The Laser Guide Star Adaptive Optics System for the LBT

S. Rabien

L. Barl, U. Beckmann, T. Blümchen, M. Bonaglia, J. L. Borelli, J. Brynnel, L. Busoni, L. Carbonaro, C. Connot, R. Davies, M. Deysenroth, O. Durney, M. Elberich, S. Esposito, V. Gasho, W. Gässler, H. Gemperlein, R. Genzel, R. Green, M. Haug, M. Lloyd Hart, P. Hubbard, M. Kulas, C. Loose, E. Masciadri, J. Noenickx, G. Orban de Xivry, D. Peter, A. Quirrenbach, M. Rademacher, H. W. Rix, P. Salinari, C. Schwab, J. Storm, L. Strüder, M. Thiel, G. Weigelt, J. Ziegleder

The ARGOS Consortium

- MPE, Garching
- MPIA, Heidelberg
- INAF, Firenze
- MPIfR, Bonn
- University of Arizona, Tucson
- AIP, Potsdam
- LSW, Heidelberg
- LBTO, Tucson
- HLL/ PNSensor

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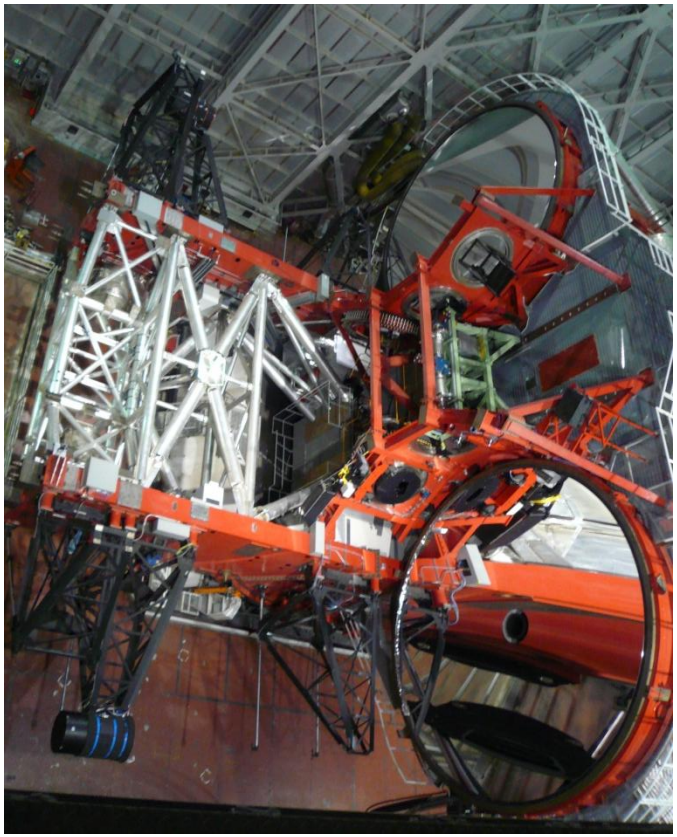
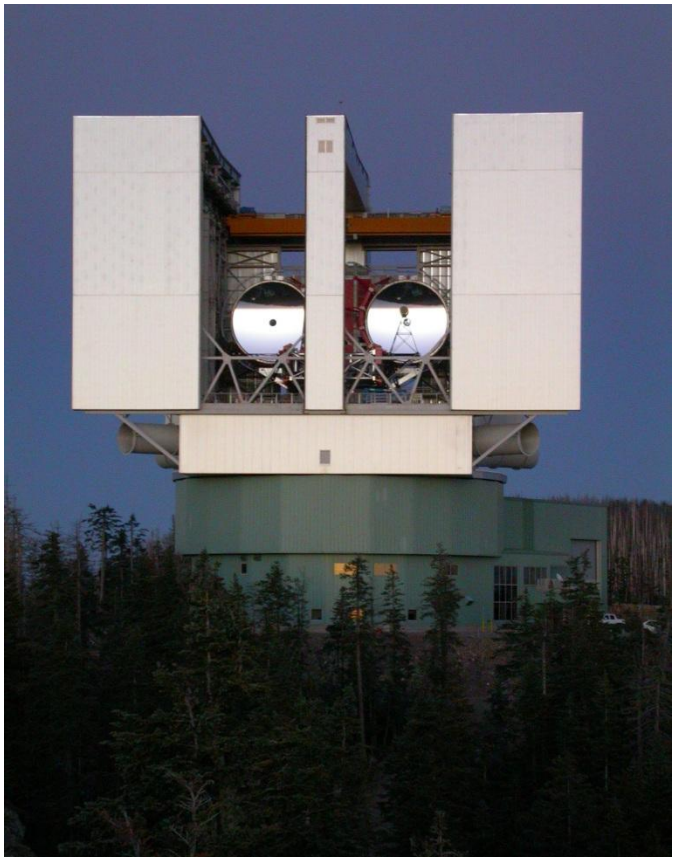
The LBT



- Located on Mt Graham, Arizona at 3300m altitude
- 2 x 8.4m mirrors
- 14.4m center-center

- AO
- Adaptive secondaries
- Pyramid based FLAO

- Instruments:
- 2x IR MOS (Luci)
- 2x Vis MOS (MODS)
- 2x Prime Focus cams
- High res. spectrograph: (PEPSI)
- LBTI
- Linc-Nirvana

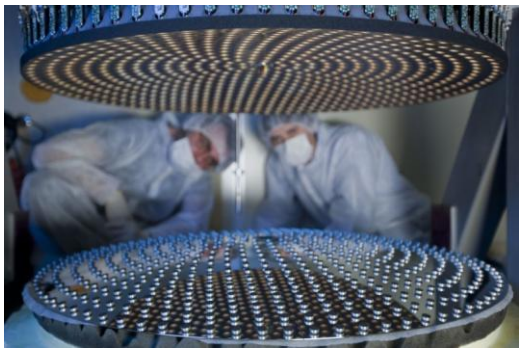


FLAO at the LBT

The deformable Mirror

LBT672a unit

- 911mm diameter
- 1.6mm shell,
- 672 actuators
- Settling time < 1ms
- 30nm WFE

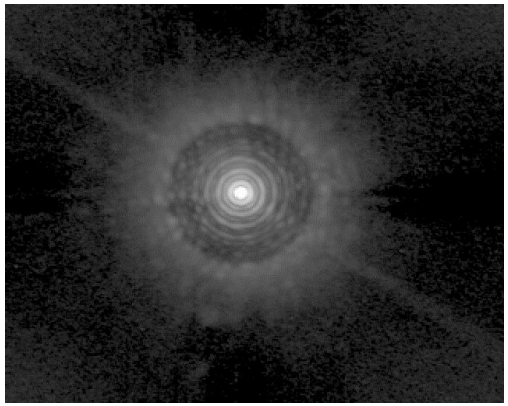


Esposito et al.

The Wavefront Sensor

LBT WFS unit

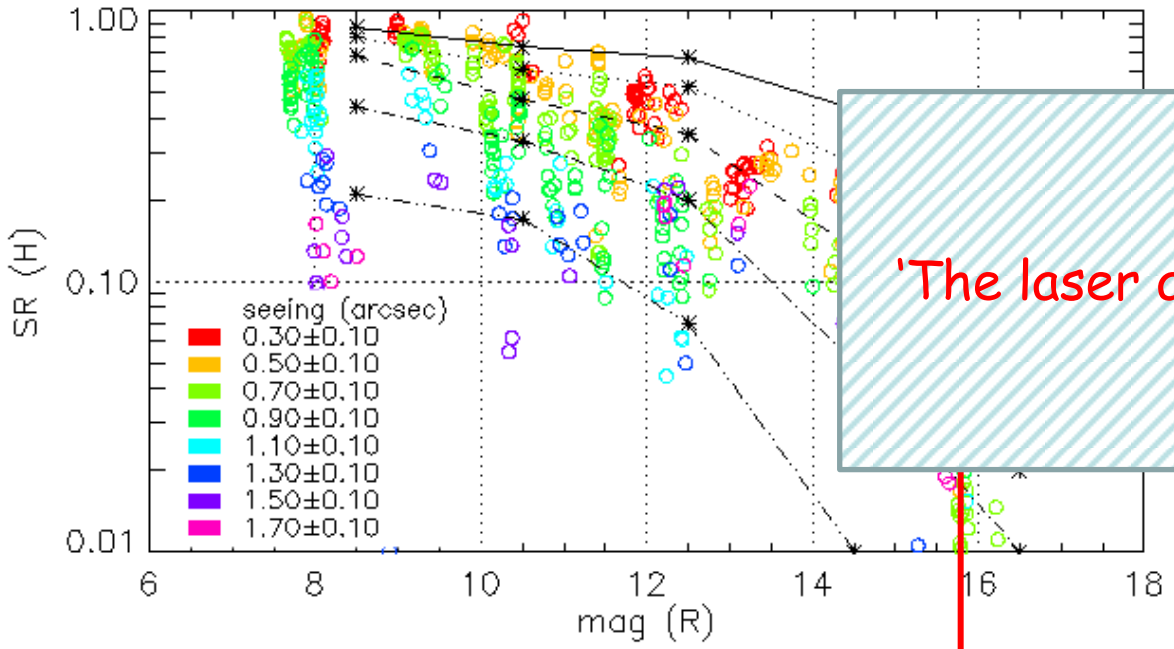
- Pyramid sensor
- 30x30 to 5x5 subap.
- Tilt mod. □ 2-6 λ/D
- 1Kfps max [30x30]



Sharpest image ever!
SR 80…93% demonstrated

FLAO performance

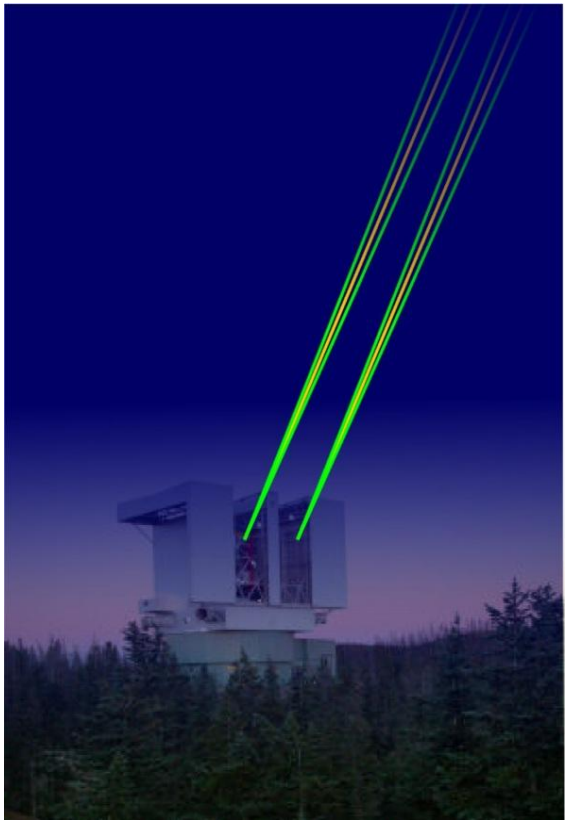
- Highest strehl ratios achieved
- Excellent performance



15-16mag star needed
Correction is on-axis
Small corrected field

Esposito et al.

ARGOS



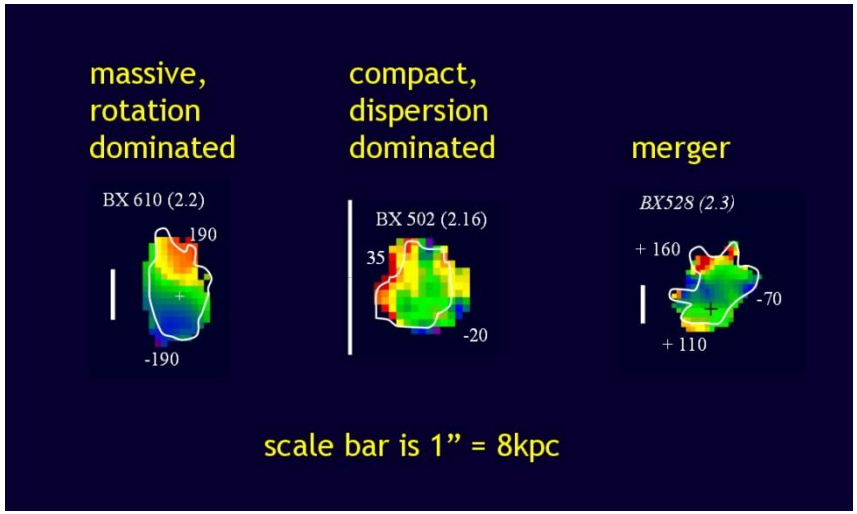
- A Ground layer AO system
- Wide field AO correction

- A multi-laser star constellation
- High power pulsed green lasers
- ‚Rayleigh beacons' created at 12km
- Adaptive secondary correction
- Gated SH wavefront sensors
- Prepares for a Na Laser hybrid constellation

Highlight science case: Galaxy Formation & Evolution at z~2

Many questions still open:

- how were galaxies built up (mergers vs slow accretion)?
- how did galaxies acquire their morphology (bulges, disks, ellipticals)?
- how did galaxies get their angular momentum (disk sizes)?

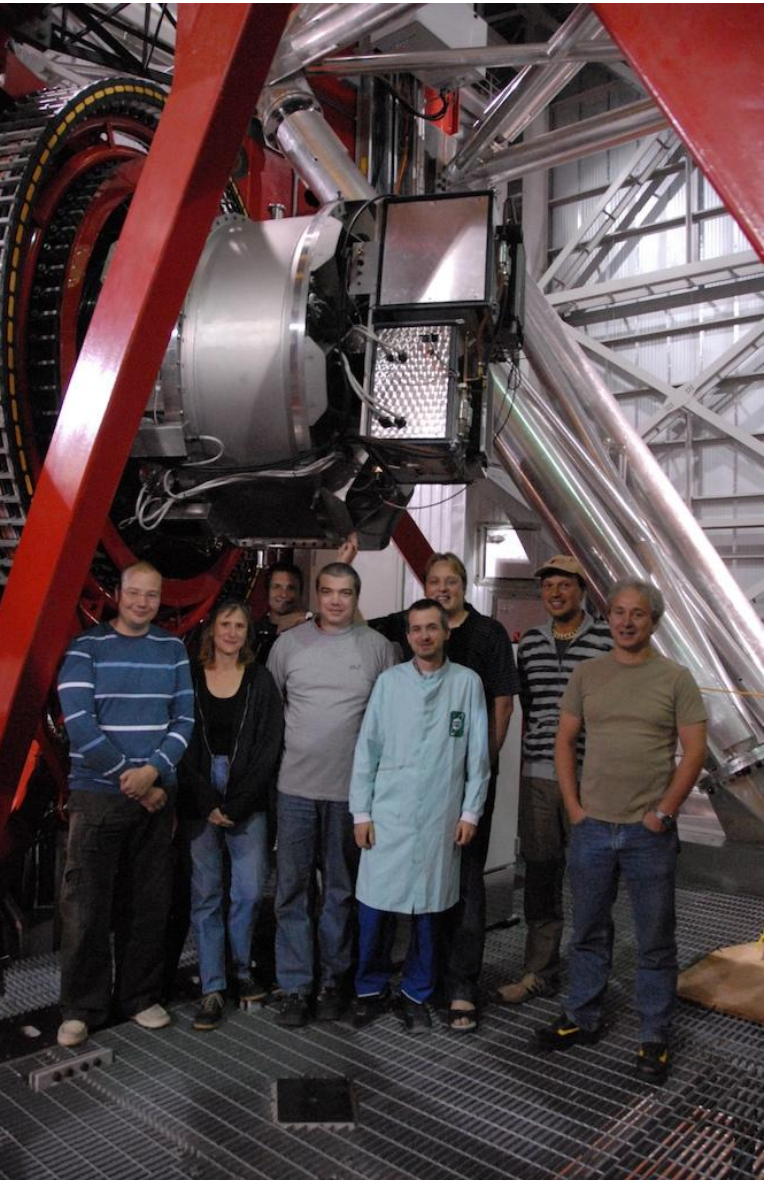


But studying z~2 galaxies is challenging:
too small for seeing limited work; *too faint* for diffraction limited work

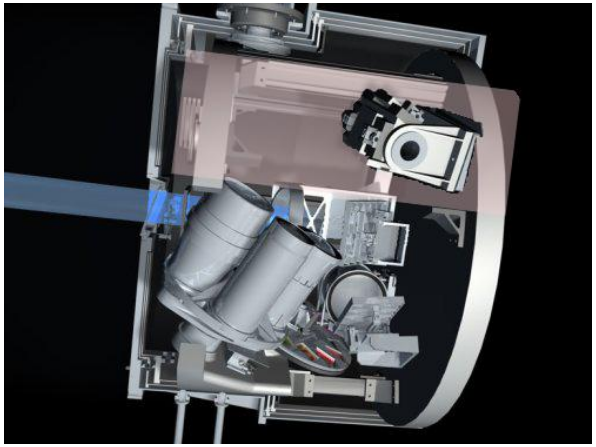
It requires:

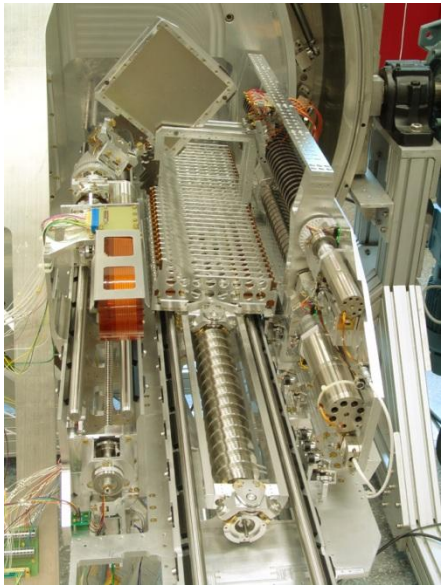
- *GLAO resolution* as trade-off between spatial scales & S/N; 0.25" ~ 2kpc
- *near-IR* to probe rest frame optical
- *spectroscopy* to measure emission line flux, distribution, & kinematics
- *wide field capability* for multiplexing & large samples

Lucifer Instruments

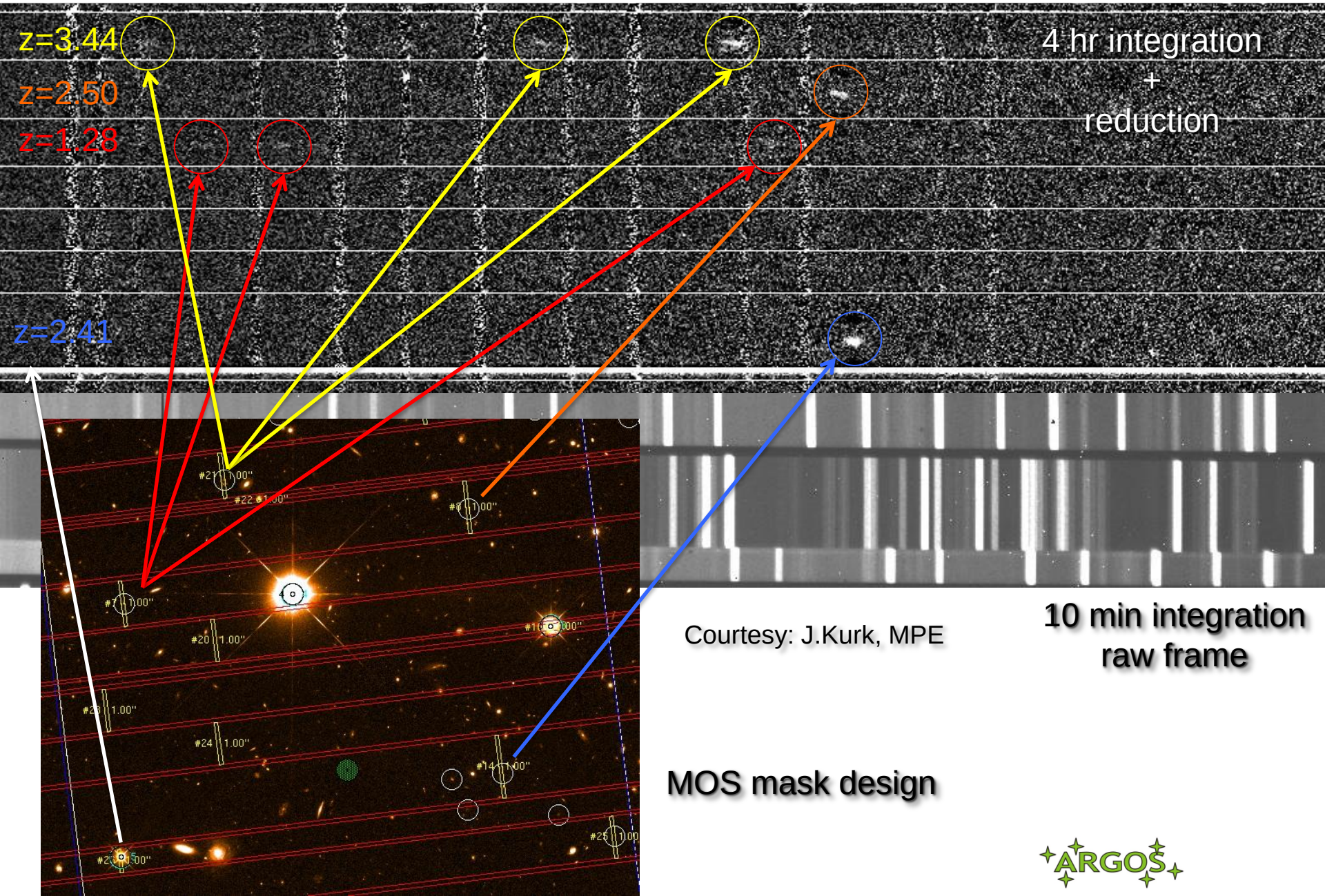


- IR imager and spectrograph
- MOS slit mask spectrograph
- 0.9-2.5 μm
- Cryogenic mask exchange robot
- 4x4 arcmin field

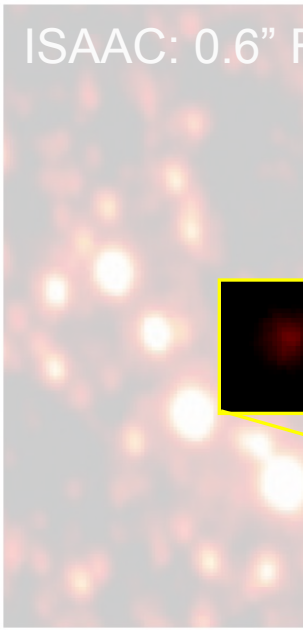


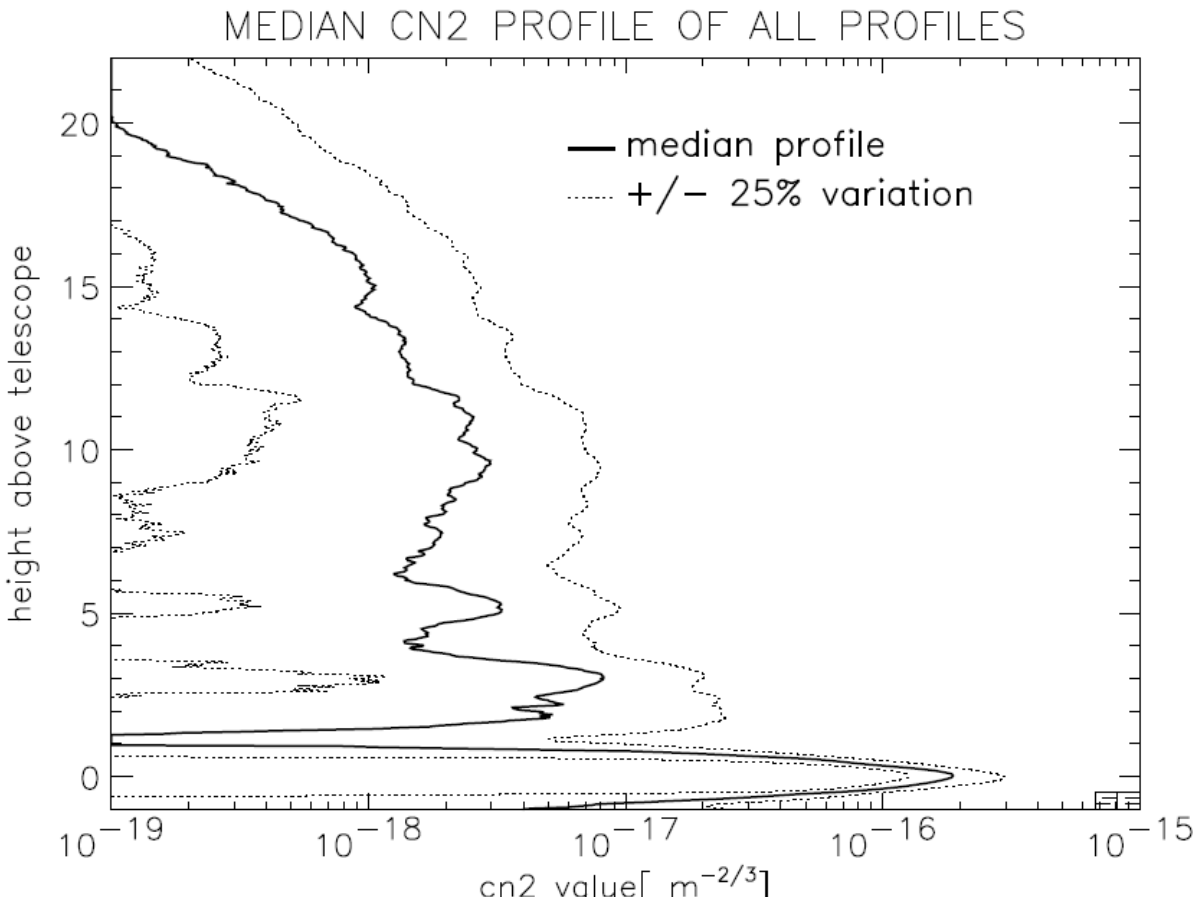


LUCIFER MOS extragalactic example



Ground Layer Correction

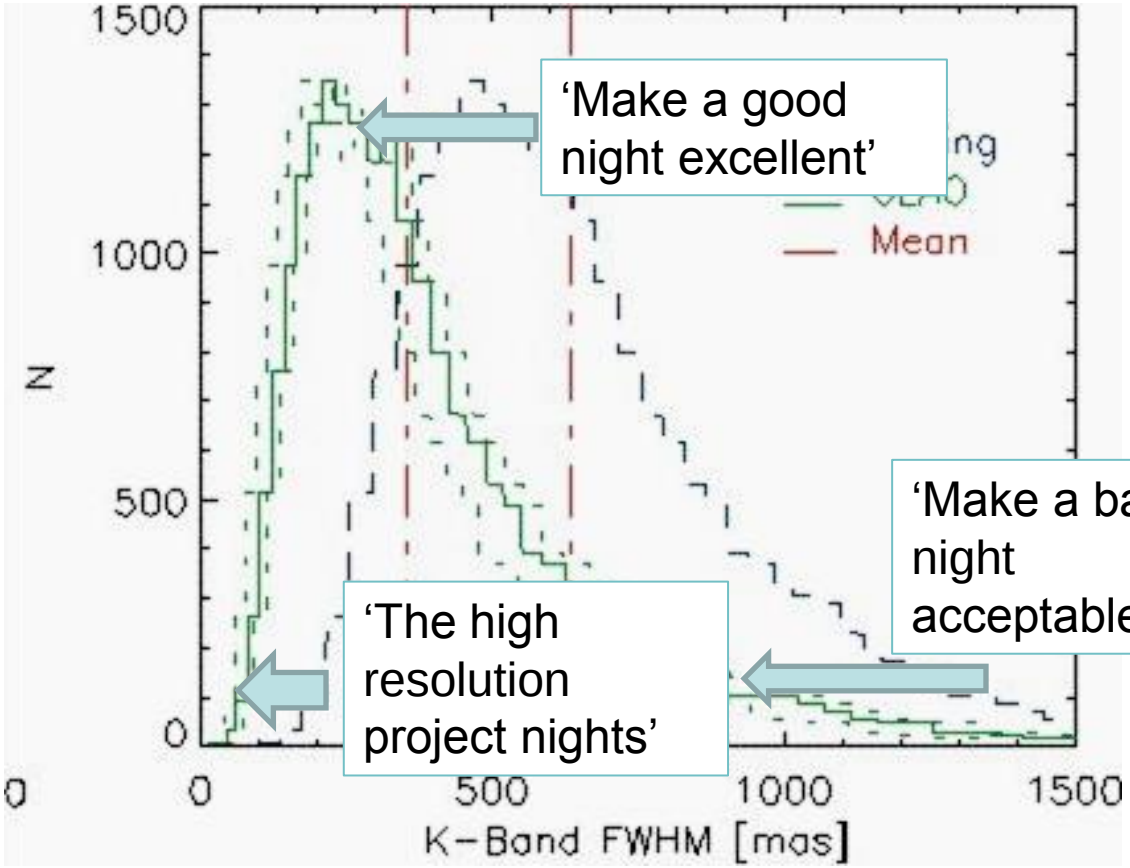




A strong ground layer is always present!

ARGOS Performance

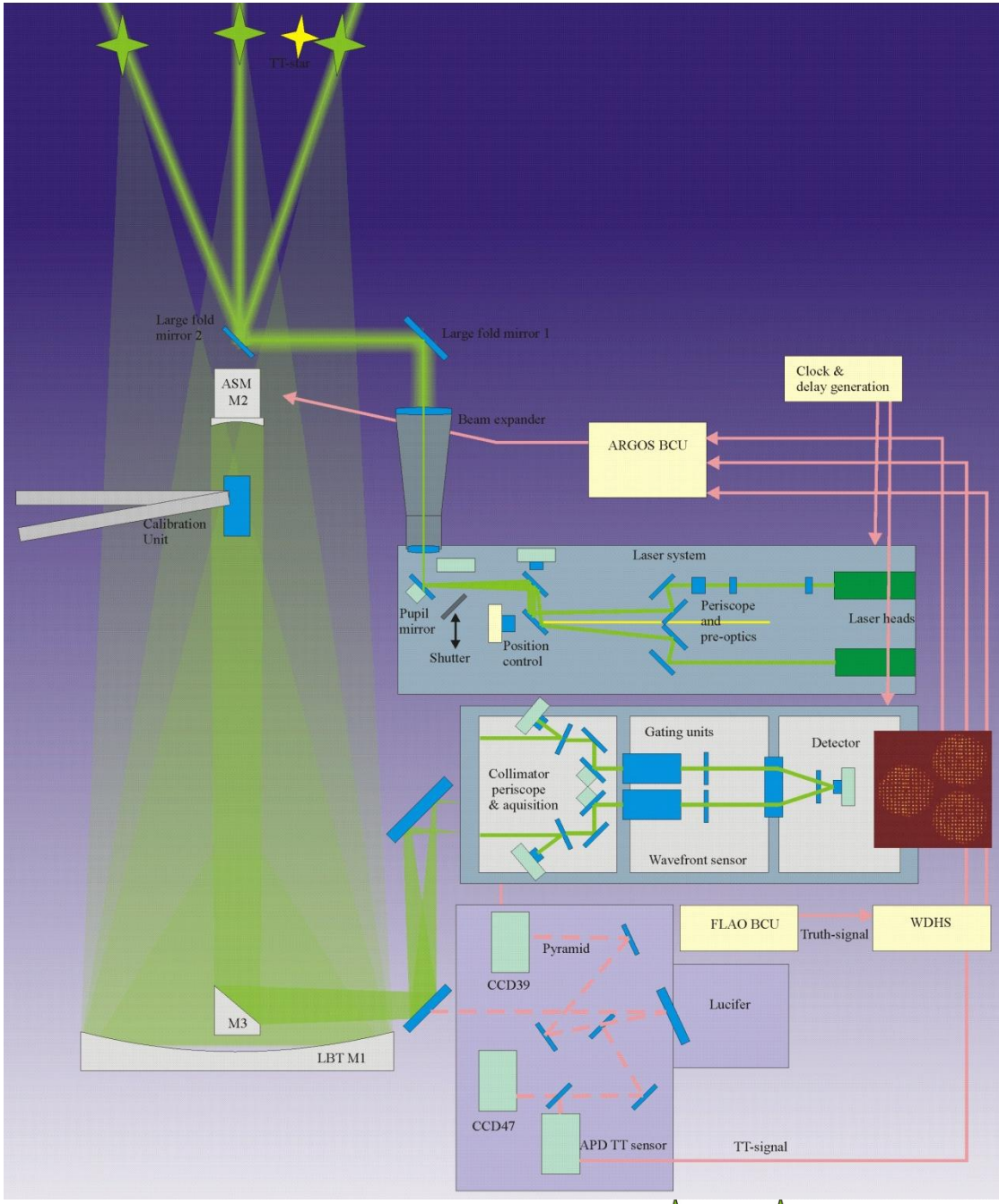
- Multiple independent performance simulations computed (Italy, Garching, Arizona)
- Raytracing included in the simulation: marries optics design and AO simulation



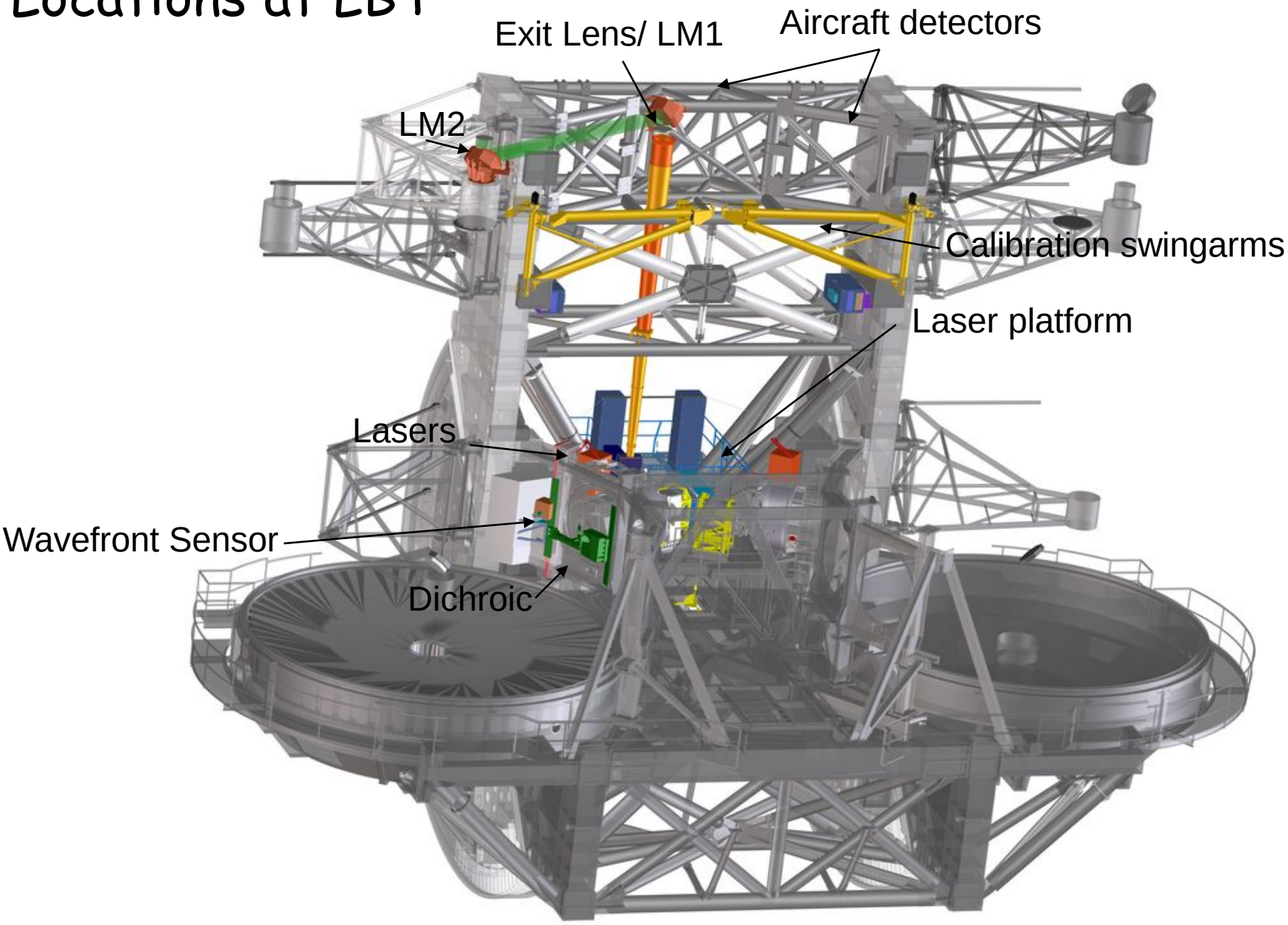
-> Factor 2-3 reduction in PSF size

Overview

- Laser pulses are generated in the Laser system, pre-expanded, steered to the proper location and send via a fast TT mirror into the launch system
- The launch system expands the beams to ~30cm diameter and sends the pulses to sky with large flat mirrors.
- After 80.06 μs time of flight the photons scattered at 12km arrive back at the telescope, are directed with the dichroics to the WFS and the shutter opens for 2μs, equivalent a 300m range.



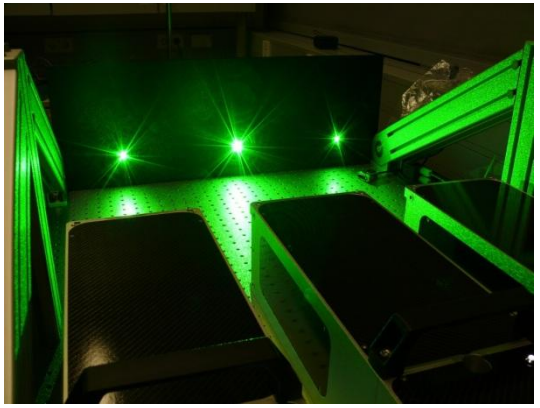
Locations at LBT

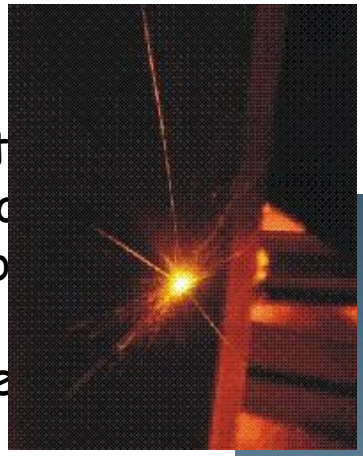


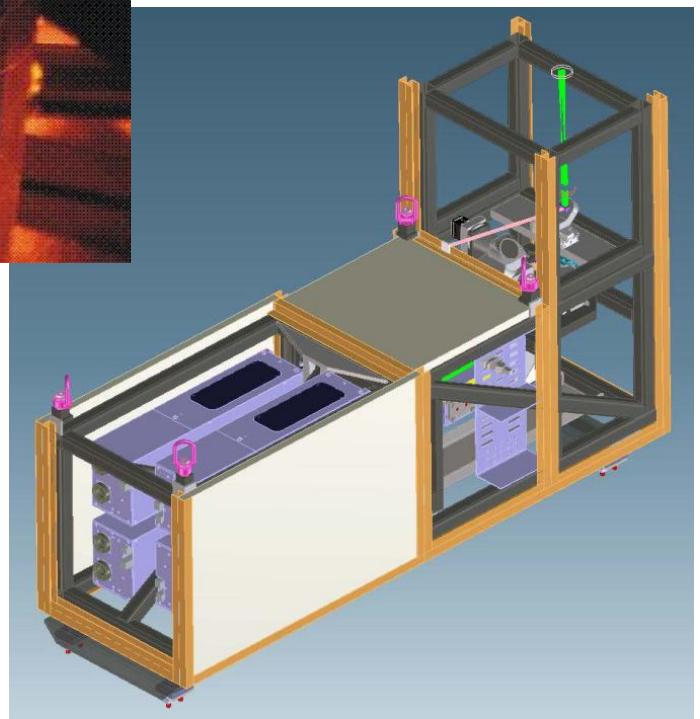
Laser system

The laser system contains:

- Three 18W pulsed lasers
- A beam pre-expander
- Polarization adjustment
- Periscopes to position the const
- Closed-loop field position contro
- Closed loop pupil position contro
- Alignment aids
- Fast photo diodes to detect the individual pulses
- The main laser shutter
- A power meter for laser health check
- A position to inject a central 589nm laser
- A sealed, thermally controlled housing



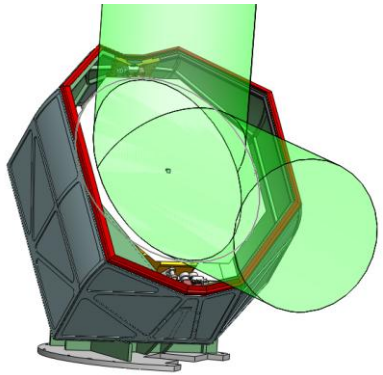




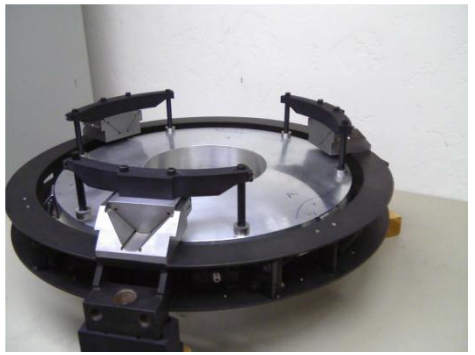
Launch system

- Expands the laser beams to 40cm
- Directs the beams to sky
- Compensates for flexure and vibration
- Refractive aspheric beam expander
- Built into the LBT structure
- Flat folds to direct the light towards sky
- Dust covers for optics protection
- Motors for focus and flexure compensation
- Accelerometer based active vibration compensation system

Poster vibration compensation:
Diethard Peter

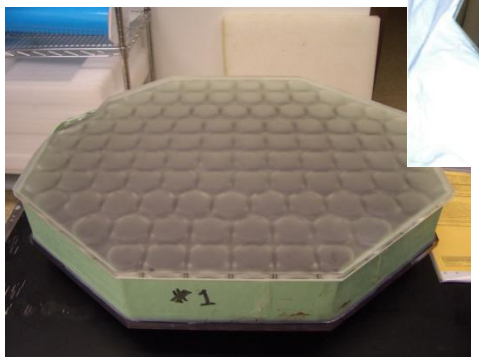


Above M2



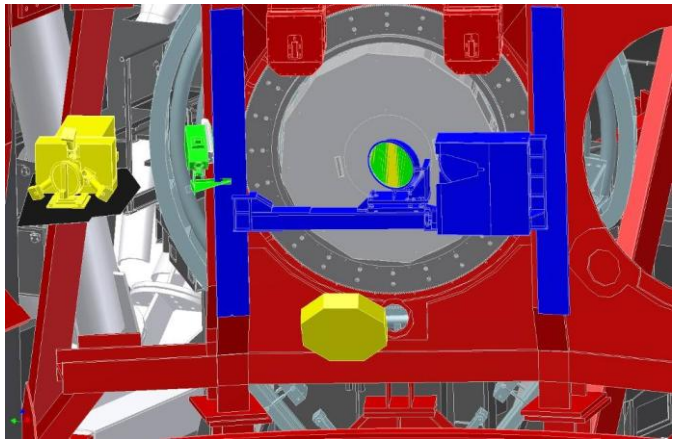
45cm lens polished & mounted

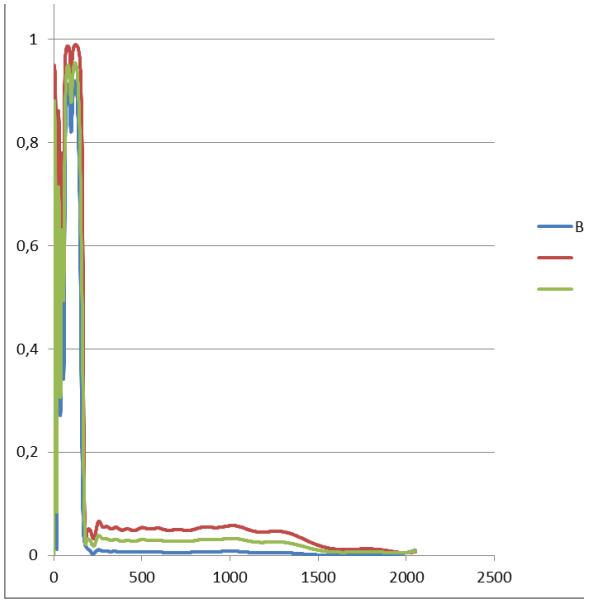
Protected Silver coating



Hextek blank mirrors

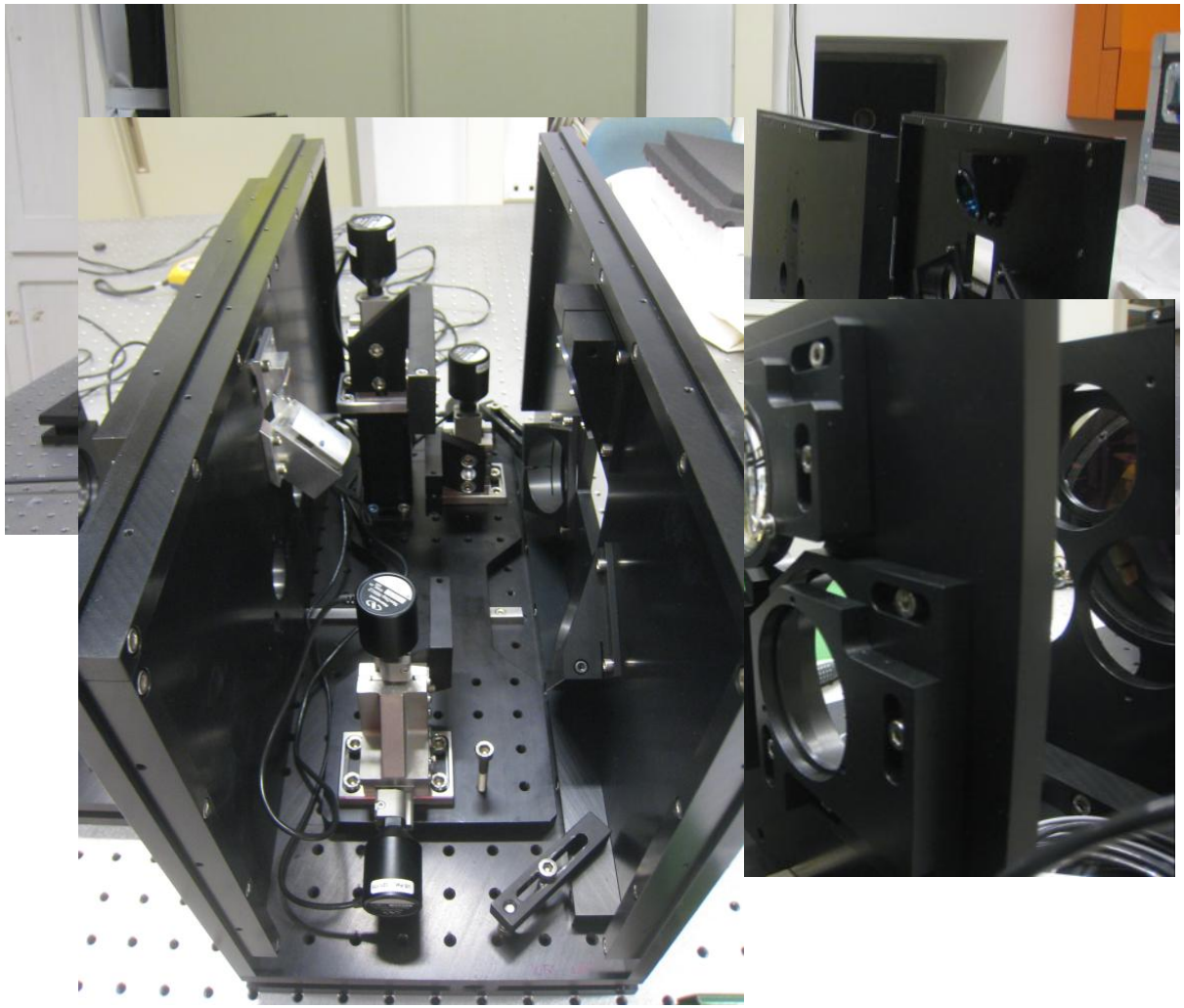
Dichroic Beam Splitters





- Separates 532 &589 laser light to WFS, infrared light to Lucifers, visible light to TT sensor and truth sensor
- Magnetron sputtered dichroic coating
- Backside is wedged for color correction and cylindrical for astigmatism correction

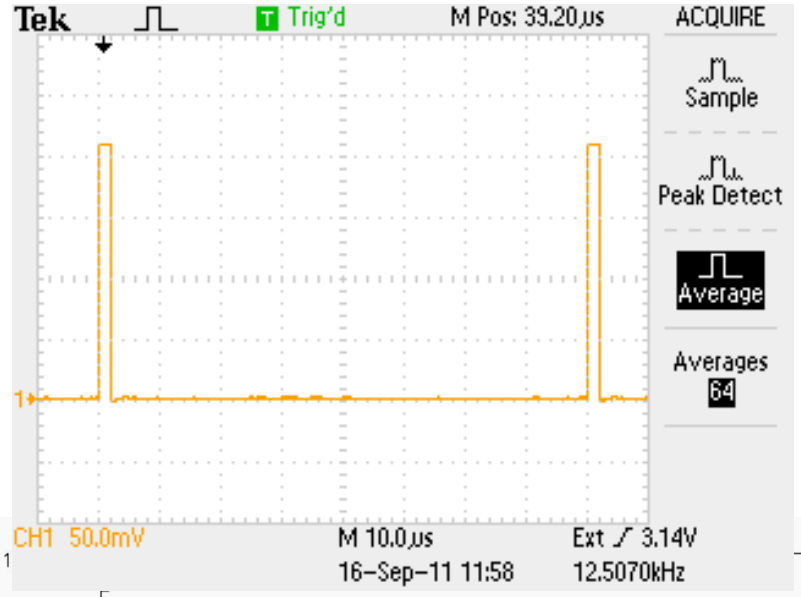
Wavefront Sensors

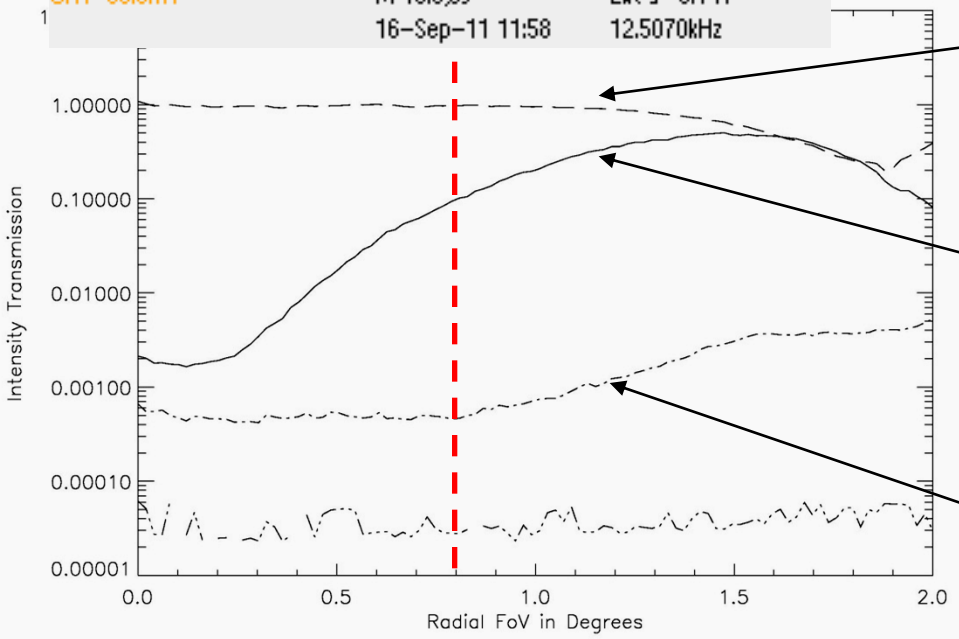


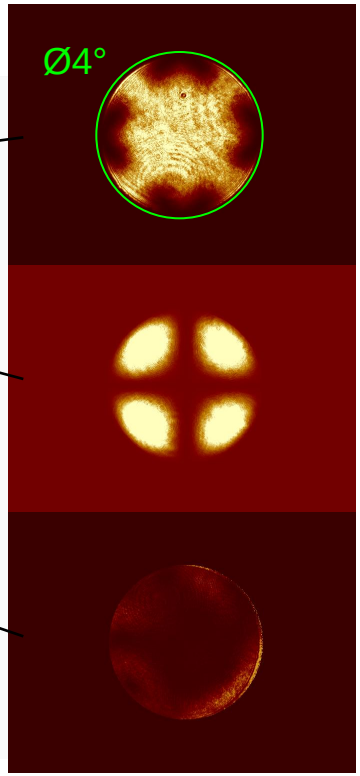
- WFS is based on a Shack Hartmann system
- Three guide stars are combined on a single detector
- 15x15 subapertures
- 8x8 pixel per subapp
- Detector: PnCCD 1kHz framerate
- Shuttering is done with Pockels cells
- Aquisition cameras for automatic star finding
- Internal calibration sources
- Internal PZT laser jitter control
- MDM for test and setup
- Closed loop uplink jitter and flexure control

Gating with Pockels cells

- Own development of a wide field high suppression cell
- BBO crystals for zero ringing performance
- Rise time ~10ns
- High suppression ratio





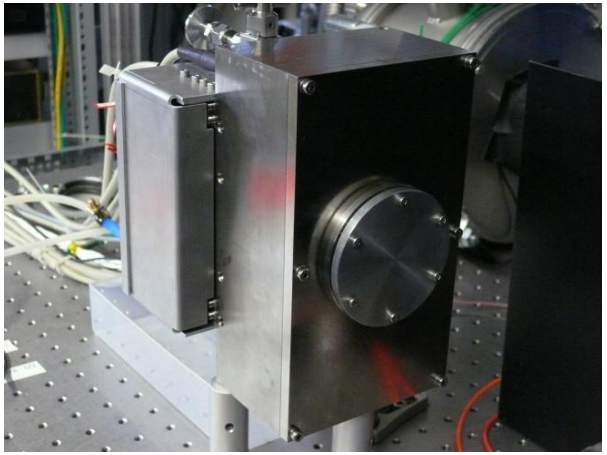


Transmitting cell

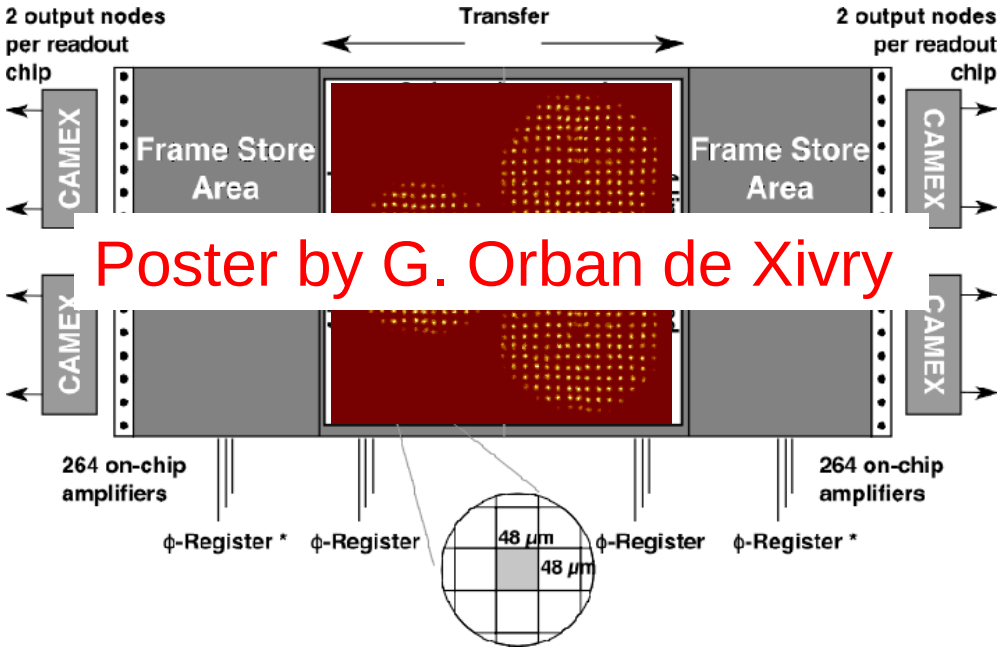
‚normal PC', high field dependence

MPE cell, highest supression over large field

Detectors & computing



- PnCCD deep depletion CCD (HLL & PNSensor)
- 248x256 illuminated Pixel
- 48µm pixelsize
- ~3…4e- read noise
- QE ~1
- Split frame transfer mode
- 1kHz Framerate

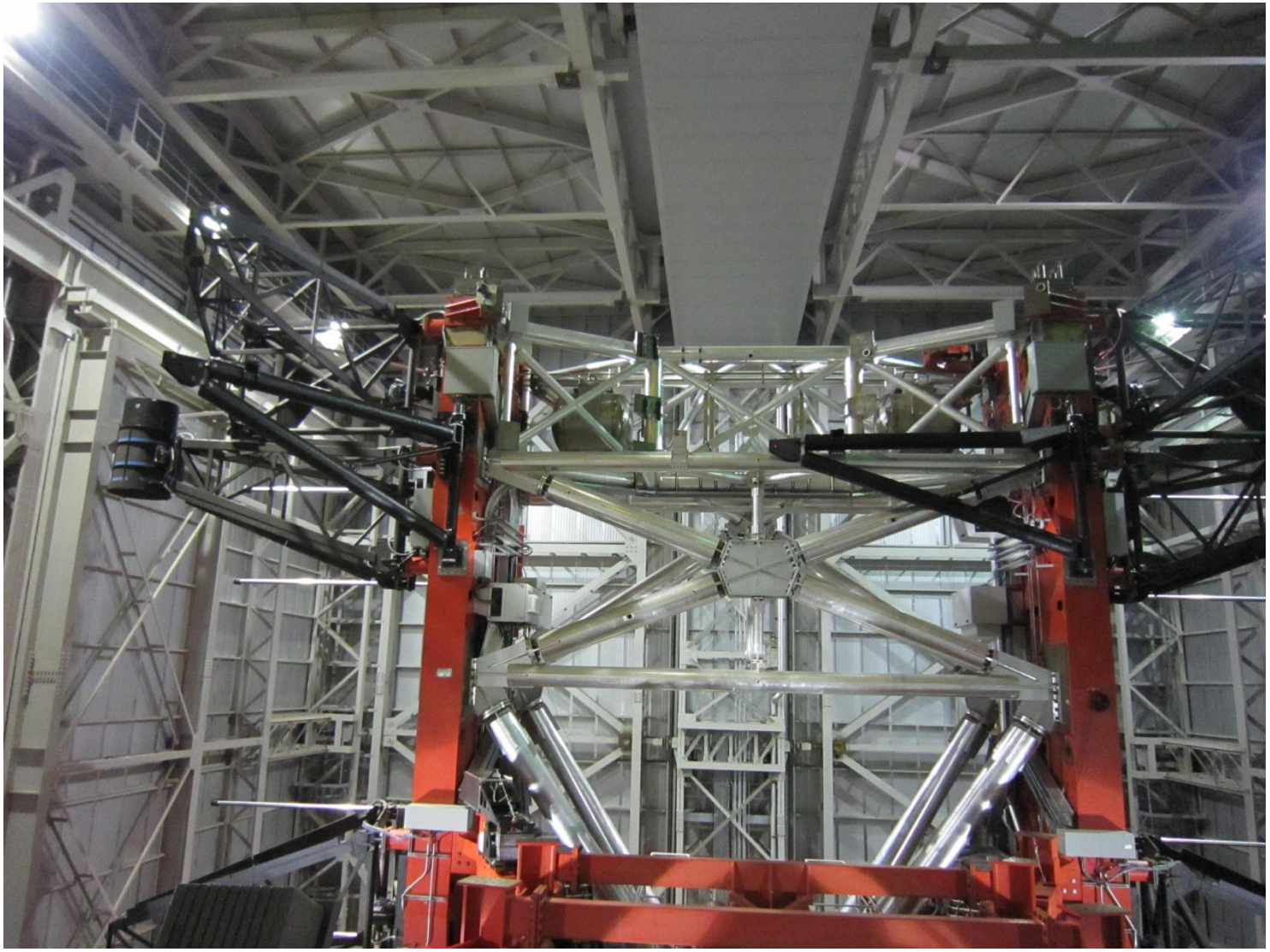


Poster by G. Orban de Xivry

Real time computing:

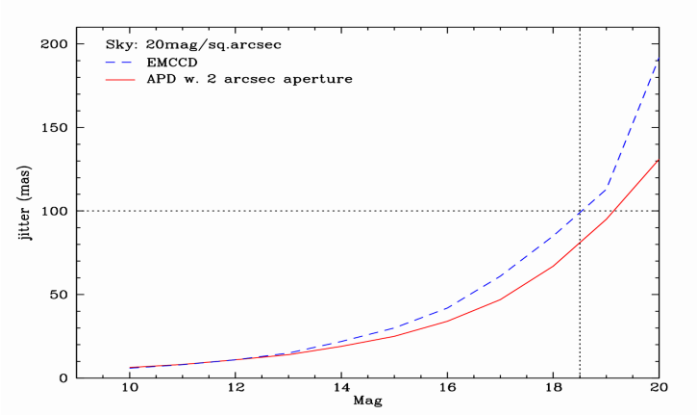
- Microgate BCU for slope computing and Reconstruction

Calibration system

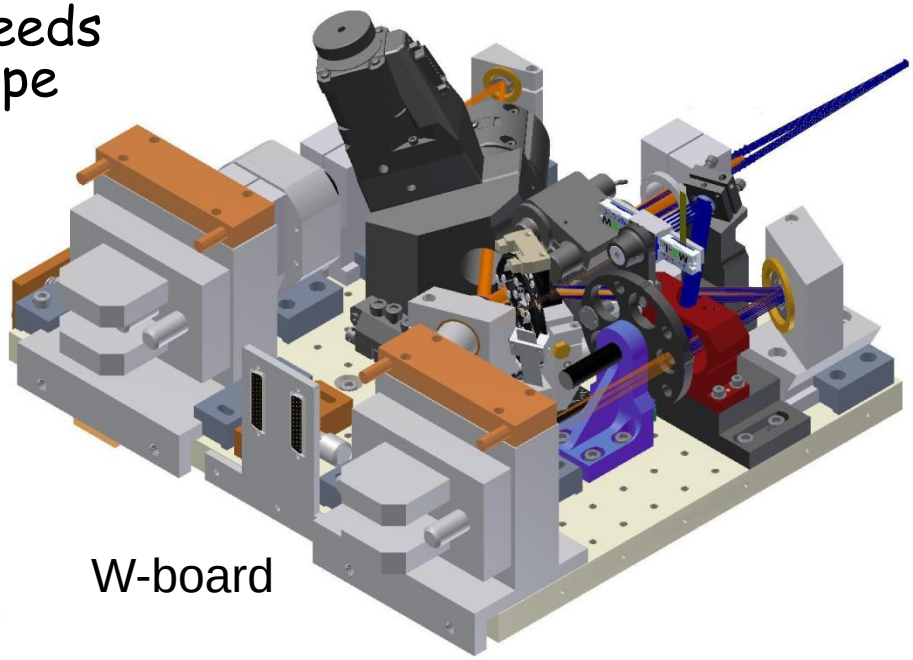


Tip-Tilt-Truth control

- APD Quadcell based TT-system
- Fibre fed
- Pick off located on the w-board (FLAO)
- TT calculator board´: own development
- ‚Truth' sensing: FLAO with pyramid on ~10% of the TT star light. Feeds offset slopes to the ARGOS slope computer



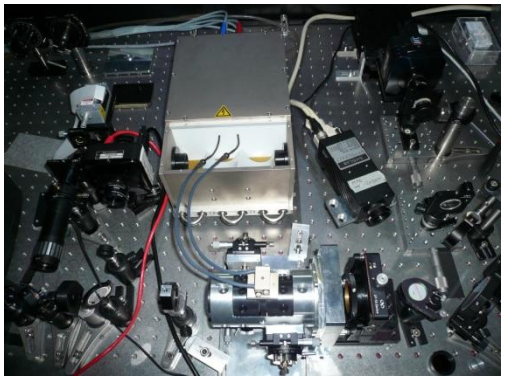
APDs and slope calculator



W-board

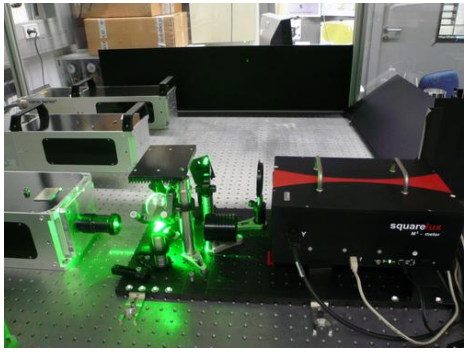
Bits & Pieces

CCD power supply

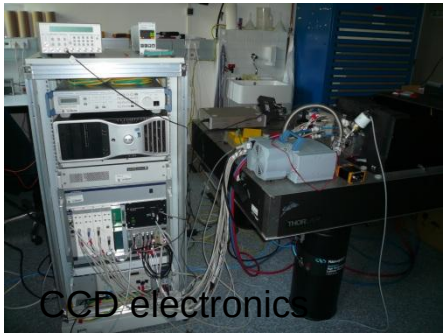


Pockels cell

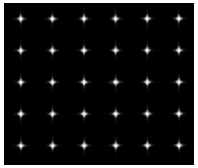
Telescope simulator



lasertesting

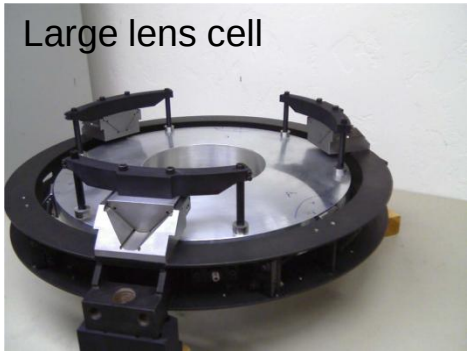


CCD electronics

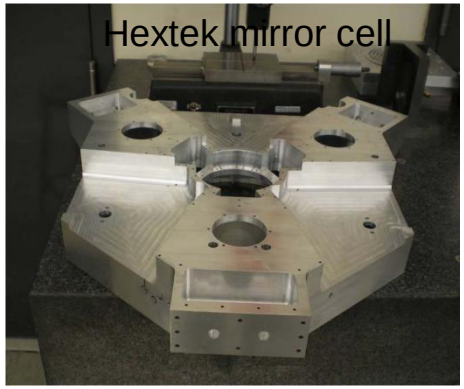


Lenslet array

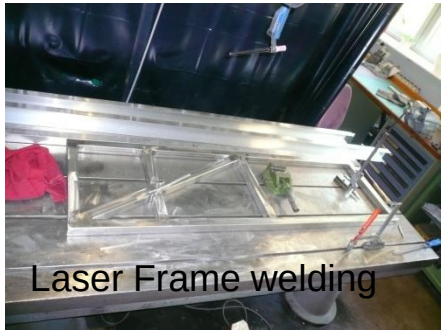
Motor controllers



Large lens cell



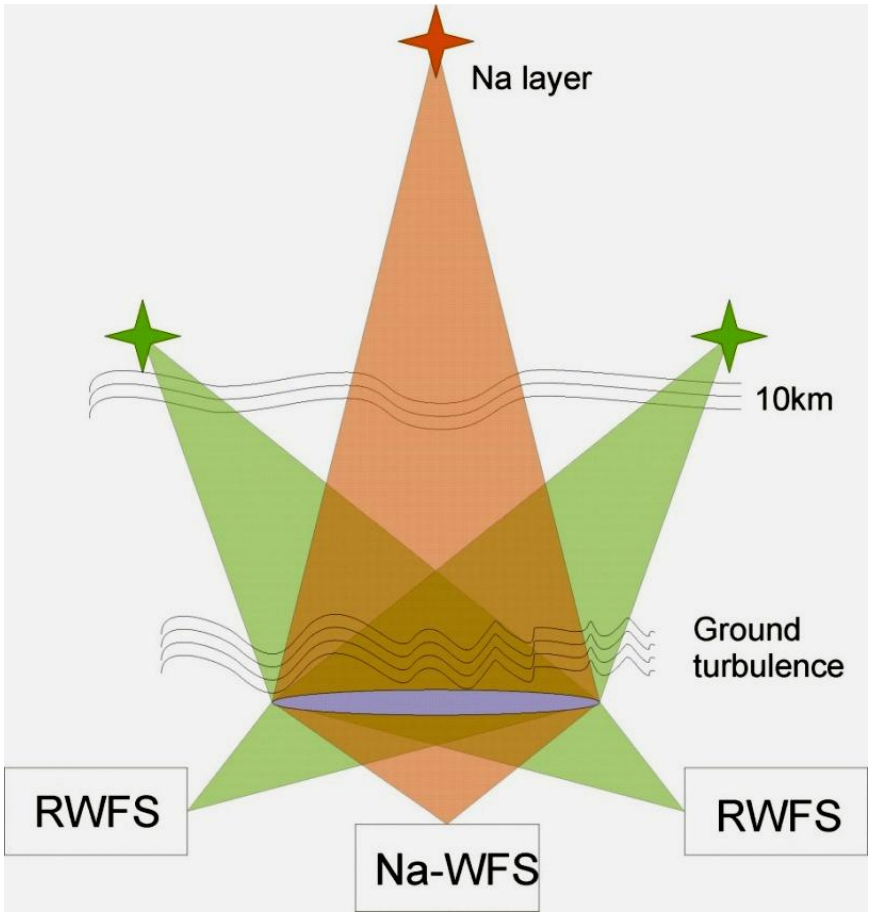
Hextek mirror cell



Laser Frame welding

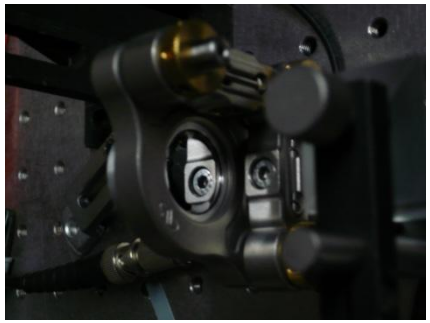
Next: Hybrid LGS guiding

- High power GLAO correction ‚cleans' up the ground turbulence
- Increases the limiting magnitude of NGS AO
- Adding a sodium laser opens up the path from GLAO to the diffraction limit
- Na-line laser detects higher layer turbulence
- Only moderate power Na-laser is required.
- Very nice path to MCAO, as only a single TT-star is required



Research in the ELT context

- Pyramid sensors with LGS - Poster: Enrico Pinna: 'Pyramids with extended Reference sources'
- Uplink correction -> get smaller LGS spots
- Pulsed lasers -> get rid of scatter
- Dynamic refocussing -> get rid of elongation



Membrane mirror 5kHz refocussing

100µs

Work in the ELT context:

- Learn on LGS GLAO efficiency
- Learn on multi laser facilities
- Deliver on vs. off axis WF data.
- Compare NGS, Na and Rayleigh: atmospheric statistics
- Hybrid guiding
- Dynamic refocussing, gated wavefront sensing

The ARGOS Team