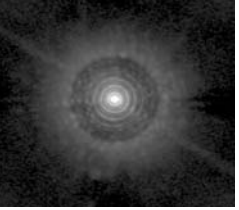

A pyramid sensor based AO system for Extremely Large Telescopes

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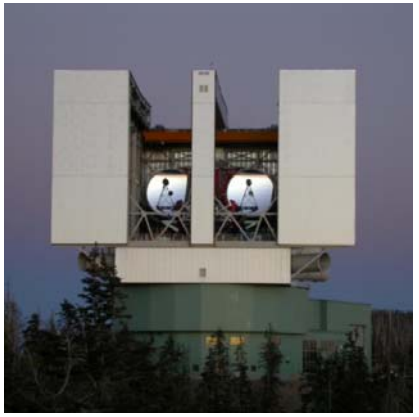
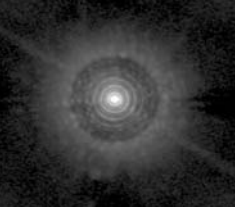
[1] INAF – Arcetri

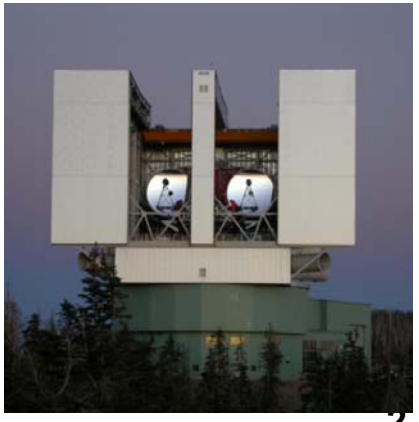
[2] MPE – Garching





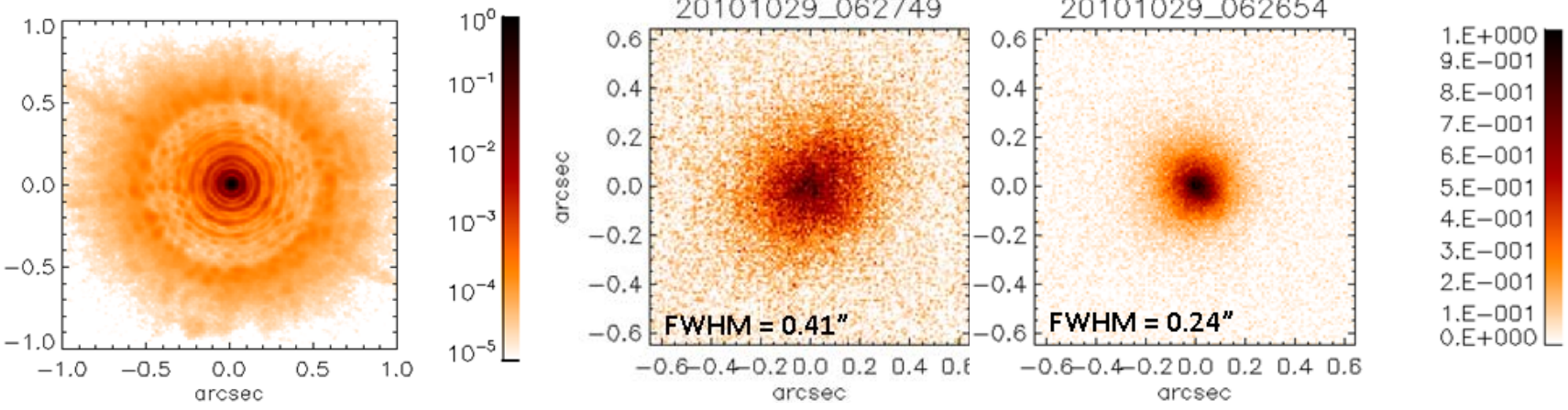
Outline

- Extrapolating LBT AO results to an ELT: an heuristic approach
- A pyramid-based first-light AO system for ELTs?
- Preliminary numerical simulations



Summary of LBT AO results

Bright end ($M_R < 10.0$)	30x30 subaps 400 modes	SR in H >80% Contrast of 10^{-4} @ 0.4”
Faint end ($M_R \approx 17.5$)	7x7 subaps. 10 modes	FWHM halved w.r.t seeing-limited

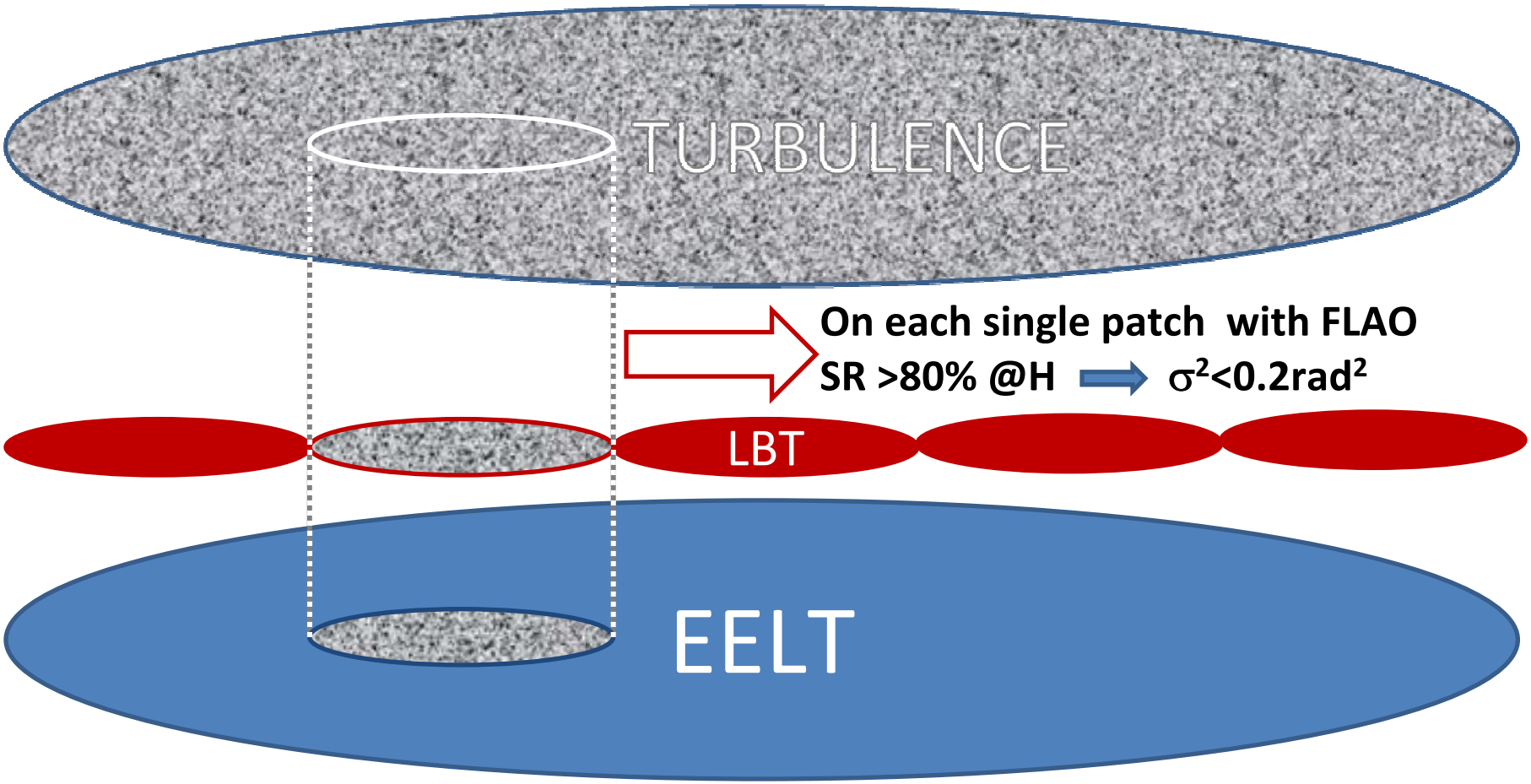


Seeing ~ 0.7”

Seeing-limited

AO-corrected

From 8.4m to 42m: DEELT /DLBT = 5

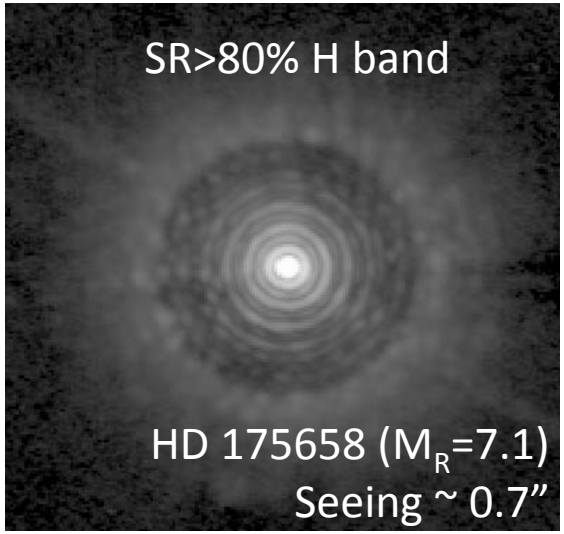


- 400 modes on LBT → 400× 5^2 = 10000 modes on EELT
- Power on low order modes boosted on a 42m pupil
- The same correction at high order frequencies (with the same equivalent modulation)

Scaling LBT results to an ELT

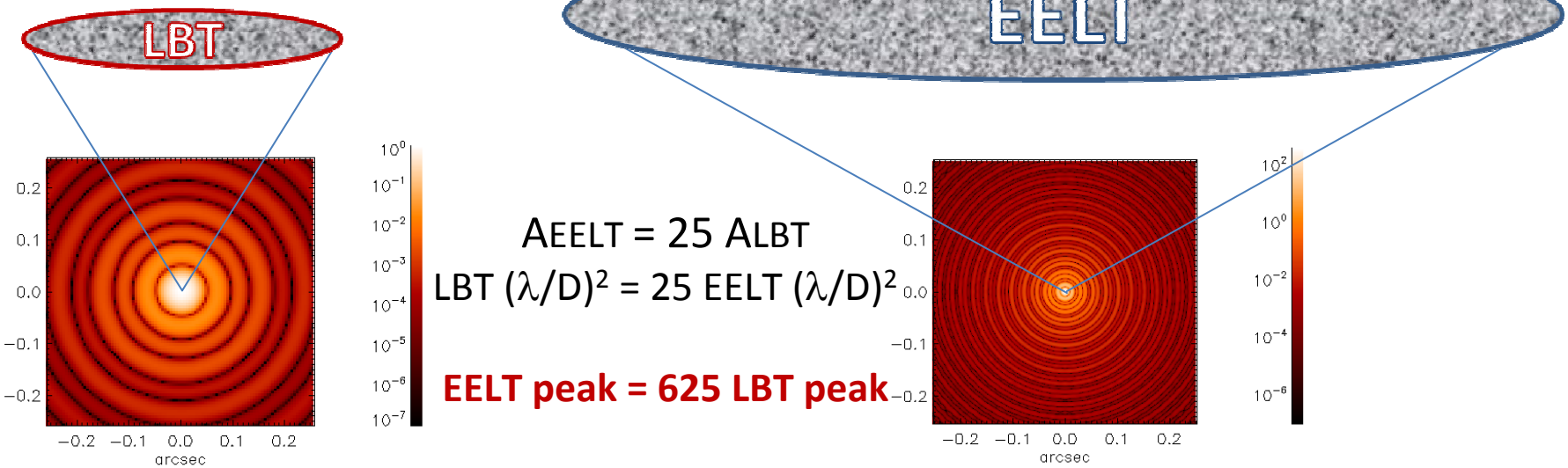
Telescope	D (m)	#modes	WFS sampling	Framerate	modulation
LBT	8.4	400	30×30	1kHz	±3λ/D
EELT	42	10000	150×150	1kHz	±15λ/D

- A 150x150 pyramid WFS could provide on the EELT *the same level of correction obtained by FLAO*
- *…but the contrast scales….*



Scaling the contrast

Same flux per m²



$A_{EELT} = 25\ A_{LBT}$

$LBT\ (\lambda/D)^2 = 25\ EELT\ (\lambda/D)^2$

EELT peak = 625 LBT peak

Same AO correction at a given frequency

same % of incoming flux injected at a given angular distance

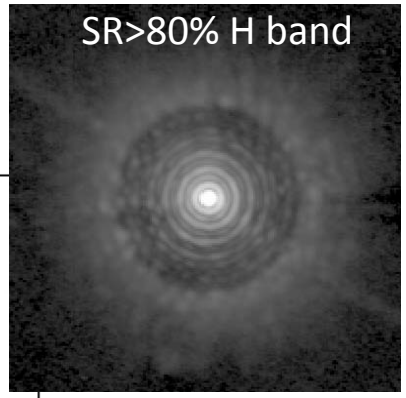
$\Delta I_{LBT}(\theta)$ = AO residual intensity on LBT at θ from the main peak

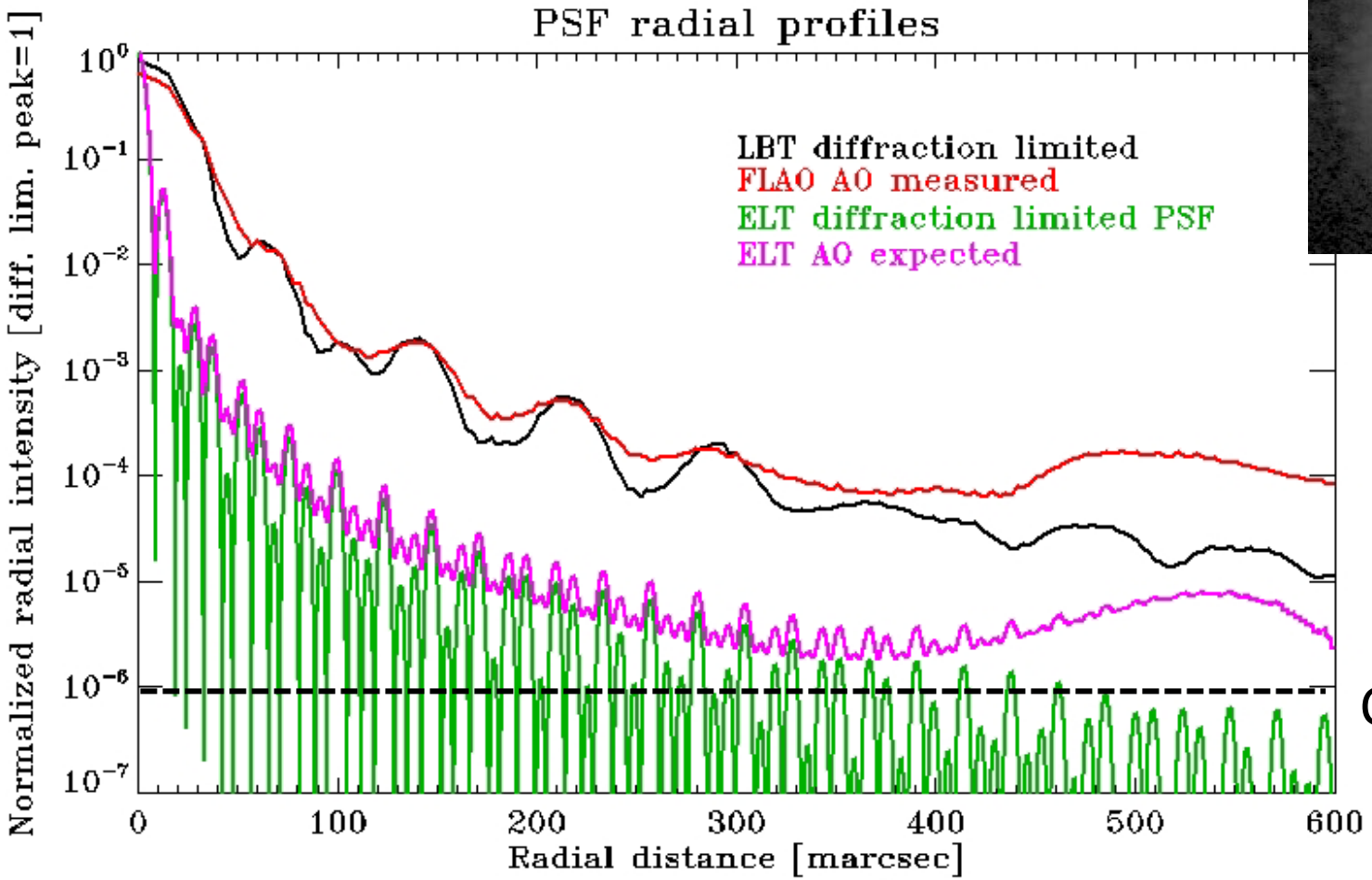
Expected AO residual intensity on EELT: $\Delta I_{EELT}(\theta) = 25\ \Delta I_{LBT}(\theta)$

$$C_{EELT}(\theta) = \Delta I_{EELT}(\theta)/I_{EELT}(0) = 25\Delta I_{LBT}(\theta)/625 I_{LBT}(0) = C_{LBT}(\theta)/25$$

Scaling LBT PSF to E-ELT

EELT with 150x150 pyramid and 10000 modes





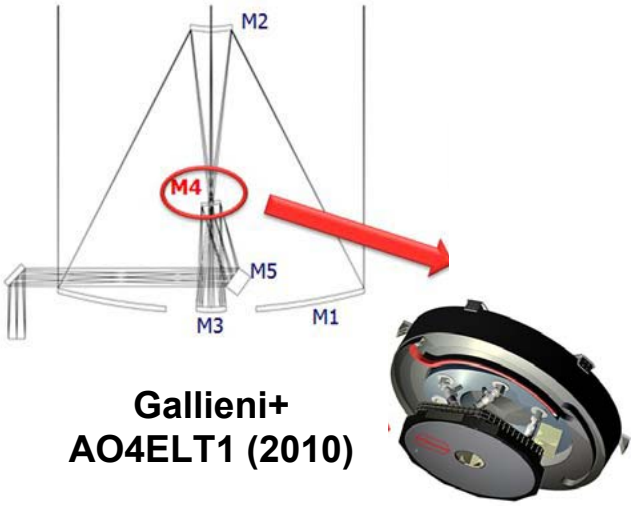
θ = 400mas

$C_{LBT}(\theta) \sim 10^{-4}$

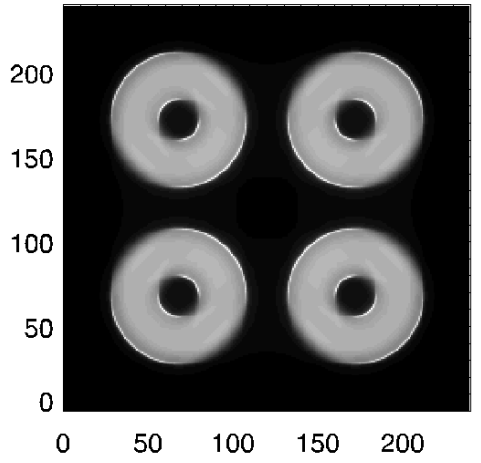
$C_{EELT}(\theta) \sim 4 \times 10^{-6}$

First-light AO for EELT?

- M4 corrector (~0.5m pitch)
- ~80x80 pyramid sensor
- EMCCD 240x240 (E2V's CCD220)
  - Sub-electron readout noise
  - Fast readout (<1.5kHz) (OCAM^2)
- Reconstruction Matrix-vector OK
  - ~10000 slopes x ~5000 modes
  - Parallel implementation



Gallieni+
AO4ELT1 (2010)



Off-the-shelf components!

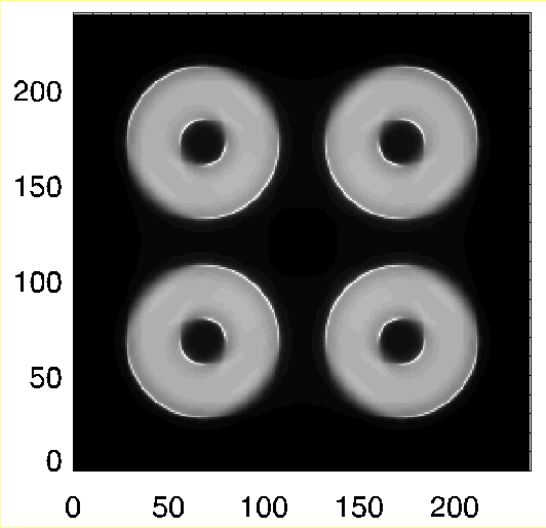
Closed-loop E2E simulator

EELT
- D=42m
- oc=30%

DM
- no Inf. functions
- pure KL modes

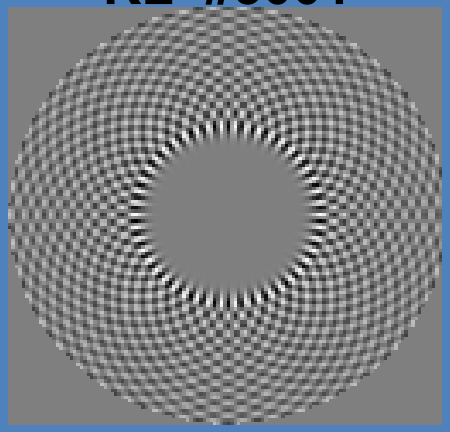
Turbulence
- Translating VK phase screens
- L0=50m, V=12.5m/s, s=0.8”

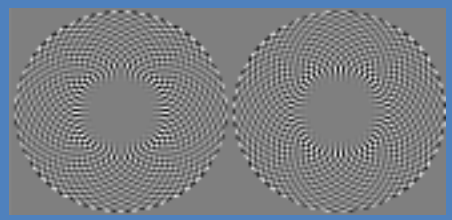
80x80 Pyr WFS
- full E2E Fourier code
- RON=0e$^-$ (~EMCCD)
- sensing in V or R band



IM calibration

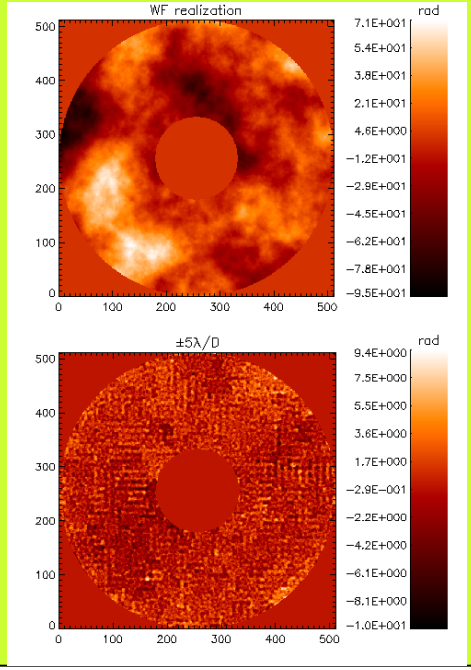
KL #3001





Sx Sy

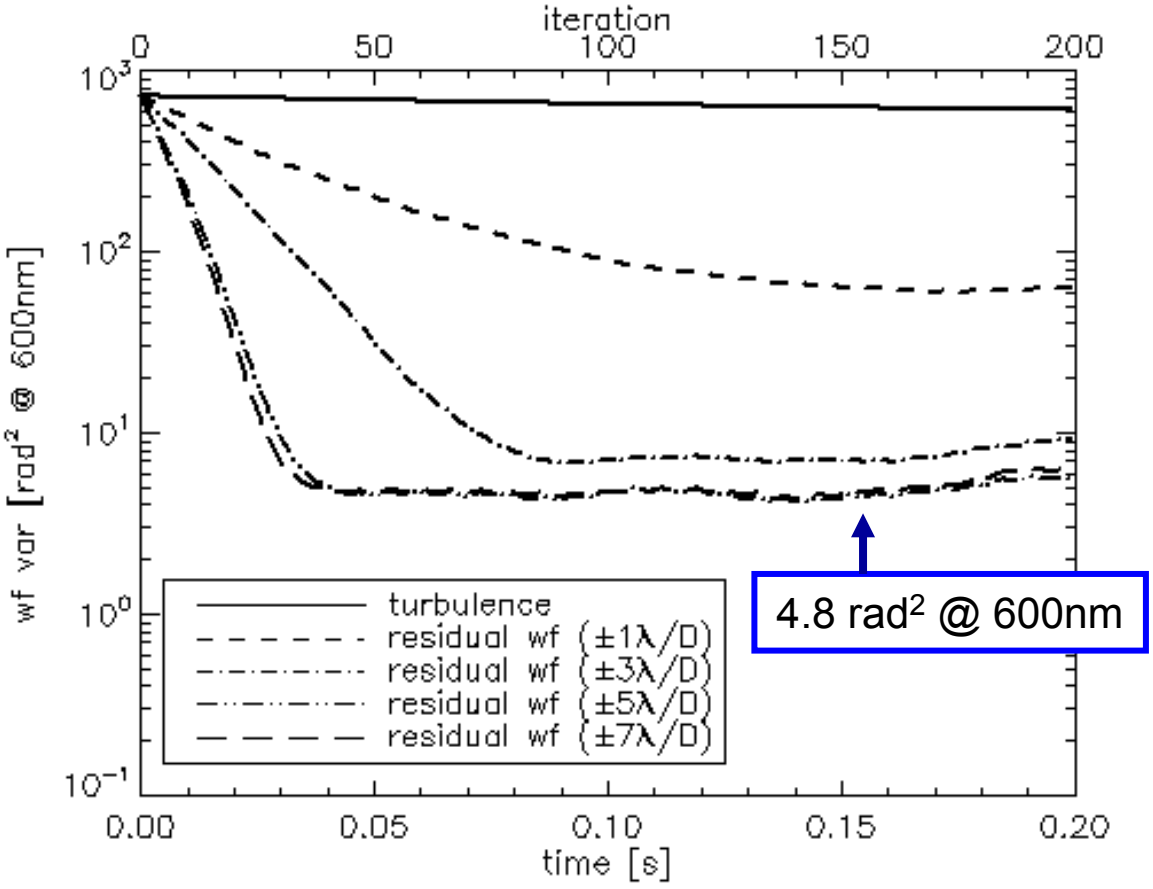
Closed loop
- ‘classical’ reconstruction
- integrator controller



Closed-loop bootstrap

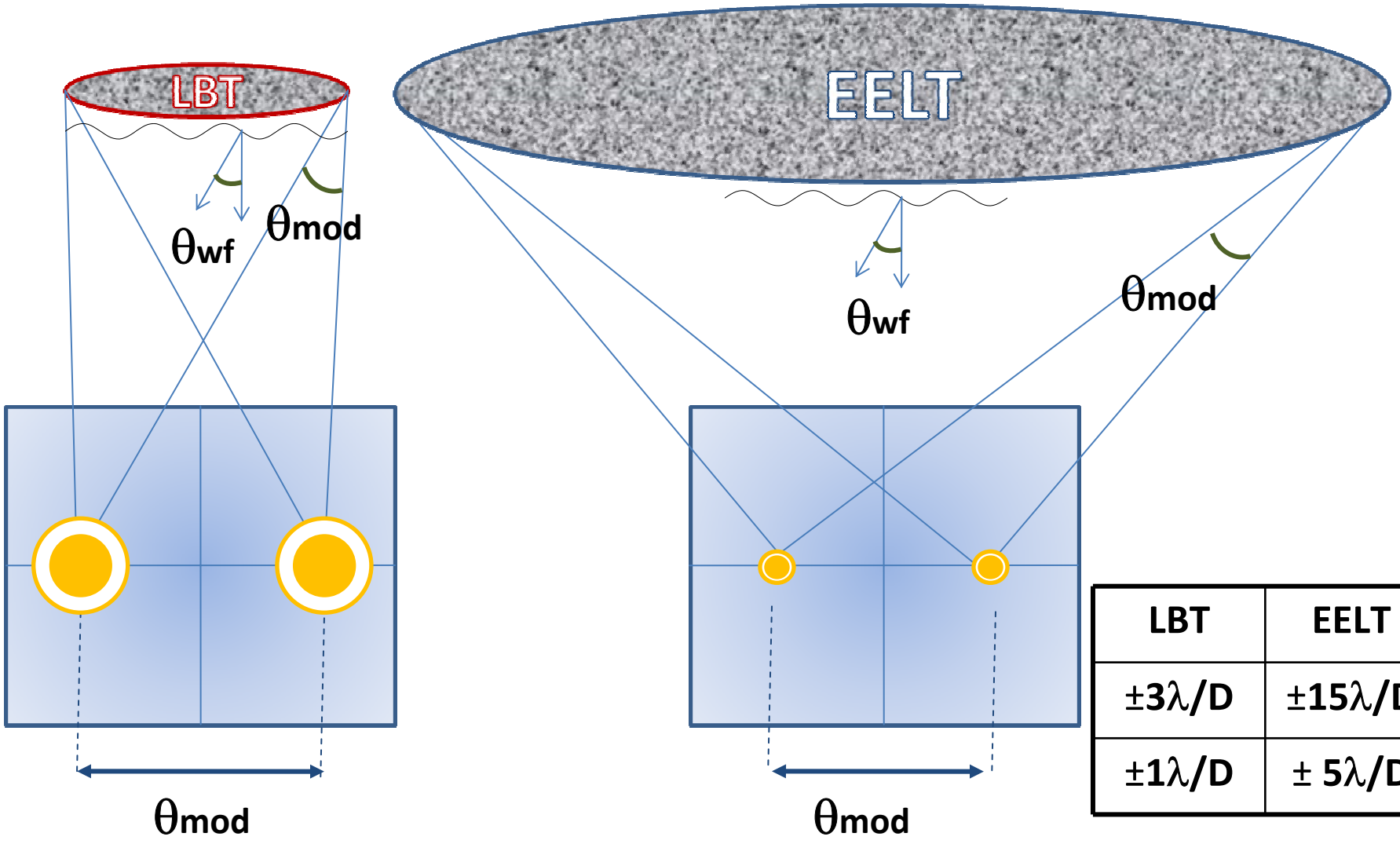
Simulation parameters:
- 80x80
- 4016 KL modes
- WFS λ_s = 600nm
- Closed-loop @ 1kHz
- Integrator: g=0.8
- High flux, no RON

Mod = ±5 λ/D on EELT is sufficient for the pyramid bootstrapping



c.f. Perfect correction after removal of 4016 Zernikes is 3 rad² @ 600nm.

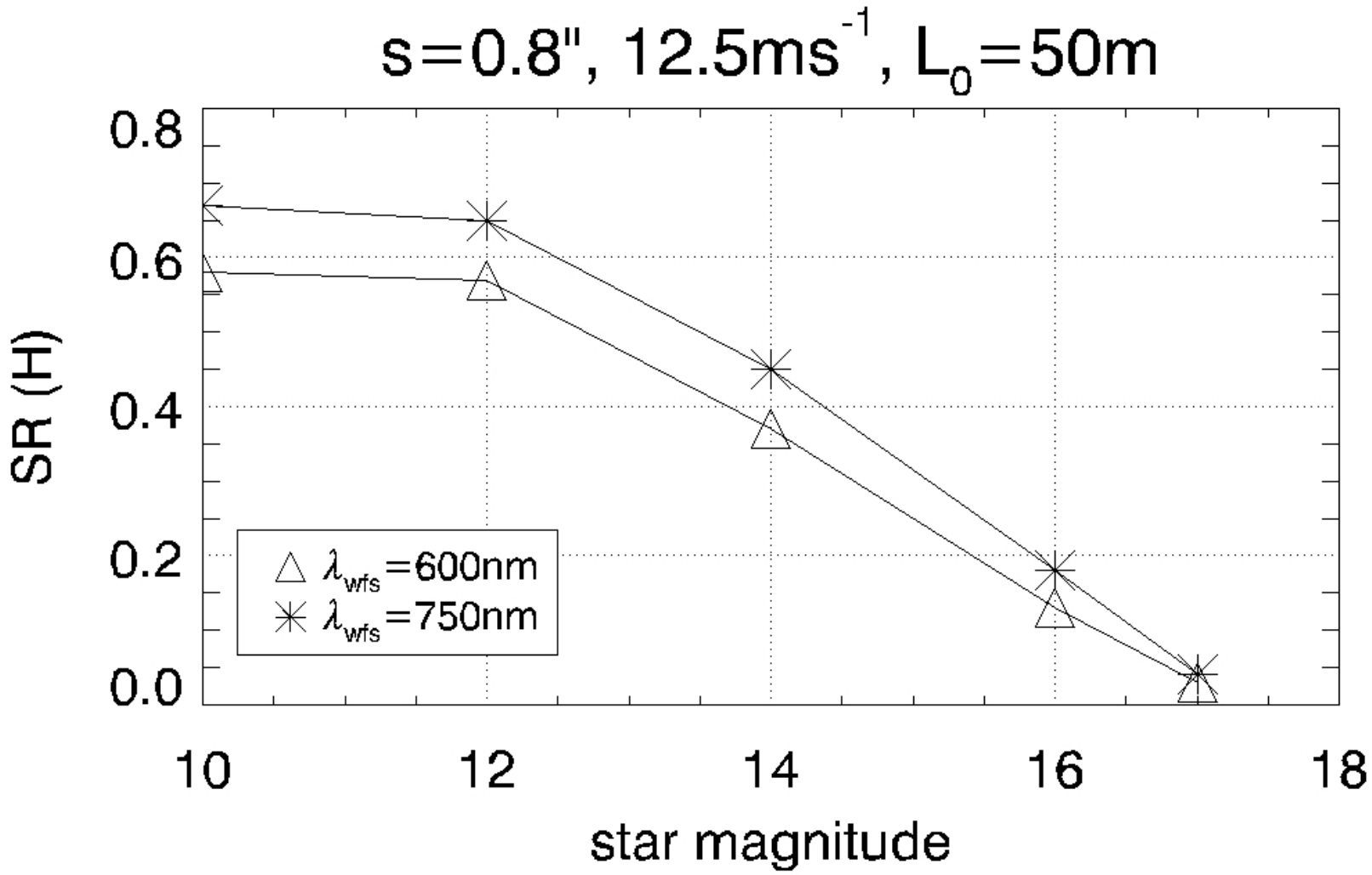
Scaling the pyramid modulation



LBT	EELT
±3λ/D	±15λ/D
±1λ/D	± 5λ/D

Same on-sky angle of modulation => same WFS sensitivity

80x80: Performance on EELT

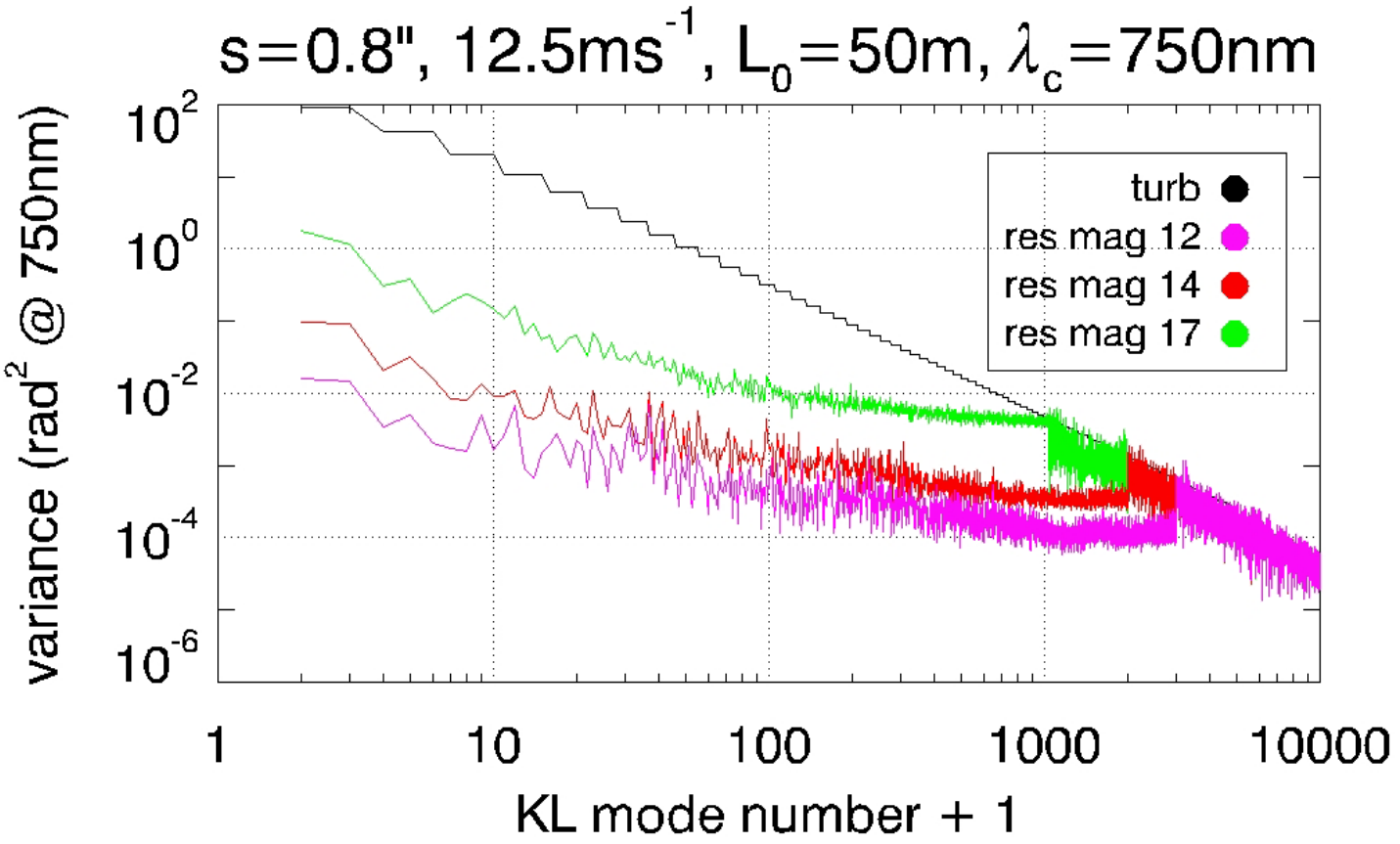


Deep-depleted EMCCDs for R-WFS available off-the-shelf too

Modal performance

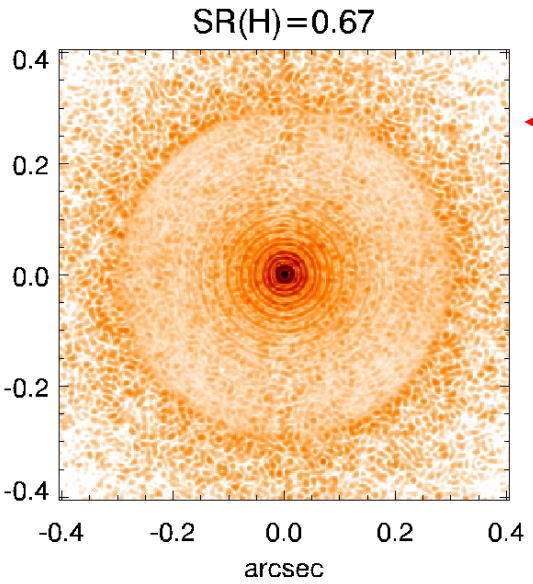
Fixed parameters: 30x30, RON=0, 1kHz, modulation ±5λ/D

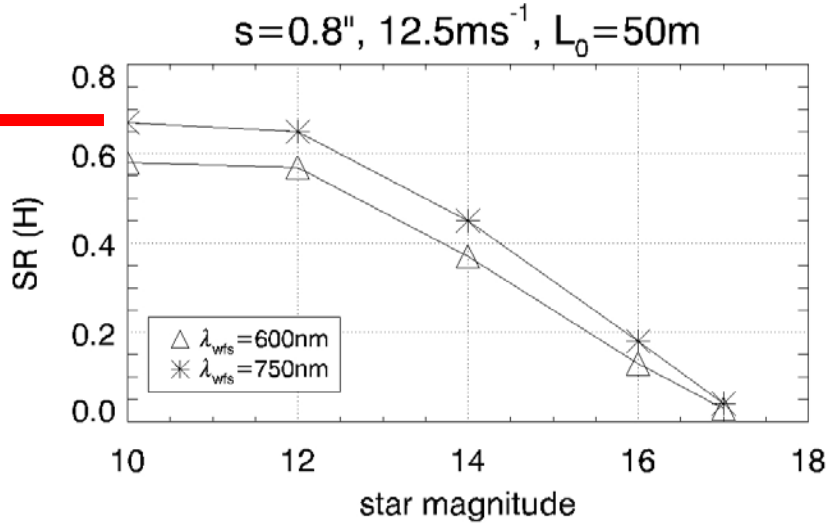
Mag(R)	10	12	14	16	17
#modes	4016	3000	2014	2014	1030

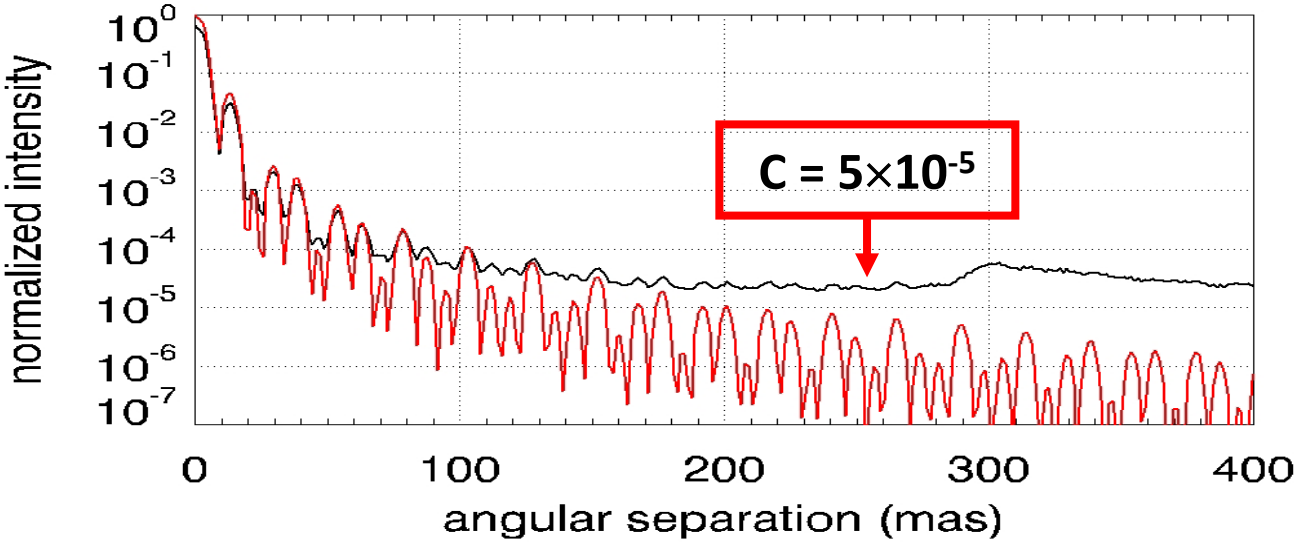


Bright end: PSF profile and contrast

diff. limited core: FWHM=8 mas

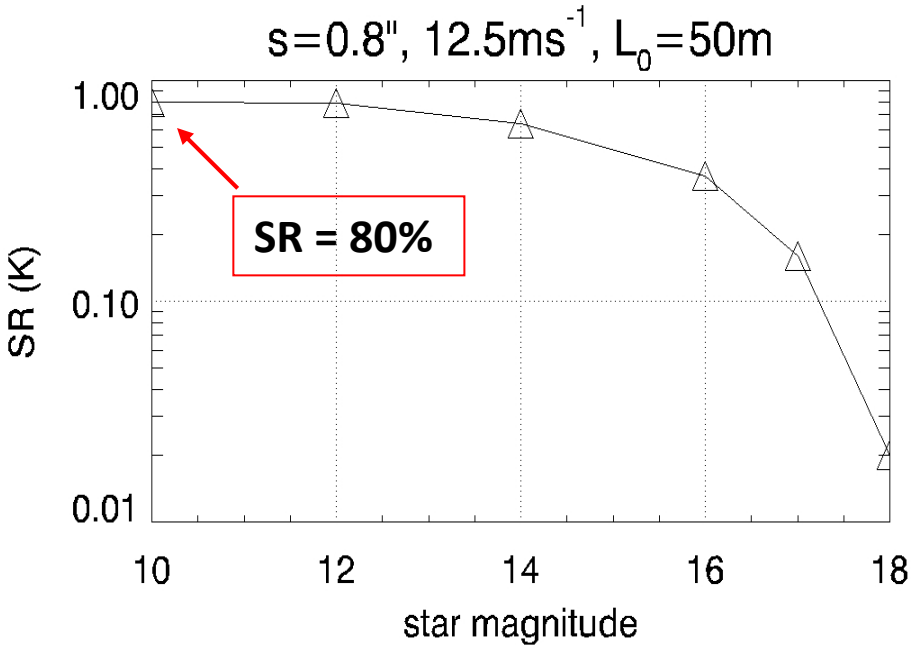


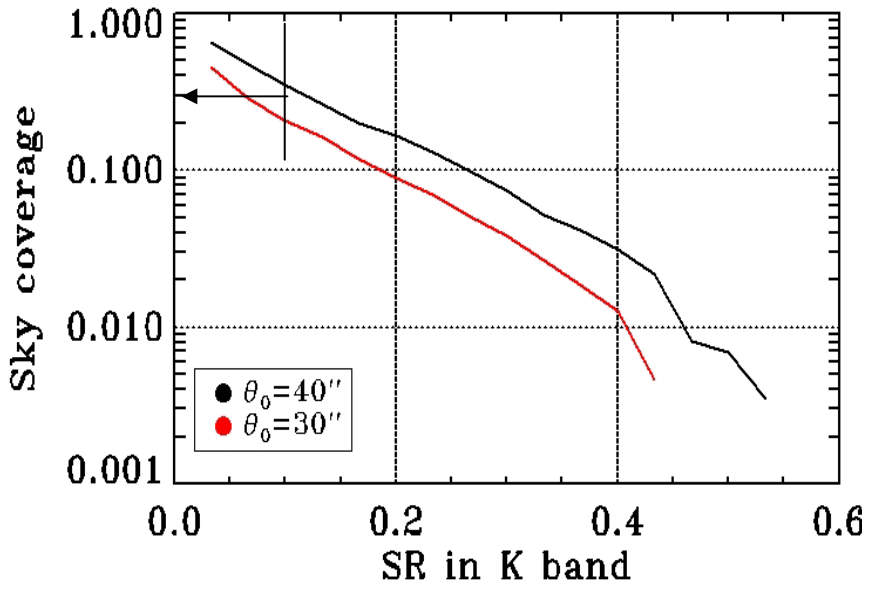




K band performance & sky coverage

Sky Coverage computed for a sample of 830 galaxies at z~3 in 16 different fields located at high galactic latitude [Steidel, 2003].





Conclusions

- ~80x80 NGS WFS for ELTs available now!
- SR<65% in H (SR<80% in K) feasible for First-Light AO instruments.
- Why not same SCAO unit solution for different systems?
  - SCAO for MICADO, METIS, …
  - First stage of EPICS