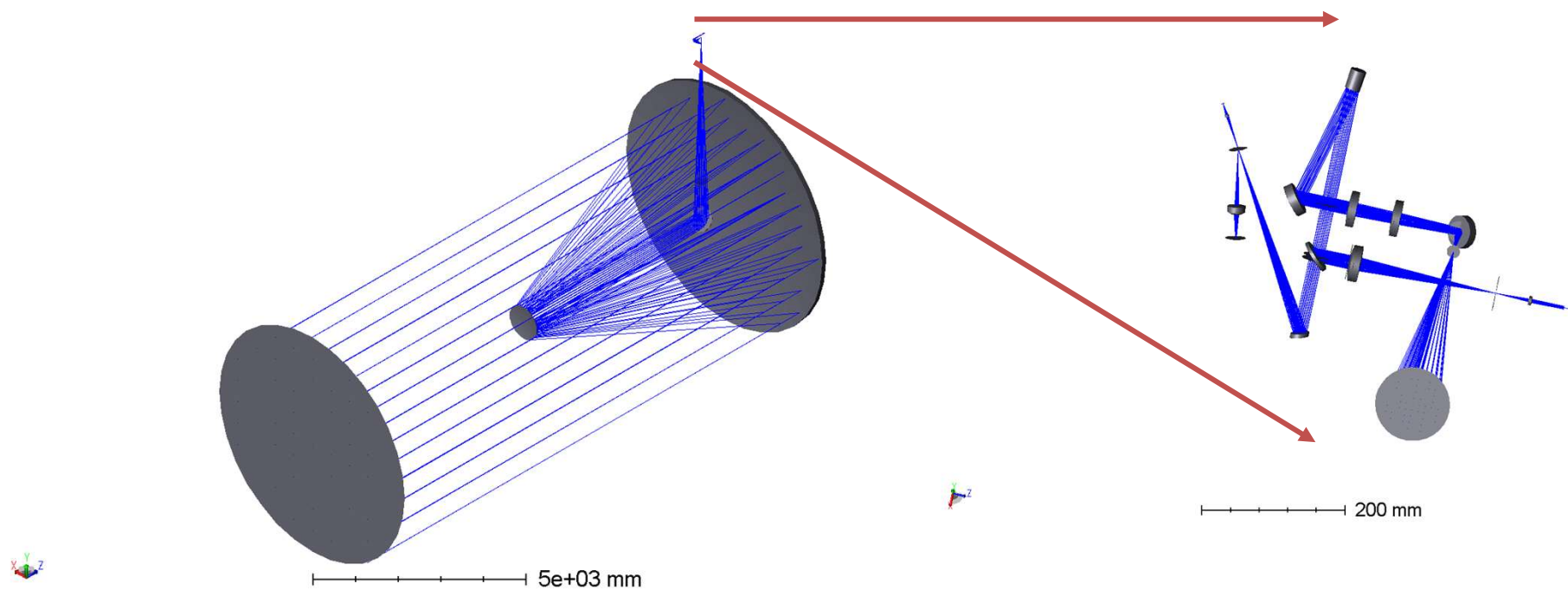
## OOMA end-to-end AO simulation

TABLE 3.2. Deformable mirrors tested in the end-to-end simulation, their price, and their respective encircled energy results.

Name	Characteristics	Price (kUSD)	EE(0.4")
ALPAO 97-15	97 actuators DM	41.4	48.96%
ALPAO 69-15	69 actuators DM	32.1	46.71%
Dynamic Optics DM6422	64 actuators, with tip-tilt stage	24.5	46.26%
Thorlabs DMP40-P01	40 actuators, with tip-tilt stage	4.4	41.00%
OKOTECH MMDM 15mm	17 actuators with tip-tilt stage	10.3	35.33%
Seeing-limited	0.8" diameter seeing @ 500 nm		17.87%

# Methods

## Optical Simulation



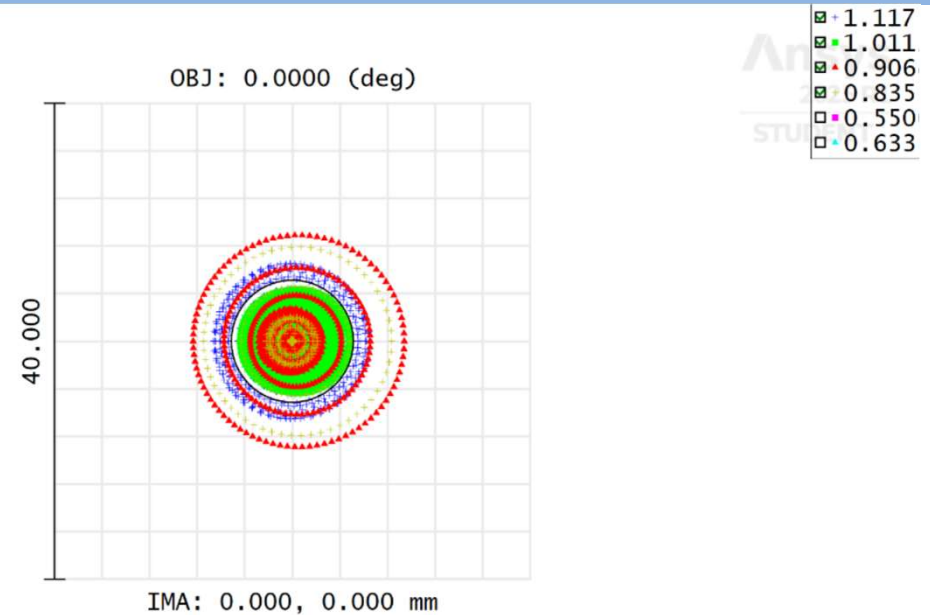
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# Methods

## Optical Simulation

- Spot diagram:
  - Y-band of TARdYS 0.843 – 1.117  $\mu\text{m}$
  - Airy diameter = 10.3  $\mu\text{m}$



Surface: IMA

Spot Diagram

TARdYS Front-End Design Version 4, 10/10/2025  
Units are  $\mu\text{m}$ . Airy Radius: 5.133 $\mu\text{m}$ . Legend items refer to Wavelengths  
Field : 1  
RMS radius : 3.723  
GEO radius : 9.412  
Scale bar : 40.000 Reference : Centroid

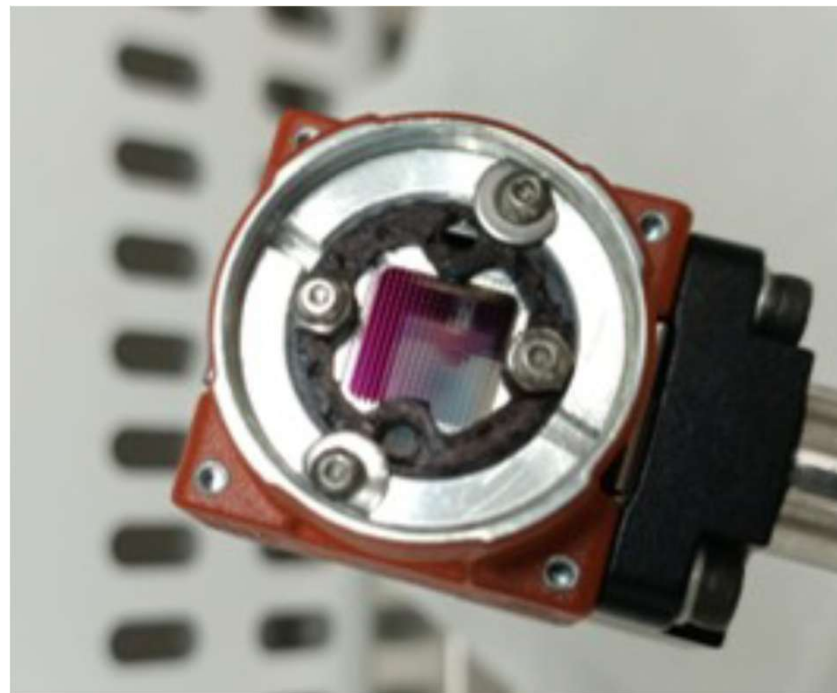
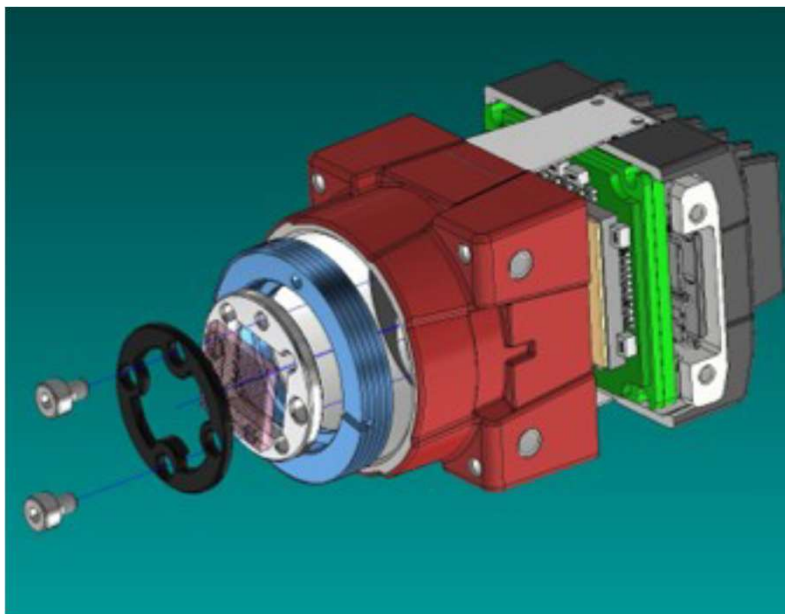
Zemax  
Ansys Zemax OpticStudio 2024 R2.02

TARdYS\_front-end\_optical1-design\_FIXEDv4.zmx  
Configuration 2 of 3

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# Methods

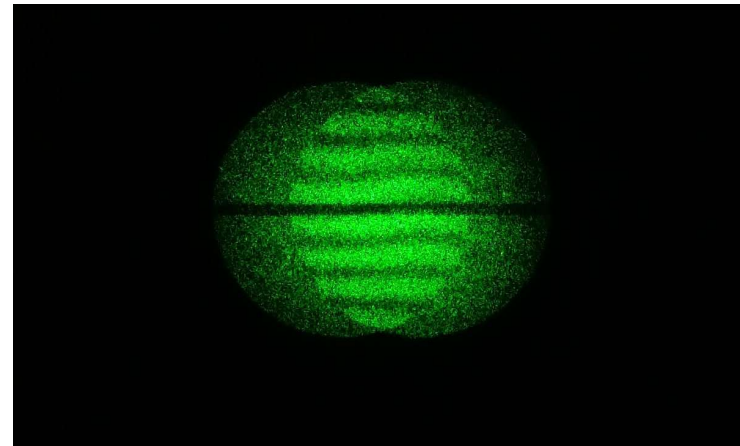
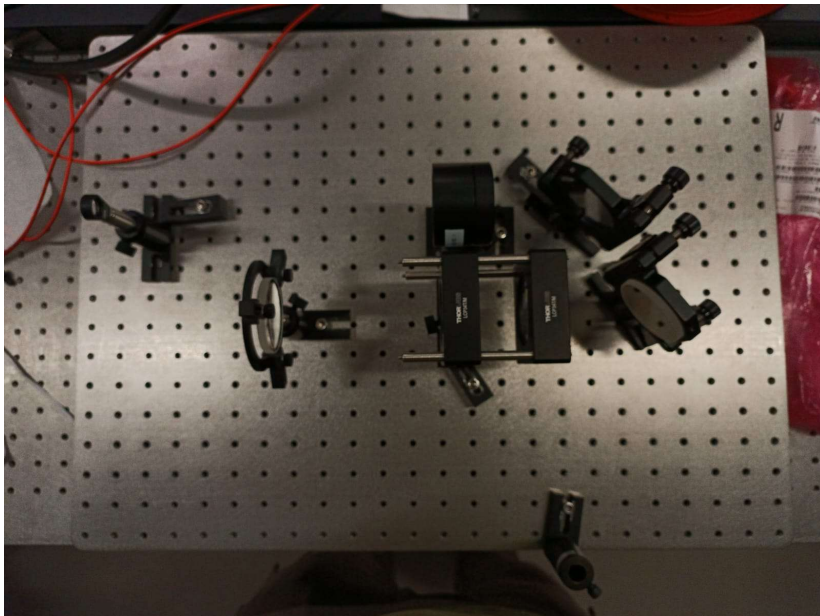
## Shack-Hartmann Wavefront Sensor Assembly



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# Methods

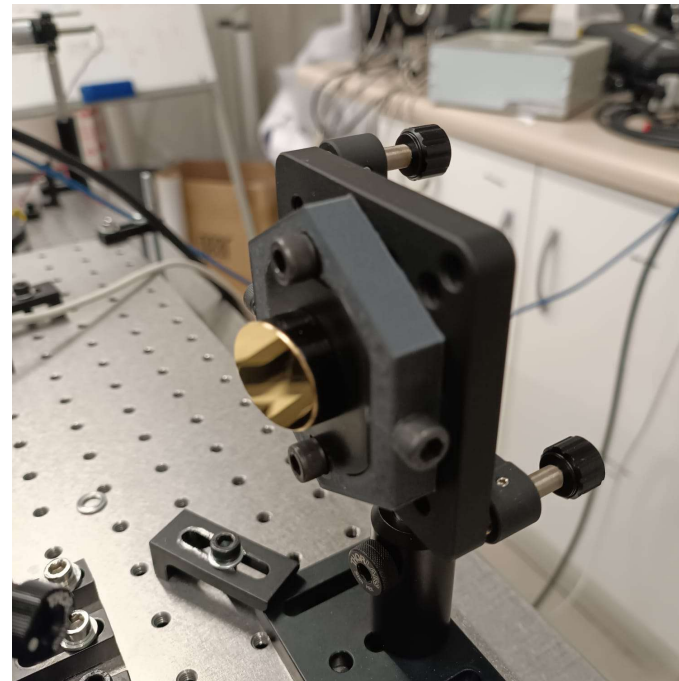
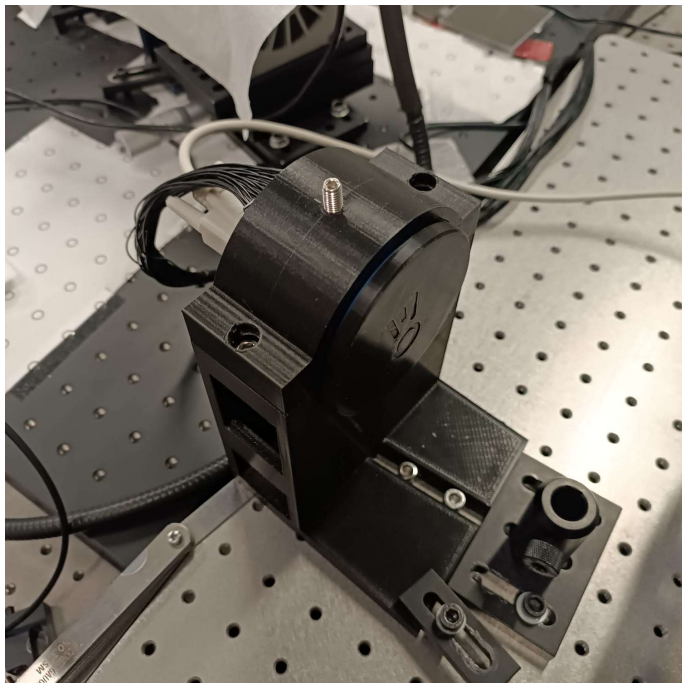
## Optical Setup Alignment



- Shear Interferometer to check for collimation

# Methods

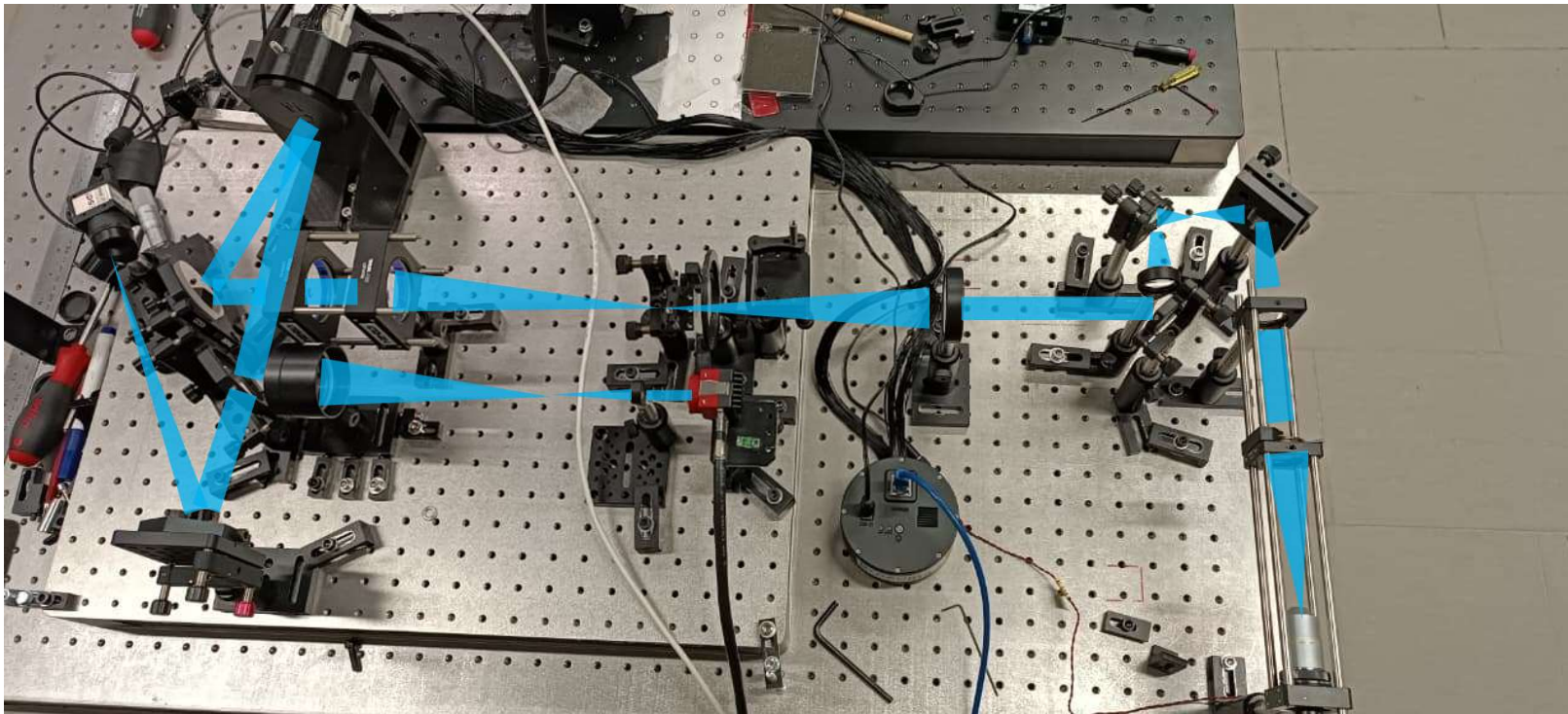
## Optical Setup Custom Optomechanics



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# Methods

## Optical Setup



$$\frac{D}{r_0} = 38.1975$$

- 4f system with turbulence screen.
- $r_0 = 0.4\text{mm}$
- Beam = 15.279mm

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# Results

## NCPA Calibration



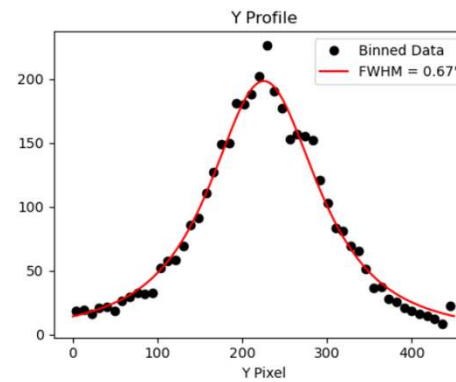
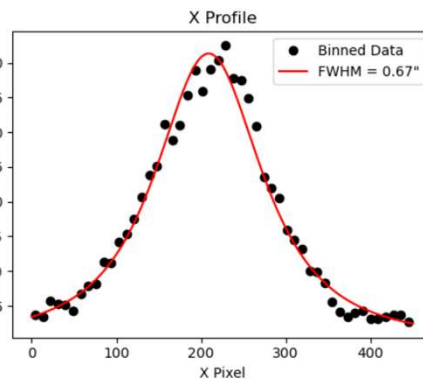
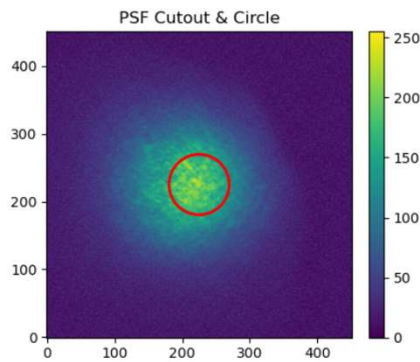
Tip-Tilt



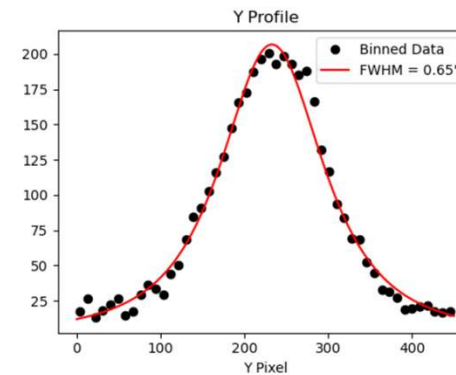
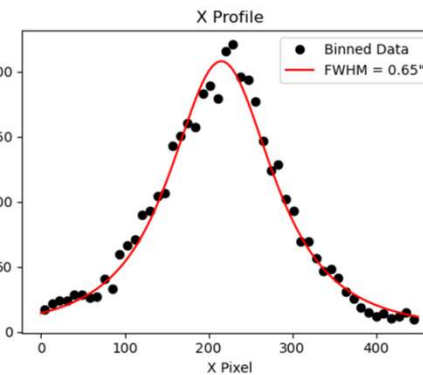
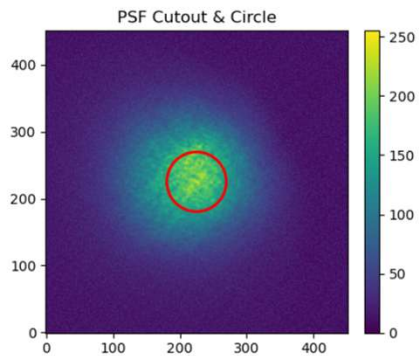
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# Results

## AO Zonal Loop Test



- Moffat FWHM = 0.67"
- EE(0.4") = 13.26%

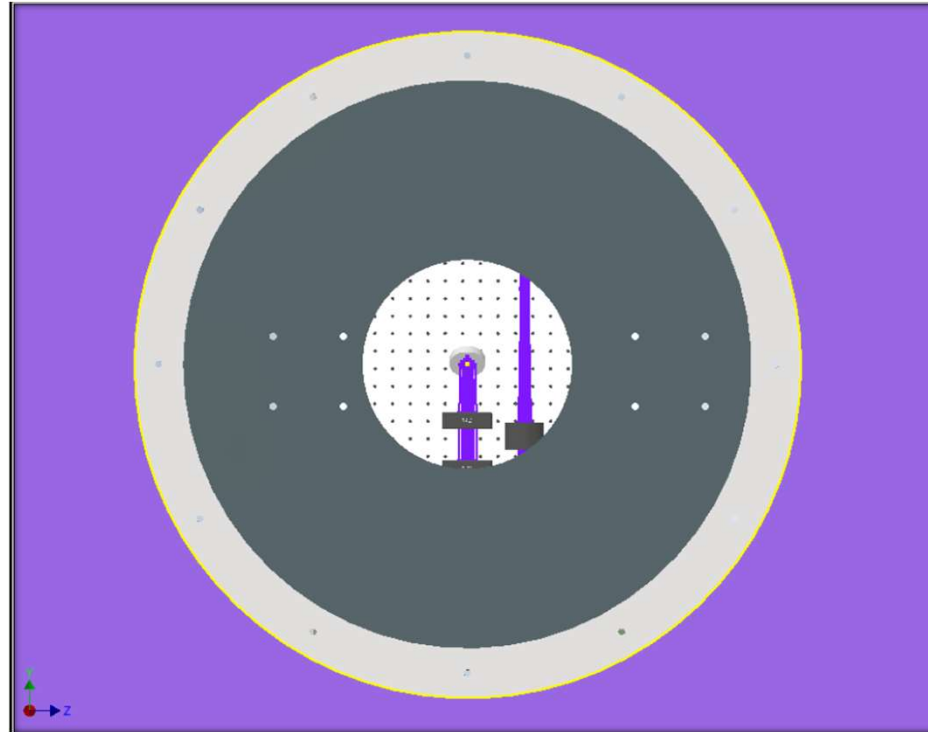
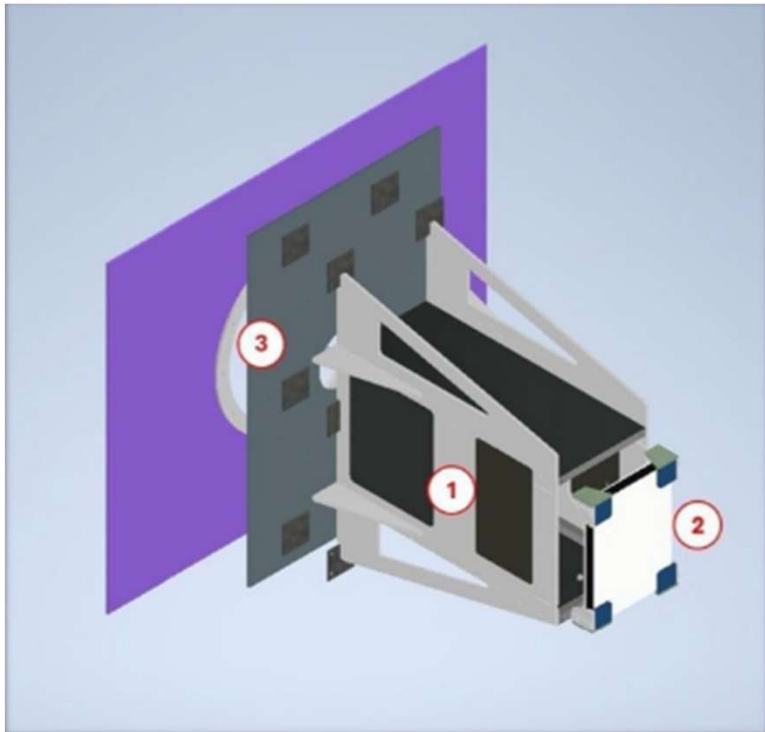


- Moffat FWHM = 0.65"
- EE(0.4") = 13.91%

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# Recent developments

## Mechanical Interface



- 370kg total
- FE analysis was carried out.

Gabriel Olguin, 2025, ME Undergraduate Thesis

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# Summary

- A prototype interface was built in the laboratory.
- NCPA can be corrected with no problem
- There are issues with the control of the loop, such that it does not close.
- **Future work:**
- Detect the source of the issue in the control loop.
- Tip-tilt stage integration.
- Closed loop with simulated turbulence.
- AIUC visit to TAO to install monitoring units.
- Search for more funding to complete the project.

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