1st Generation Adaptive Optics for OWL: Preliminary simulations

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ESO simulation tool capabilities

- Current capacity
  - 48 processors
  - ~100 GBytes of RAM
  - GigaBit Ethernet Card
  - End-to-End realistic simulations

    - Fourier optics
    - noise (photon, detector ..)
    - temporal evolution atmosphere, loop delays...
    - reconstruction algorithms

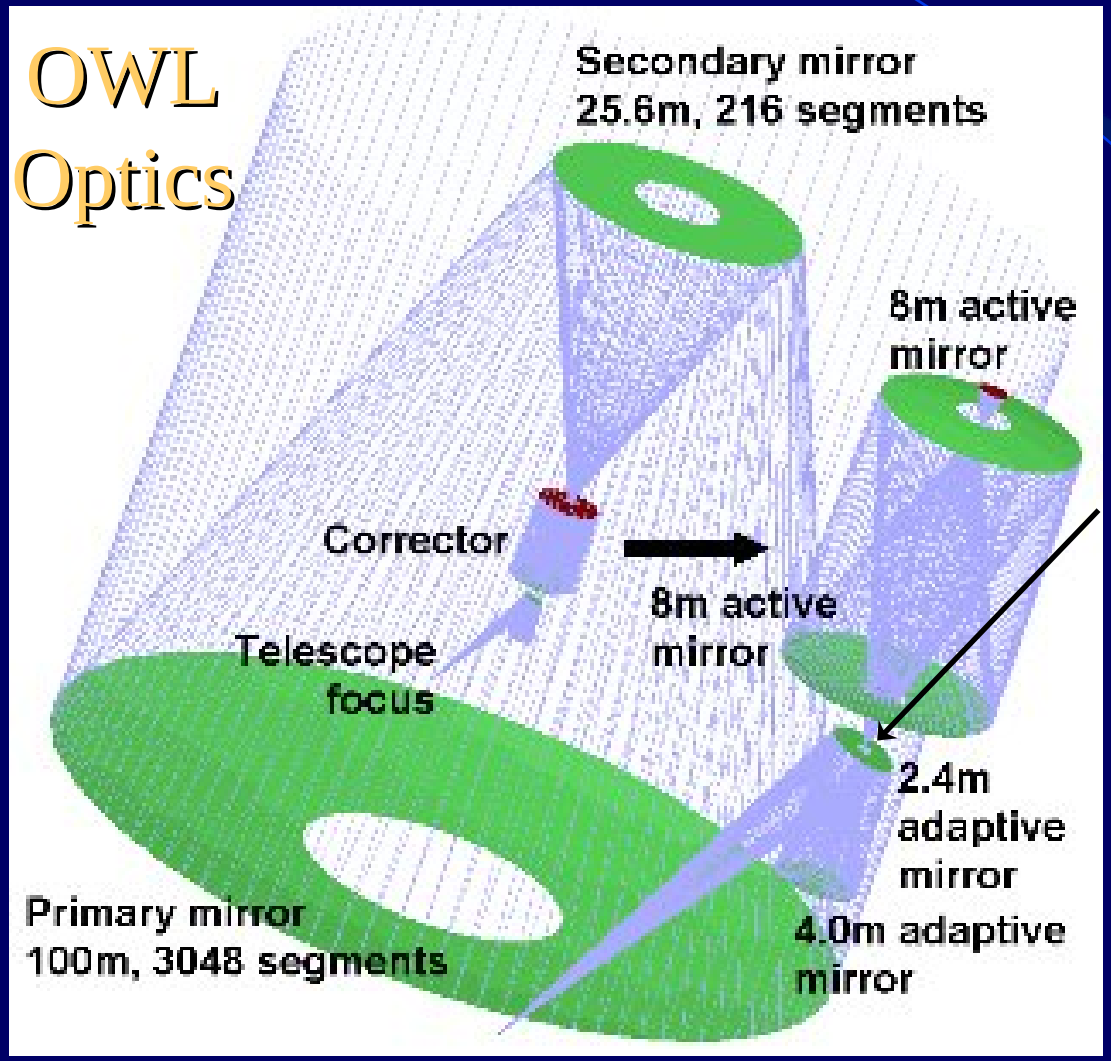
  (one 100 m run ~ few days !)
- Future capacity
  - Plan to port code to super-computer (FP6)

Scope

- Study of two **1st generation AO** systems for OWL with **Natural Guide Stars only** :
  - **Single Conjugate AO** (SCAO)
    - Correction on-axis diffraction limited
    - 1 “bright” natural guide star :Mv < 16
    - PSF shape in K / segmentation, co-phasing effects
  - **Ground Layer AO** (GLAO)
    - Wide field correction, “enhanced seeing” : 6’
    - several natural guide stars : 3-6 in 6’ FOV, Mv < 16-17
    - Ensquared Energy in K
- Possible evolutions: Multi-Object AO, Multi-conjugate AO

1st Generation AO:
“reasonable” extrapolation from current technology

Optical design



Deformable mirror M6:

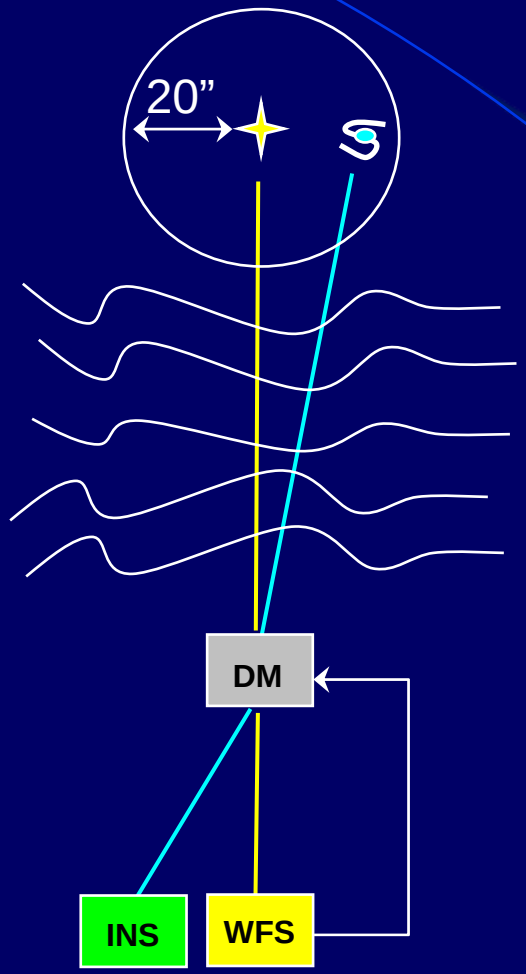
- Conjugated to ground
- Adaptive Secondary technology
- Actuator spacing (as projected on 100 m pupil)
  - **1 m** (baseline)
  - **80 cm** (goal)

Single conjugate AO

Atmosphere:

Seeing : 0.7 “

L_0 : 26 m, ι_0= 4 ms



One Natural Guide Star

Mv < 16

One corrected direction

(Anisoplanetism limited)

DM Deformable mirror

10000 actuators

spacing: 80 cm

conjugated to the ground

INS Science Instrument

Sim. Results :K band PSFs

WFS Wave-front sensor

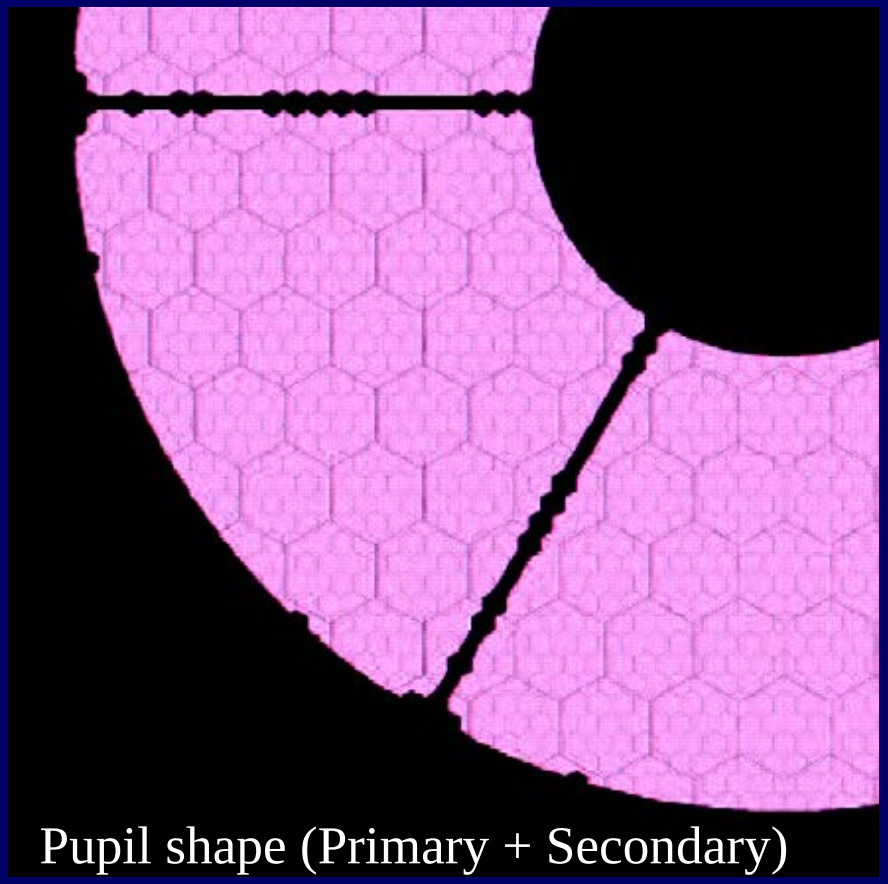
-Shack-Hartmann

400x400 detector, 3e ron

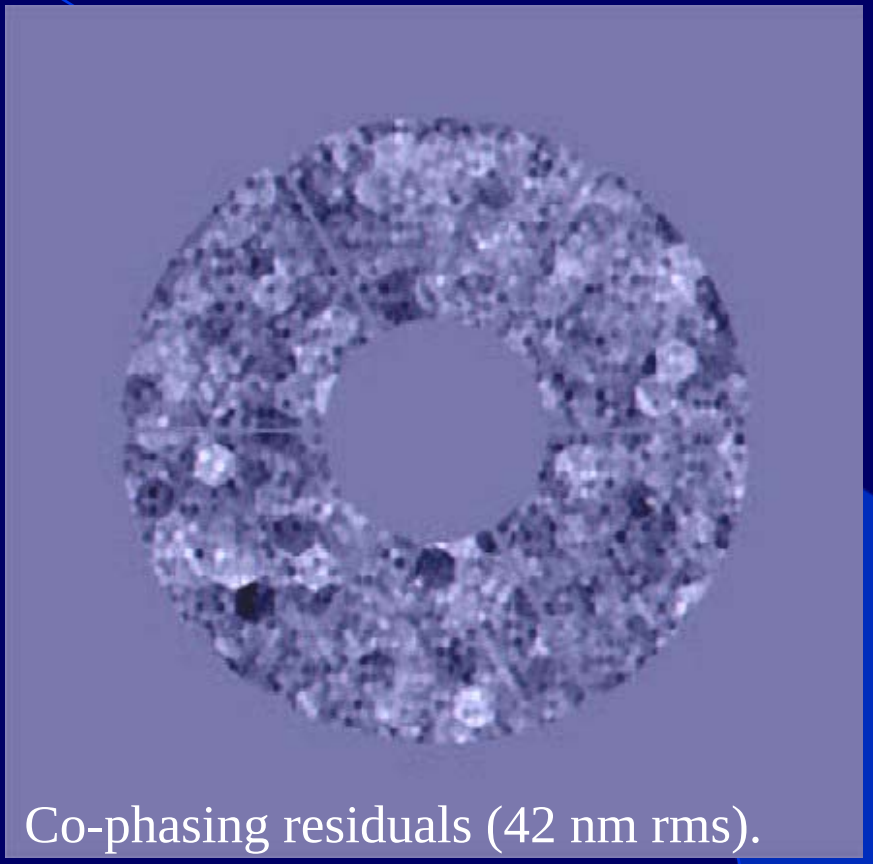
-Pyramid

256x256 detector, 3e ron

Pupil shape & co-phasing



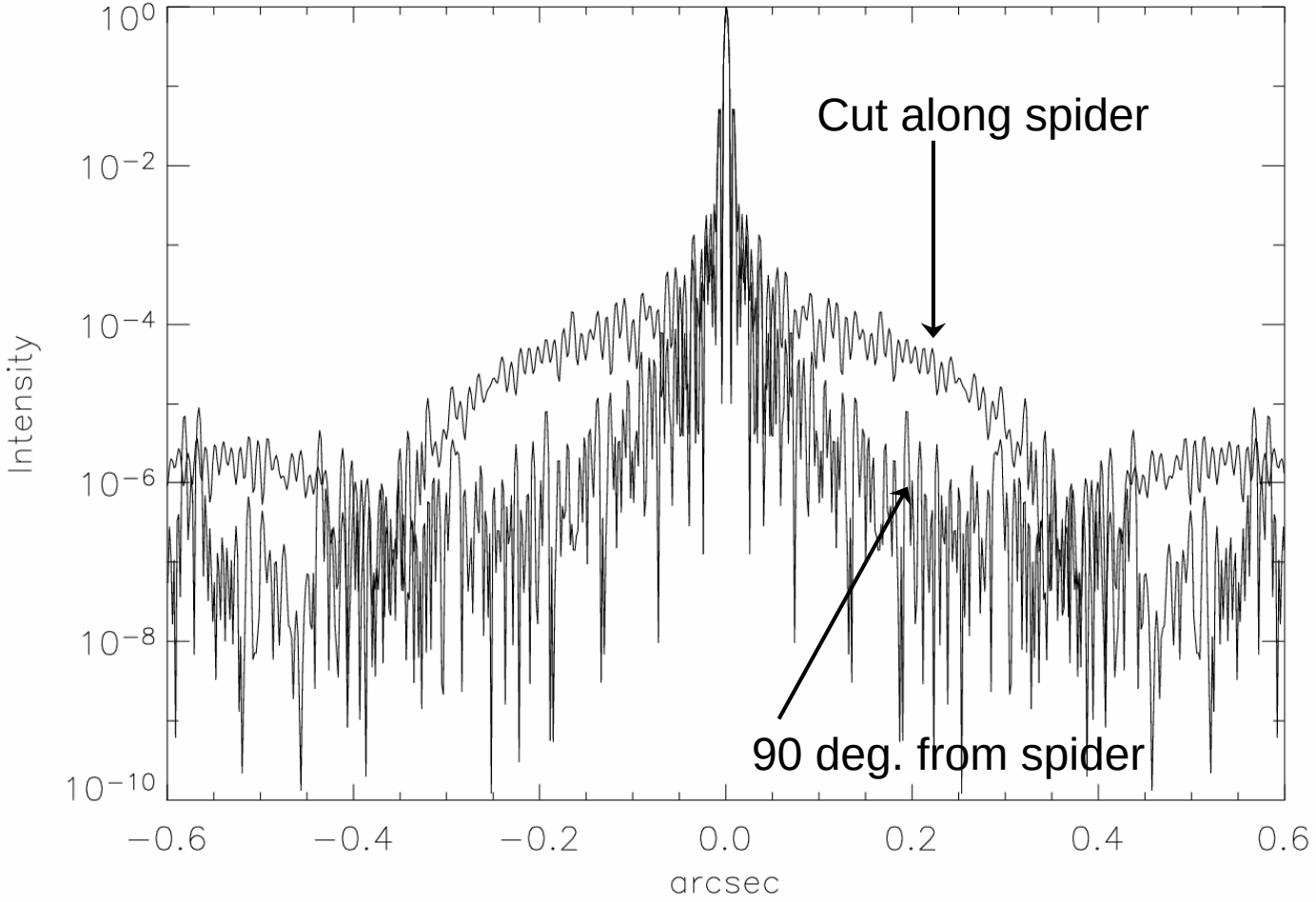
Pupil shape (Primary + Secondary)



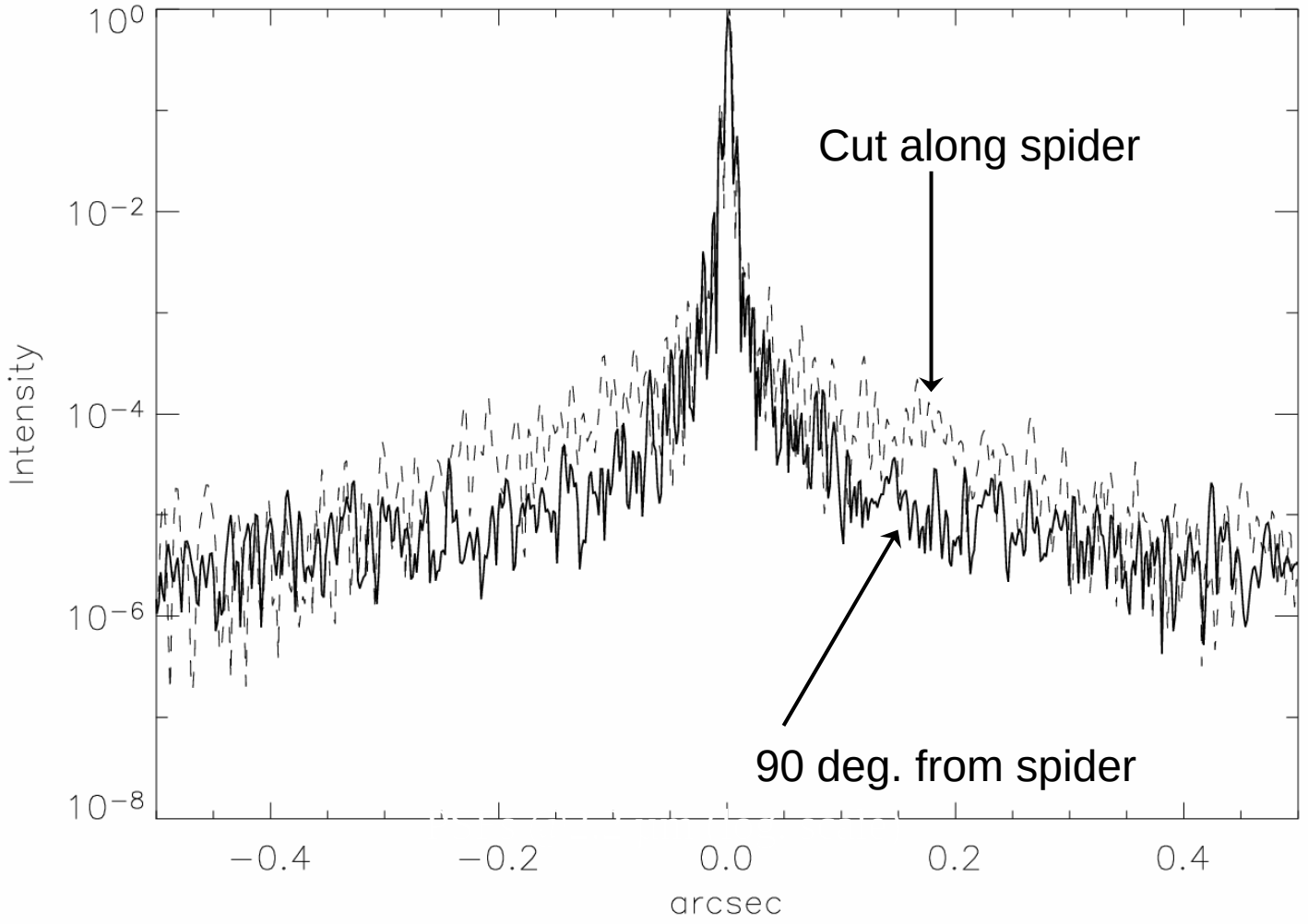
Co-phasing residuals (42 nm rms).

For the moment , in our simulations **AO doesn’t see segmentation**, only **imaging camera does**.

PSF shape (segmentation only)

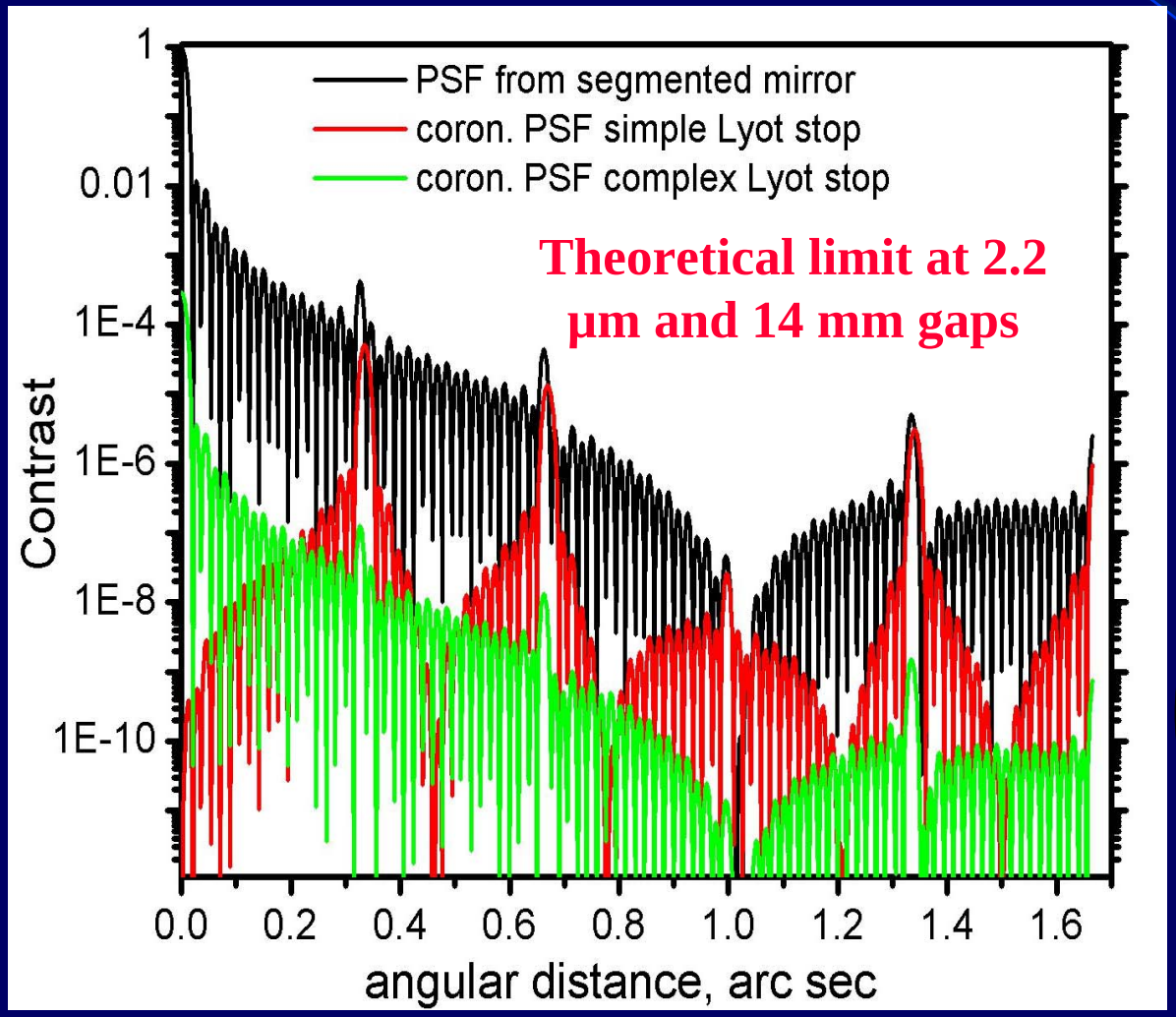


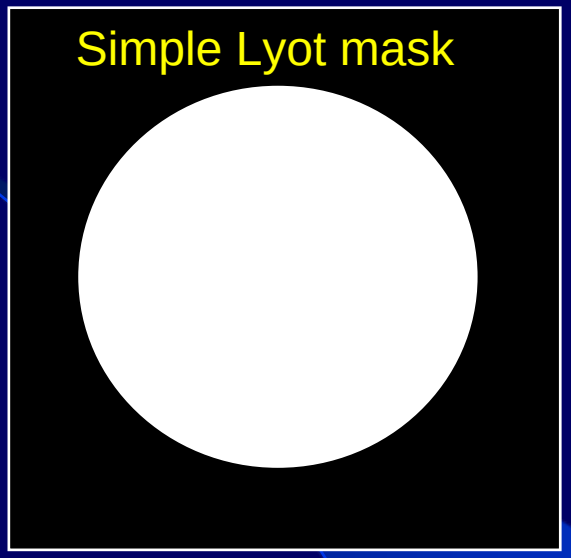
Single Conjugate AO PSF shape

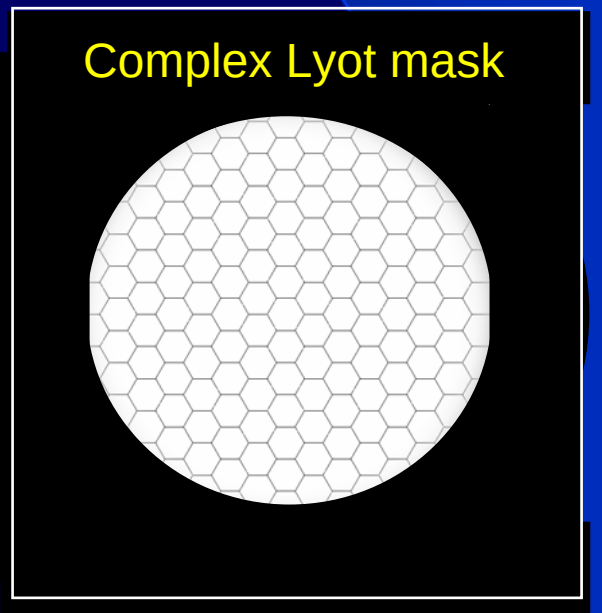


Coronagraphy (Lyot, no atmosphere)

Effect of gaps between segments:



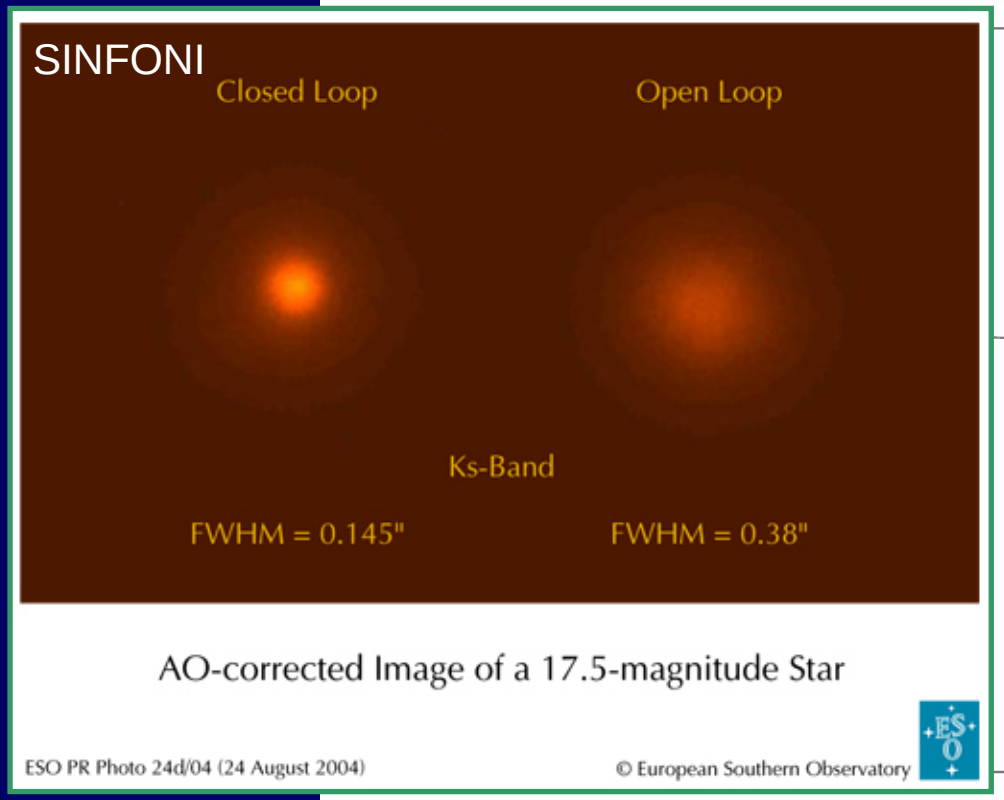




SCAO :Strehl vs. magnitude

- Filled aperture 100 m, throughput : 20 %
- Seeing : 0.7”, 4 ms, ι_0= 4 ms

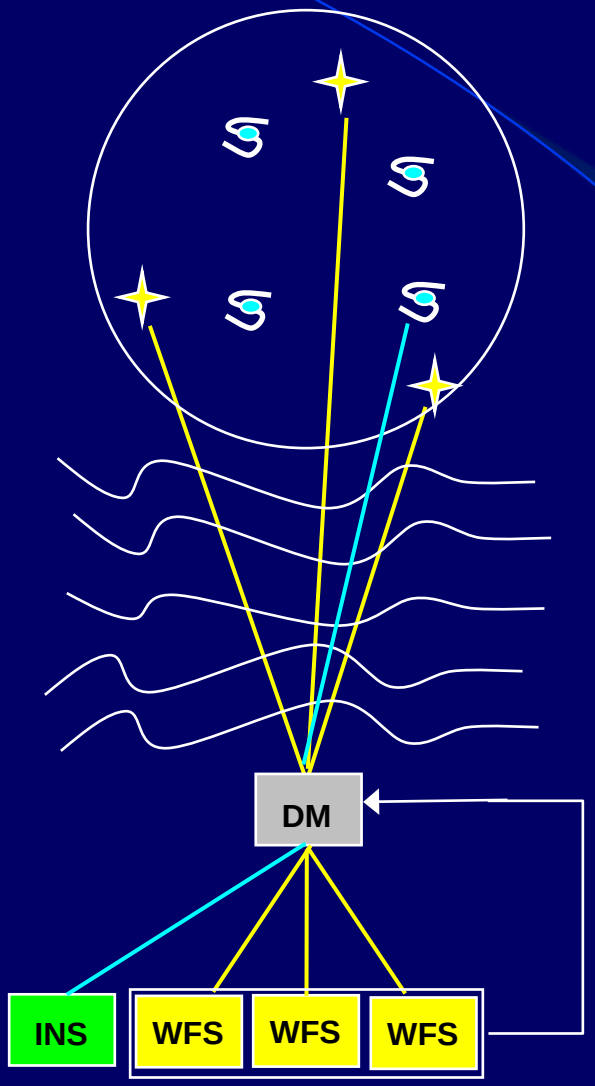
- Pyramid sensor (@700 nm) , 3 e ron
- actuator spacing size: 1 m



Ground Layer AO

« Improved seeing »

AO system



6’ technical FOV

Up to 6 Natural Guide Stars Mv < 15-16

Atmosphere:

Seeing : 0.5 “

L_0 : 26 m, τ_0= 4 ms

DM 8000 actuators

spacing: 1 m

(conjugated to the ground)

INS Science Instrument

Sim. results: K Ensquared Energy

WFS 3-6 Shack-Hartmann

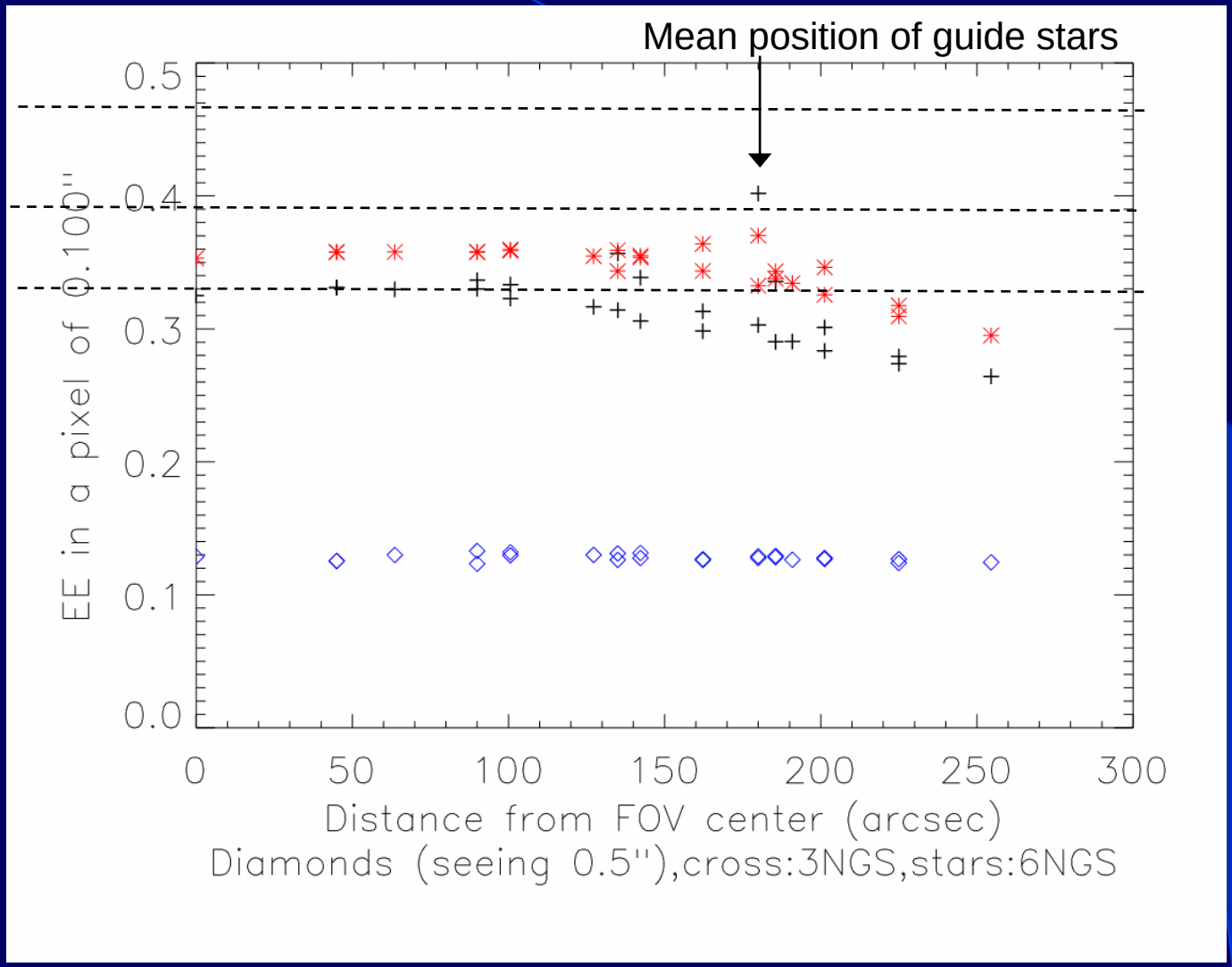
400x400 detector, 0 e ron

GLAO: Ensquared energy (K)

3 NGS in 1.5 ’

3 NGS in 3 ’

3 NGS in 6 ’



x3.6

x3.0

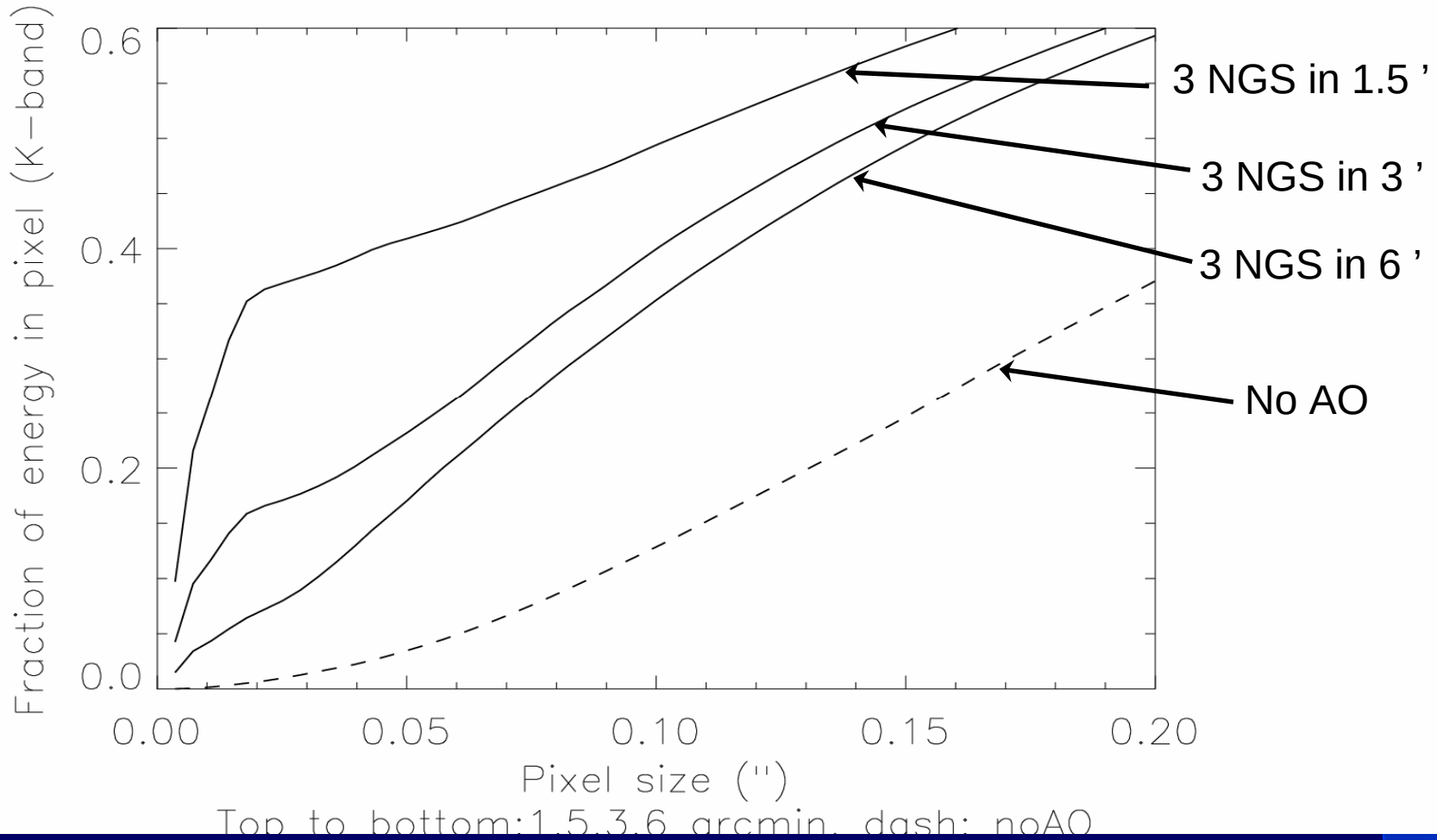
x2.6

Seeing

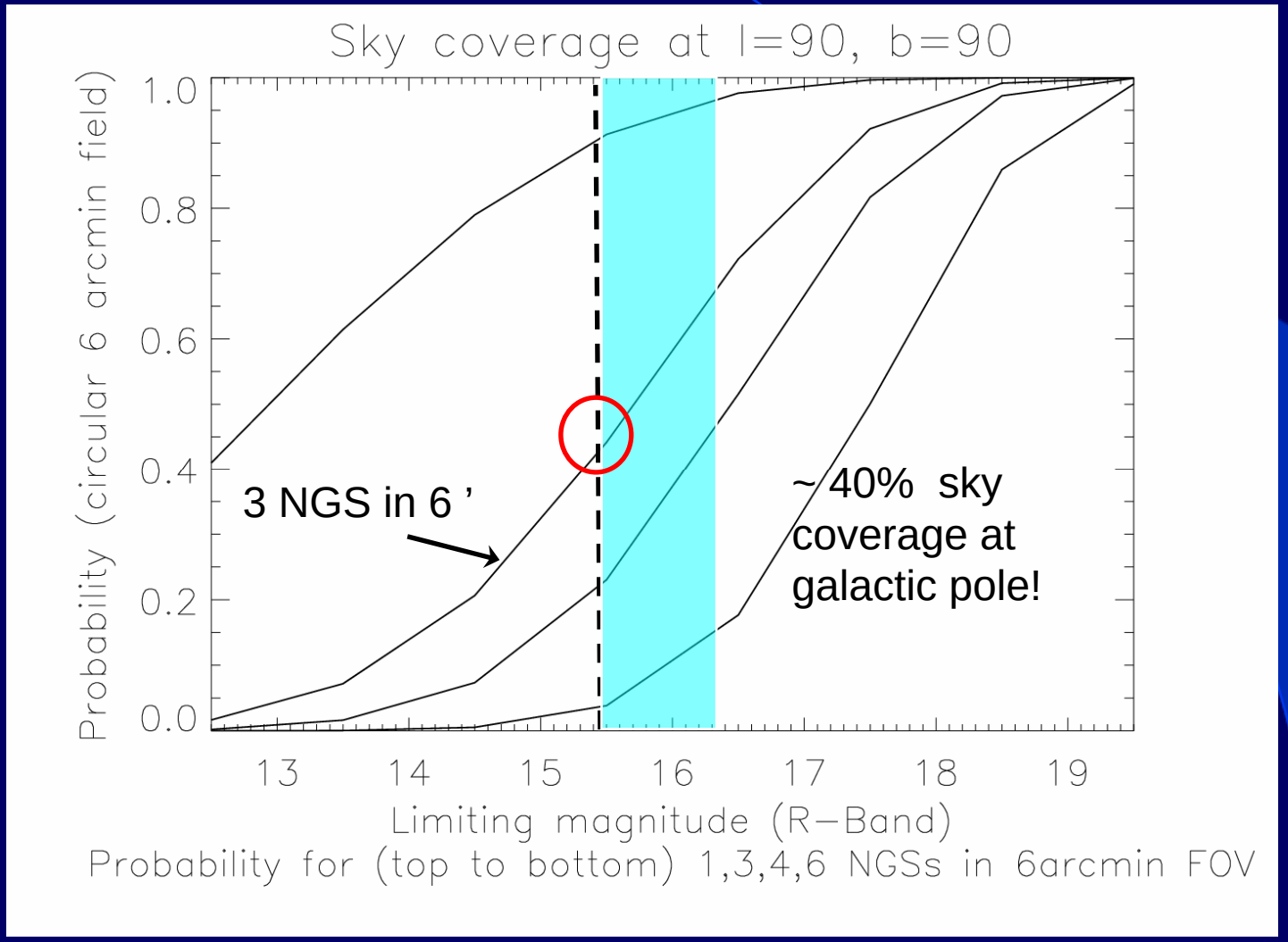
Seeing : 0.5 “, 15.5th mag. NGS , 8000 act.

Ensquared energy vs. pixel size

Seeing : 0.5 “ 15.5th mag. NGS , 8000 act.



GLAO sky coverage galac. pole

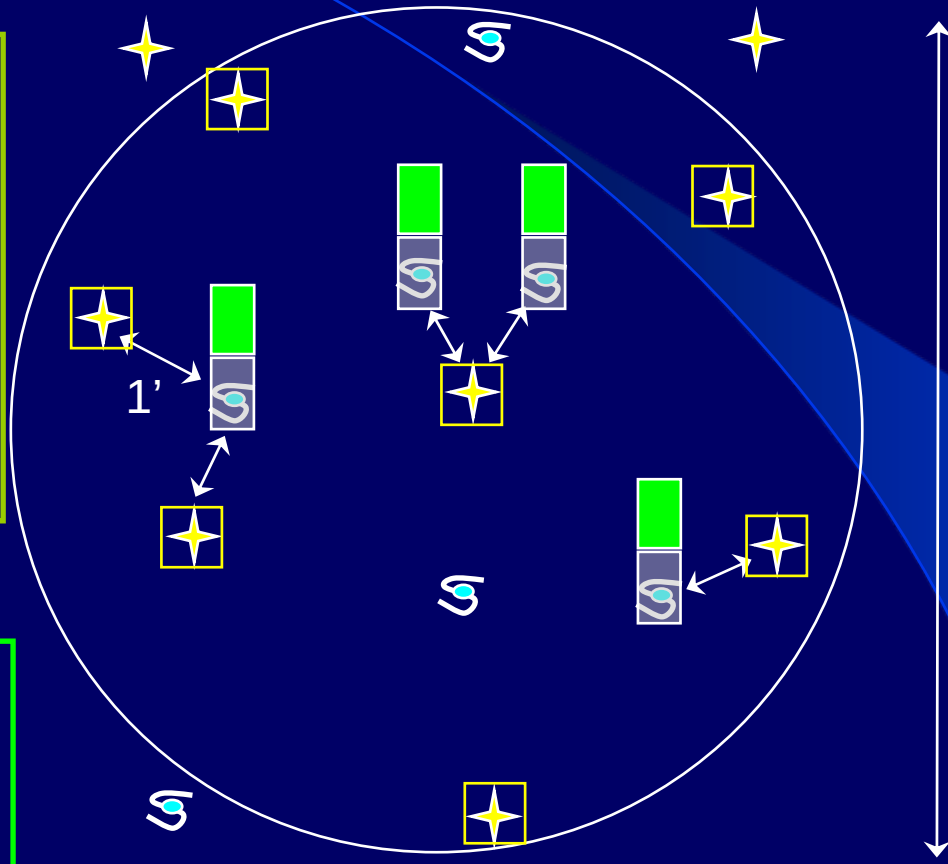


Future Possible evolution: MOAO

Multiple Objects Adaptive Optics

-2 stages correction:

- ground layer correction with large DM (M6)
- local correction with small DM



Wave-front sensor button

DM + IFU button

Performance depends on proximity and brightness of guide star(s) to object(s):

From « Seeing improvement » to « Diffraction limited »

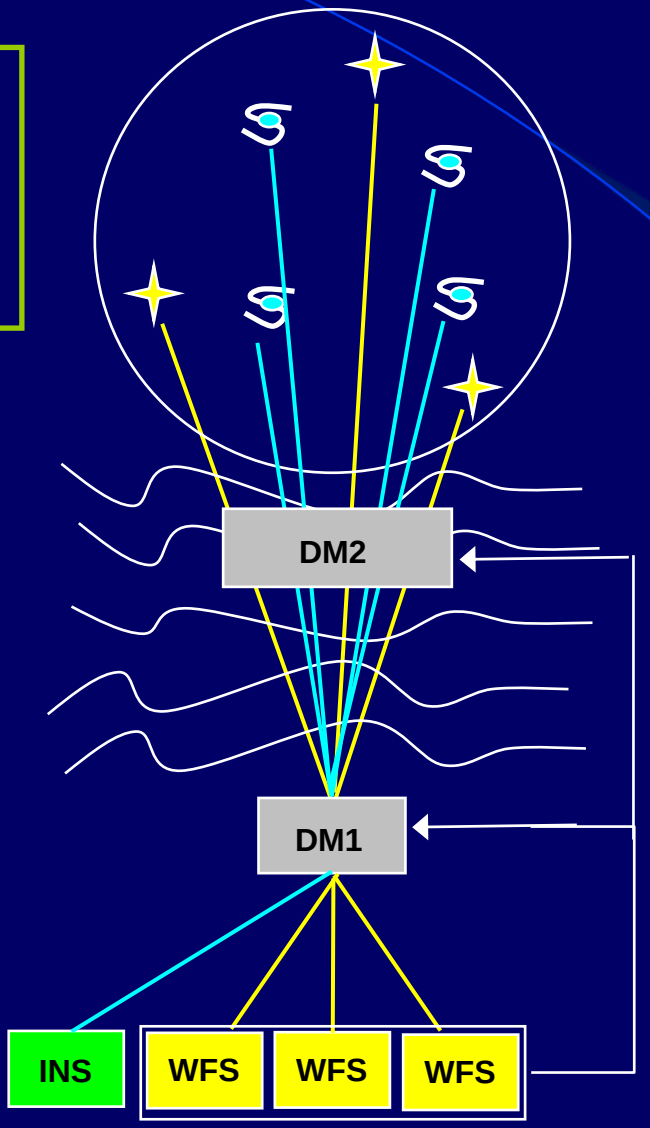
EE x 2-3 **S=20-30%**

Future possible evolution: MCAO

Multi-conjugate AO

-1 ground DM

- 1 high altitude DM



1-2’ FOV

3-6 Natural Guide Stars

Mv < 15-16

Performance:

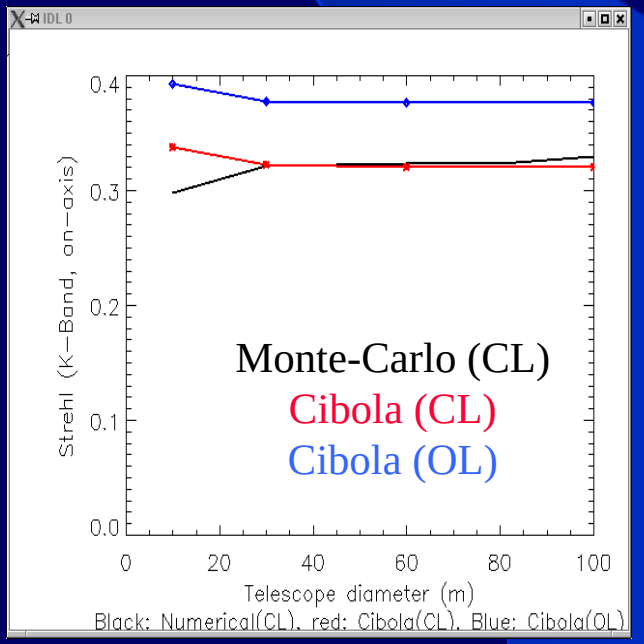
« Diffraction limited»

Strehl (K) : ~20%

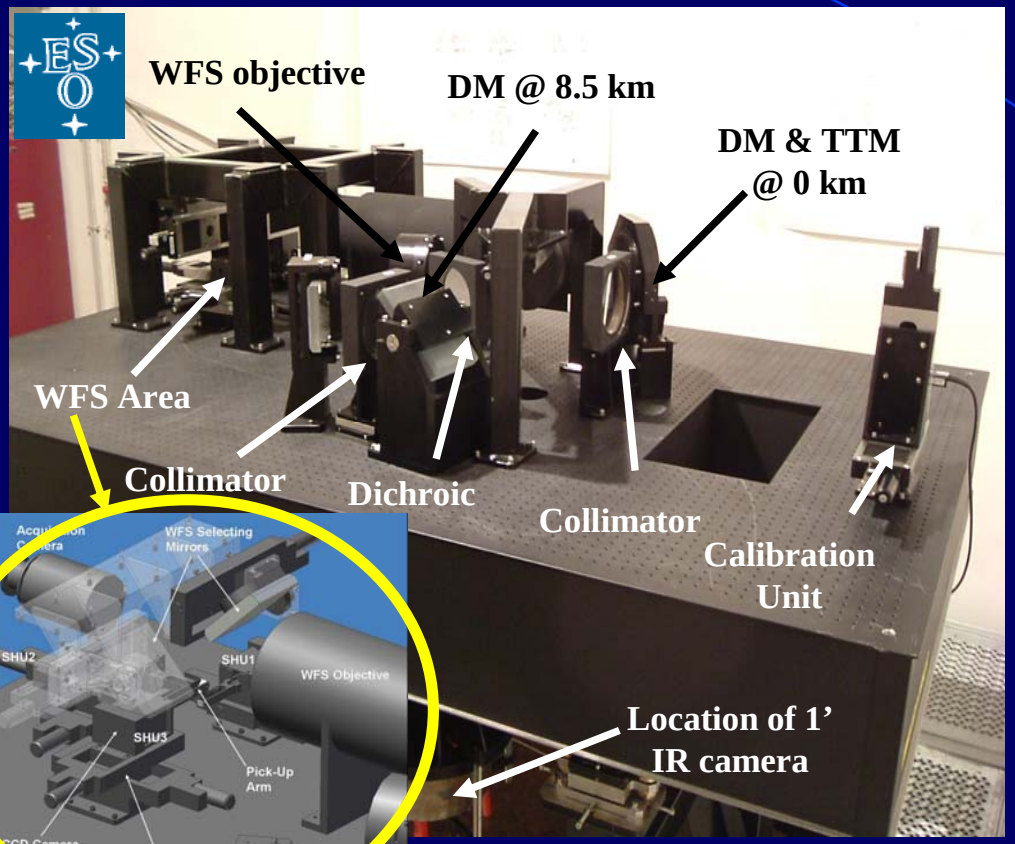
-PSF uniformity to be studied

-Limited Sky coverage

Preliminary results: bright NGSs



From simulations to the sky : MAD



Multi-conjugate Adaptive Optics Demonstrator

- Lab. tests during 2005 , On Sky: end of 2005
- A Testbed for validating simulations and preparing AO on OWL :
  - Single Conjugate / Ground Layer / Multi-conjugate AO / Layer oriented
  - Sophisticated reconstruction / control algorithms

And AO with LGS on OWL?...

- Several critical issues to be investigated:

  - Cone effect: need multi-Laser Guide Stars

  - spot elongation, some solutions :dynamic refocalosation, dedicated CCDs, Pseudo Infinite Guide Stars ...

  - Very poor LGS image quality through telescope
  very large aberrations, vignetting, 90 km vs infinity !

- Need for new LGS concepts for ELTs : lot of research going on and ahead !

- No Laser Guide Star for 1st generation AO !

-In case the issues cannot be solved:

Could we live without LGS even for 2nd generation AO ?

Conclusion

- SCAO / GLAO 1st results
- Further coronagraph simulations
- On sky validation with MAD soon
- Future MOAO/ MCAO ?
- LGS require new ideas
- Feedback + Science Cases welcome
- More detailed simulations and conceptual designs in frame of ELT design study.