“Wide” Field Imaging simulations on ELT: NGS GLAO

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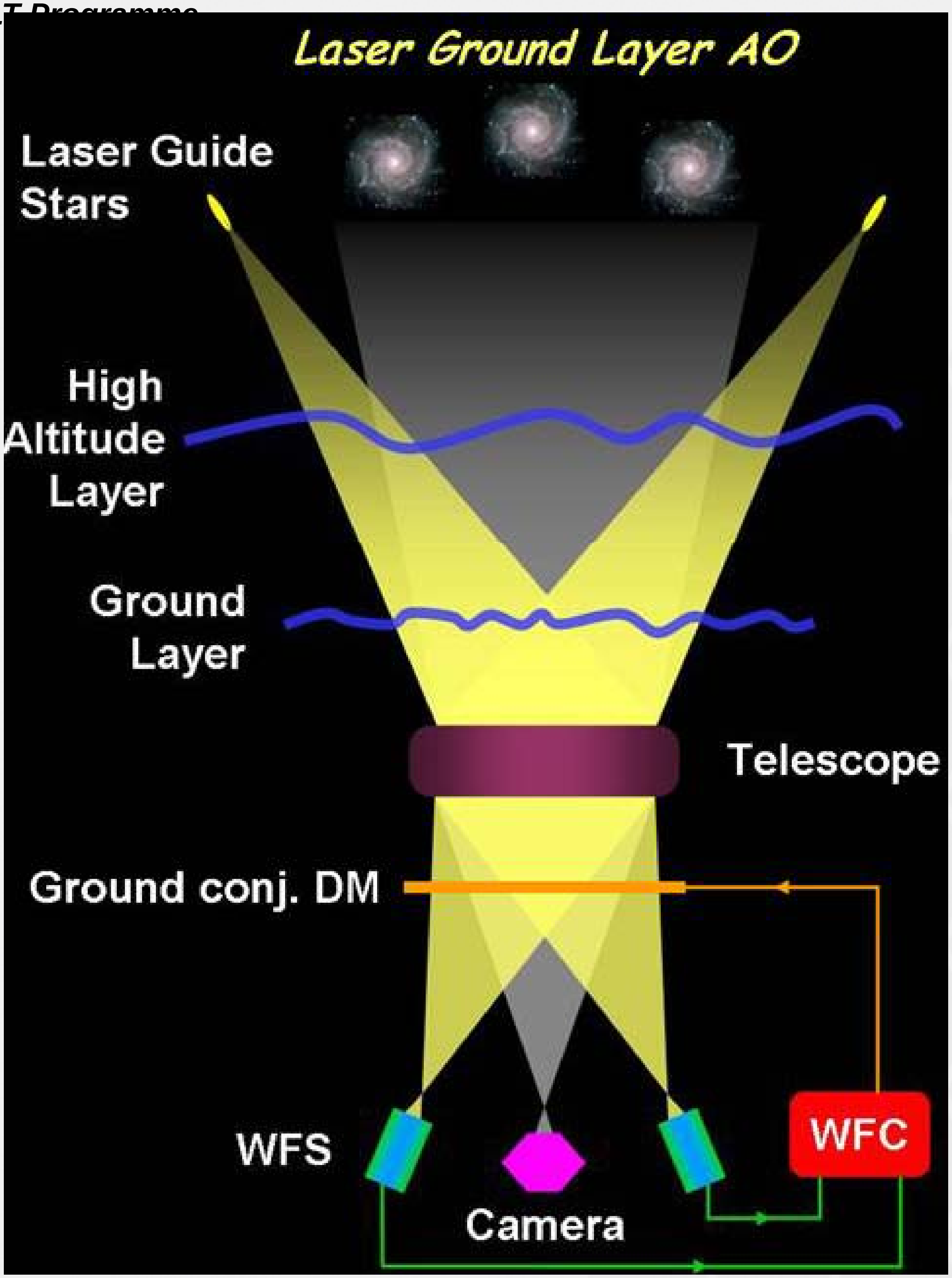
ESO - AOD

Introduction

- Simulations are work in progress
- Concentrate on AO aspects rather than telescope aspects
  - Most telescope (like segmentation, wind shake) effects not taken into account
  - Most limitations here come from atmosphere & AO system itself
- Probably optimistic
  - Full error budget not (telescope, instrument…) integrated in these simulations
  - Order of magnitude is correct

What is Ground Layer AO

- Goal is to improve seeing over a "wide" field of view → No diffraction limited images..
- "Wide" = 2' → ~5'-10'
  - GRAAL @ VLT: 7.5', near IR
  - GALACSI@VLT: 1', visible
- Multiple reference stars, single DM
- Average measurements of stars to average out part not common to all reference stars,
  → keep only common part (i.e. turbulence close to the telescope).
- Added bonus: corrects telescope "errors" + dome seeing as well.
- Validated on MAD
- Ground layer must be strong for GLAO to work well…



Courtesy E. Marchetti

NGS GLAO for ELT AO simulations

- 84x84 sub-apertures to fit the M4 DM
- 5402 modes corrected with M4
- 3 NGS in an equilateral triangle configuration.
  - All have the same brightness unless otherwise noted
  - Symetric constellation unless otherwise noted
- Metric:
  - Size of 50% Ensquared Energy
  - Gain in size of 50% EE (compared to seeing)
  - PSSn = total(psf^2) / total(psf_noAO^2)
    - Only partially implemented now
- Framerate: 500Hz
- Configuration different from E-ELT baseline
  - Performance should be comparable however

Simulation conditions

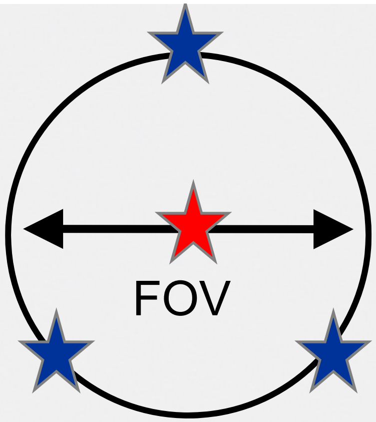
Layer	Height (m)	% of C_n^2	Wind speed (m/s)
1	47	53.28	15
2	140	1.45	13
3	281	3.5	14
4	562	9.57	10
5	1125	10.83	9
6	2250	4.37	15
7	4500	6.58	25
8	9000	3.71	40
9	18000	6.71	21

Seeing 0.8'' ALOS at 0.5 um, small telescope

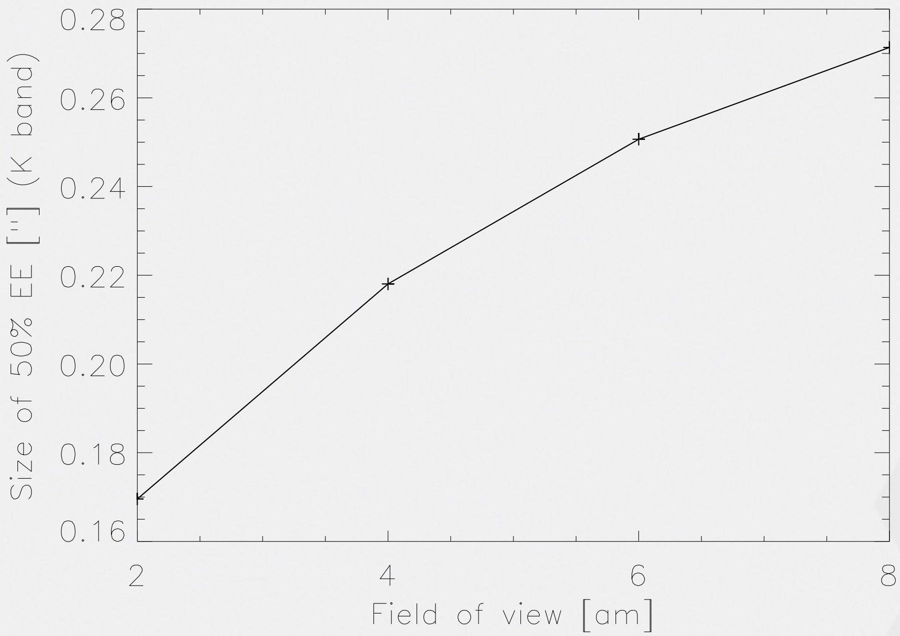
→ ~0.43'' 50%EE @ K on E-ELT, with L0=25m (Atm only)

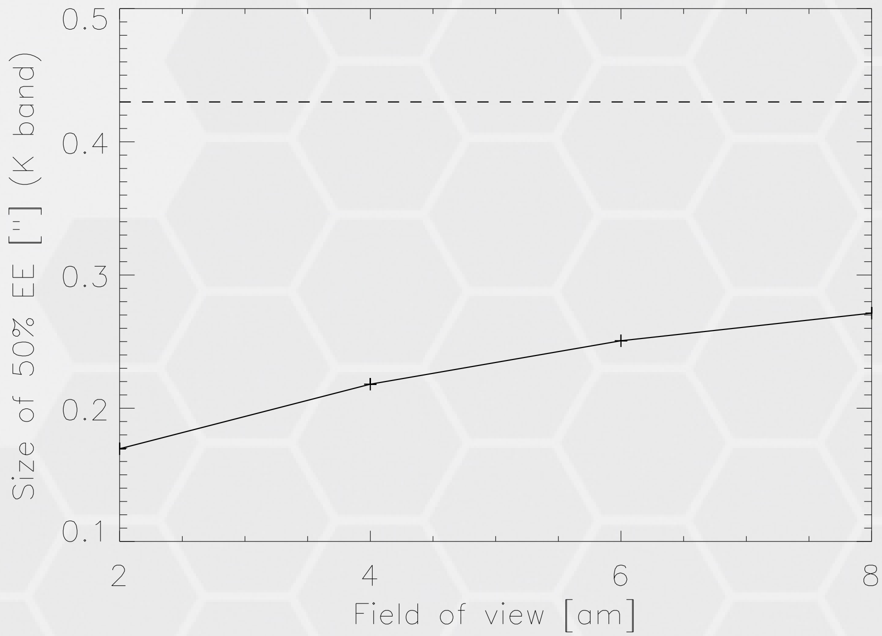
θ_0 ~2''

τ_0 ~3ms



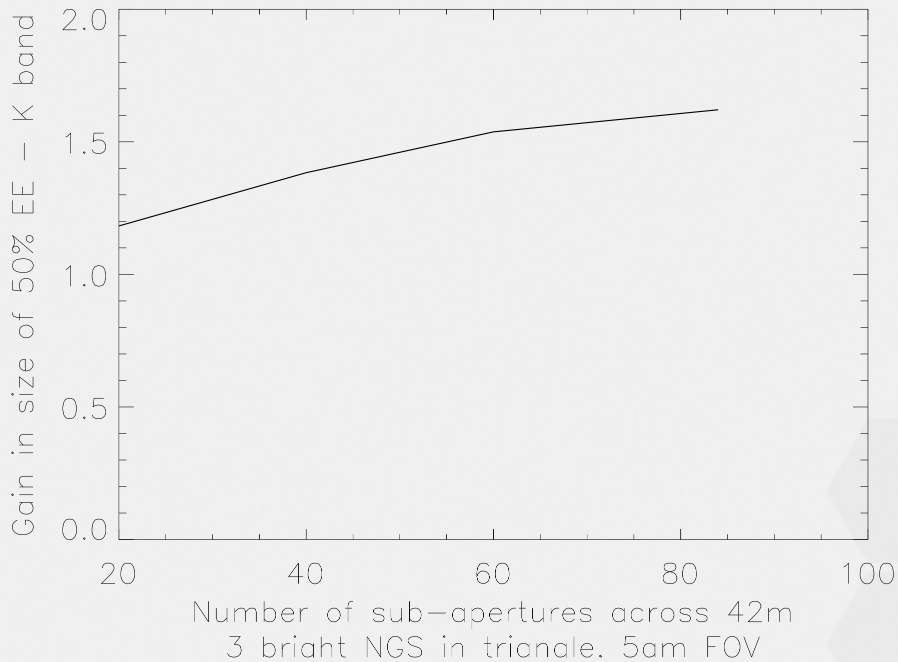
Size of field of view



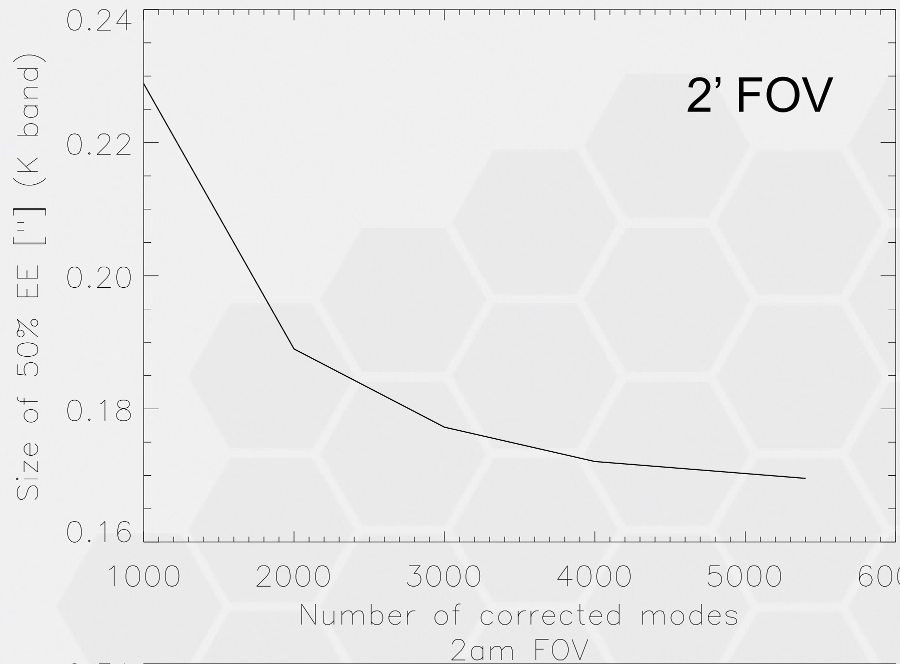


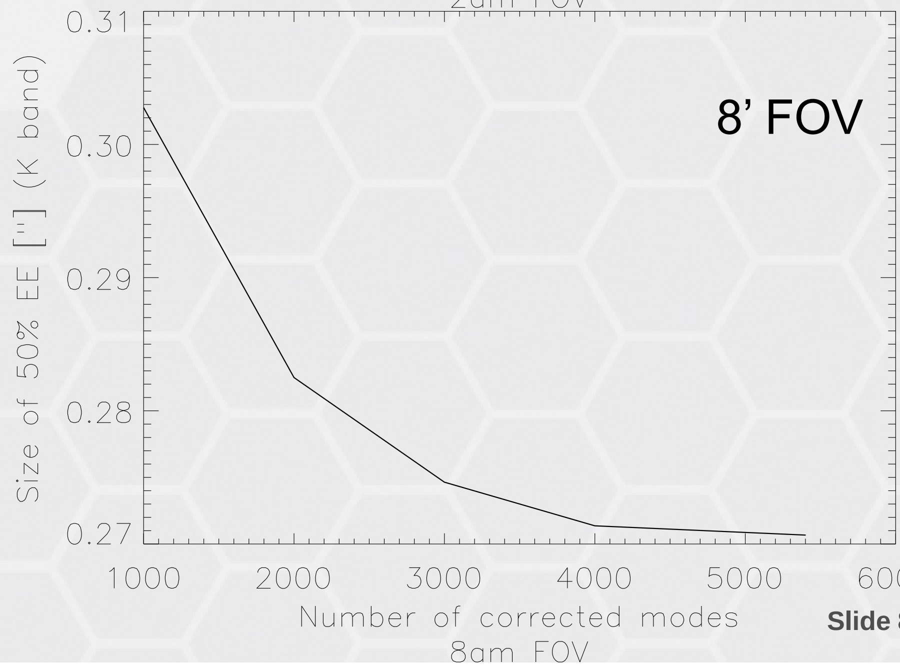
→Mild (but existing) dependence on FOV size.
→Sensitivity to GL content increases with field (correct thinner layer)

Number of sub-apertures / modes



5' FOV



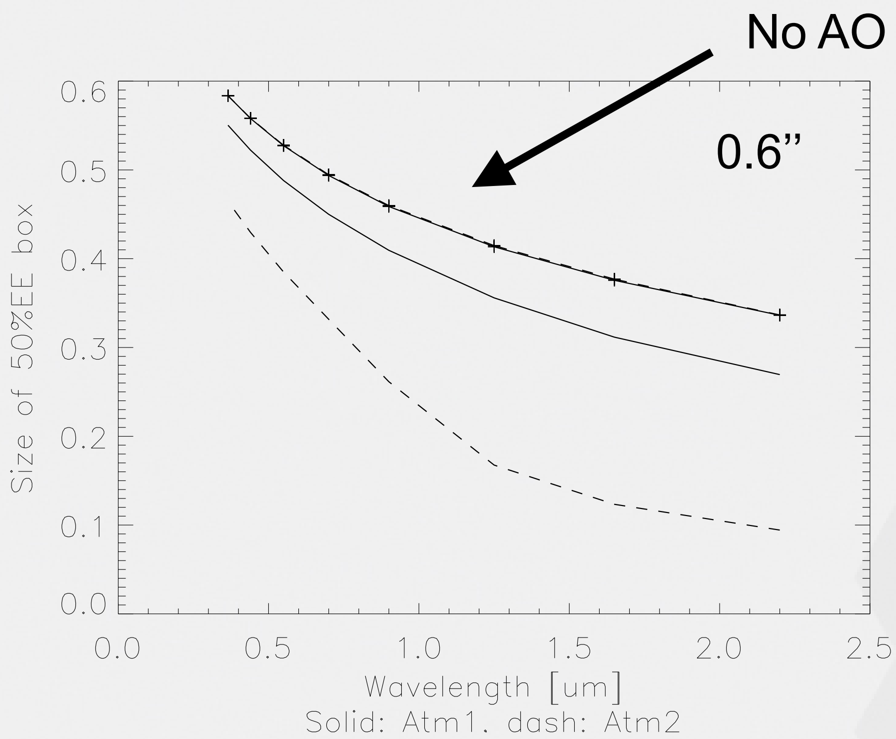


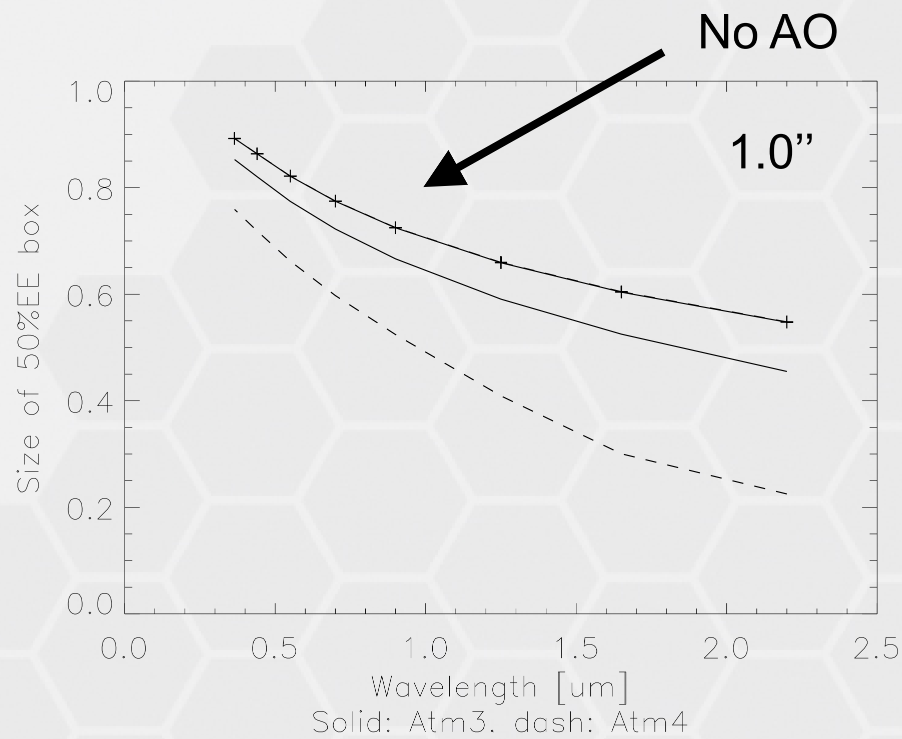
→~4000 modes need correction

→ ~60x60 sub-apertures

Impact of C_n^2 profile (5' FOV)

Difference between 25% best and 25% worst profiles @ Paranal





Model 1: 46 % in first 500m, 0.6'' seeing
Model 2: 90% in first 500m , 0.6'' seeing

Model 3: 35% in first 500m, 1'' seeing
Model 4: 80% in first 500m ,1'' seeing

→ Largest impact of all parameters for GLAO

Atmospheric models

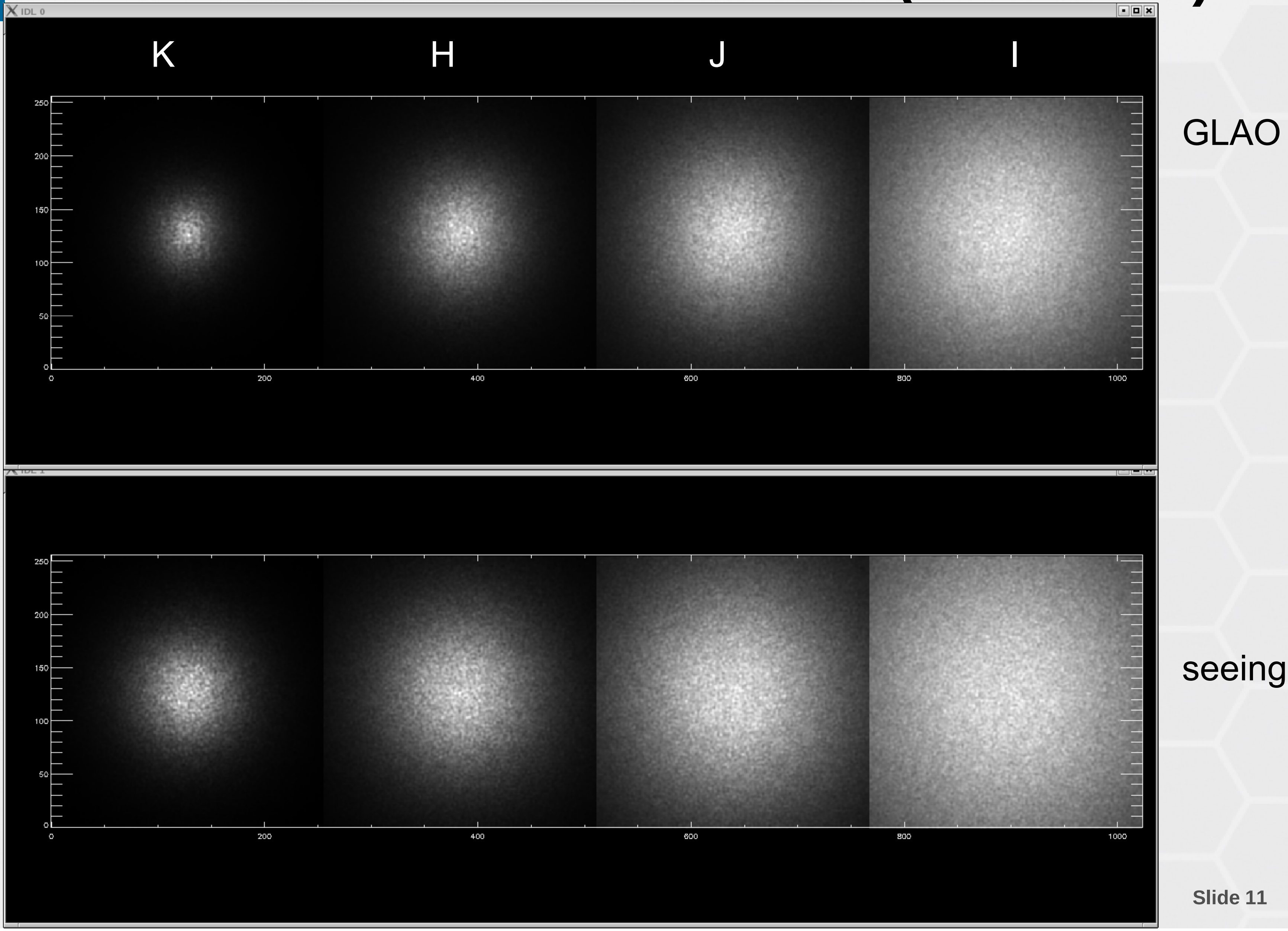
0.6'' seeing → Measurements still on-going @ Paranal for VLT

Height [m]	Strength Model 1 [% of Cn2]	Speed Model 1 [m/s]	Strength Model 2 [% of Cn2]	Speed Model 2 [m/s]
47	41	0.895 * 5.6	78	1.48* 5.6
140	1	0.895 * 5.1	1	1.48* 5.1
281	3	0.895 * 4.4	4	1.48* 4.4
562	6	0.895 * 3.9	7	1.48* 3.9
1125	0	0.895 * 4.4	0	1.48* 4.4
2250	8	0.895 * 7.2	0	1.48* 7.2
4500	14	0.895 * 14.2	1	1.48* 14.2
9000	14	0.895 * 30.4	4	1.48* 30.4
18000	13	0.895 * 10.0	5	1.48* 10.0

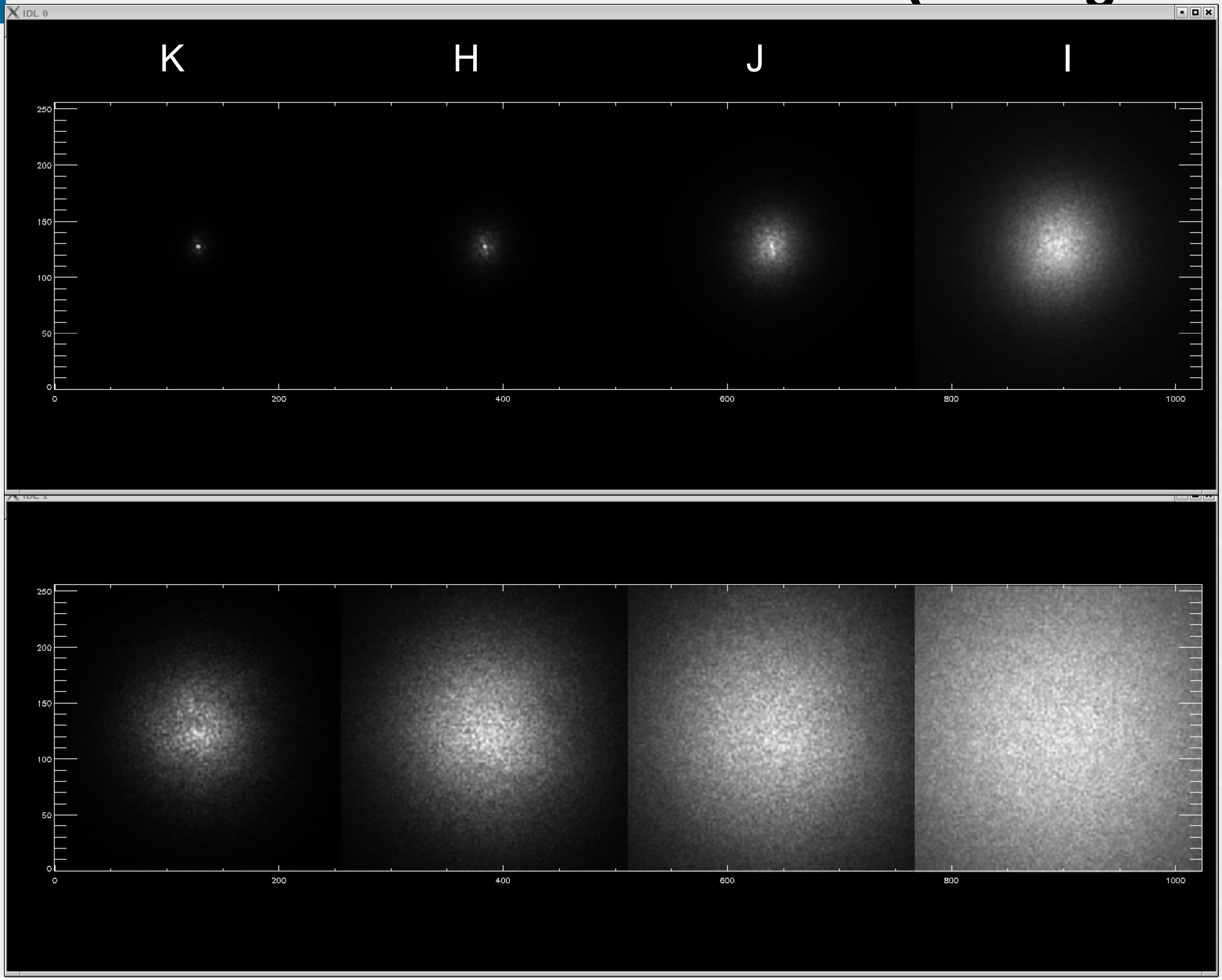
1'' seeing

Height [m]	Strength Model 3 [% of Cn2]	Speed Model 3 [m/s]	Strength Model 4 [% of Cn2]	Speed Model 4 [m/s]
47	30	1.5 * 5.6	70	2.0 * 5.6
140	1	1.5 * 5.1	4	2.0 * 5.1
281	4	1.5 * 4.4	6	2.0 * 4.4
562	9	1.5 * 3.9	6	2.0 * 3.9
1125	11	1.5 * 4.4	0	2.0 * 4.4
2250	17	1.5 * 7.2	1	2.0 * 7.2
4500	13	1.5 * 14.2	3	2.0 * 14.2
9000	8	1.5 * 30.4	4	2.0 * 30.4
18000	7	1.5 * 10.0	6	2.0 * 10.0

PSFs of GLAO Atm 1 (0.6’’ “bad”)



PSFs of GLAO Atm 2 (0.6’’ “good”)

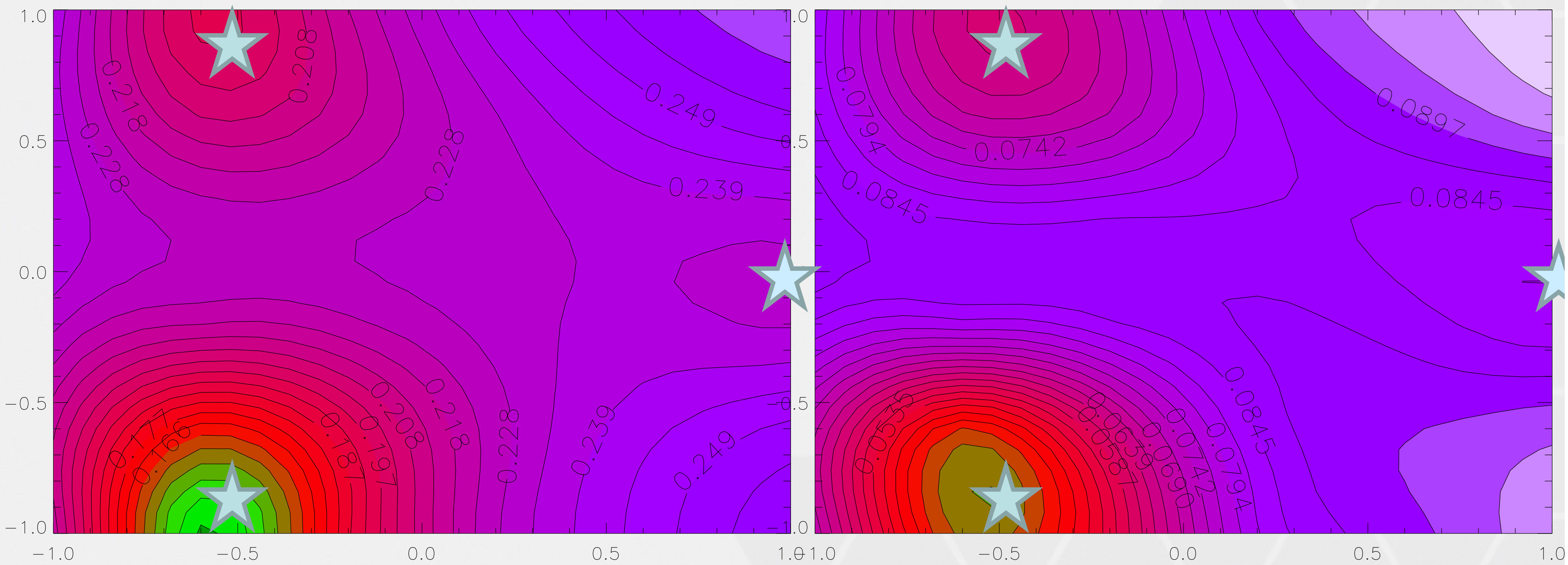


GLAO

seeing

PSF uniformity

atmospheric model 1 (0.6'' "Bad") atmospheric model 2 (0.6'' "good")

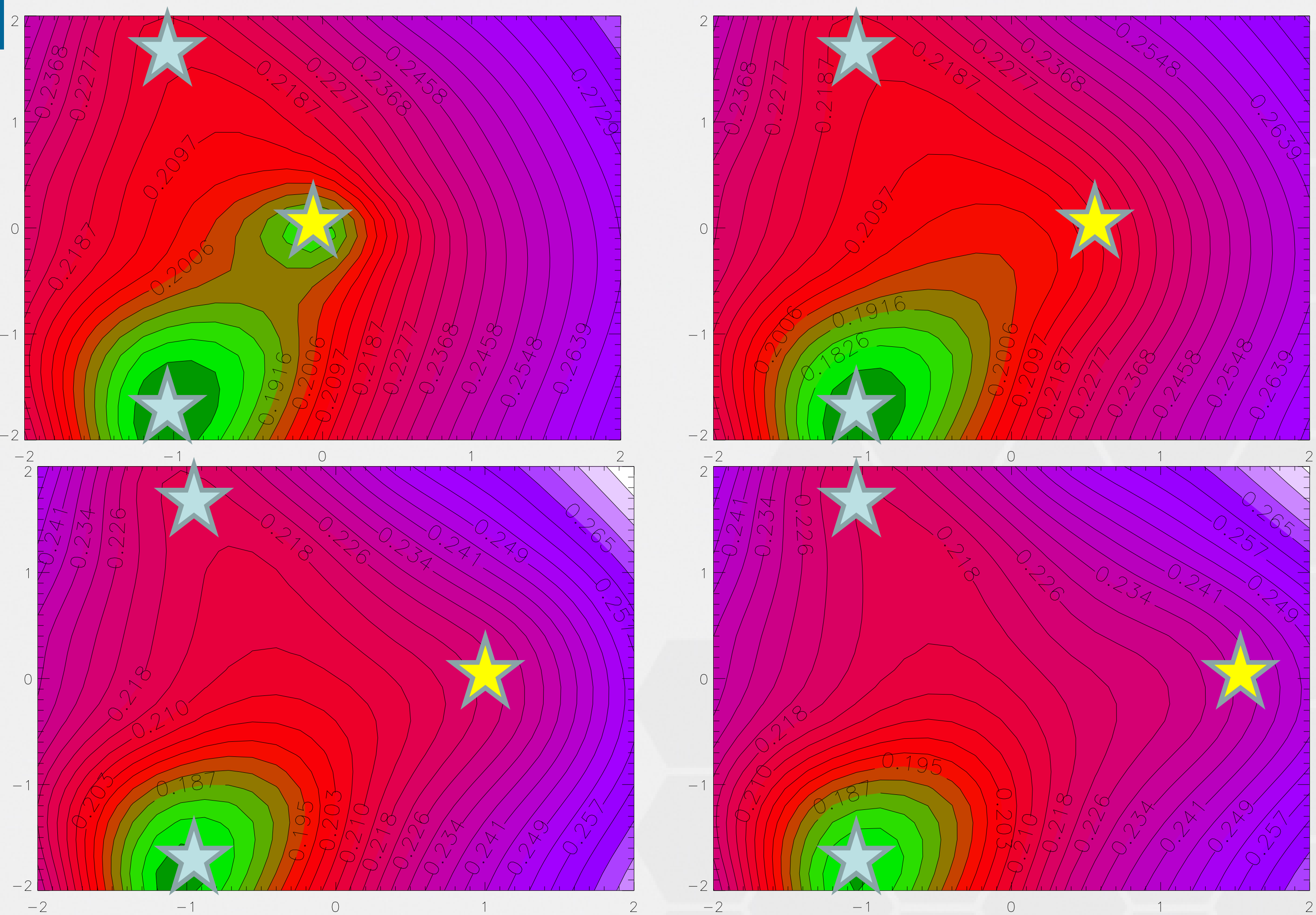


Size of the 50% EE box, with bright NGSs, of the 84x84 system 2' FOV NGS GLAO system.
K-Band.

Simulation not fully converged → Slight asymetries

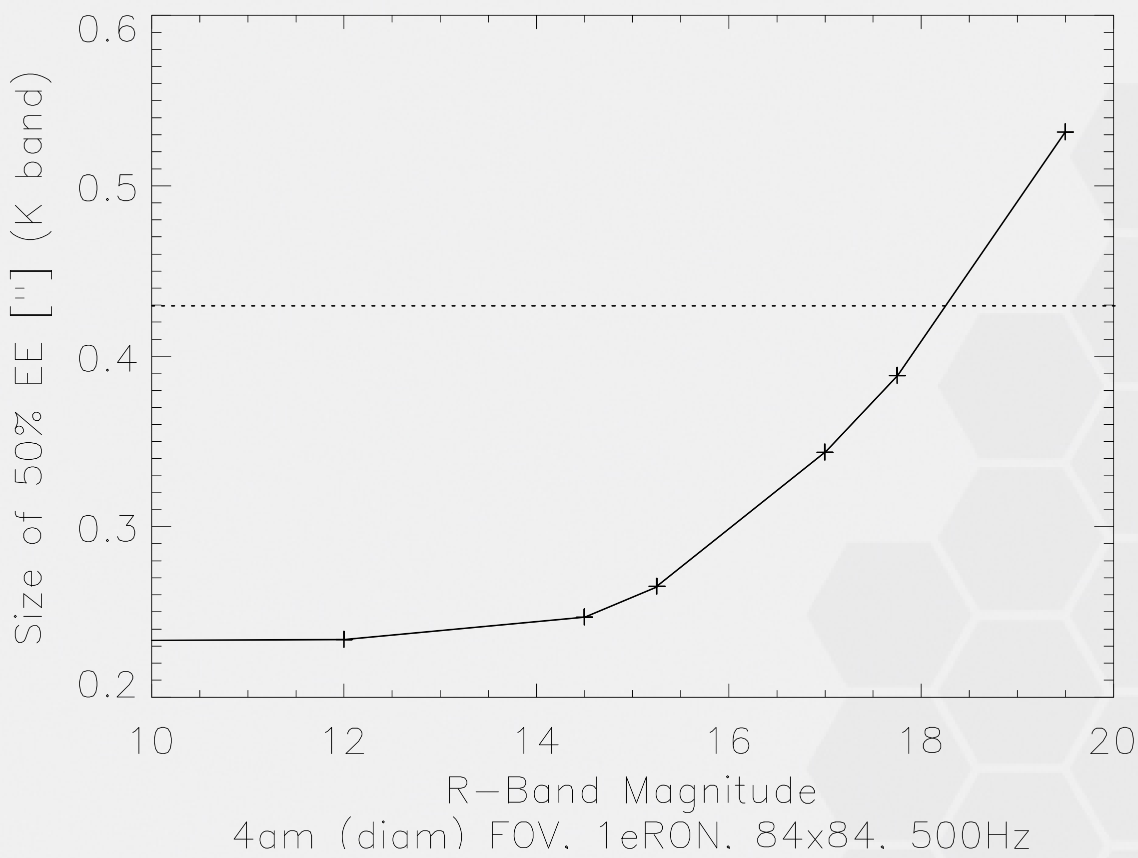
E-ELT Programme

NGS position



Size of the 50% EE box evolution when one changes the position of the “yellow" NGS. The axes are in arcmin.

Limiting magnitude (4' system)

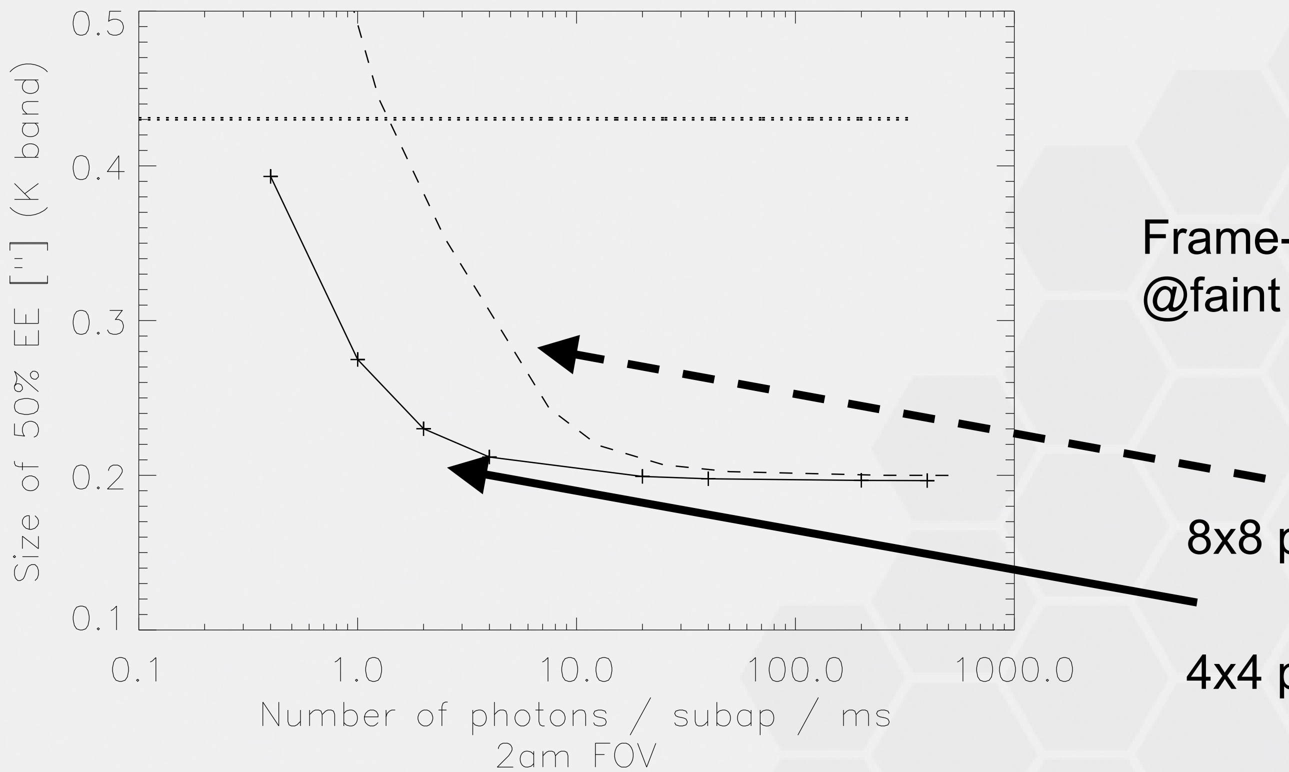


Sky coverage being Estimated & cross checked.

Should be "high" even towards Galactic poles

Approximate magnitude per guide star

60x60 3NGS GLAO



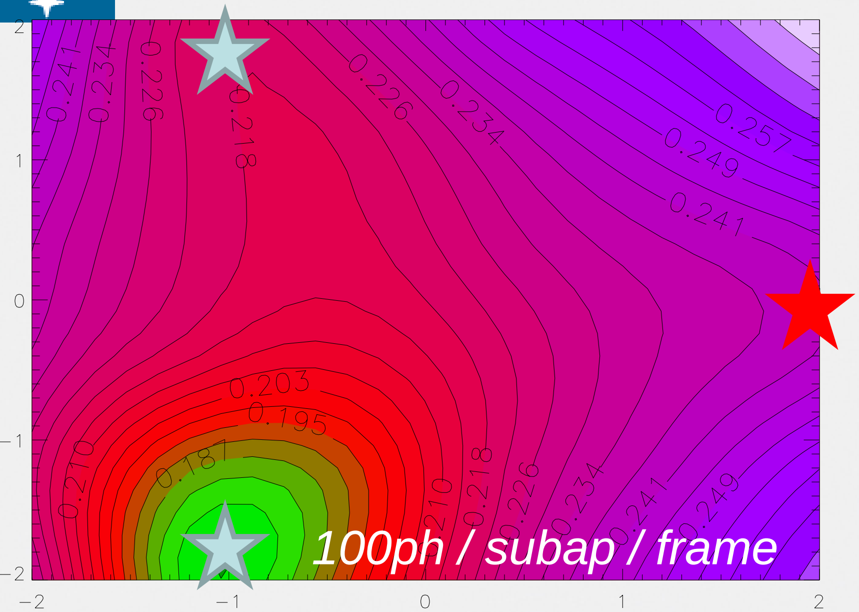
Frame-rate optimized @faint fluxes

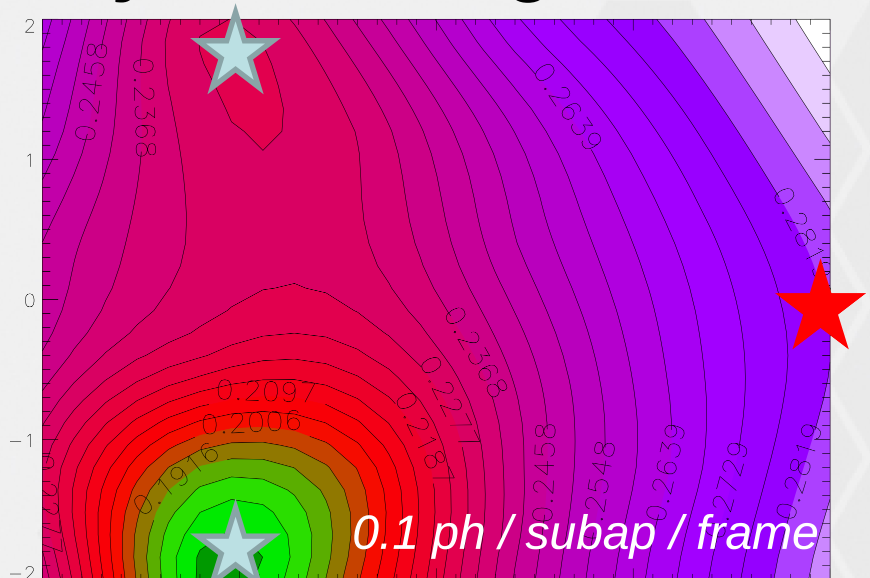
8x8 pixels, 3e RON

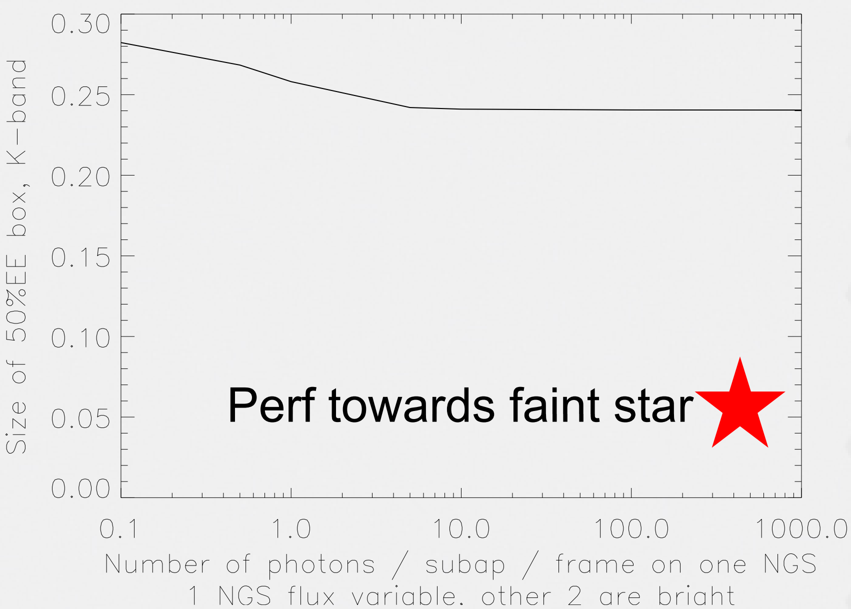
4x4 pixels 1e RON

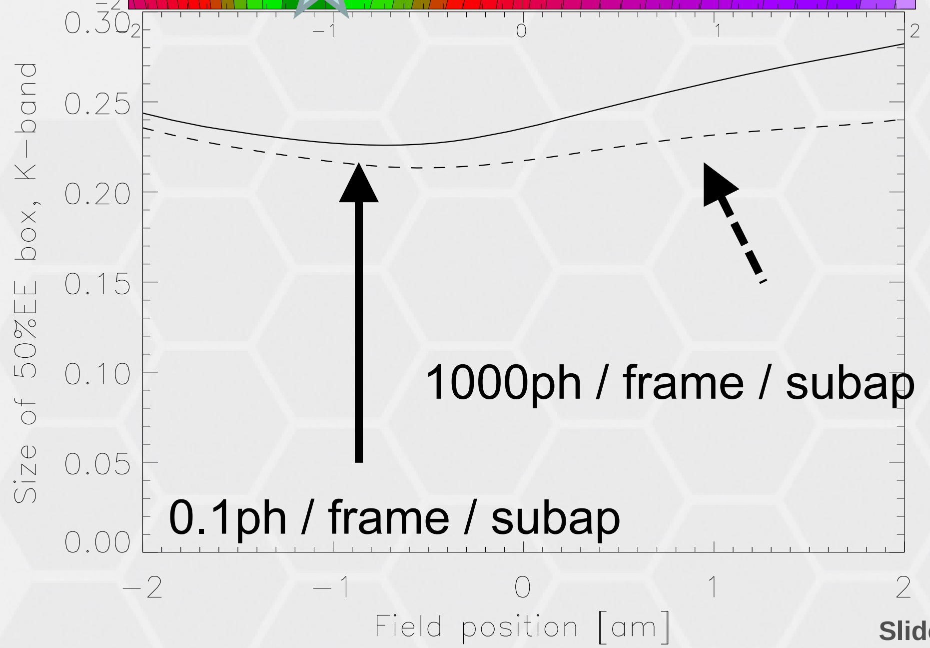
- 2' asterism
- 4x4 pixels on 60x60 subap → L3 CCD→ 0-1 e RON.
- 8x8 pixels on 60x60 subap → Demonstration prototype of LGS WFS CCD → 3e RON
- number of photons sub-apertures / millisecond / guide star

Asymetric magnitudes

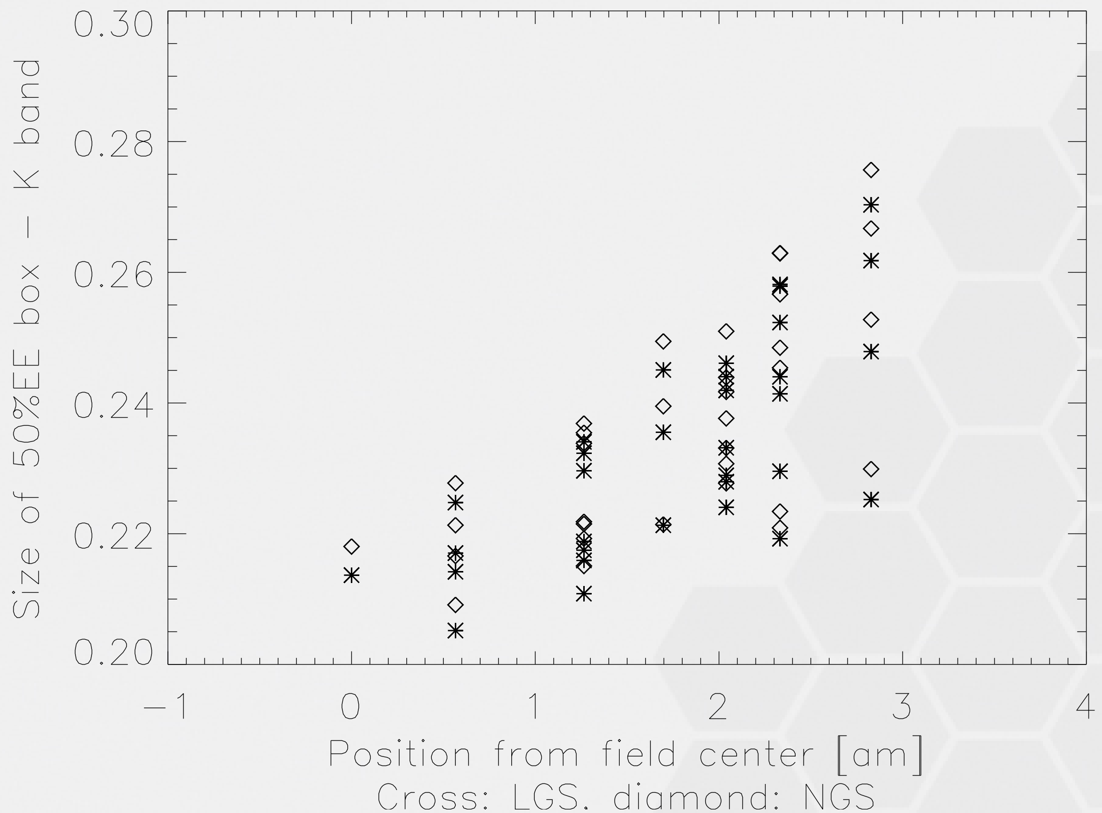








LGS vs. NGS



Operationally LGSs much more complex

→LGS allows to go deeper (increased SC). How much TBD…
→Not significantly different in performance (cone effect negligible for GLAO) for bright guide stars
→EXCEPT size of pick-offs (i.e. min FOV)

MCAO vs. GLAO

- MCAO corrected FOV ~2’ (max)
  - Limited by “technology” i.e. number of DMs and LGSs
- In that field, one gets diffraction limit in H, K.
- Pros:
  - Much better performance
  - “Strehl” instead of EE
  - SC (compared to NGS/GLAO with similar field)
- Cons
  - Technological complexity
    - ⇨ First light presumably after GLAO
    - ⇨ Availability (LGS → Cirrus, LGS → Reliability)
  - Transmission (?)
- See talk on MAORY later in this workshop

Conclusions

- GLAO "gain" sensitive to
  - Cn2 Profile
  - Corrected field (2' -> ~8')
  - NGS magnitude and position
- "Reasonable" Sky coverage for "large" fields
- Similar analysis to be done for LGS GLAO
  - WFS more complex
  - ~100% SC (thanks to lasers)
  - Technologically much more challenging (Lasers, Detectors, operations…).