GeMS 2.0 begins: Results of a successful new laser commissioning and beyond

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GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

SEG2018, San Francisco, CA, USA

GeMS

Outline

- GeMS instrument
  - Brief presentation & Status
  - Performance achieved with GeMS (2013-2018)
- New laser integration: TOPTICA
  - Performance of the laser
  - Science performance
- Direct comparison Lockheed Martin Coherent Technologies (LMCT) –Toptica lasers
  - Photometry
  - Na return analysis
  - AO analysis
- Conclusions

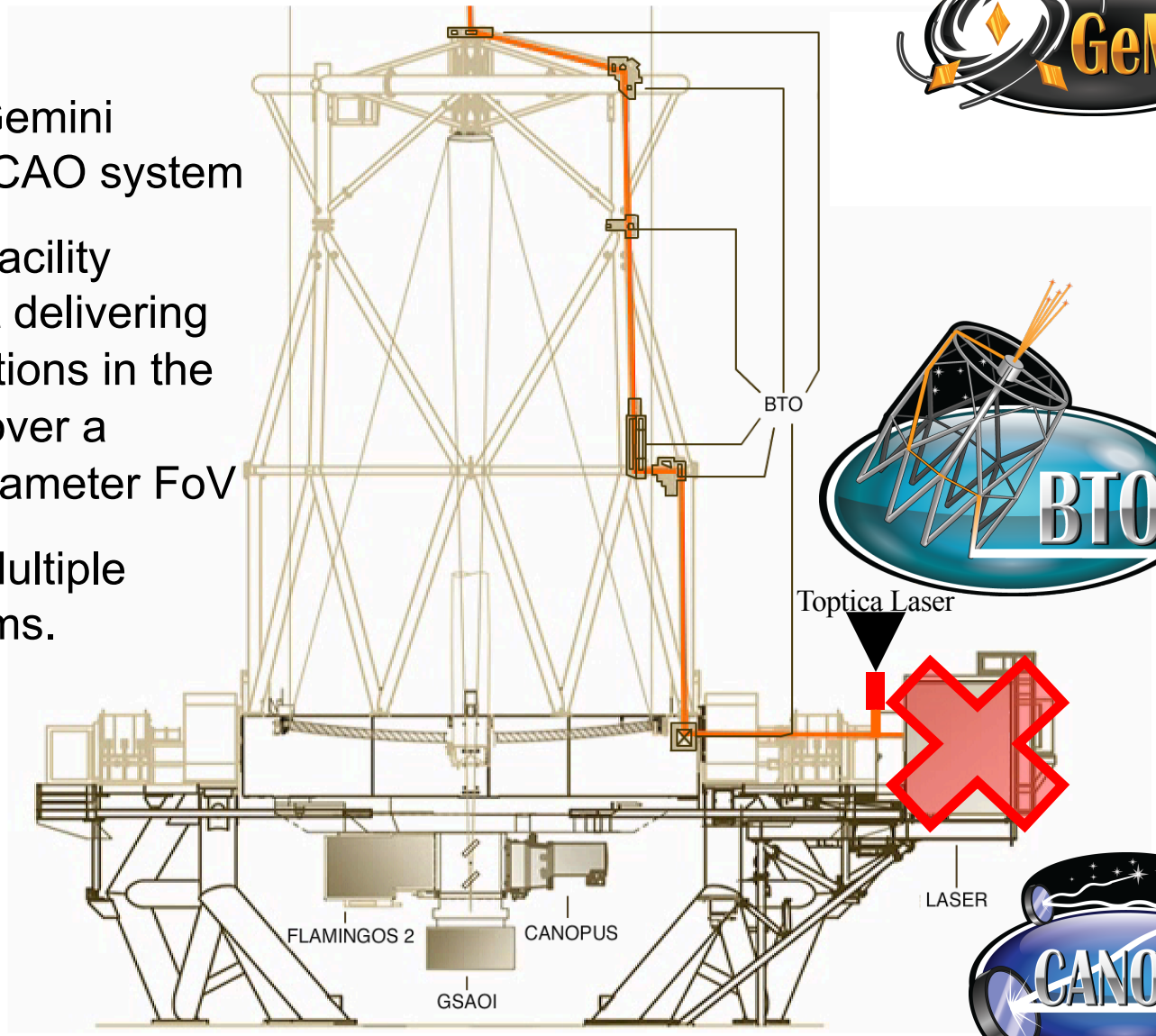
Introduction to GeMS

GeMS Intro.

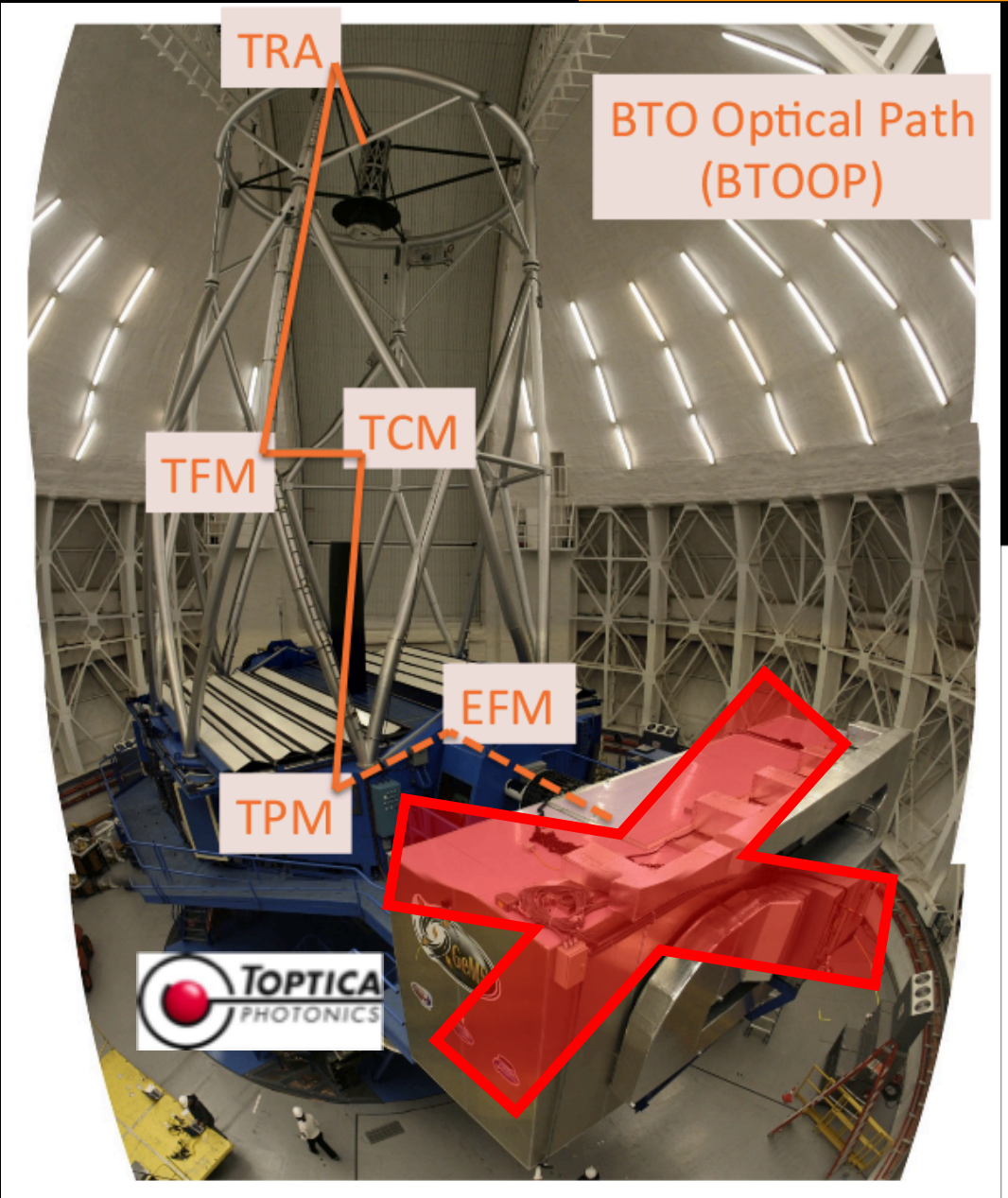
GeMS = Gemini (South) MCAO system

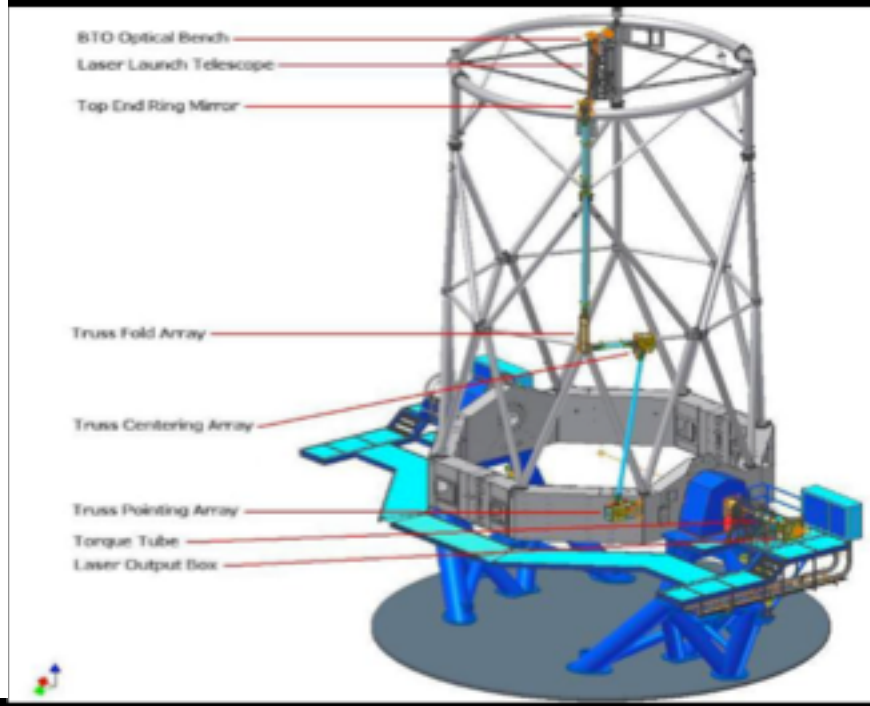
GeMS = Facility instrument delivering AO corrections in the NIR, and over a 2arcmin diameter FoV

GeMS = Multiple sub-systems.

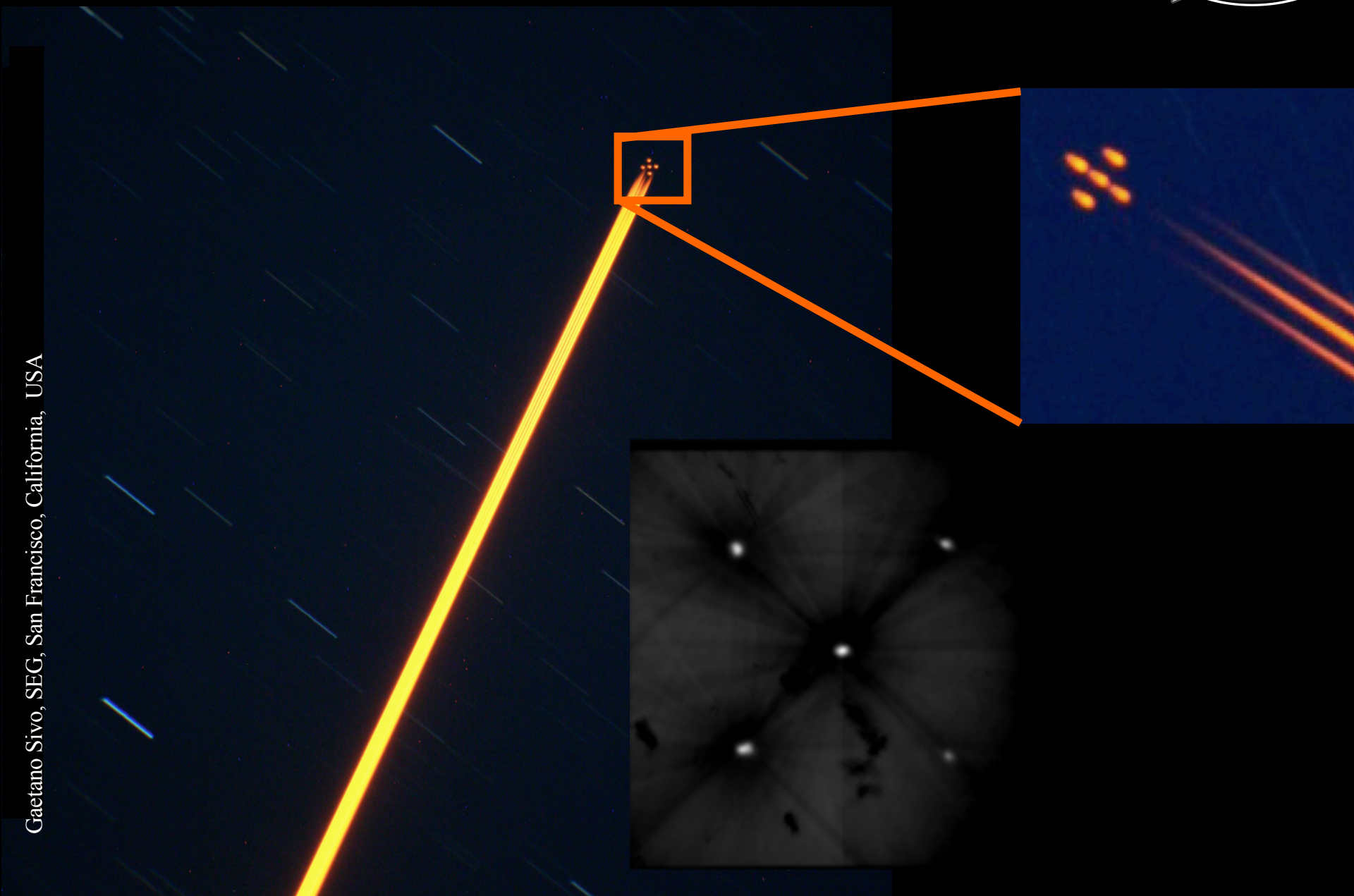


Beam Transfer Optics (BTO)



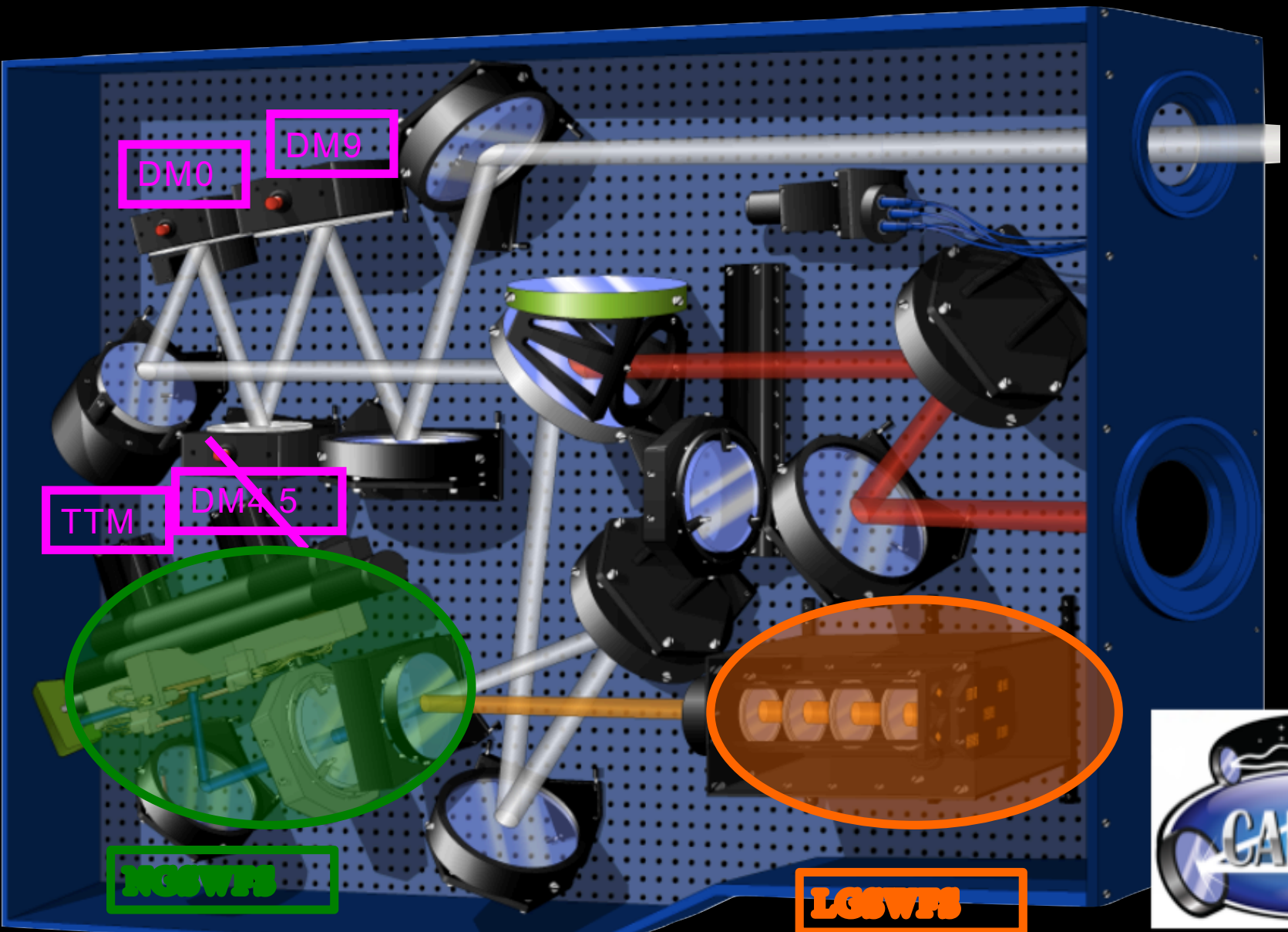


Asterism on-sky (2011)



Gaetano Sivo, SEG, San Francisco, California, USA

Canopus

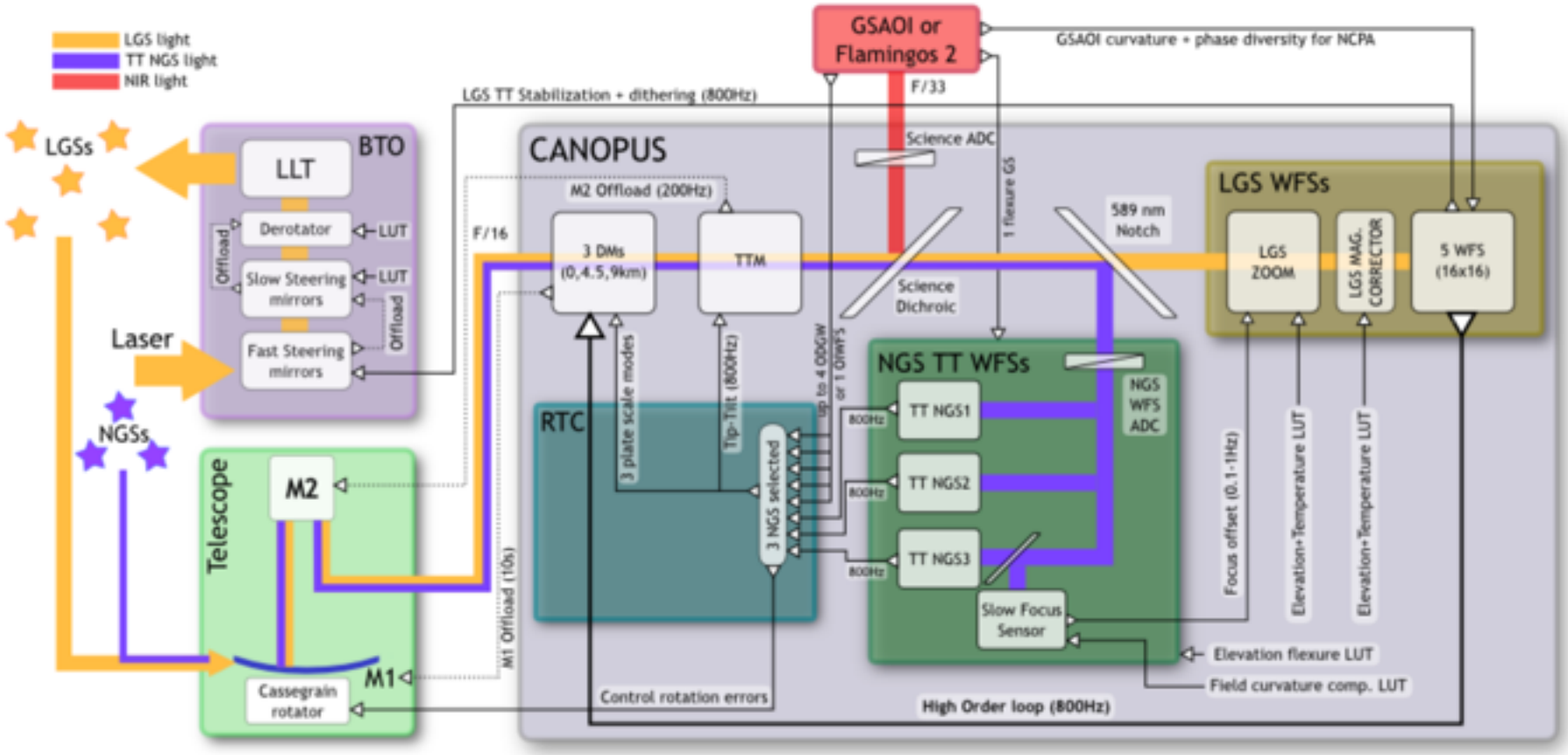


Entrance shutter

Exit shutter

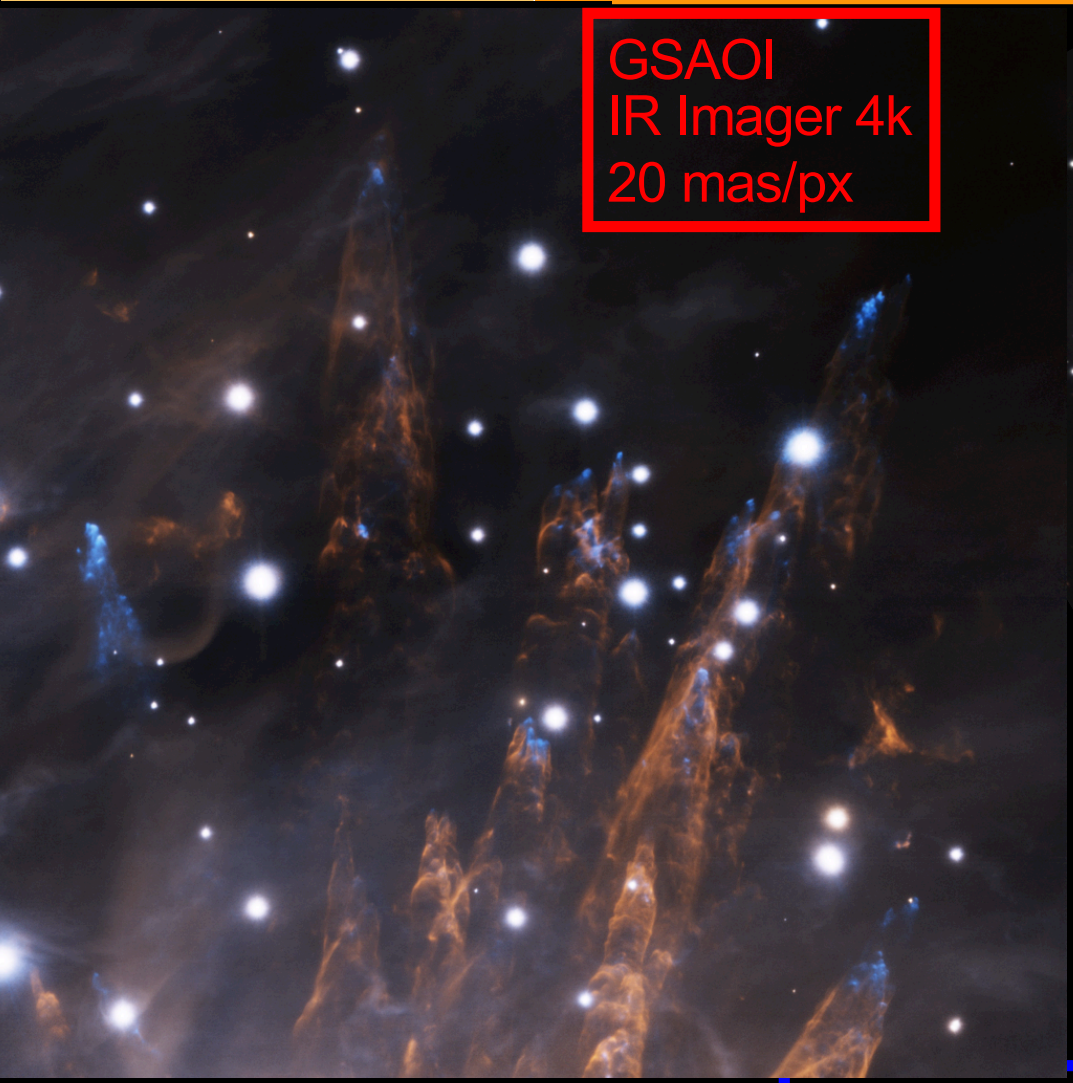
GeMS diagram

- 1 x 50W laser is divided in 5 x 10W beams placed on the corner and center of a 1' FoV
- 5 (16x16)SHWFS - 3DMs (totaling 917 actuators) - 800Hz
- 3 APDs based NGS TT WFSs - 800Hz - Plate scale modes - Slow Focus Sensor
- 2 dedicated NIR instruments (GSAOI 4k²-80"-20mas, F2 MOS-2')
- Many 2nd loops, LUT, offloads…



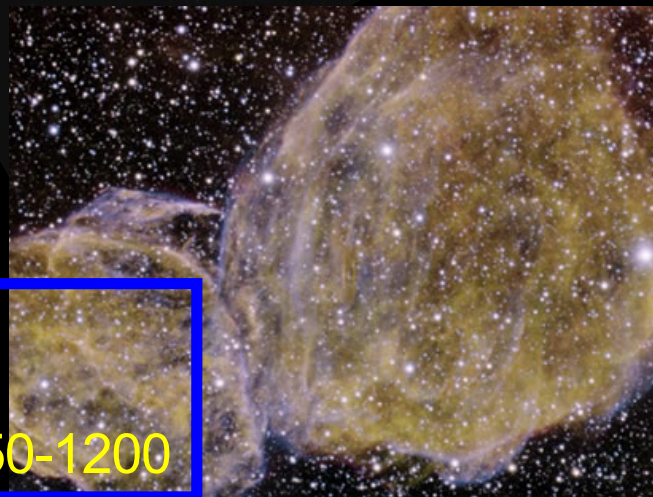
# of loop = 20

Science instruments



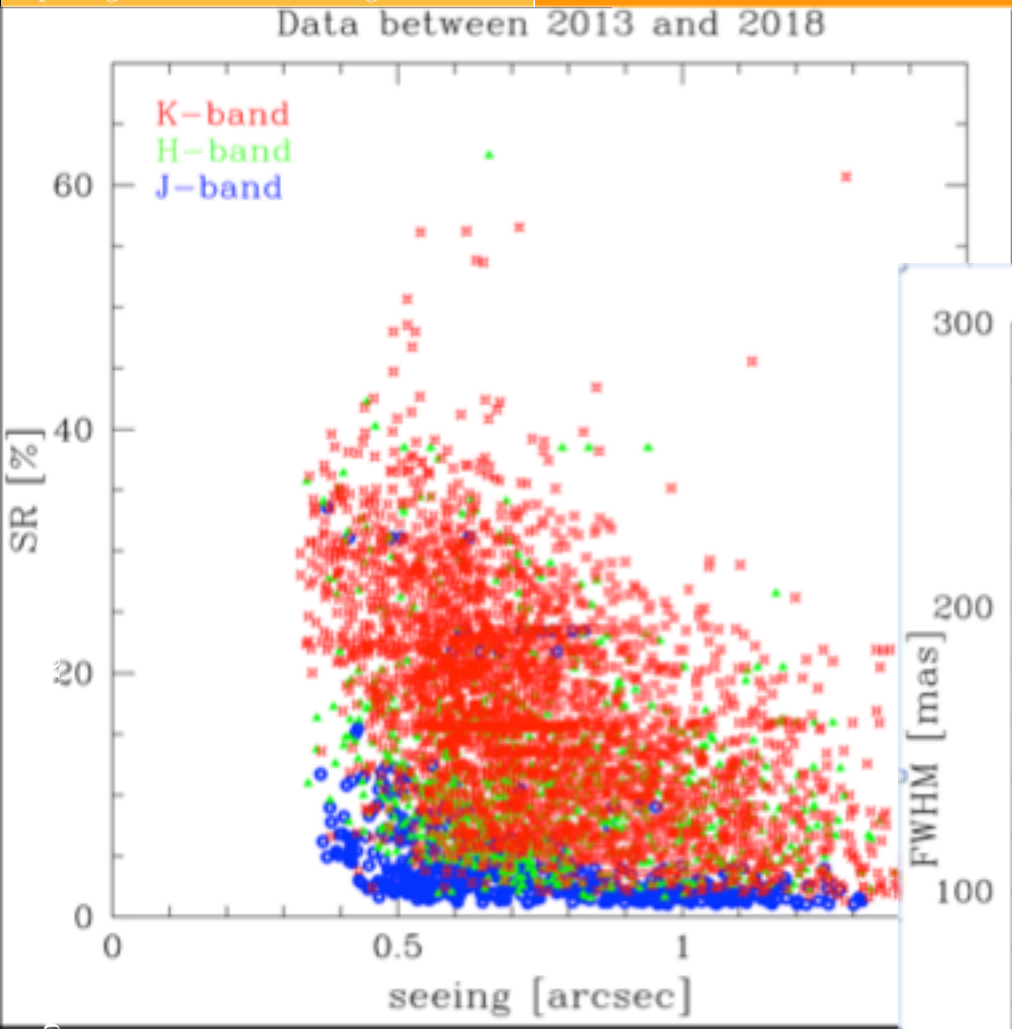
GSAOI
IR Imager 4k
20 mas/px

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

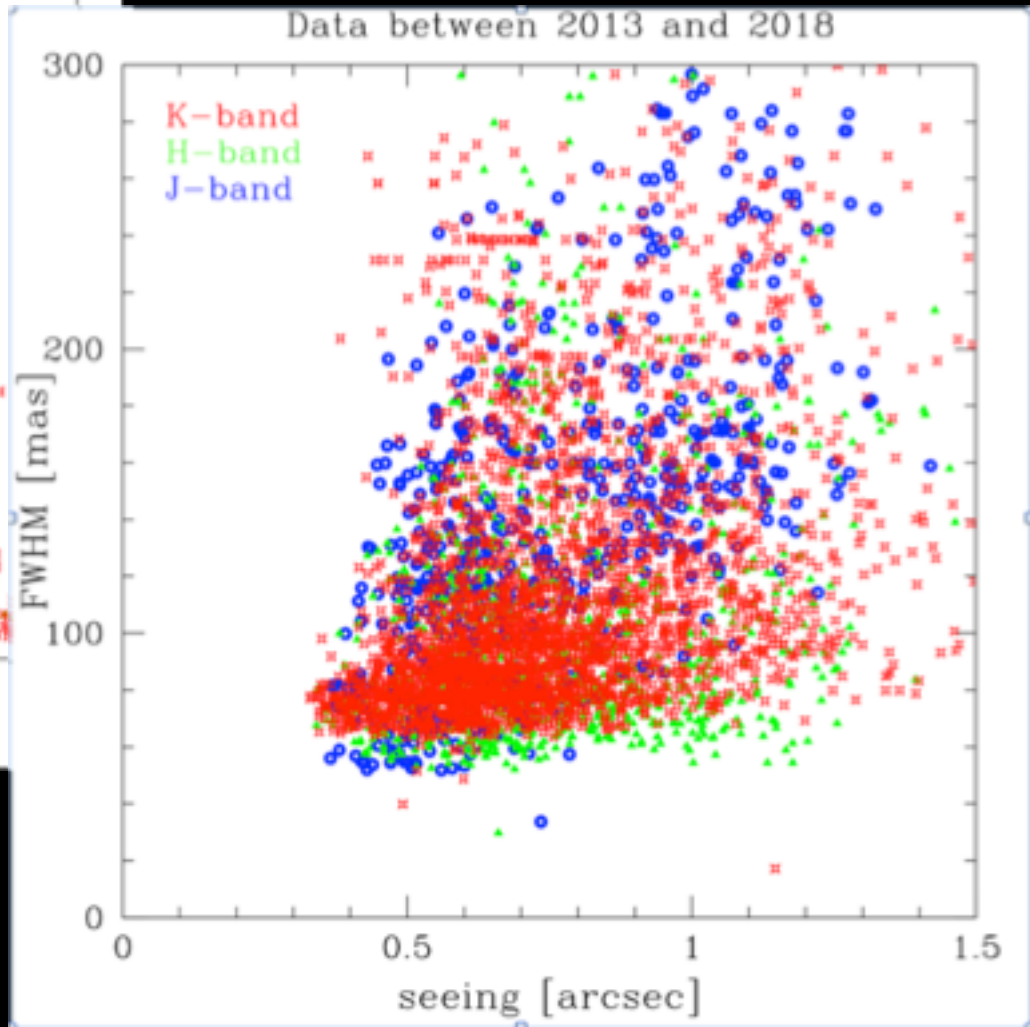


GMOS-S
MOS+IFU vis
R=4440-8800 R=150-1200

Overall performance 2013-18

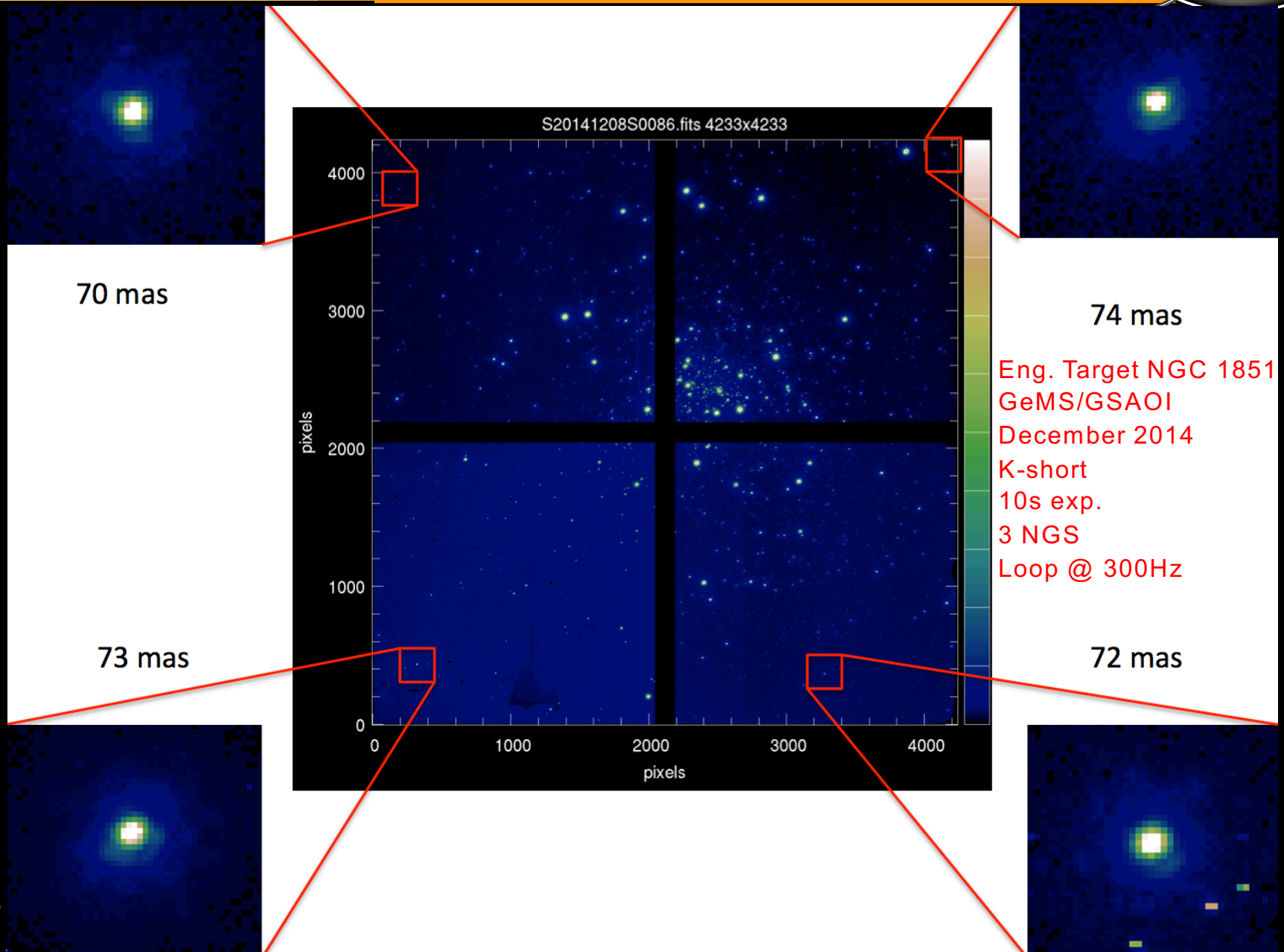


1 DM missing
LGS loop @ [100-600] Hz
800 Hz max
NGS up to mag = 15.5



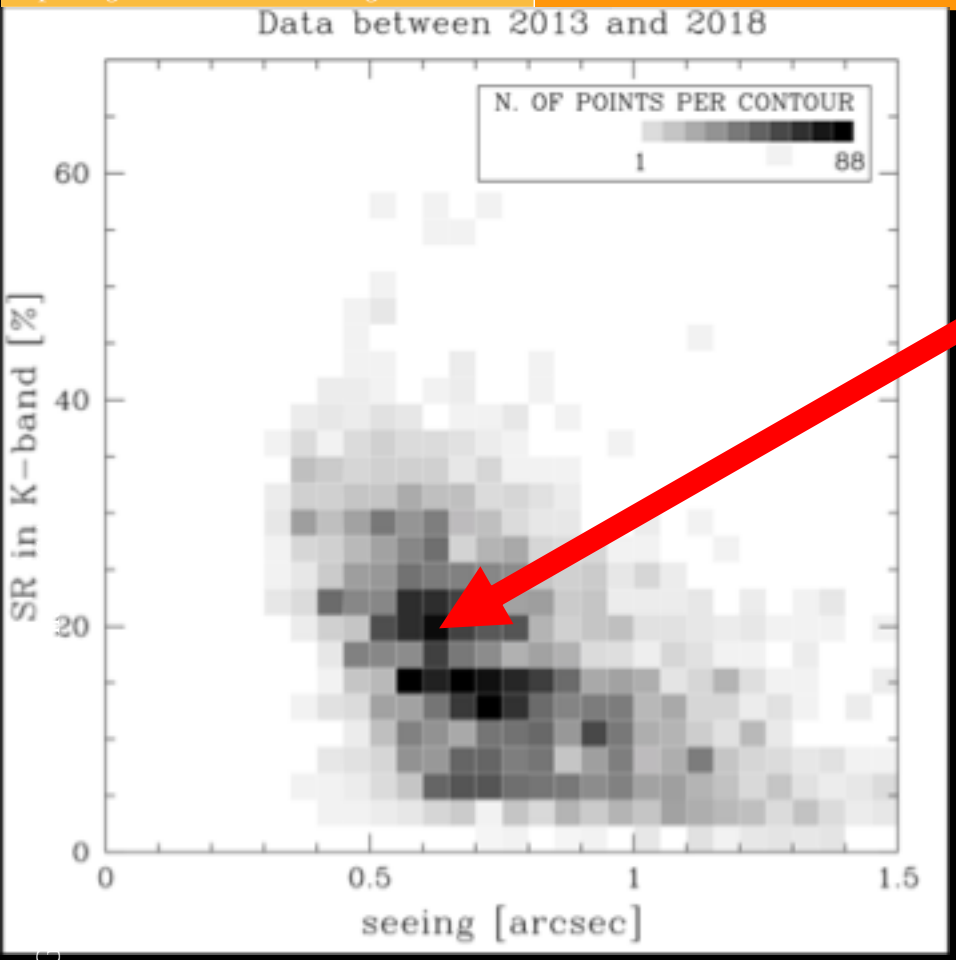
But still
a lot of science can be done !
128 science nights

Performance on science



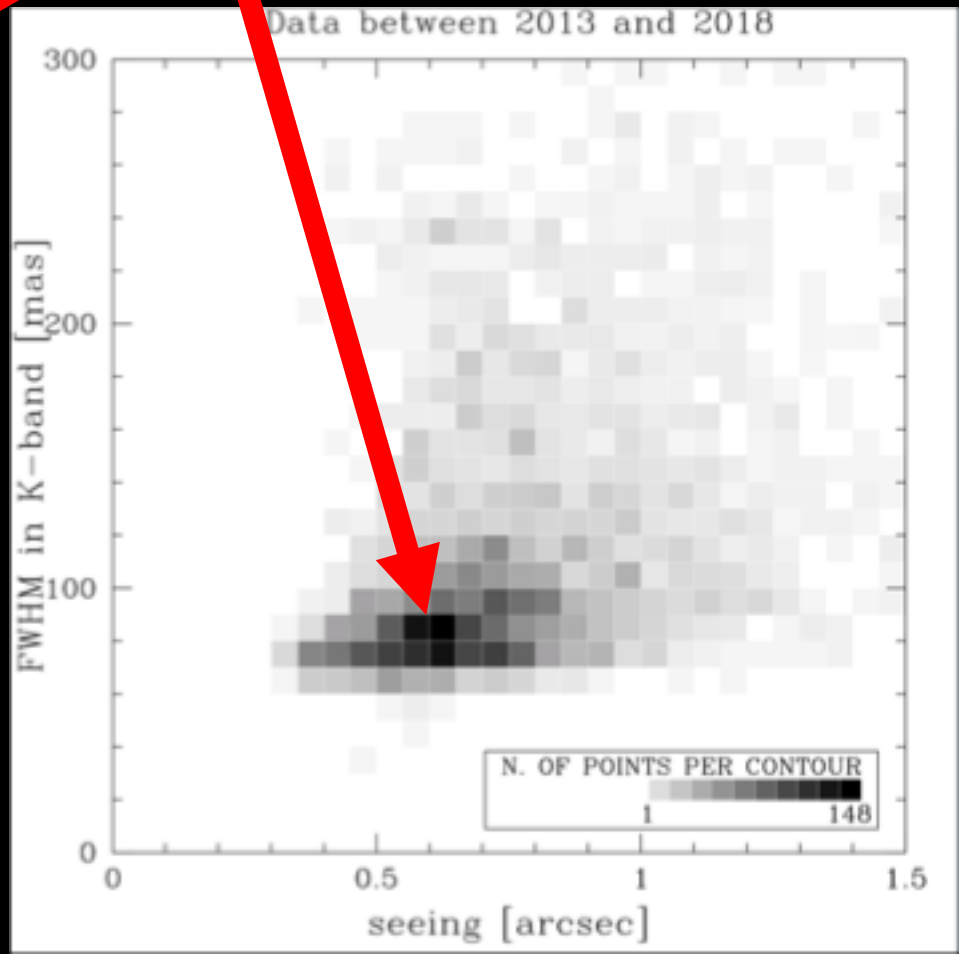
Eng. Target NGC 1851
GeMS/GSAOI
December 2014
K-short
10s exp.
3 NGS
Loop @ 300Hz

Overall performance 2013-18



Working point
SR = [15-20]%
FWHM = [75-85]mas

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



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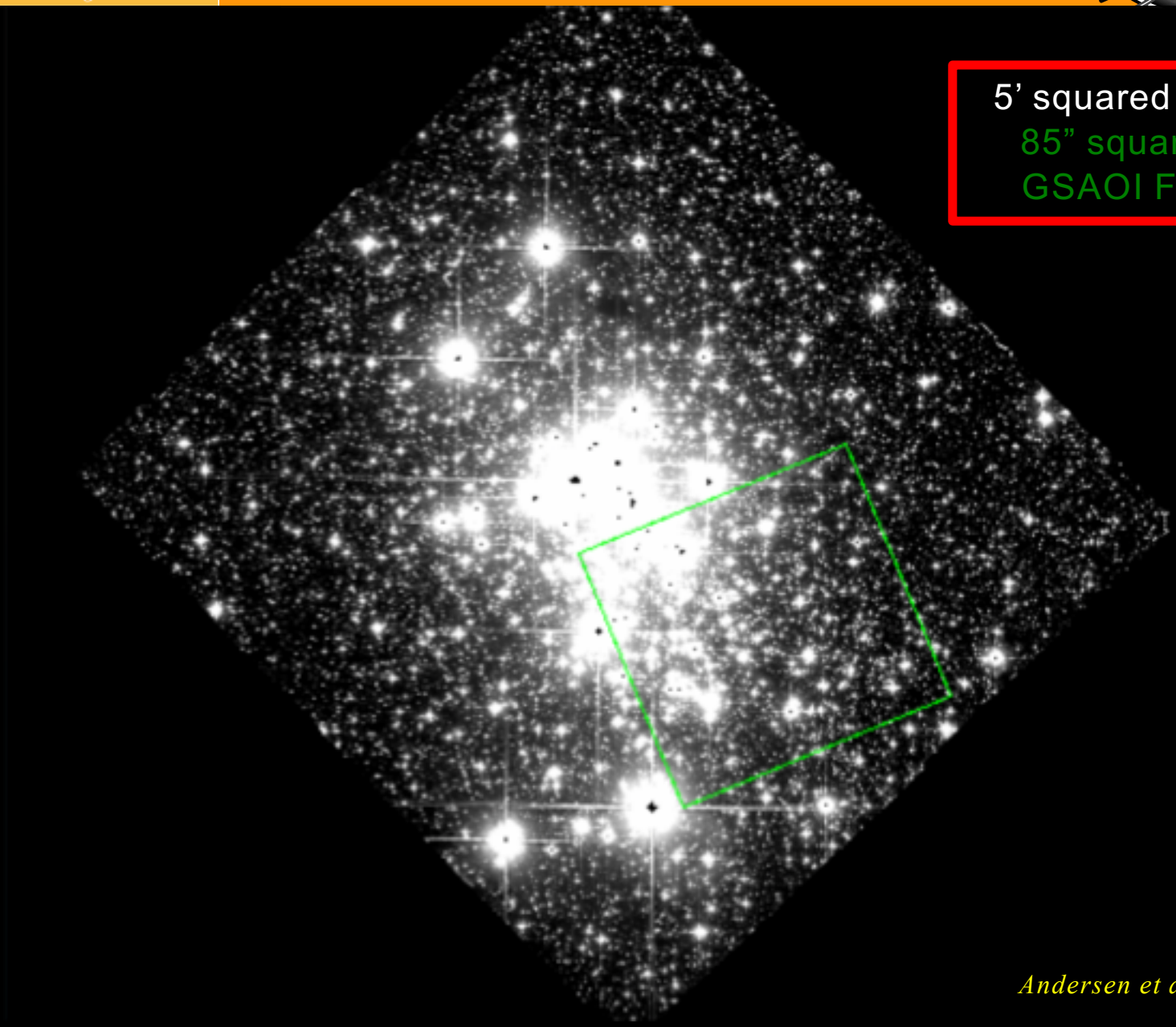
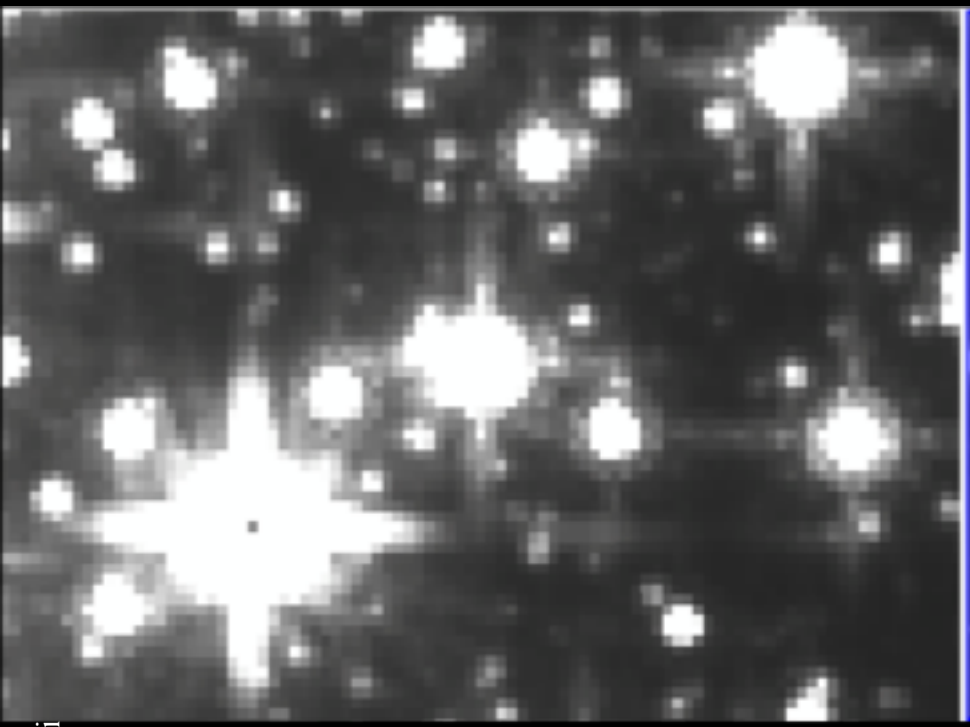
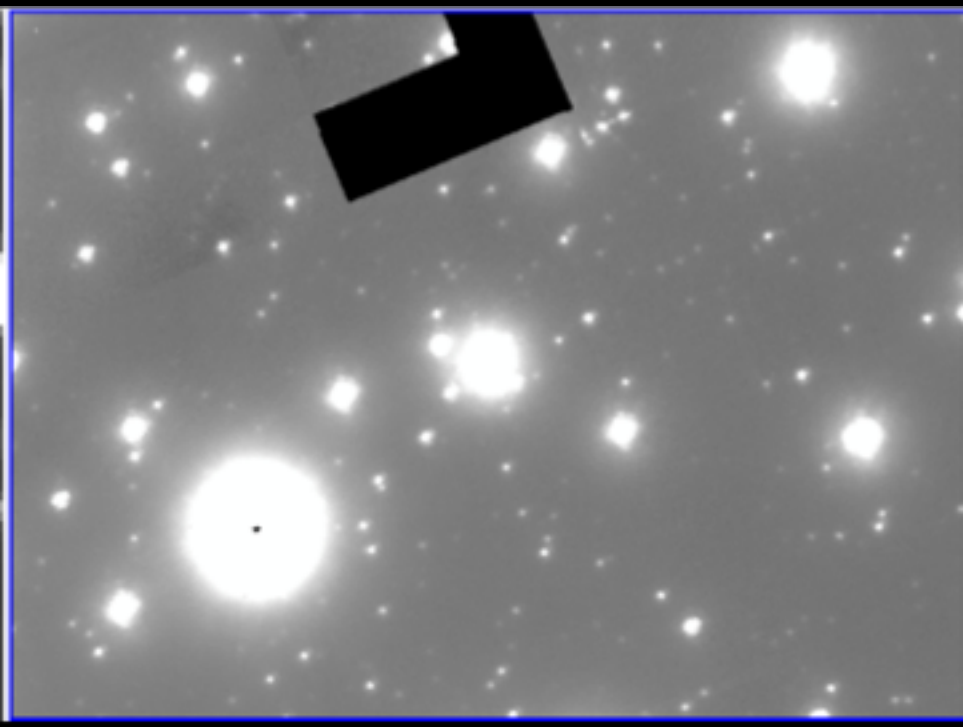
Ex. of science: Westerlund 1



Andersen et al, 2017

Ex. of science: Westerlund 1





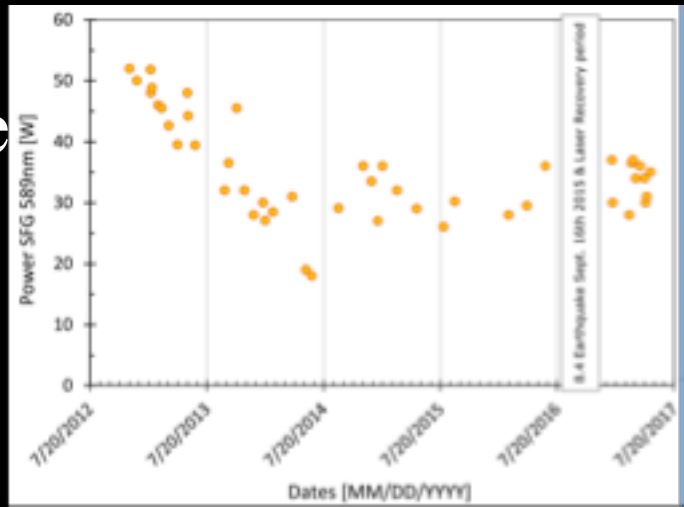
HST
H-band
150mas
2094s

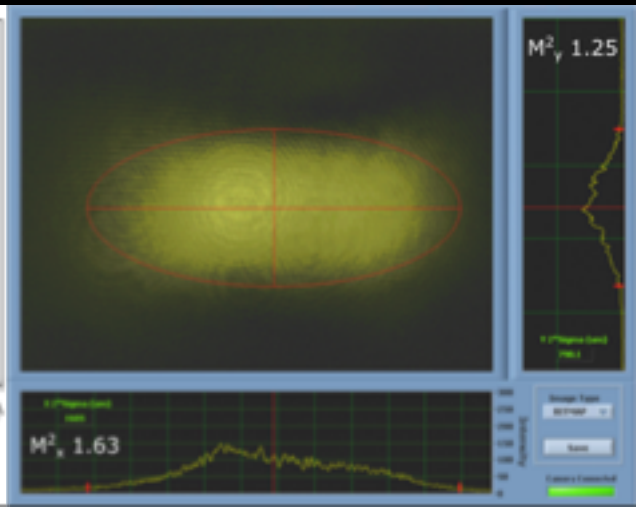
GeMS-GSAOI
Ks-band
85mas
900s

Courtesy G. Lawrence & M. Andersen

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 issue

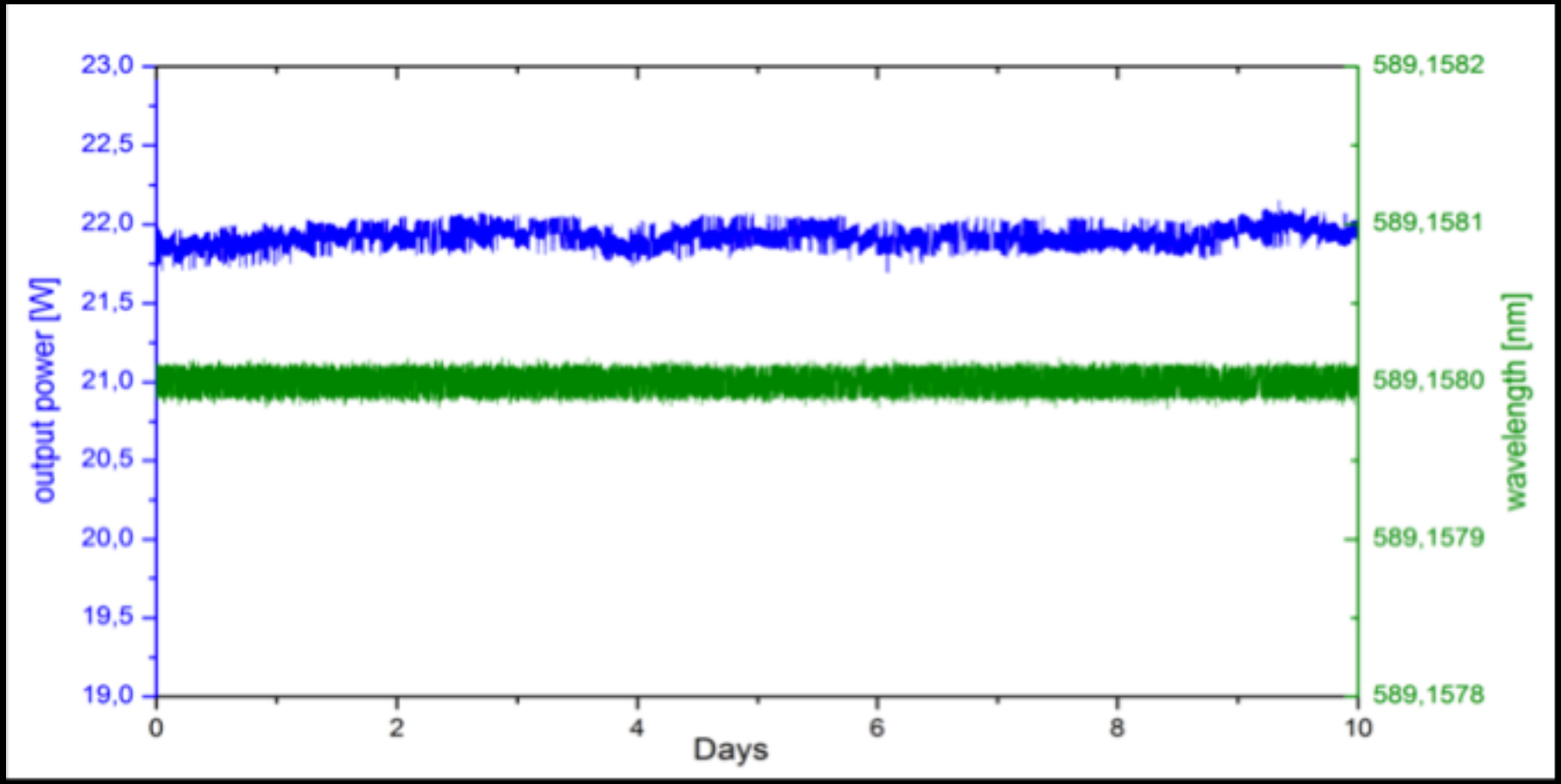




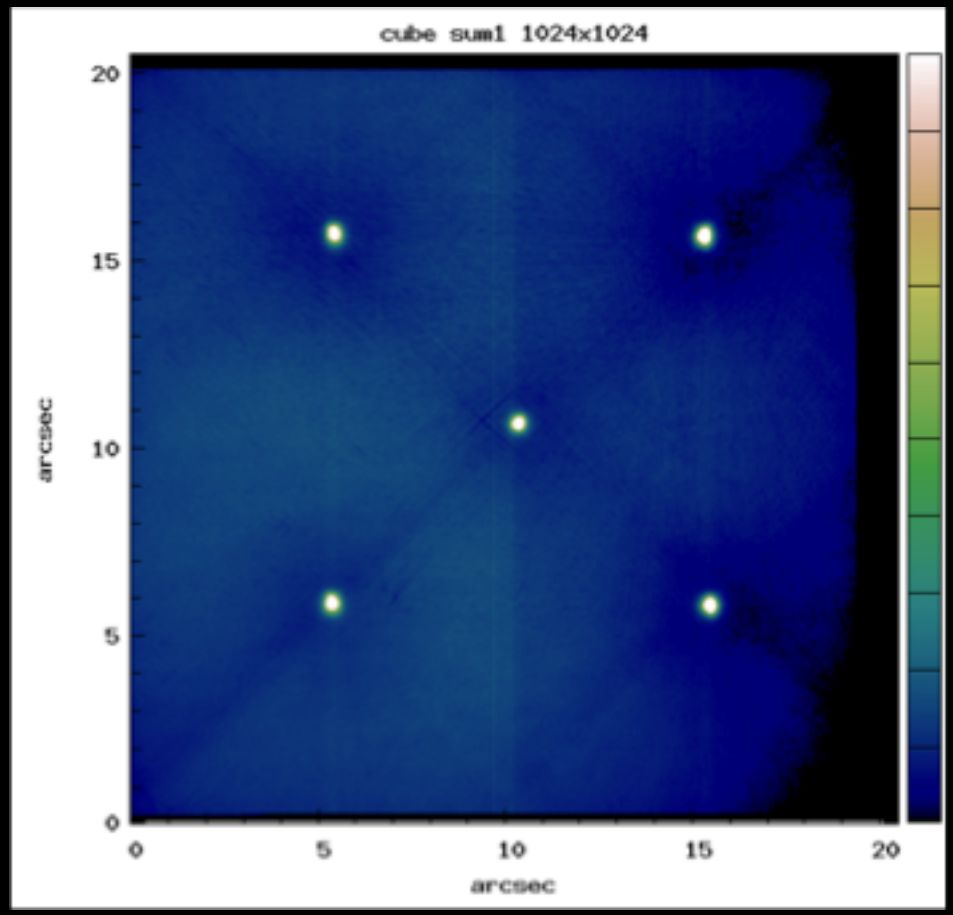
New Laser

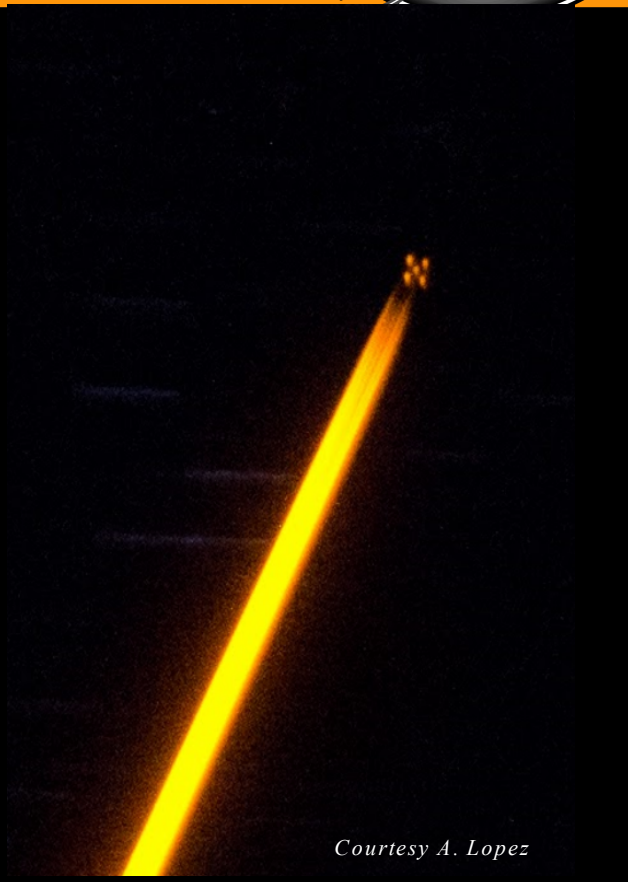
- Main requirements:
  - Photon return ≥ $5x10^6$ photons m^{-2}
  - Central wavelength: 589.159nm with repumping option (589.157nm)
  - Stability better than 100 MHz over 14 hours (if pure D2a CW)
  - Beam quality: M2 < 1.4
  - Demonstrated robustness (long term operations without power drops)
  - Operational at 2700m in altitude
  - Total mass shall not exceed 1000kg
- After the revision and selection process, the Toptica SodiumStar 20/2 laser was selected.

Toptica output power/λ stability



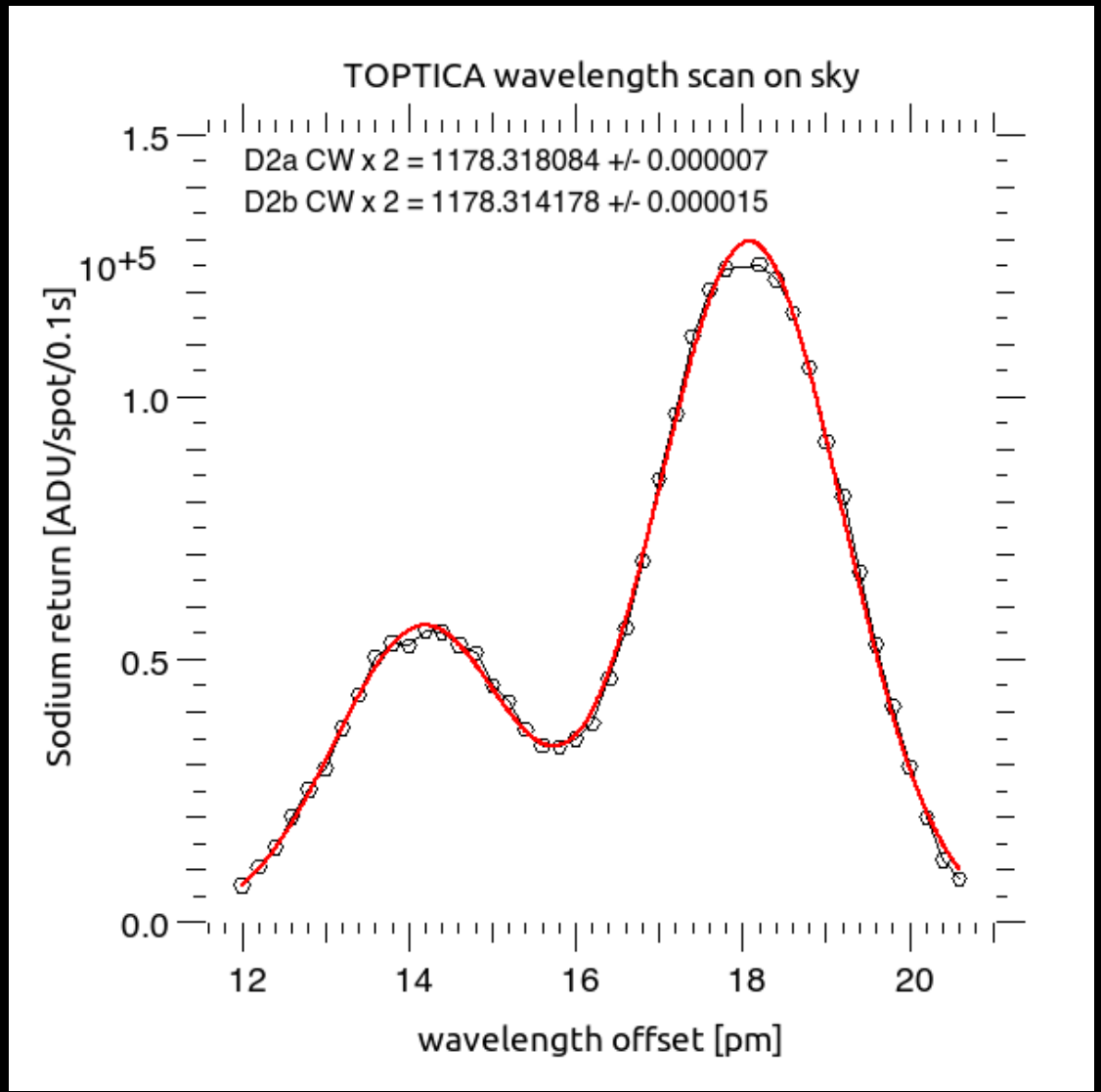
Toptica on-sky





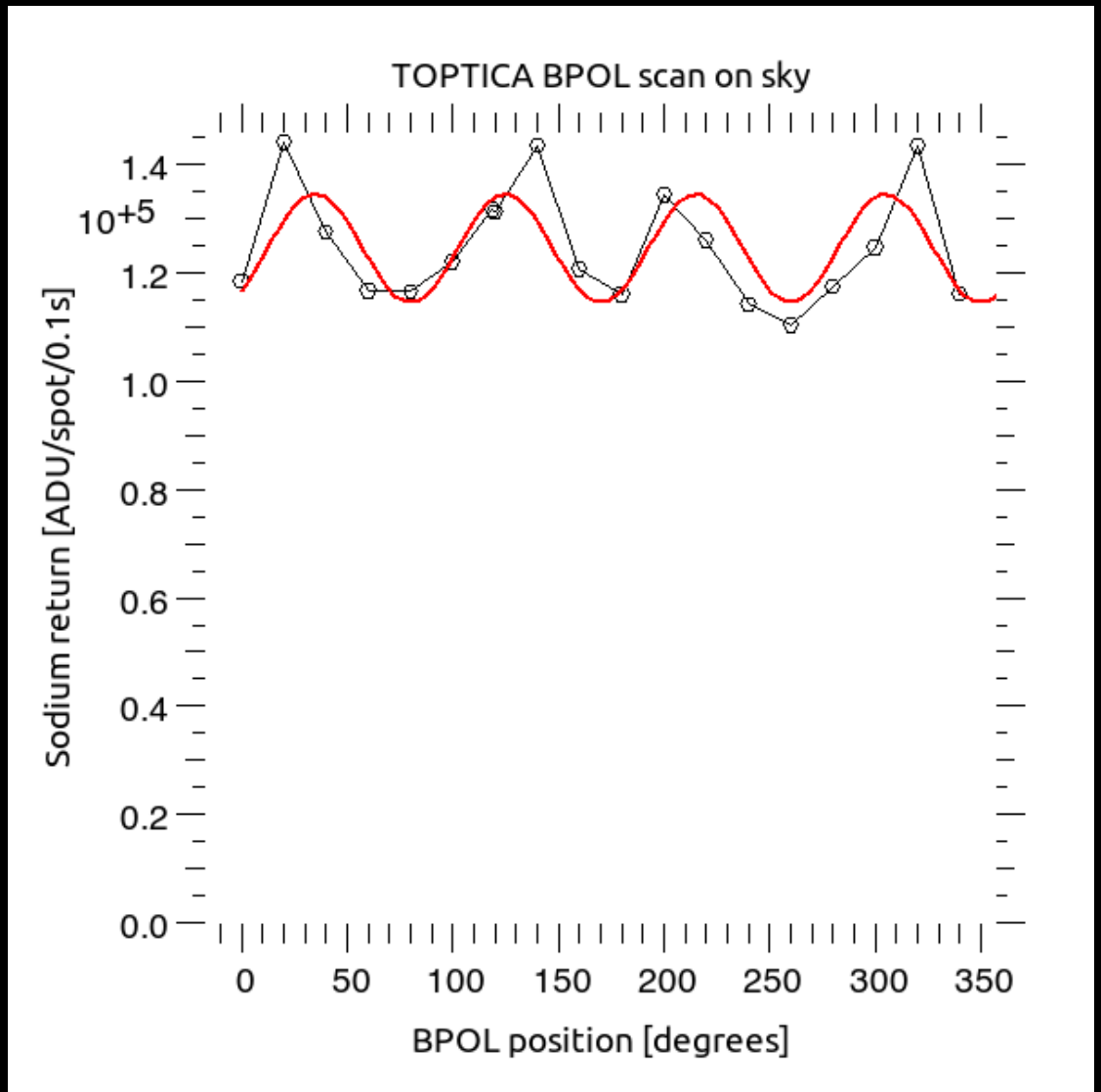
Optimization on-sky: wavelength scan

- Scan seed laser wavelength (before doubling) ➔ find best value for D2a line peak

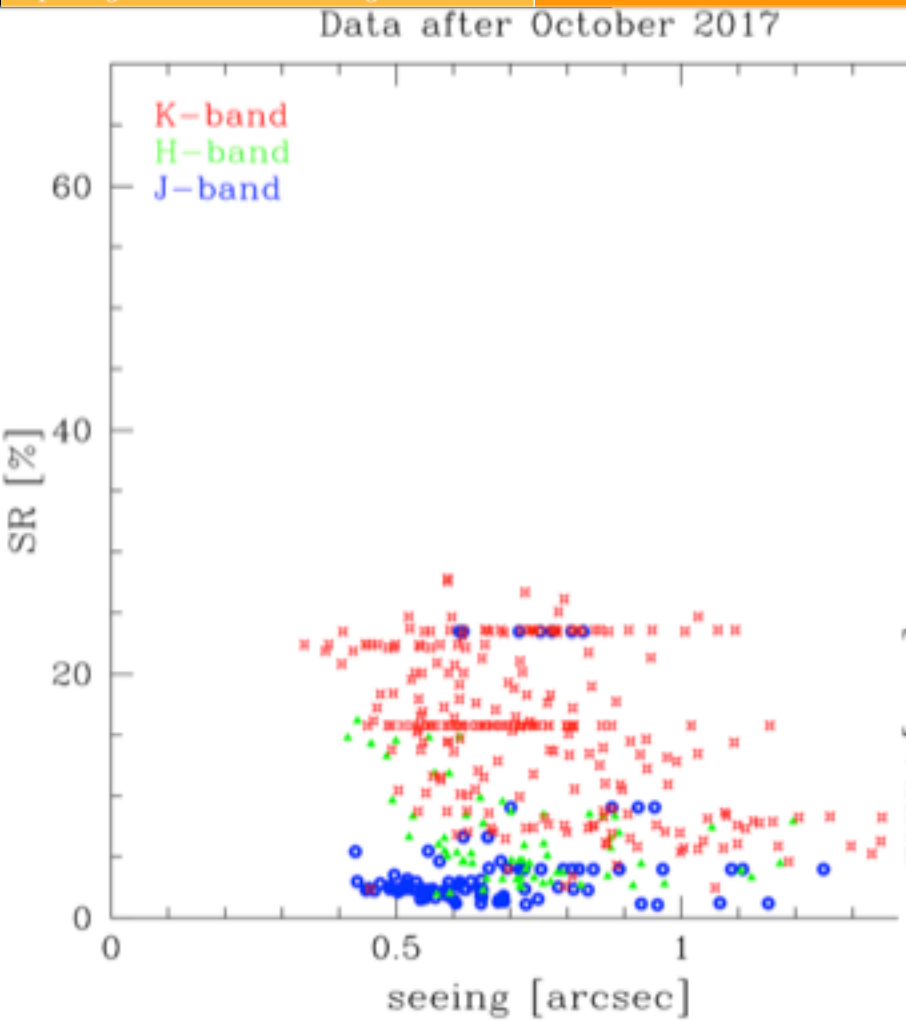


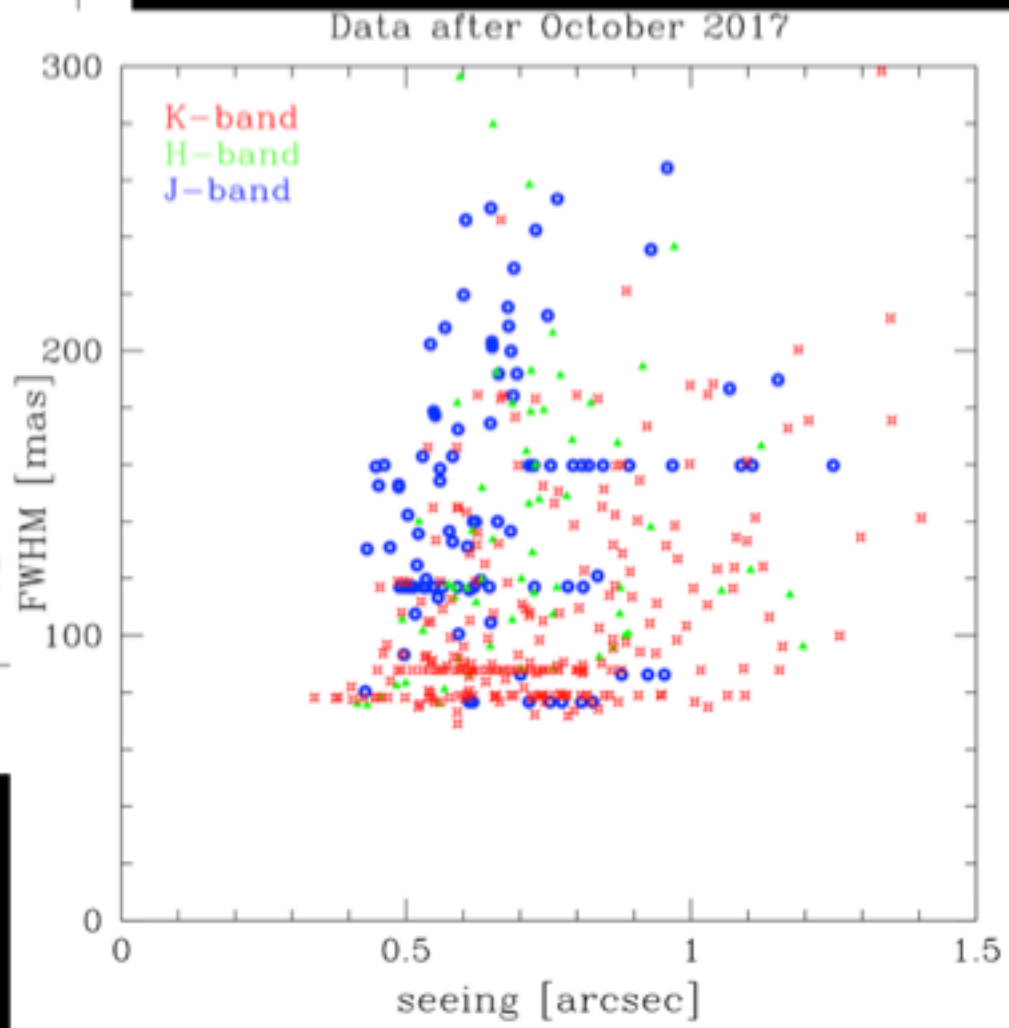
Optimization on-sky: Bpol scan

- Scan of polarization angle optimum by rotating Bpol ➔ 4 peaks



AO performance using Toptica laser





Gaetano Siv

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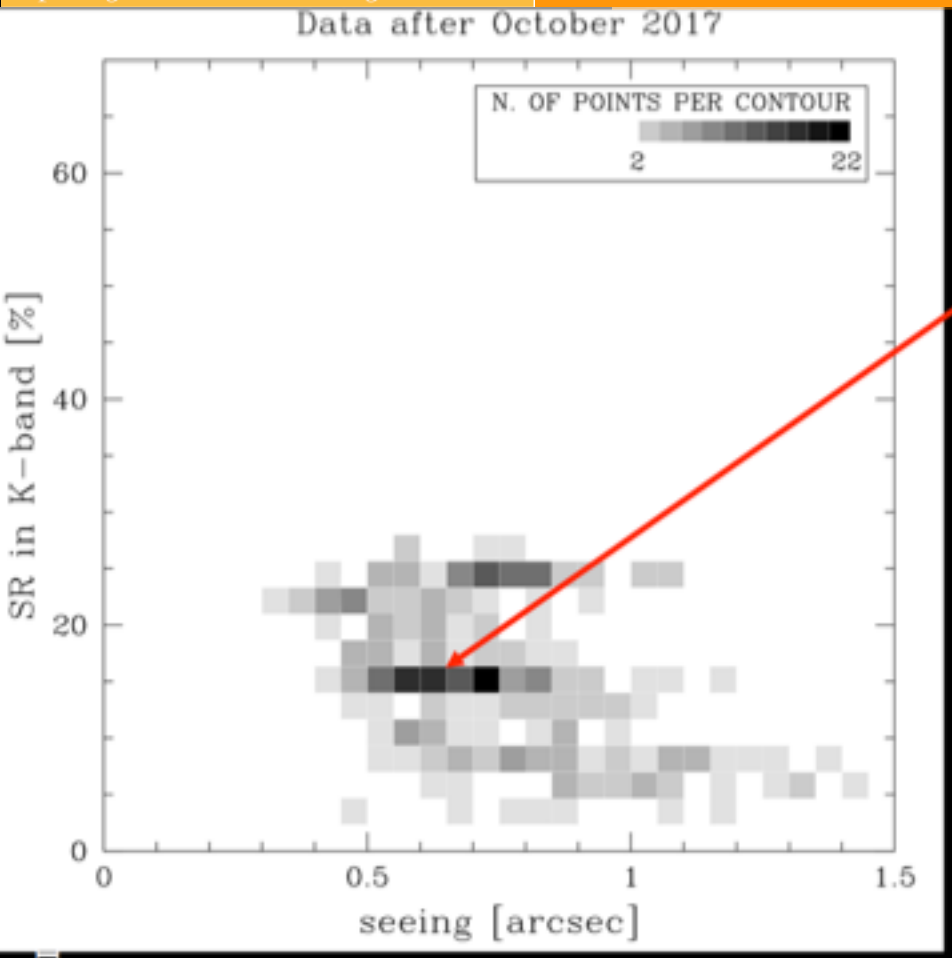
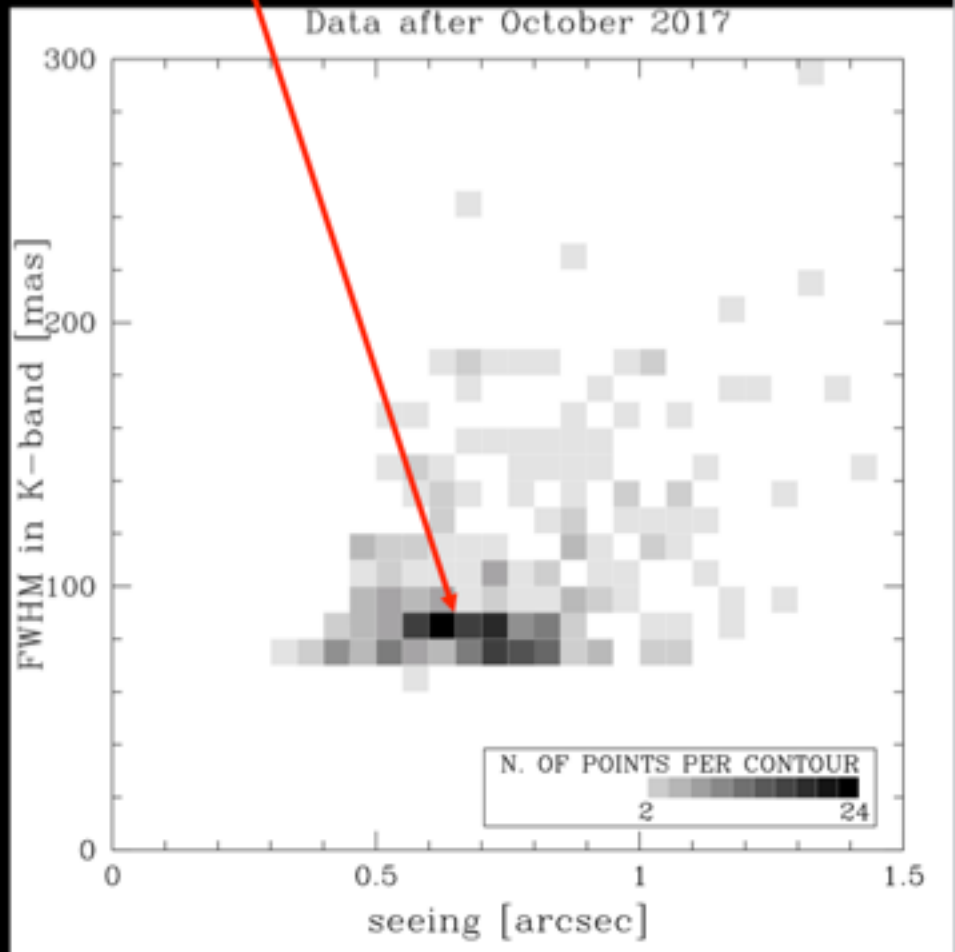
But still
a lot of science can be done !
12 science nights

AO performance using Toptica laser



Working point in K
SR ~15%
FWHM~80mas



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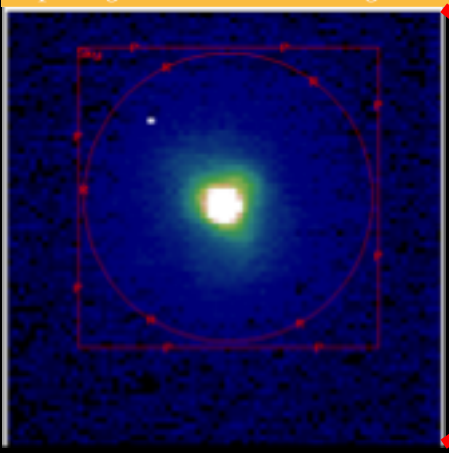
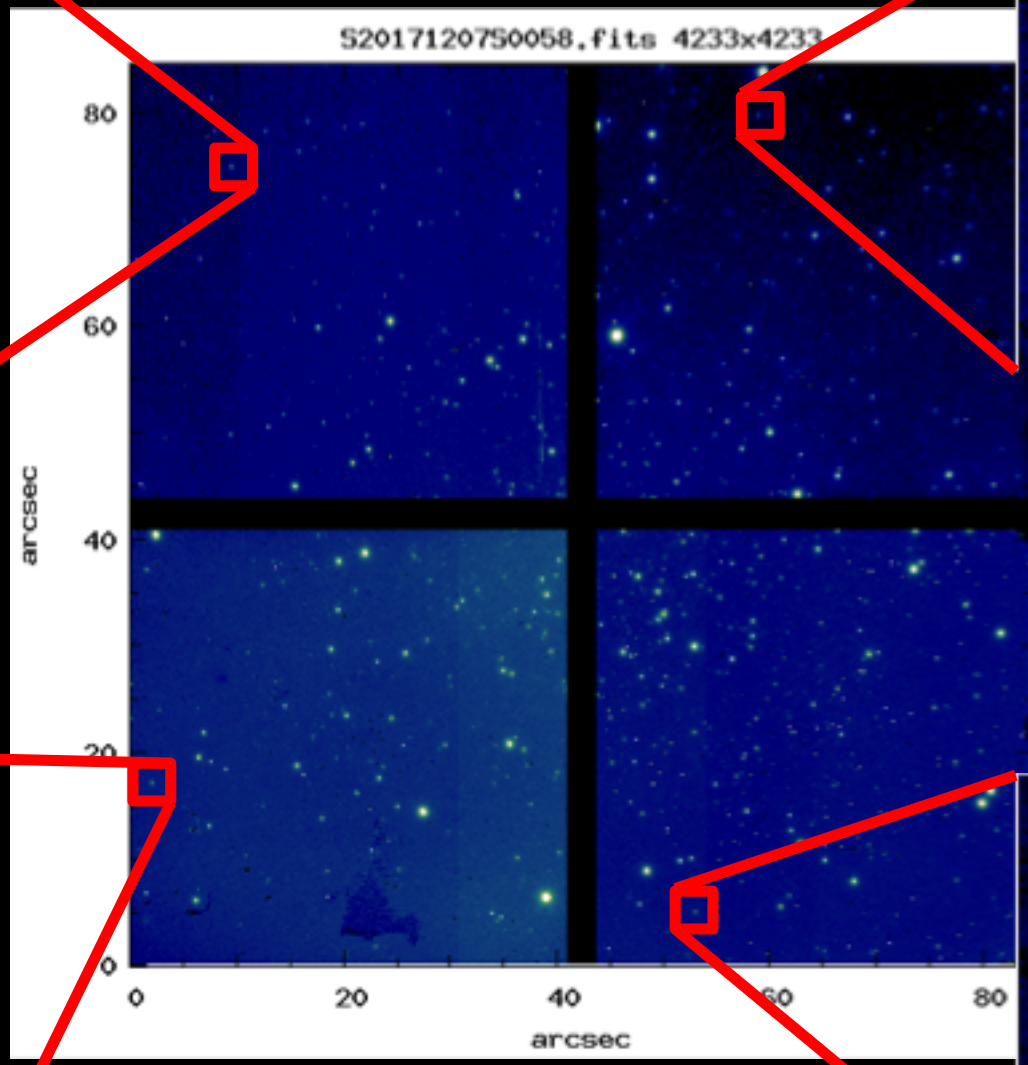
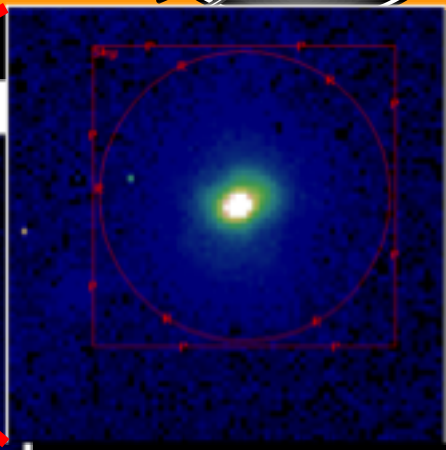
Performance on science



85mas



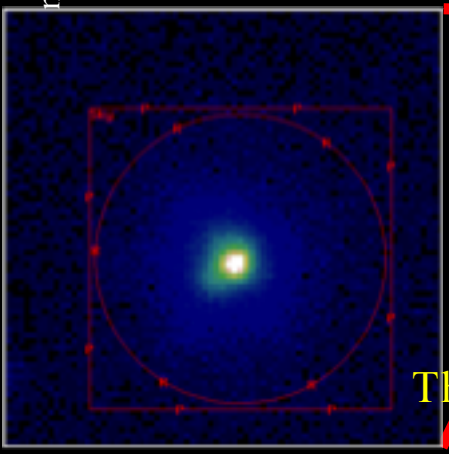


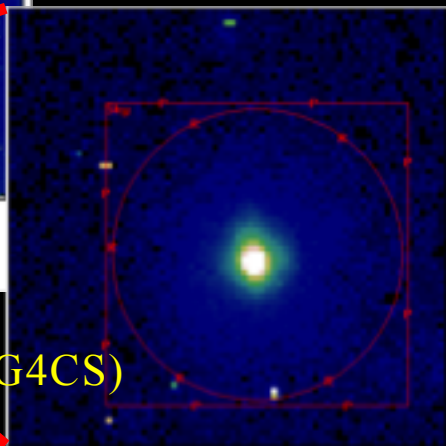
91mas

ID: GS-2017B-Q-25
PI: T. Puzia (PUC)
K-short
30s exp.
3 NGS
Seeing: 0.7”

91mas

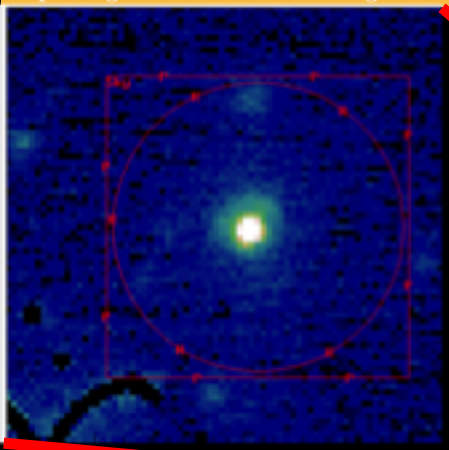
89mas



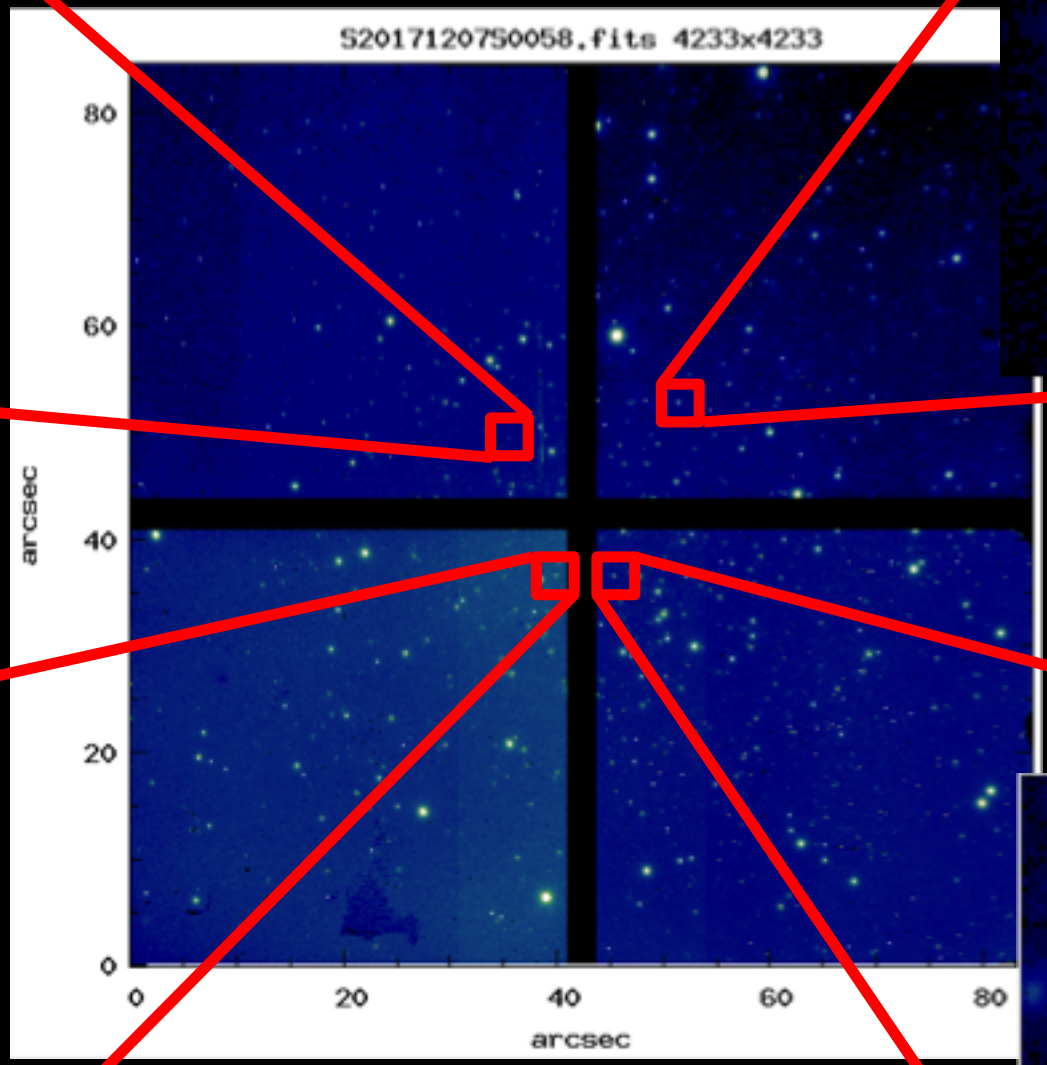


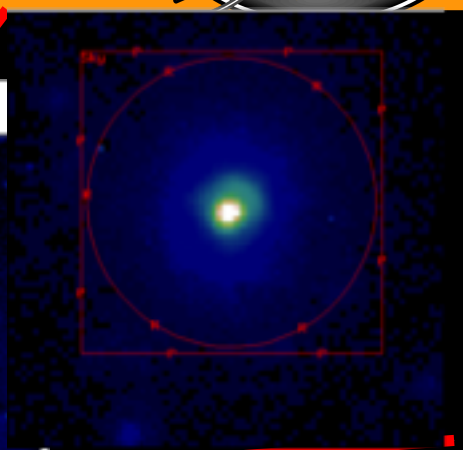
The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS)

Performance on science



75mas

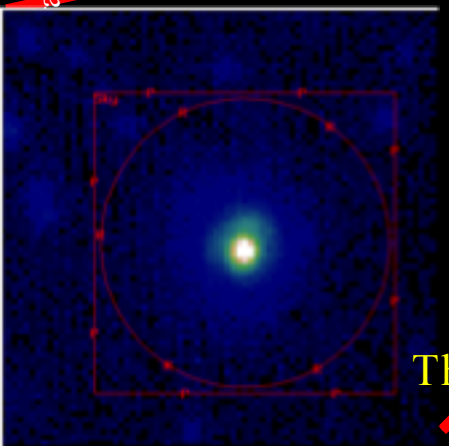




79mas

ID: GS-2017B-Q-25
PI: T. Puzia (PUC)
K-short
30s exp.
3 NGS
Seeing: 0.7”

78mas



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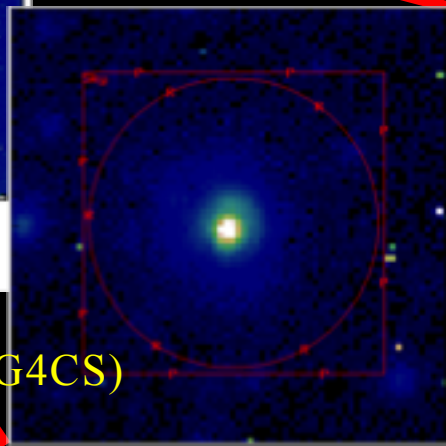
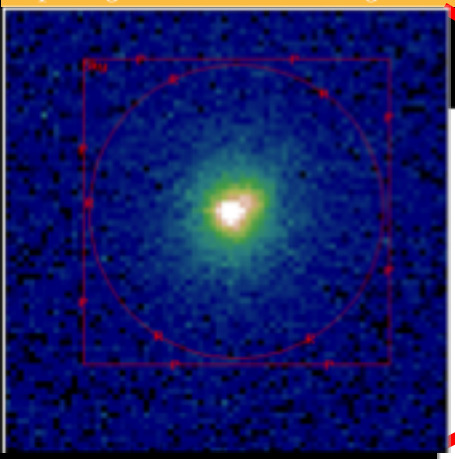
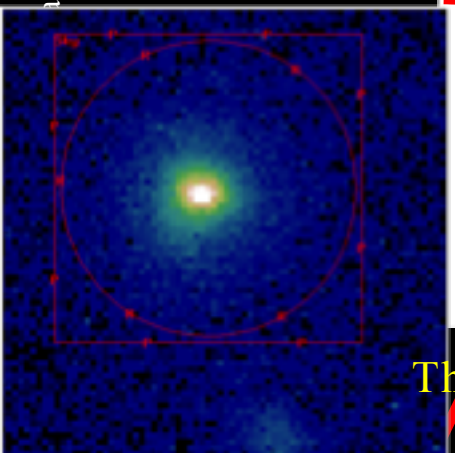


The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS)

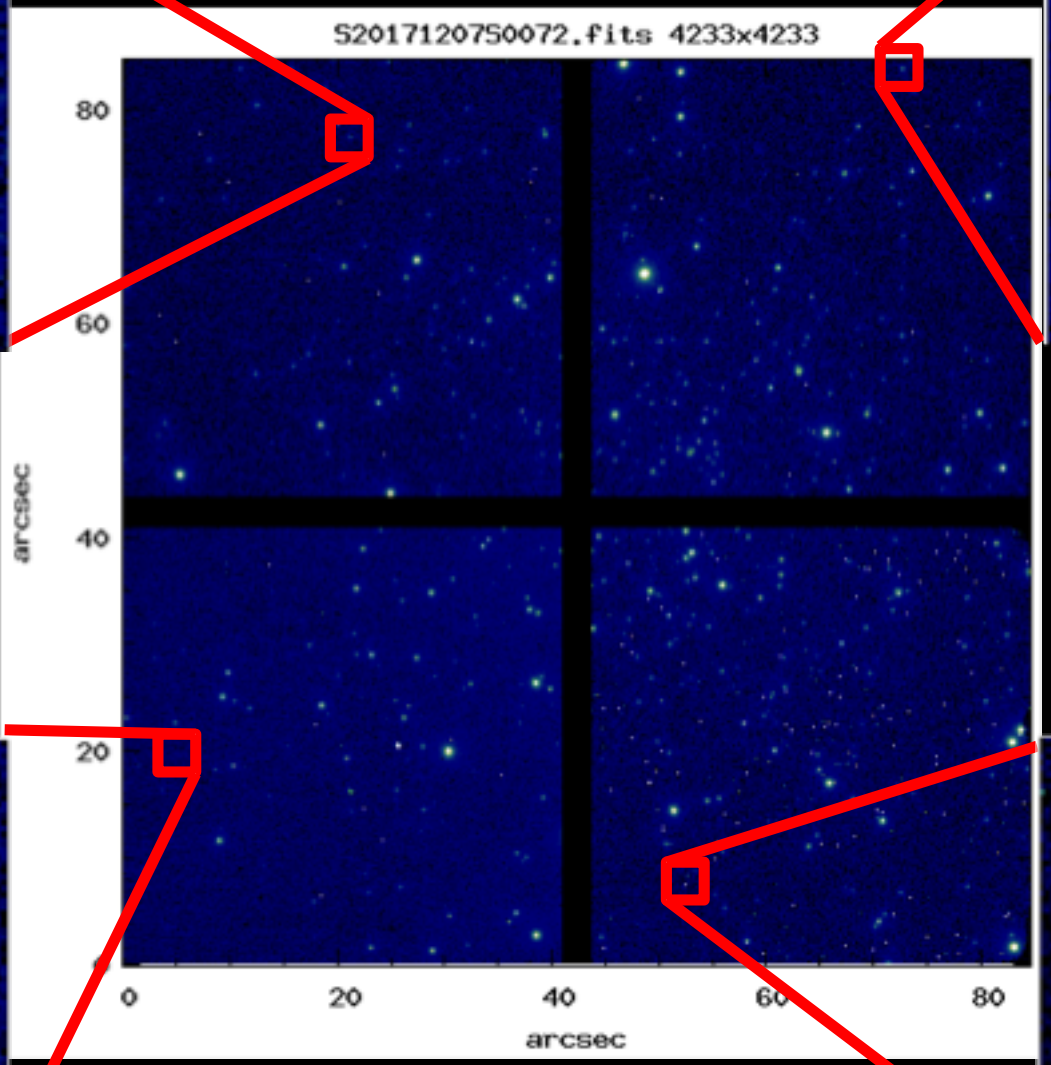
Performance on science

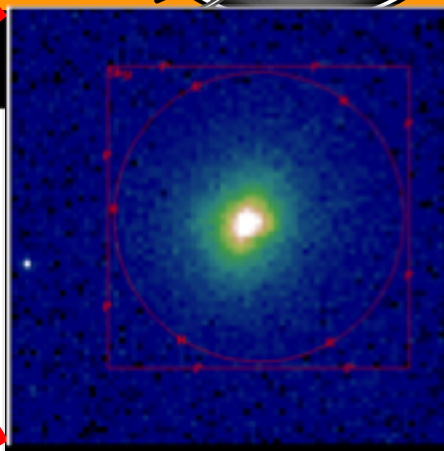


131mas



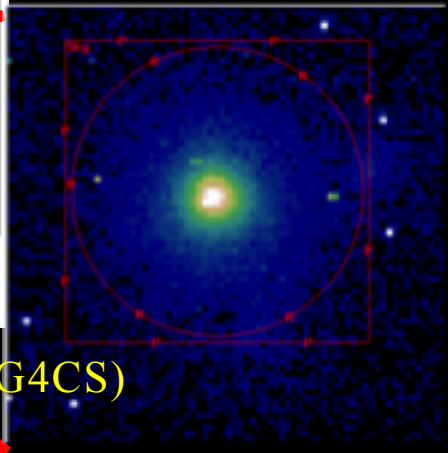
136mas





140mas

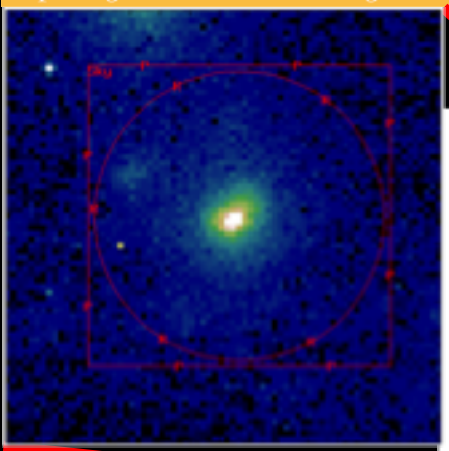
ID: GS-2017B-Q-25
PI: T. Puzia (PUC)
J
30s exp.
3 NGS
Seeing: 0.7”



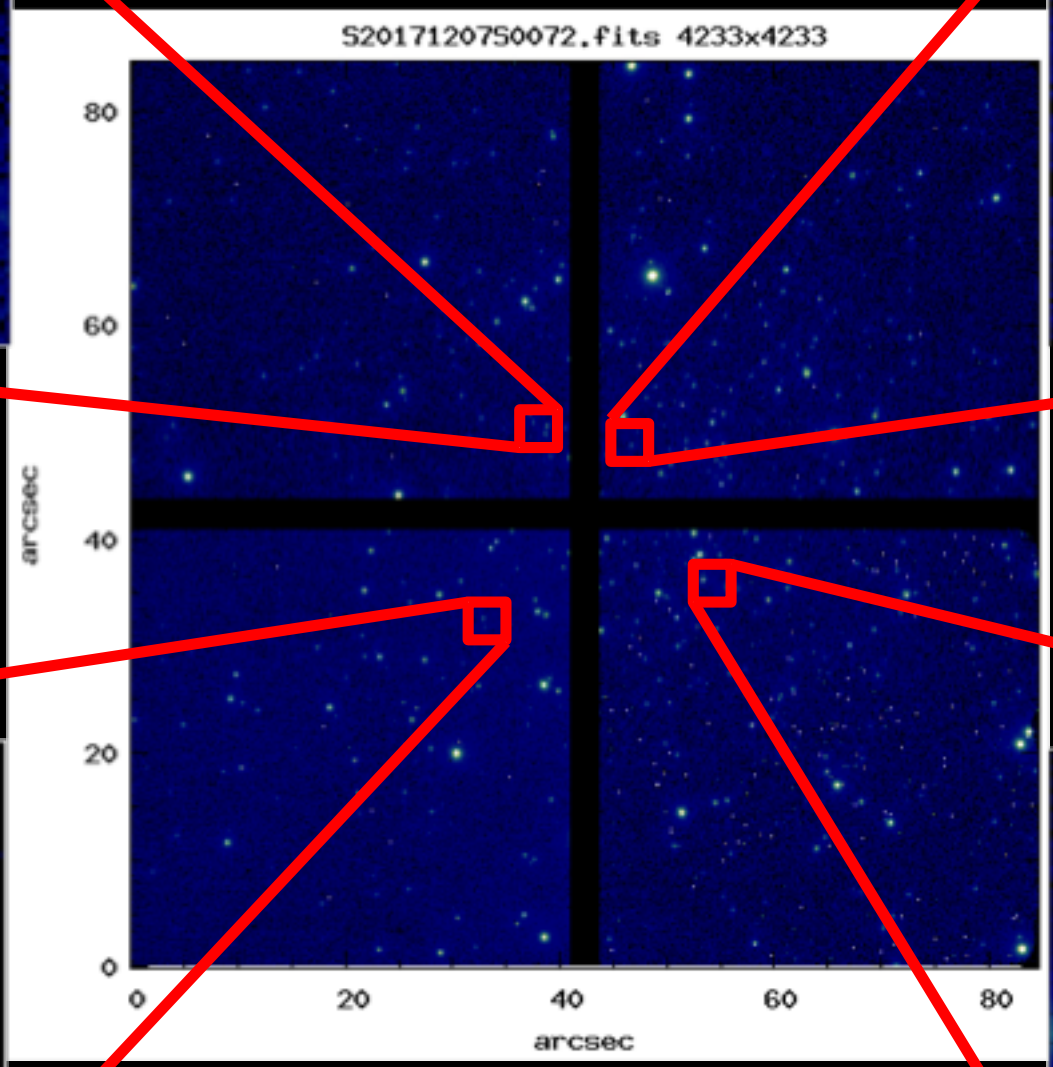
135mas

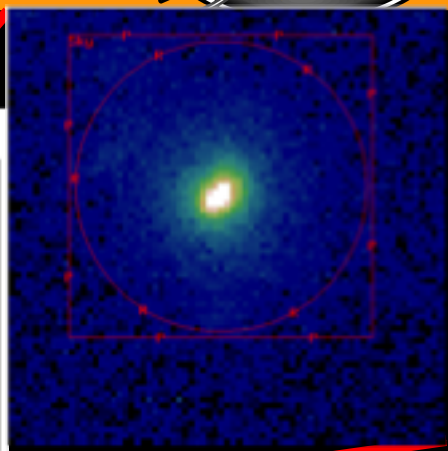
The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS)

Performance on science



96mas

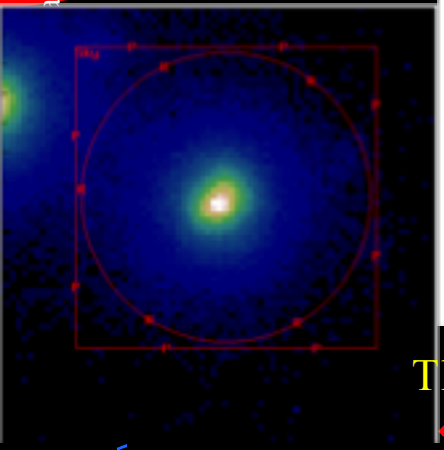




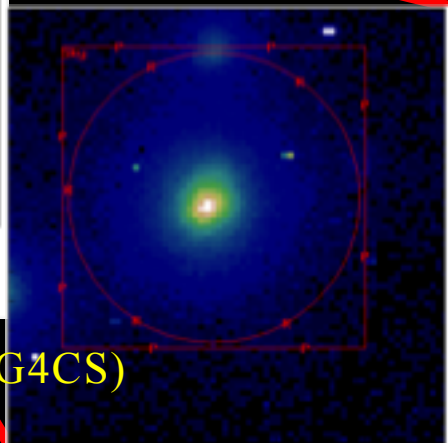
101mas

ID: GS-2017B-Q-25
PI: T. Puzia (PUC)
J
30s exp.
3 NGS
Seeing: 0.7”

120mas



110mas

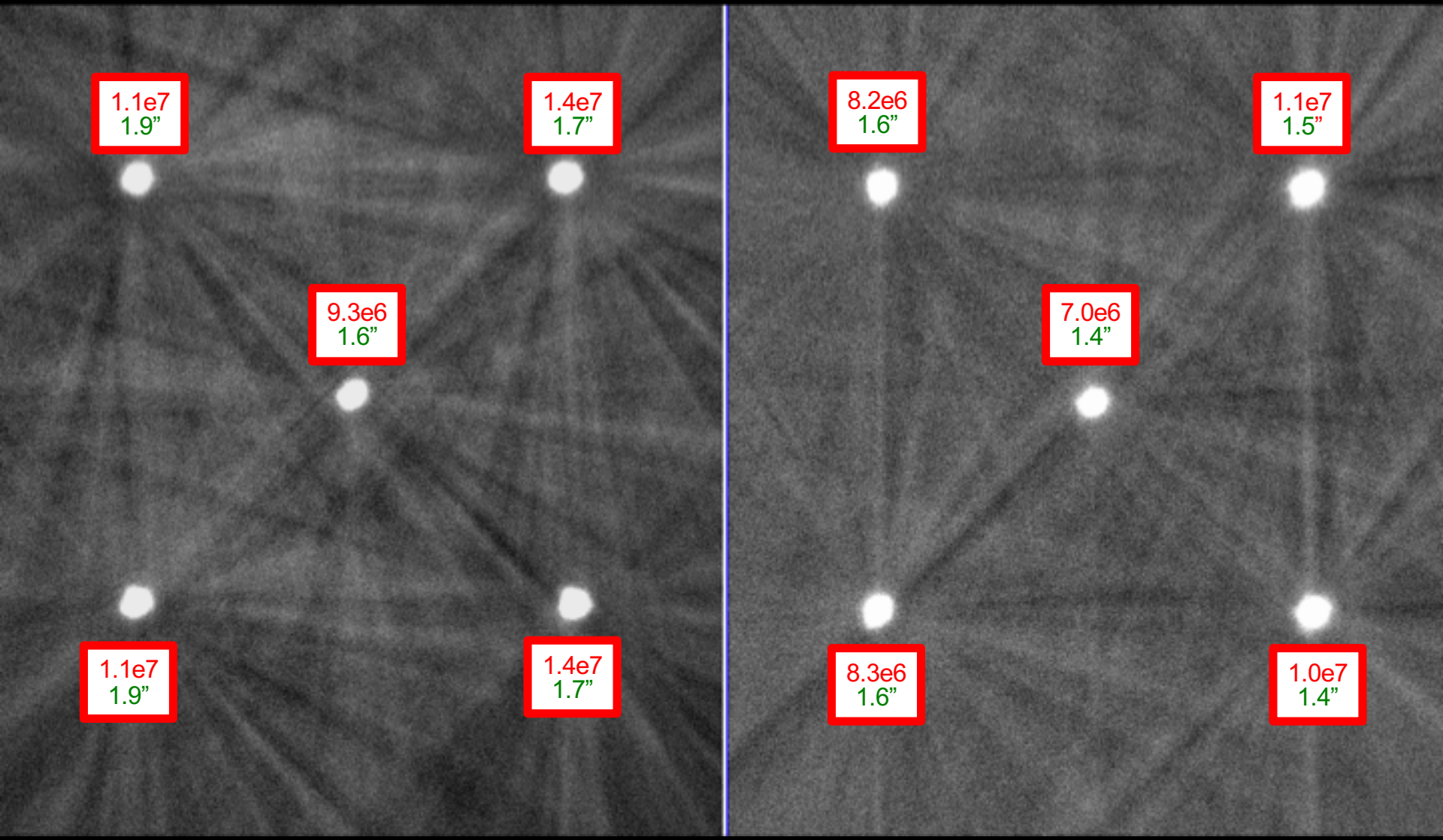


The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS)

Comparison Toptica/LMCT

LMCT 44W

Toptica 22W

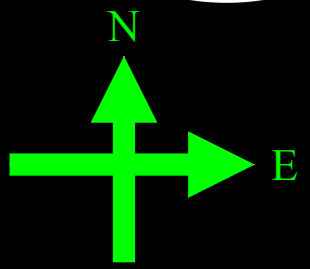


5 images stacked and Rayleigh subtracted

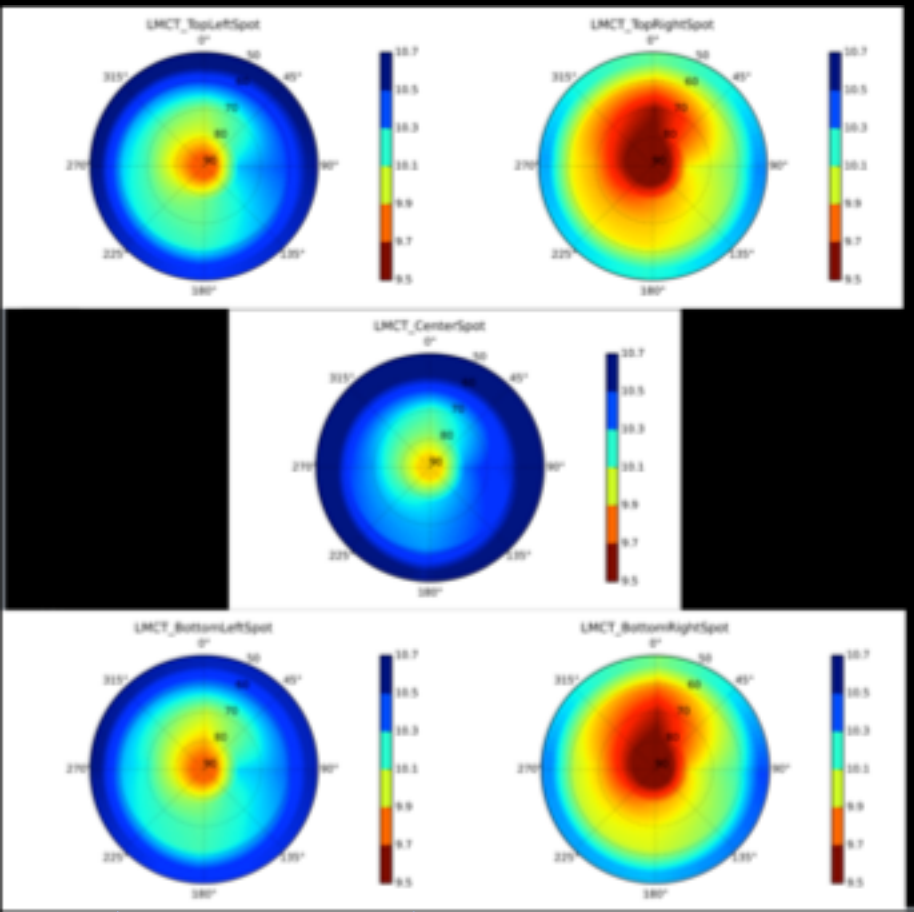
Smaller spot on sky !

Na return wrt telescope pointing

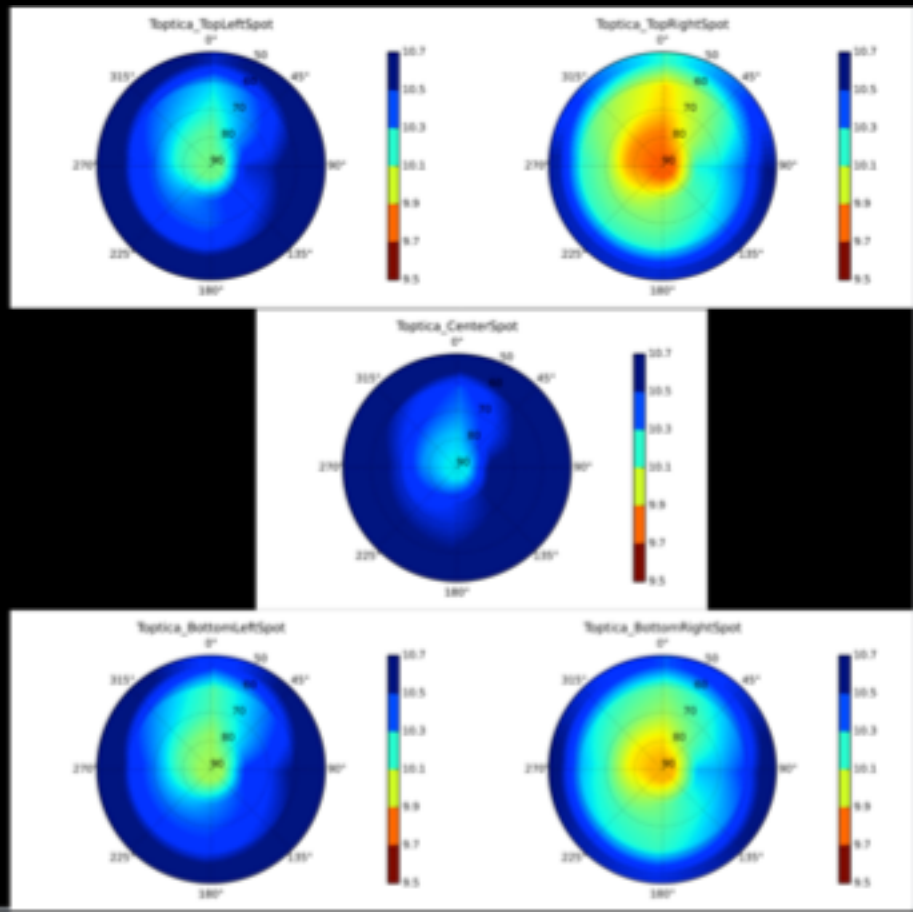
- For both laser: AcqCam images recorded at:
  - AZ = [0,90,180,270]
  - EL = [90,80,70,60,50]



LMCT



Toptica

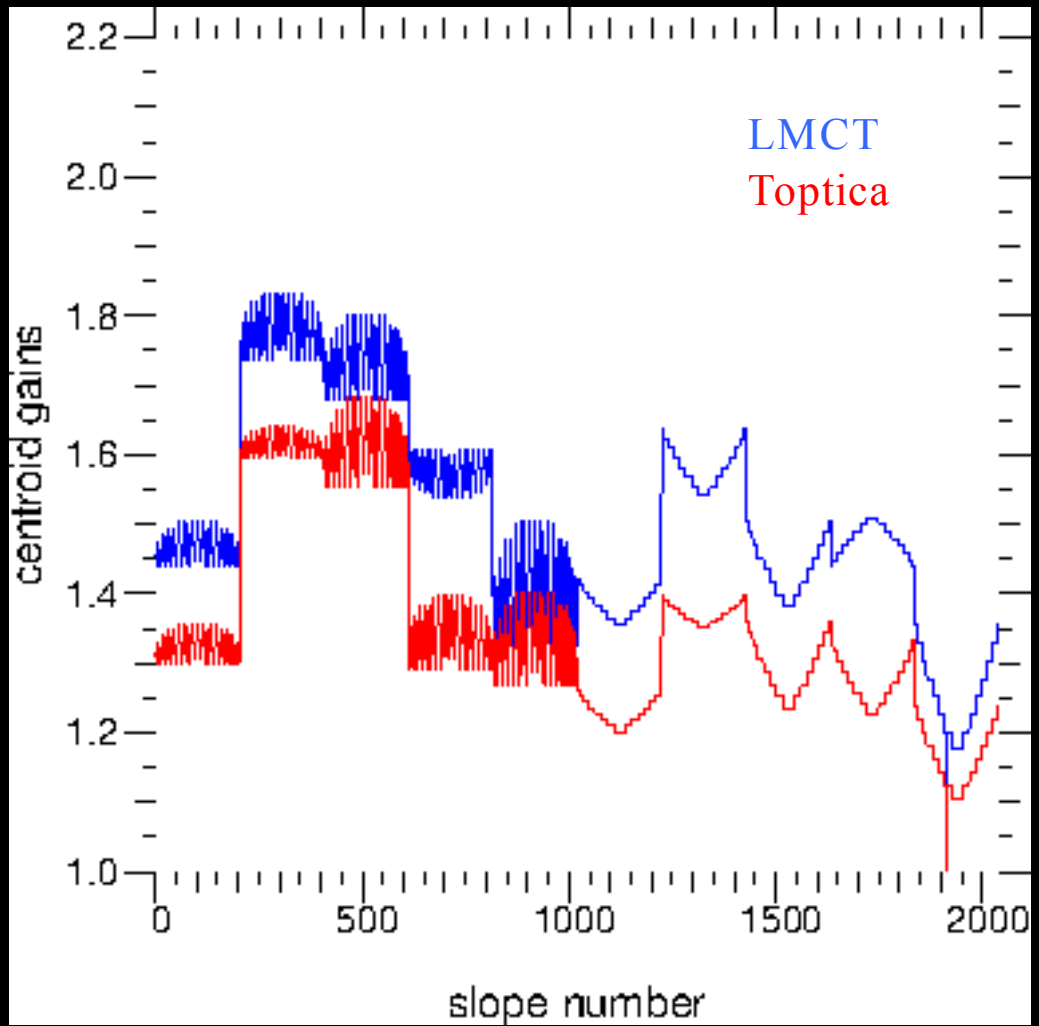


Back to laser requirements

- Main requirements:
  - Minimum photon return: 5×10^6 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 term operations without power drops)
  - Operational at 2700m in altitude
  - Total mass shall not exceed 1000kg

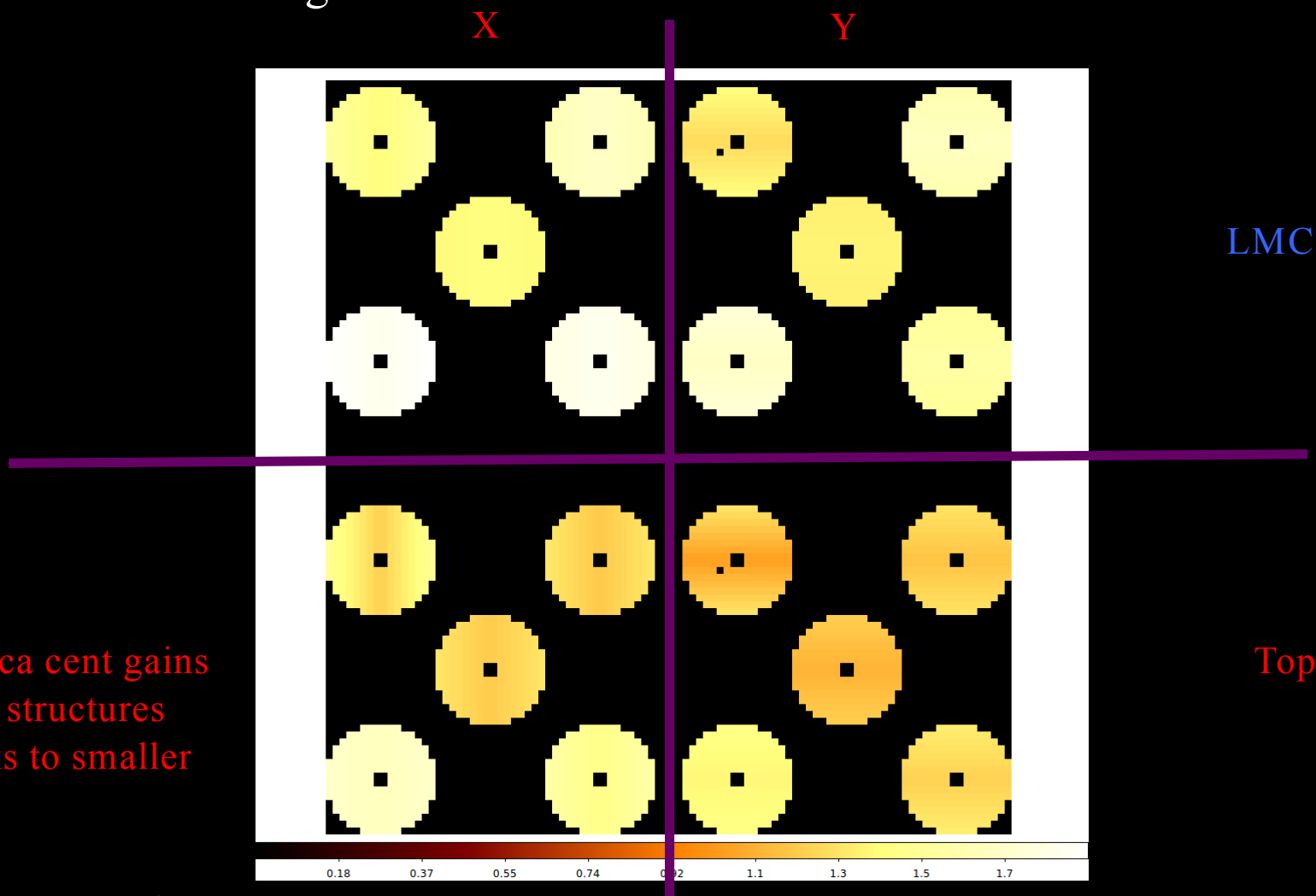
AO performance using Toptica laser

- Centroid gains comparison (centroid to arcsec conversion)
  - Cent gains Toptica < cent gains LMCT (~15%) ➔ Toptica spot ~15% smaller in the quadcell
  - Noise ~ FWHM/sqrt(N) ➔ 15% smaller spot ➔ noise measurement decrease by 30%



AO performance using Toptica laser

- Centroid gains comparison (centroid to arcsec conversion)
  - Cent gains Toptica < cent gains LMCT (~15%) ➔ Toptica spot ~15% smaller in the quadcell
- Structure of centroid gains



Toptica cent gains more structures thanks to smaller spots

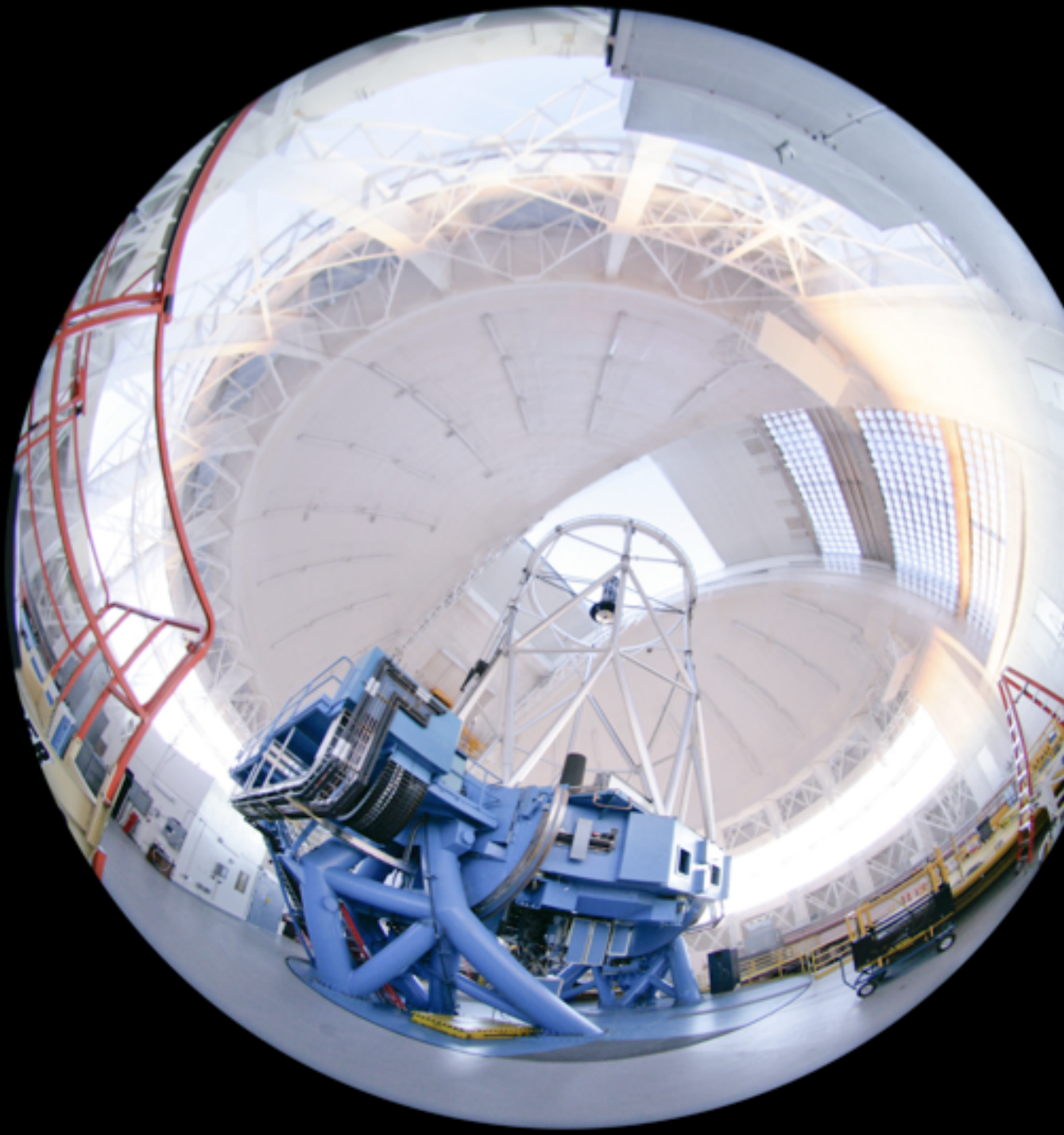
GeMS roadmap

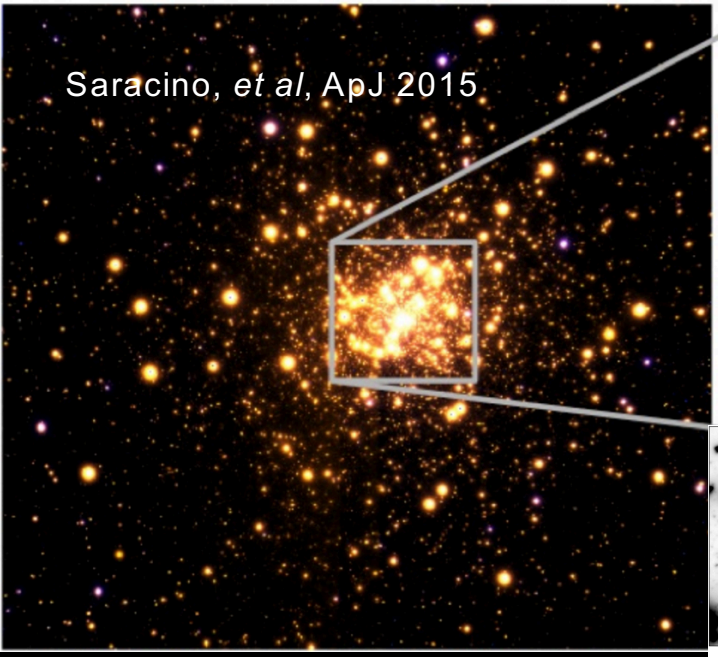
- GeMS is in “regular” operation since 2013
  - Performance under specs but still very good and unique
  - Provide good science, more and more papers being published
- GeMS 2.0 has started
  - New laser is commissioned
    - Improved reliability, stability and performance
    - Unique comparison has been done with older technology
  - NGS2 on its way
    - Commissioning 2019?
  - New DM0 is built
    - Electronics is almost ready
    - FAT sometime in 2018

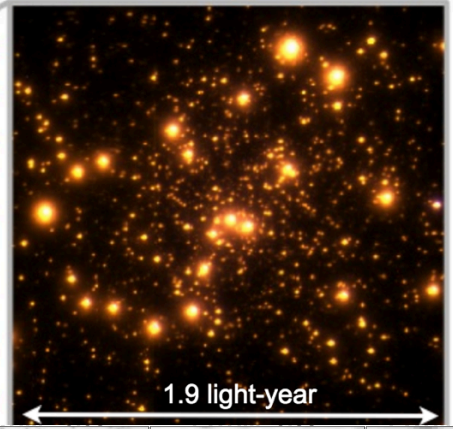
GeMS roadmap 2

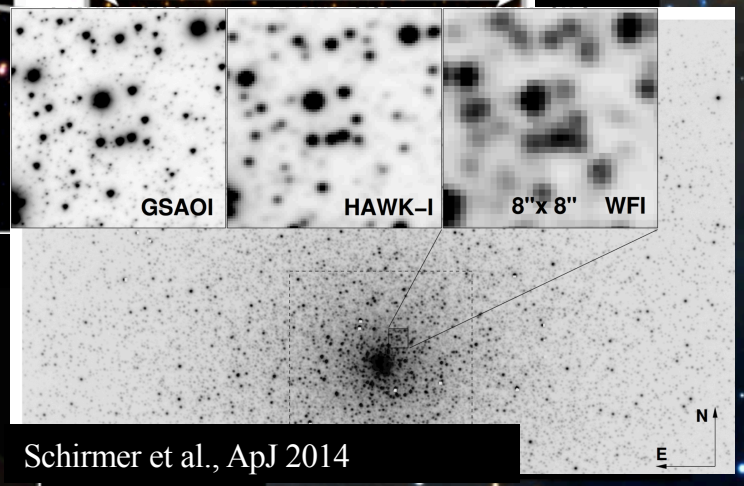
- New RTC considered
  - Looking at options
  - Preparing requirements ➔ Facility RTC, non-black box
- Reduction number of person to operate GeMS at night
  - From at least 4 ➔ at most 3
  - BTO upgrade feasibility study started
    - Looking at possible upgrades
    - Increase FSA range
    - Motorize XSA
    - Polarization control?
- GeMS to GN?

The end

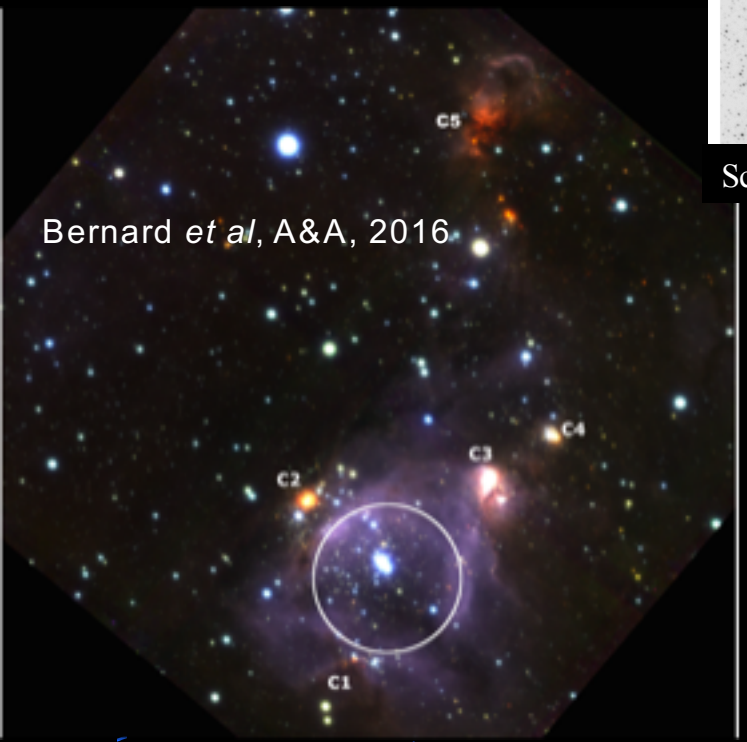




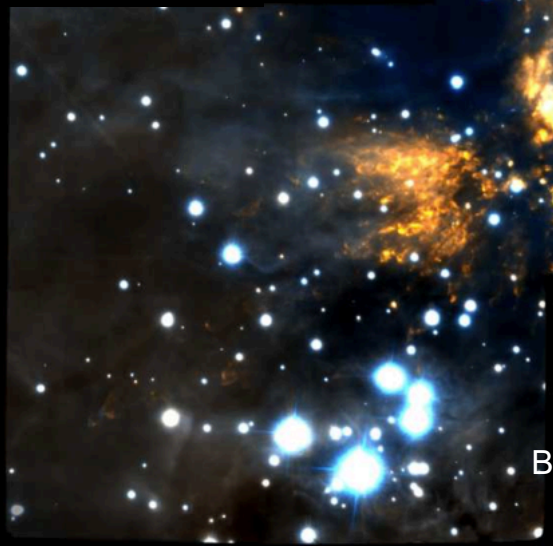


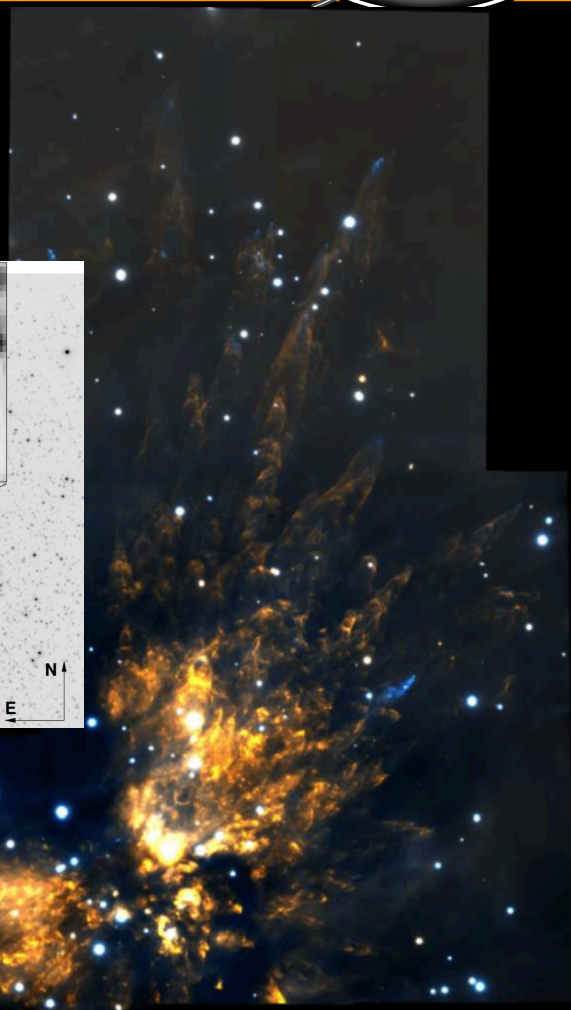


Schirmer et al., ApJ 2014



Bernard *et al*, A&A, 2016





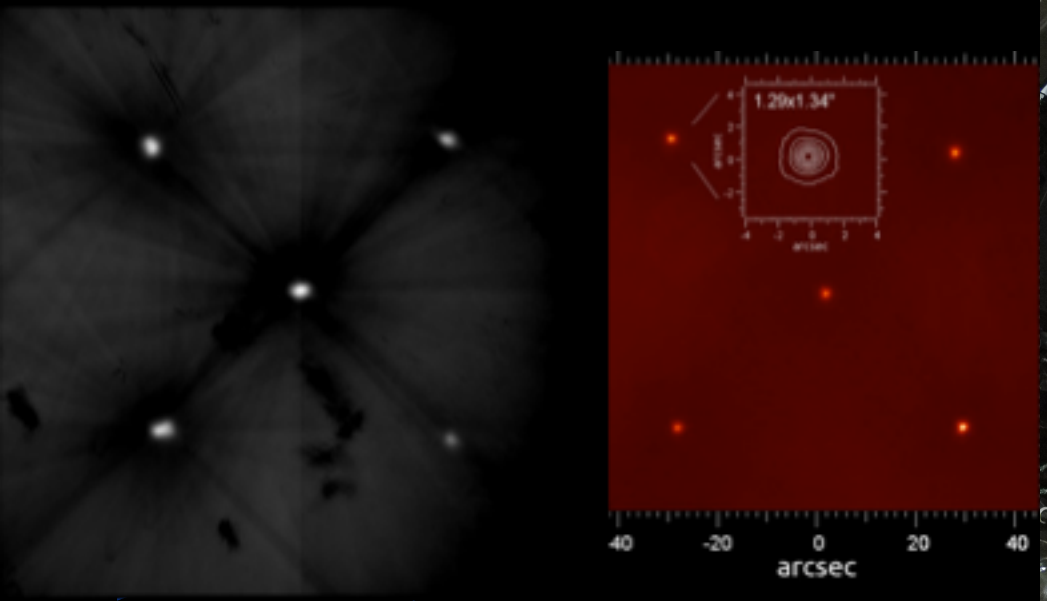
Bally *et al*, A&A, 2015

LGS WFS

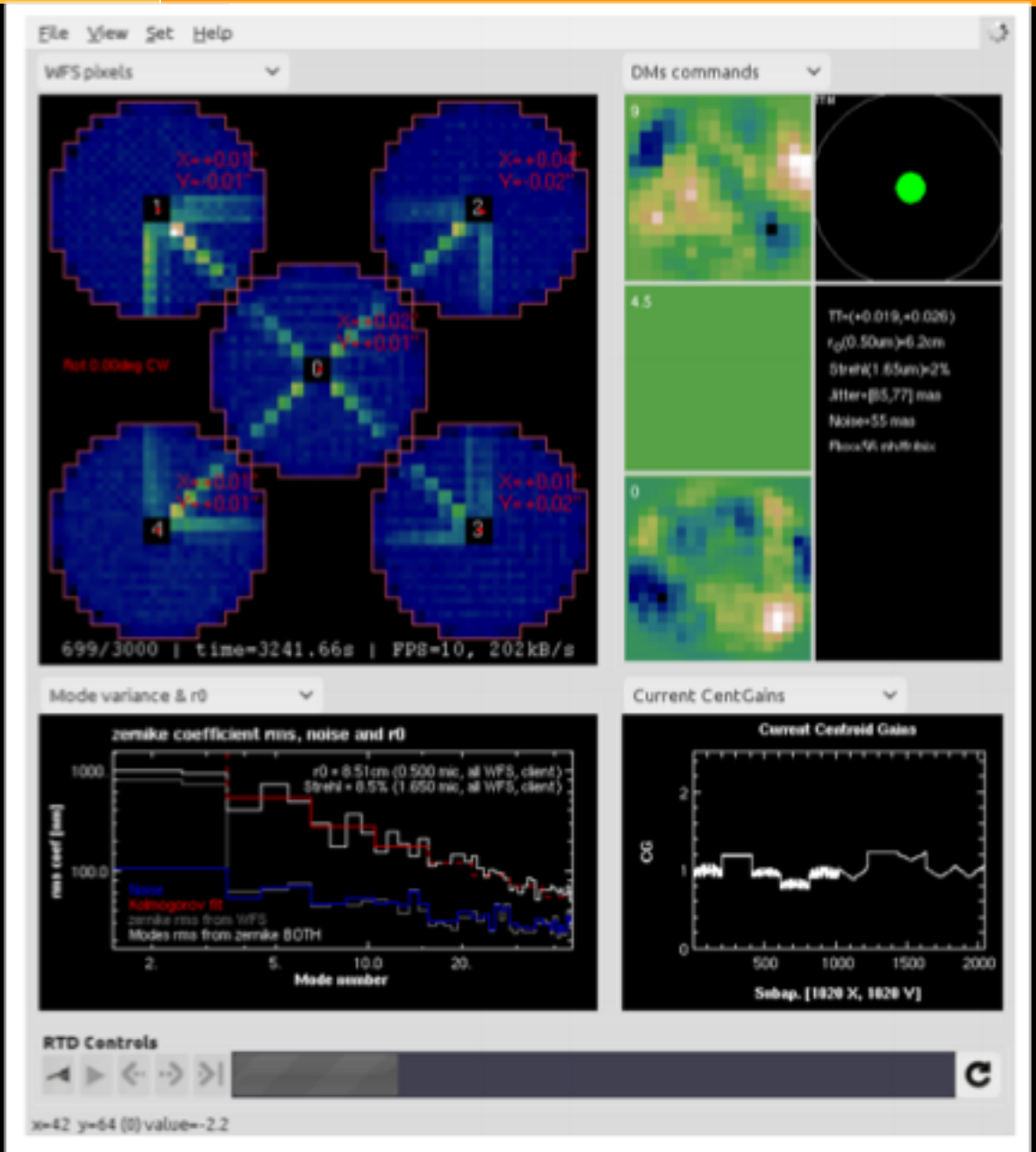
5 16x16 SHWFS

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

A

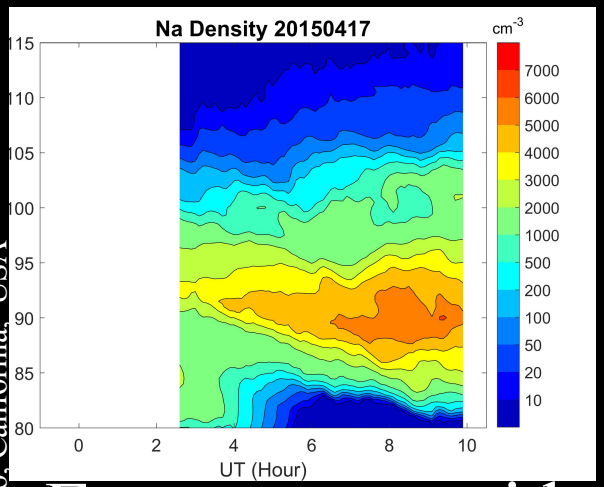


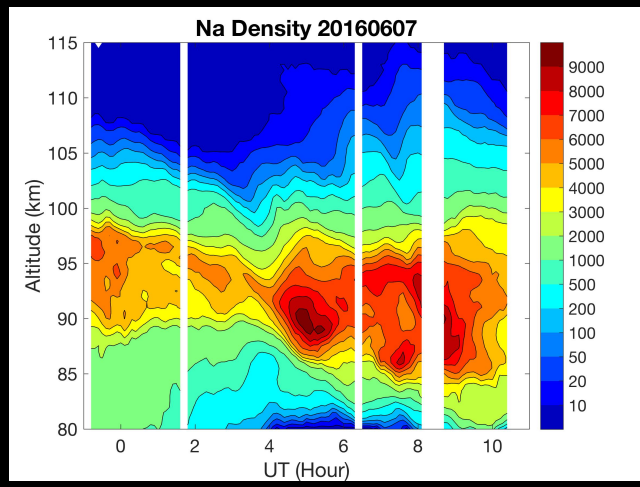
LGS WFS (RTD)


File View Set Help
WFS pixels
DMs commands
699/3000 | time=3241.66s | FPS=10, 202kB/s
Mode variance & r0
Current CentGains
Zernike coefficient rms, noise and r0
Mode number
Current Centroid Gains
RTD Controls

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

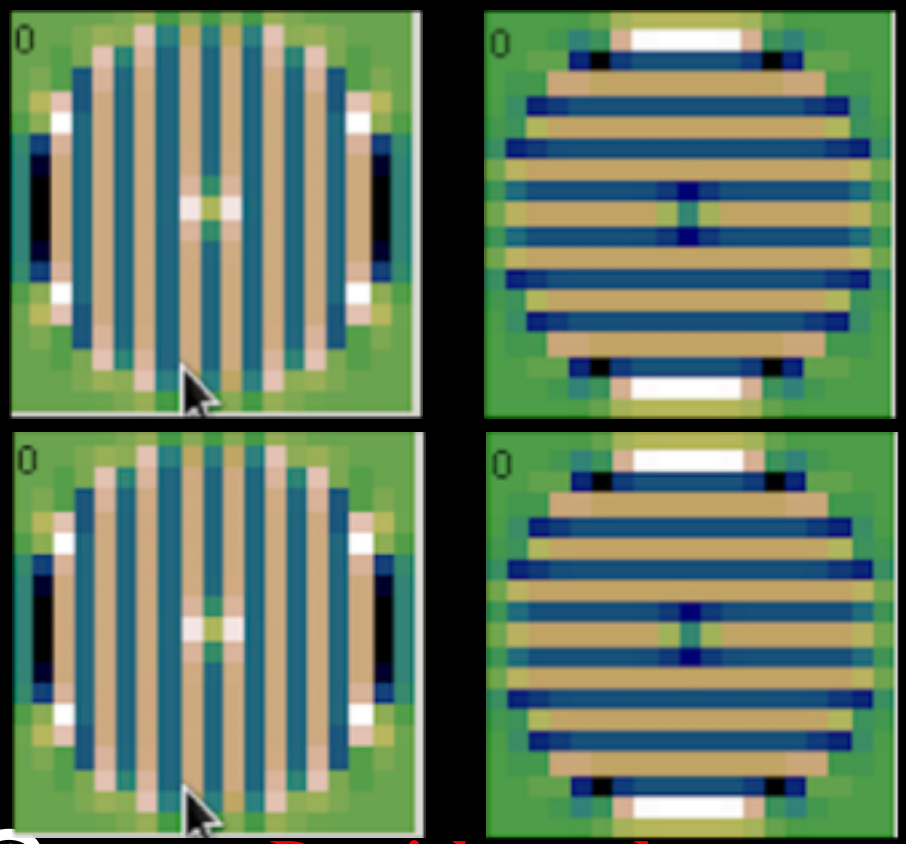
Need to calibrate centroid gains online

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