Enabling Technologies for
MICADO
The E-ELT First Light Imager
Richard Davies
On behalf of the MICADO consortium
1. MICADO overview
2. Filters
3. Detectors
4. Manufacturing
5. Adaptive Optics
Picture credit: MICADO, MAORY, ESO

MICADO Key Capabilities

➢ **Sensitivity & Resolution**

- resolution of 6-10mas over 1arcmin field
- sensitivity up to 0.5mag deeper than JWST with advanced filters
- up to 3mag deeper in crowded fields

➢ **Precision Astrometry**

- <40µas over full 1arcmin field (see Trippe+ 10)
- 10µas/yr = 5km/s at 100kpc after 3-4 years
- bring precision astrometry into mainstream

➢ **Long Baseline Spectroscopy**

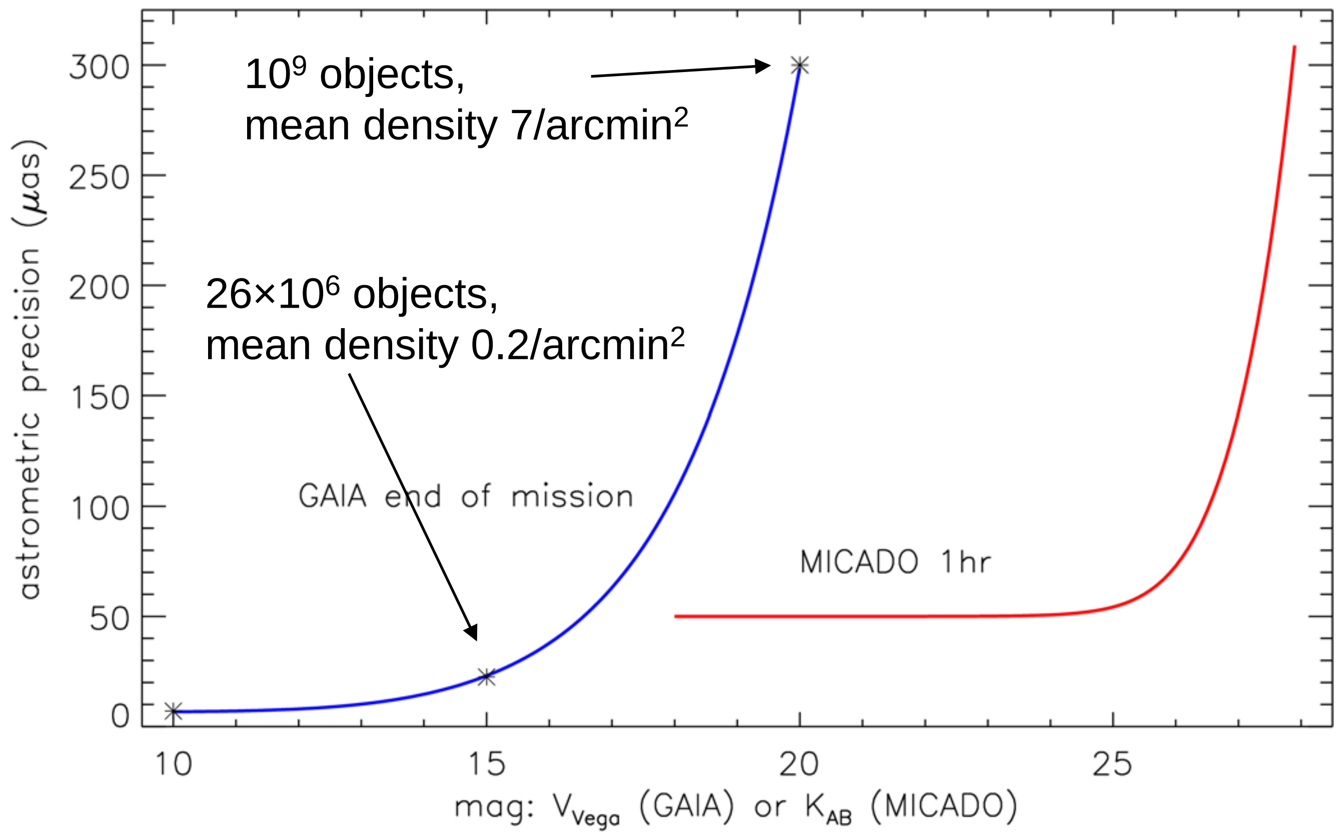
- simple high-throughput slit spectroscopy
- ideal for compact sources
- simultaneous 0.8-2.5µm coverage at R~5000

➢ **Simple, Robust, Available early**

- optical & mechanical simplicity for stability
- exemplifies most unique features of E-ELT
- flexibility to work with SCAO & MCAO

Aside on astrometry: GAIA & MICADO

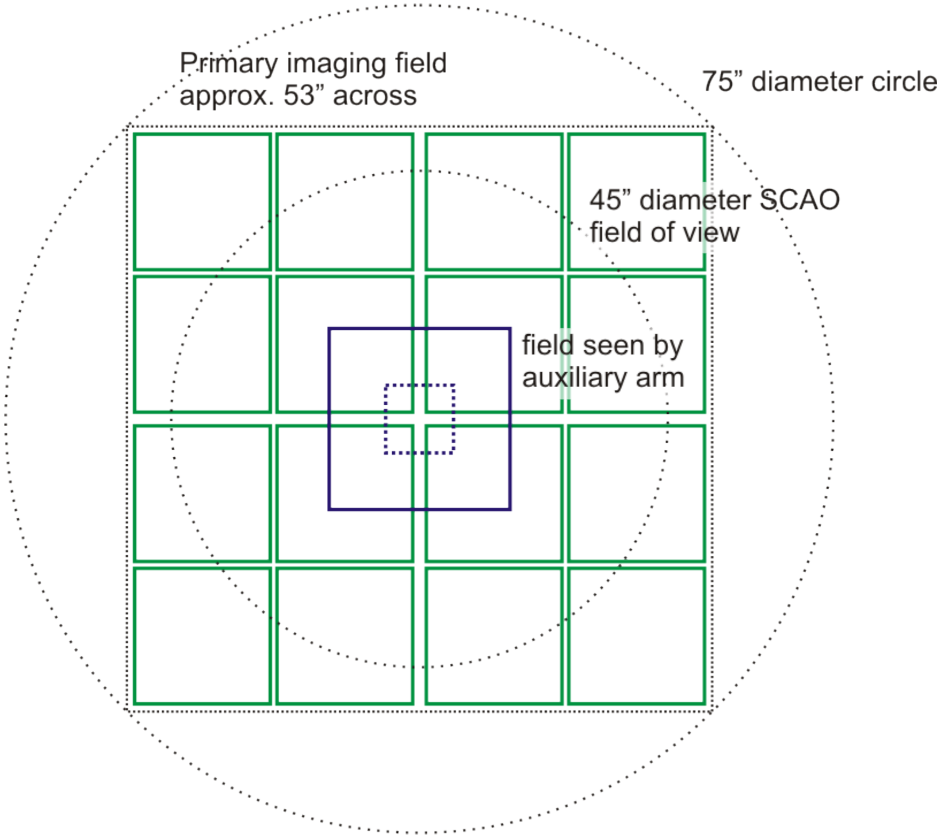
- Very different science as GAIA & MICADO will measure proper motions in very different regimes of stellar magnitude & density.
- Little opportunity for MICADO to reference positions to GAIA, since at the required precision there will be on average only 0.2 GAIA sources per MICADO field.



V_vega and K_AB magnitudes are roughly equivalent

MICADO: *M*ulti-AO *I*maging *C*amer*a* for *D*eep *O*bservations

- 0.8-2.5µm



Primary Imaging Field

- 53” across, 3mas pixels
- high throughput (>60%)
- 4×4 HAWAII 4RG detectors
- 20 filter slots

Auxiliary Arm

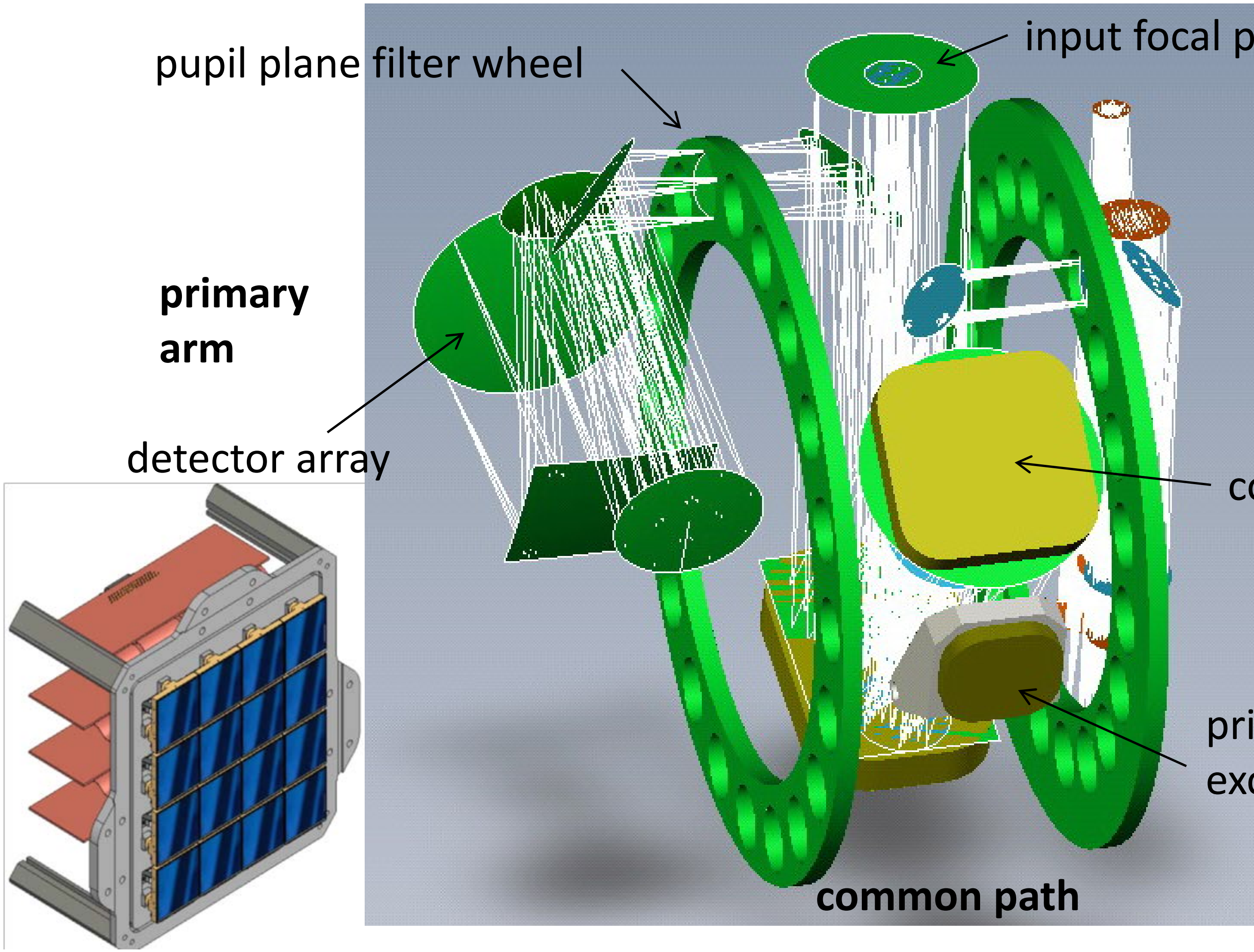
- mainly for spectroscopy
- potential for additional options, e.g.
  tunable filter (dual imager)
  high time resolution

Changes since Phase A

- incorporate spectroscopy into primary arm, to enable
  simultaneous 0.8-2.5µm spectroscopy in ‘XShooter-like’ mode

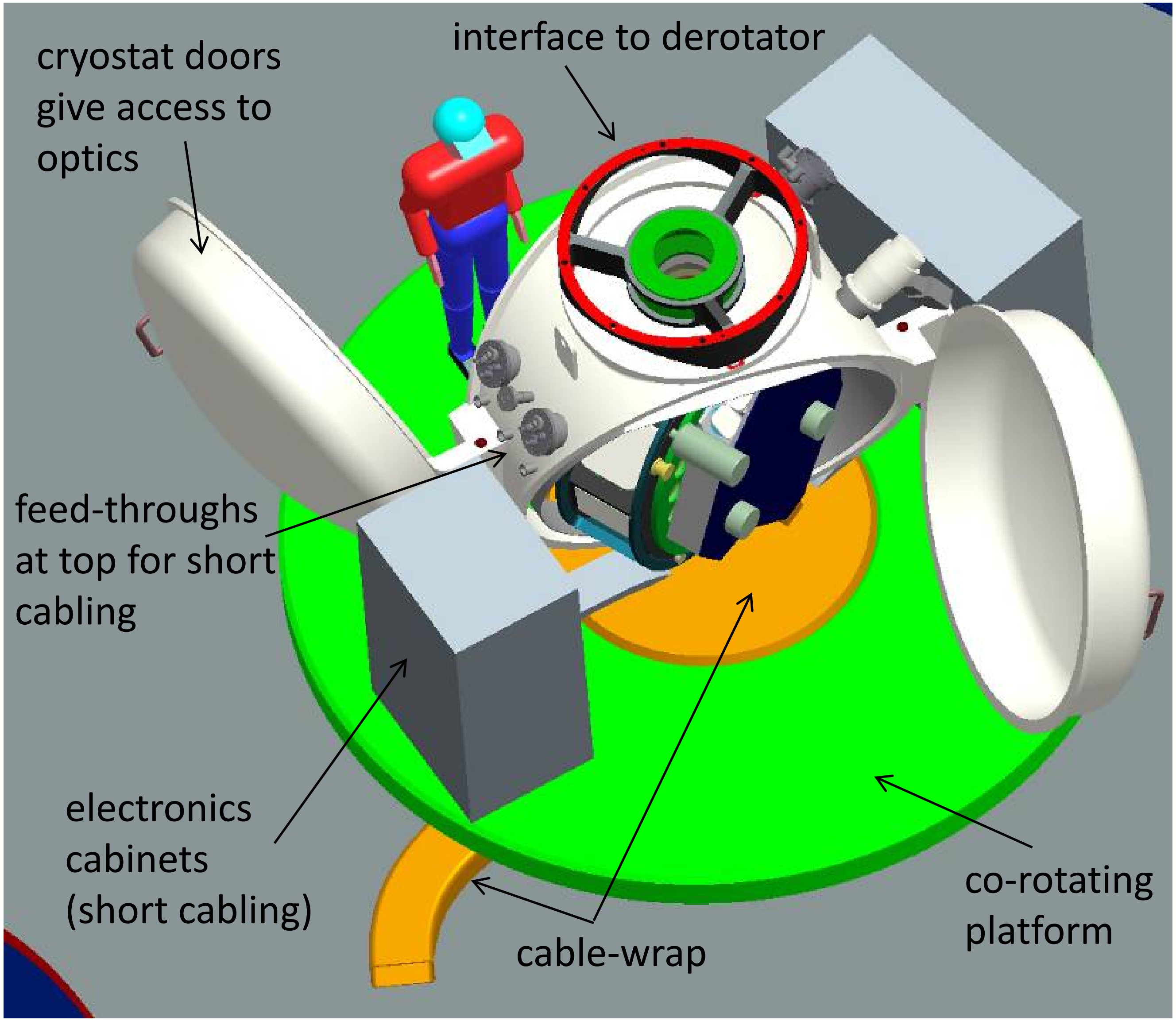
MICADO opto-mechanics overview

- gravity invariant high-throughput reflective design using only fixed mirrors;
  optimised for photometric & astrometric precision



Mechanics: instrument & cryostat

- cryostat ~2m across; mounts underneath SCAO & MAORY

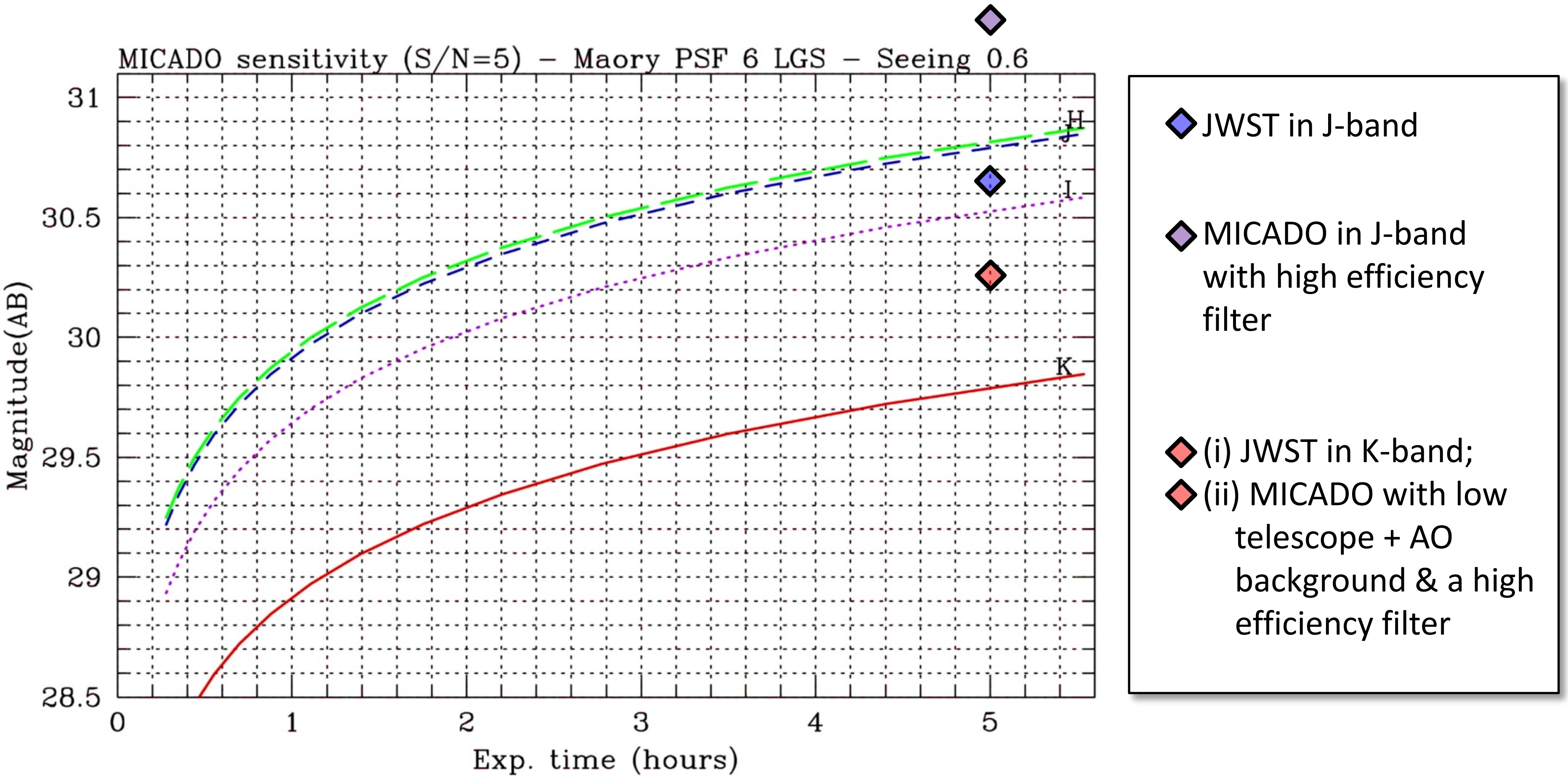


Mass:

under derotator	3000 kg
on Nasmyth	2800 kg
calibration unit	500 kg

Sensitivity: imaging

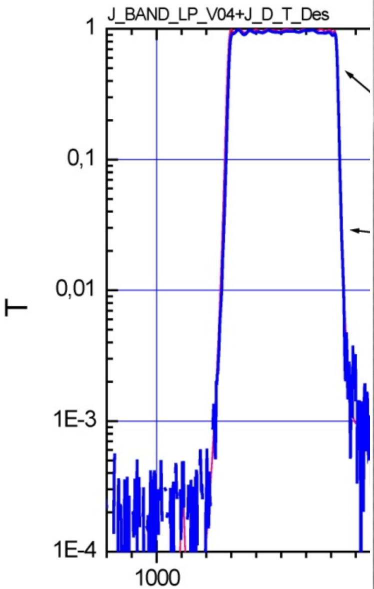
Isolated Point Sources to 5σ

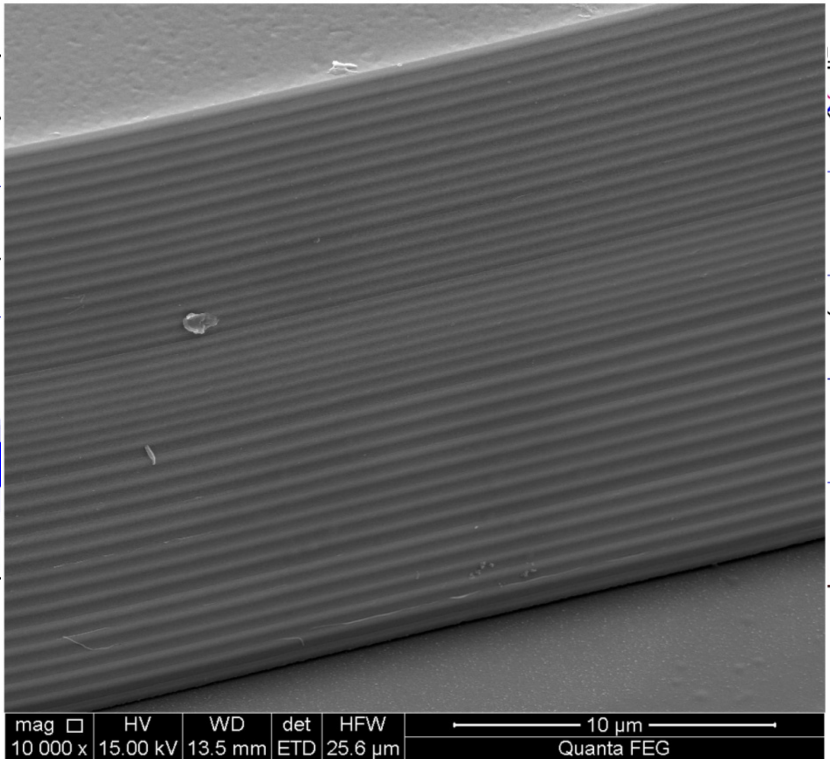


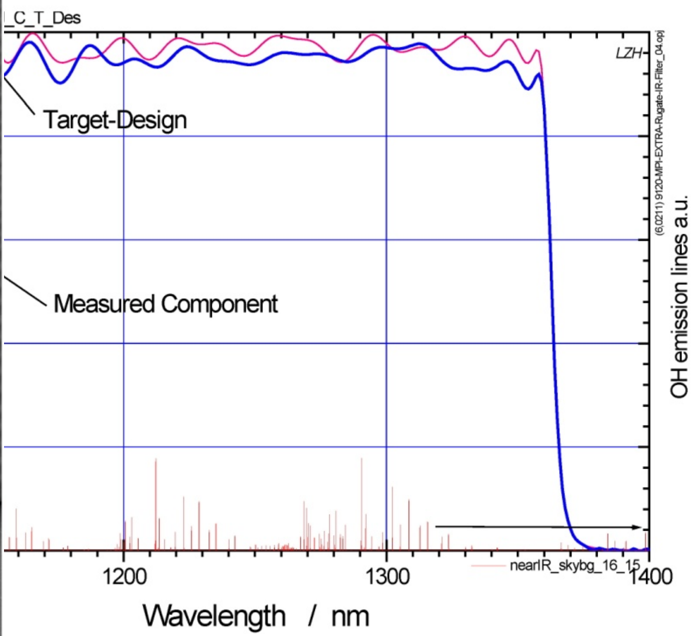
5hrs, 5σ	J_{AB}	H_{AB}	K_{AB}
Imaging	30.8	30.8	29.8
Imaging with advanced filters	31.3	31.3	30.2

Advanced Filters

- collaboration with LZH
- manufactured J-band filter, 95% throughput (80 layers, 20µm thick); also OH blocker
  ×1.34 increase in S/N wrt HAWK-I filters
- many issues clarified: tension warping, cold cycling
- ongoing HW & SW developments in progress to reach MICADO requirements
  - 5nm resolution filter, design is 100µm thick, (manufacturability?)
  - homogeneity over large (10cm diameter) filter size
- together with USM, we have been awarded BMBF funding to 2014







Günster, Ristau & Davies, 2011

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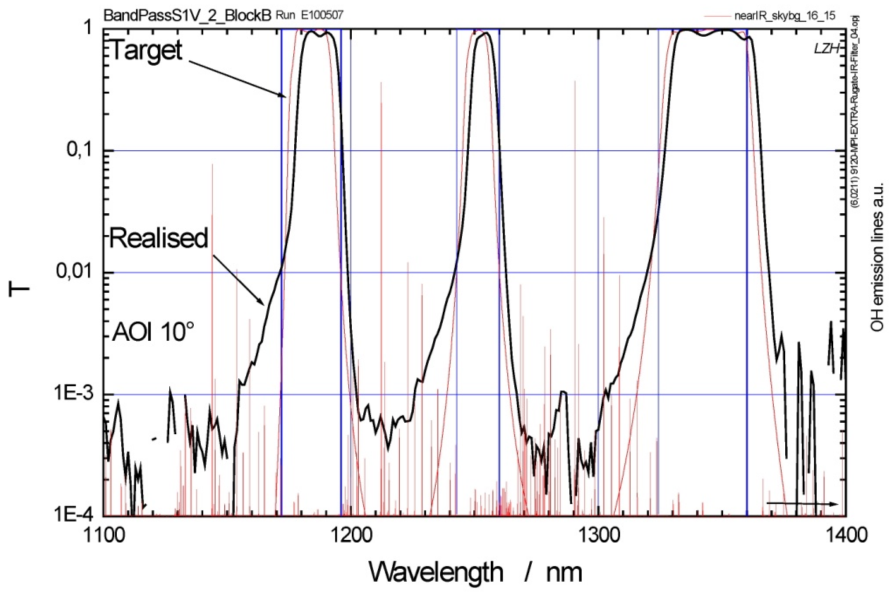

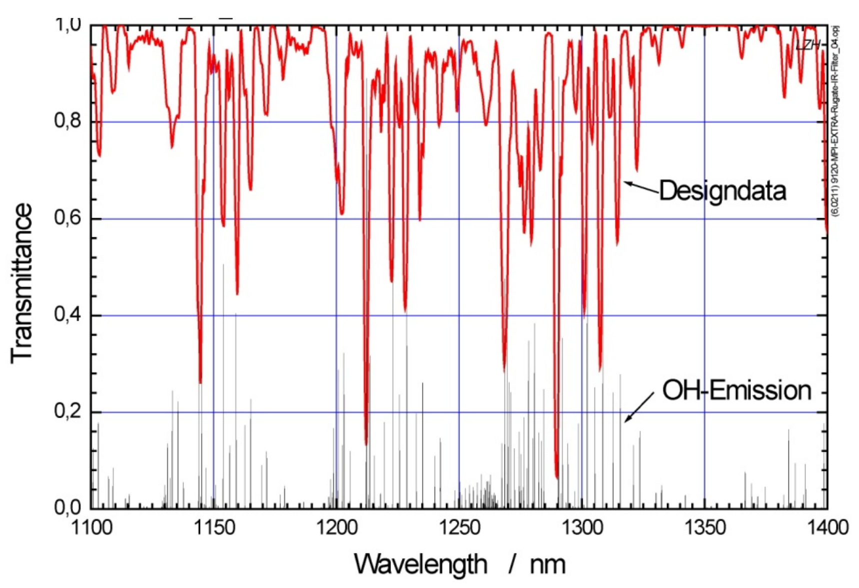

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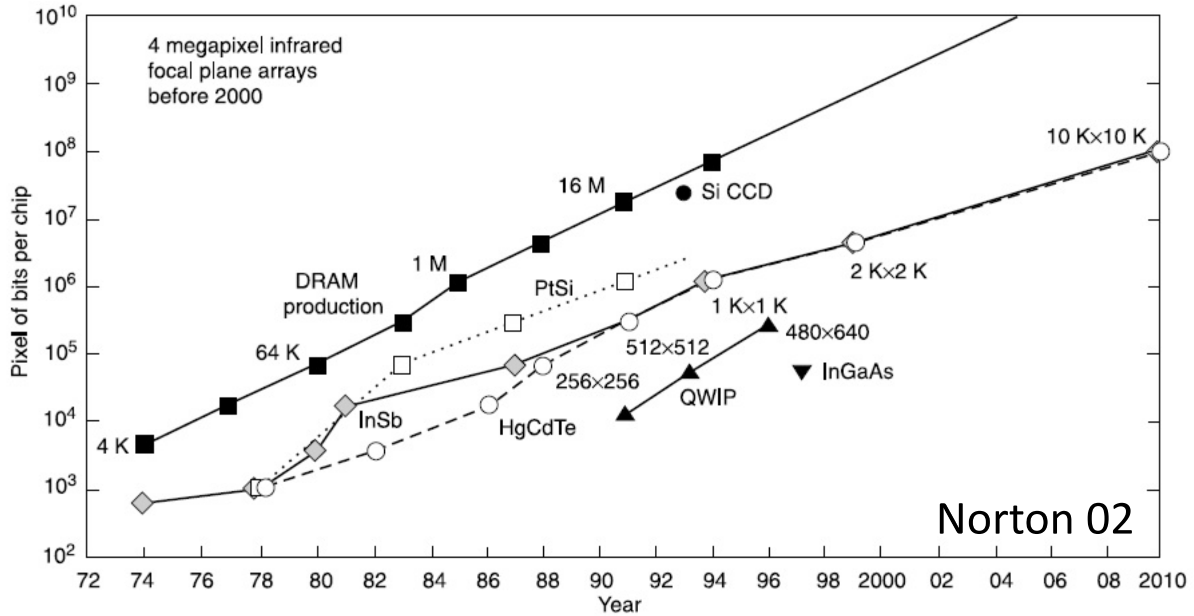
Detectors

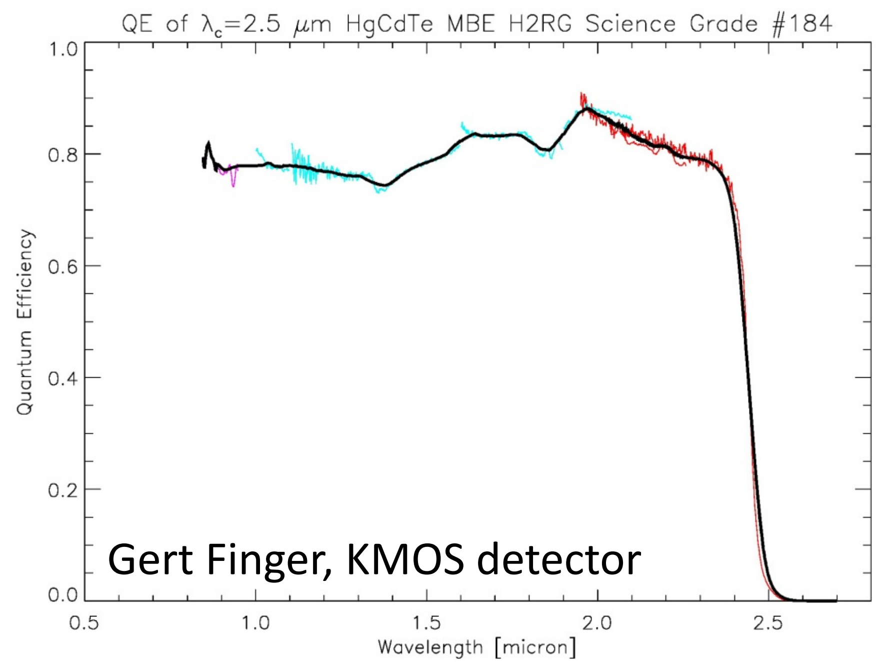
HAWAII detectors

- *Large format*
- *High QE* over large λ-range
- Developed for 'space *astrometry* mission' with 'stringent positional stability requirements' (<10nm / 2μas)

but

- *Persistence* – reduced by x10 with 'global reset de-trapping'
- *Electronic ghosts* – interchannel crosstalk reduced by x10 with slower read-out (8μs/pix)
- *Saturation*: PSF of 14mag or brighter saturates pixels within 1sec.
- Richard Blank: define multiple windows for faster readout; it is 'only a matter of software' to identify bright pixels so they can be read out faster





Precision Manufacturing

- Large mirrors of almost arbitrary shapes
- ‘plug-n-play’ optics

Primary arm

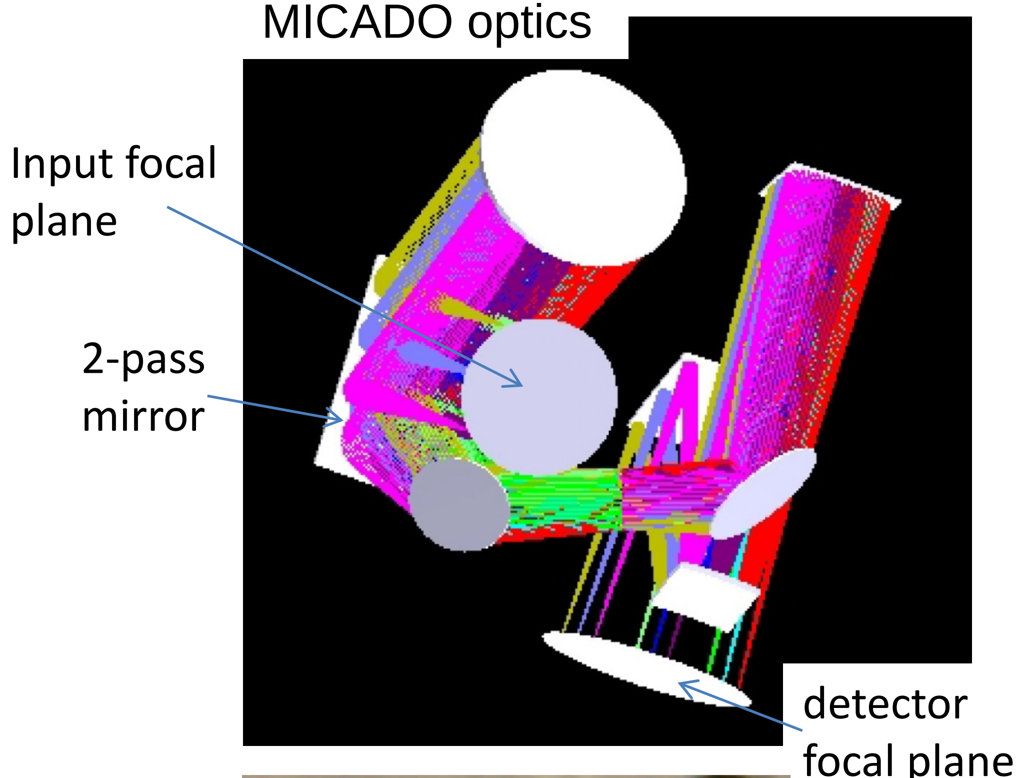
Size of 3 flat mirrors:
160×230 & 260×380 mm

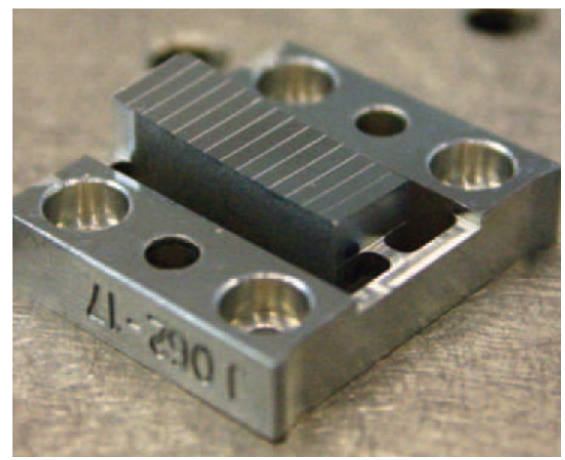
Size of 4 working mirrors:
150, 200, 250, & 370 mm diameter

MICADO tightest mirror tolerances

Radius of curvature	0.1mm
Decenter (x,y,z)	0.05mm
Tilt (x,y,z)	0.01deg

MICADO optics



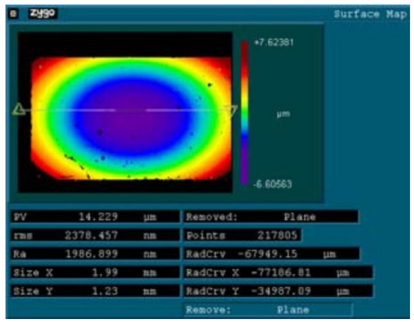


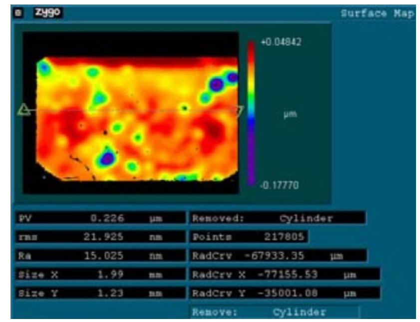
KMOS slicing mirror: 14 butted spherical surfaces pointing in different directions

Precision Manufacturing

- but there can still be nasty surprises

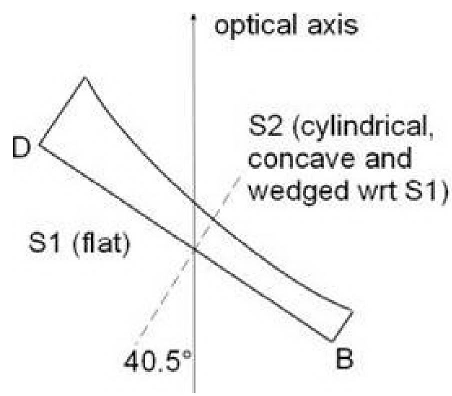
Impurities limit smoothness of diamond turned mirrors for KMOS on VLT (solved)



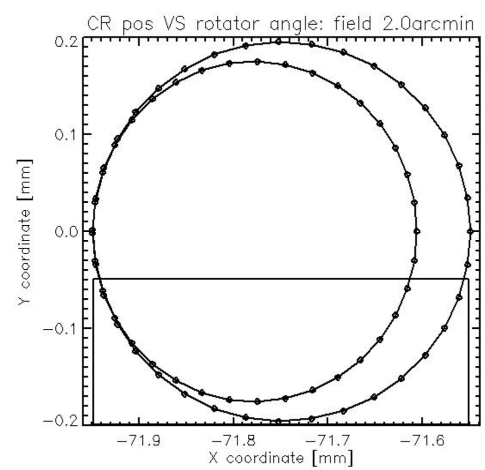


Optical/IR dichroic for ARGOS on LBT (solution in progress)

400x300mm

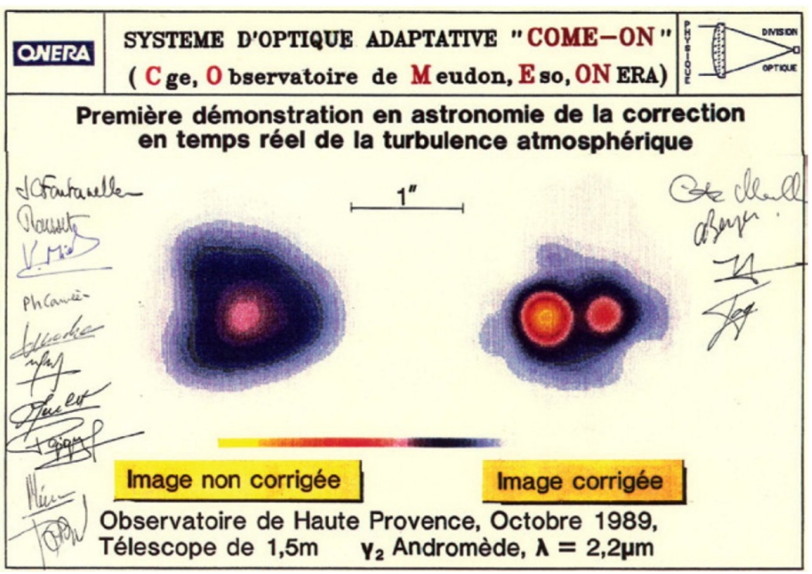


rotation & location dependent distortion: up to 0.65” at 2’ off-axis

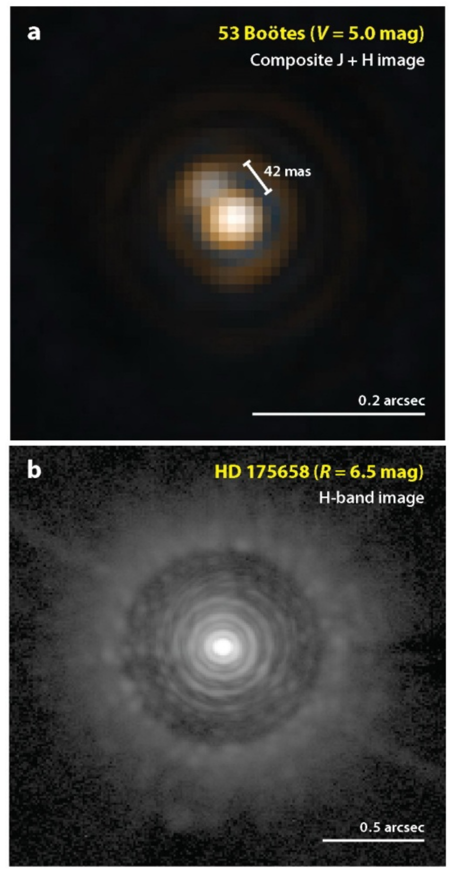


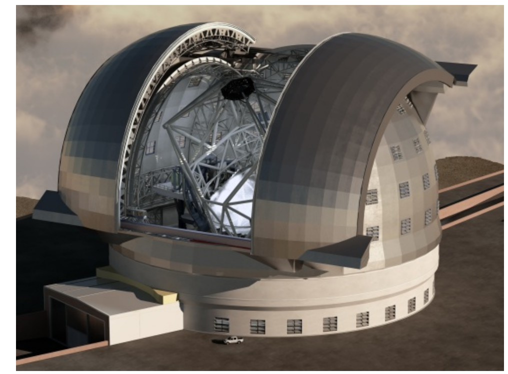
Adaptive Optics Developments

A history of astronomical adaptive optics in 1 slide



First AO correction



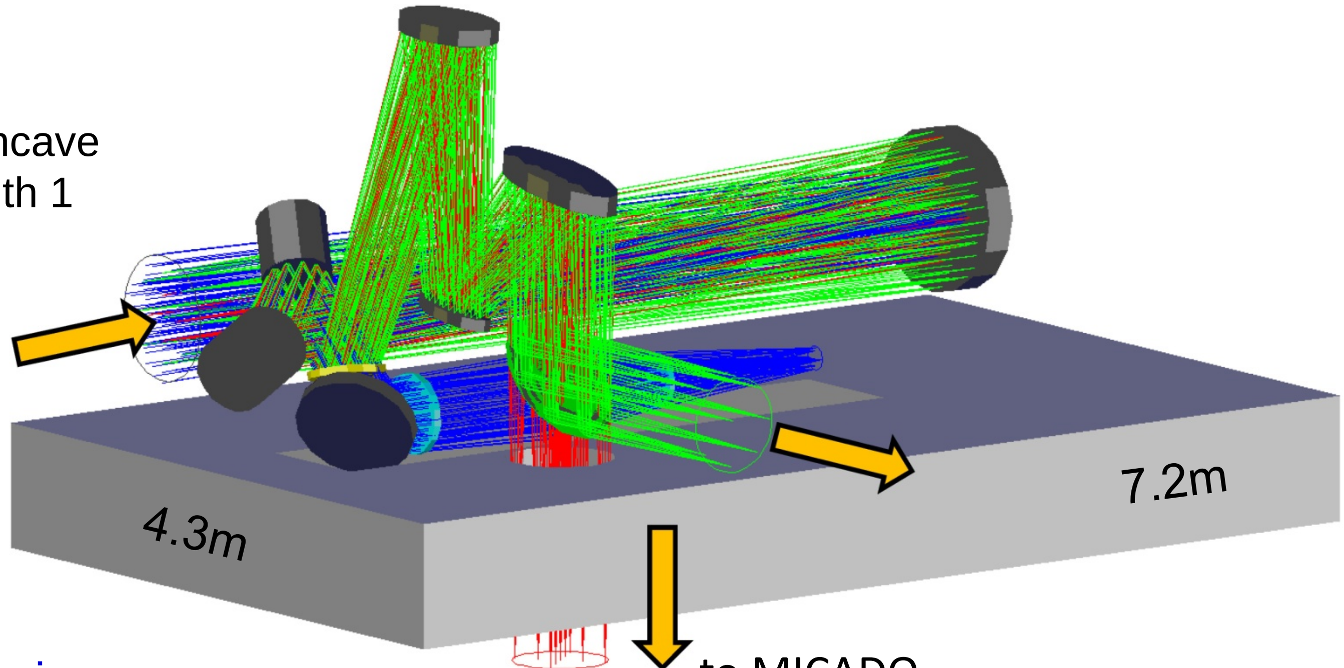


First telescope designed from start to have AO ‘built in’; ASM + pyramid; first extreme AO performance

MAORY: Multi-conjugate Adaptive Optics RelaY

INAF + University of Bologna, ONERA, ESO

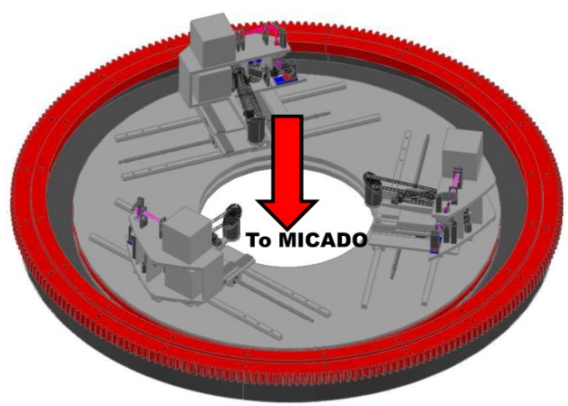
- revised design has 3 concave & 1 convex surface, with 1 pupil image: no field curvature
- 6 LGS & 3 NGS
- controls telescope DM + 2 post-focal DMs



Performance in 0.8” seeing

sky coverage @ NGP:

	39%	80%
strehl ratio:		
K	53%	41%
H	34%	22%
J	14%	6%

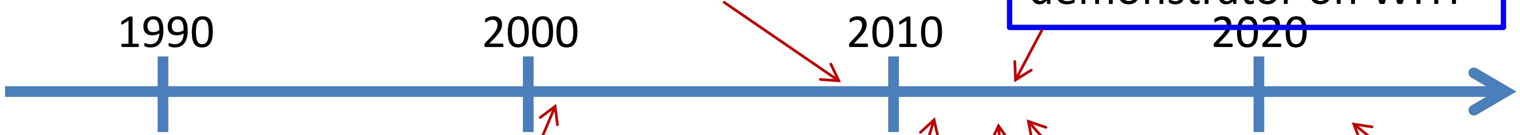


NGS WFS (2 tip-tilt + 1 tip-tilt-focus) mounted on top side of derotator

Laser Guide Star Multi-Conjugate Adaptive Optics ?

GLAO on MMT

CANARY MOAO demonstrator on WHT



"…operation of complete [LGS-] MCAO system beginning in early 2006."

Gemini South MCAO Preliminary Design Review, 2001

"…it appears that there is a window of ~6 years for Gemini/MCAO to pursue unchallenged NGST science."

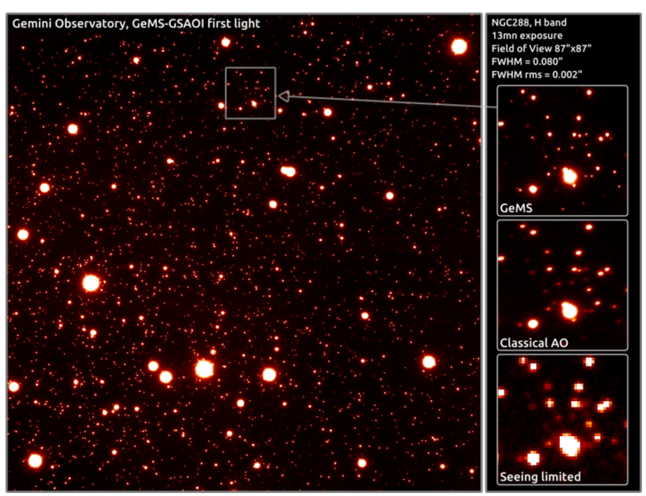
Gemini MCAO Conceptual Design Review, 2000

Multi-LGS for GLAO on LBT

ESO's AOF: multi-LGS tomography – but not MCAO

MICADO phased approach: NGS-SCAO first, then LGS-MCAO

GeMS



Jan 2011: installed.

Jan 2012: "it's working" after 7 runs.

Mar 2012, after 10 runs:

FWHM 80-120mas in Iz bands.

Commissioning continues through 2012

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