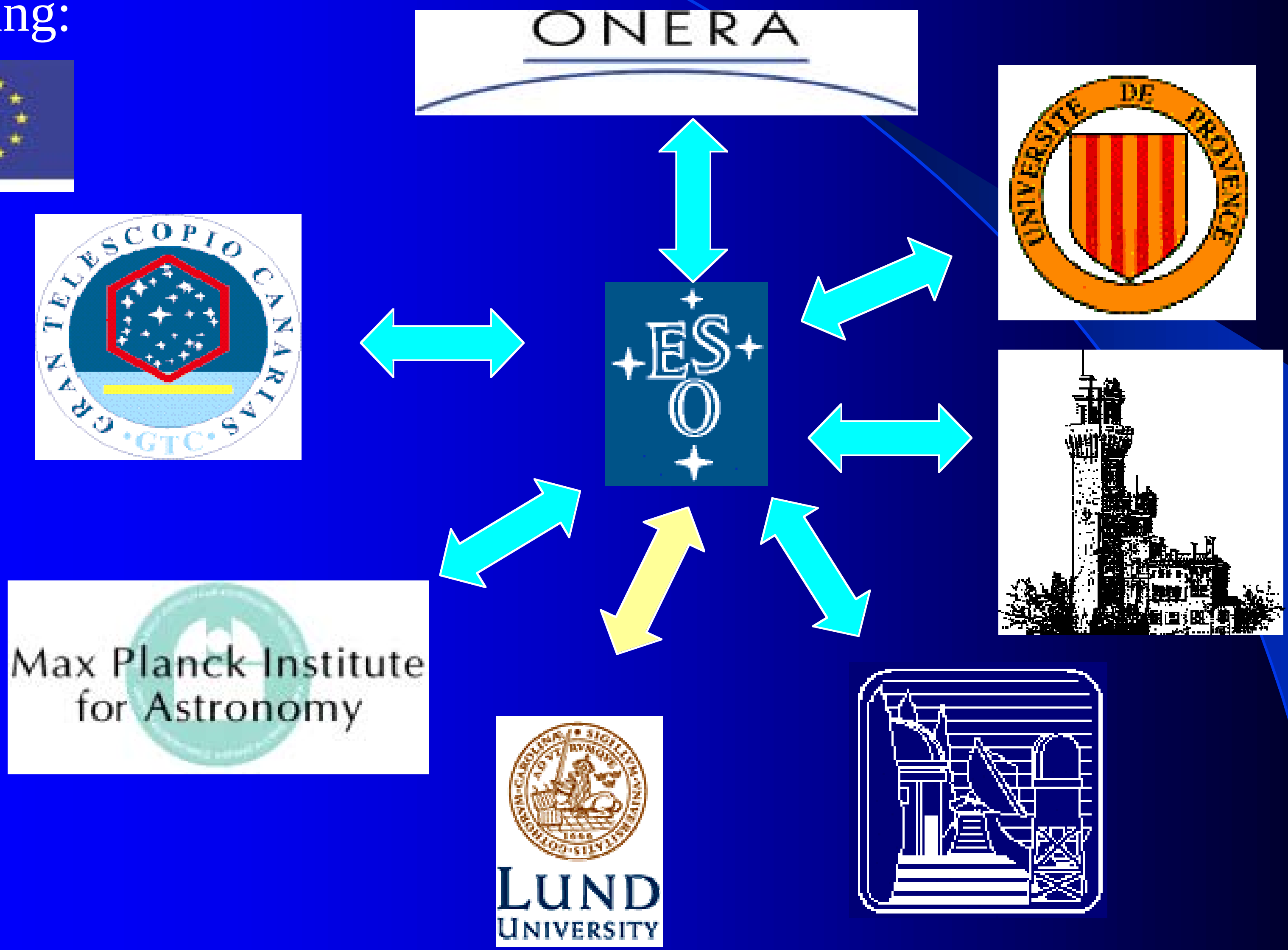
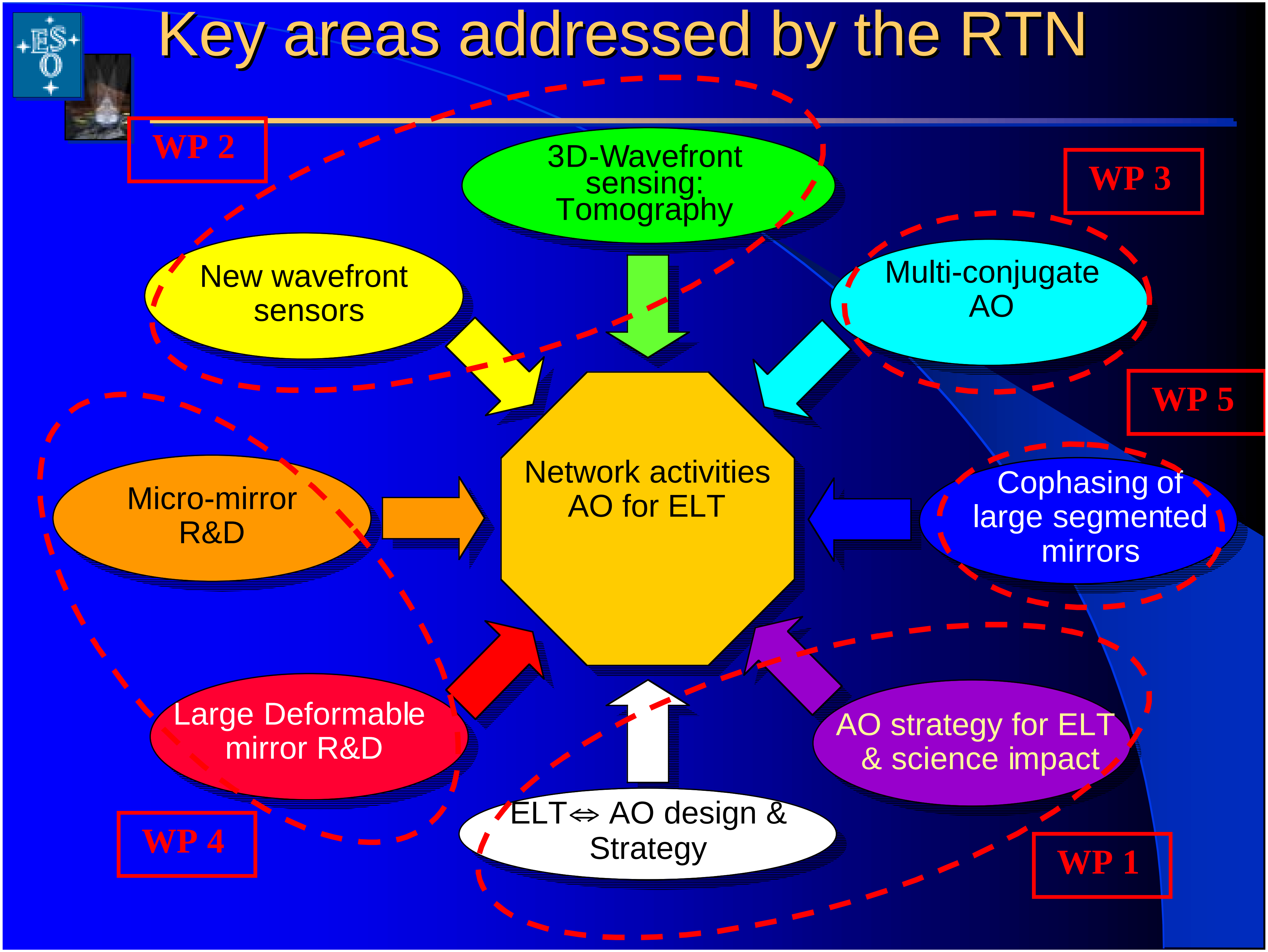
The European RTN (Research Training Network) on AO for ELTs

M. Le Louarn

NETWORK PARTNERS

Funding:



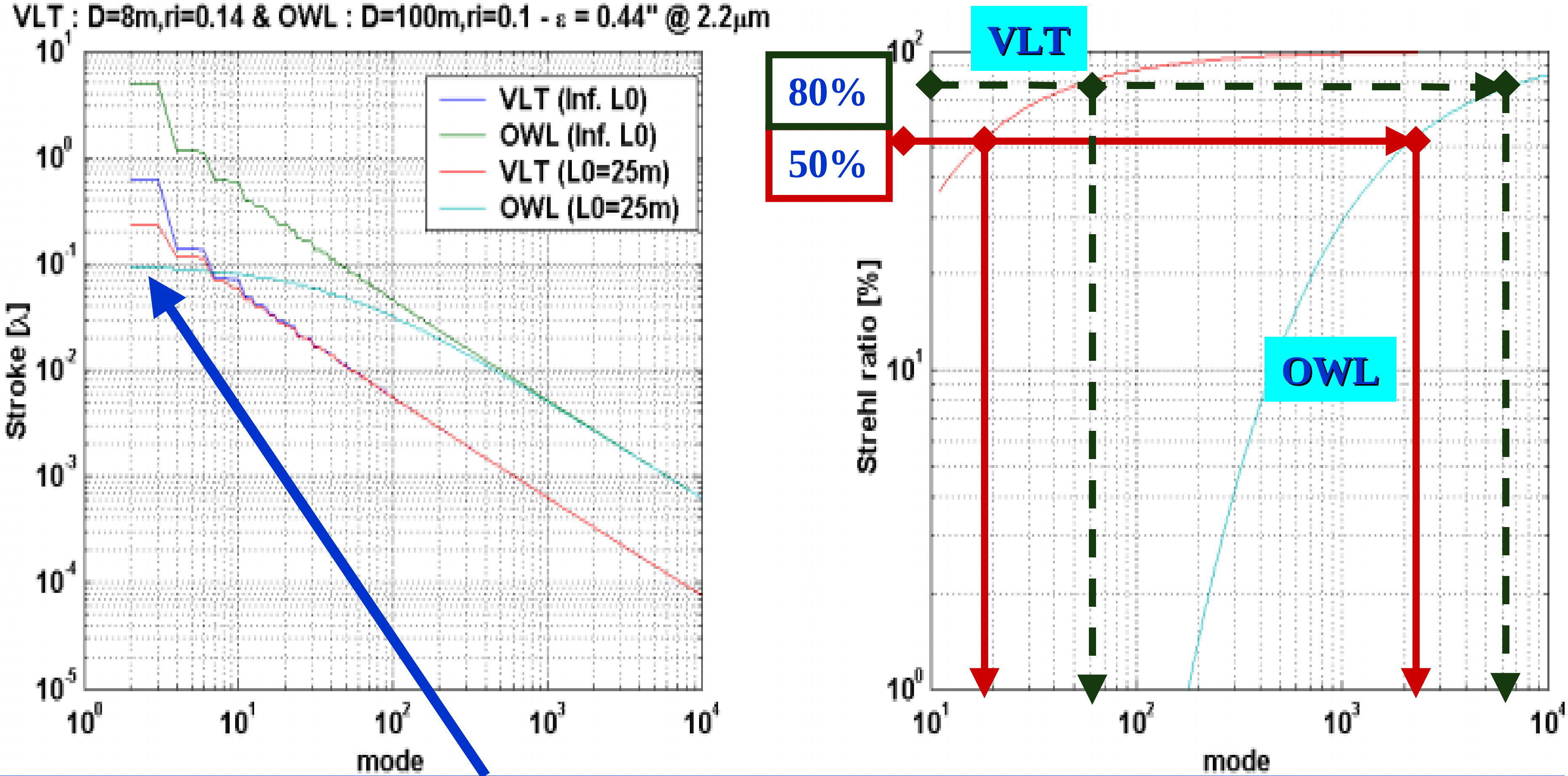


Key areas addressed by the RTN
WP 2
3D-Wavefront sensing: Tomography
WP 3
New wavefront sensors
Multi-conjugate AO
WP 5
Micro-mirror R&D
Network activities AO for ELT
Cophasing of large segmented mirrors
Large Deformable mirror R&D
AO strategy for ELT & science impact
ELT⇔ AO design & Strategy
WP 4
WP 1

WP1 Science & Networking

Top level requirements
ELT design and AO constrains
Finite outer scale effect
Deformable mirror requirements
Knowledge of the atmosphere
Preliminary road-map for AO on ELTs

Analytic AO simulation : L0 effect



Effect of a finite outer scale of turbulence on the turbulent modes to be corrected: 100 first modes are much attenuated for OWL

R. Conan et al. 2002

WP2 & 3 Science & Networking

Adaptive Optics Tomography

Wavefront sensing and 3 D WFS

Multi-Conjugate Adaptive Optics (MCAO)

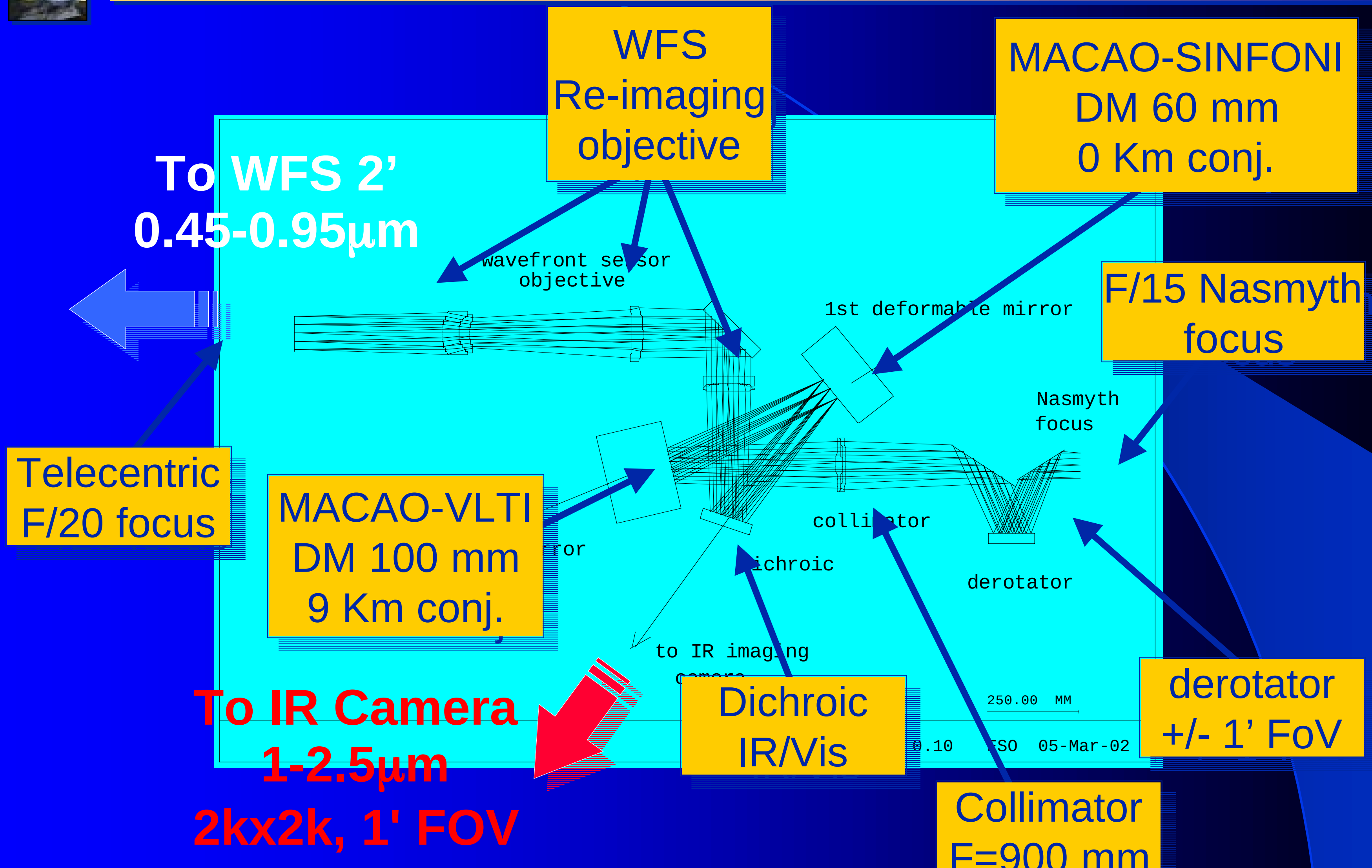
Star oriented MCAO

Layer oriented MCAO

Multi-FOV Layer Oriented MCAO

LGS MCAO

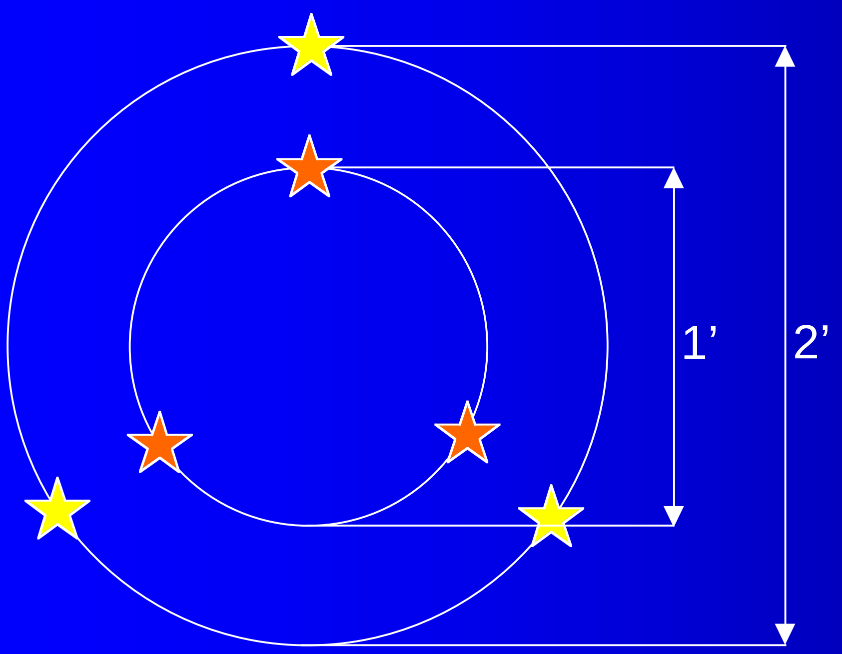
MAD optical design



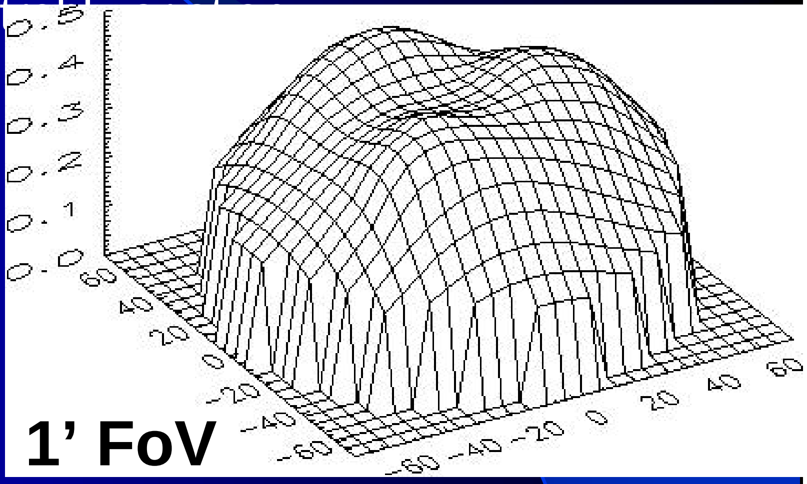
Thorough lab testing w/ turbulence generator to test control algorithms + understand MCAO. Compare Star and Layer oriented approaches

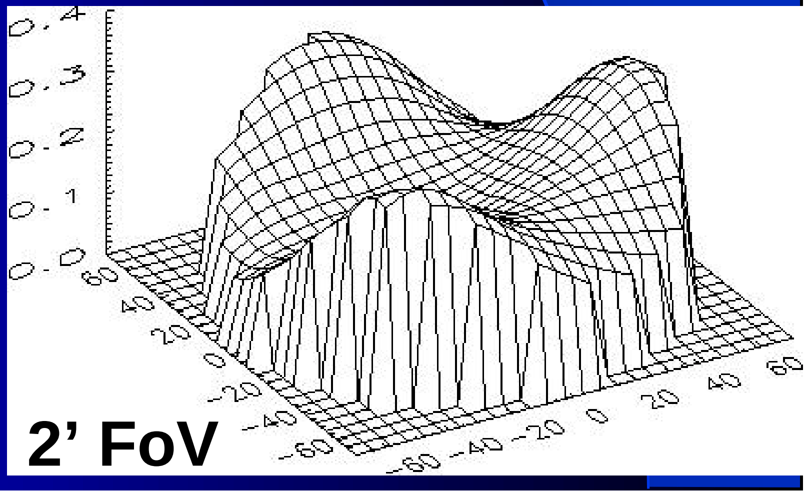
MAD Star Oriented expected performance

- Numerical simulations
- 7 layers atmosphere, seeing 0.65” at zenith and 30° from zenith
- MAD system, 3 Natural Guide Stars
- Performance in K band (2.2 μm): Peak Strehl / St



FoV	Zenith	30°
1’	0.45/0.13	0.42/0.21
2’	0.31/0.13	0.28/0.21



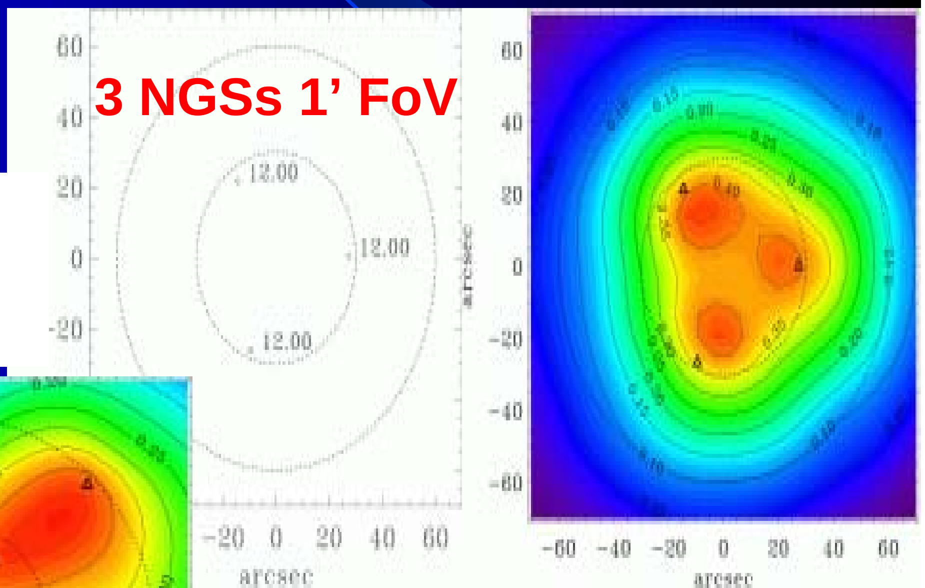


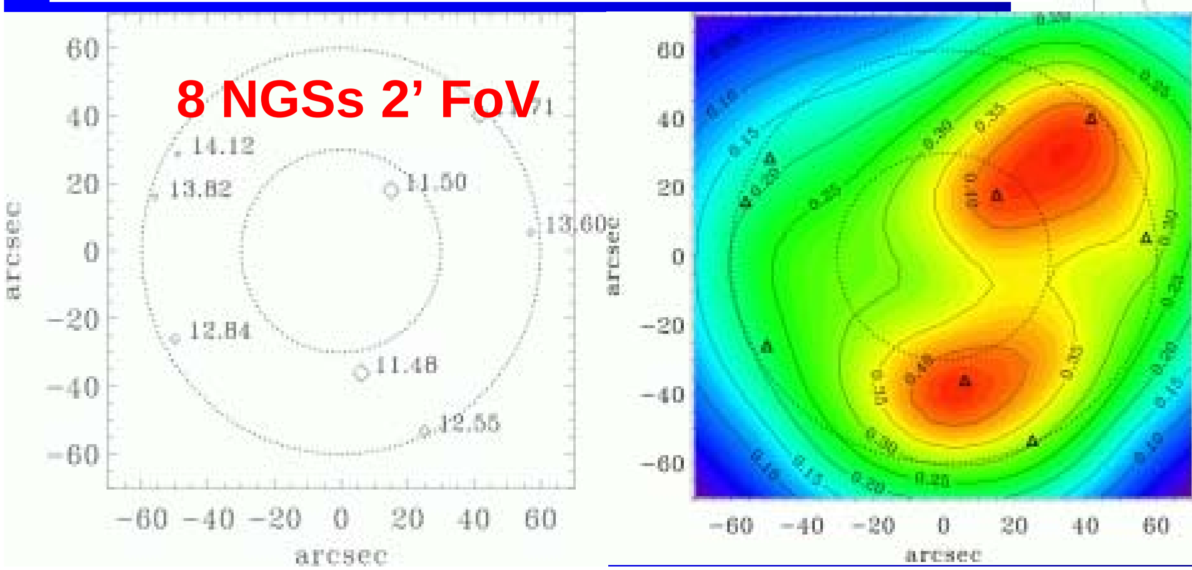
Layer Oriented expected performance

- Numerical simulations
- 7 layers atmosphere, seeing 0.67”, no outer scale, at 30° (no zenith)
- MAD system, 3-8 NGSs integrated magnitude m_v<14
- Performance in K band (2.2 μm): Peak Strehl / Strehl rms

# NGS	1’ FoV	2’ FoV
3 NGS	0.43/0.05	0.31/0.06

# NGS-2’ FoV	m_{int}:10	12	14
6 NGS	0.43/0.09	0.40/0.05	0.29/0.05
8 NGS	0.44/0.06	0.41/0.06	0.28/0.06





WP4 Science and Networking

High Density deformable mirrors
Large deformable mirrors
High density micro-mirrors

Adaptive "secondaries" (Arcetri)

- A cost-effective design optimised for MCAO and for low sensitivity to error sources
- Prototype adapt. second. @ VLT ?

M2 - Flat, 33.4-m, *segmented*

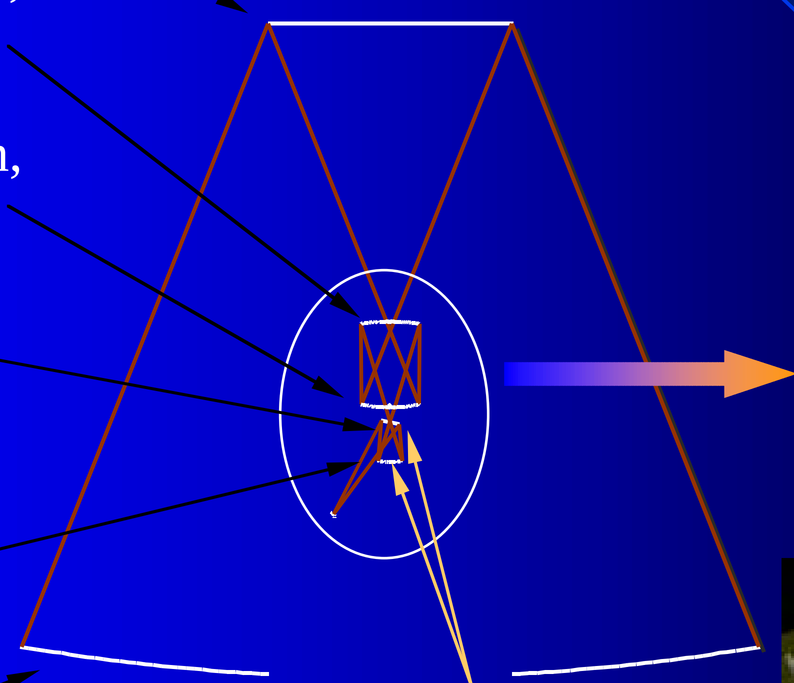
M4 - Aspheric, 8.1-m, thin *active* meniscus

M3 - Aspheric, 8.2-m, thin *active* meniscus

M6 - Flat, 2.5-m, Exit pupil, *field stabilization*

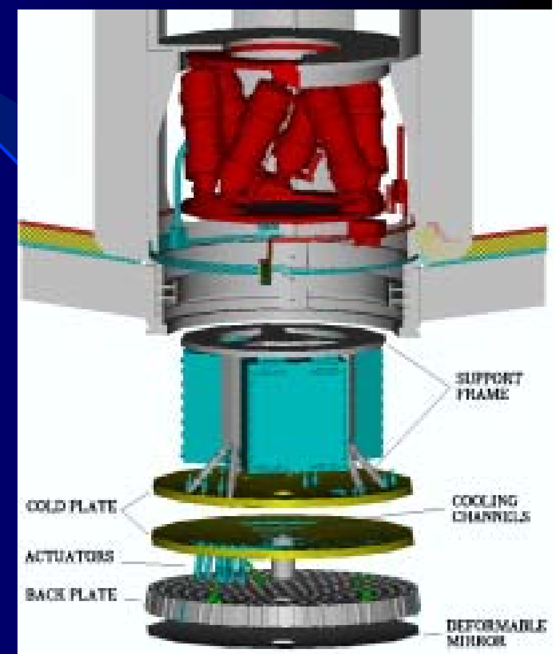
M5 - Aspheric, 4.0-m, *Focusing*

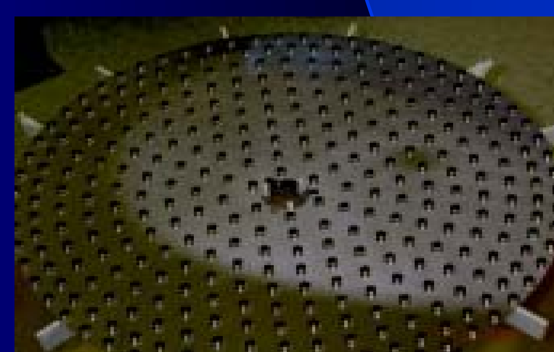
M1 - Spherical, 100-m, f/1.42, *segmented*



Adaptive mirrors (conjugated to 0, 8 km)

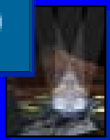
7000-20000 actuators





MOEMS (obs. Marseille)

- MDM conception, realization and characterization, since 2001
  - Collaboration with LAAS (Toulouse-France)
  - Manpower: LAM (2 p. + PhD student);
    LAAS (2 p. + Post-Doc (AO-ELT, starting this fall))
  - Device characterization
    - Characterization bench under development
    - Tests on prototypes developed by LAAS
- Projects
  - VLT 2nd generation
    - PF (LAOG, LAM, Obs. Paris-Meudon, Obs. Nice, ...)
    - FALCON (Obs. Paris-Meudon, LAM)
  - OWL
    - AO-ELT network



Science and Networking WP5

Large segmented mirrors

Effect of segmentation cophasing

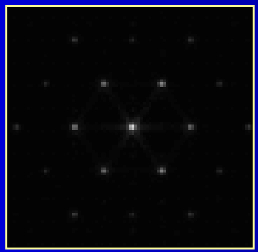
Point Spread Function quality

Wavefront sensing for cophasing

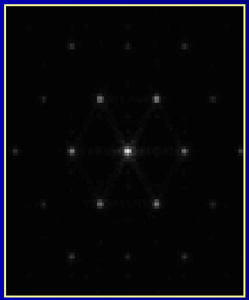
Mach Zehnder, curvature, Shack Hartmann, Pyramid…..

Segmentation PSF errors

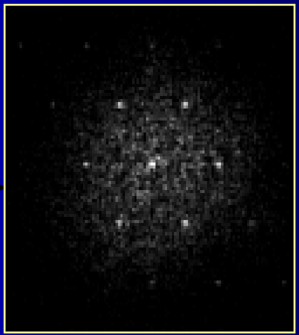
Gaps



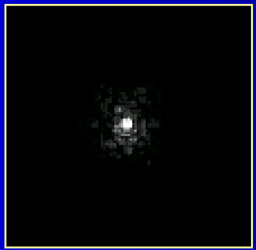
Edge misfigure



Tip-tilt error



Piston error



Diffraction peaks

Yaitskova et al. 2002

All effects: Strehl ratio and relative intensity of the first order diffraction peaks

Effect	Critical parameters	Typical value	Strehl ratio		Relative intensity of A_1 peaks	
			Expression	Value	Expression	Value
Gap	gap size, δ segment size d	12mm 1.5m	$(1-\delta/d)^4$	0.98	$0.7(\delta/d)^2$	4_10^{-5}
Turned edges	depth, ε width, η	0.25μm (WF) 20 -10mm	> 1-3.3_(2η/d) + 4.5_(2η/d)^2	0.94 – 0.97	< 0.5(η/d)^2	7_10^{-5} – 3_10^{-4}
Tip-tilt	rms segments, N	λ/30 (WF) 3300	1-rms^2+ rms^4(2.34+2/N)/4	0.96	0.013rms^4	2.5_10^{-5}
Piston	rms segments, N	λ/30 (WF) 3300	exp(-rms^2)	0.96	—	—

Yaitskova et al. 2002

	Shack-Hartman	Curvature	Mach-Zender	Pyramid
1-Cycle-Piston-Step-Precision (at the wavefront)[a]	~17nm rms measured[b] ~5nm rms simulated	≤360nm measured[c] ≤150nm (30nm rms) sim.	TBD	
End-Precision (Piston rms at mirror surface)	~2nm simulated	66nm measured[d] ~4nm simulated	TBD	25nm[e] (sim., seeing ltd) 13nm (sim., diffr. ltd)
Range ($Piston_{max}$ at the mirror surface)	±30μm (broadband, Keck) ±1μm (2-λ) ±100μm (3-λ) TBC	± ≥5μm (3-λ) TBC	±20-30μm TBC	±0.6μm (3-λ) TBC
Sensibility to seeing	low	low (adjustable!)	very low	high[f]
Sensibility to edges	no[g]	low TBC[h]	high (show stopper?)	low, TBC
Sens. to atmosp. dispersion	dispersion may help	low, TBC	high (broadband)	low, TBC
Magnitude limit (1min exposure per cycle)	11-12(+)	14+ [i]	14+	TBD
Fabrication Complexity	high	easy	easy (TBC)	easy
Alignment Complexity	high	low	low	low
Detector Size (OWL)	2k	2k-4k	2k-4k	~1k
Phase 2 mirrors?	difficult	yes[j] (TBC)	yes (Fourier Filter)	TBD
Use observation time?	no	no[k]	no	no
Iterations needed?	no perhaps yes for 2 mirrors	yes (~5) no if Piston < ±λ/30(MS)	no (weakly)	yes (10-20)
Wavelength	650nm, 850nm (Keck, GTC) visible - IR	3μm (Keck) visible - IR	visible - IR	visible - near IR

[a] Precision (measured at the wavefront) of one single piston step measurement when the piston step is within the non-ambiguity range ([-λ/2, +λ/2] or [-λ/4, +λ/4]). For simulations following conditions are assumed: r_0(@ 500nm)=24cm, 1 Min exposure time (photonic noise included).

[b] Keck result: Chanan et. al report 12-nm mirror surface rms differences between measurements performed at different wavelengths. This results in $12 \times 2/\sqrt{2}$nm=17-nm rms wavefront error for one wavelength. The given error therefore excludes errors due to segment aberrations, just like the simulations. The better precision of the simulation is due to a different analysis method – using an analysis similar to Keck, one achieves comparable results.

[c] Keck result; λ=3.31μm

[d] λ=3.31μm. Keck result: This is the difference between C and S-H measurements and is believed to arise from segment abberations; the repeatability of C is stated as 40nm(@MS). This bad repeatability may be due to a weak analysis method. The simulation was done with seeing and photon noise included, but excluding segment aberrations (like edge effects); using a smaller wavelength enhances end precision; increasing the exposure time, the rms error tends to zero

[e] simulation differs to Curv. and S-H: no photon noise included; atmospheric turbulence introduced by different phase screens vs. convolution

[f] high precision with AO, low precision without

[g] using a mask to block the gap/edge. This mask at the same time relaxes requirements on alignment accuracy and distortion in the pupil imaging

[h] should be low, because large part of the segment surface contributes to the signal. But not yet included into simulations