Getting ready for GeMS 2.0: a workhorse AO facility

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And all **GeMS team**

1: Gemini Observatory
2: Max Planck Institut for Extraterrestrische Physik
3: Laboratoire d'Astrophysique de Marseille
4: Australian National University
5: Flat Wavefront

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

AO4ELT5, Tenerife, Canary Islands, Spain, 2017/06/26

GeMS

Outline

- GeMS instrument
  - ► Brief presentation & Status
  - ► Performance achieved with GeMS
- GeMS ongoing upgrades
  - ► New laser integration: TOPTICA
  - ► New NGSWFS integration: NGS2
  - ► New diffractive mask for astrometric calibrations
- Conclusions

Introduction to GeMS

Gemini South Observatory
Cerro Pachón, Chile
2700m altitude
30.24073° S 70.73659° W

D=8.19m
Cassegrain reflector

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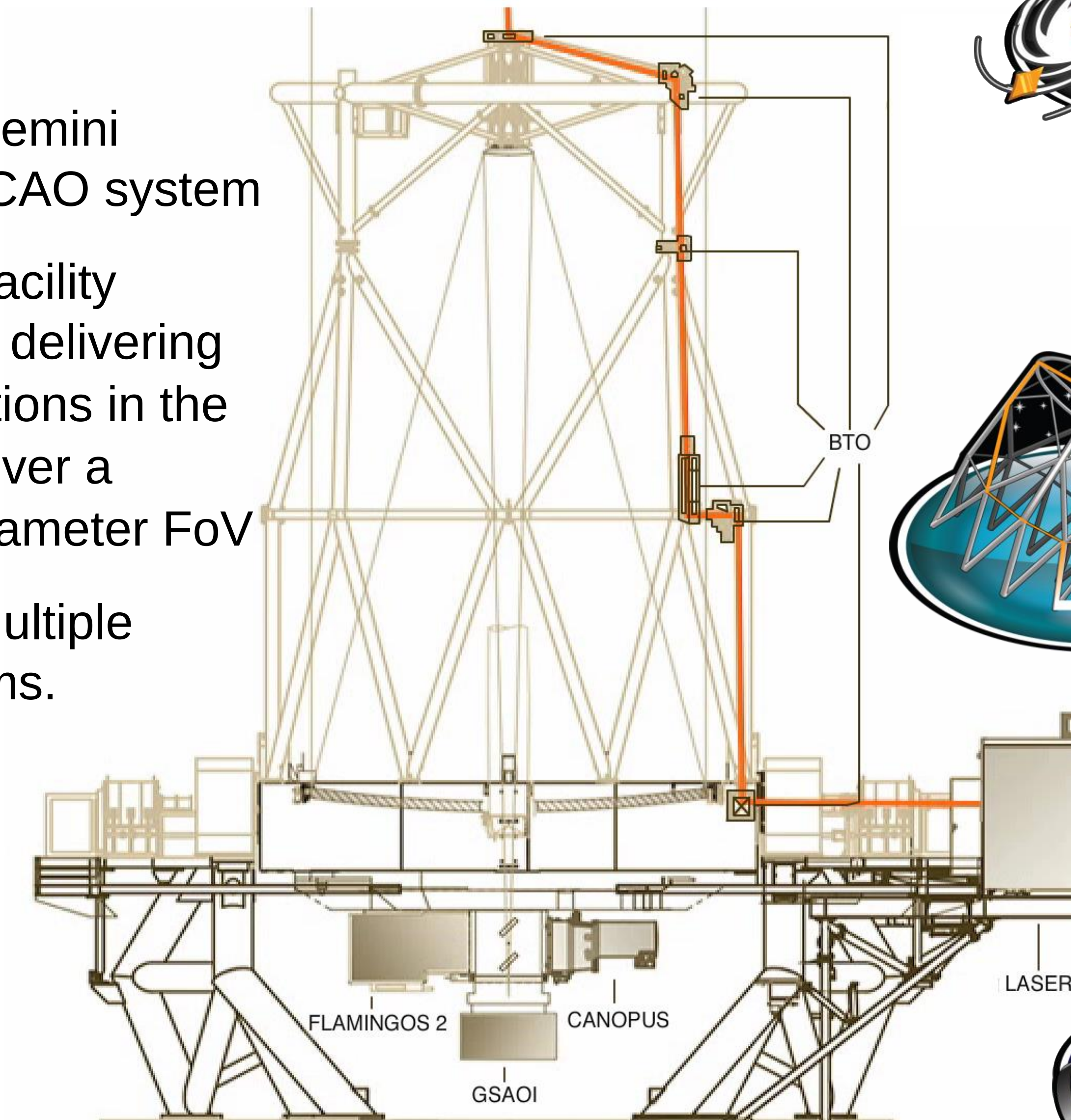
Introduction to GeMS

GeMS Intro.

GeMS = Gemini (South) MCAO system

GeMS = Facility instrument delivering AO corrections in the NIR, and over a 2arcmin diameter FoV

GeMS = Multiple sub-systems.

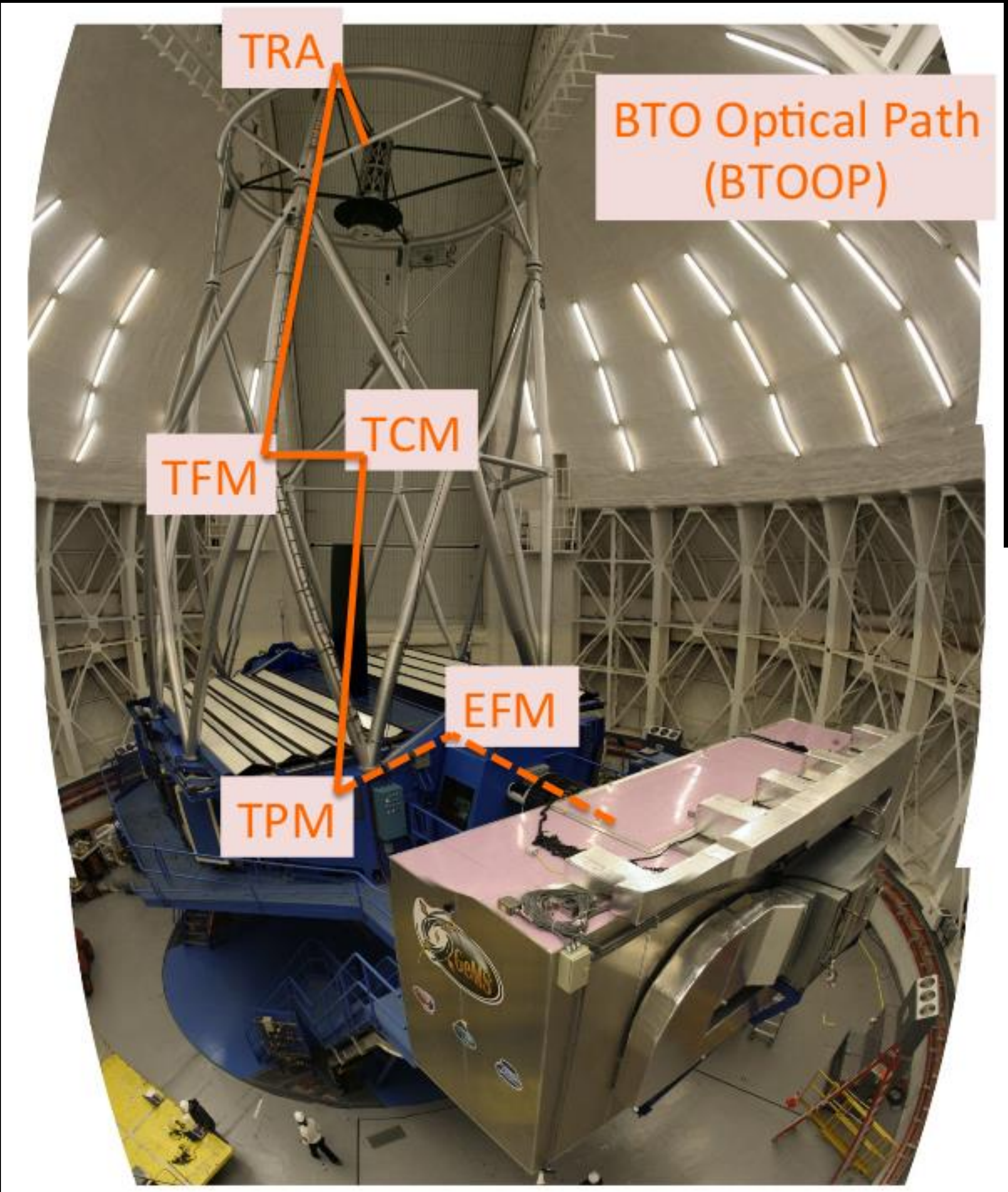


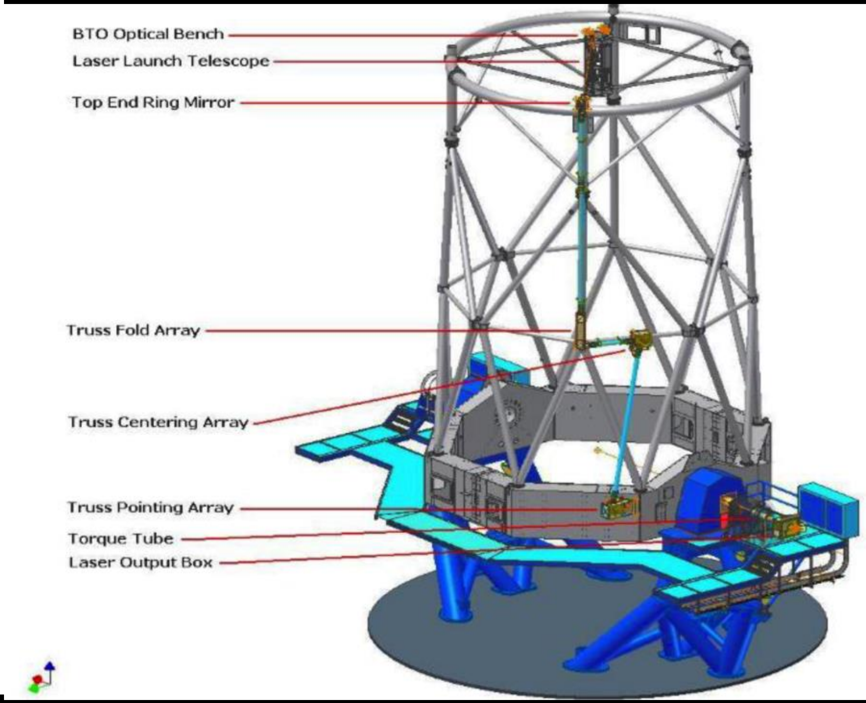
GeMS

BTO

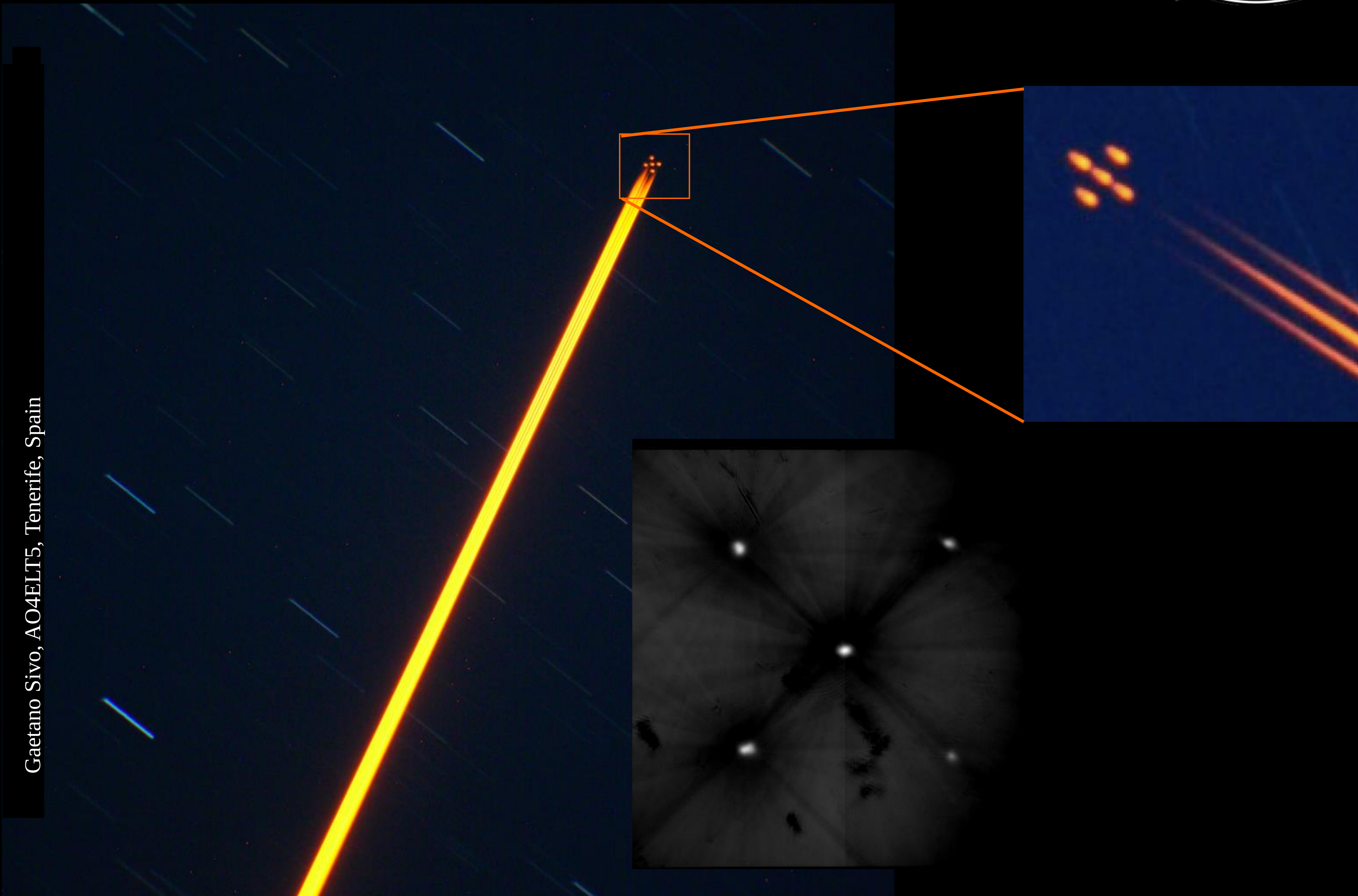
CANOPUS

Beam Transfer Optics (BTO)





Asterism on-sky



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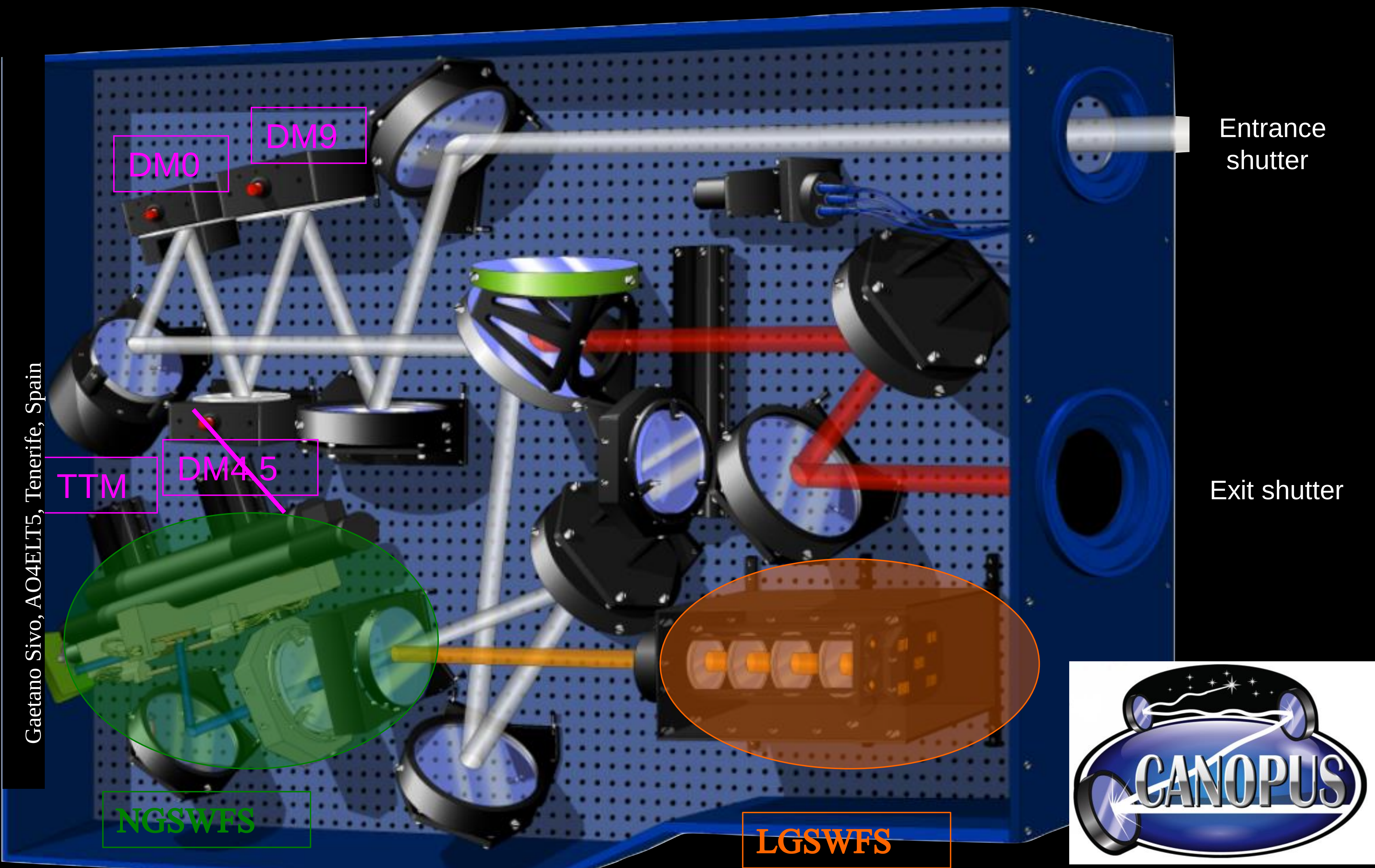
Canopus



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Science instruments

GSAOI
IR Imager 4k
20 mas/px

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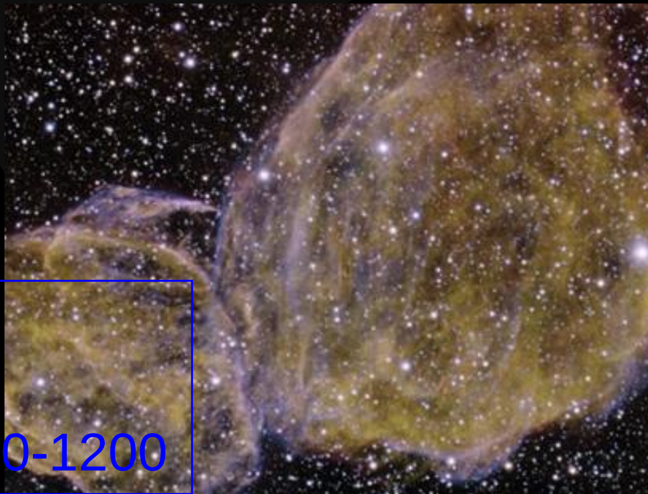
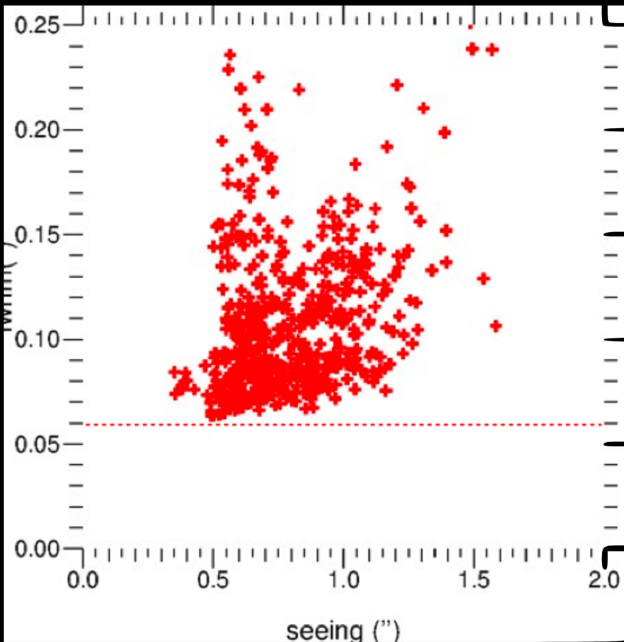
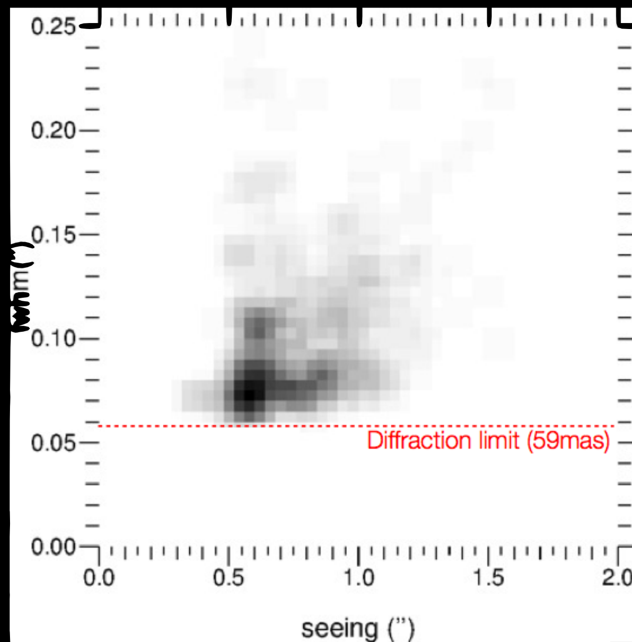
FLAMINGOS 2
MOS IR
R = 1200-3000
Slit 1-8px



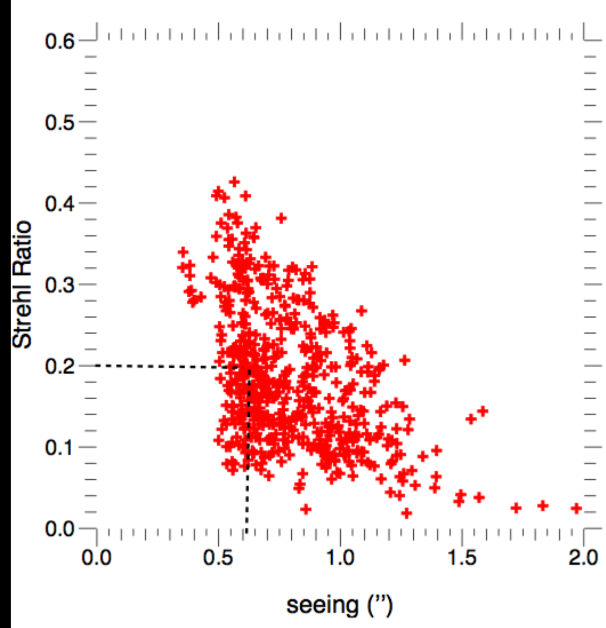
GMOS-S
MOS+IFU vis
R=4440-8800 R=150-1200

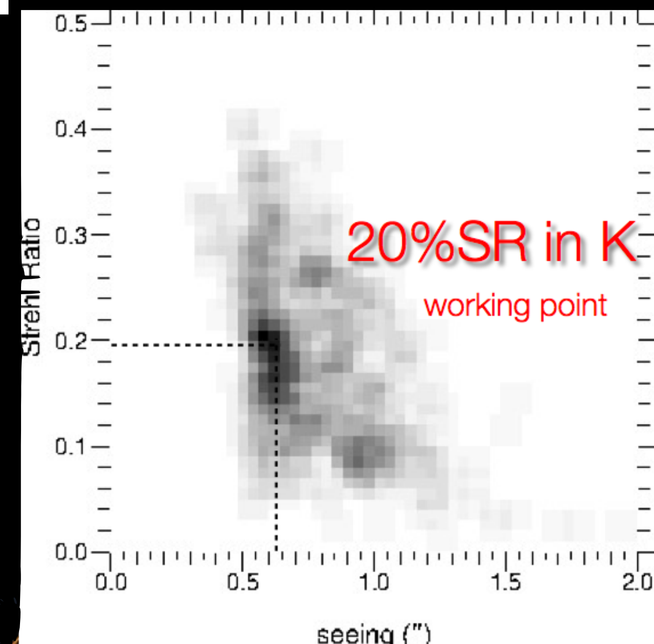
Overall performance [12-13]



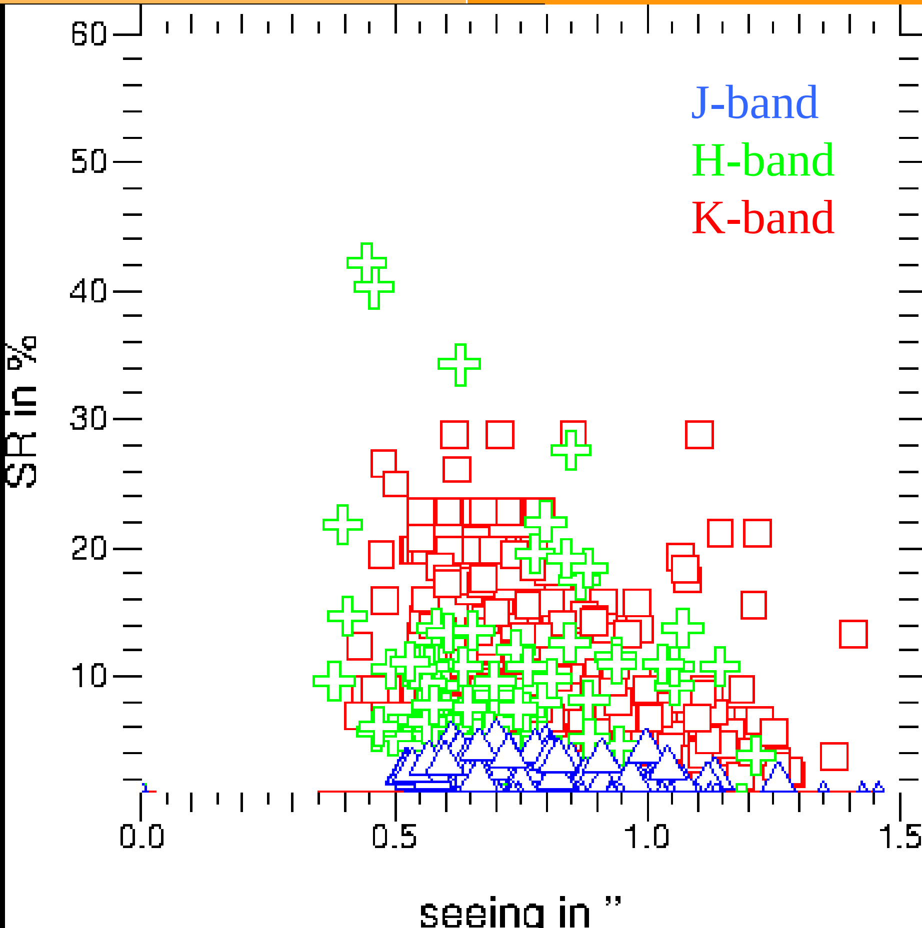


1 DM missing
LGS loop @ [100-600] Hz
800 Hz max
NGS up to mag = 15.5





Performance from SPIE 2016 to AO4ELT 2017



1 DM missing
LGS loop @ [100-600] Hz
800 Hz max
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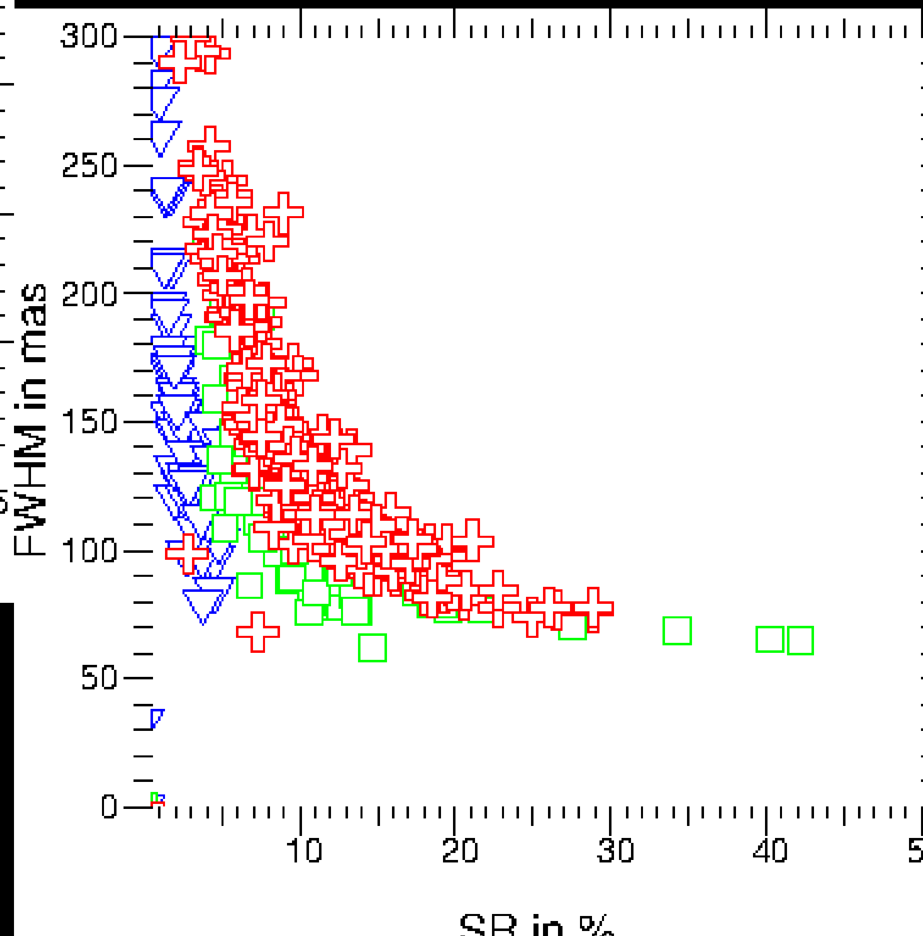
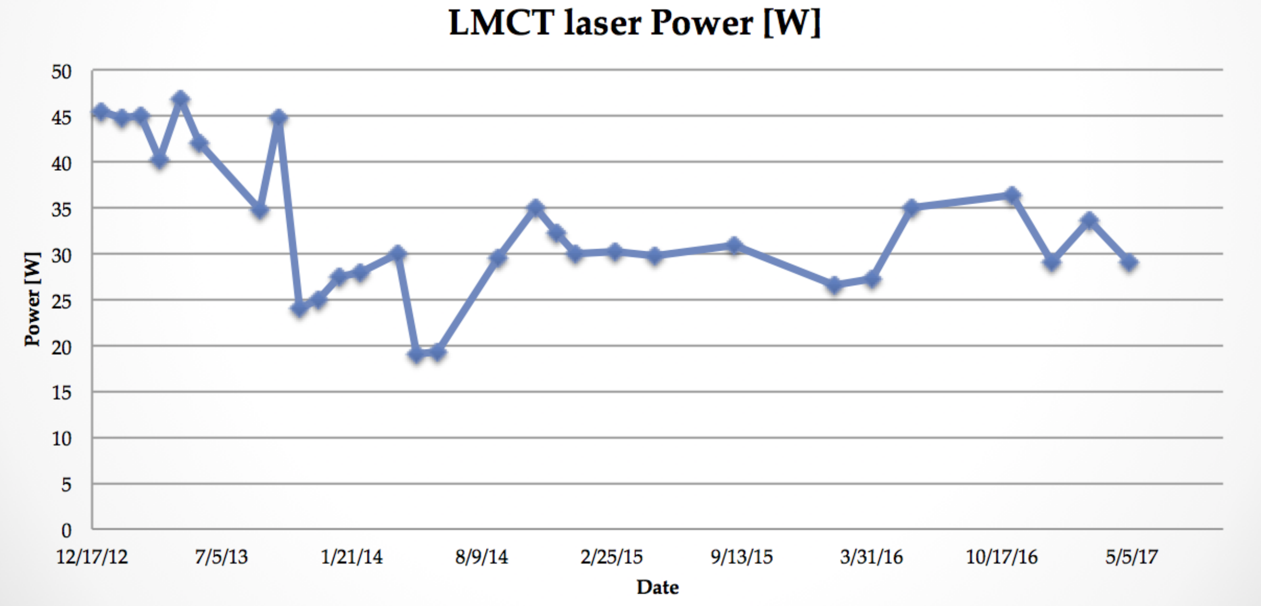


But still
many science can be done !

Multi-conjugate adaptive optics images of the molecular hydrogen in the planetary nebula NGC 2346 obtained with GSAOI [P2050], Arturo Manchado
Correction of distortions for wide field adaptics optics images [P3060], Anaïs Bernard

LMCT status

- Operating at GS from 2011
- Demanding in terms of FTE hours (40-80 hrs before each laser run + several maintenance a year (~3))
- Services required:
  - Coolant: 4.7 gl/min (~18 l/min)
  - Compressed air: 66 psi
  - Power consumption: 8 KW
- Sensitive to misalignment and aging issues.



New Laser

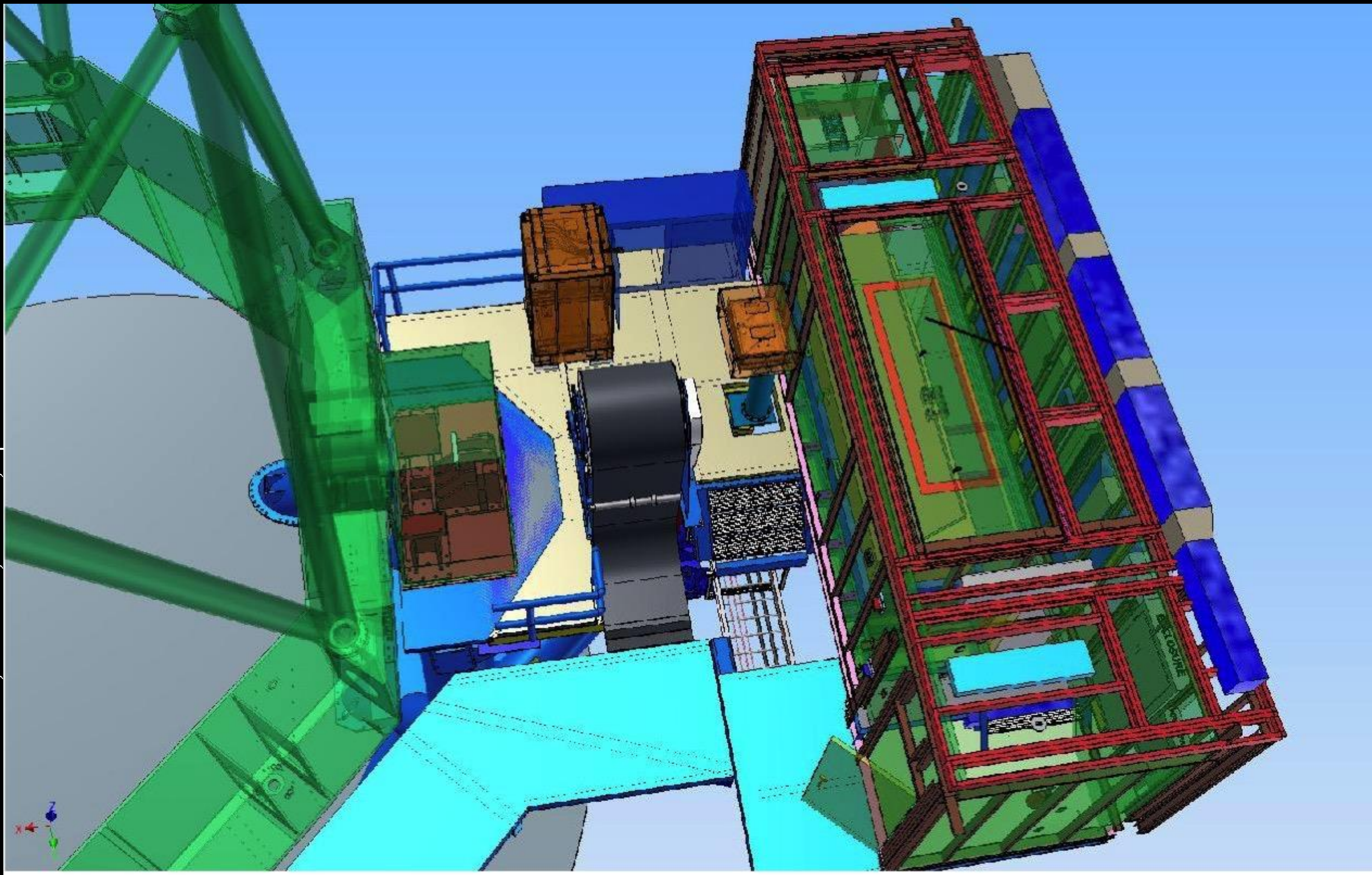
- Gemini decided to call for quotes in order to replace the current laser.
- Main requirements:
  - Minimal photon return: $5x10^6$ photons m^{-2}
  - Central wavelength: 589.159nm with repumping option (589.157nm)
  - Stability better than 100 MHz over 14 hours (if pure D2a CW)
  - Beam quality: M2 < 1.4
  - Demonstrated robustness (long terms operations without power drops)
  - Operational at 2700m in altitude
  - Total mass shall not exceed 1000kg

Winner: TOPTICA

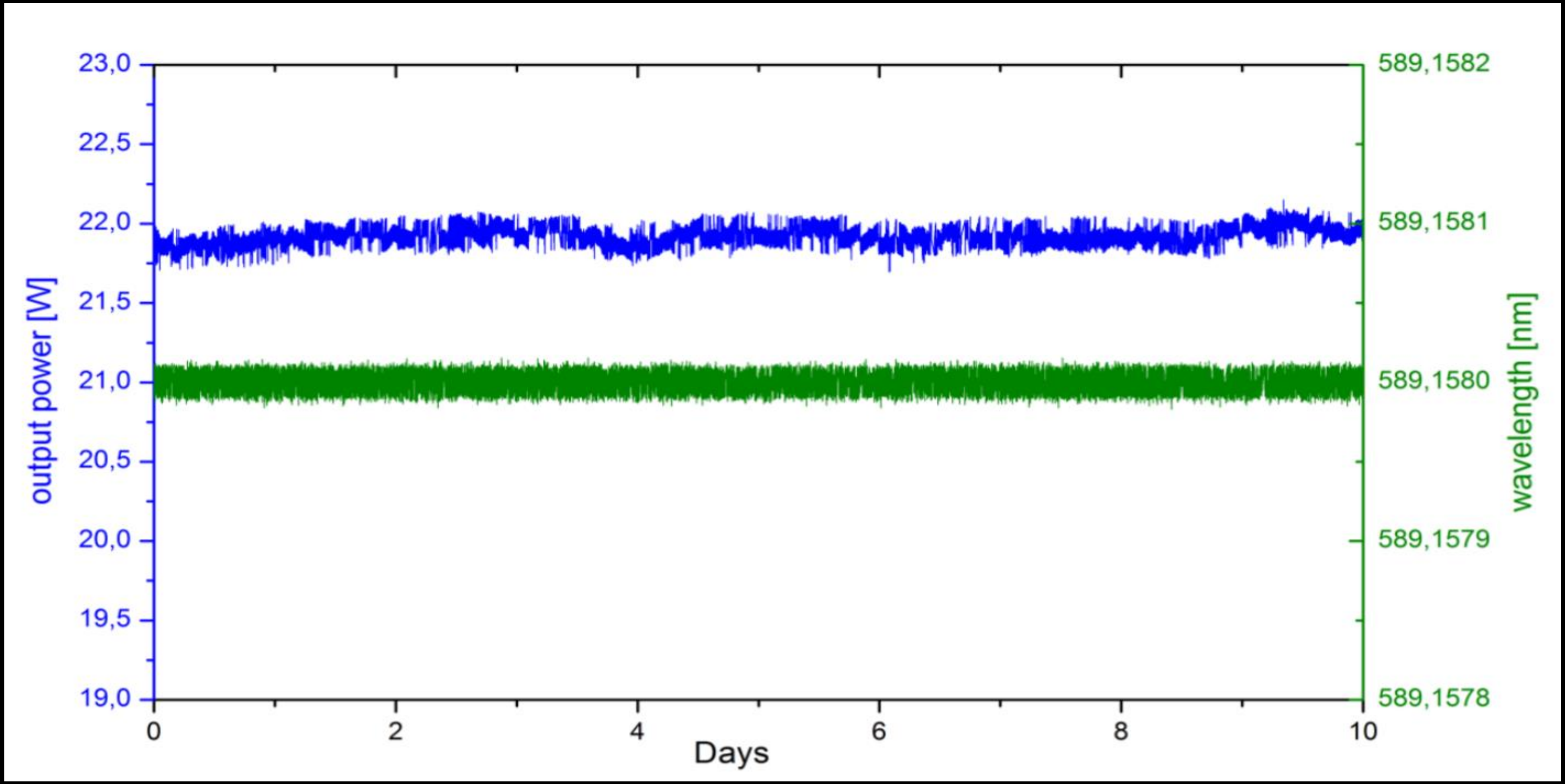
SodiumStar 20/2 Laser Specifications:

- Main Optical Specs:
  - **Laser output power ≥ 20 W**
  - **Laser wavelength 589.159 nm**
  - Optical beam diameter (4σ) 3 mm
  - Beam quality (rms wavefront error) < 70 nm
  - Beam pointing rms < 160 μrad
  - Beam shift rms < 50 μm
  - Polarization extinction ratio > 100 : 1
- Cooling system requirements:
  - Coolant temperature 15 ° C
  - Temperature stability ± 0.75 K
  - Coolant flow rate < 5 l/min
- General Specifications
  - Electrical power consumption < 2 kW
  - Operating temperature range -10 .. 25 ° C
  - Operating altitude (above sea level) < 4300 m
  - Dimensions Laser Head including insulation cover 93 x 73 x 44 cm3
  - Weight Laser Head 80 kg
  - Dimensions Electronics Cabinet 93 x 91 x 173 cm3
  - Weight Electronics Cabinet 600 kg

Location on LSE



Toptica output power/λ stability



Any changes in overall GeMS design?

YES

- As it is needed to continue with the operation of the LMCT laser, it was decided to prepare a beam injector that does not interfere the LMCT beam path and use a linear stage to insert a mirror when the Toptica laser needs to be used.

Beam Injector Module

- High-power attenuator based on polarizing optics
  - Use of Half wave plate (HWP)
  - With a Thin Film plate Polarizer (TFP)
  - Or a Polarizing Beam Splitter cube (PBS)

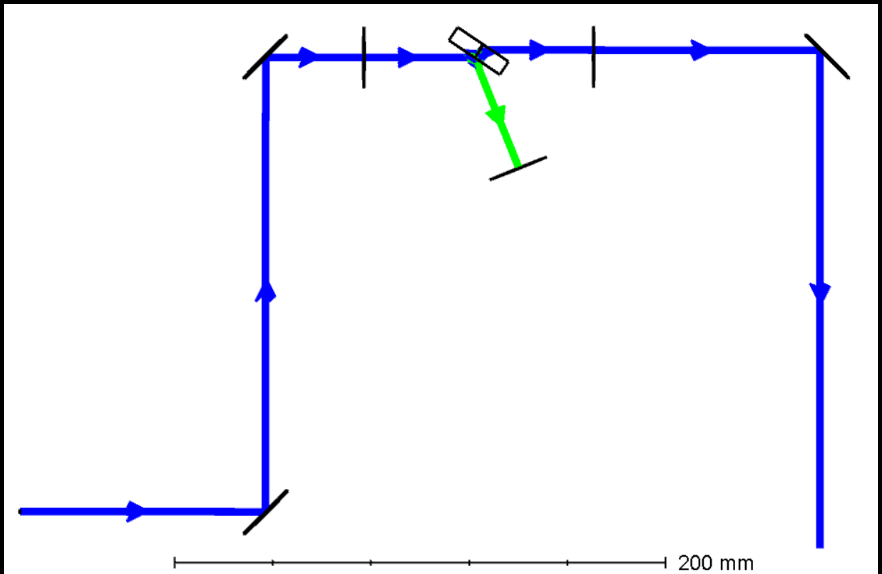
- Advantages of TFP compared to PBS
  1. High damage threshold (MW/cm^2)
  2. Low wavefront distortion
  3. High extinction ratio
  4. Low transmission losses
  5. Already tested in LMCT bench

- Drawbacks of TFP
  1. Shift of the beam (Brewster angle)
  2. Optical alignment

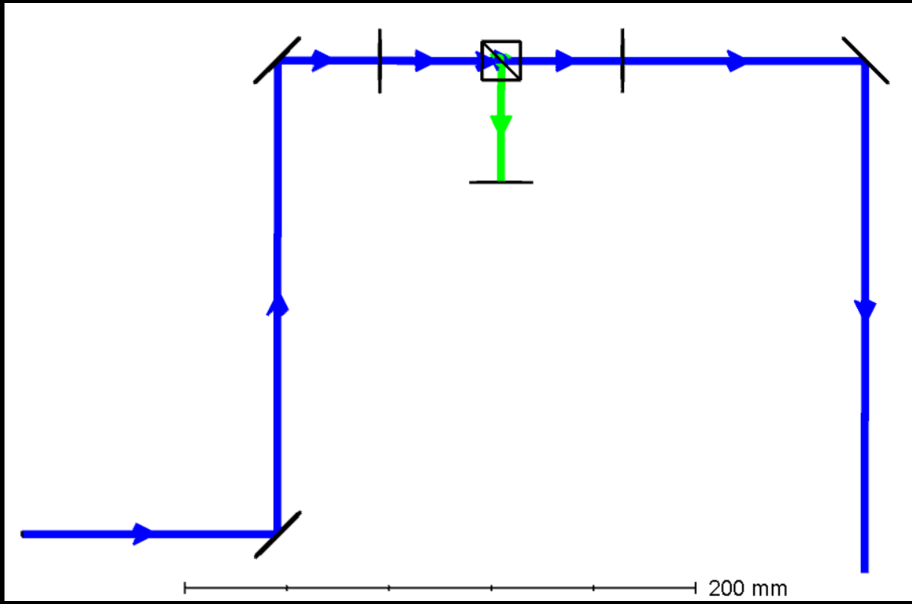
Design by E. Chirre, C. Moreno & GeMS team

Beam Injector Module

TFP at Brewster angle:

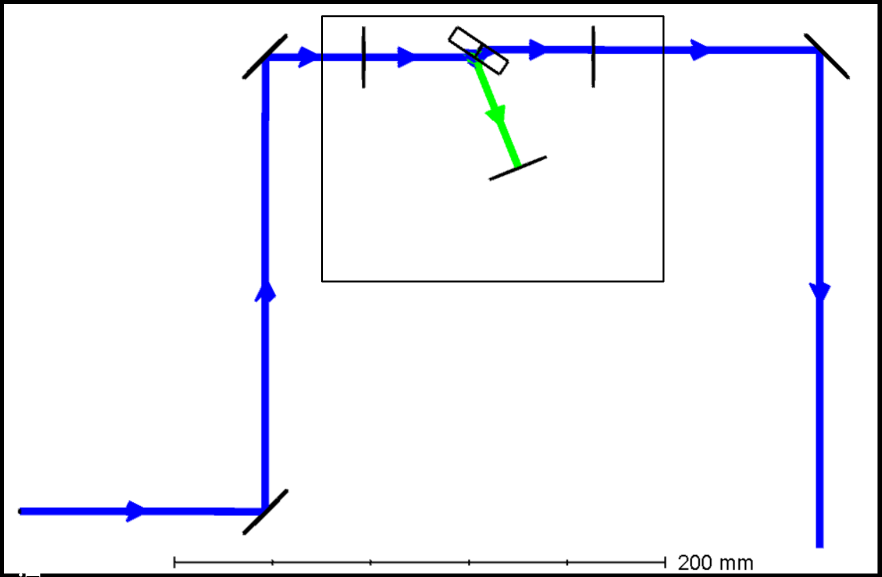


PBS cube:

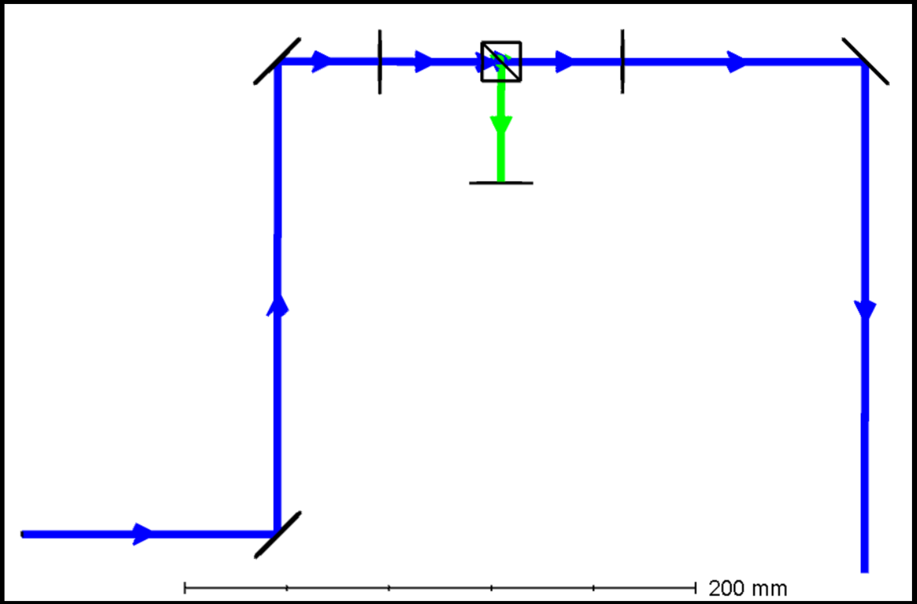


Beam Injector Module

TFP at Brewster angle:

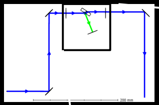


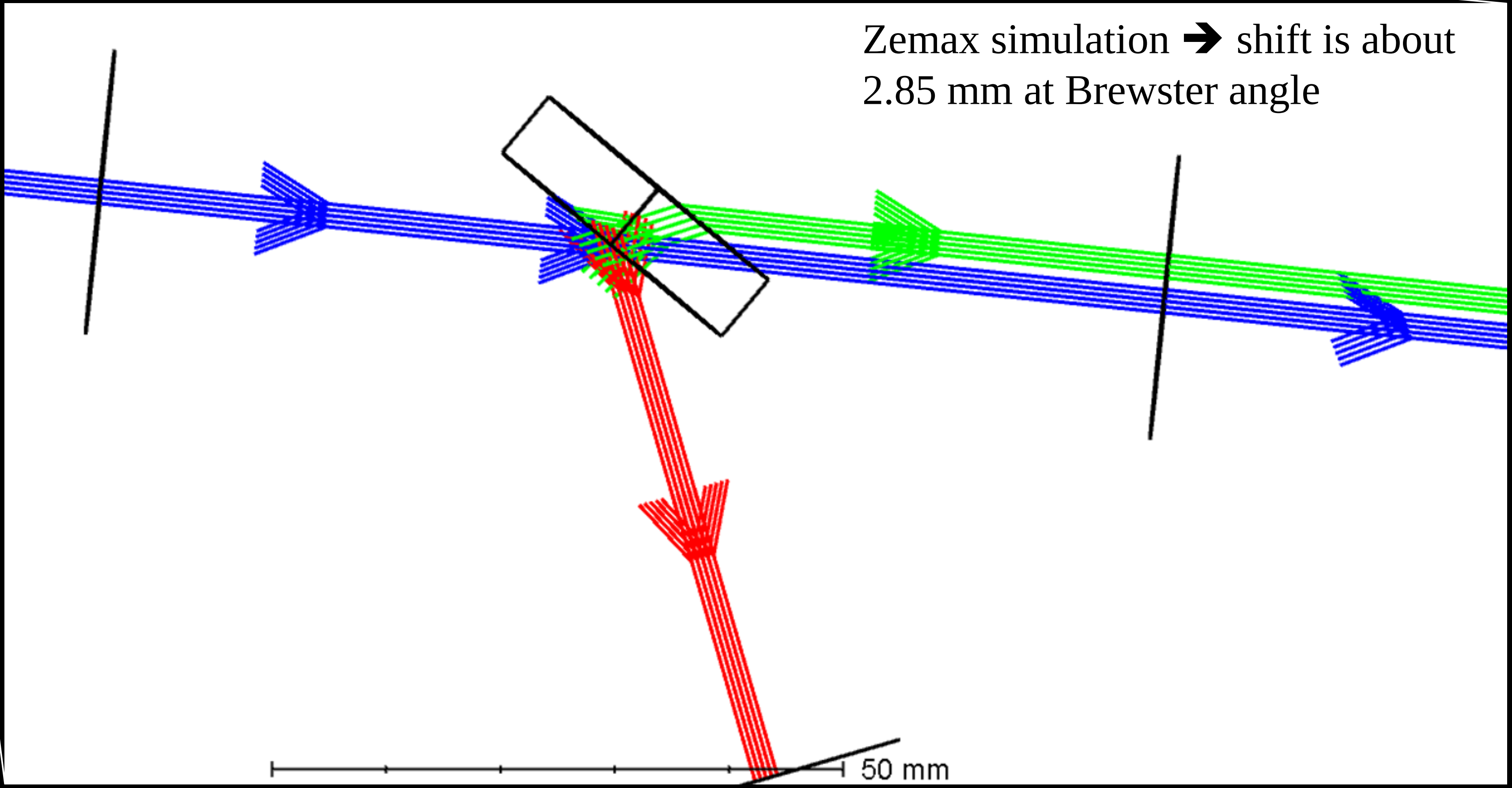
PBS cube:



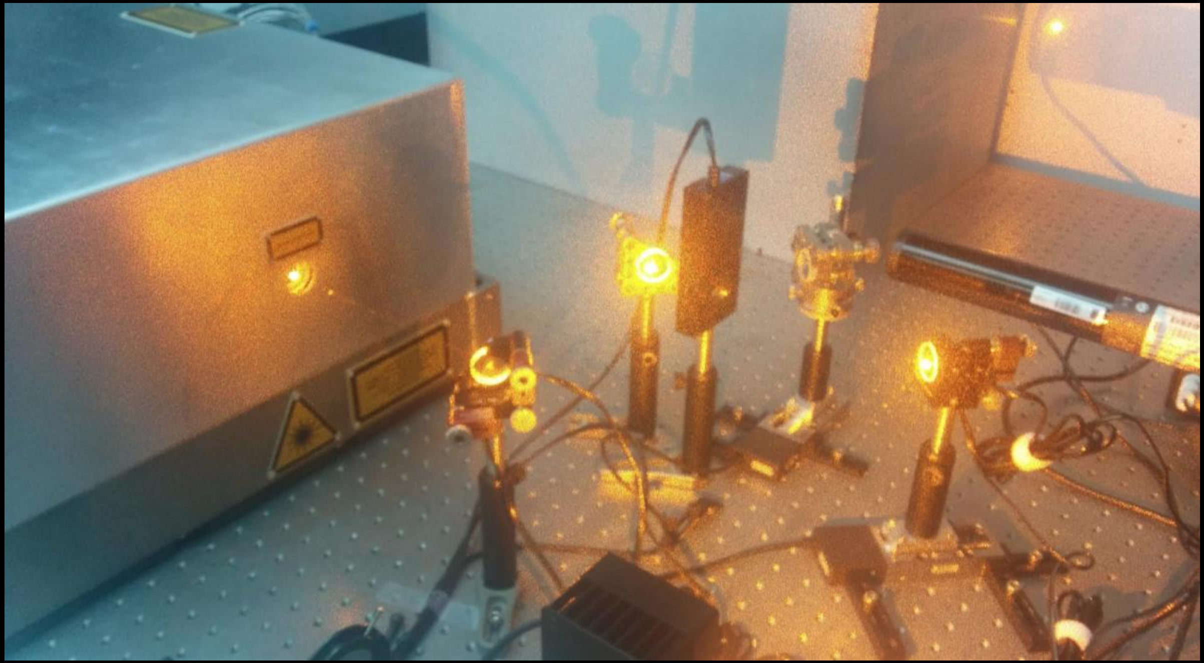
Beam Injector Module

TFP at Brewster angle:





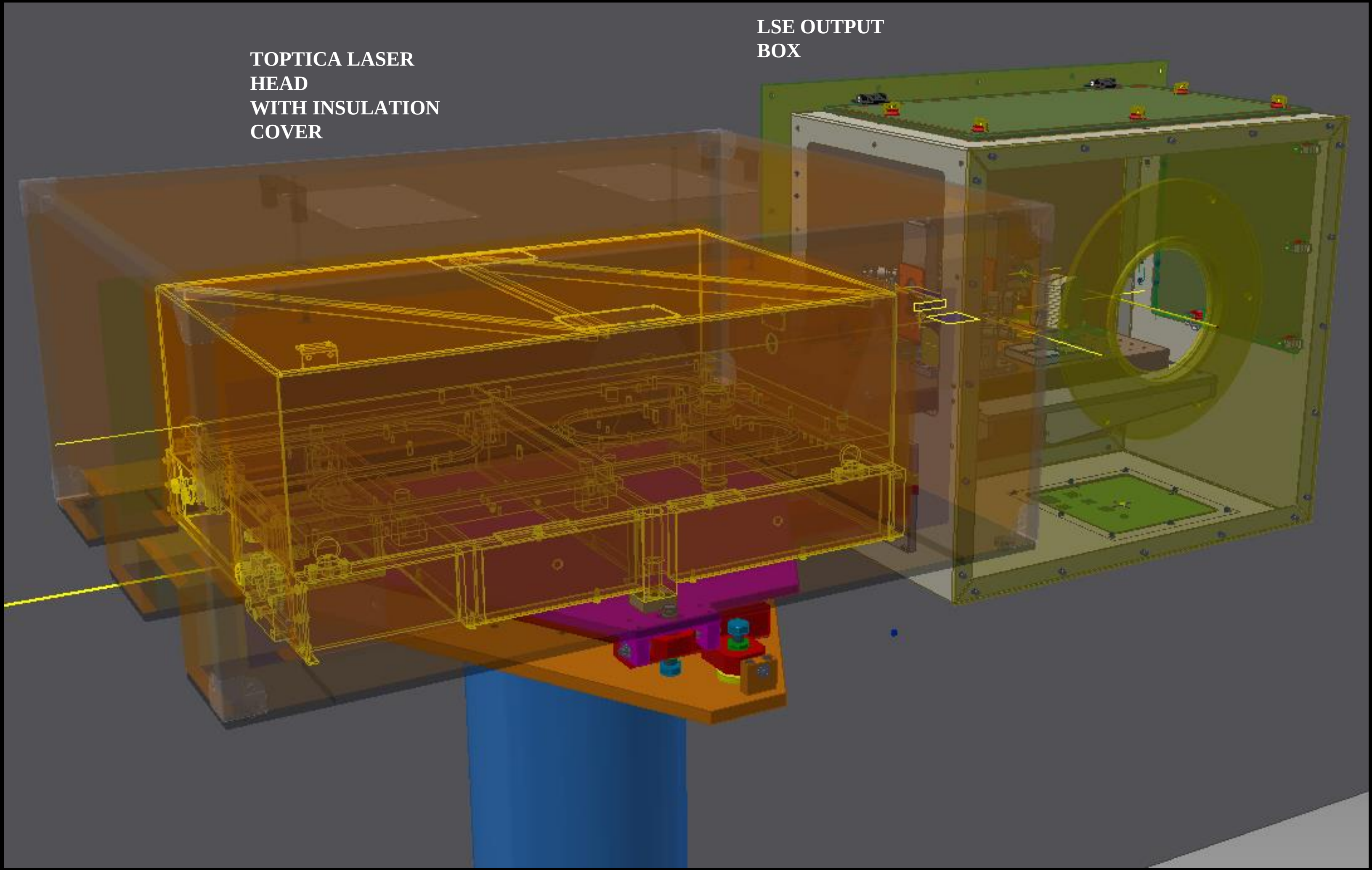
Power loss



- Experimental Results:
- Laser output power: 22.6W in average
- Power after M3 without attenuator: 22.4W in average (T>99%)
- Power after M3 with attenuator (TFP): 20.5W in average (T=90.7%)

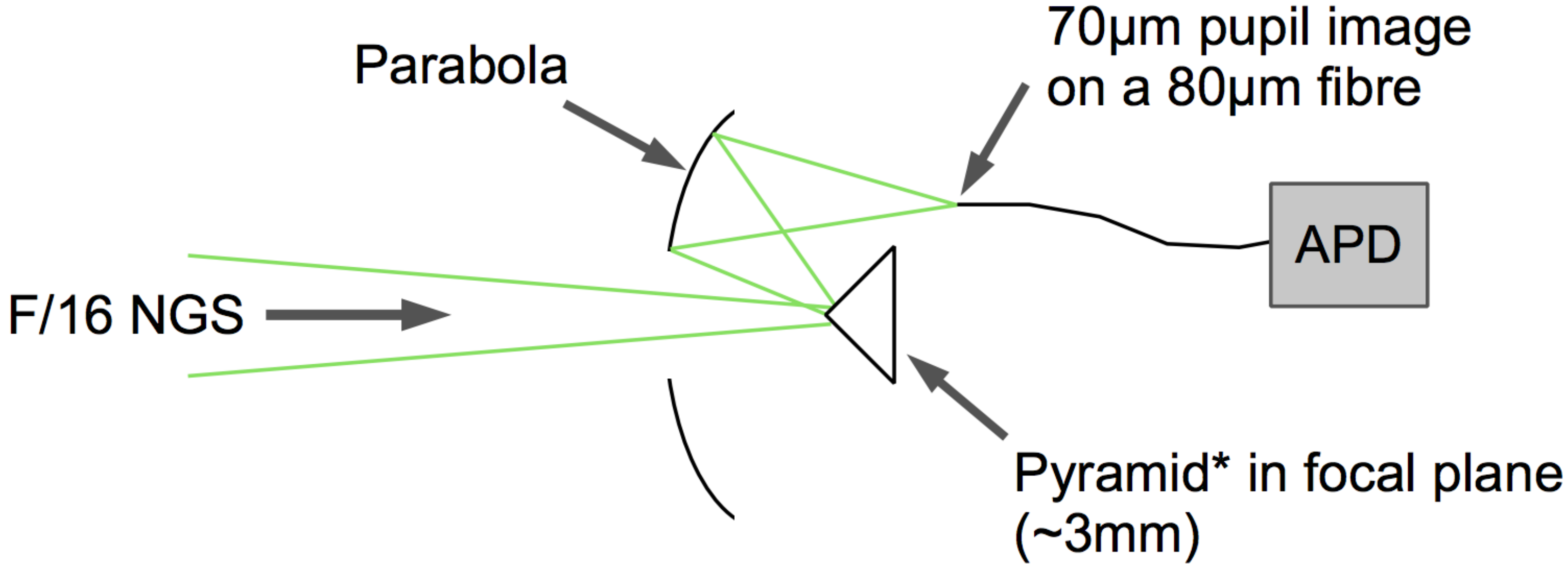
- According to these results, a Polarizing Beam Splitter will be used.
- At the moment we are waiting for the Cube to be tested.

Mechanical drawing



NGS2 upgrade

Current NGSWFS



- Tiny, difficult to align fibre feed
- 4% optical throughput!
- Several attempts to fix but little improvement.

Long overhead in operations
GeMS optical design with 2 parabola ➔ important field distortions in science image

Credit: F. Rigaut

* Note that this has nothing to do with pyramid sensing

Focal plane solution

- “Simple” re-imaging system
  - Throughput excess 75%
  - Solves limiting magnitude / sky coverage issue
- Access to full field
  - Full frame imaging during acq… cquisition
  - Field distortion can… include … ndow positionin…
- No moving m… more reliable

See François Rigaut’s poster

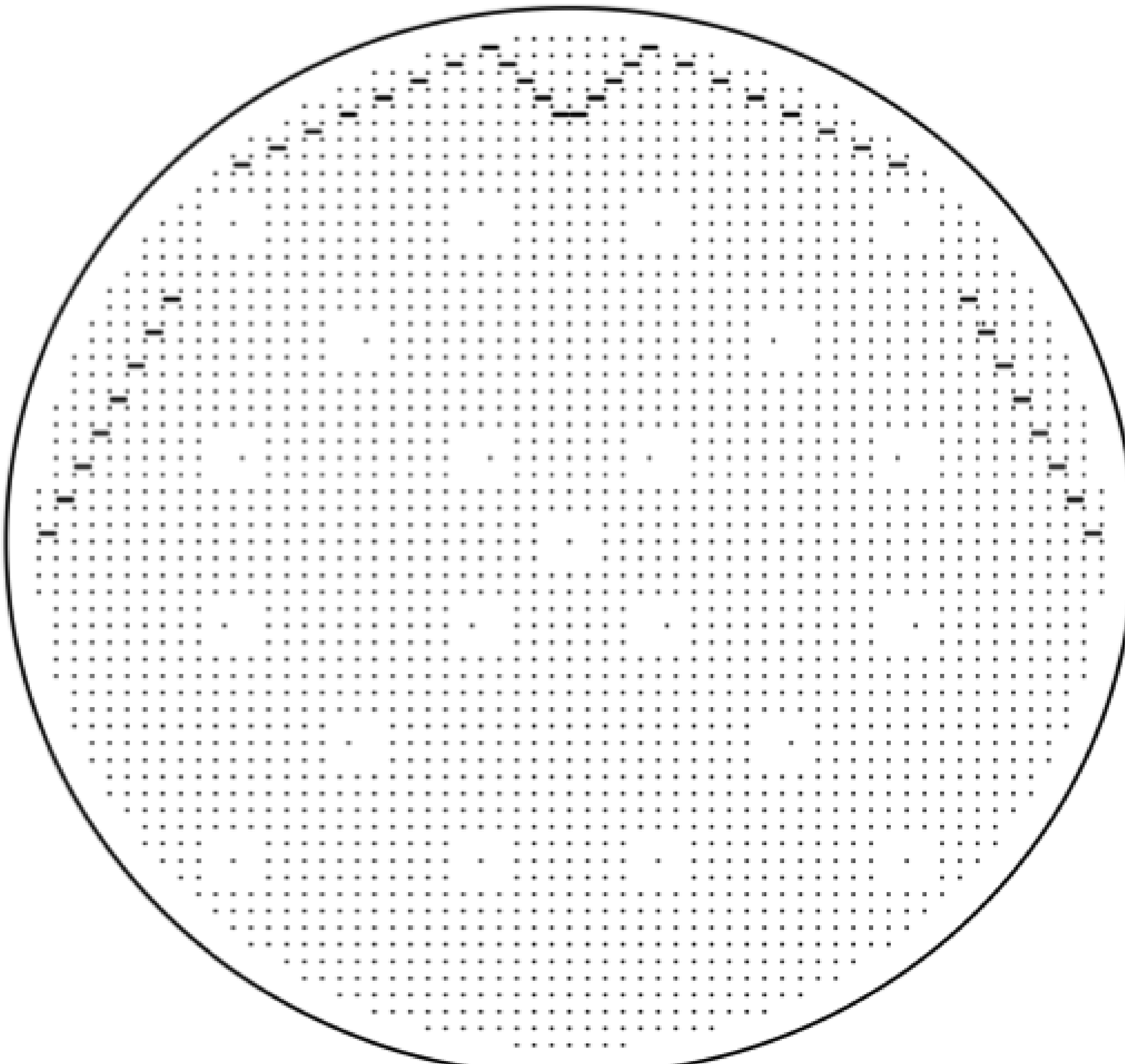
See Eduardo Marin’s poster

- Negative points:
  - SFS WFS has to be transferred to another subsystem
  - Impose some limitations on Guide Stars brightness difference

Astrometry with GeMS

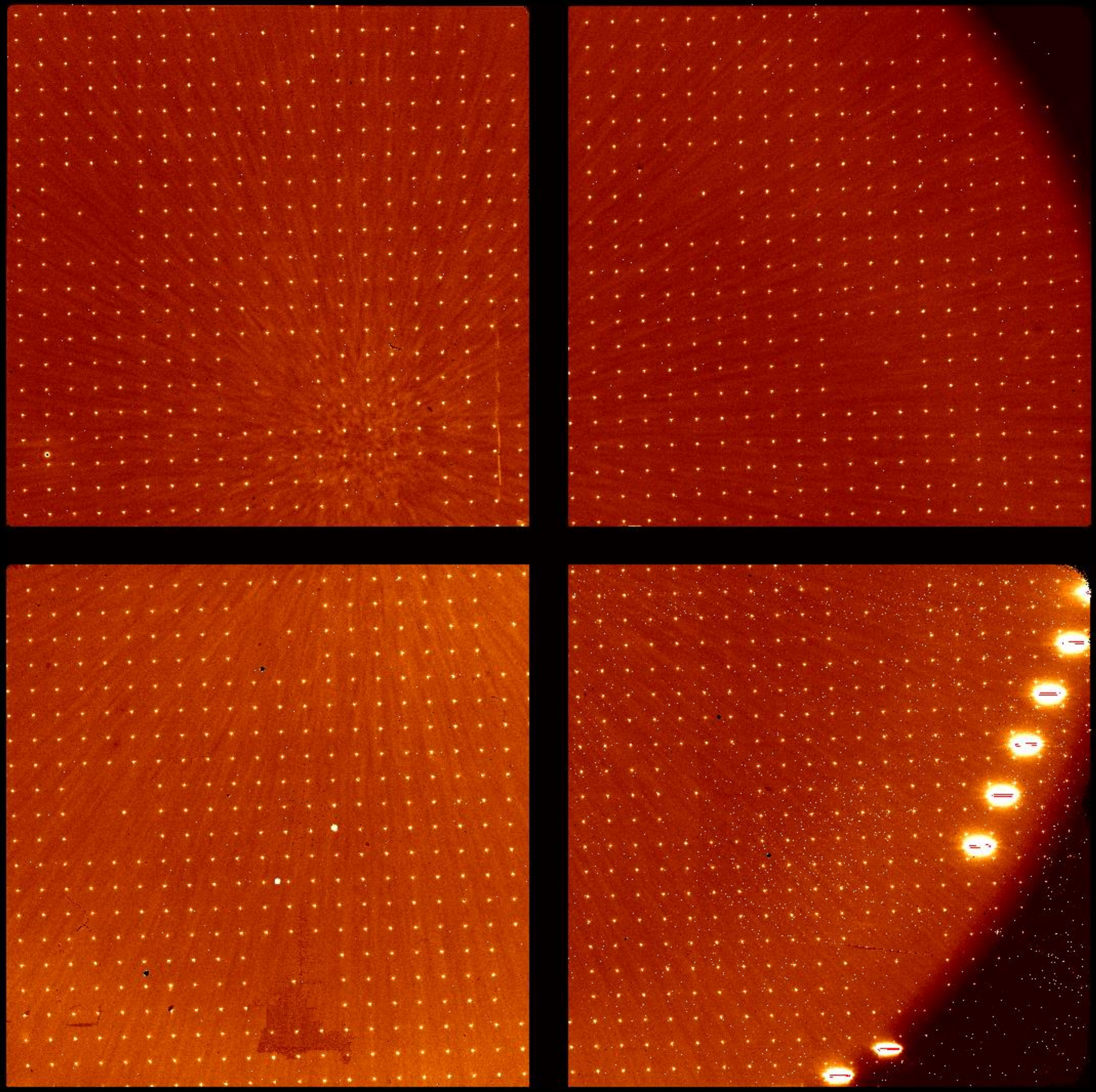
Mask built by HTAphotomask
~1600 usable pinholes
Pitch: 1.19255mm
Diameter: 10um
Corresponds to 96pix in GSAOI and 8 in NGS2

Tenerife, Spain



Astrometry with GeMS

Closed loop
With NCPA applied
Exp: 120s
H-band



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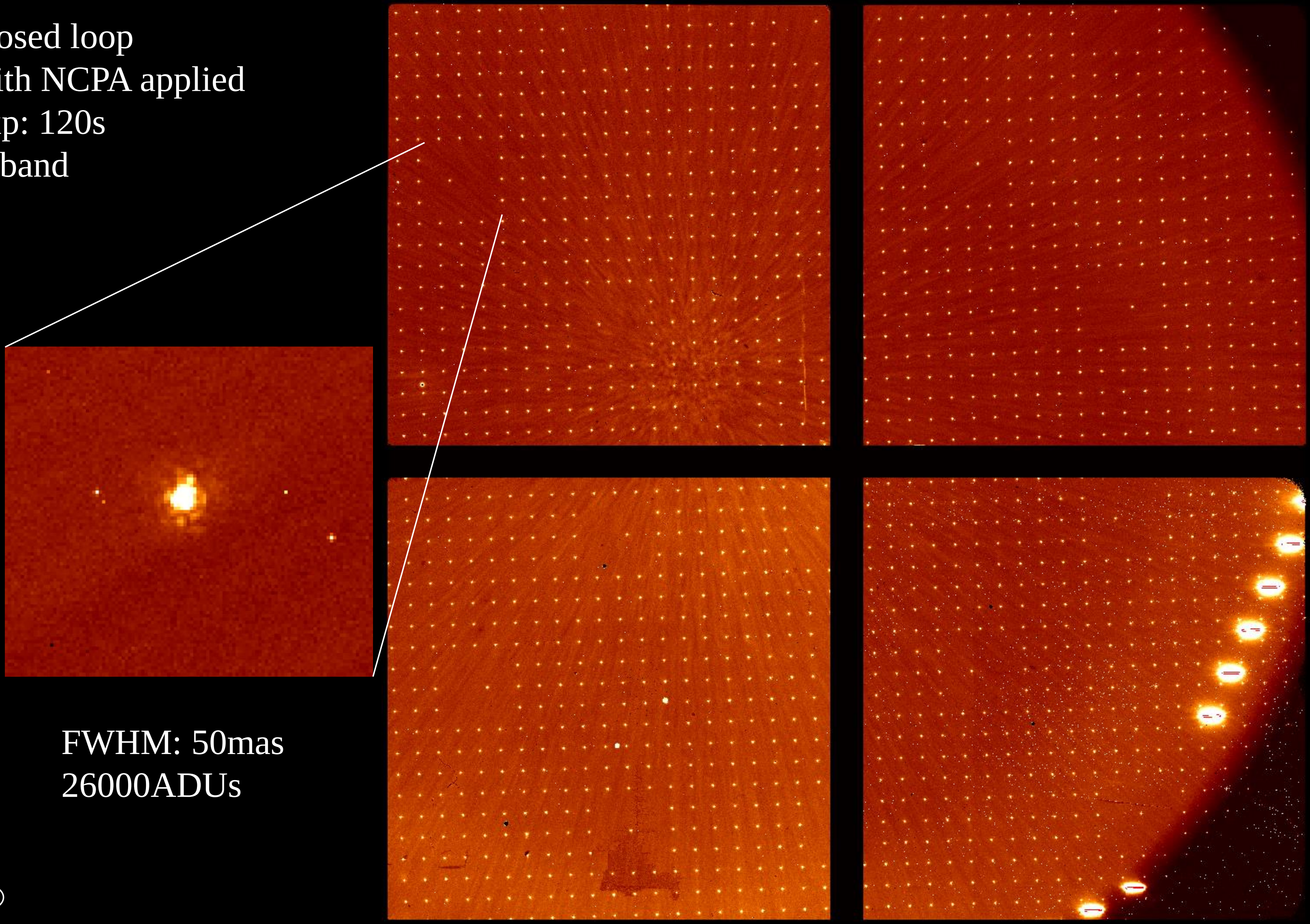
Astrometry with GeMS

Closed loop
With NCPA applied
Exp: 120s
H-band



FWHM: 50mas
26000ADUs

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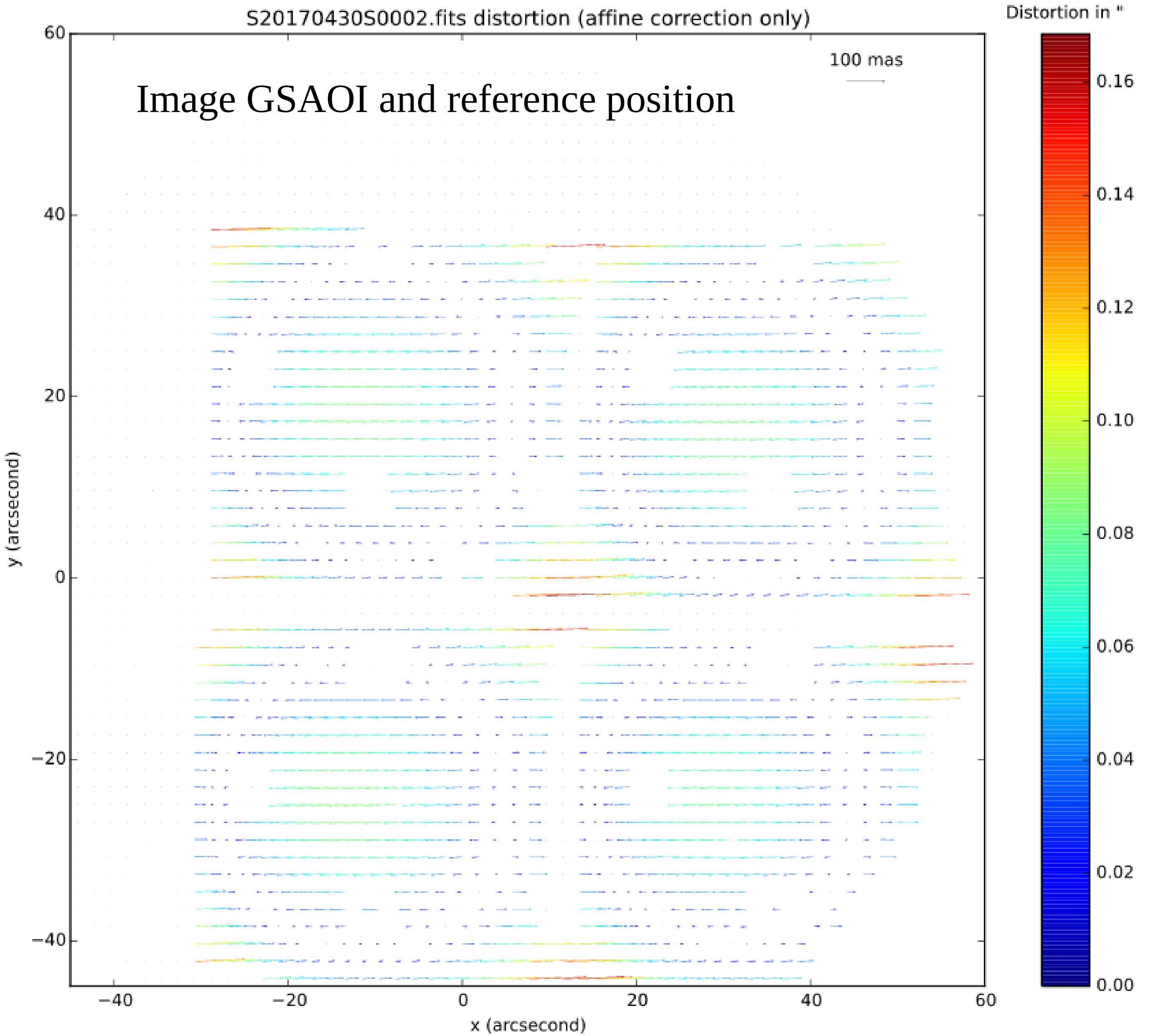
Astrometry with GeMS

Use PSFex and sextractor
Results similar to Massari et al 2016
On each quadrant, similar distortion effect, pure x-axis: intra-instrument



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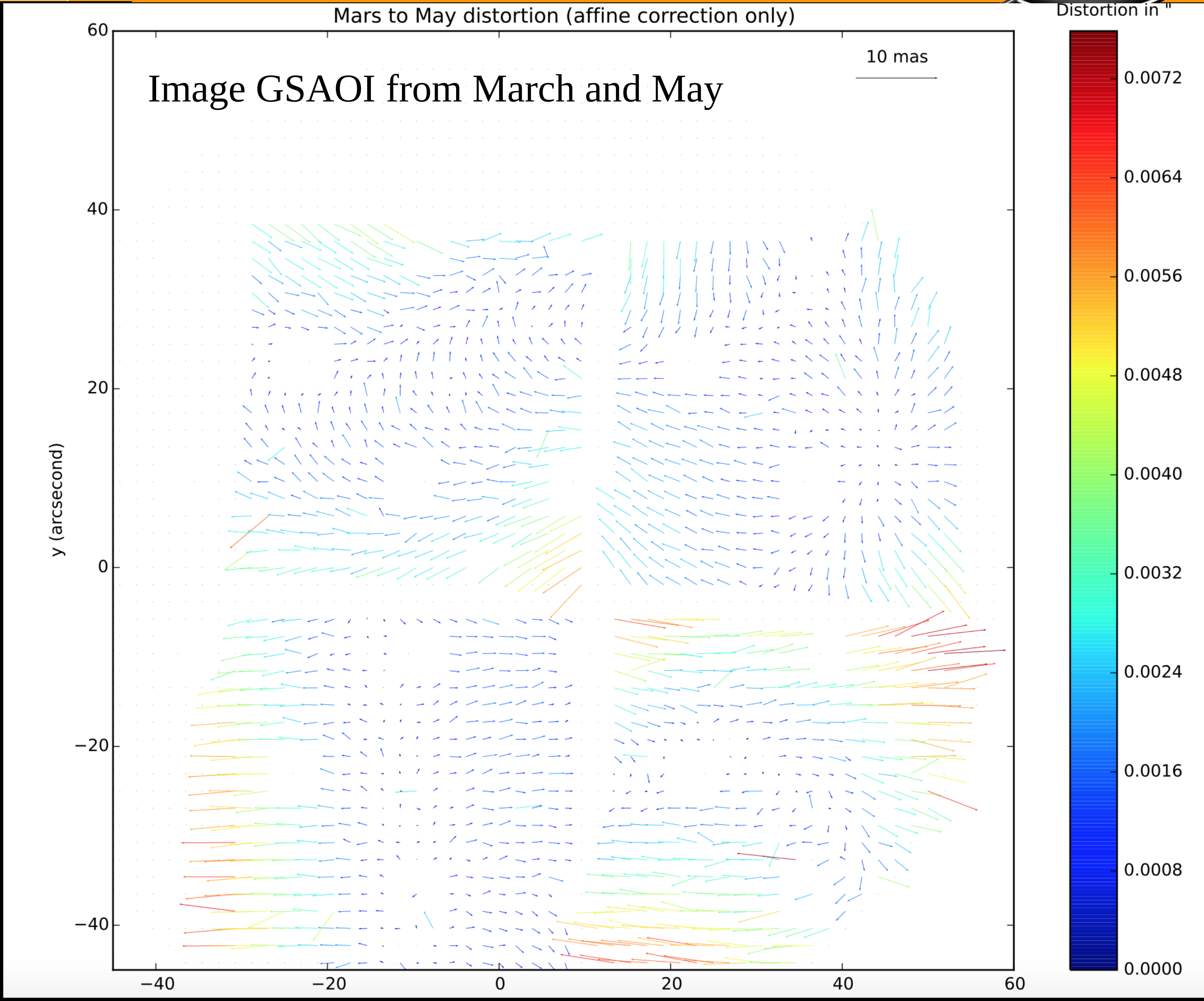
Astrometry with GeMS

Use PSFex and sextractor
Exactly same configuration:
-zenith
-same CR
Only difference is instrument removal and re-install



Astrometry with GeMS

- We know how to reproduce the static distortion (big components)
  - See Gabriele Rodeghiero's talk on Tuesday
- Much smaller components (~5mas) seen by mask introduced only by instrument changing
- Ongoing work: measure distortions due to flexure and compare if match with what is seen on-sky
- Goals is to provide first calibration to user putting the mask inside the program during observation

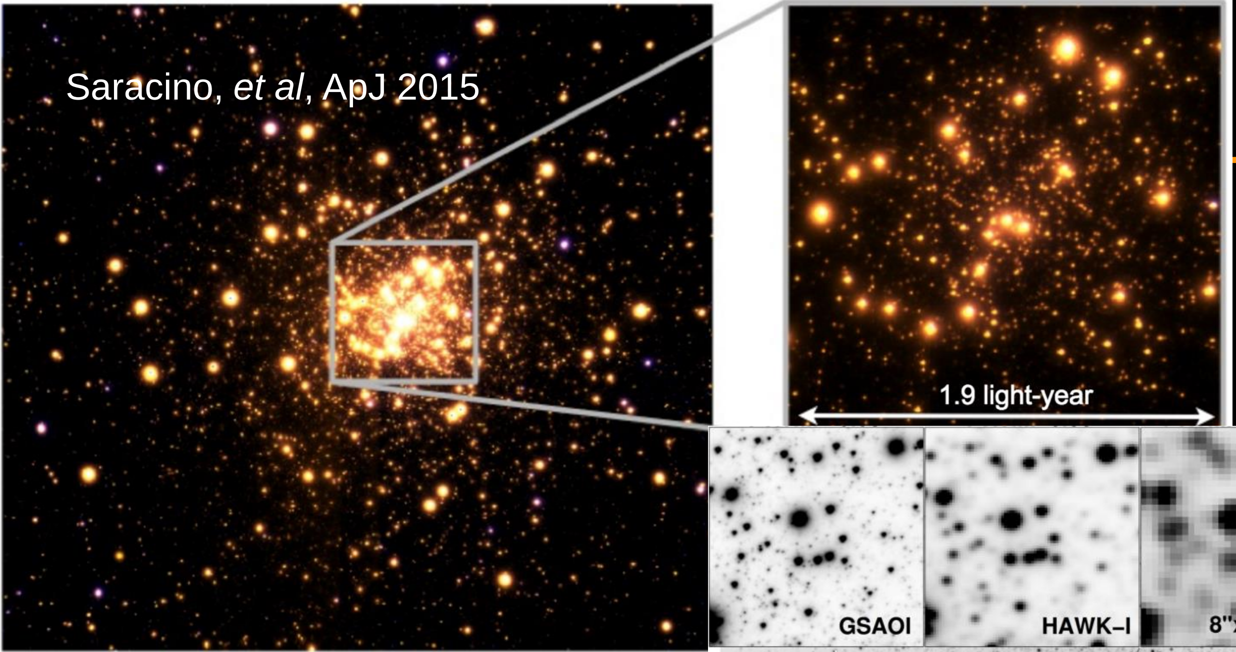
Conclusion

- GeMS is in “regular” operation since 2013
  - Good performances, slightly under specifications
  - Provide good science, papers are coming out
- GeMS 2.0 getting ready
  - New laser is coming
    - Everything ready in the lab
    - Installation on telescope in August
    - Commissioning end of October
  - NGS2 on its way
    - Commissioning 2018A
    - Much more sky coverage expected

Conclusions

- Astrometric calibration is ongoing
  - Mask installed
  - Static distortions is characterized
  - First fit polynomial will be provided to user once commissioned
    - Method is currently under design

The end



Saracino, *et al*, ApJ 2015

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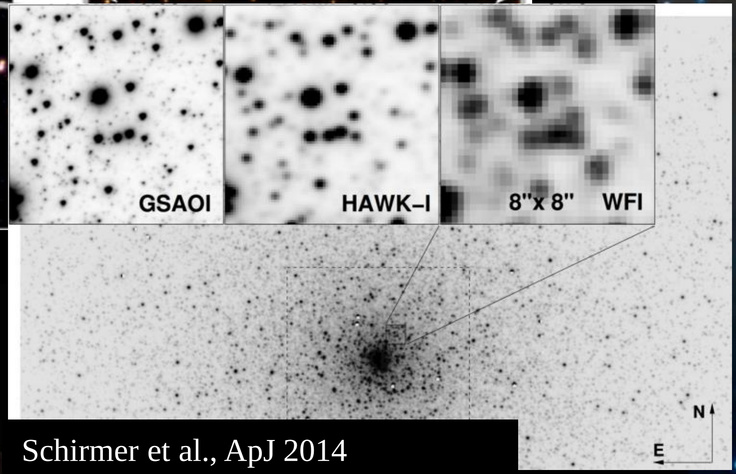
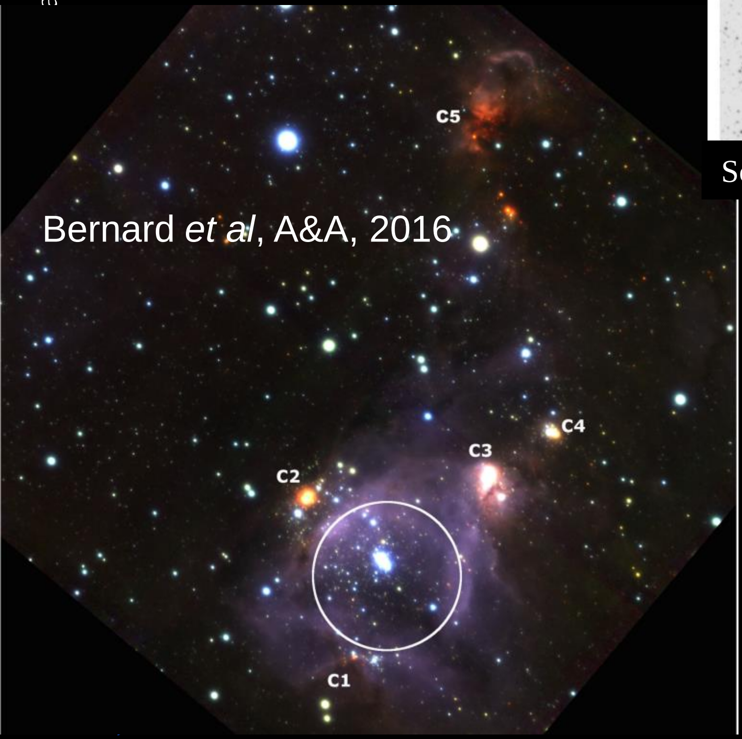


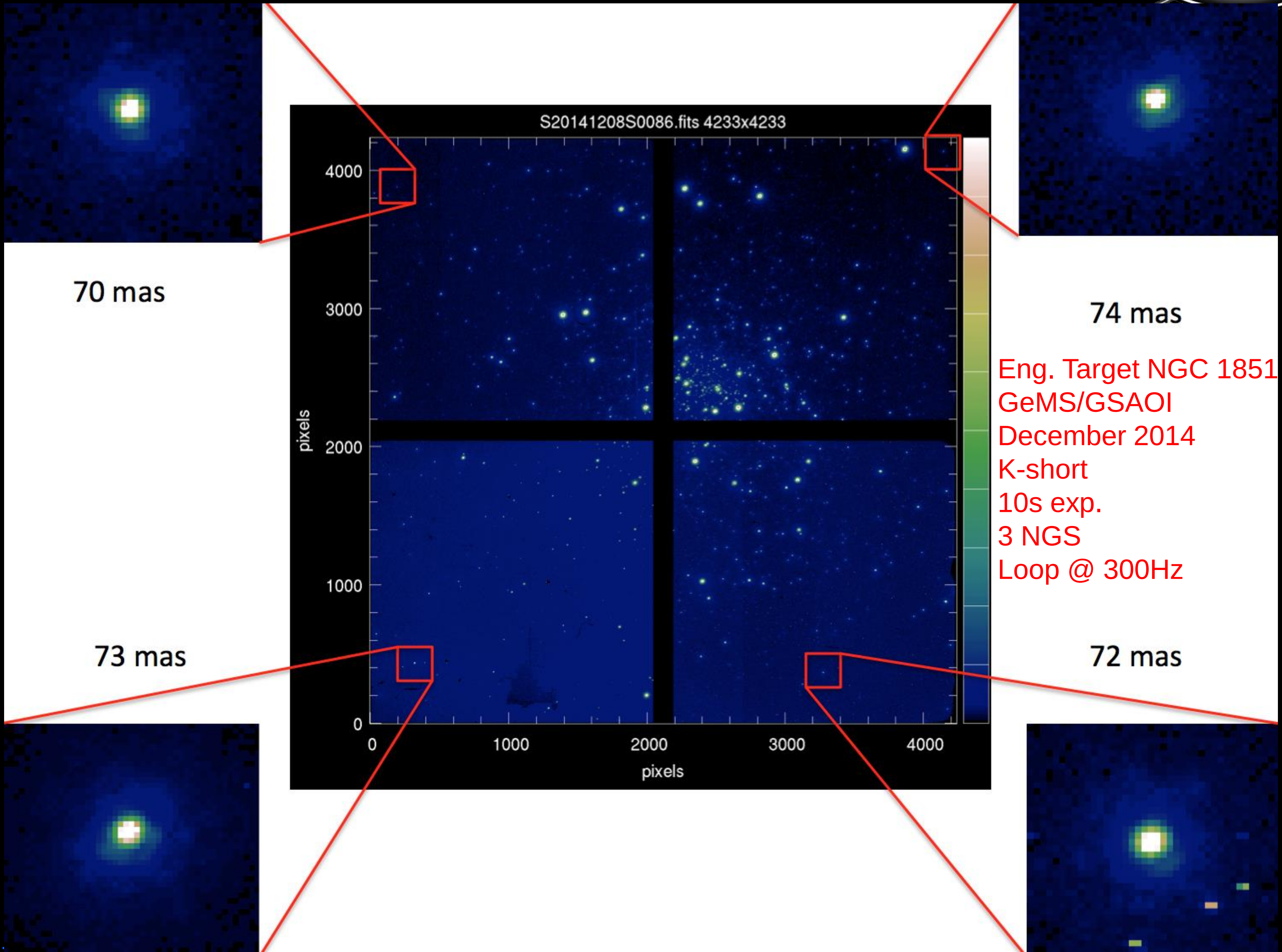
Schirmer et al., ApJ 2014



Bernard *et al*, A&A, 2016


Bally *et al*, A&A, 2015

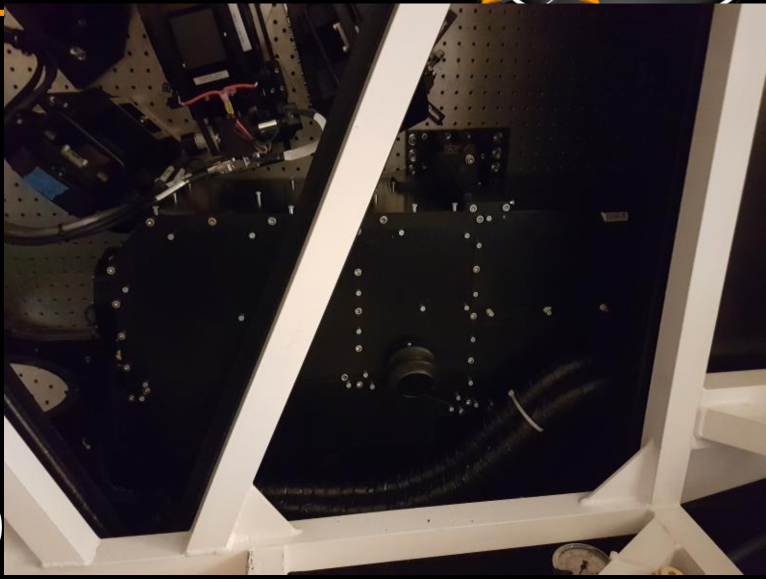
Performance on science

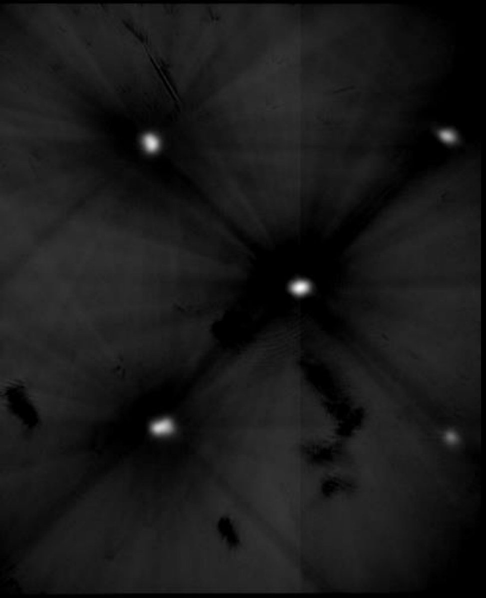


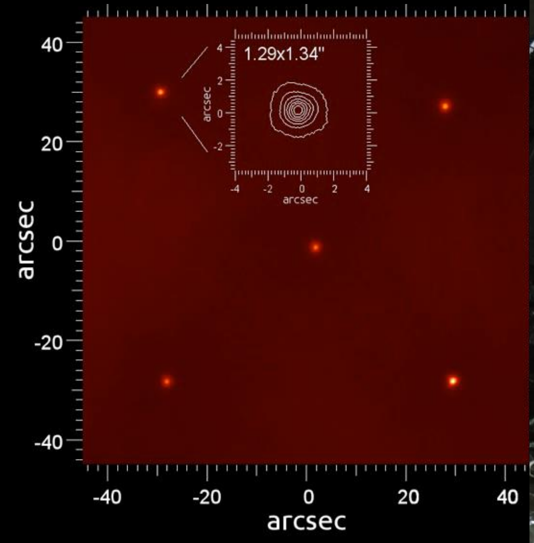
Eng. Target NGC 1851
GeMS/GSAOI
December 2014
K-short
10s exp.
3 NGS
Loop @ 300Hz

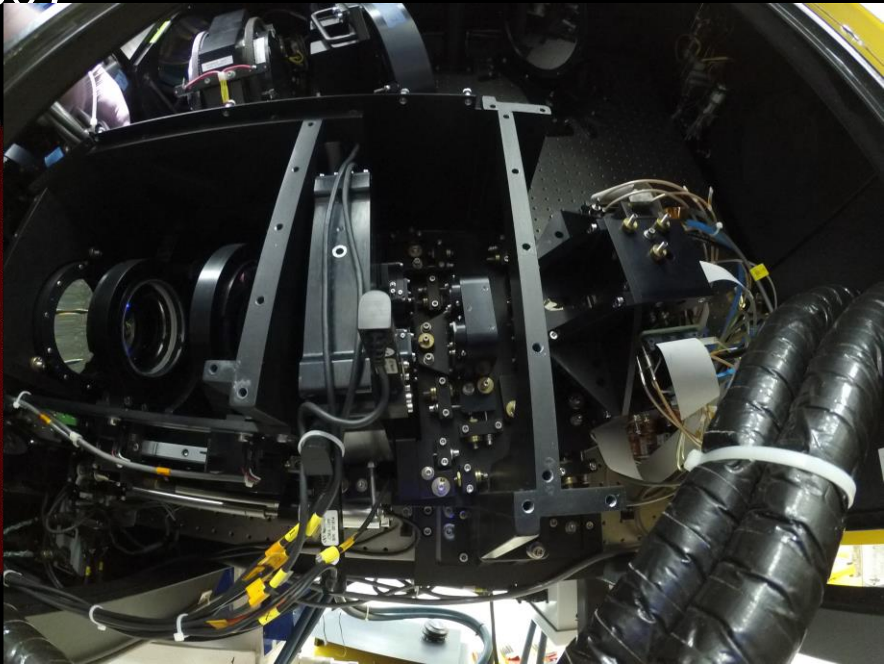
LGS WFS

- 5 16x16 SHWFS
  - 204 subapertures
  - 2x2 pix / subap
  - 1.38”/pix
  - Up to 800Hz (depending on Na return)
  - Constellation (0,0) and (±30, ±30)

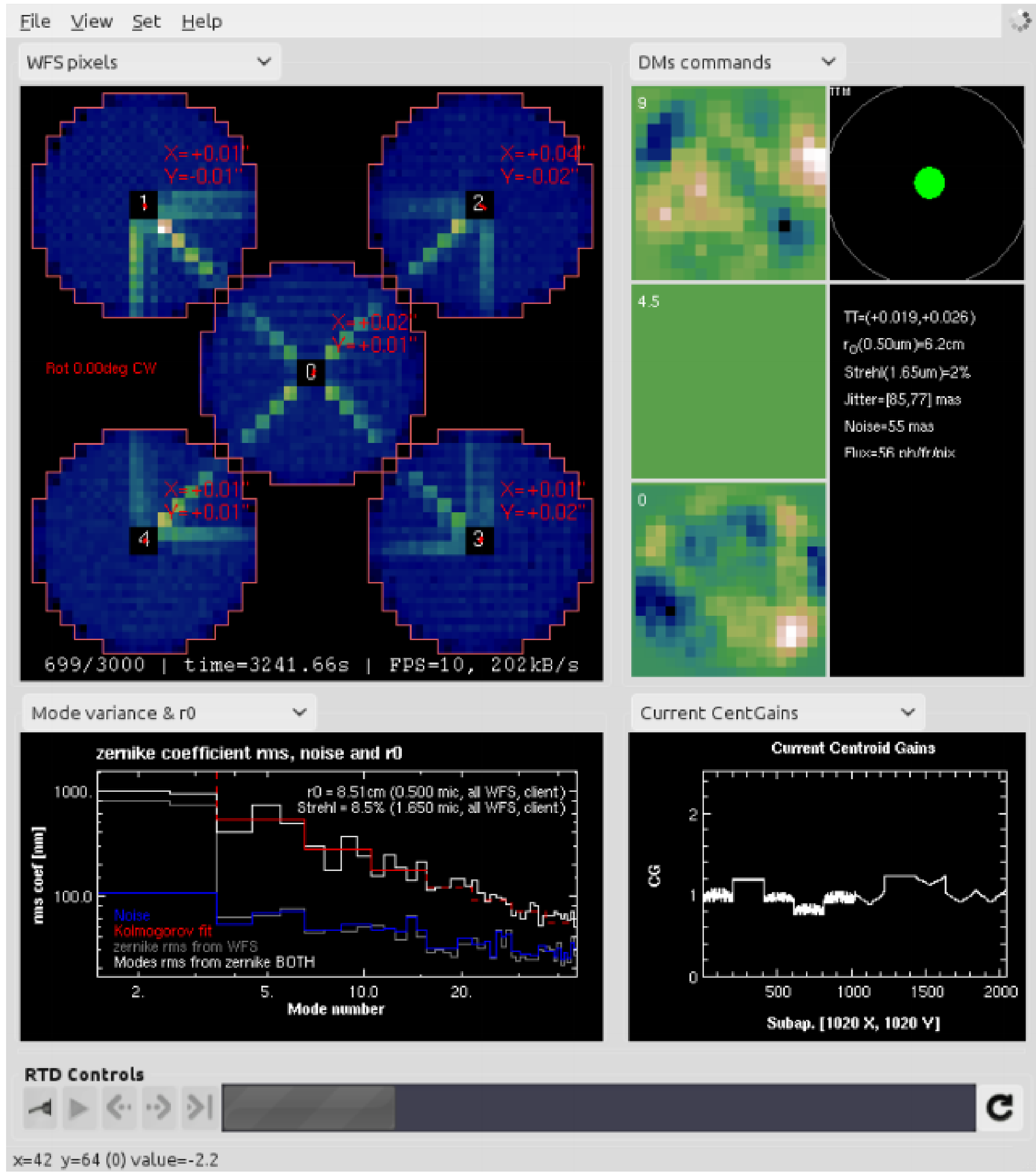








LGS WFS (RTD)



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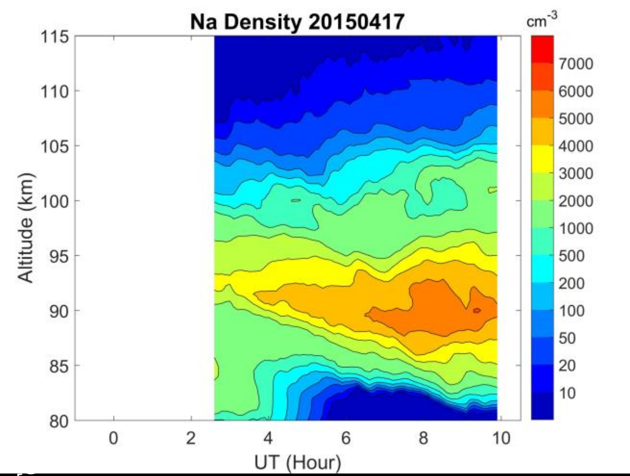
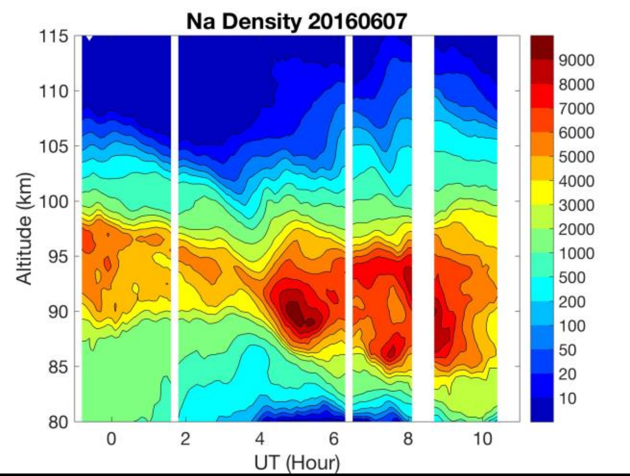
LGS WFS centroid gains

- Centroid gains calibrations:
  - ► Provides a response of the quadcell to a spot position
  - ► Spot size changes with seeing, Na characteristics





Credit: ALO
http://lidar.erau.edu/data/nalidar/201606.php

- Error on centroid gains produce
  - ► Wrong loop gain in closed loop
  - ► Wrong NCPA
  - ► Differential aberration between all WFSs
  - ► Wrong tomography

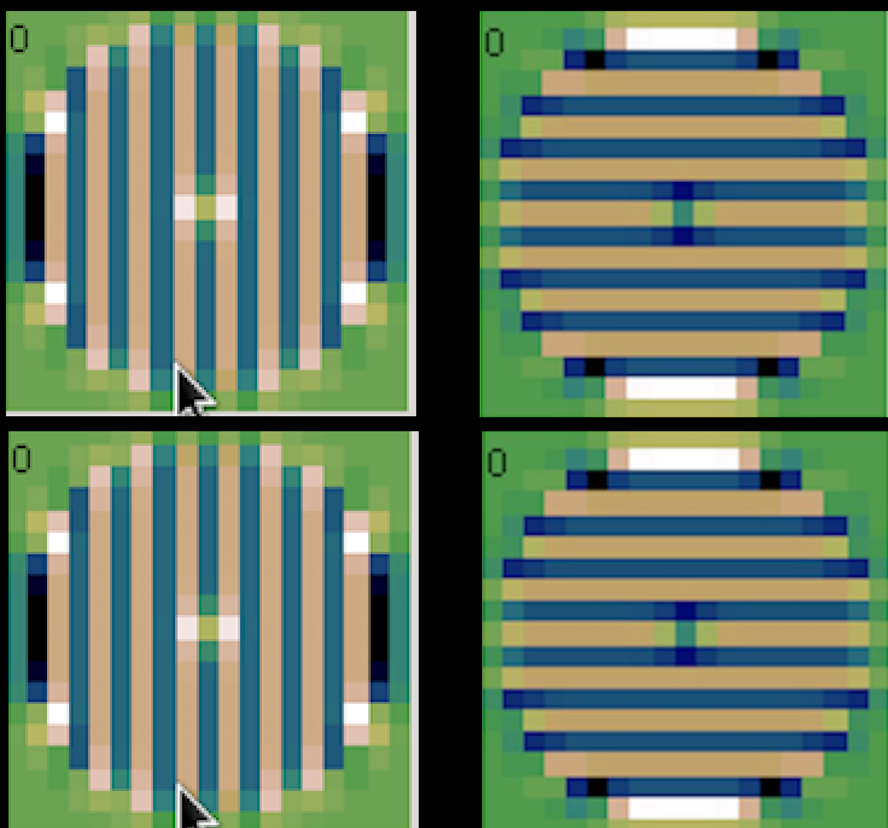
Need to calibrate centroid gains online

LGS WFS centroid gains

Quad-cells transfer function & centroid gain

=> Centroid gains need to be calibrated on-line

Method: Apply a “sine wave” on the DM at a given frequency and do a lock-in detection.



Derviche mode

- Pattern of small amplitude and known shape ➔ Filtered through reconstruction
- Pattern is enough to create a synchronous detection and give an estimate of spot size
- Pattern small enough to be unseen on science image
- Slow update of centroid gain
- Insensitive to vibrations
- Not (really) seen by the WFSs, so not corrected
- Small amplitude required (20nm rms)
- Would create satellite spot on the images, but lost in noise.

LGS WFS centroid gains