



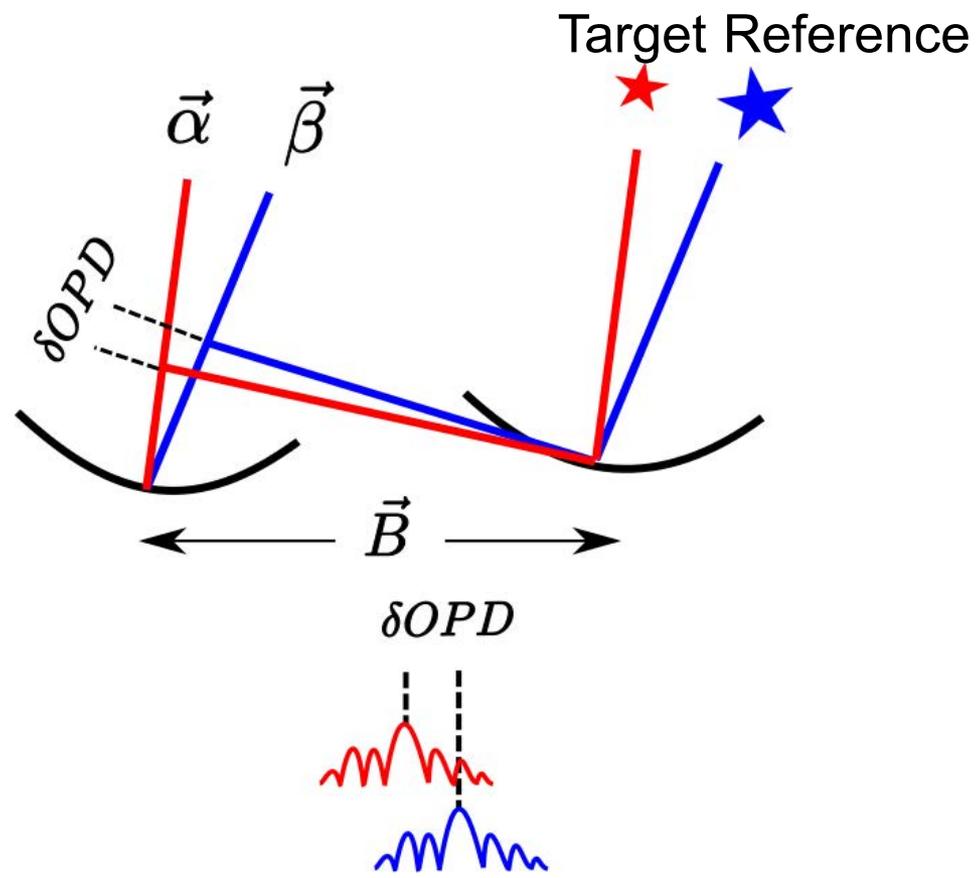
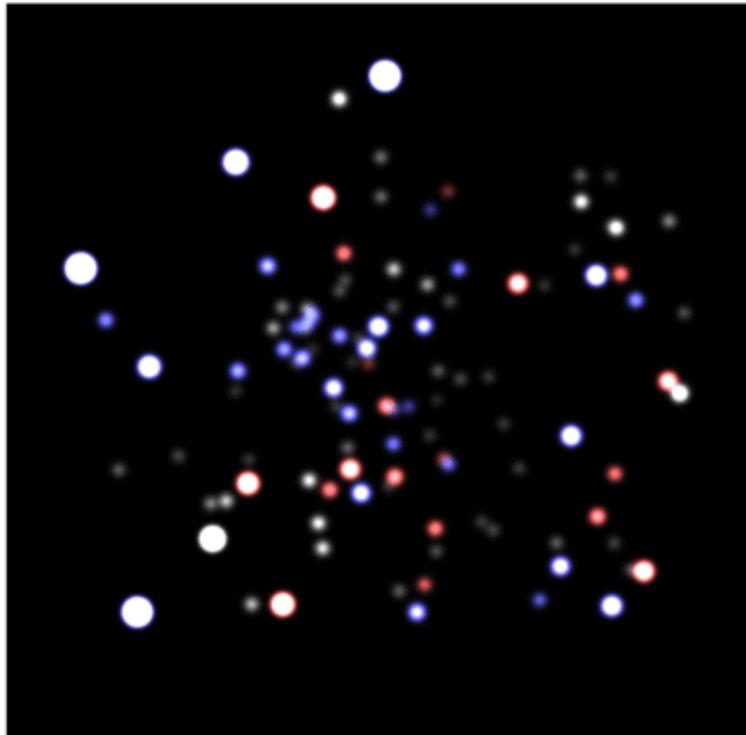
# GRAVITY acquisition camera

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14<sup>th</sup> January, NICE



# GRAVITY: phase-reference interferometer



$$\delta OPD = \vec{B} \cdot (\vec{\alpha} - \vec{\beta})$$

$\uparrow$  5 nm       $\uparrow$  500  $\mu$ m       $\searrow$  10  $\mu$  arcsec

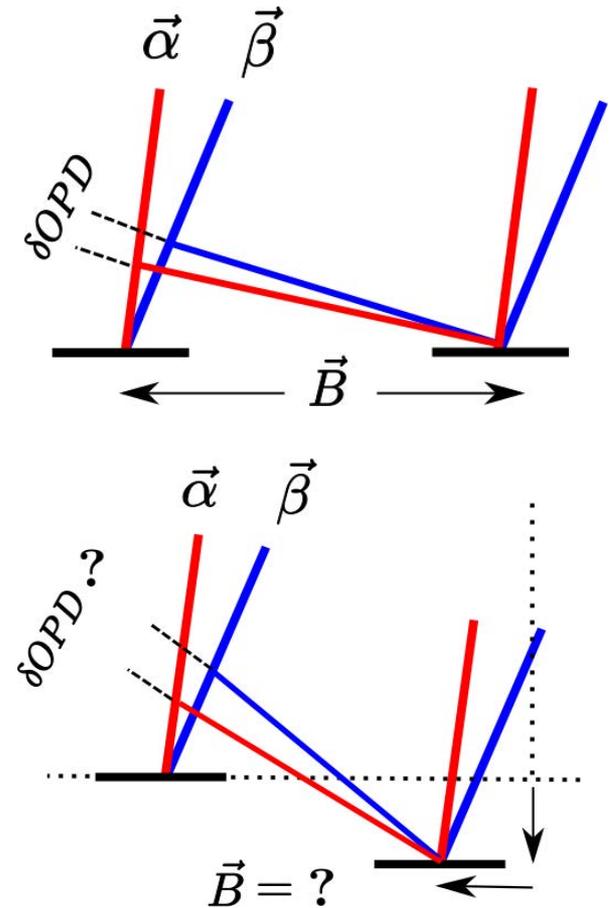
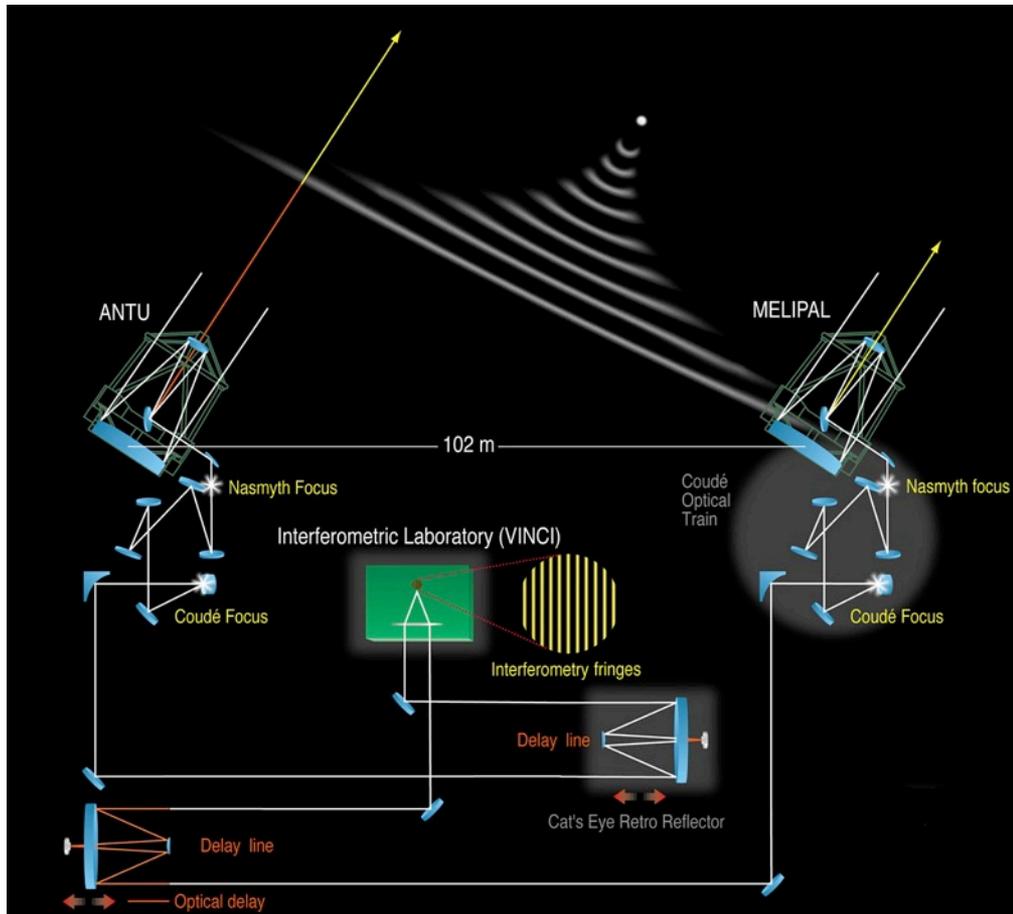


# GRAVITY subsystems

- Adaptive optics
- Metrology system
- Integrated optics
- Fringe tracker
- Fiber coupler and laser guiding system
- Acquisition camera



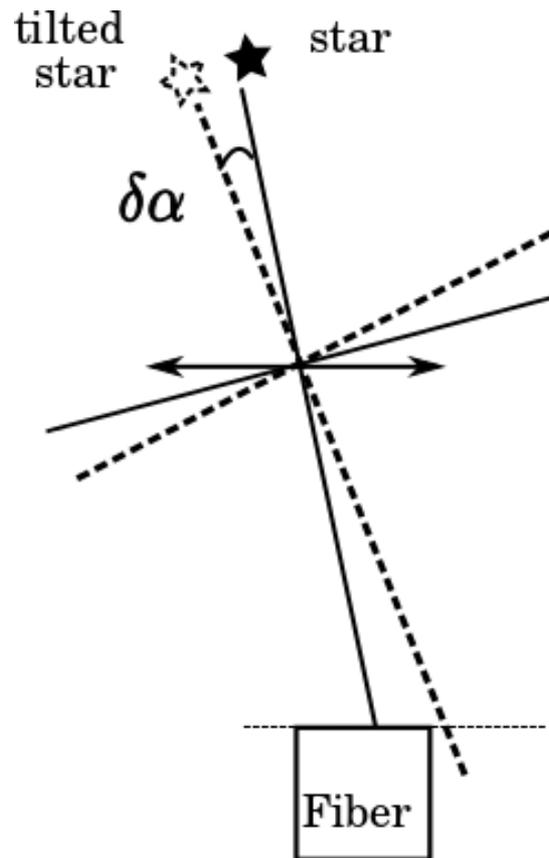
# Why acquisition camera: To stabilize pupil motions





# Why acquisition camera (2): atmospheric tip-tilts

In GRAVITY the coherent beam combination implemented with fiber fed integrated optics



## Problems:

1. Flux injection
2. Astrometric error



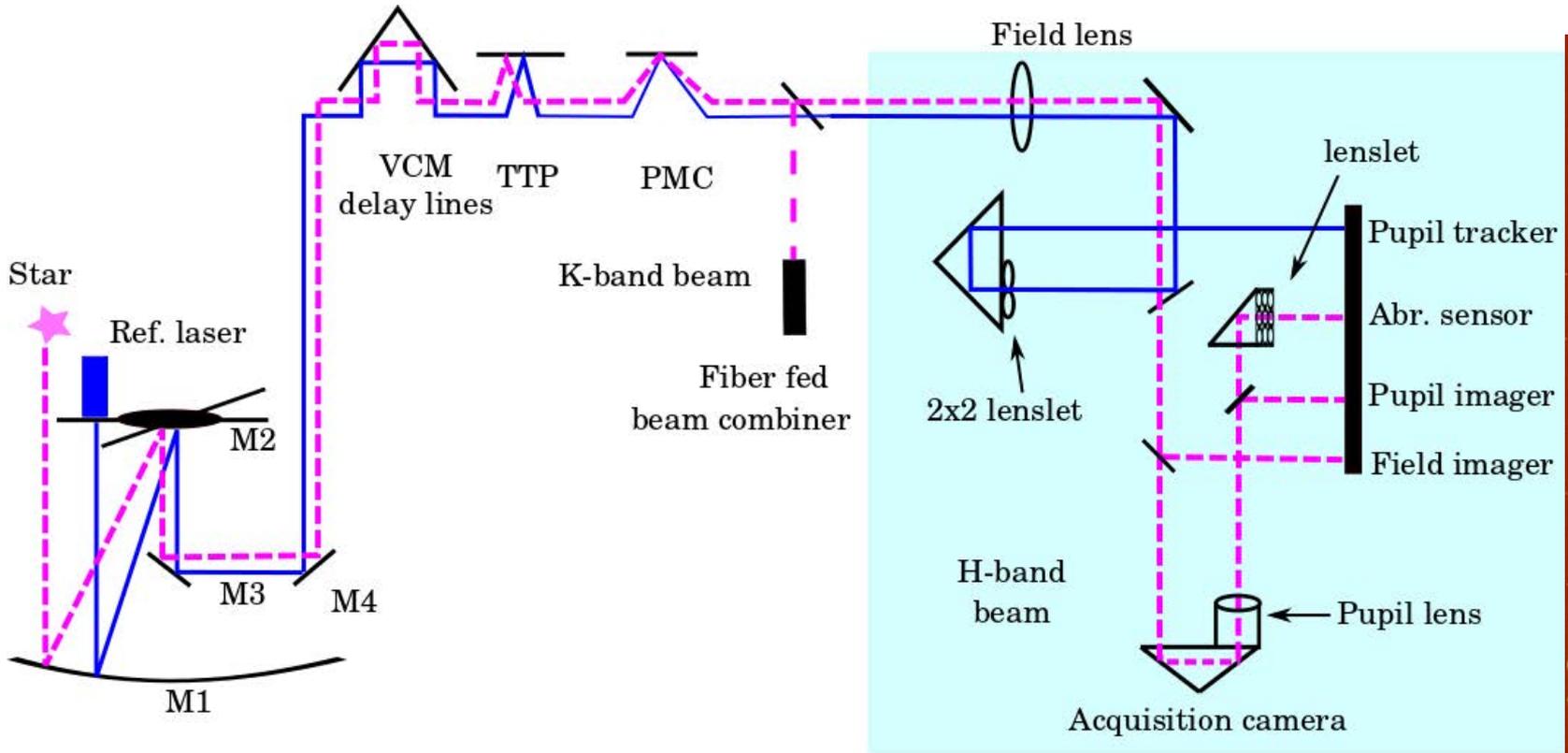
# Technical requirements to achieve GRAVITY aims

To achieve 10 micro arcsec astrometry, GRAVITY requires

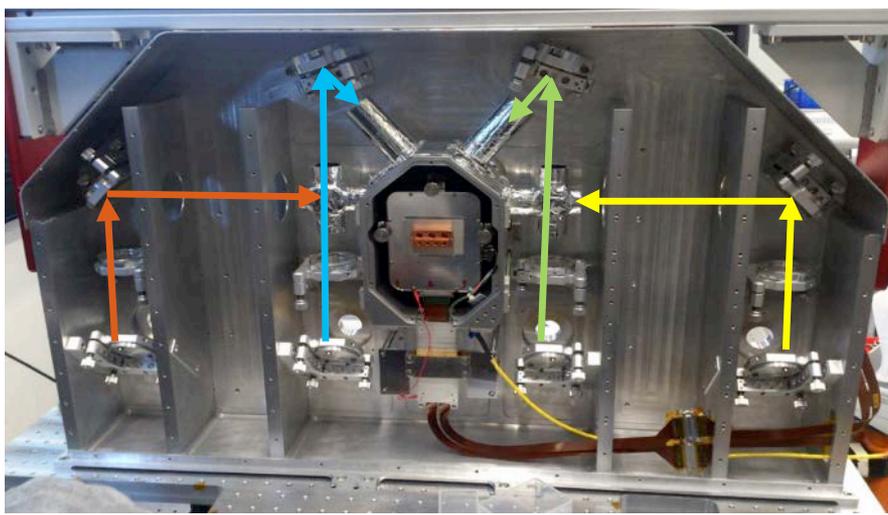
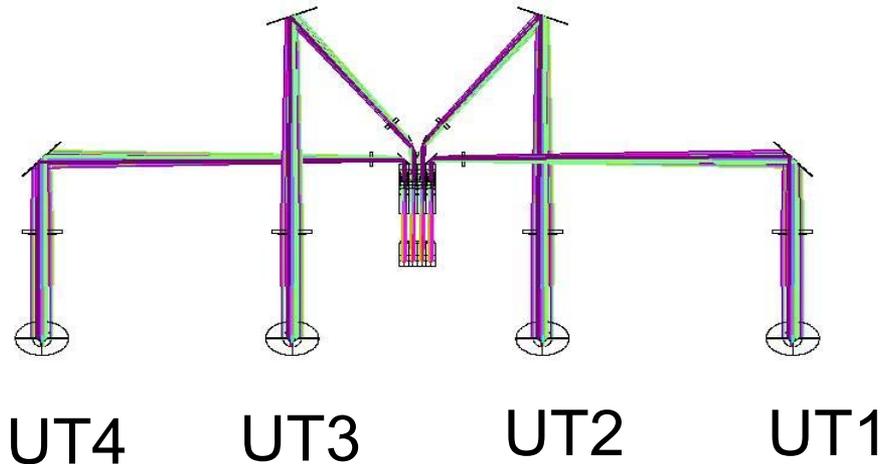
1. Field stability (error  $\leq 2$  mas)
2. Pupil stability:
  - lateral position error  $\leq 4$  cm, i.e., 0.5% 8m telescope;
  - longitudinal pupil position error  $\leq 1$  m.
3. Wavefront sensing (error  $\leq 80$  nm)

**So we need a beam analyzing system and correction system !!**

# Acquisition camera optical layout

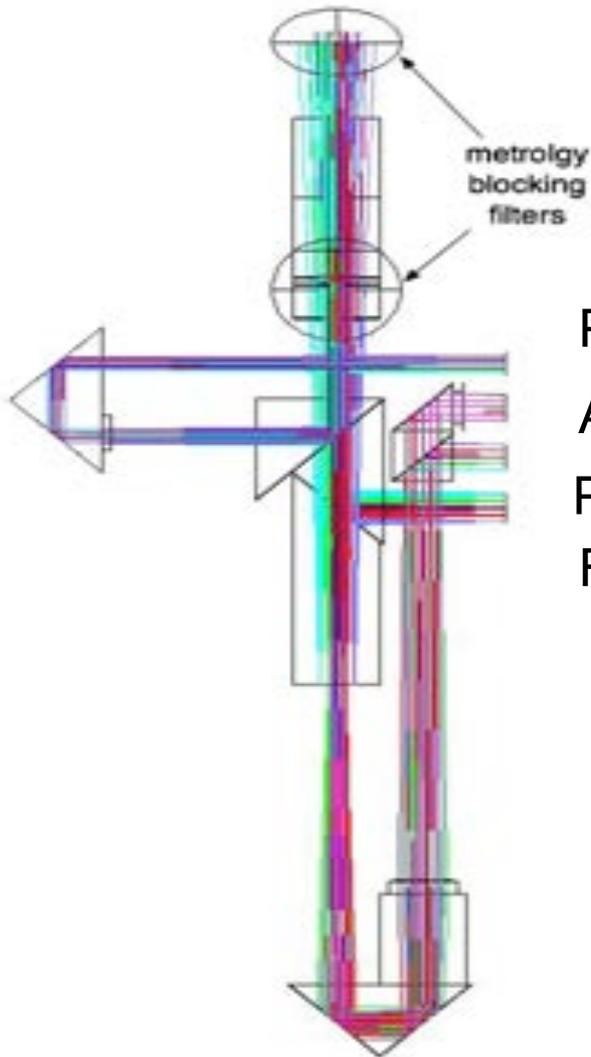


# Acquisition camera: folding optics

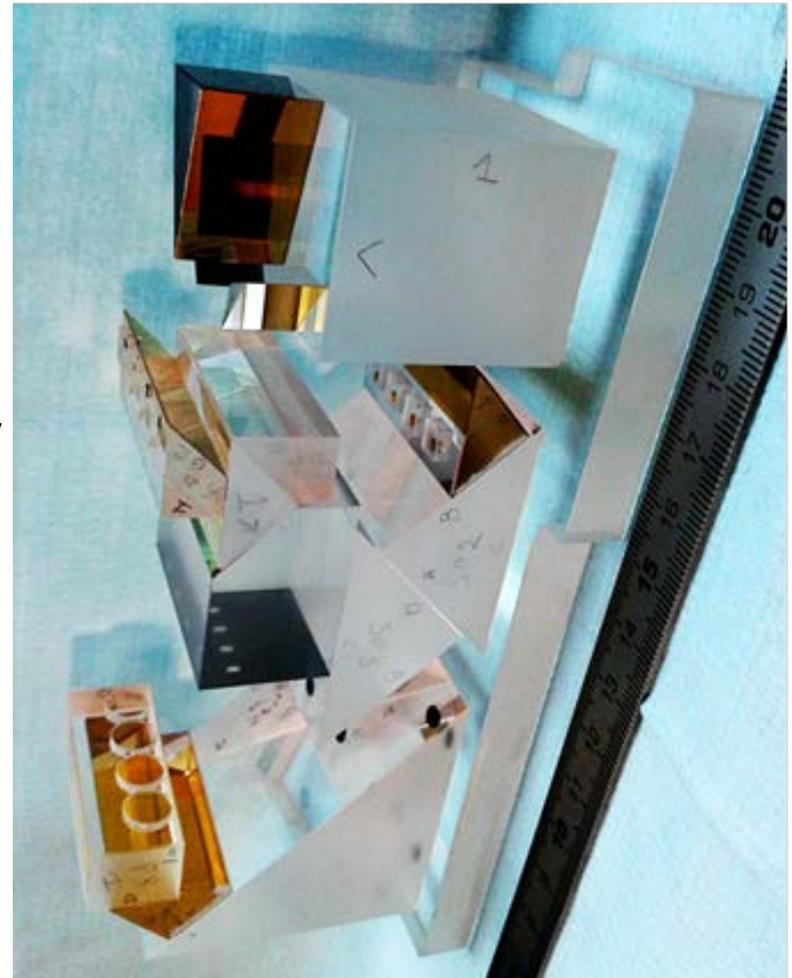




# Acquisition camera: core beam analyzer



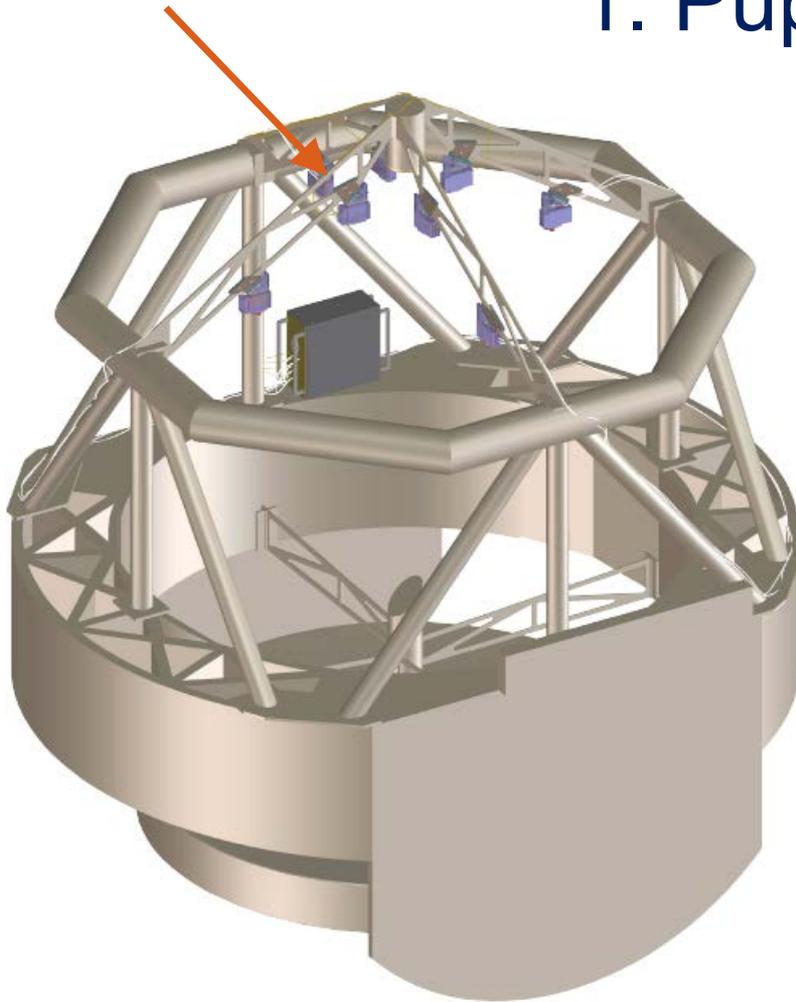
- Pupil tracker
- Aberration sensor
- Pupil imager
- Field tracker



Optics embedded in it



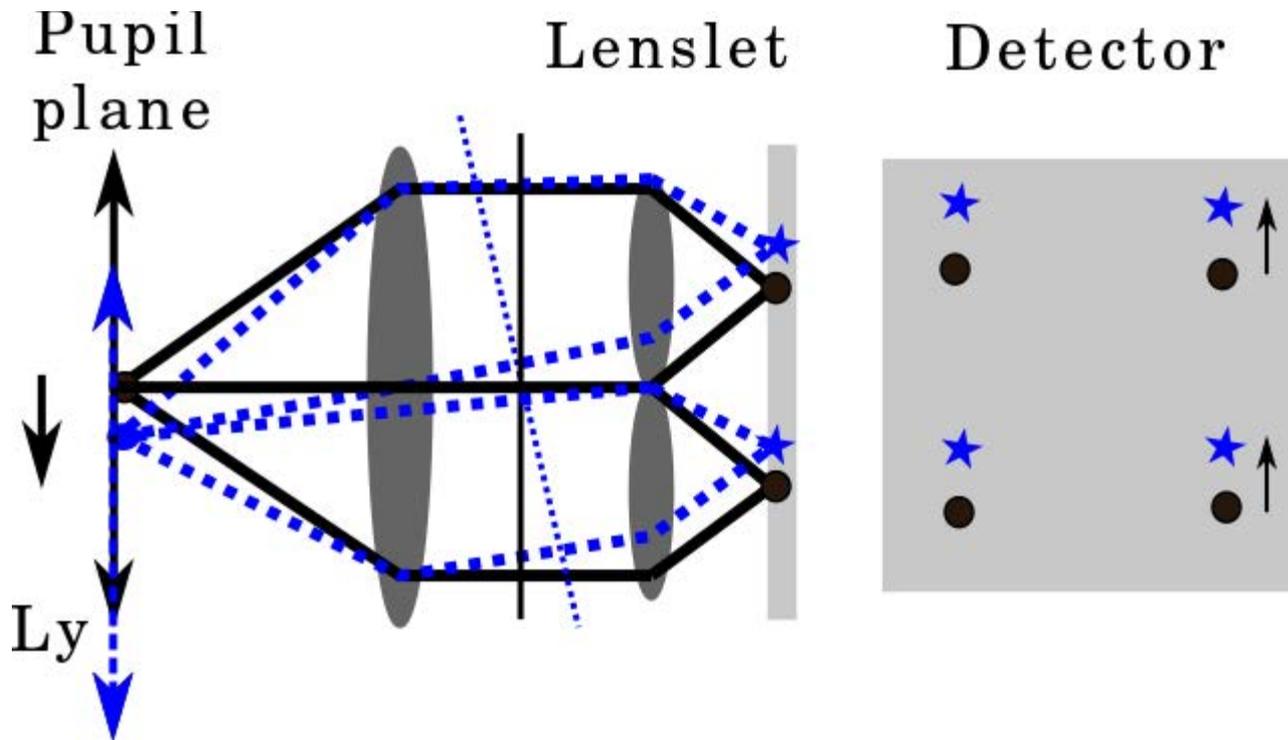
# 1. Pupil tracking



- ✓ To track telescope pupil motions, 4 lasers are mounted on M2 spiders.
- ✓ Lasers are imaged with 2x2 lenslet.



# a) Lateral pupil tracking

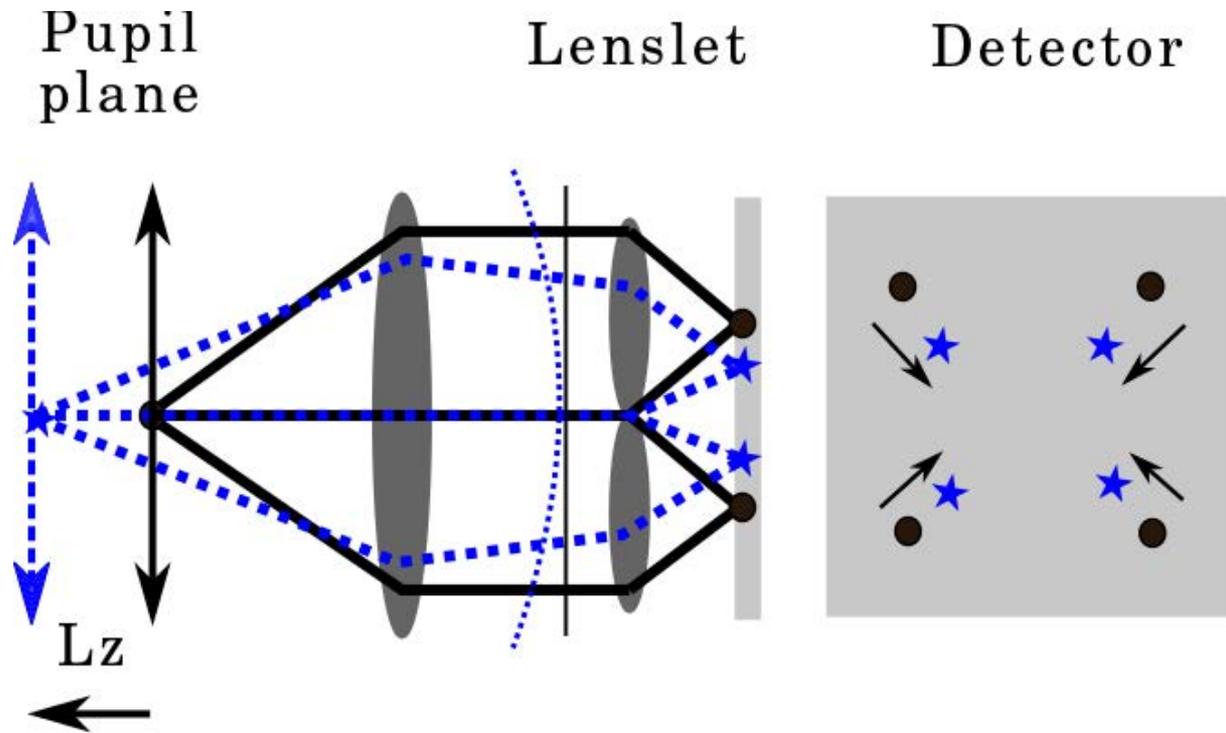


(a) Optical layout of lat. pupil shift

(b) Lat. pupil shifted spots



## b) Longitudinal pupil tracking

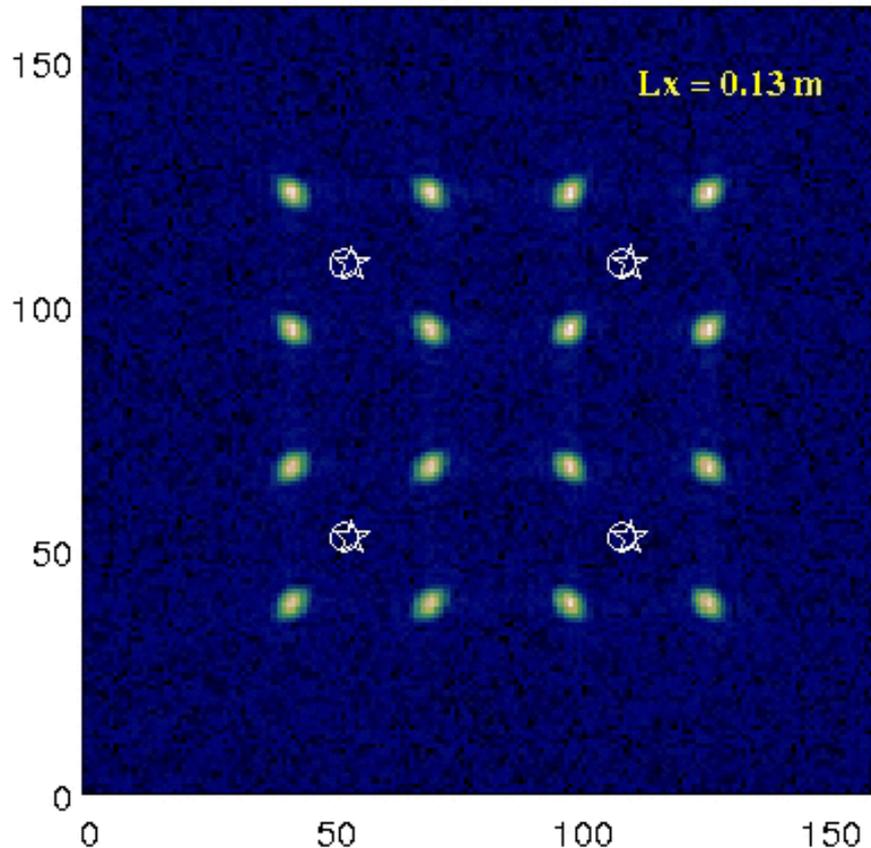


(c) Optical layout of long. shifted case

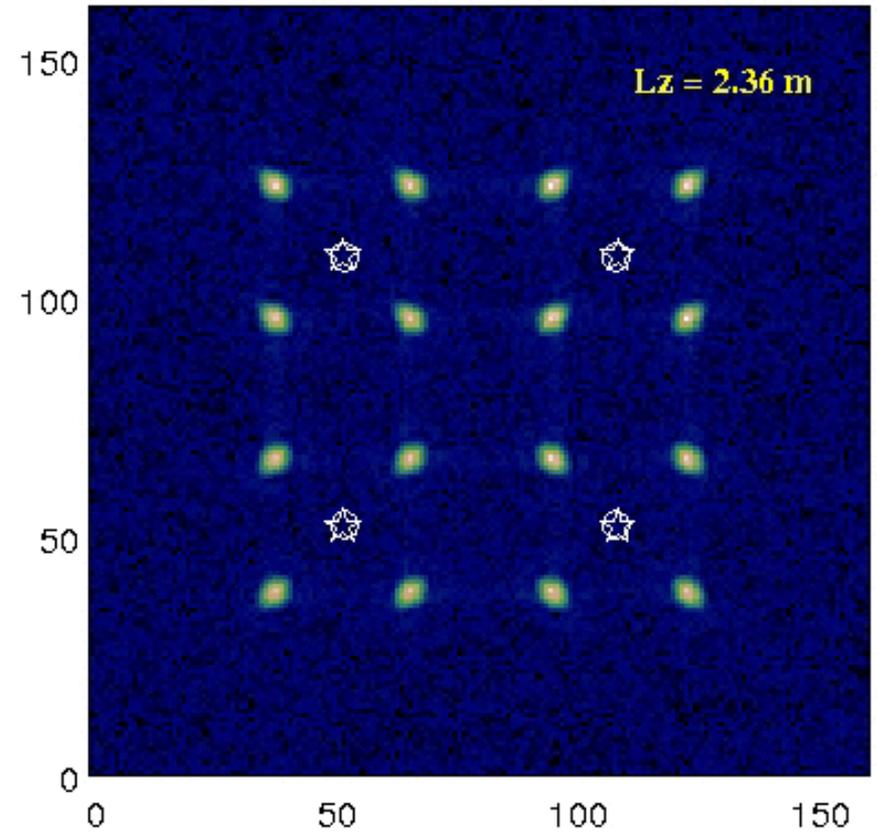
(d) Long. pupil shifted spots



# Pupil shifts measurement

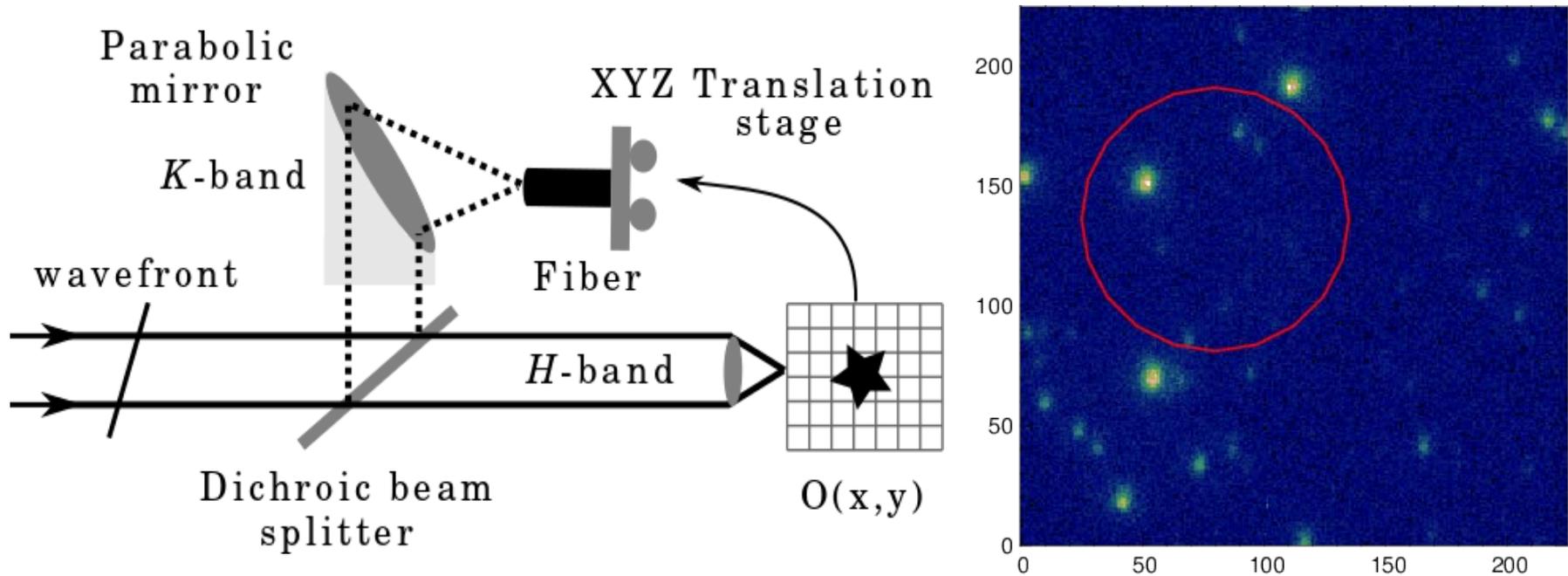


Lateral pupil shifts



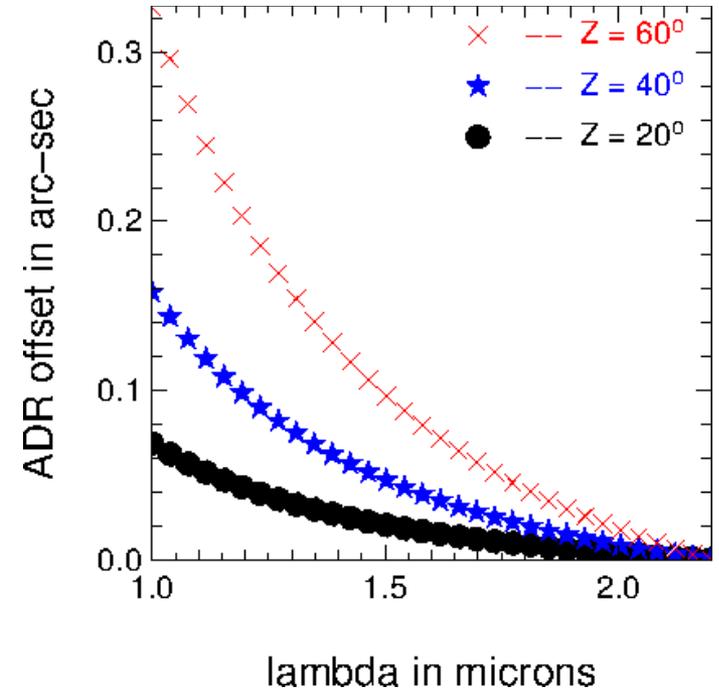
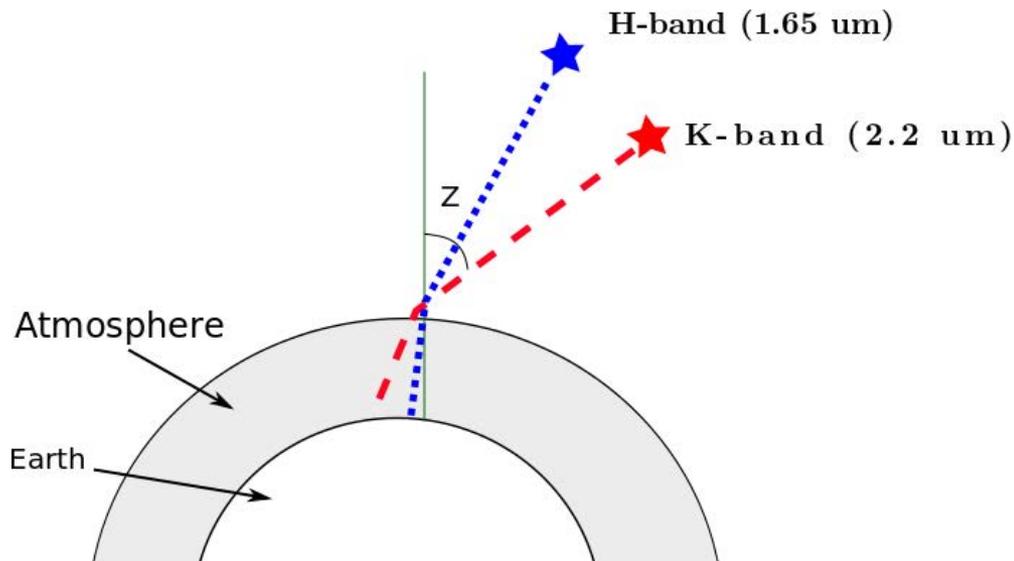
Longitudinal pupil shifts

## 2. Field imaging and tracking



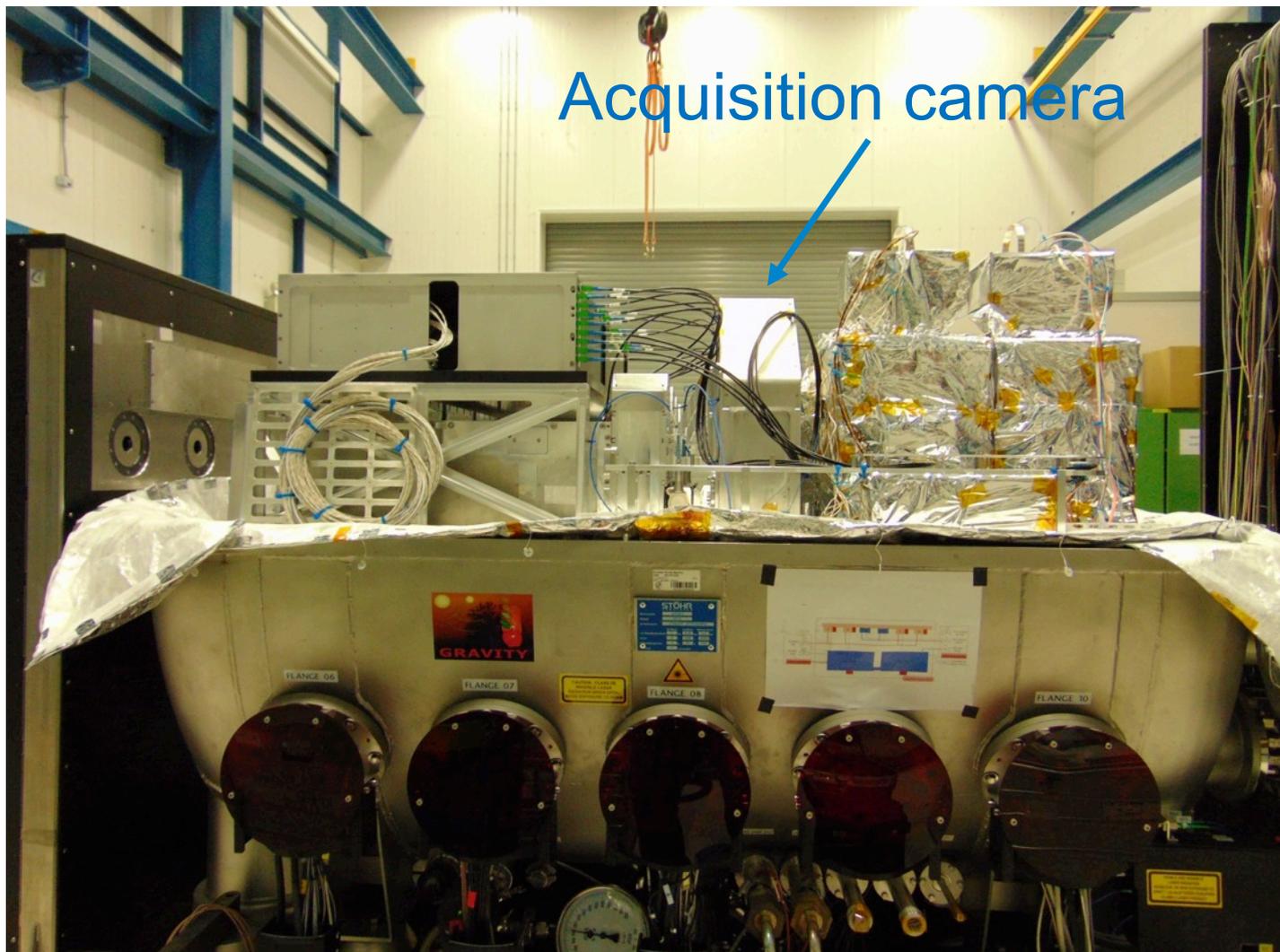
AO residual and tunnel seeing tip-tilts are measured with a precision of 2 milliarcsecond.

# Atmospheric dispersion shifts between acquisition camera and K-band fiber





# GRAVITY



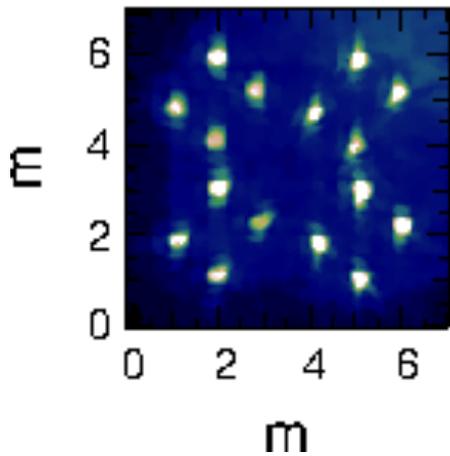


# Acquisition camera Real Time Display

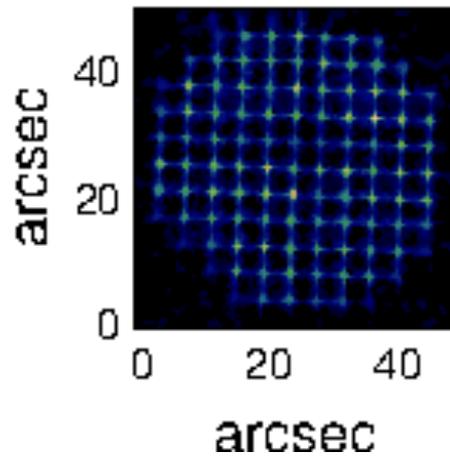
The screenshot displays the 'Acquisition Camera RTDC - @wgv' software interface. The main window is divided into a 4x4 grid of panels, each showing a different camera feed. The top row shows 'Pupil Guiding' feeds with a 2x2 grid of stars. The second row shows 'Aberration Sensor' feeds with a circular grid of points. The third row shows 'Pupil Viewer' feeds with a circular pupil outline. The bottom row shows 'N/A' feeds with a central star and crosshairs, labeled 'On-Axis'. On the left side, there is a control panel with a 'Cursor Information' section (X, Y, VALUE), a 'Scale' section (1x, 1/2x), a 'Bias' section (0, No Image Loaded), a 'Name' field, and a 'Camera' section (NGCIR1, Attached). At the bottom, there is a 'Apply graphics configurati...' button.



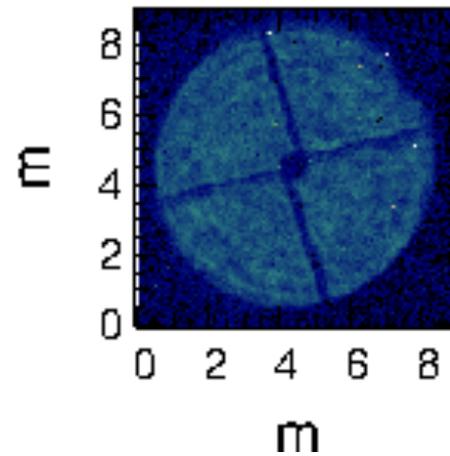
# For one telescope



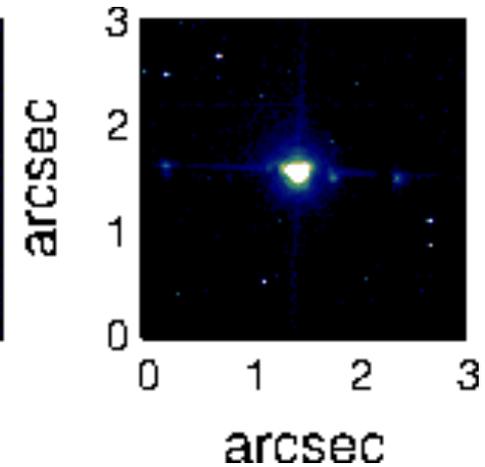
Pupil tracker



Aberration sensor



Pupil imager



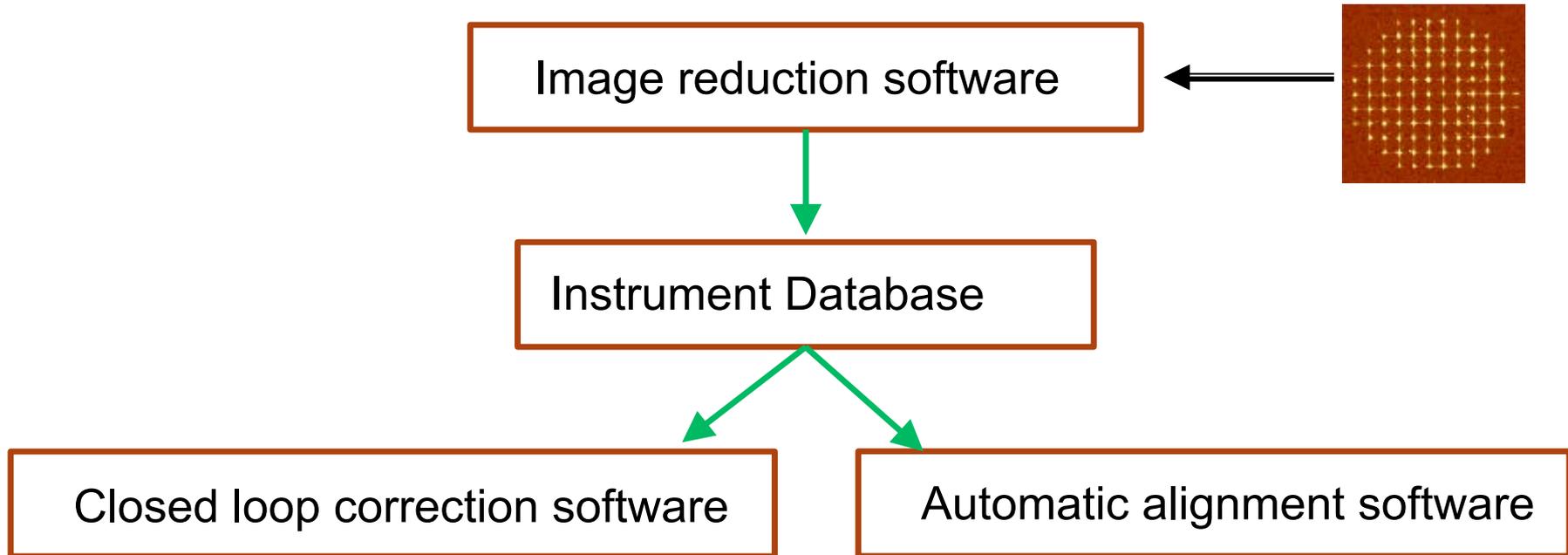
Field imager



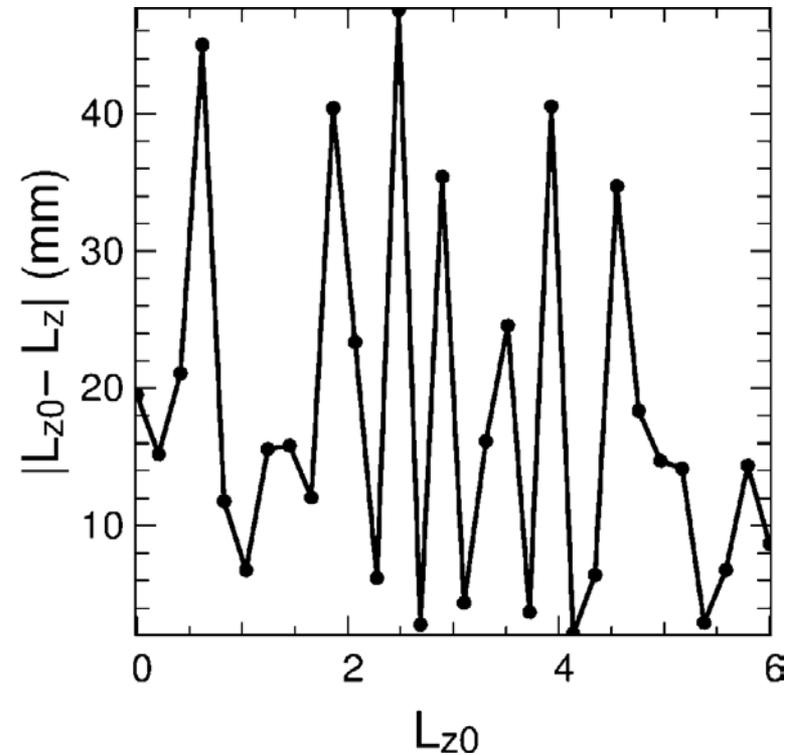
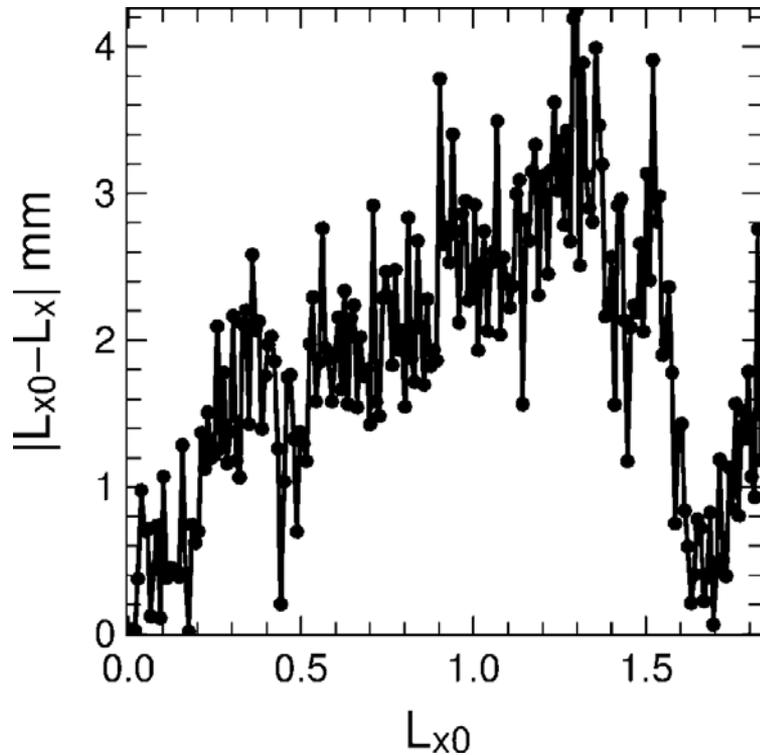
# Software developed

## Main tasks:

1. Image reduction software
2. Closed loop correction software.
3. Automatic alignment of GRAVITY with the VLTI optics.

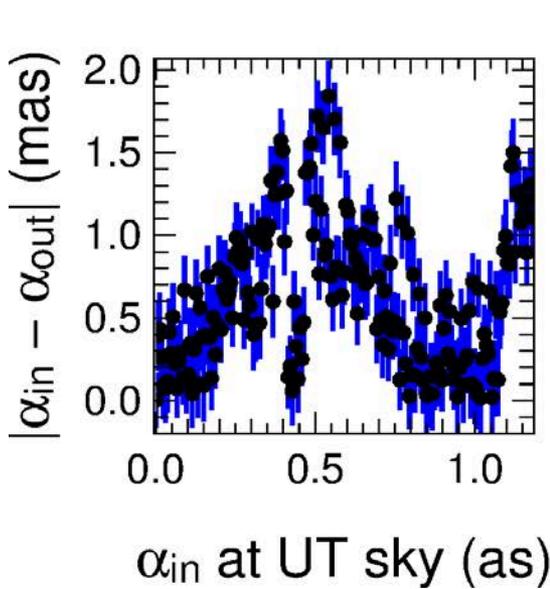


# Pupil tracking characterization with calibration unit

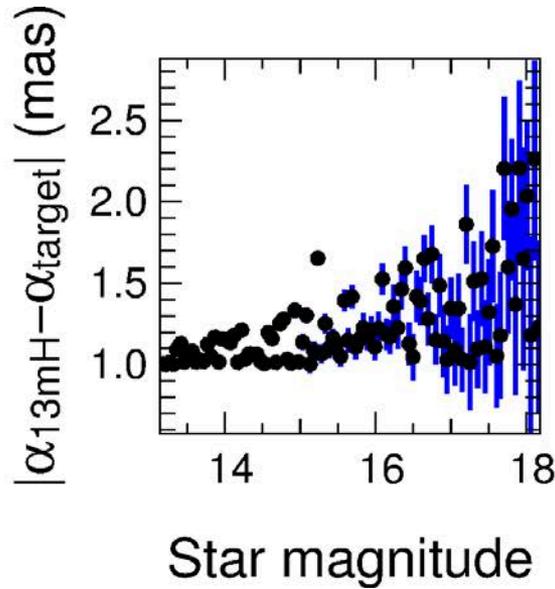


By applying known pupil shifts the pupil tracker is characterized.

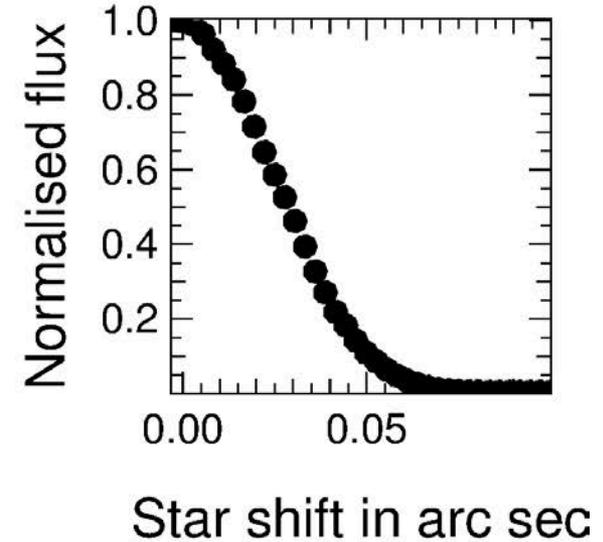
# Field tracking characterization



Tip-tilts



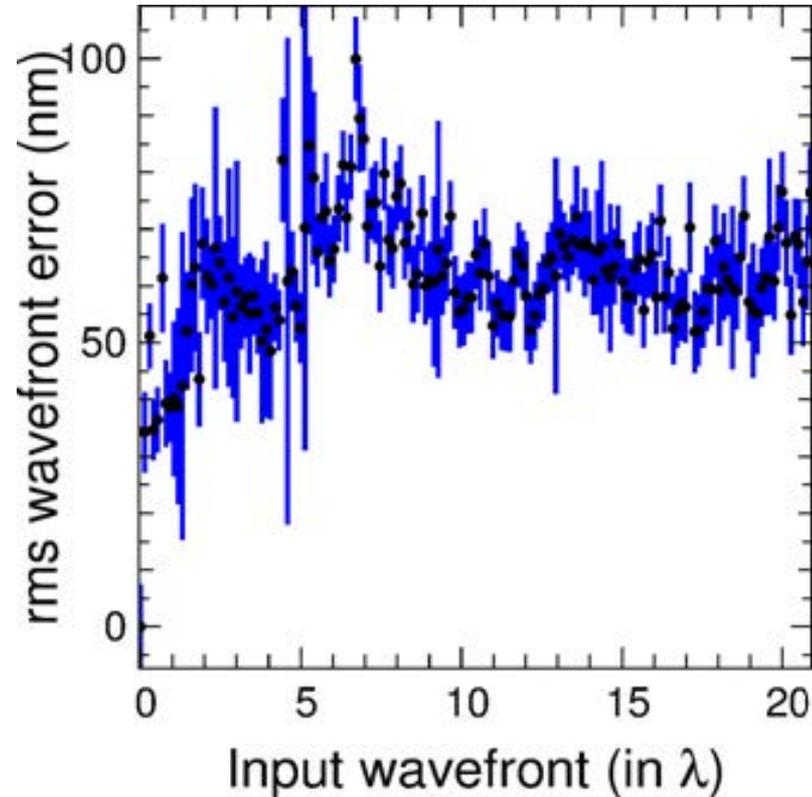
Star magnitude



Fiber flux



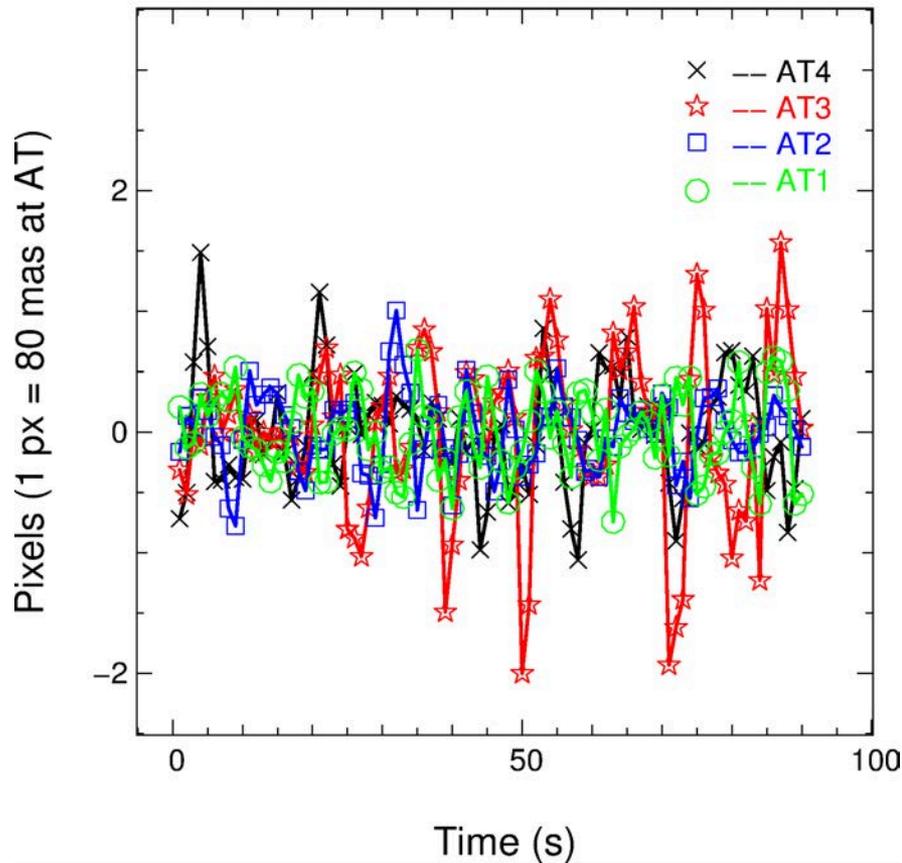
# Aberration sensor characterization



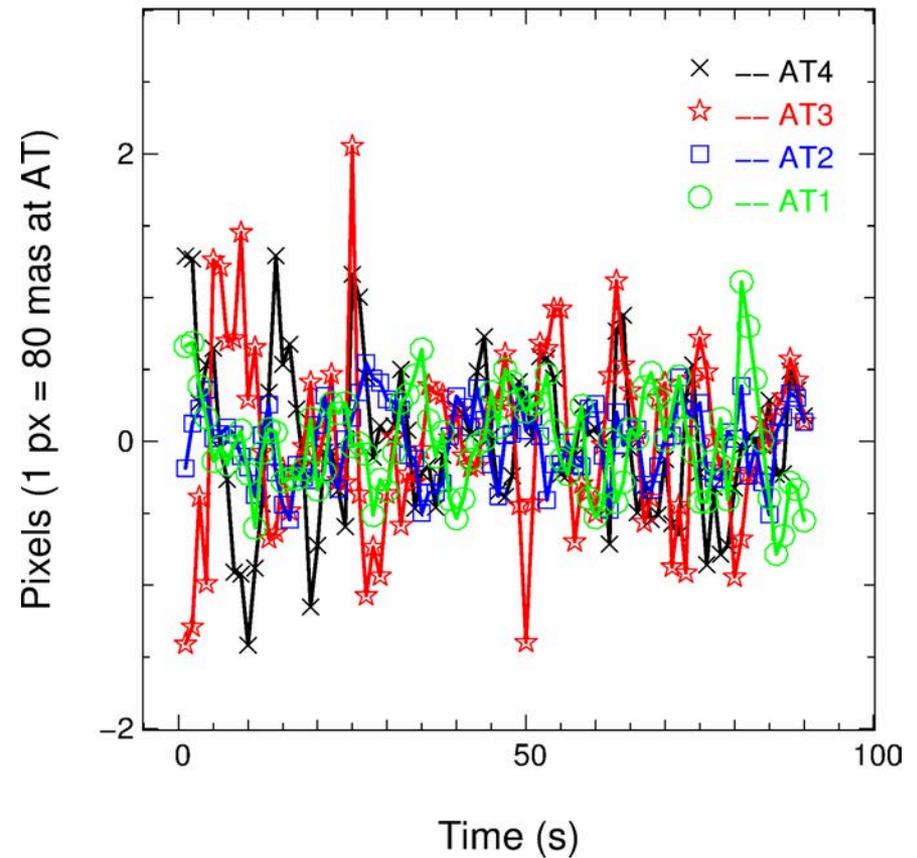
By applying known wavefront error the aberration sensor characterized.

# On-sky field residuals

Field movements along x-axis

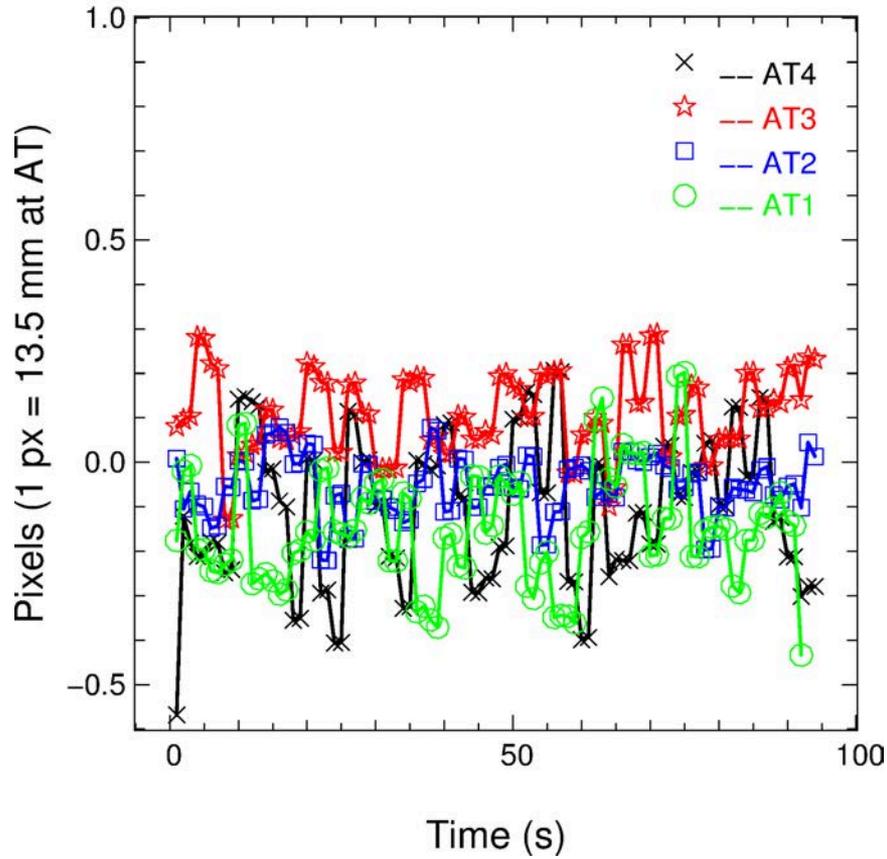


Field movements along y-axis

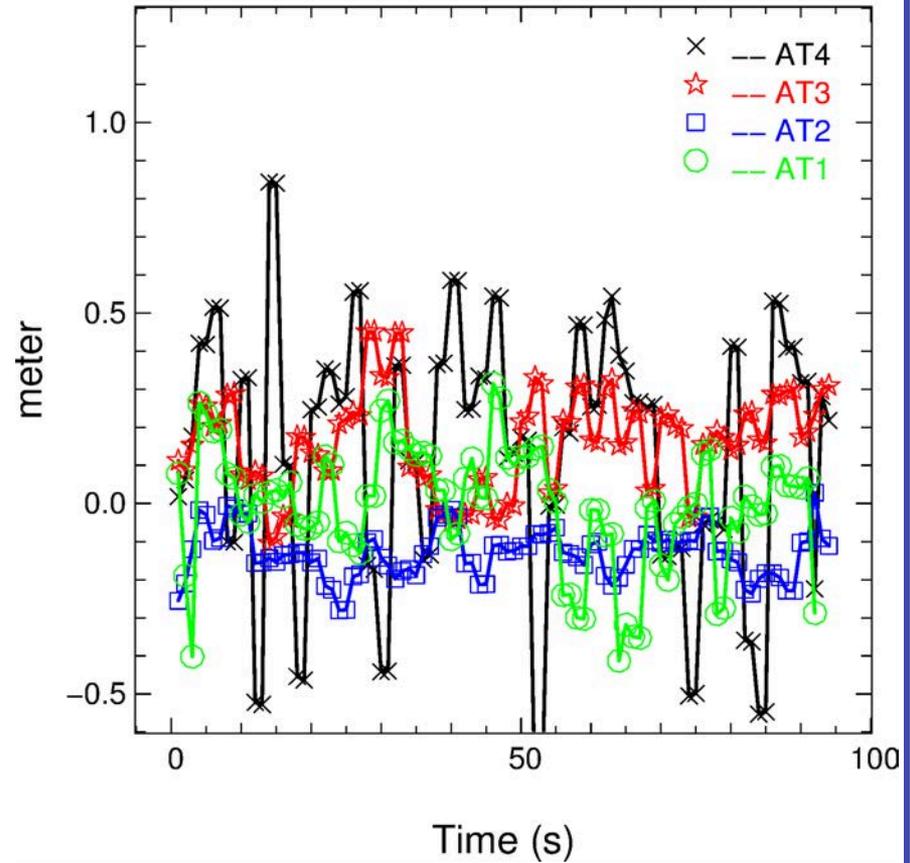


# On-sky pupil residuals

Lateral pupil shift along y-axis



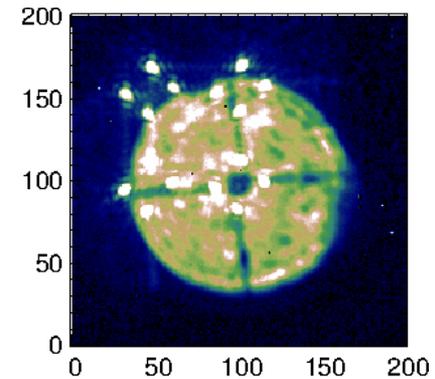
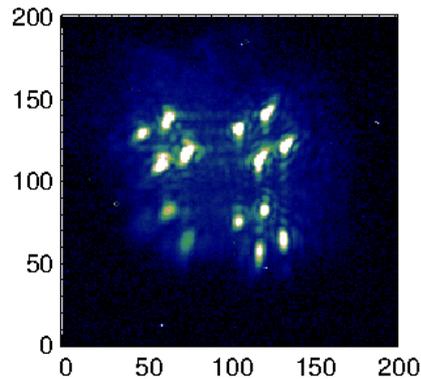
Longitudinal pupil shift





# Further improvements progressing

1. Robust pupil sensor in the presence of background and vignetting.



2. Wavefront sensing in the presence of low SNR and in vignetting cases.



# Conclusions

**Field Tracker:** Active in closed loop field stabilization.

**Pupil Tracker:** Active in pupil stabilization.

**Aberration tracker:** Quasi-static higher order wavefront aberrations measurement. Currently they are used for defocus correction.

- ✓ Used in automated alignment of GRAVITY with the telescopes.
- ✓ The beams guiding satisfies GRAVITY specifications.



Many thanks



Observatoire de la COTE d'AZUR