ELT-elongated Sodium LGS experiment at WHT: a progress report

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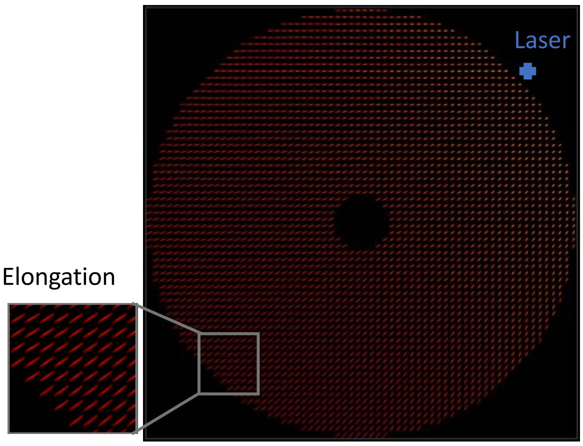
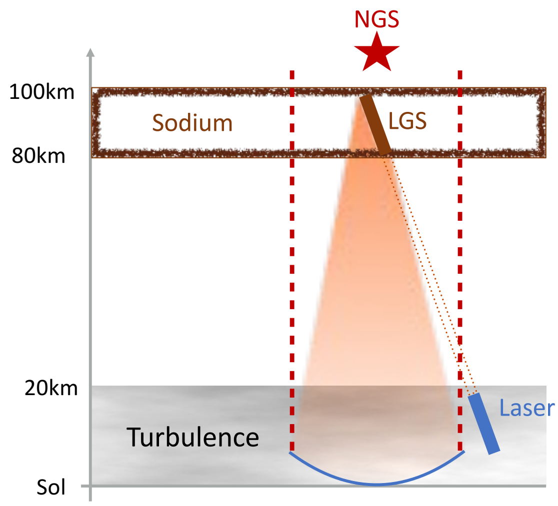
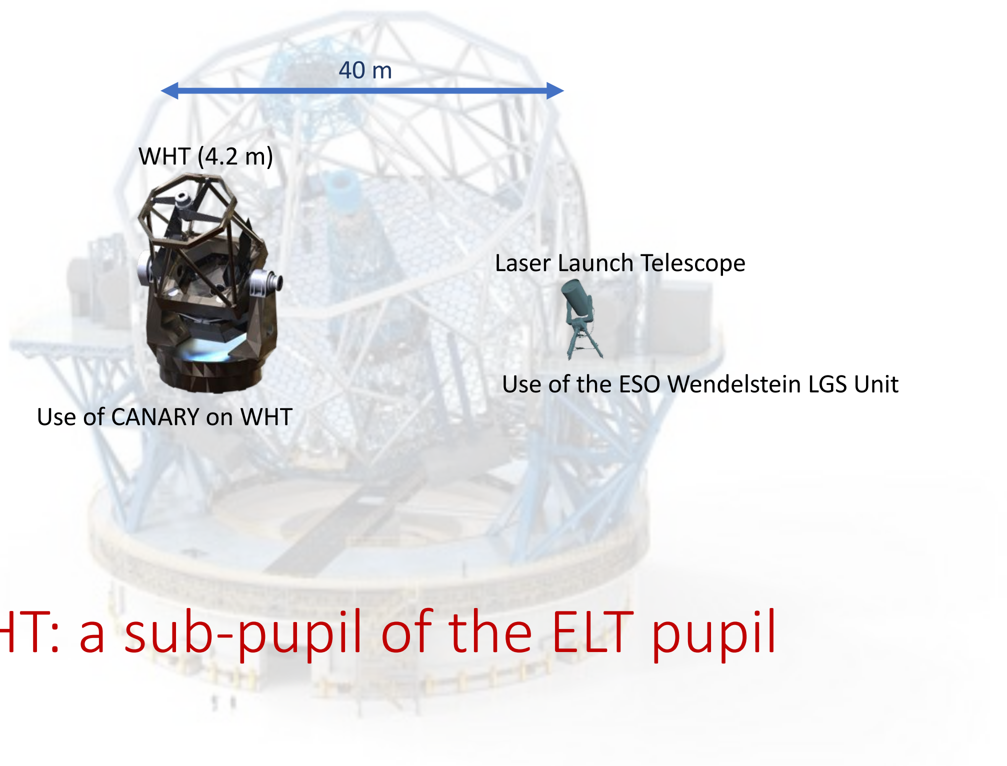
LGS spot elongation on the ELT



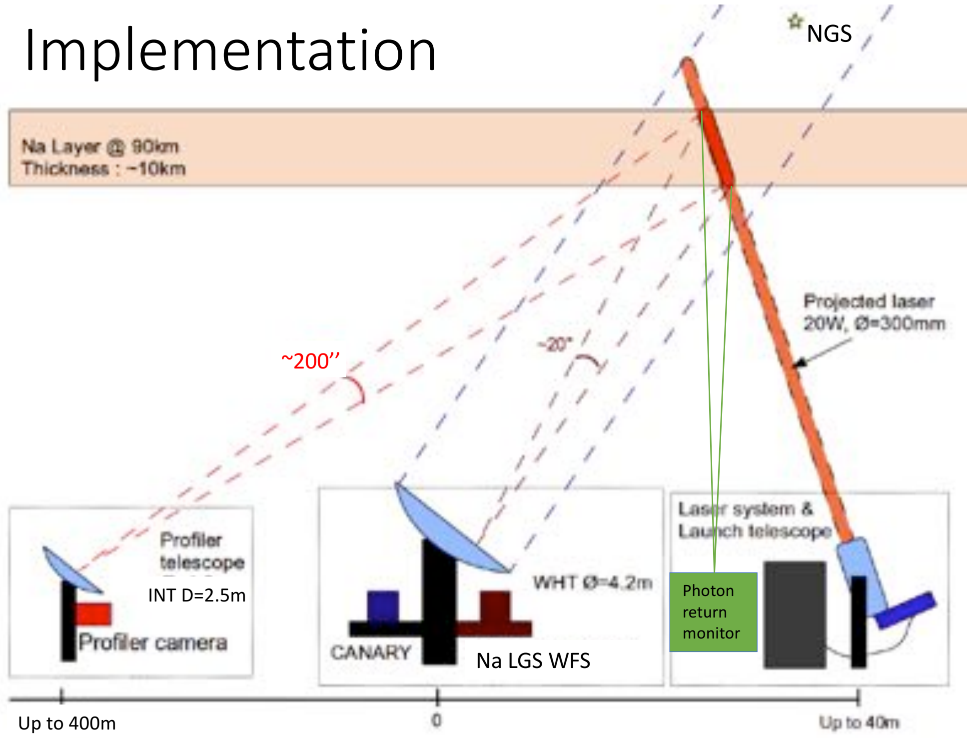


On-sky experiment principles at WHT

- Goal: to record “reference” Na LGS SH WFS data at the ELT scale including all phenomena involved in high altitude mesosphere and low altitude turbulence
- Means:
  - To place the laser launch telescope up to 40m (ELT diameter) from the WHT
  - To propagate the laser toward the NGS asterism observed by the WHT
  - To synchronously measure on-axis wave-fronts on the Na LGS and one NGS
  - To monitor the Na profile in parallel and in real-time
  - To monitor the photon return from the mesosphere



Implementation



On-site localisations

ESO WLGSU

Laser parameters

- Fiber Raman amplifier (CW)
- Power at 589nm (2.5–20 W)
- Linewidth (6-32 MHz)
- Polarization (lin ver,hor,+45,-45, circ)
- D2b intensity (0–30%)
- D2b frequency (1673–1753 MHz)

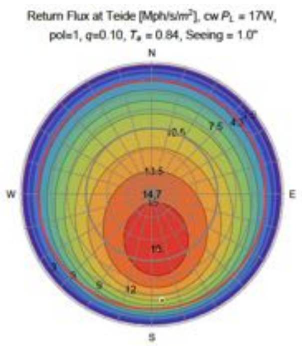
Launch telescope

- 350mm diameter
- LGS Pointing error ±2”
- Tracking <0.25’’

Photometric Receiver

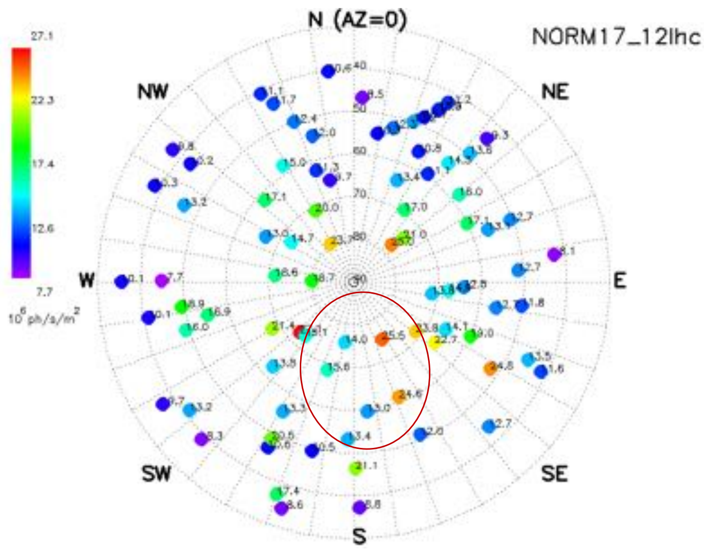
- 350mm telescope
- to measure LGS flux, fwhm
- 0.33 “/pixel
- FOV: 20’x30’
- Johnson band filters
- Automatic Tx/Rx pointing

LGS return flux on Canary islands

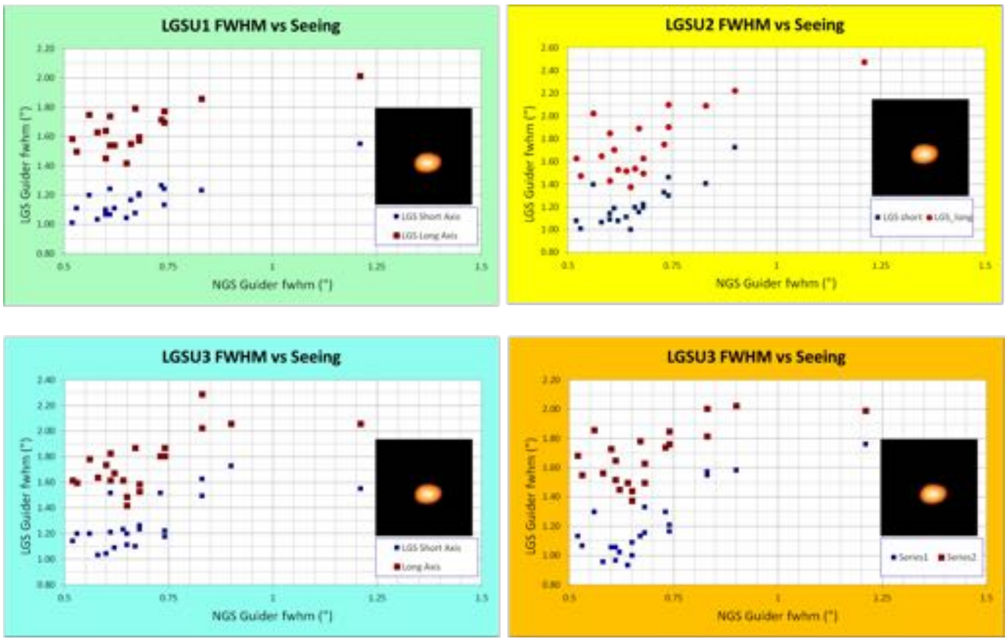


Close to prediction

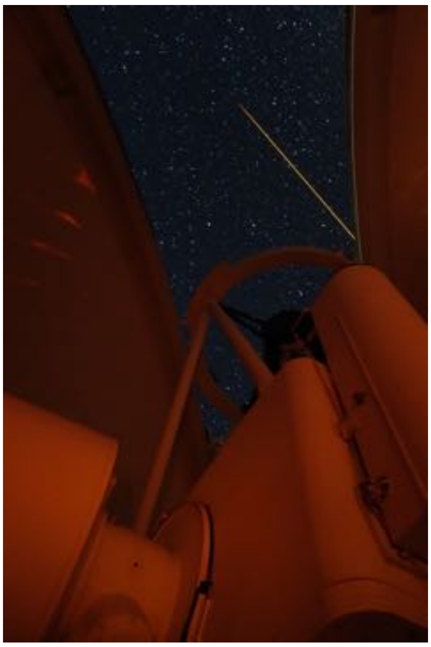
For these data: flux varying from 7.7 to 27 Mphot/m^2/s



LGS FWHM at Paranal (ESO, 4 LGSF)



Similar behaviour observed at WHT

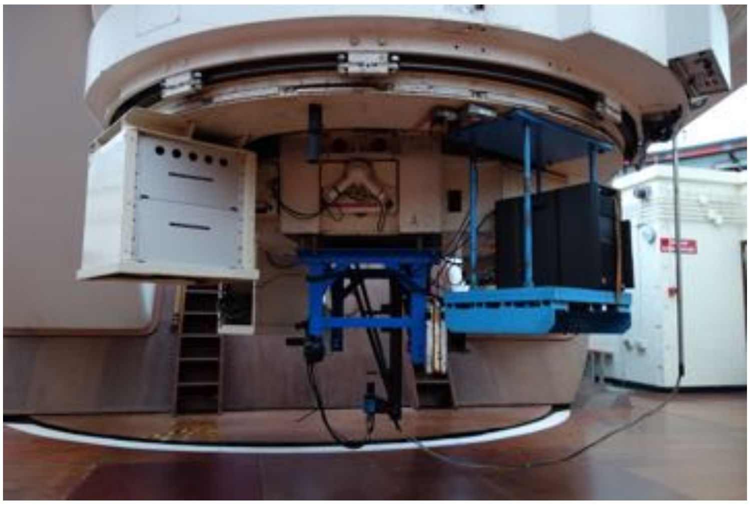


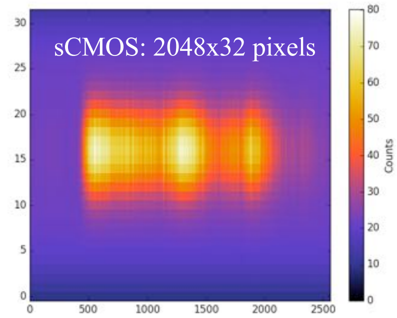
INT Na layer profiler

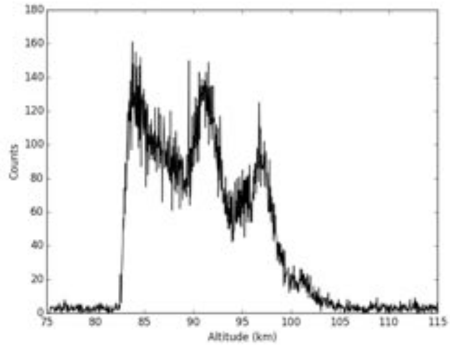
- Goal: high resolution altitude profiles for site characterisation, data analysis and high resolution reference synthesis for centroid algorithms

- Na plume imager on the INT (2.5m diameter)
- 427 m off-axis => ~180 arcsec plume elongation
- PCO sCMOS: 2048x2048, ~100m altitude resolution, windowing/binning
- WFS-synchonized unprecedented 150Hz frame rate
- Derotation, refocus and plume pointing

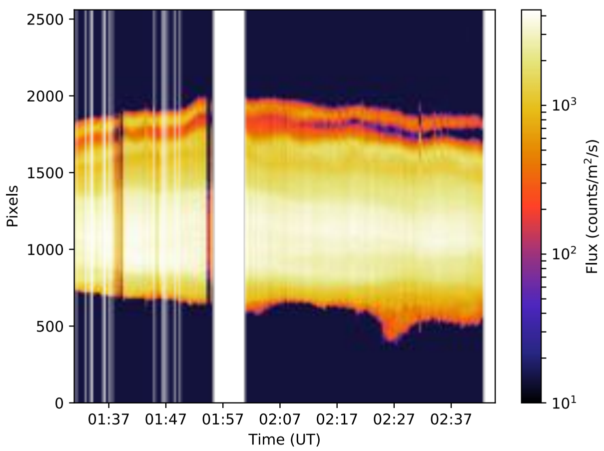
INT Na layer profiler

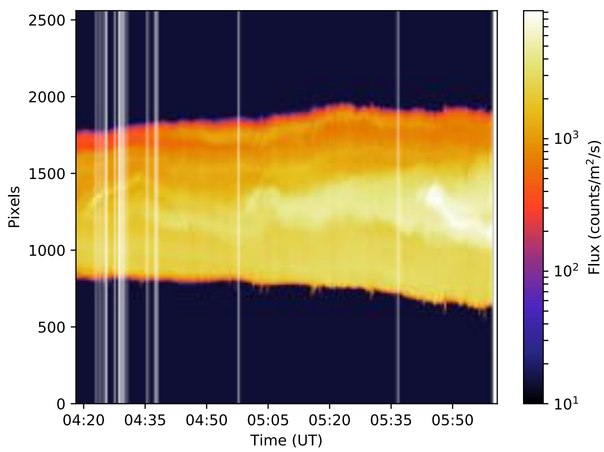






Variability of the Na profiles over one hour!





LGS wavefront sensor in CANARY

Goal: compare measured LGS WFs to NGS ones (both on-axis)

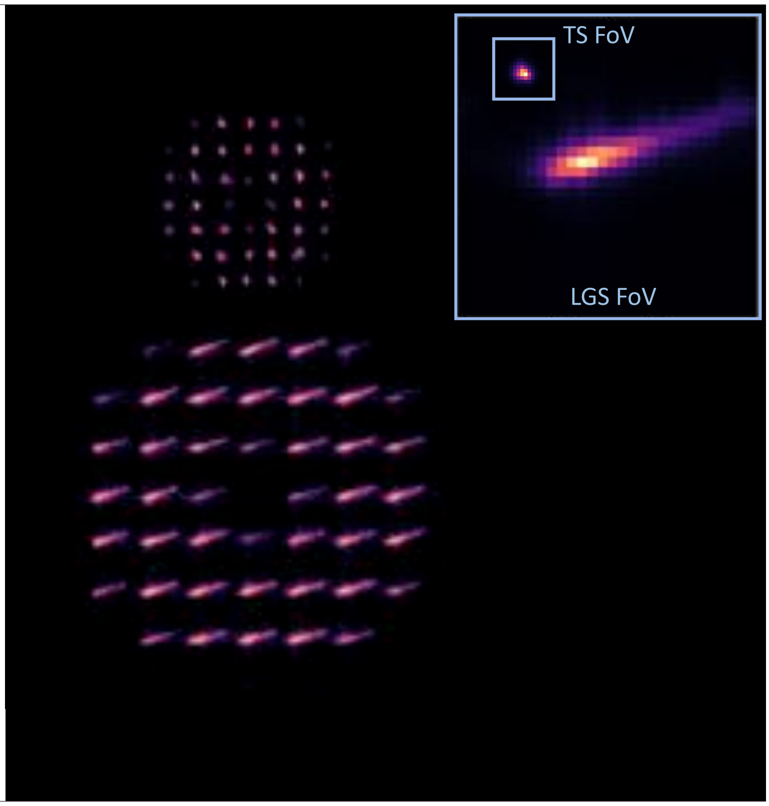
- On-axis Na LGS WFS with 60 cm subapertures (7x7 array) with field stop and notch filter
- Tip/tilt correction on LGS WFS channel, off-load to Launch Telescope
- Focus tracking on LGS WFS to compensate for the distance variation of the Na layer with zenith angle
- LGS WFS at 150 Hz rate, synchronized with the 4 CANARY NGS WFSs (on-axis truth sensor + 3 off-axis sensors)
- Possible spot dithering for centroid gain estimation
- Data recorded at full frame rate: SH spot images, WFS slopes, actuator commands, Na profiler images

CANARY Truth Sensor:

- On-axis NGS
- 0.23’’ pixel scale
- 3.7’’ subaperture FoV
- Andor, RON <0.6e-

CANARY LGS WFS:

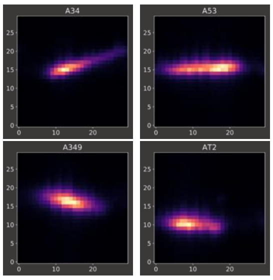
- On-axis Na LGS
- 0.65” pixel scale
- 20” subaperture FoV
- OCAM, RON <0.2e-



WF error breakdown

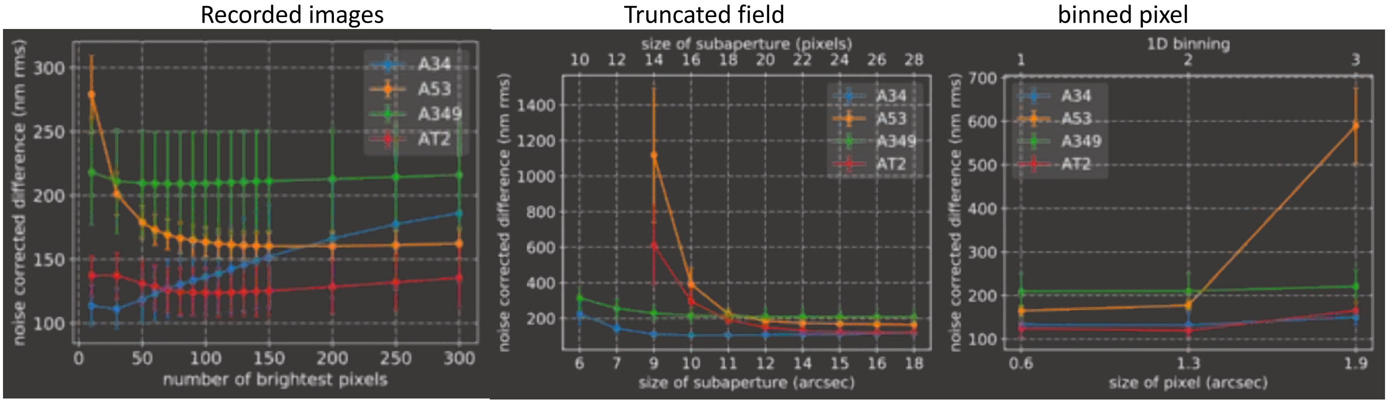
Identify the WF measurement difference variance between NGS truth sensor and Na LGS WFS:

- Estimating floor error on a common NGS (<100nm in bad seeing)
- Taking into account centroid gain variations
- Subtract identified noise variances
- Estimate cone effect (and aliasing) with the identified turbulence profile
- Final measurement difference error = centroid non linearities (+ average differential anisoplanatism/scintillation)



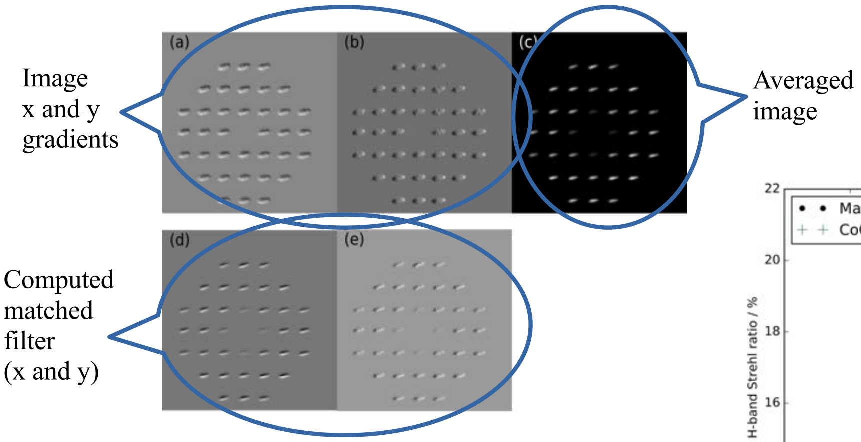
Impact of non-linearities

Recorded images Truncated field binned pixel

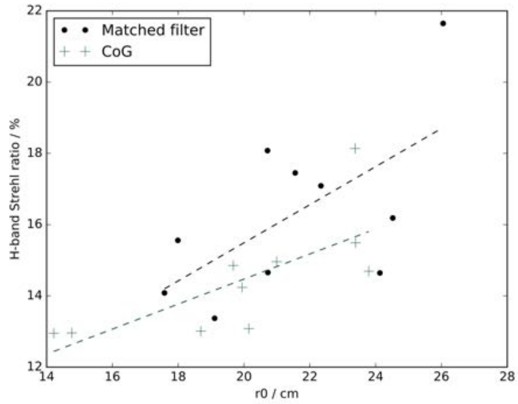


With 90 brighest pixels, FoV truncation down to 11’’, pixel scale up to 1.3’’

Closed loop tests with matched filter



Performance:
IR camera Strehl



Conclusion

- Experiment at the scale of the ELT
- 4 runs of 4 to 5 nights (the latest on-going!)
- Various conditions (seeing, Na layer)
- A number of instrumental problems…
- More than 2 TBytes of data
- Data reduction still on-going work...
- Data made available soon to instrument builders

- What's next? Discussions to start feasibility studies for pulsed laser, spot refocusing and Pyramid WFS

Thank you for your attention

To know more about:

- Gratadour D. et al., SPIE 2012
- Bonaccini Calia D. et al., SPIE 2012
- Rousset G. et al., SPIE 2014
- Bardou L. et al., SPIE 2016
- Basden A. et al. MNRAS 2017
- Reeves A. et al. AO4ELT5 2017
- Bardou L. et al., AO4ELT5 2017