Adaptive Optics at CHARA
Operations, Diagnostics, and Performance

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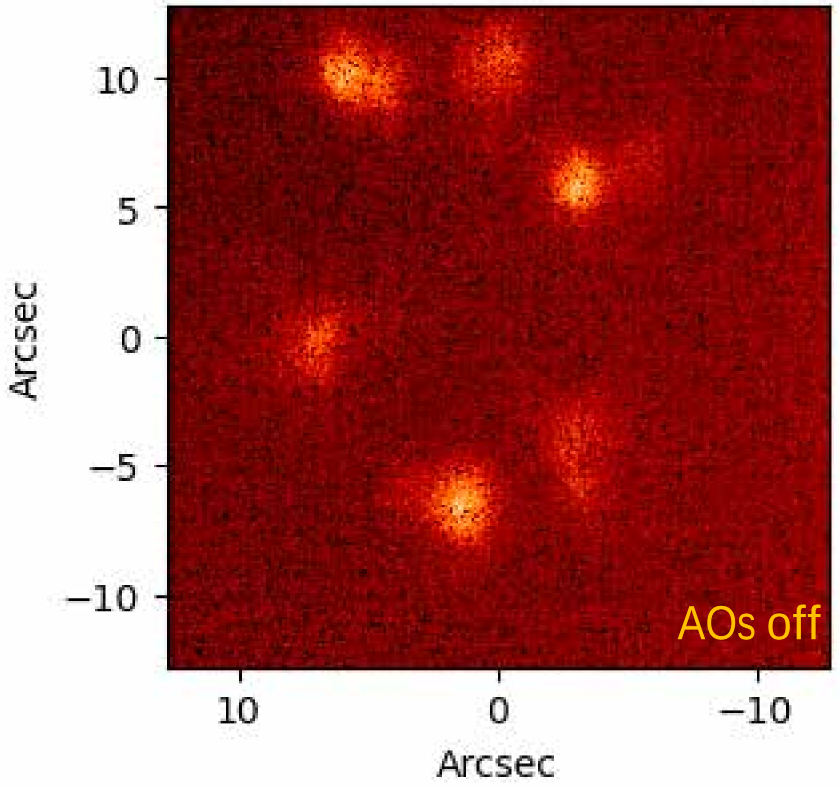
Why Adaptive Optics Matters for CHARA

Atmospheric turbulence:

- reduces coupling efficiency
- introduces flux fluctuations
- degrades fringe tracking

Adaptive optics improves:

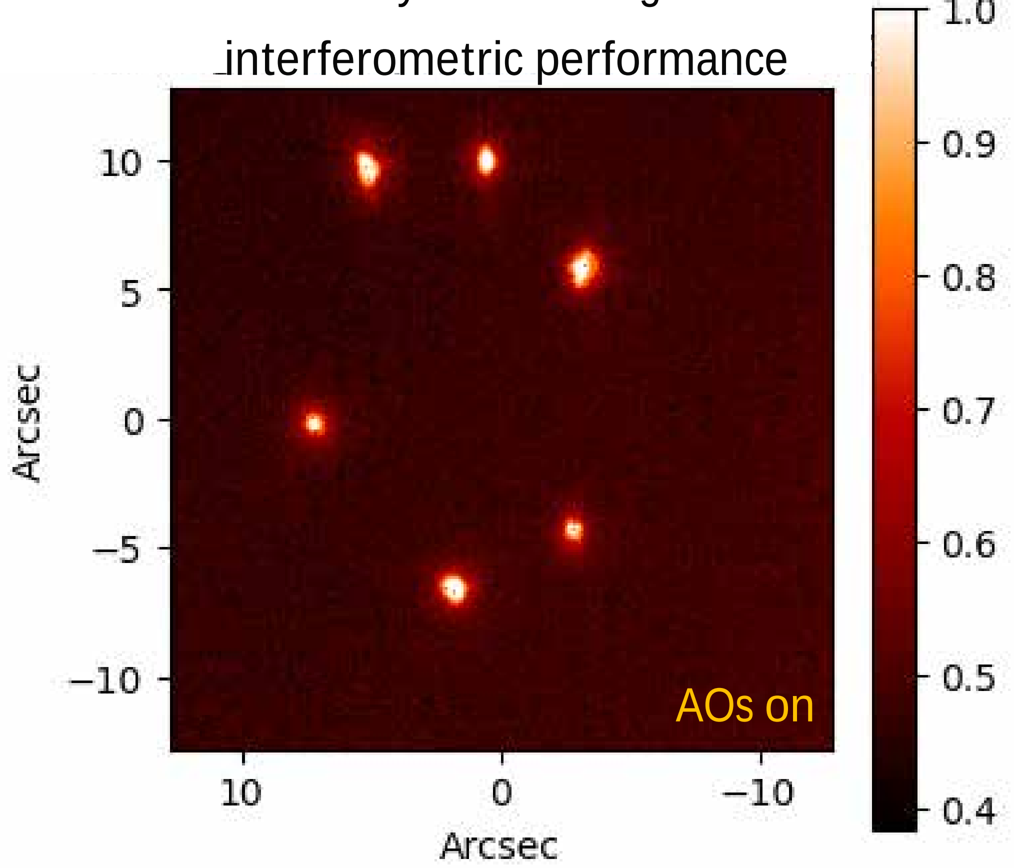
- flux stability
- sensitivity to faint targets
- interferometric performance



HD 73262

V 4.131

H 4.126

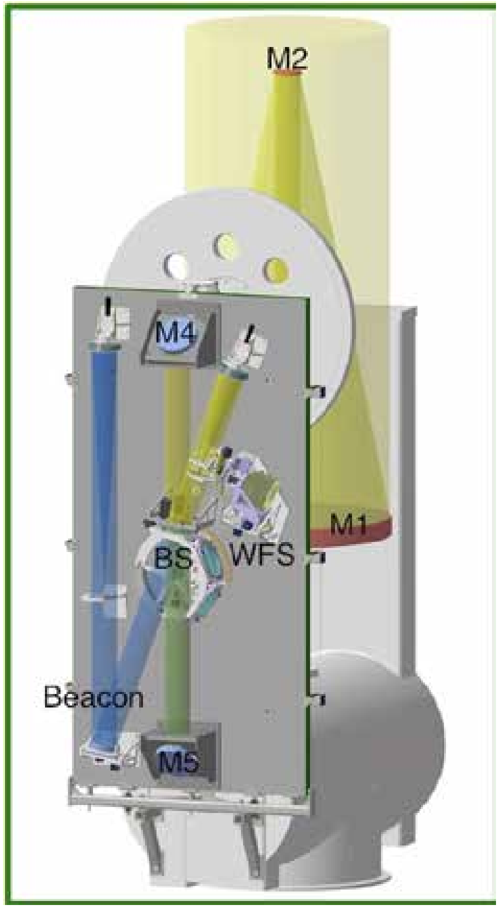


Images from STST taken on Thursday 12 of March 2026

Dual-Layer Adaptive Optics at CHARA

Each telescope uses two AO systems:

TelAO



Shack–Hartmann WFS

Andor 897 EMCCD

ALPAO 60-actuator DM

500 Hz loop

locks on the star

M2 tip-tilt

LabAO

slower WFS

OKO 36-actuator DM

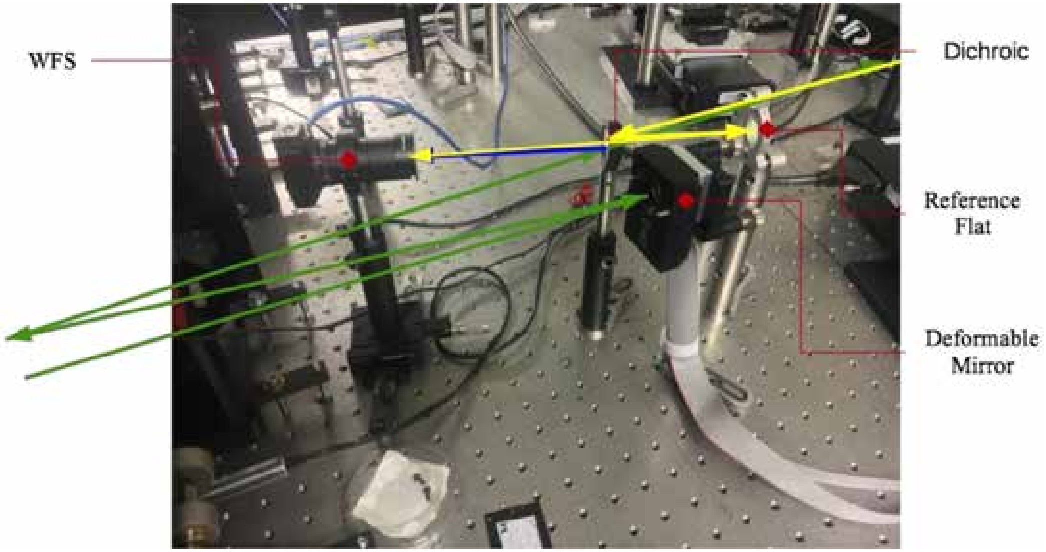
locks on internal blue beacon

corrects internal aberrations and guiding

Offload of DM tilt to M7

Total system:

12 AO systems

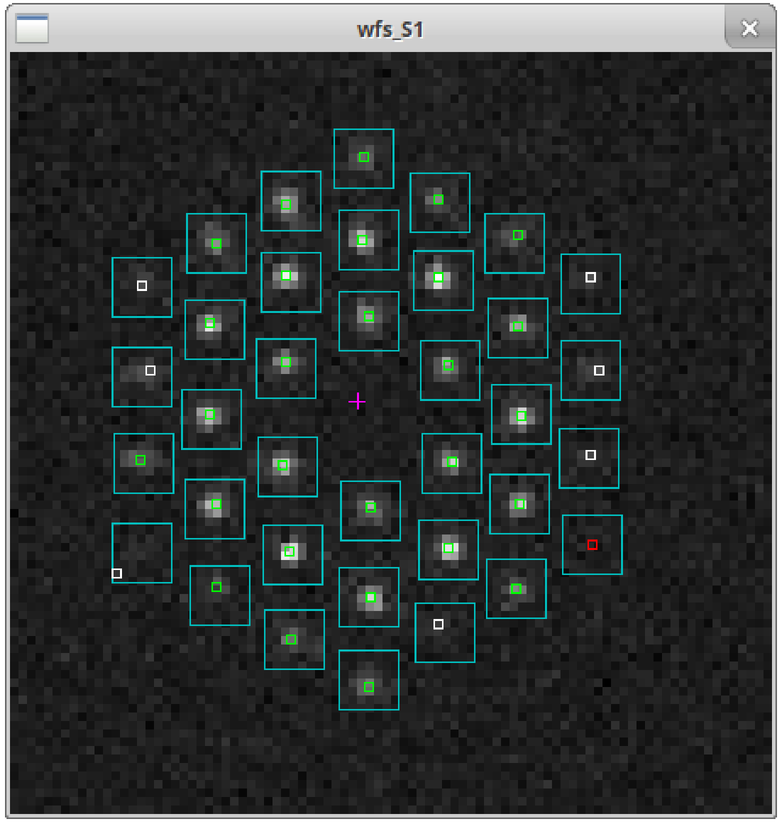


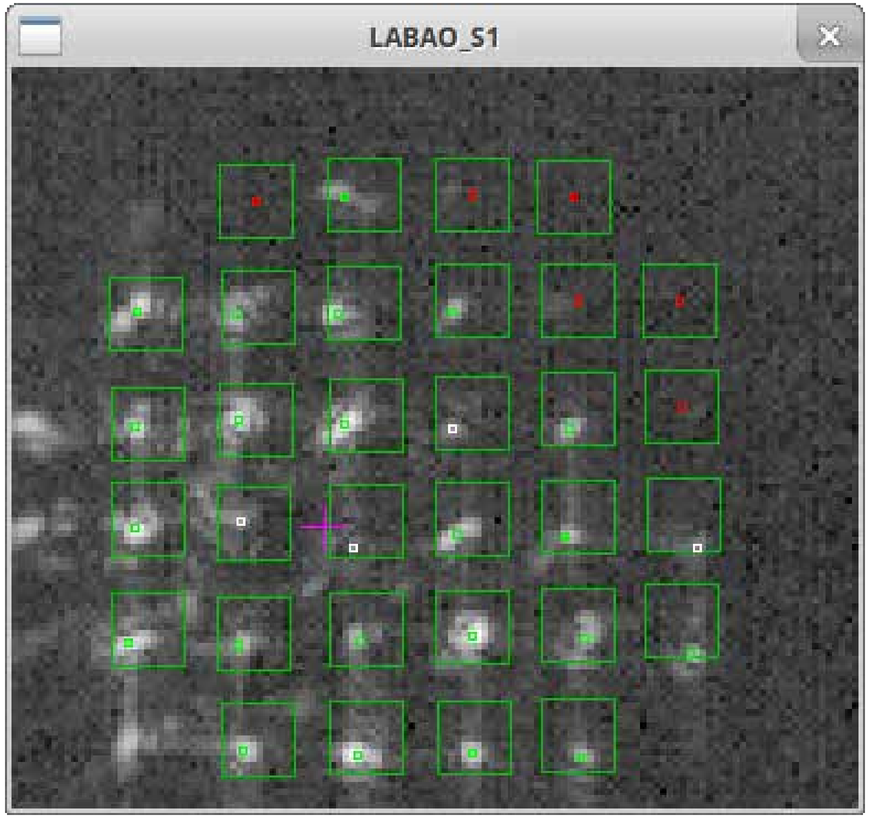
Dual-Layer Adaptive Optics at CHARA

Wavefront Sensors

Andor 897 EMCCD

500-1000 Hz





USB CCD

100 Hz

AO Control and Diagnostics Tools

Operational tools include (but are not limited to):

- actuator position monitoring
- WFS flux monitoring
- aberration tracking
- DM performance monitoring
- loop timing diagnostics
- flexible centroid algorithm

... and many others

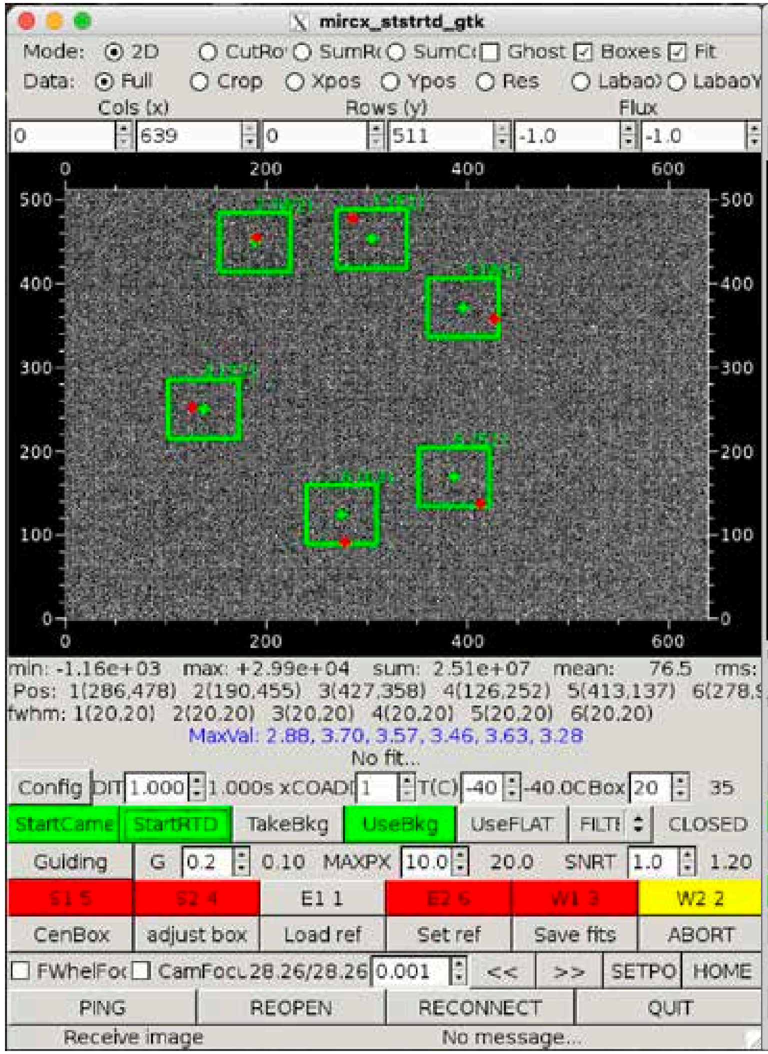
These tools allow **real-time AO performance monitoring during operations.**

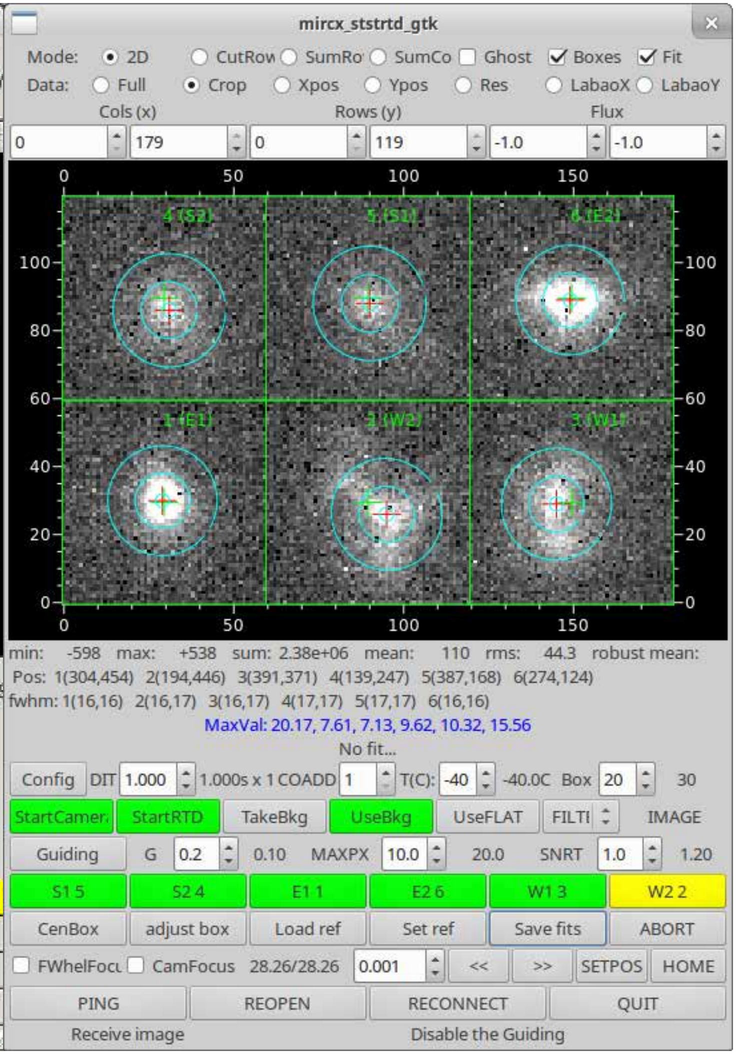
AO Control and Diagnostics Tools

STST image quality monitoring and STST guiding

STST images provide
a very useful
diagnostic for
AO performance

Daily email by Narsi.





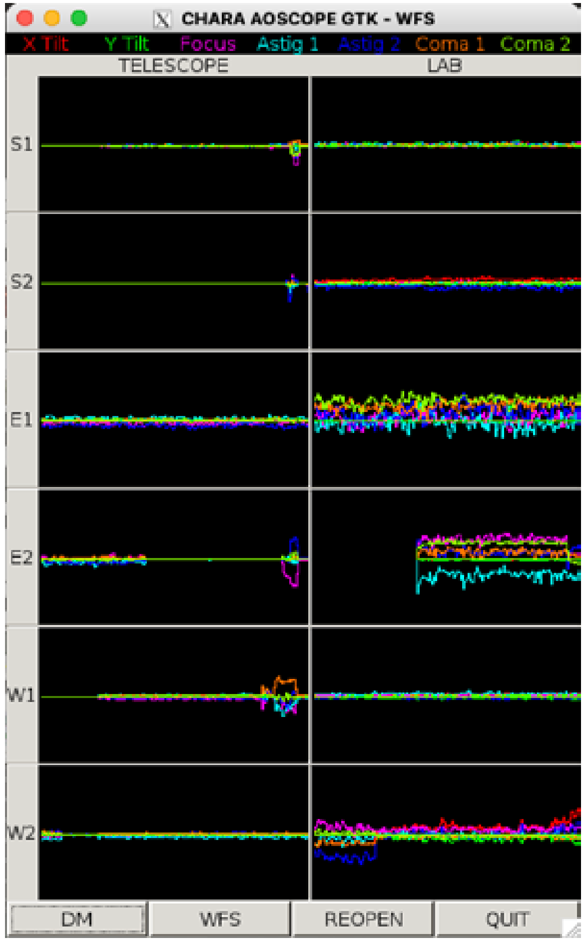
Available on VNC!

STST Guiding -
helps keep beams stable

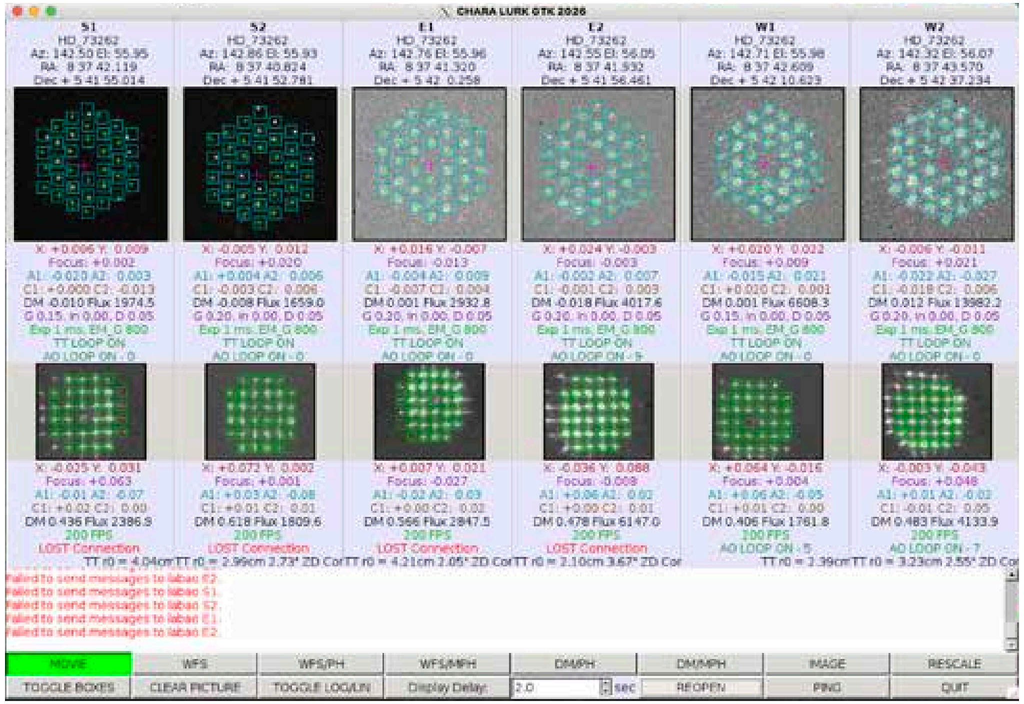
limit H<6.5 mag

AO Control and Diagnostics Tools

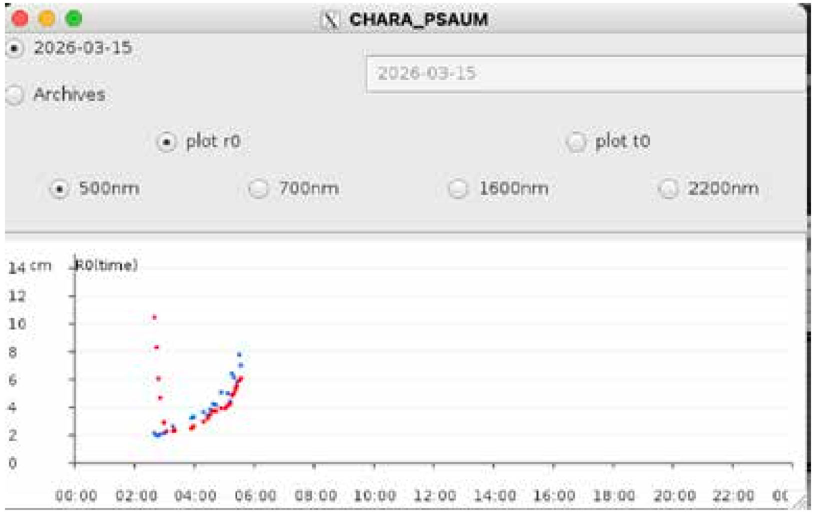
AOMON



LURKGTK



SEEING MONITOR



Available on VNC!

Alignment and Operational Challenges

we are learning to manage

Operating 12 AO systems across 6 telescopes introduces significant complexity

- systems are similar but not identical
- precise alignment requires time and operator expertise

Main sources of instability

temperature and mechanical flexure
laboratory and coude path seeing
telescope seeing at the start of the night

Additional complications

dichroic configuration changes
sensitivity to beam path modifications (LDC insertion/removal)
imperfect calibration sources

AO maintenance

Changes in the optical configuration require system recalibration

Lab changes require:

- lab realignment (E-table, dichroic, DM, BRT, IR targets, STST, STS IR)
- verification of LabAO performance
- telescope beam alignment

Telescope changes require:

- LabAO performance verification
- TelAO performance verification
- new reconstructors and DM flats

Typical workload

- Lab preparation for LDC configuration: 6–7 hours
- TelAO performance verification: ~2 hours per telescope

Example stability differences:

- E1 stable for ~1 year with same reconstructor
- S1 / S2 required frequent recalibration

2025 STATISTICS

	Semester A	Semester B
	21 weeks (151 observing nights)	20 weeks (143 observing nights)
How many time LDC in/out	12in /12 out	14 in/14 out
Telescope dichroic changes	14 IR to VIS 14 VIS to IR	13 IR to VIS 13 VIS to IR
Configuration changes (beam order)	13 in total	18 in total

Total in 2025

	TelAO		
	FLAT	RECON	REF
S1	41	41	49
S2	76	59	87
E1	6	7	5
E2	16	9	42
W1	148	65	93
W2	93	60	71

	LabAO		
	FLAT	RECON	REF
S1	42	37	49
S2	82	93	70
E1	57	50	76
E2	55	54	51
W1	66	52	73
W2	62	72	104

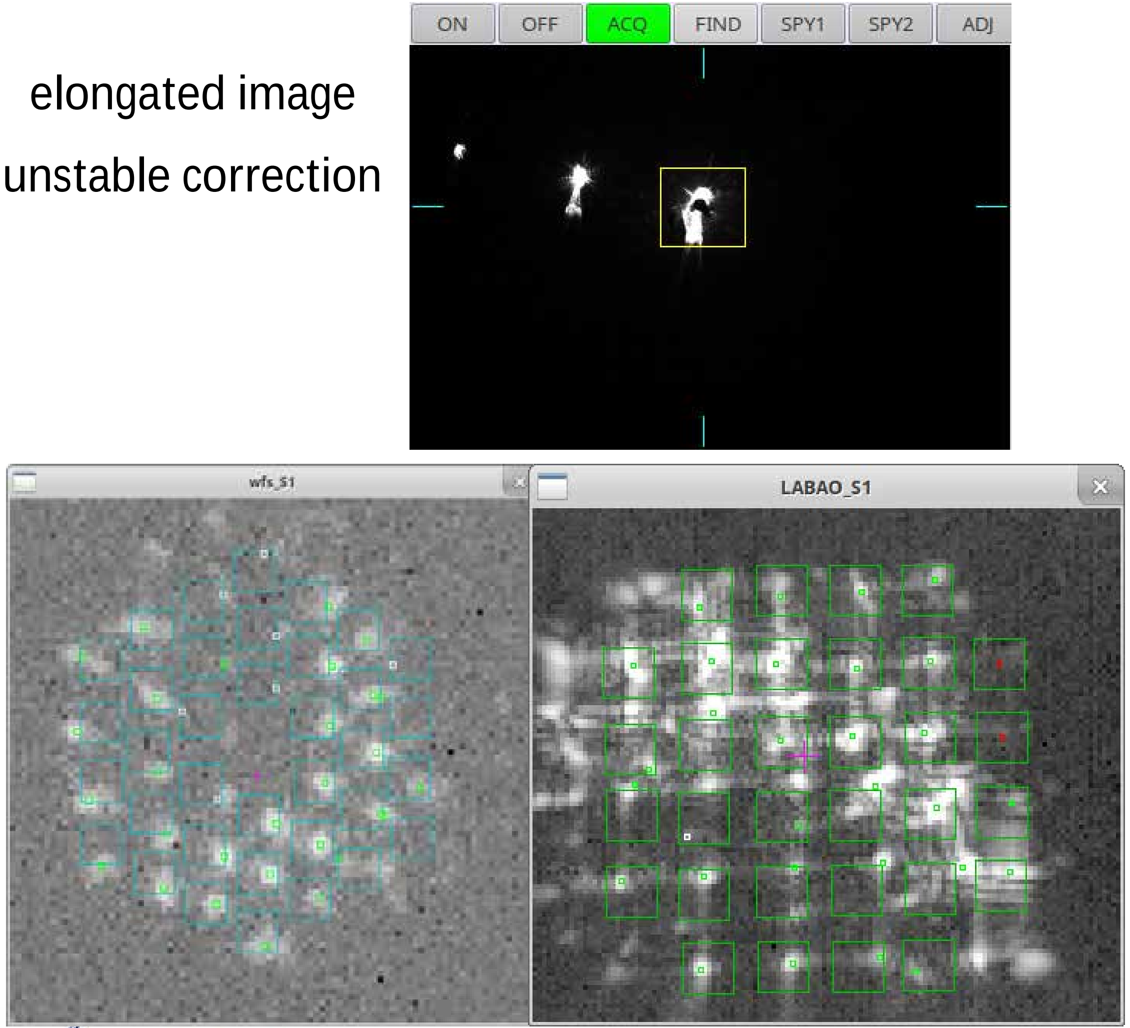
Amount of work

S1 AO Performance Improvement

During the day - Thursday 12th March 2026

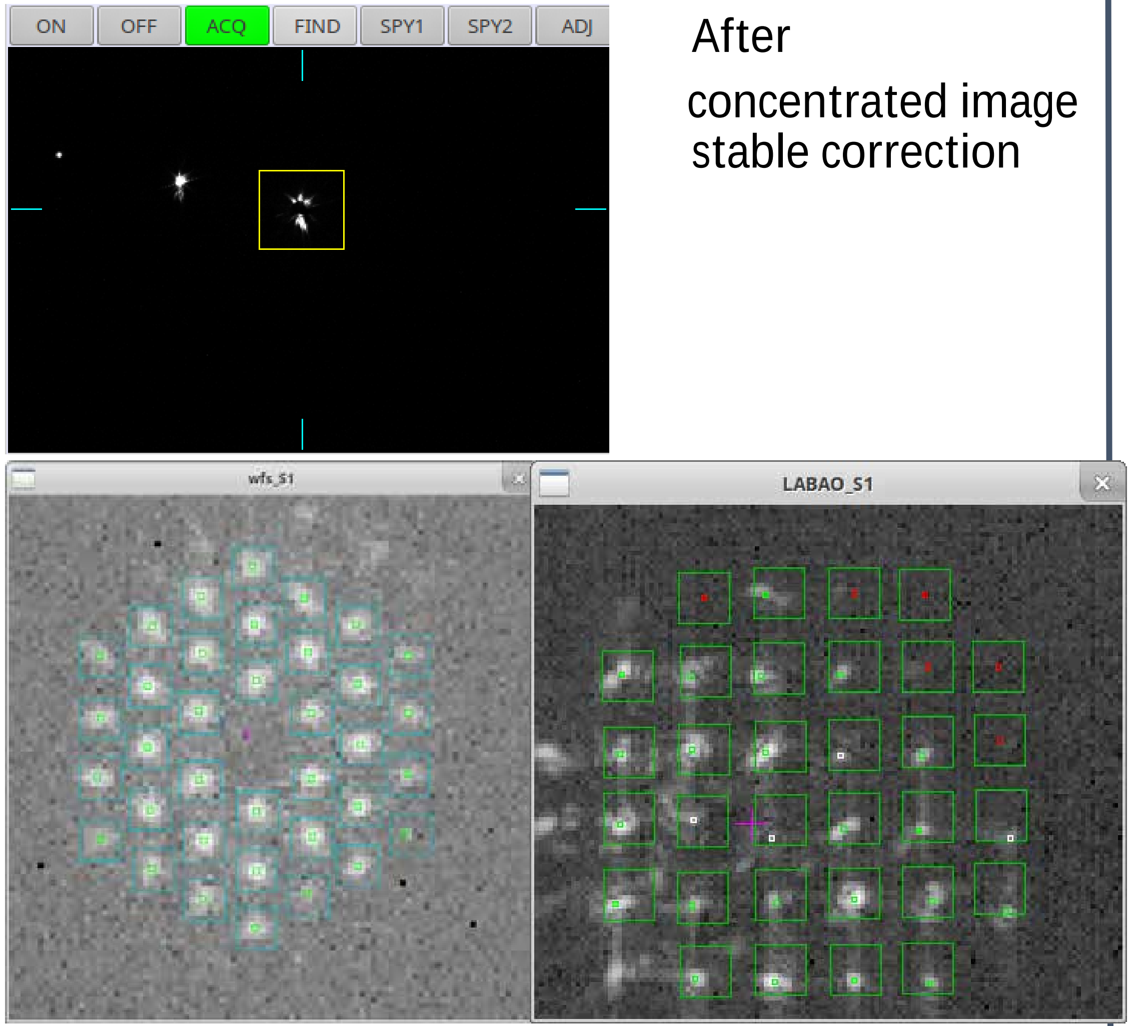
elongated image

unstable correction



After

concentrated image
stable correction

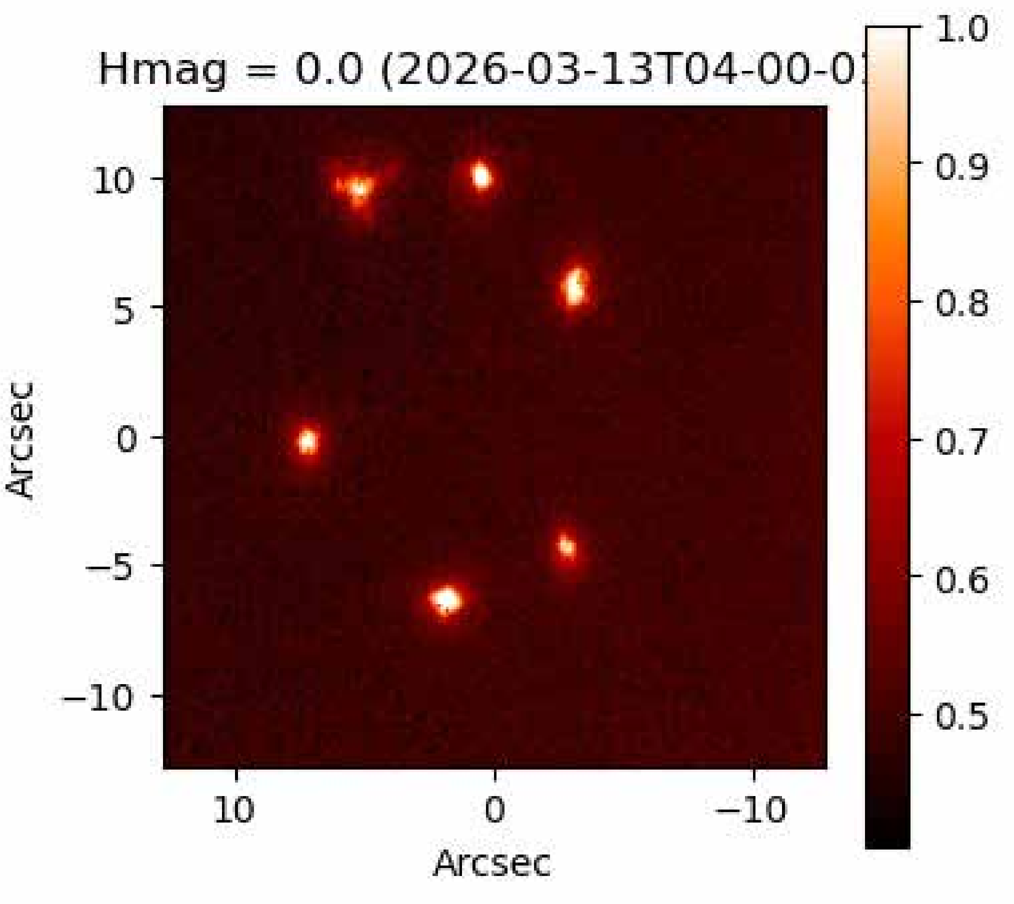


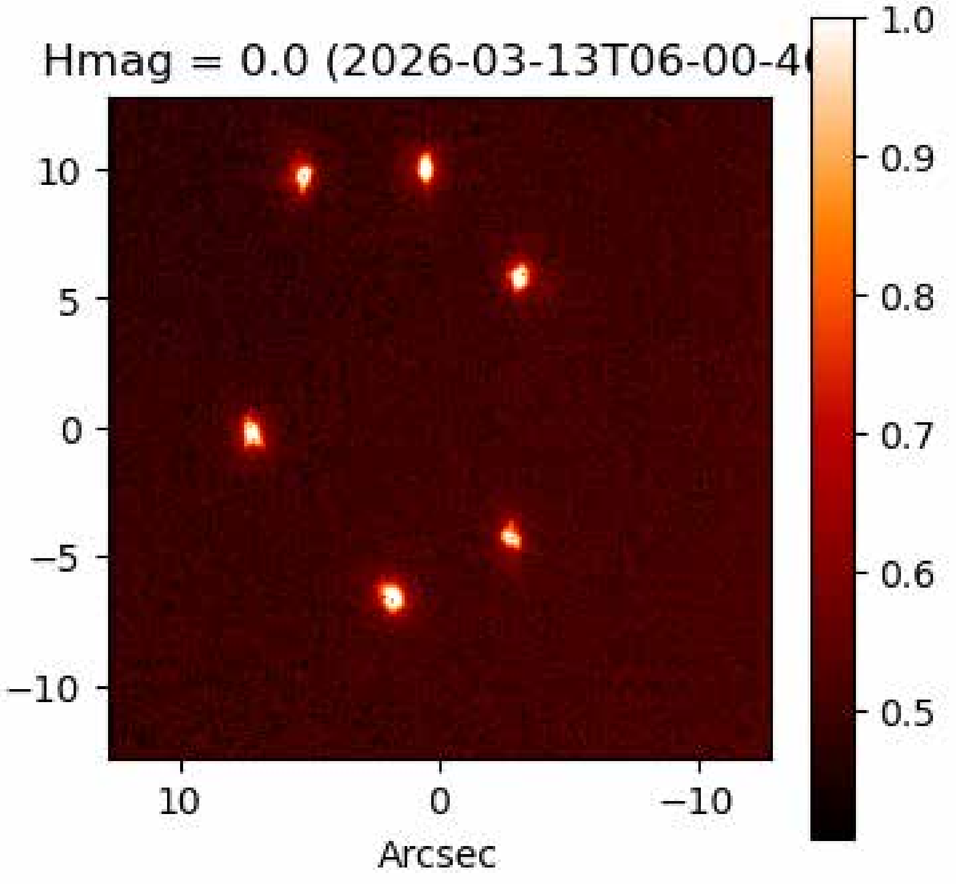
S1 - Final check up of the day

STST Performance Diagnostics - beyond morning coffee image overlook

STST data enables quantitative monitoring of AO performance:

- PSF quality
- Strehl proxy
- flux stability
- image quality trends

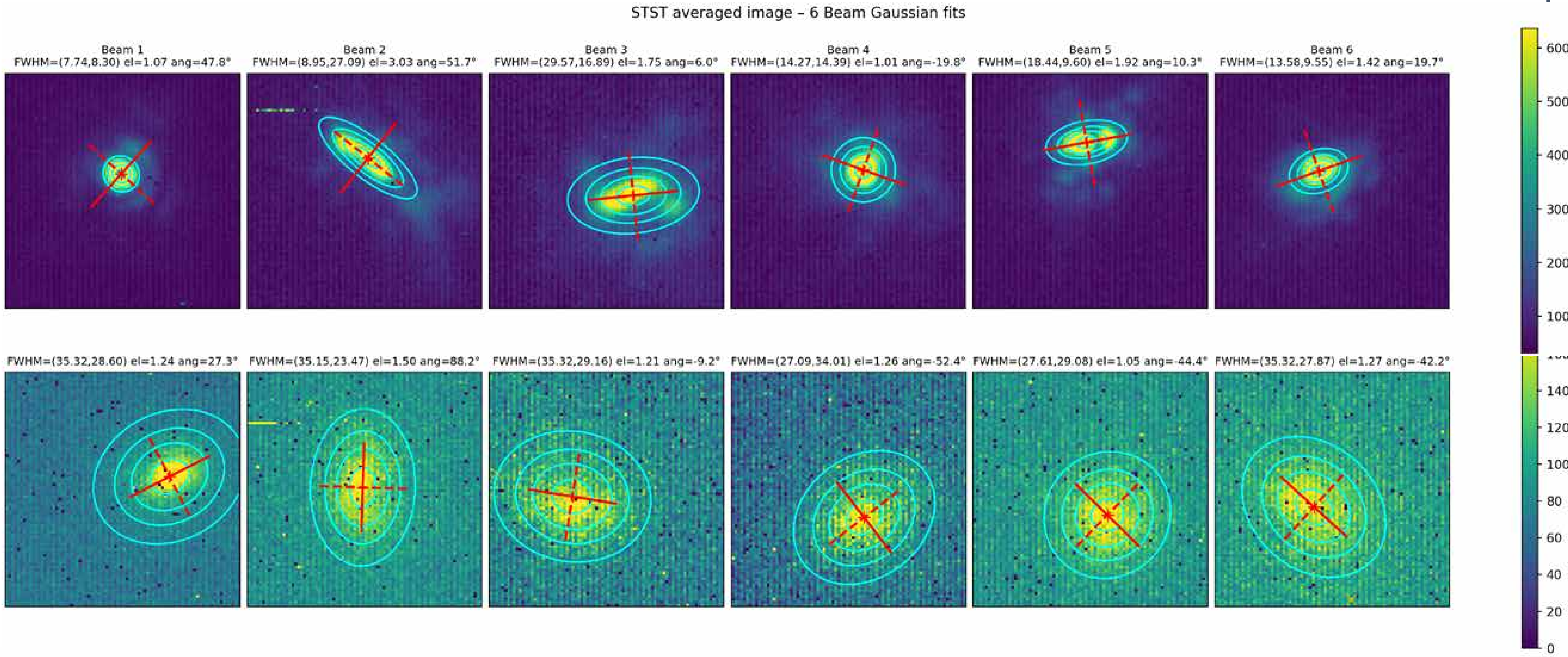




This provides a **continuous diagnostic of array performance.**

STST Performance Diagnostics

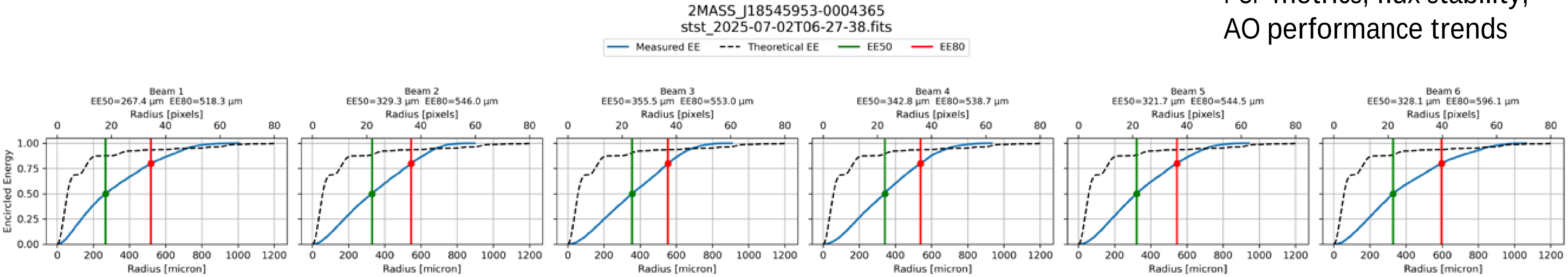
Work on developing automated analysis of STST data

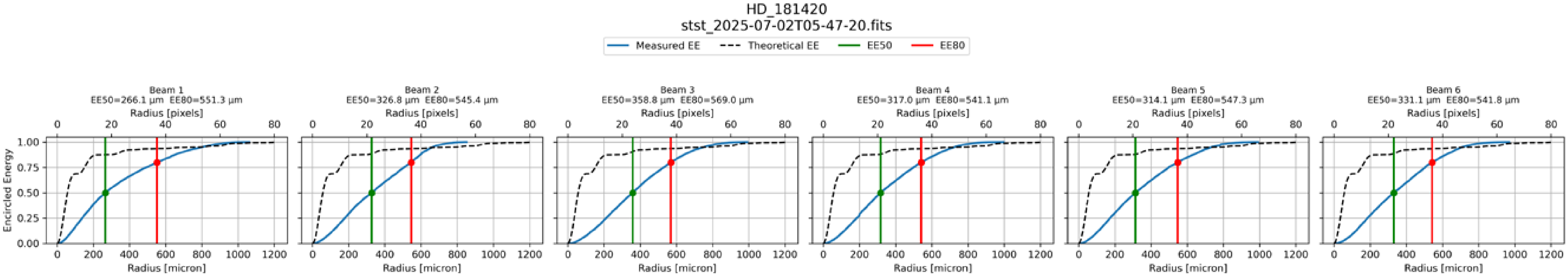


STST Performance Diagnostics

Work on developing automated analysis of STST data to measure:

PSF metrics, flux stability, AO performance trends





Automated AO Log Analysis

Night Diagnostics and Performance Monitoring

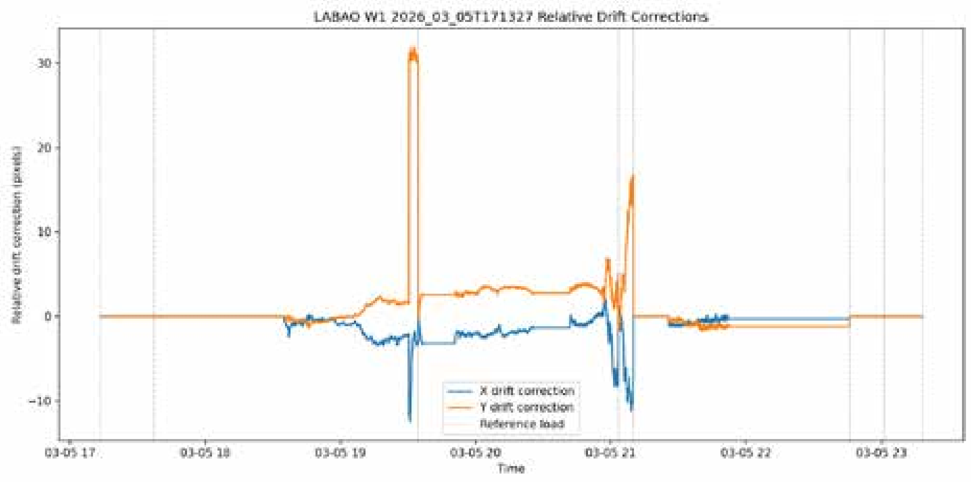
Automated analysis of AO logs allows:

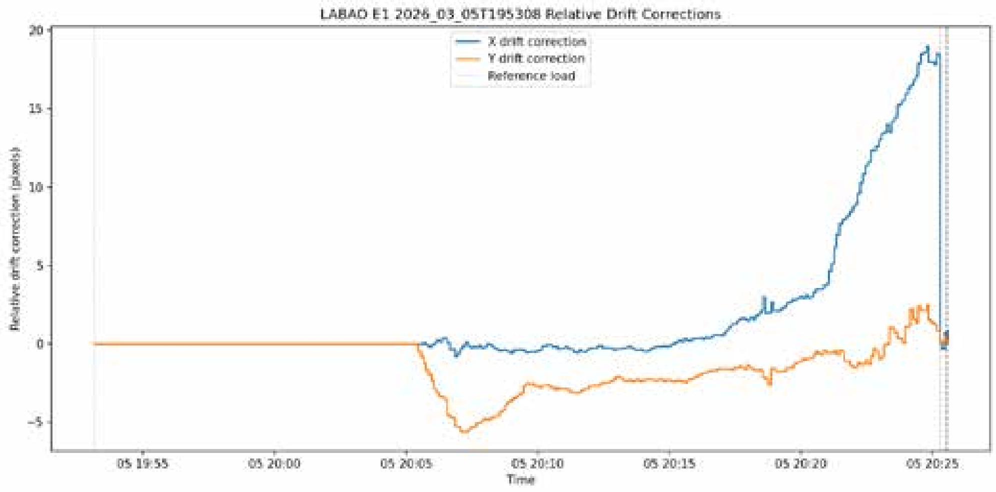
- monitoring of AO system behavior over the night
- identification of abnormal events
- correlation with telescope or instrument issues
- long-term performance tracking

Goal: automated nightly AO health report

Ex: This looks like a clear runaway box drift.
The magnitude is far beyond normal guiding corrections.

Example: STST guiding diagnostics - runaway guiding drift





Reload interval : 117.12 min
Reload interval : 65.25 min
Reload interval : 71.89 min
Reload interval : 116.24 min

S2 – S2_2026_03_05T171324
Early large event (~19:45)
- X jumps to about +120 px
- Y jumps to about -90 px

Later event (~21:50)
- massive negative drift
- X reaches about -120 px
- Y reaches about -220 px

Current Status of CHARA AO

System deployment

AO operational on all 6 telescopes and 6 laboratory beams

Uniform AO control software deployed on all 12 systems and on T7 NIB

Operational improvements

improved telemetry and logging system

new AO diagnostics tools

improved alignment procedures and documentation

regular coordination with CHARA operators

Remaining challenges

increasing complexity of alignment and calibration

large operational workload

fragmented logging across multiple systems

Next Steps

AO performance

development of on-sky reconstructors
quantitative AO performance monitoring

Automation

automated diagnostics from AO logs
automated STST performance analysis

System improvements

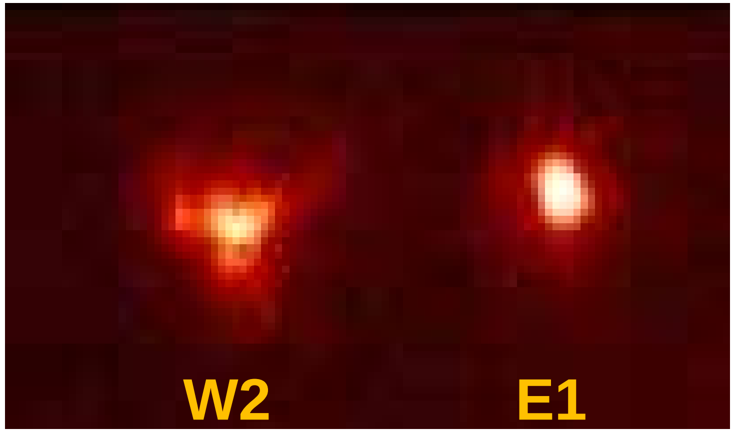
blue beacon wavelength change (405 → 450 nm to reduce pupil rotation)

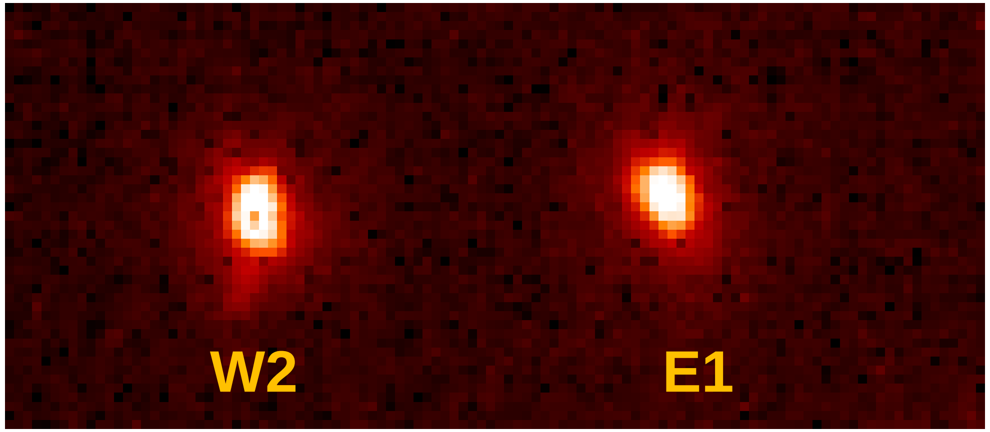
modernization of camera-link servers (currently being tested on T7)

Goal: more stable AO operation with reduced operator workload.

AO performance on the last engineering night!

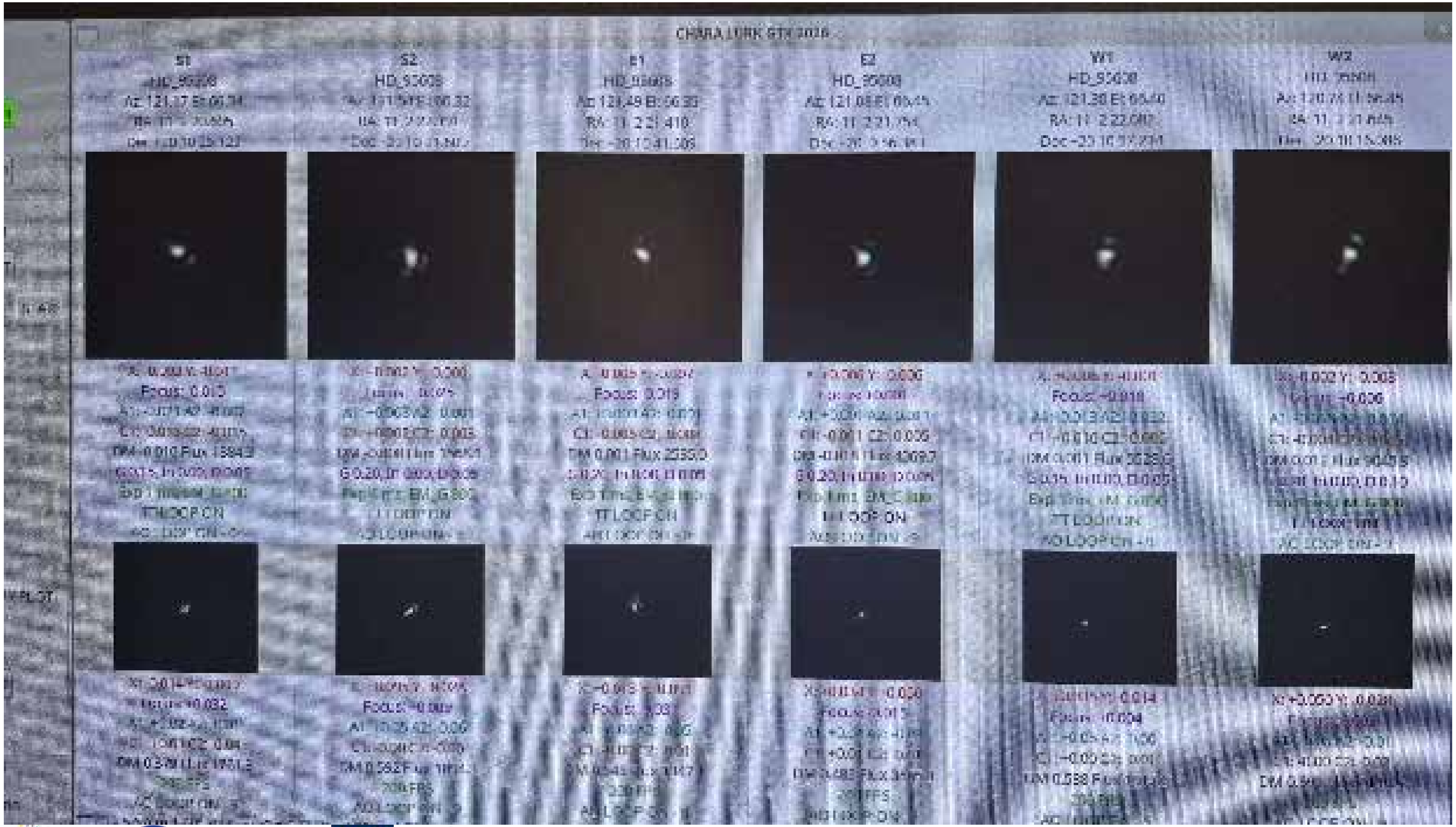
W2 elongation on STST





AO performance on the last engineering night!

Images reconstructed from the WFS Phases



Take-Home Messages

CHARA operates 12 adaptive optics systems across the array

New software and diagnostics significantly improve system monitoring

STST provides a powerful tool for quantitative performance analysis

Future work focuses on automated diagnostics and performance tracking