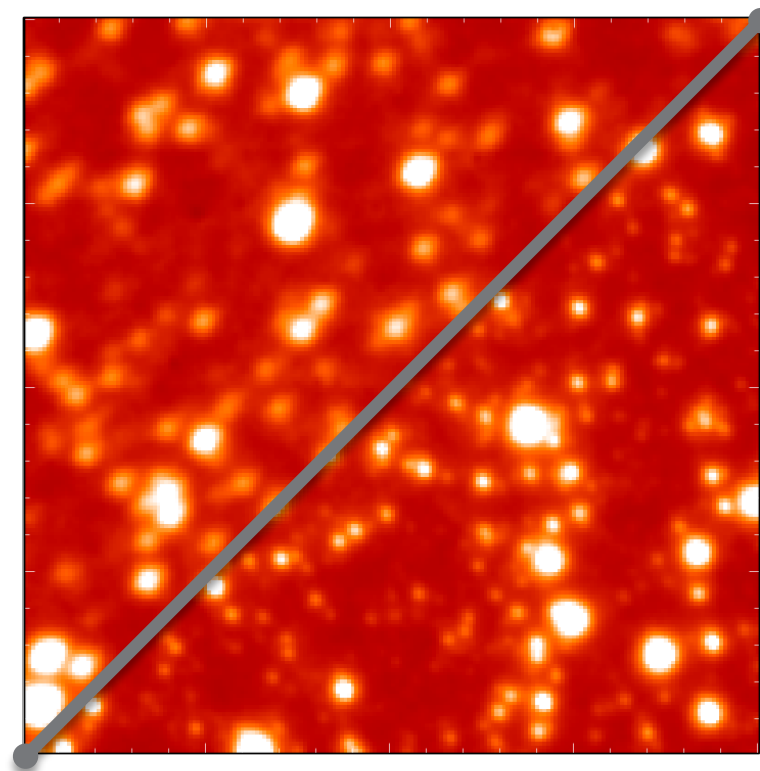


ARGOS COMMISSIONING STATUS & FIRST ON-SKY GLAO OBSERVATIONS

G. Orban de Xivry





Large Binocular Telescope



Commissioning team:

Sebastian Rabien^a, Wolfgang Gässler^b, Lorenzo Busoni^c, Simone Esposito^c Marco
Bonaglia^c, José Luis Borelli^b, Matthias Deysenroth^a, Hans Gemperlein^a, Martin Kulas^b,
Michael Lefebvre^f, Tommaso Mazzoni^c, Gilles Orban de Xivry^a, Diethard Peter^b, Alfio Puglisi^c,
Walfried Raab^a, Gustavo Rahmer^f, Julian Ziegler^a

^a MPE, Garching

^b MPIA, Heidelberg

^c INAF, Firenze

MPIfR, Bonn

University of Arizona, Tucson

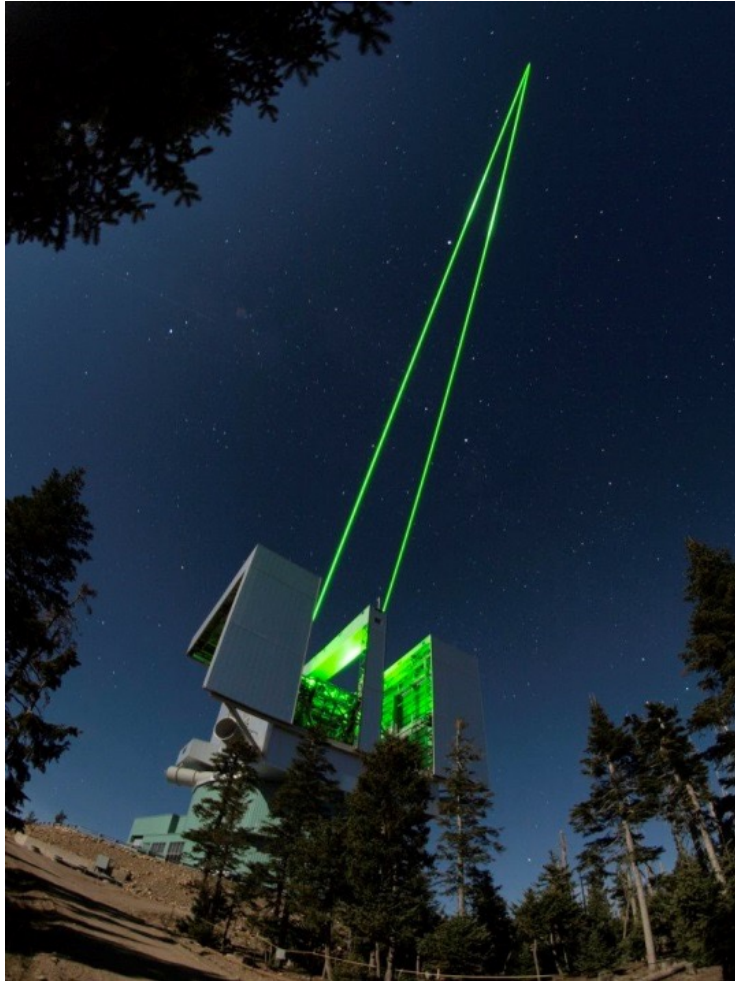
AIP, Potsdam

LSW, Heidelberg

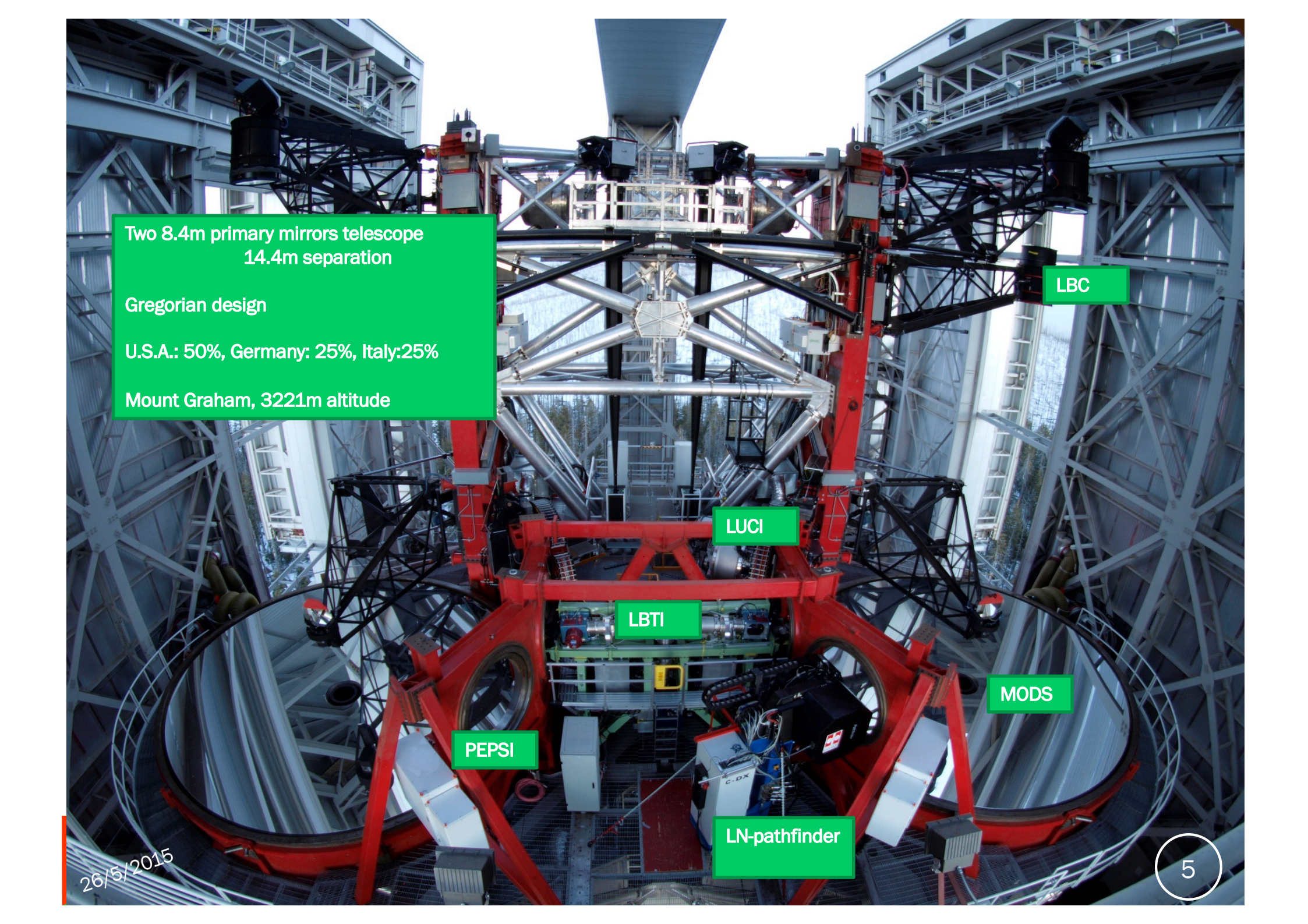
^f LBTO, Tucson

OUTLINE

- ☐ LBT & LUCI overview
- ☐ ARGOS in a nutshell, goals & performances
- ☐ Commissioning: overview & AO loop operations
- ☐ First ARGOS-GLAO data: first steps in performances evaluation and PSF characterization



LBT & LUCI OVERVIEW



Two 8.4m primary mirrors telescope
14.4m separation

Gregorian design

U.S.A.: 50%, Germany: 25%, Italy: 25%

Mount Graham, 3221m altitude

LBC

LUCI

LBTI

MODS

PEPSI

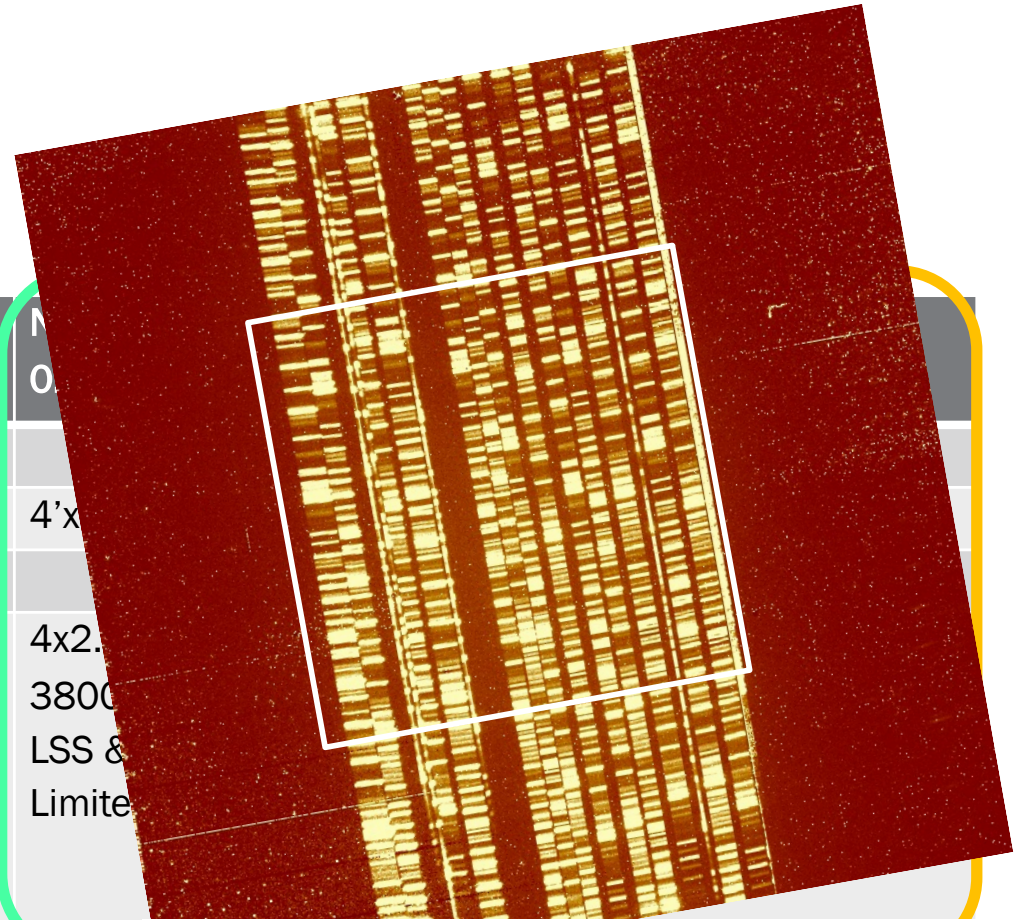
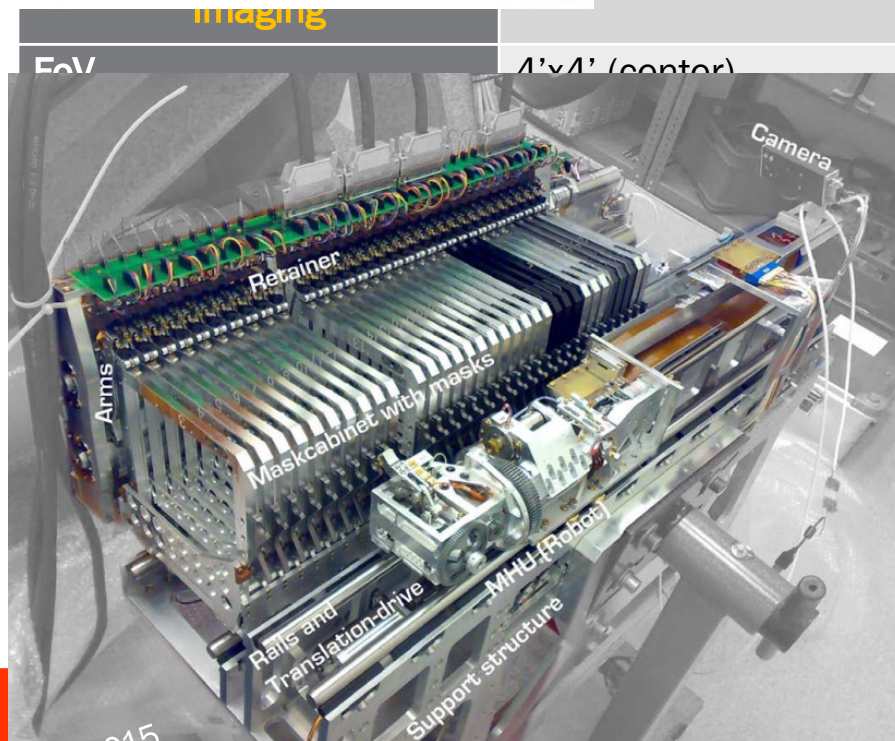
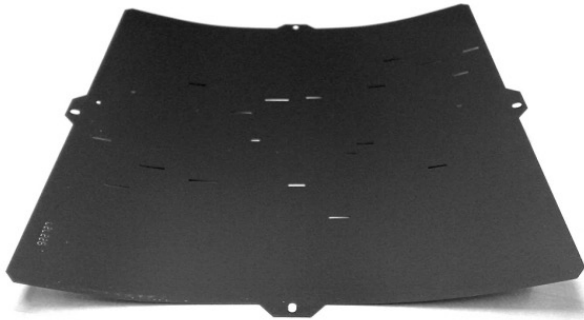
LN-pathfinder

26/5/2015

LUCI *MULTI-PURPOSE*

It is two – LUCI-1 & LUCI-2 –

- near-infrared imagers,
- long slit spectrographs and
- photometers for both LBT eye.



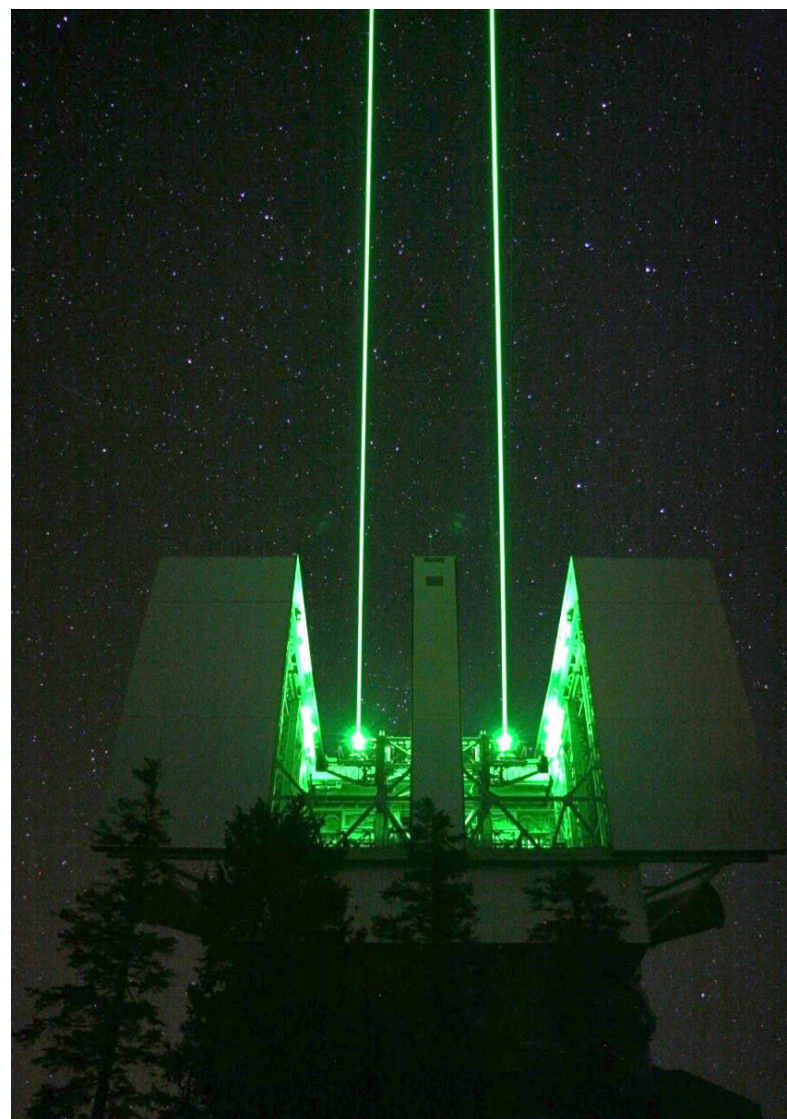
Detector image with the N1.8 camera in MOS mode

The N3.75 camera uses the full detector

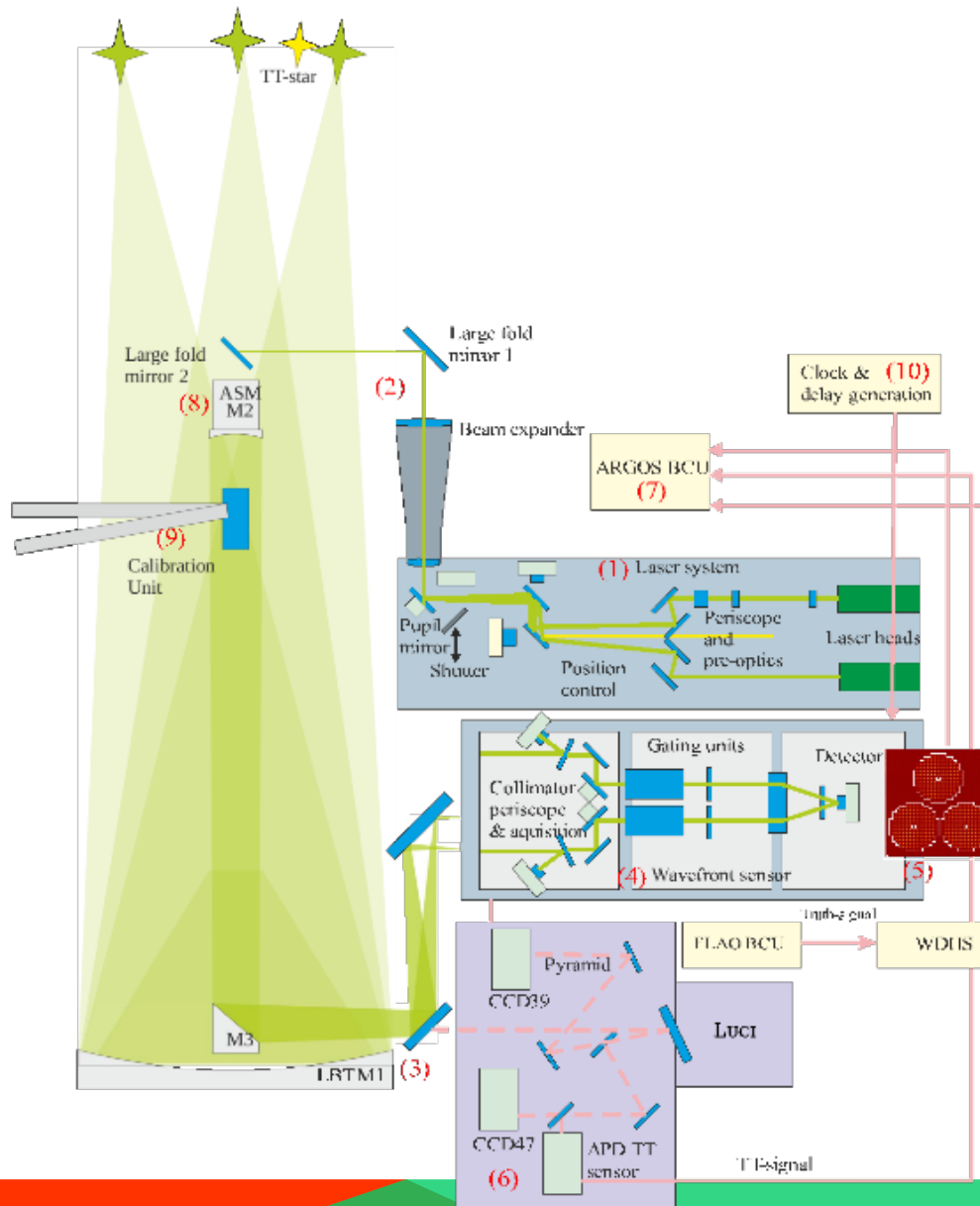
26/5/2015



OVERVIEW

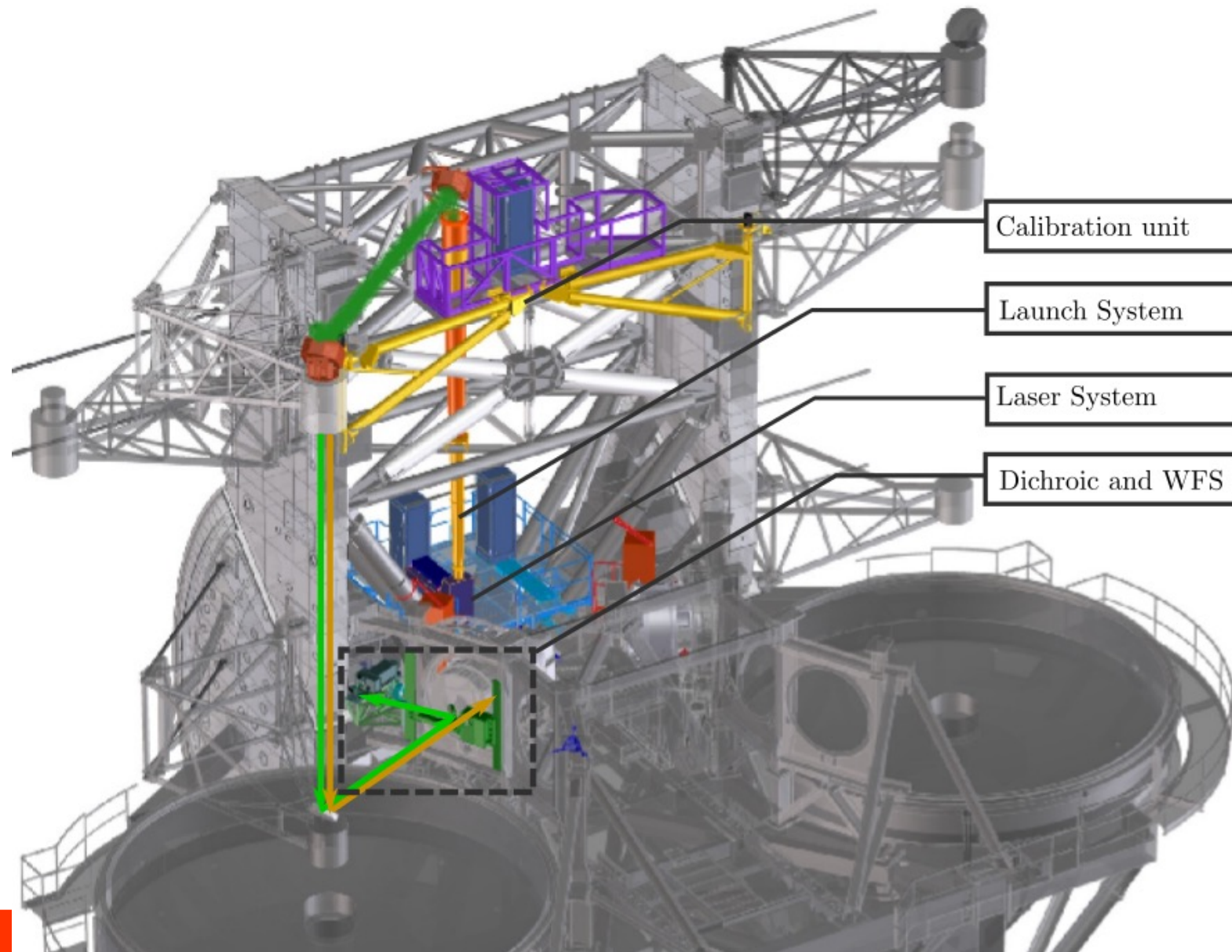


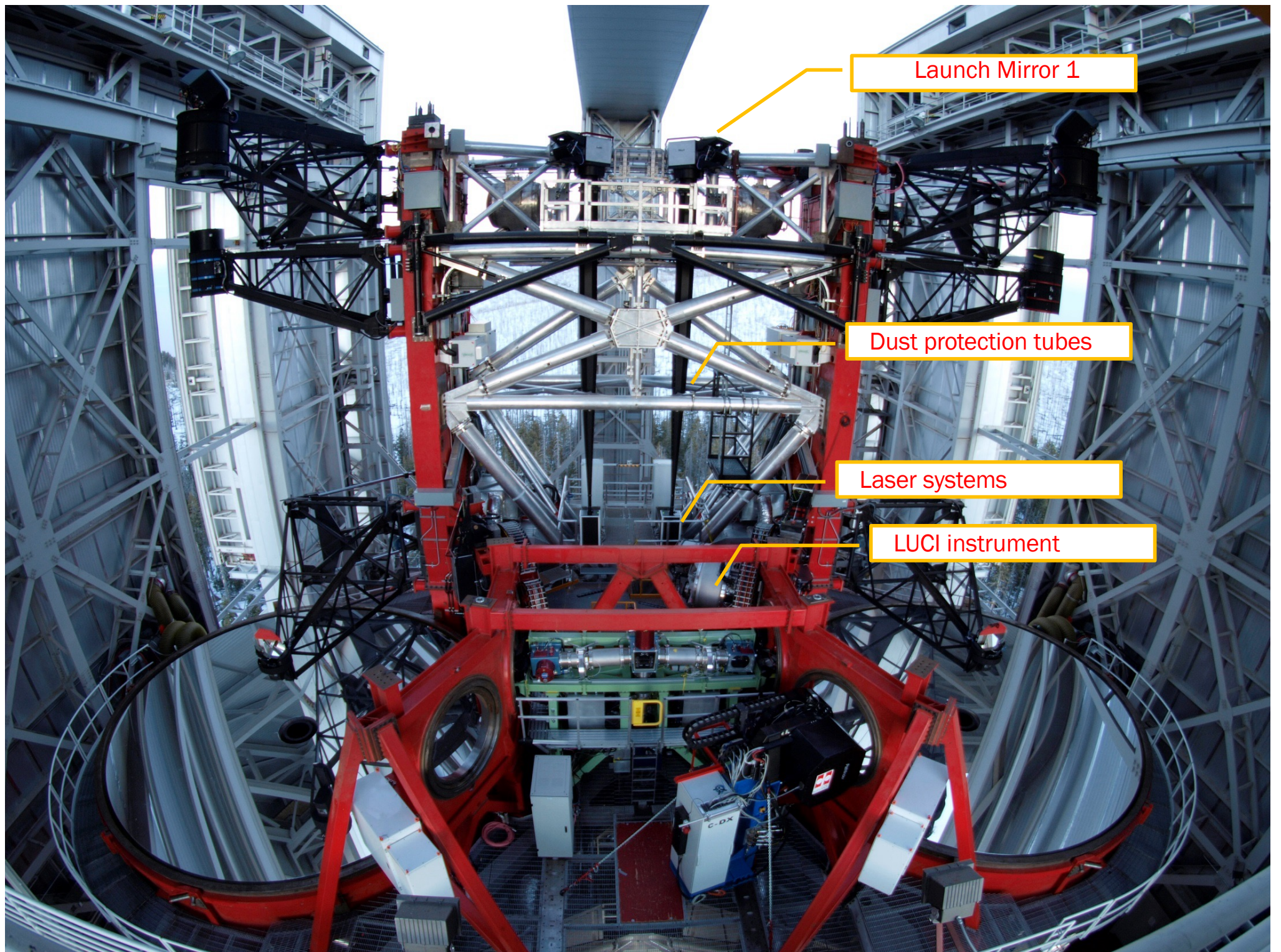
ARGOS IN A NUTSHELL



- A Ground layer LGS AO system
- Wide field correction
- Twin units- serve both sides of LBT
- Delivers correction for the two IR imaging & MOS spectrographs LUCI
- A multi-laser 4' constellation
- High power pulsed green lasers
- "Rayleigh" beacons created at 12km
- LBT adaptive secondary correction
- Gated SH wavefront sensors:
 - ~175 subap per SH pupil, 8x8 pix subaperture (4.5"/subap), 1kHz, 4e- RON

ARGOS IN A NUTSHELL





Launch Mirror 1

Dust protection tubes

Laser systems

LUCI instrument

ARGOS GOALS

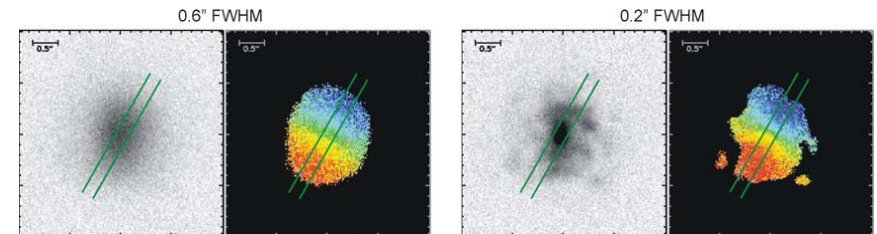
Decrease the PSF FWHM by 2:

- ~4 times less in observing time for point-like object (e.g., high-z galaxies)
- Gain spectral resolution with smaller slits
- Reduce sky background
- Better slit coupling efficiency,
- Enable spatially resolved spectroscopy
- Spatially resolved spectroscopy,
- Reduced crowding noise
- Spatial resolution

Operate under most atmospheric conditions

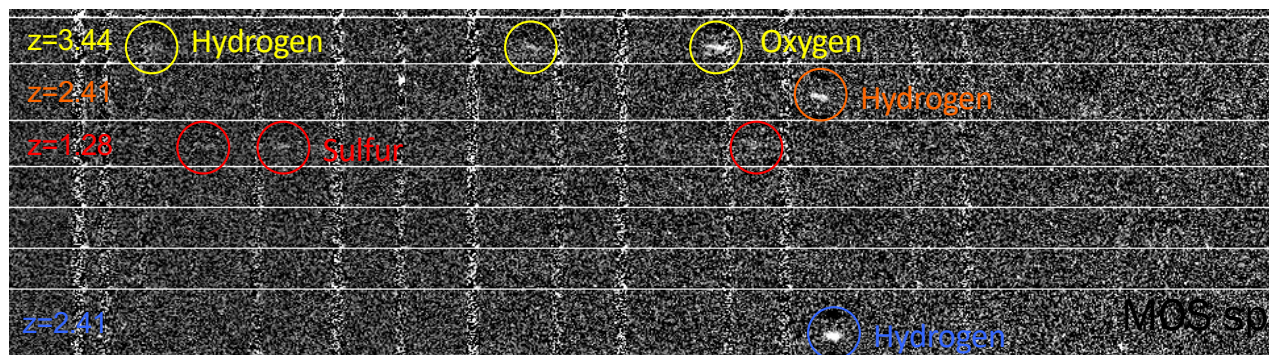
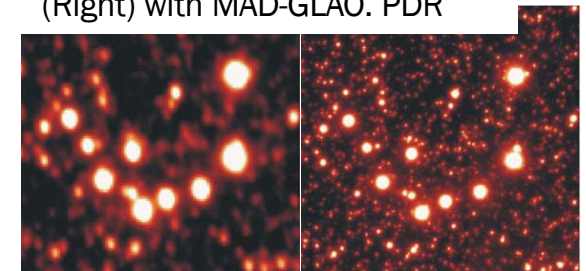
Install a reliable, low maintenance system

Slit coupling efficiency and spatially resolved spectroscopy



Simulation of a galaxy, slit of 0.25''. PDR

20'' region
(Left) with ISAAC.
(Right) with MAD-GLAO. PDR

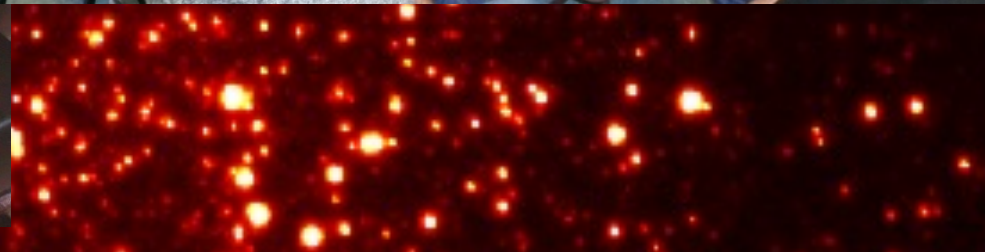
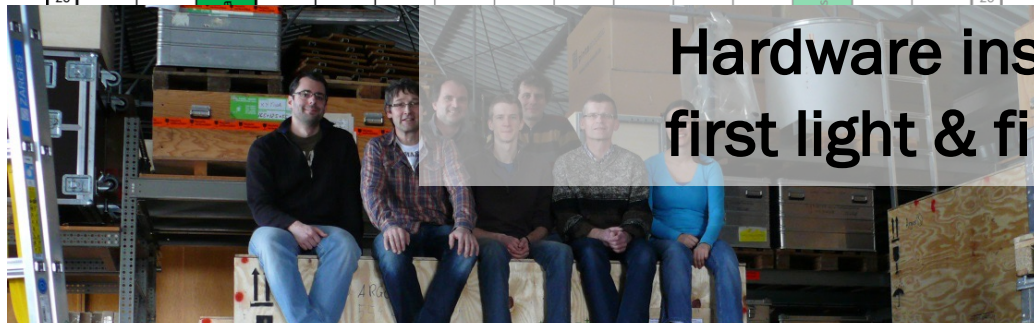
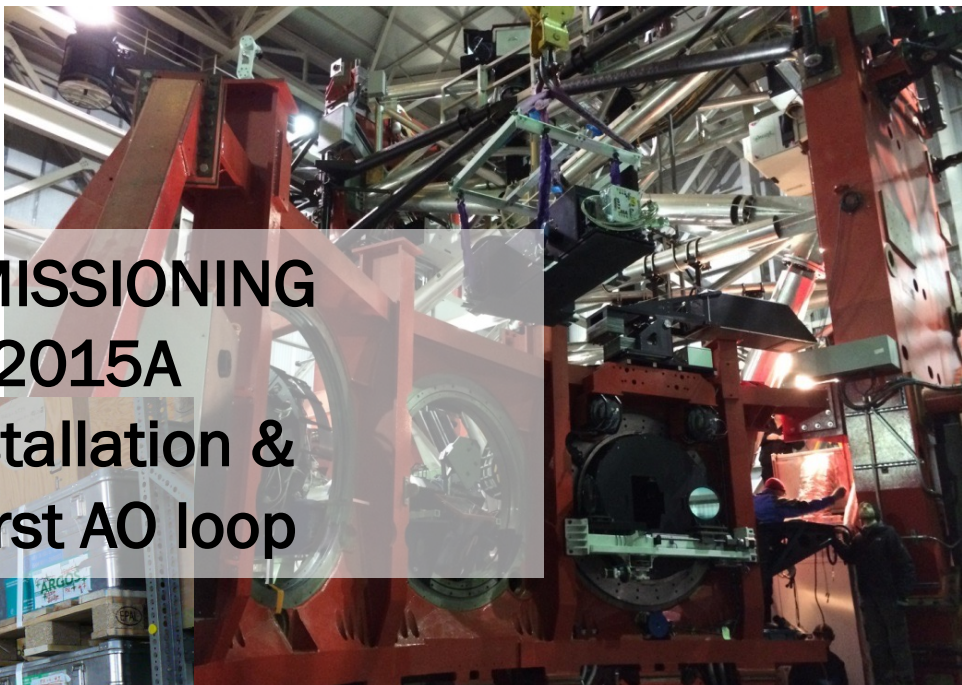


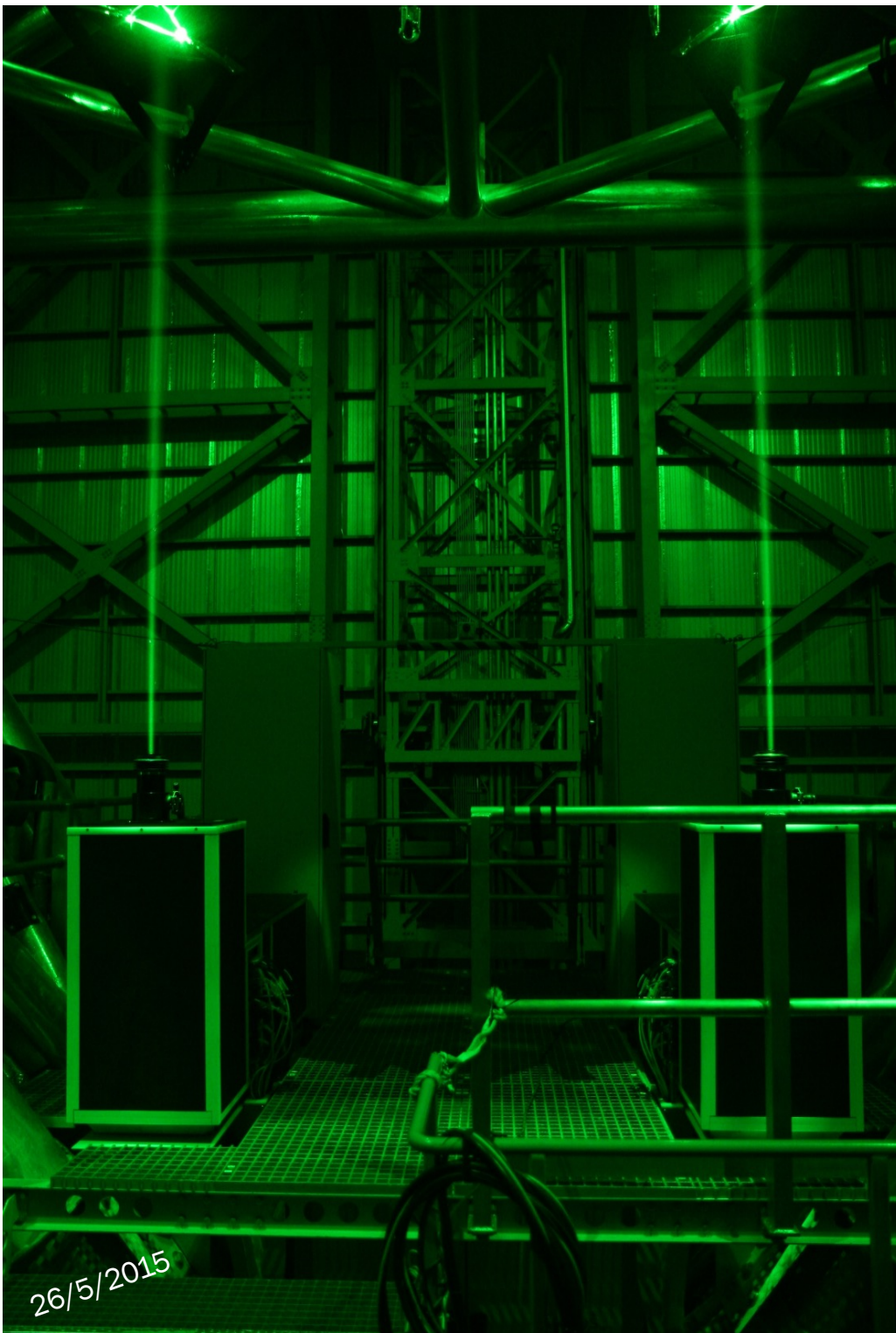
MOS spectra from high redshift galaxies

		2013			2014													
		Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec		
1																	1	
2																	2	
3																	3	
4																	4	
5																	5	
6																	6	
7																	7	
8																	8	
9																	9	
10																	10	
11																	11	
12																	12	
13																	13	
14																	14	
15																	15	
16																	16	
17																	17	
18																	18	
19																	19	
20																	20	

ARGOS COMMISSIONING 2013B- 2015A

Hardware installation & first light & first AO loop





LASER SYSTEM

3 lasers each side

18W@10kHz pulsed green YAG lasers

Controlled environment box

Beam steering & active flexure
compensation

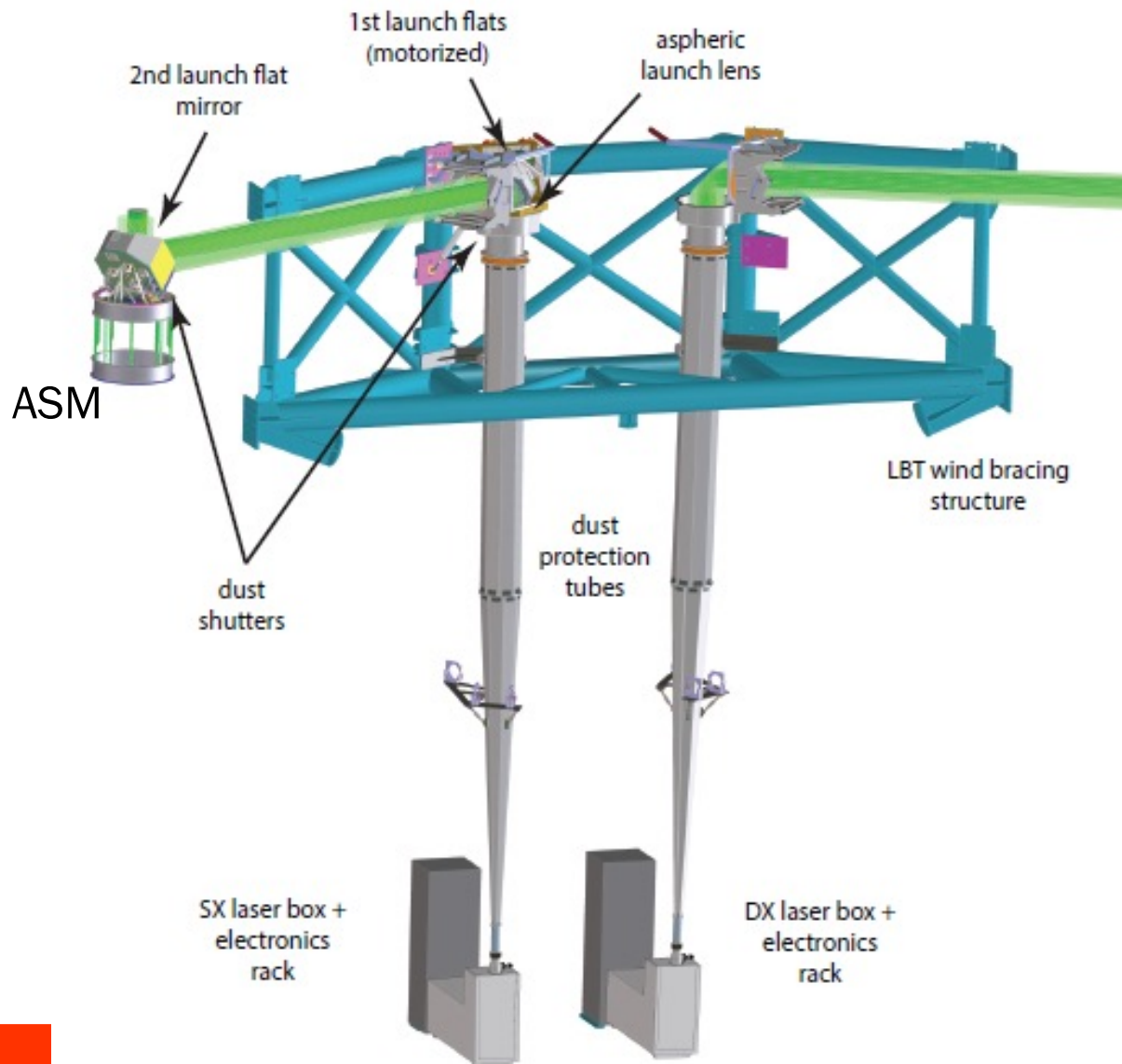
Beam diagnostics

Installed over 2013

Lasers & system now fully operational

26/5/2015

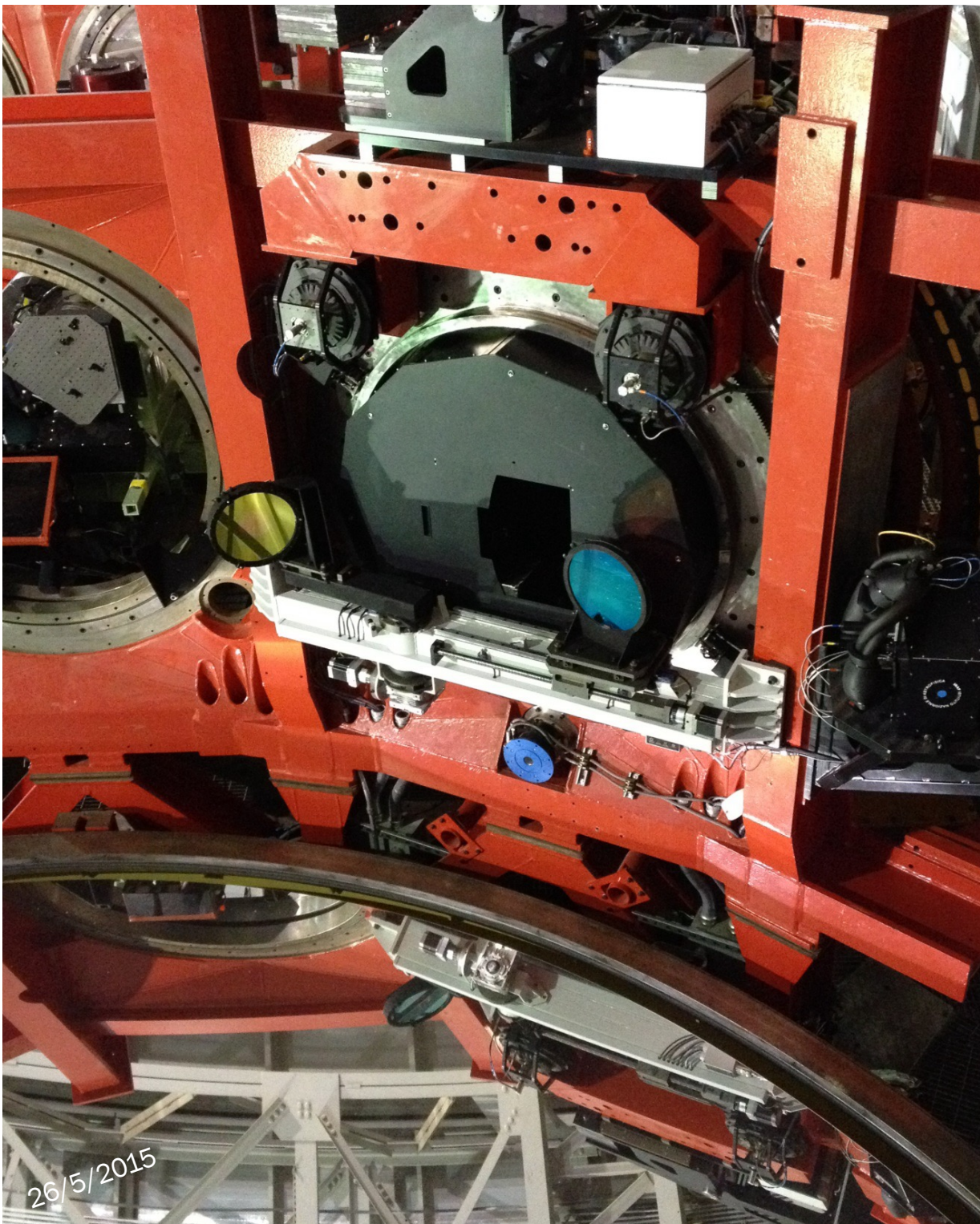
LAUNCH SYSTEM



- Refractive beam expanders
- Long focal length aspheric 45cm singlet lens
- Large fold mirrors at top of the telescope and above M2
- Flexure tracking capabilities
- Dust shutters and tubes installed

But

- High system flexure
- LM's requires active astigmatism compensation



DICHROIC SYSTEM

Reflects 532 & 589 nm light to the WFS

New dichroics & mechanics are ready

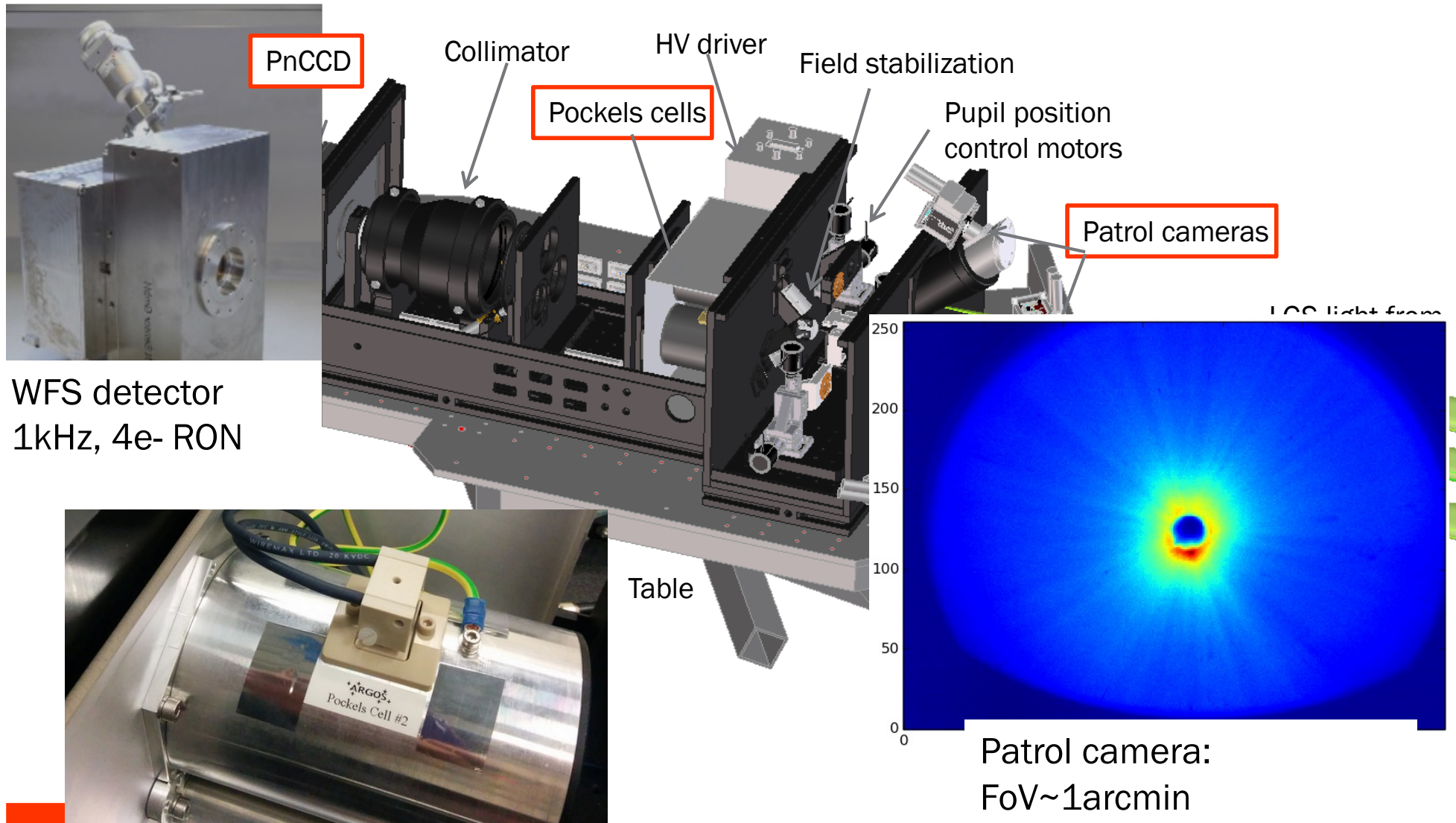
Installed & tested March 2013

No image scale effects measurable on LUCI

No laser scattered light to the NGS module

Background effect and spectral transmission still to be measured on LUCI

LGS WAVEFRONT SENSOR



26/5/2015

CALIBRATION SOURCE & NGS TIP-TILT

Calibration source:

3 off-axis, 12km, 532nm LGS sources, with holographic phase adjustment.

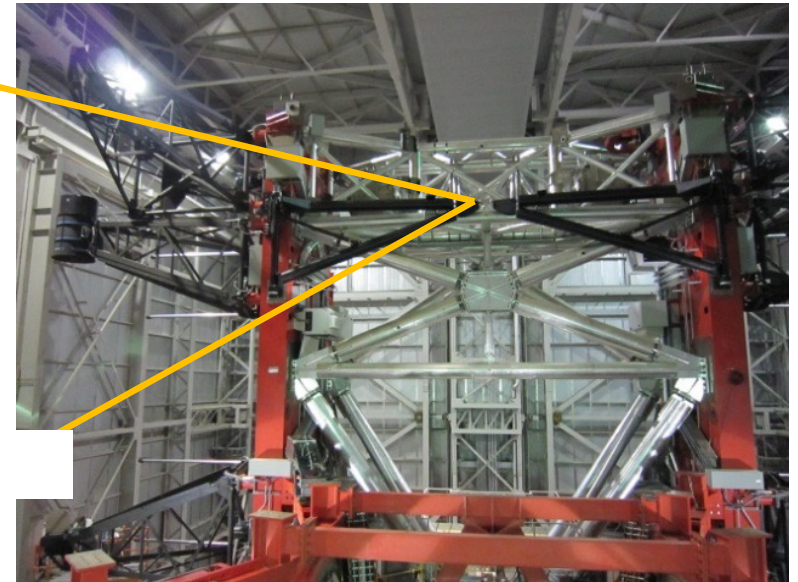
On-axis, infinite, white light source

- First light DX May 2014

- 3 off-axis stars on WFS in Nov. 2014



Calibration unit



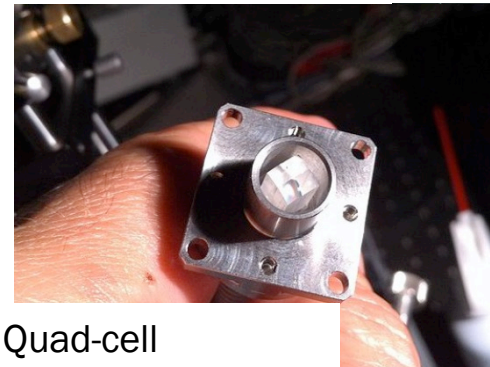
NGS tip-tilt:

Quad lens array ~2' FoV with aperture wheel

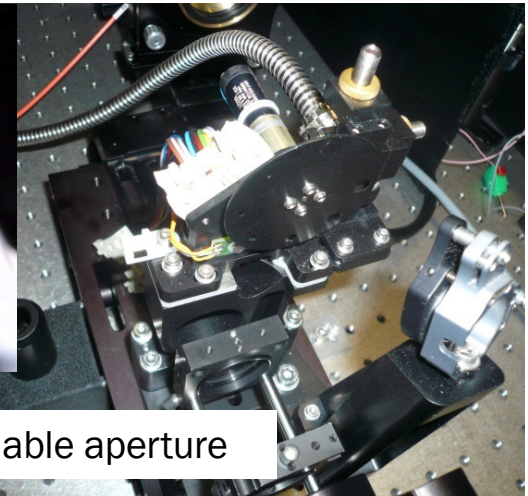
Fibre coupled APDs

1kHz custom counting unit and tip-tilt computer

First light & closed-loop Feb. 2015



Quad-cell



Variable aperture

26/5/2015

INSTRUMENT CONTROL & LOOPS

Huge number of devices to control!

Plenty of loops

ASM &

LUCI

- AO high order
- TT control
- Truth sensing
- Jitter stabilization
- LGS internal positioning
- Laser offload
- Flexure control
- Vibration control
-many more!

launch

2 of the 8 ARGOS rack

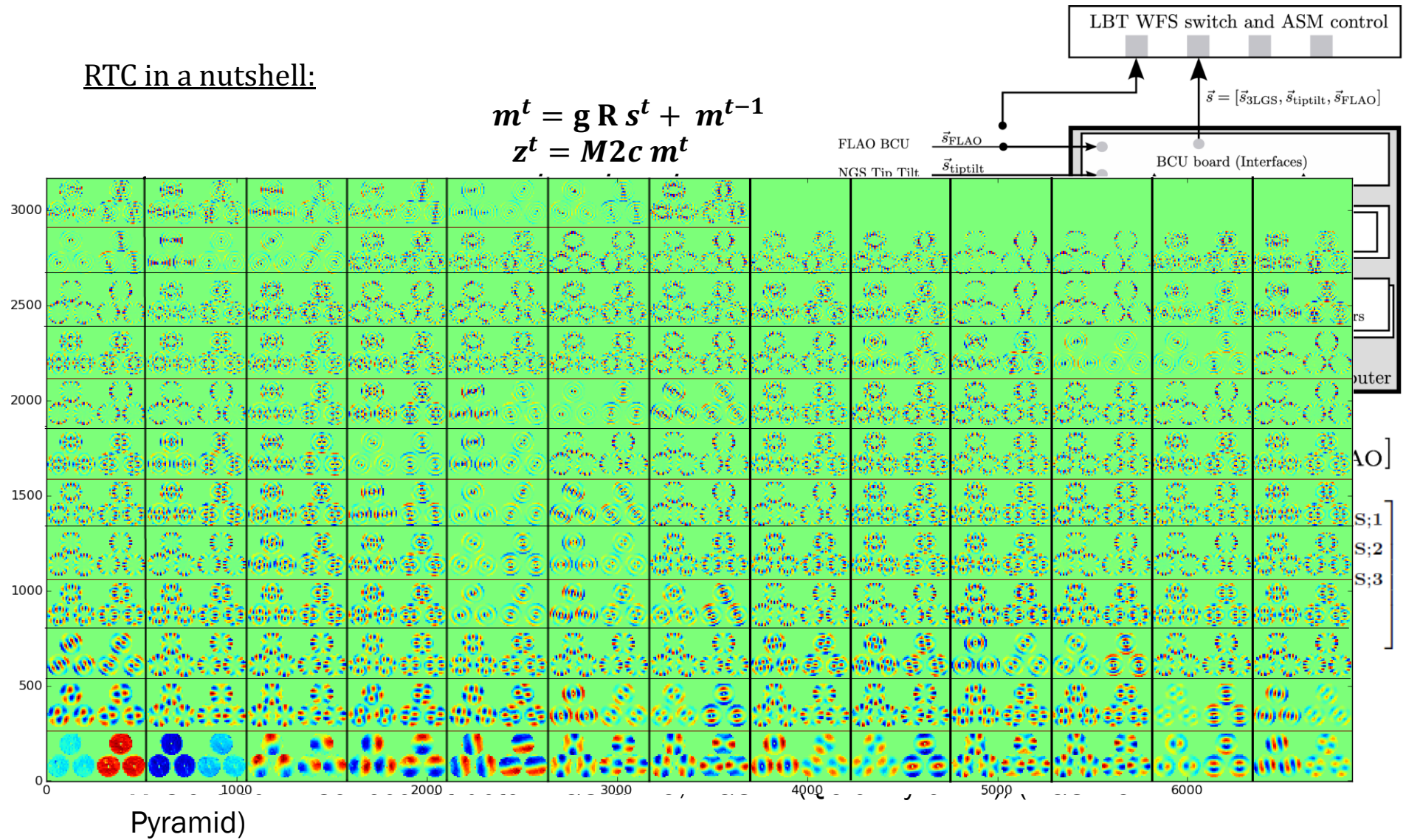
26/5/2015

IM CALIBRATION & DAYTIME CLOSED-LOOP

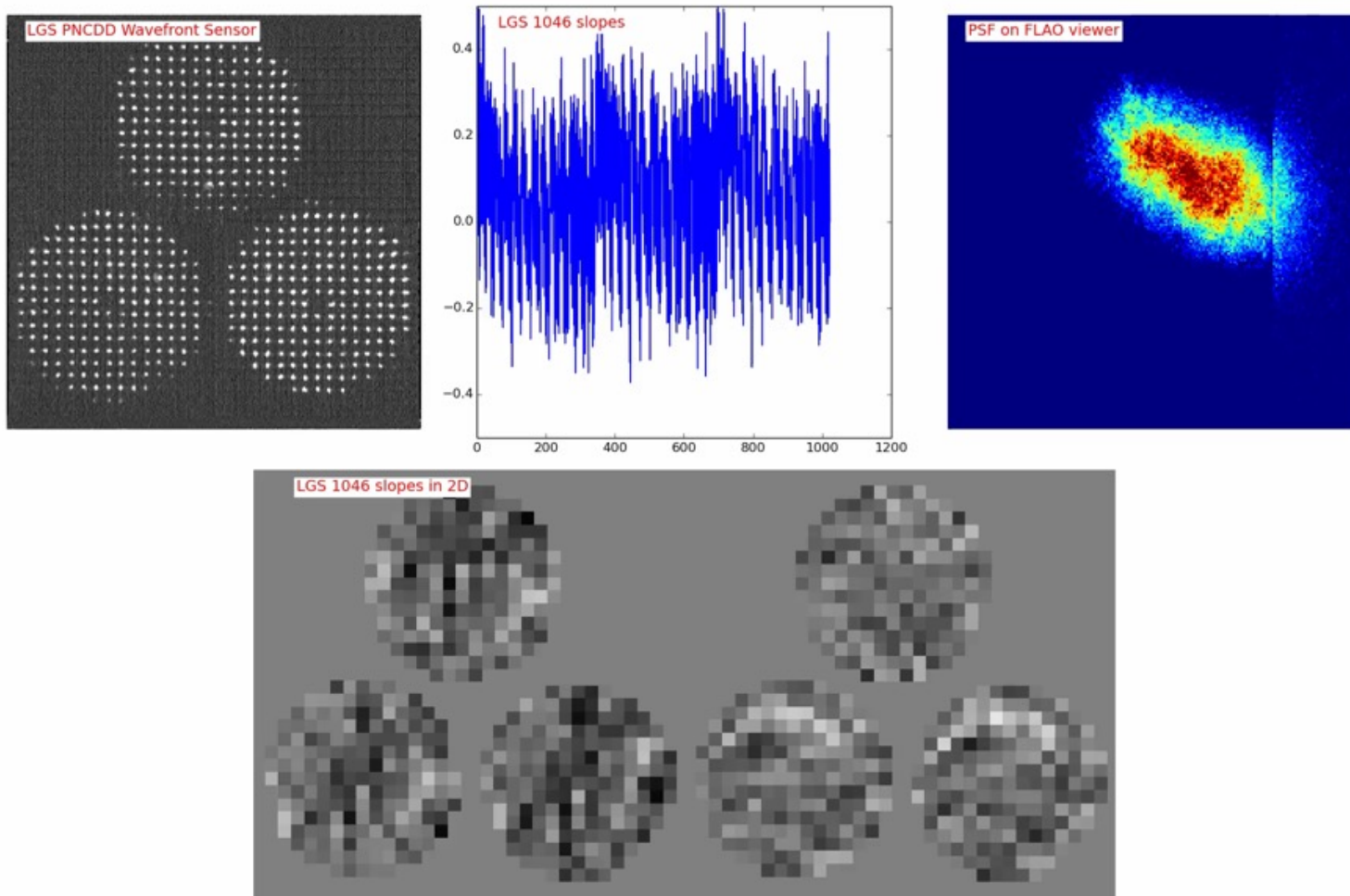
RTC in a nutshell:

$$m^t = g R s^t + m^{t-1}$$

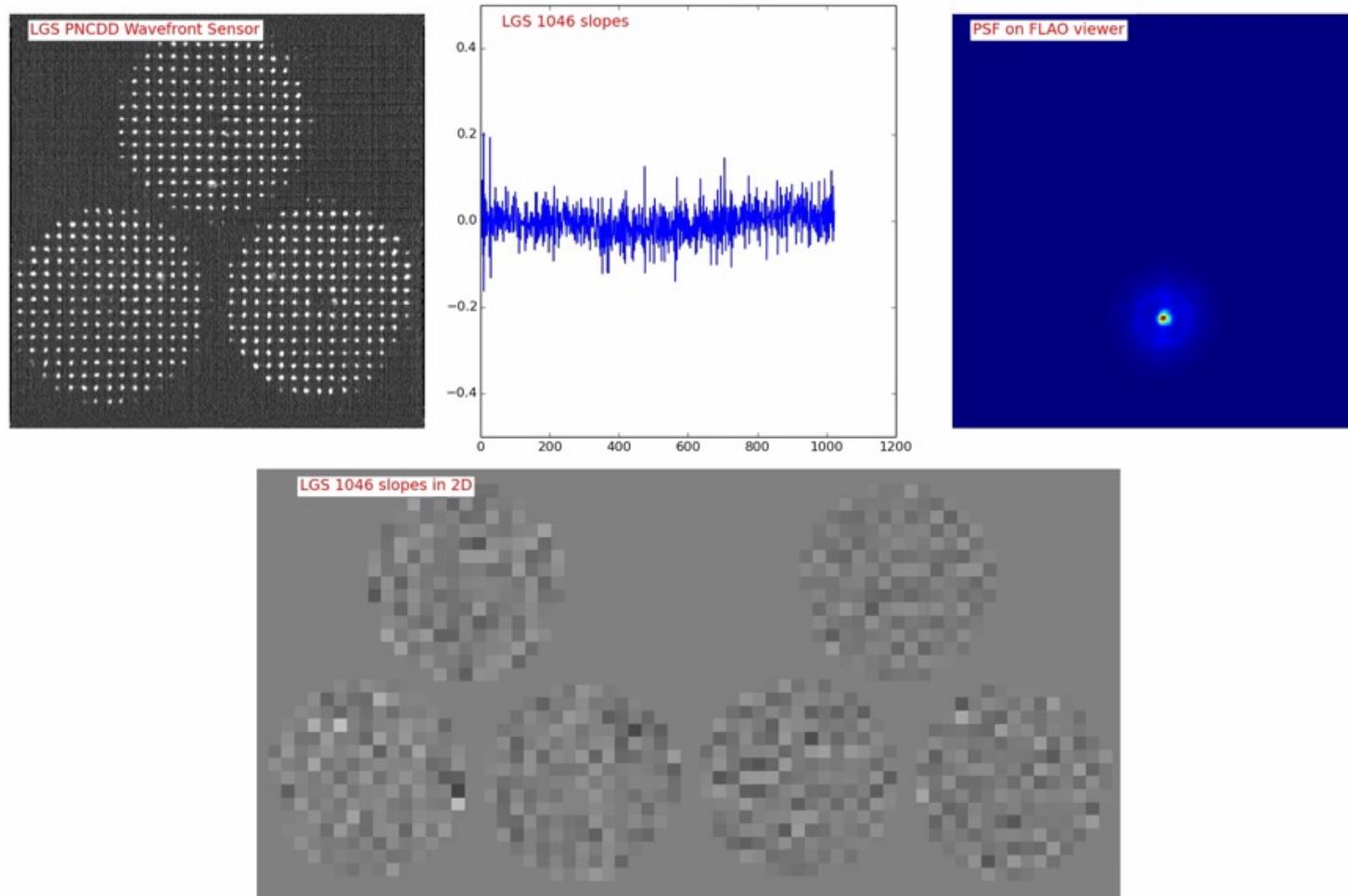
$$z^t = M2c m^t$$



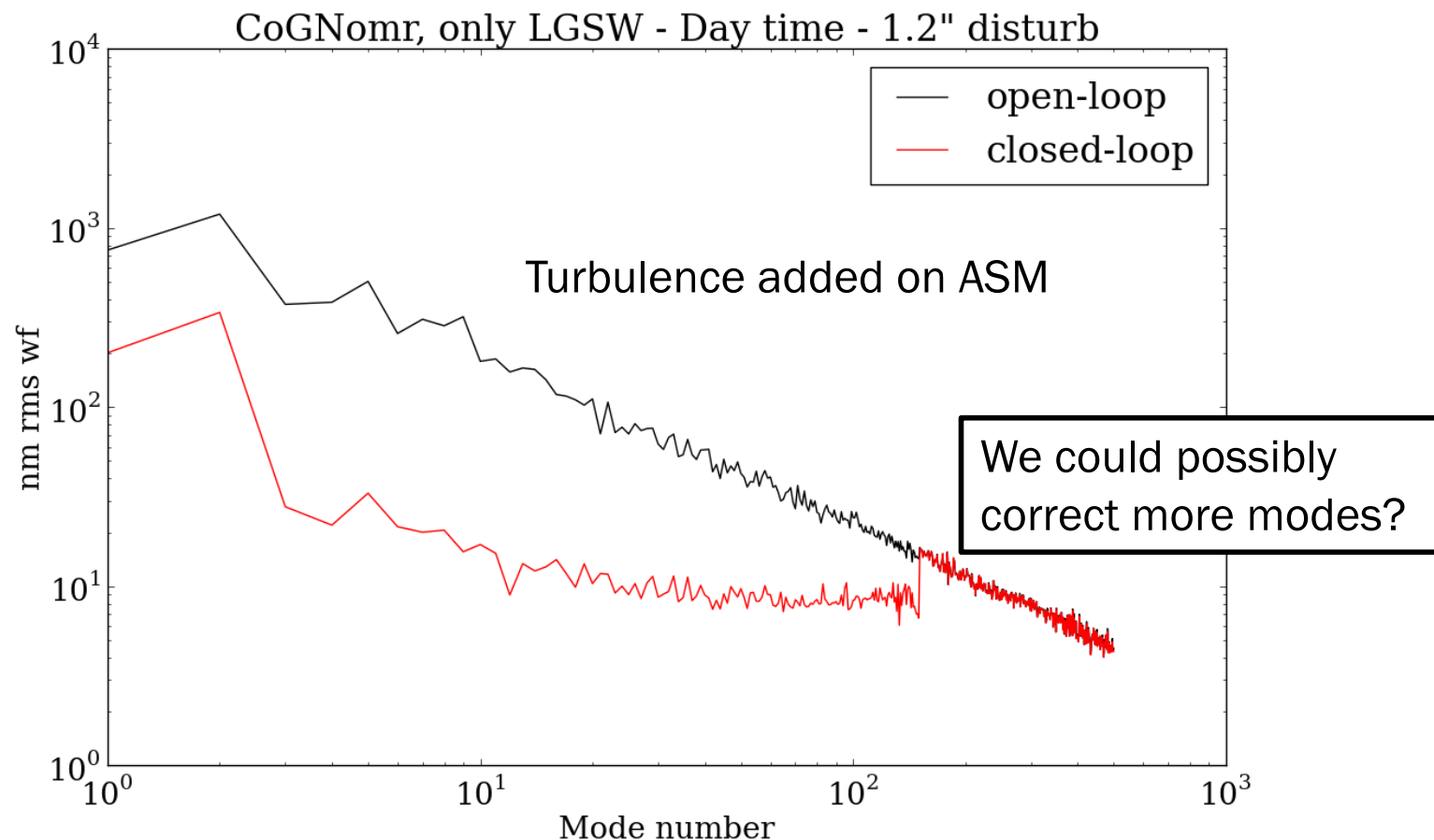
CLOSED-LOOP IN DAYTIME (1)



CLOSED-LOOP IN DAYTIME (2)



DAYTIME WITH ATMOSPHERIC DISTURBANCE

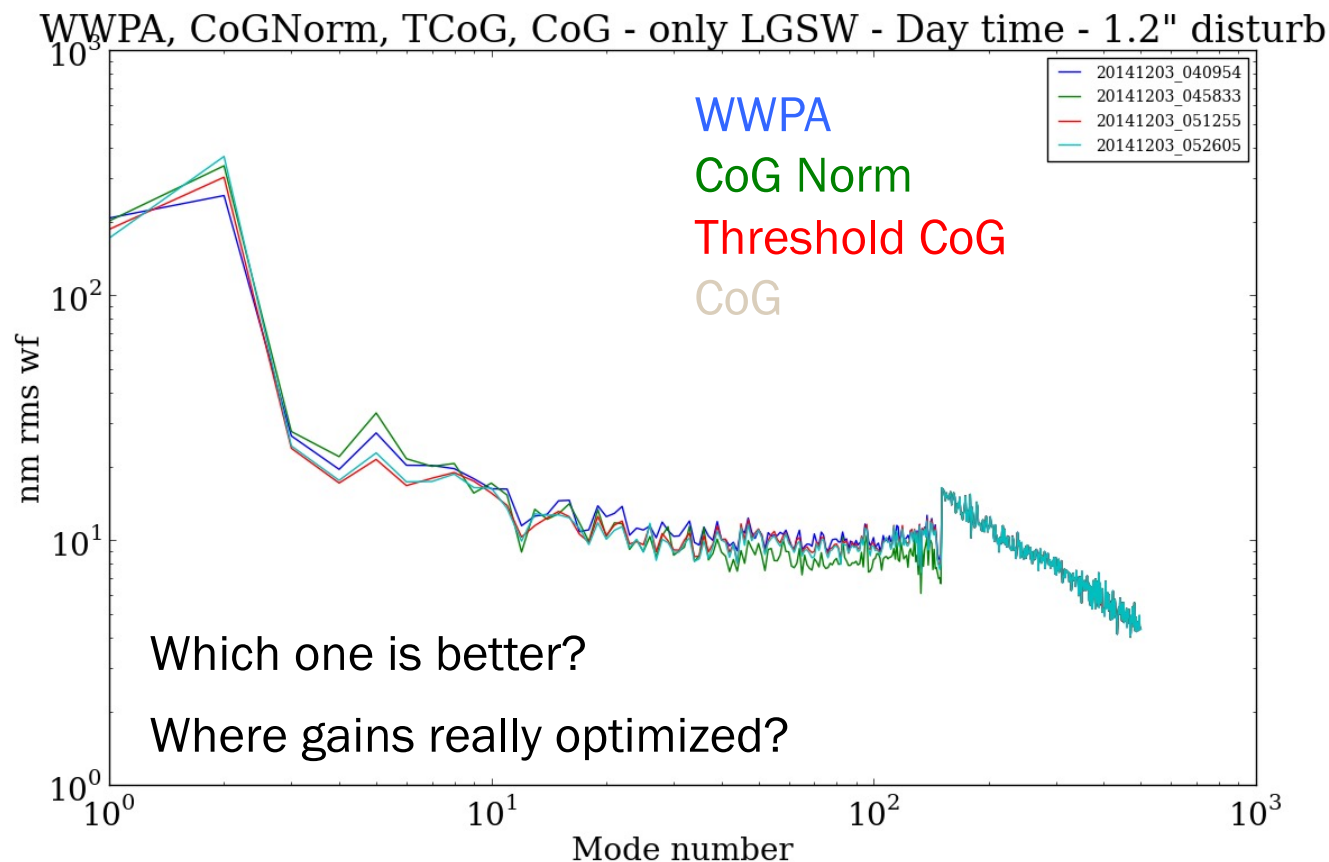


From wf rms $\sim 500\text{nm}$ $\rightarrow$ $\sim 100\text{nm}$

DAYTIME

FIRST TEST OF CENTROID ALGORITHMS

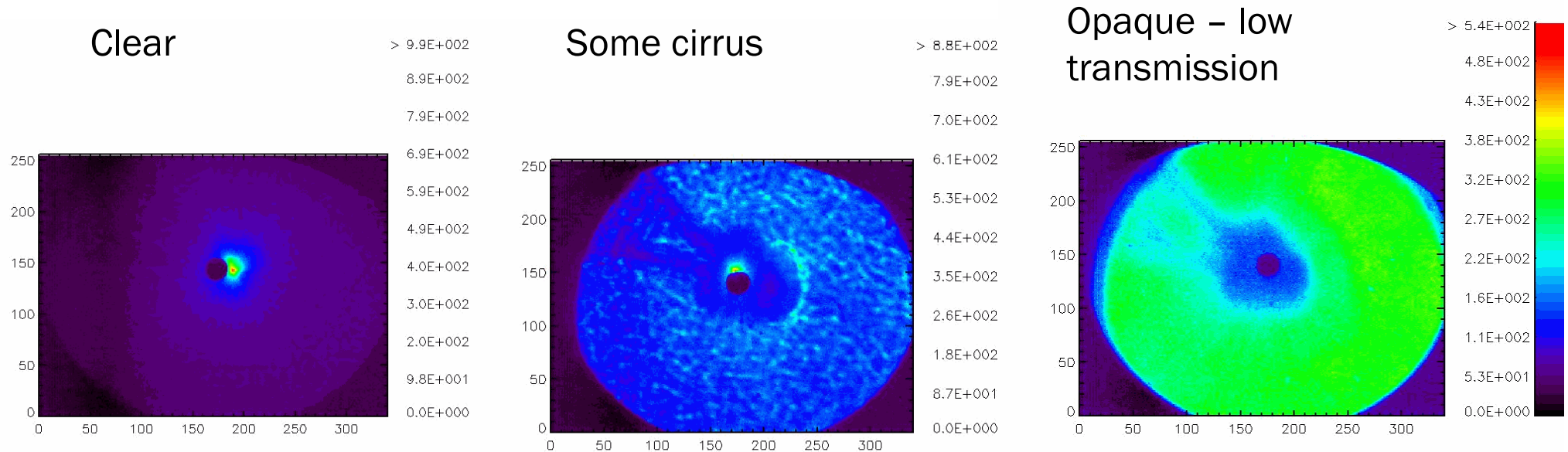
Generic formula :
$$x_a = \gamma_a K^{-1} \sum x_i W_i (I_i - I_{thres})^n$$



e.g.:

- WWPA (weighting by SNR):
 $n=1.5$
- CoG Norm: $K = \text{total flux}$
- TCoG : thres $\sim 3\text{sigma}$

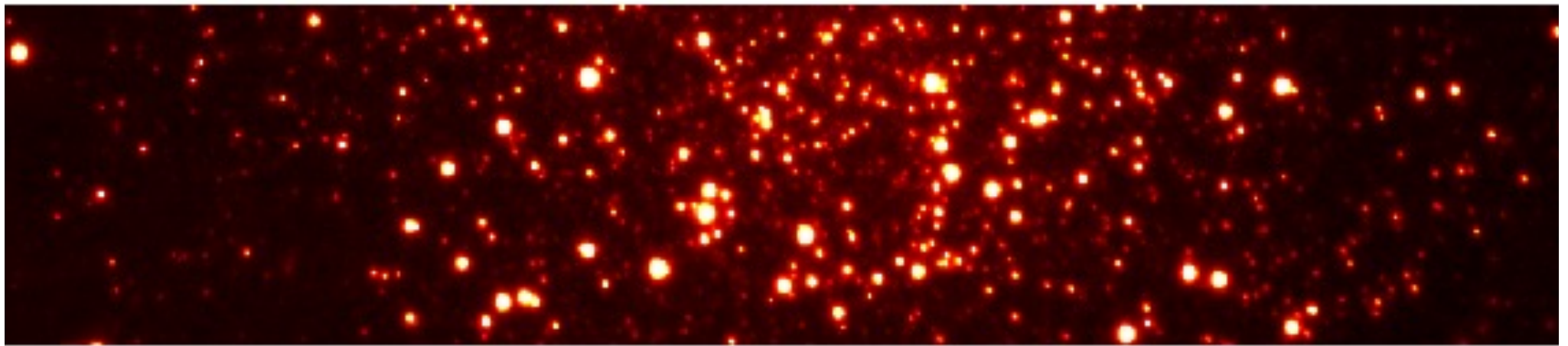
NIGHT: CLOUDS AND RETURN FLUX



- Clear sky :
~1500ph/subap/ms (for 2 μ s opening time = 300m)
- Clouds :
lower transmission, some are ok...

The high power laser (18W) allows us to work in thin cloud conditions.
Cloud monitoring with the patrol

First ARGOS-GLAO data: first steps in performances evaluation and PSF characterization



~2 arcmin

EXPERIMENTING ON THE FIRST ARGOS DATA

Total nights with GLAO data are:

- 2 nights in December 2014
- 1 nights in February 2015
- 2 nights in May 2015

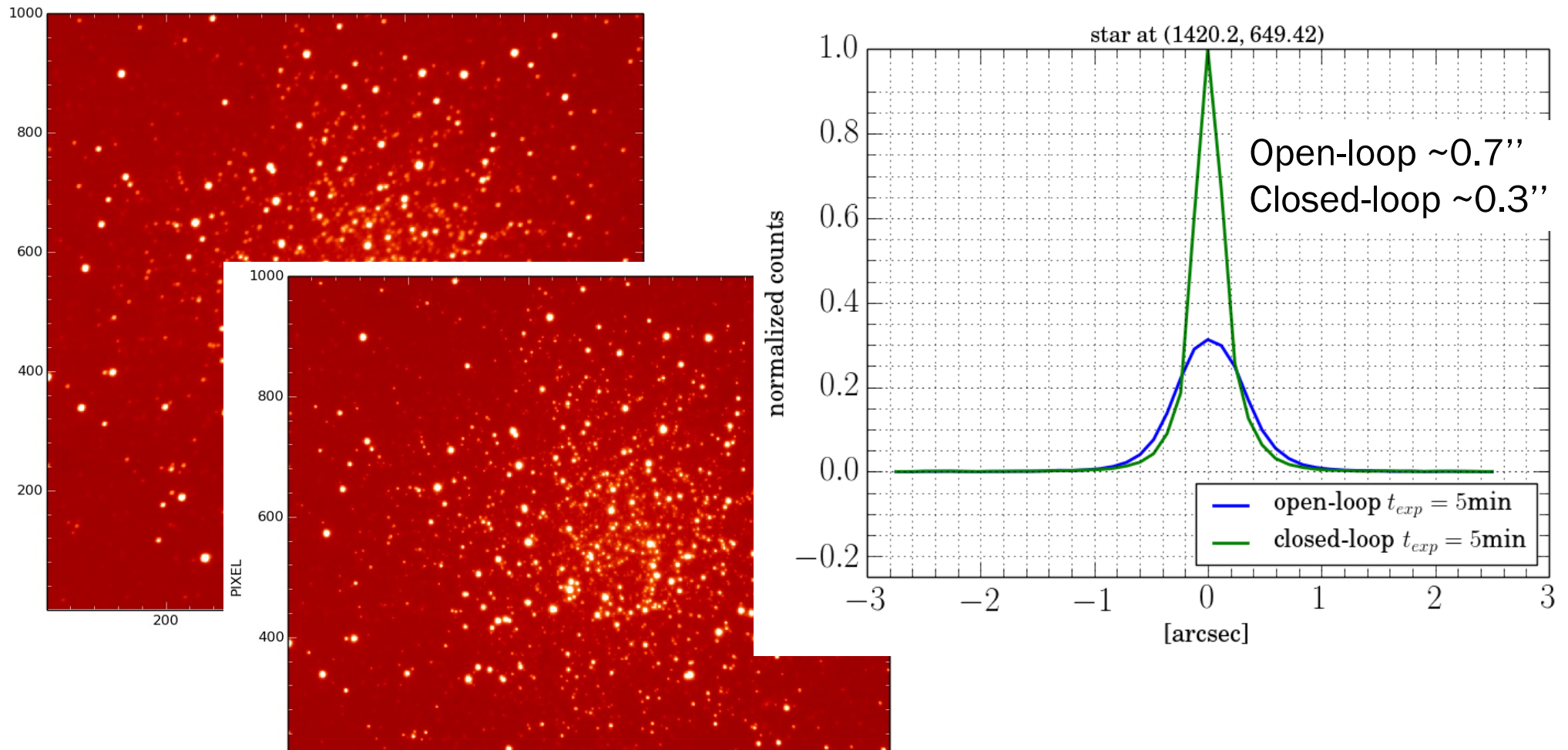
Dec. 2014: First-on sky observation : NGC2419

- FWHM improvement & uniformity
- PSF photometry with DAOPHOT:
 - PSF uniformity analysis &
crowding noise reduction estimation

May 2015: NGC6384: longer integration time,

- PSF uniformity and FWHM improvement

DEC14: FIRST GLAO CLOSED-LOOP ON SKY



First GLAO closed-loop on-sky in Nov.-Dec. 2014, on NGC2419

$\sim 15\text{min}$ H-band closed-loop over two nights with various performances

$\sim 5\text{min}$ H-band open-loop for comparison

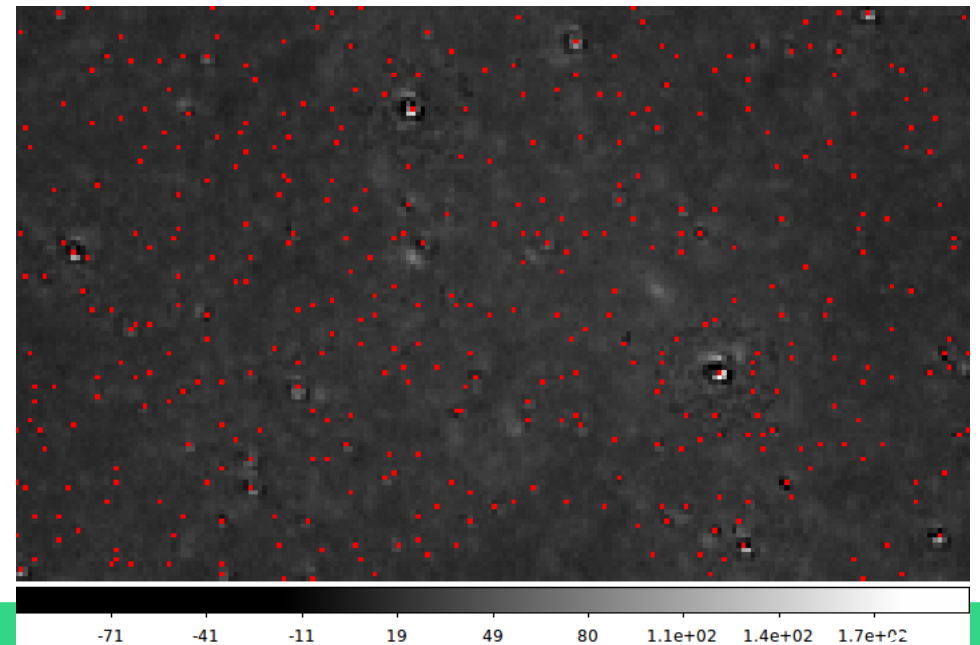
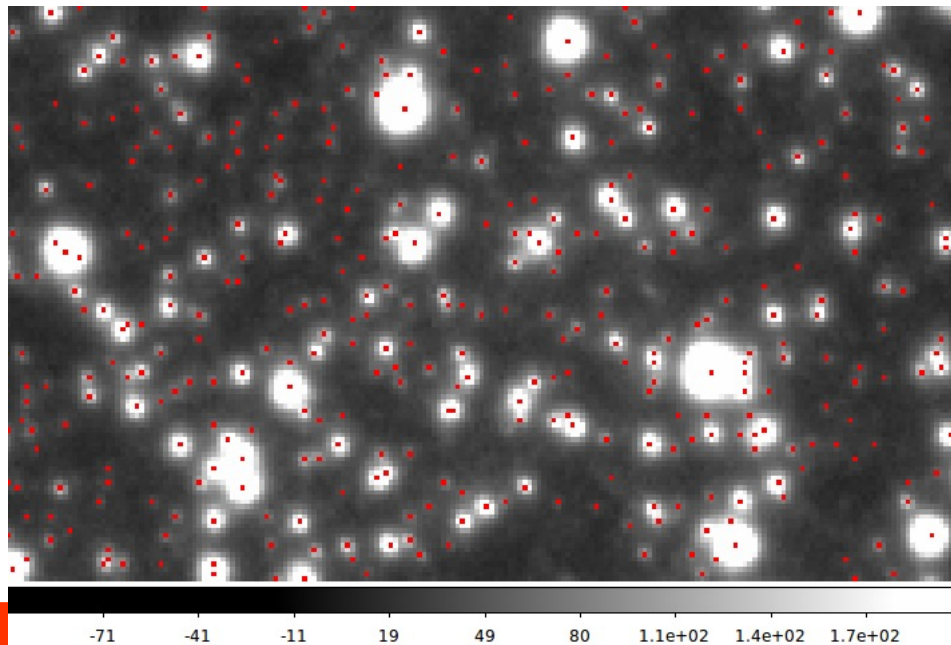
FIRST GLAO PERFORMANCE EVALUATION: PSF MODEL

Using DAOPHOT:

- Analytical model + up to quadratic empirical correction
- 20-30 PSF stars to generate the PSF model for the 4'x4'
- Deal with close neighbors

Pros:

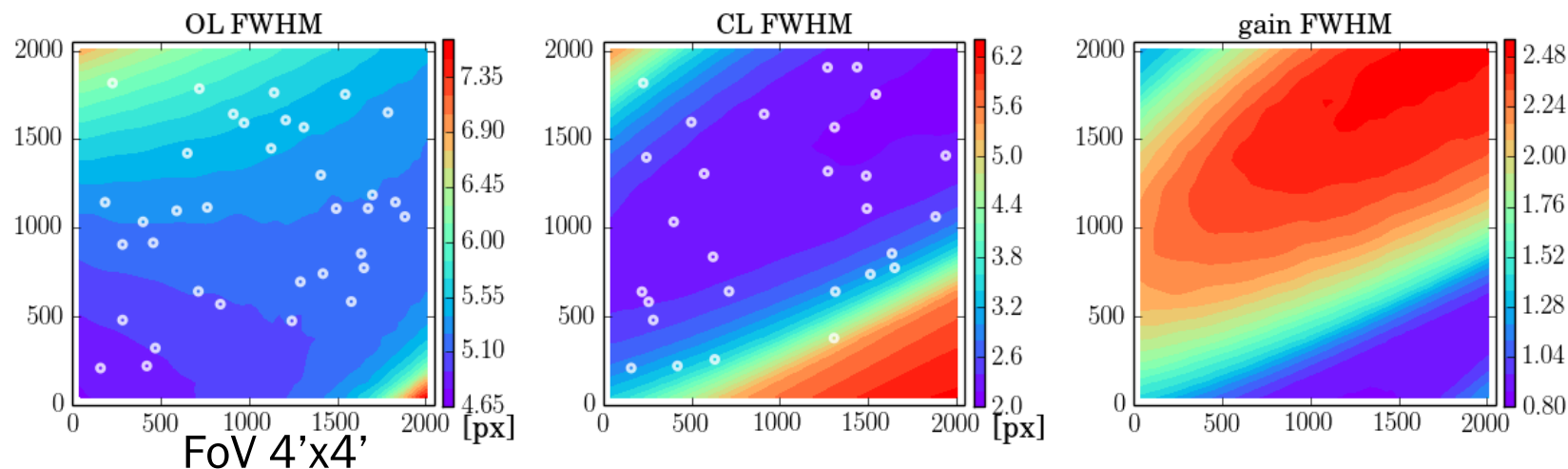
- Adapted tool for sufficiently well-behaved PSF, like GLAO ones
- A single model for the full field



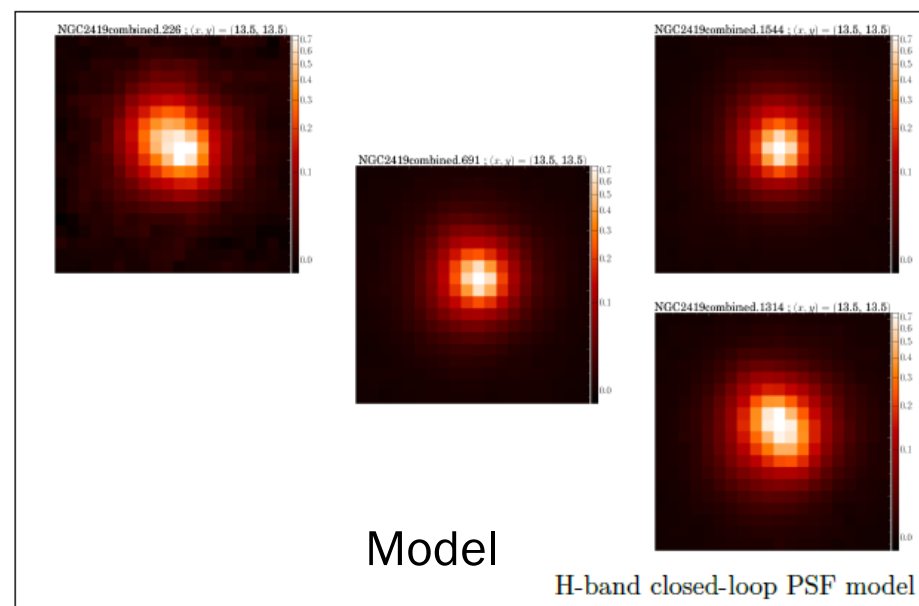
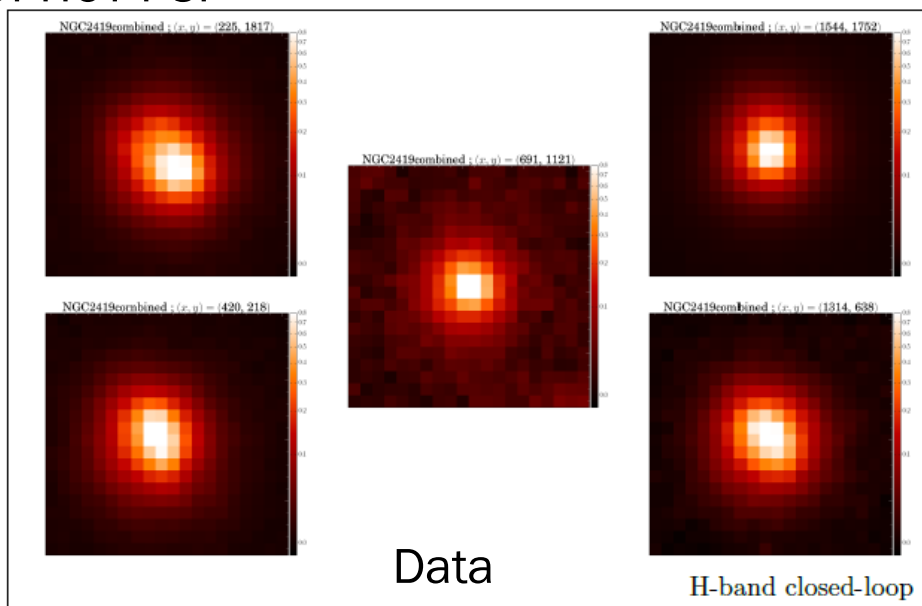
DEC14: FIRST GLAO PERFORMANCE

PSF

Direct radial
FWHM



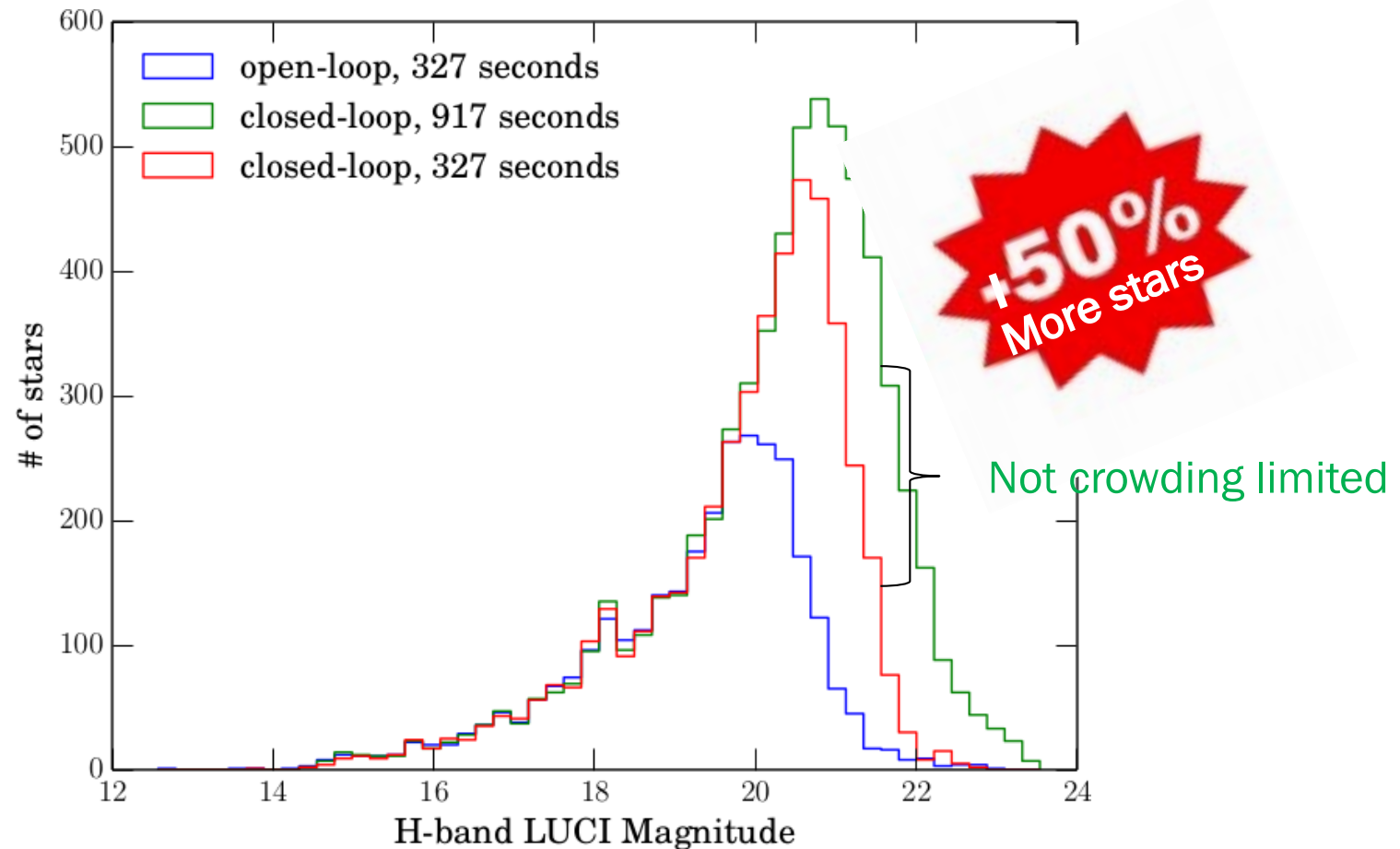
DAOPHOT PSF



DEC14: FIRST GLAO PERFORMANCE STAR COUNTS

From the H-band observation:

Star detected: (OL 327sec, CL 917 sec, CL 327 sec) : 3072, 6326, 4726

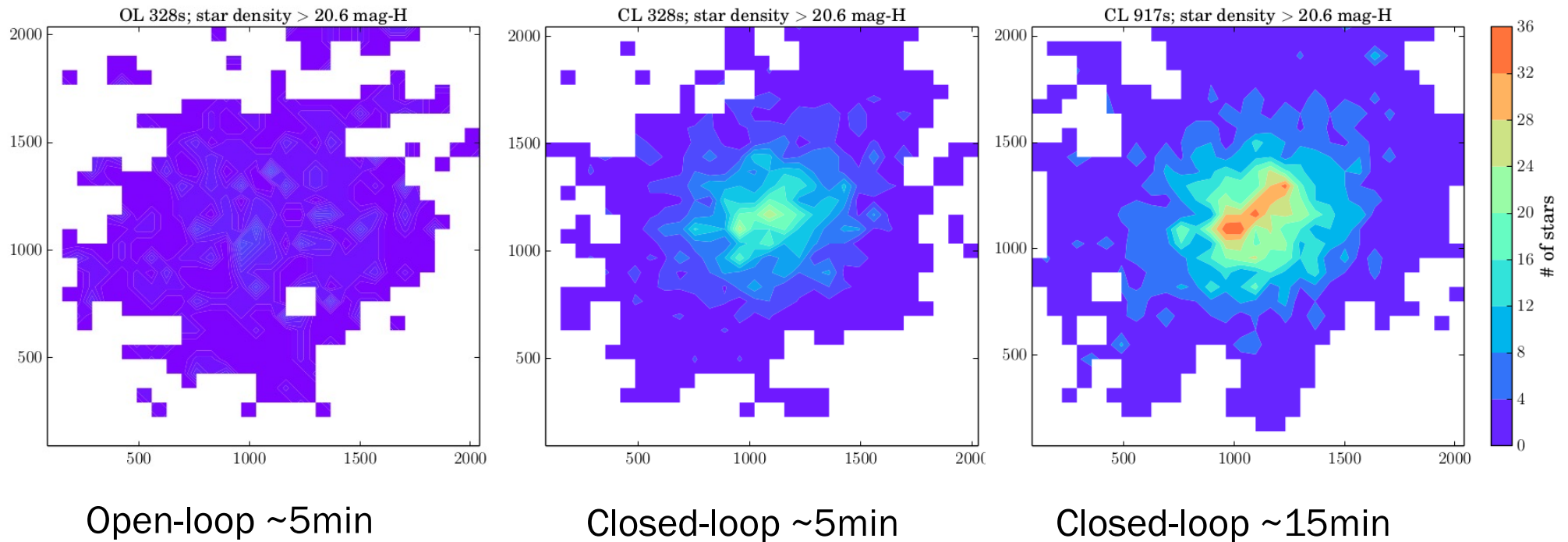


DEC14: FIRST GLAO PERFORMANCE

CROWDING

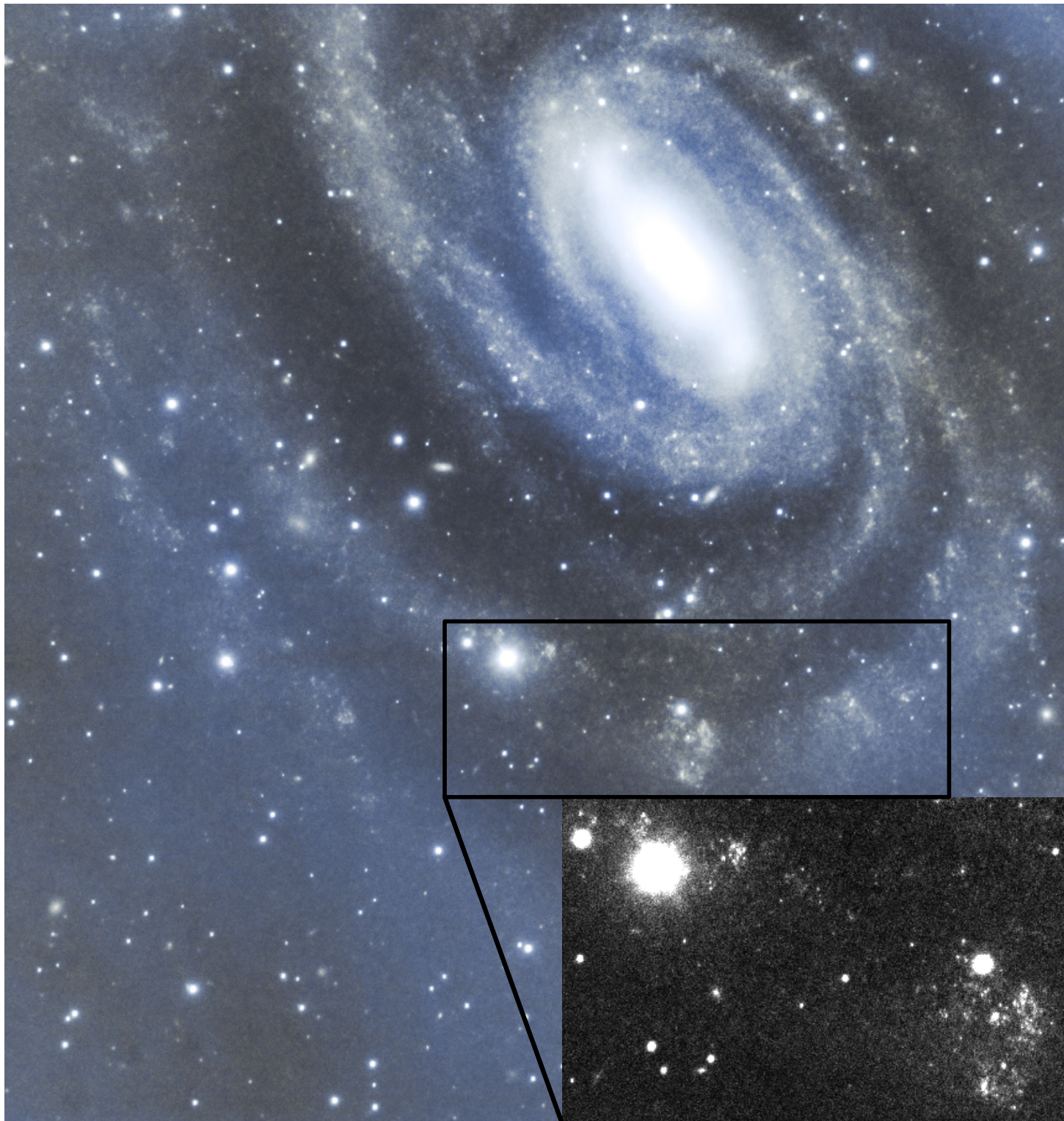
A tentative metric for crowding noise reduction:

Star density of stars fainter than 20.6 mag-H (peak of * distri of CL 5min)



Star density is ≥ 5 x larger in the cluster center:

- Gain in SNR
- Reduction of crowding noise



MAY 2015:

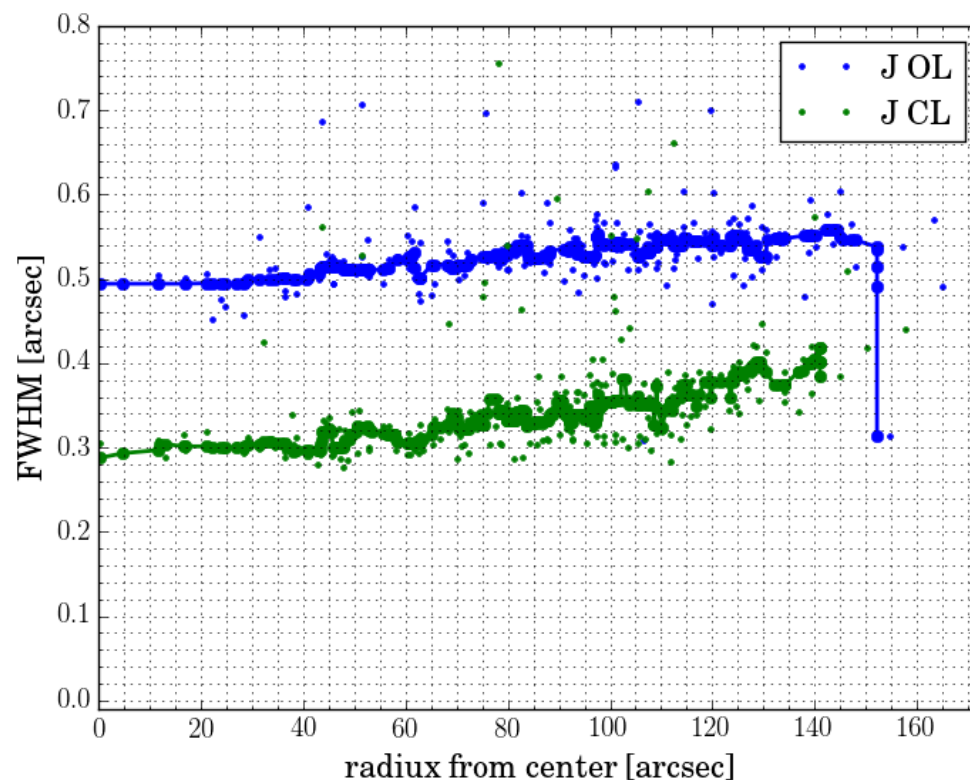
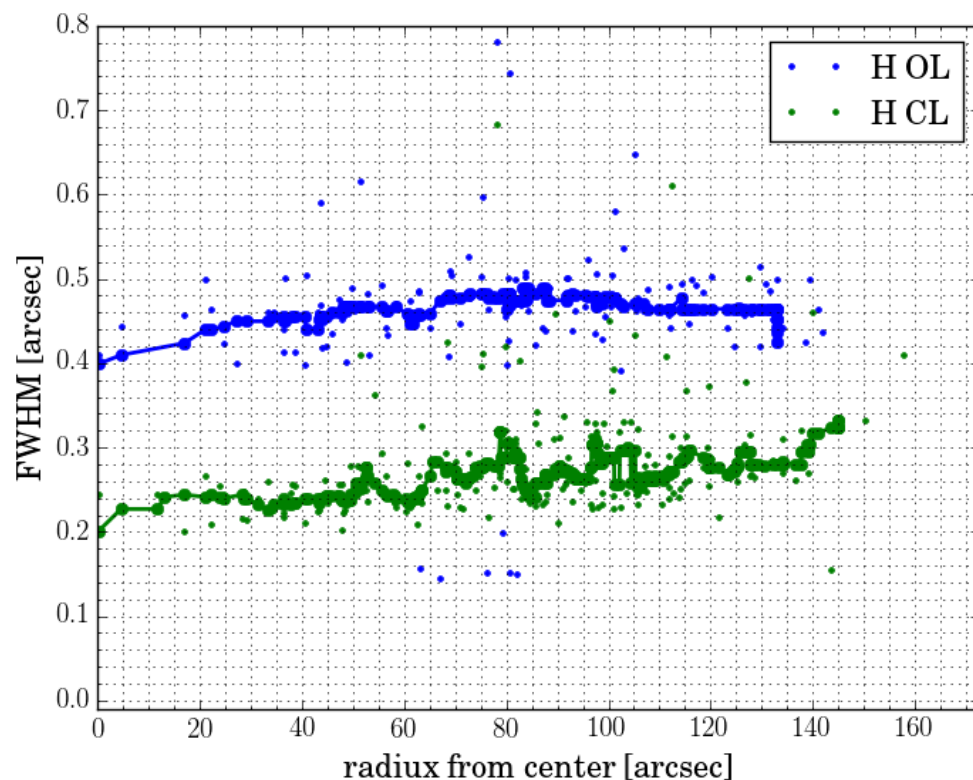
NGC6384

H-band: ~30min

J-band : ~30min

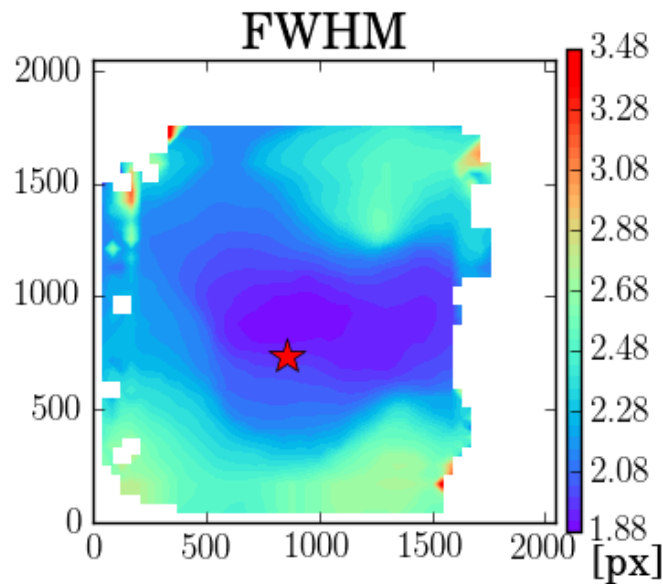
MAY15: PSF FWHM DECREASE & UNIFORMITY

- Automatic source detection &
- Elliptical Moffat 2D fit (fair description of the PSF)

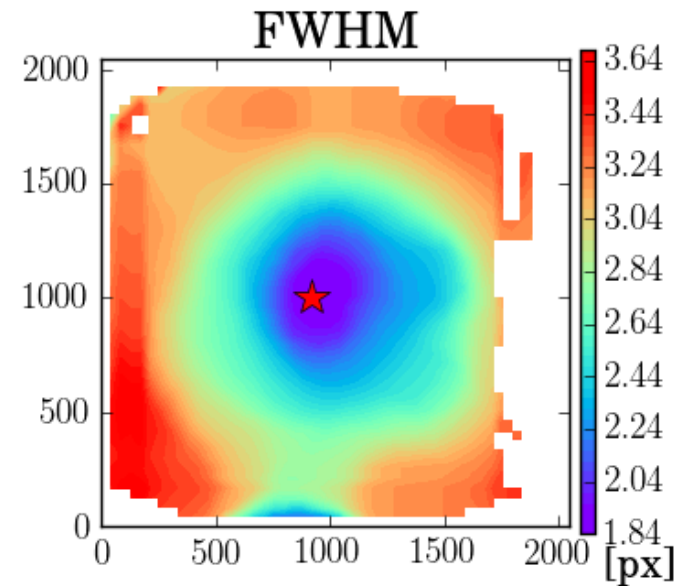


MAY15: PSF FWHM DECREASE & UNIFORMITY

H-band ARGOS

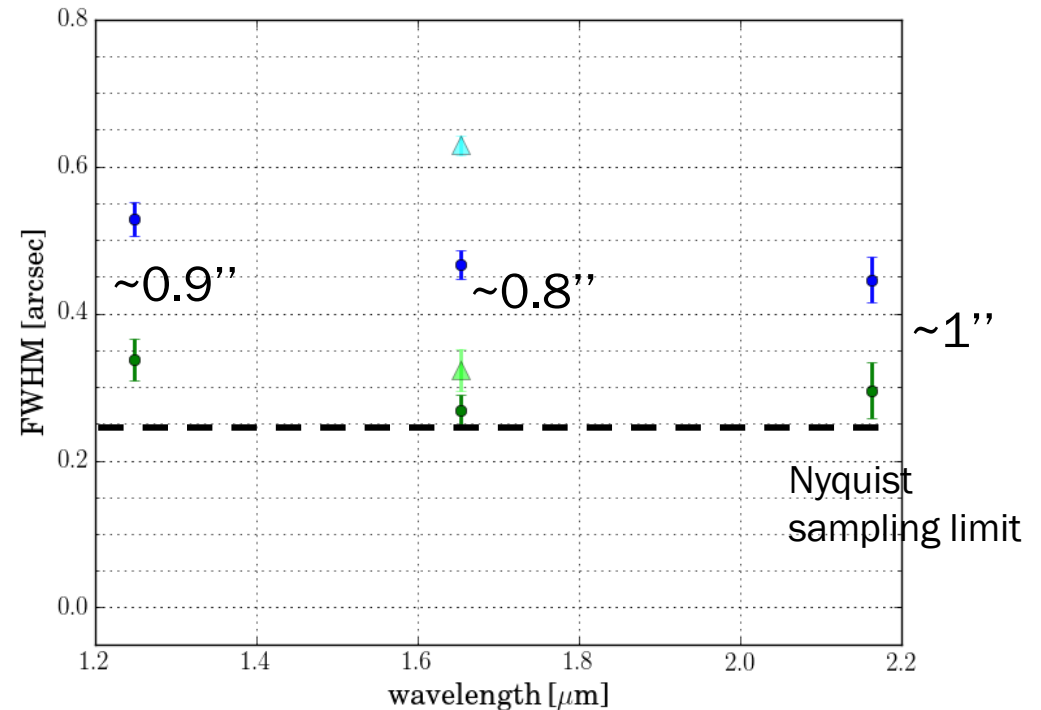
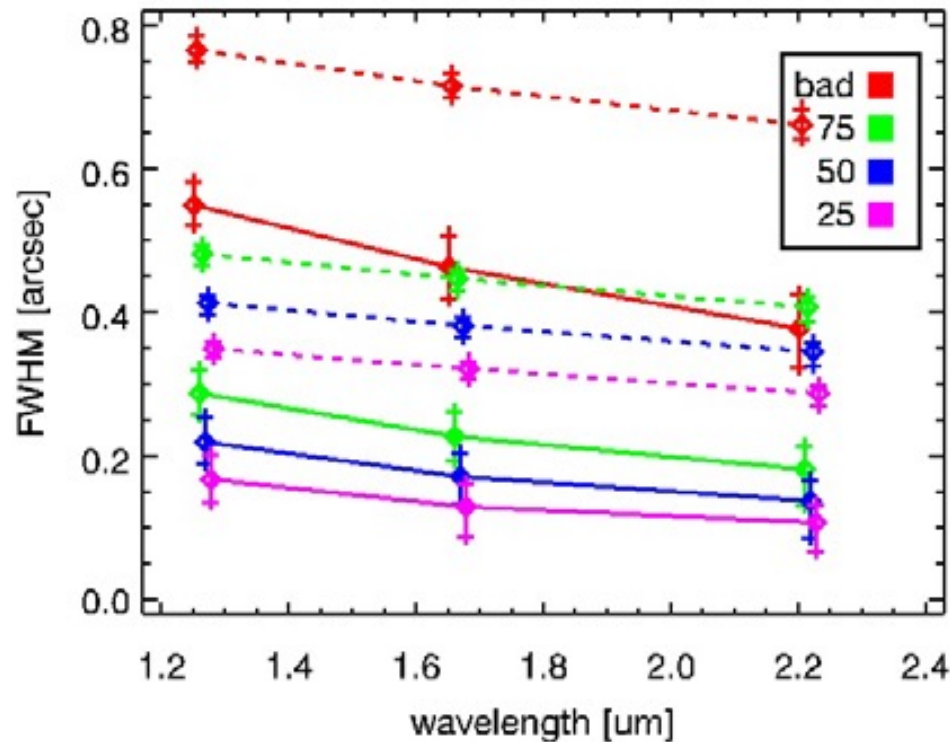


H-band FLAO



Clear anisoplanatism

MAY15: FIRST COMPARISON TO SIMULATION



- Gain of 1.5-2.5
- Many unknowns (ground-layer contribution, telescope/instrument optical quality, ARGOS performances)

CONCLUSIONS

- ARGOS **hardware** is converging (SX is not complete yet)
- **Software**, AO operation, and detailed understanding still requires a lot of work
- We are reaching a factor ~ 2 of improvement in **FWHM** over the 4'x4' FoV
- **Uniformity** seems good, and no clear sign of anisoplanatism
- Future **agenda** is:
 - June: DX observation test, SX installation
 - August: SX TT and LGS-WFS installation
 - October: SX calibration & closed-loop test, together with DX
 - December : SX & DX on-sky

THANK YOU



... AND FOR MORE STARS SUBSCRIBE ON *FACEBOOK ARGOS*

26/5/2015

MARSEILLE 2015

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