This project is supported by the European Commission's FP7 Capacities Programme for the period April 2013 - March 2017 under the Grant Agreement number 312495.

The MCAO system of the EST: DM height determination for best performance using real daytime statistical turbulence data

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  - General study of the specificities of solar AO
  - EST MCAO system performance simulations: DM height and number
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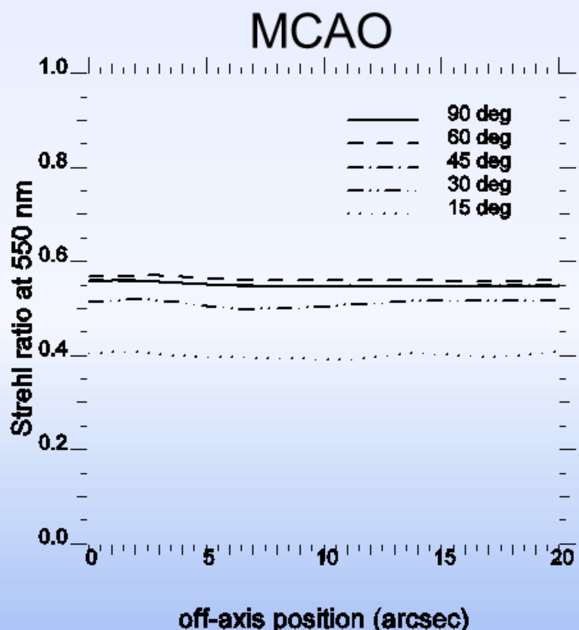
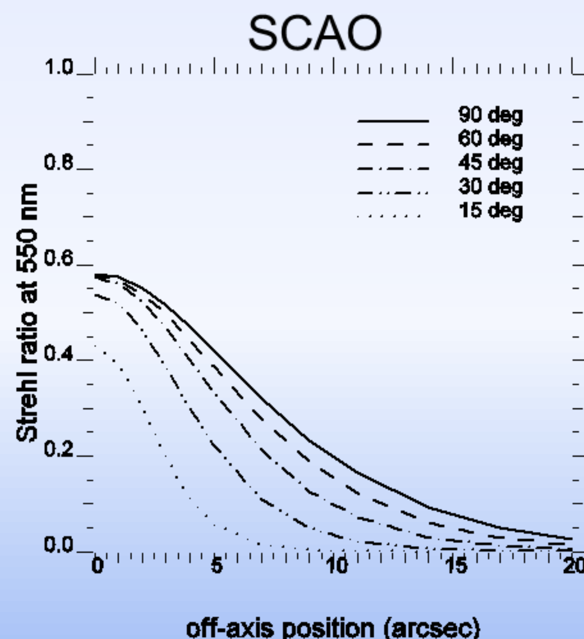
Specificities of solar AO: averaged turbulence

- correlating Shack-Hartmann WFS, with solar granulation a minimum ~8" required to have structure, usually of 10-12 arcsec
- averages the wavefront information over the field
- the increased line-of-sight distance to the turbulent layers for low elevation observations leads to bigger degradation of the performance





(Marino Optical Engineering 51; Béchet AO4ELT3; Montilla AO4ELT3, 2013)

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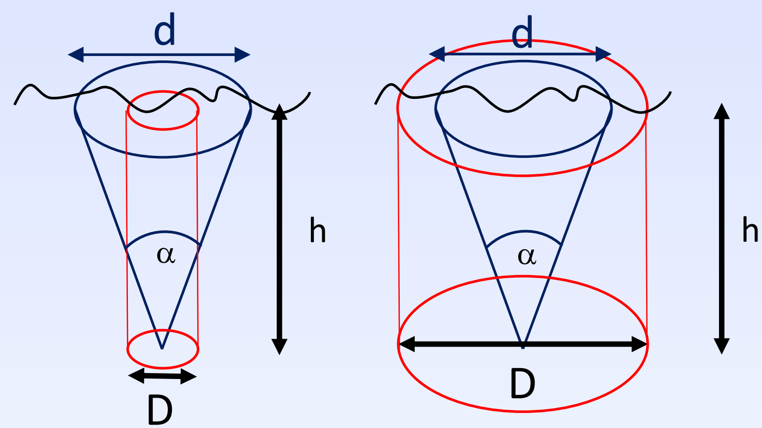
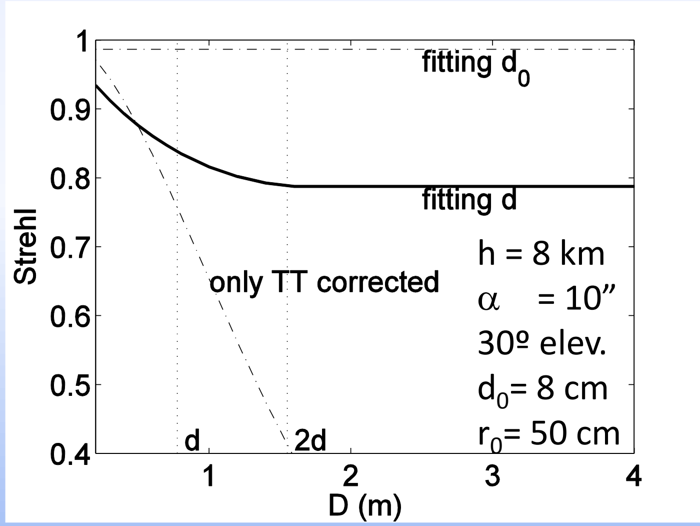
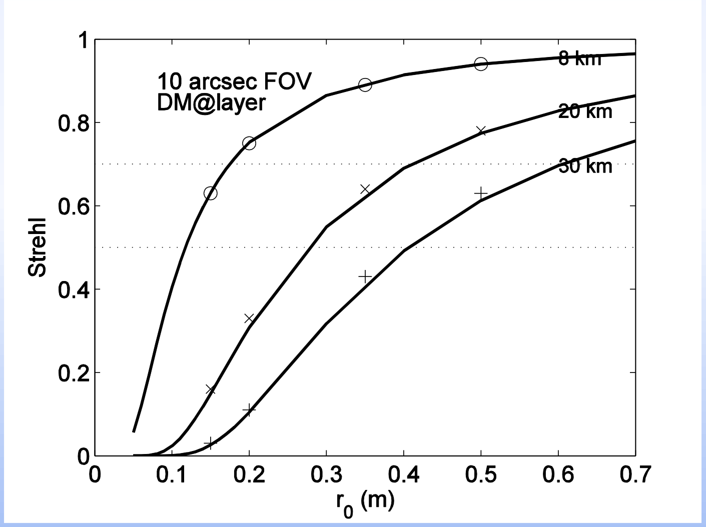
Specificities of solar AO: undersampled high altitude turbulence



d>>D, the high altitude turbulence is undersampled, it cannot be corrected

d<<D, sampling is enough to correct the turbulence, but the **fitting error is dominated by d rather than by the subaperture d_0** ⟶ we have derived the equation for the generalized fitting error





(Montilla AO4ELT4, 2015)

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EST MCAO system

Parameter	SCAO	MCAO
DM heights [km]	0	0, 5, 9, 12, 25
Spatial sampling [cm]	8	8, 30, 30, 30, 30
Sensing field points	1	19
Subaps/pupil diameter	50	13
Wavelength [nm]	550	550
FOV (arcsec)	10	60

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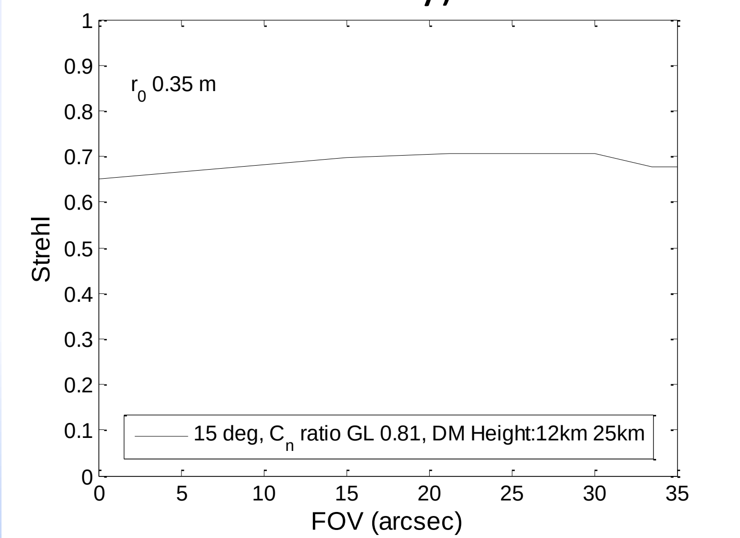
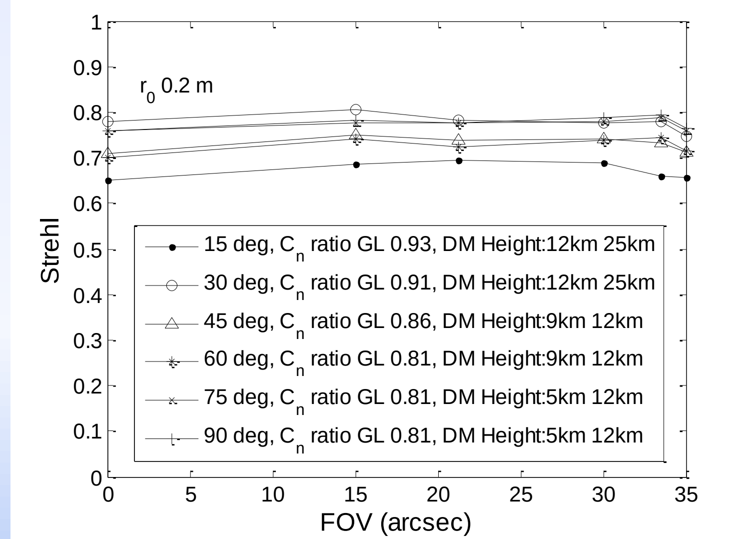
EST MCAO system performance simulations

FrIM (Lyon collaboration) end-to-end static numerical simulations with **real** daytime turbulence profiles (see Luzma Montoya poster).

Worst atmospheric conditions to reach a 40% total Strehl (~65% Strehl fitting and reconstruction error only).





The C_n ratio of the ground layer affects the performance of the system as much as the integrated r_0.

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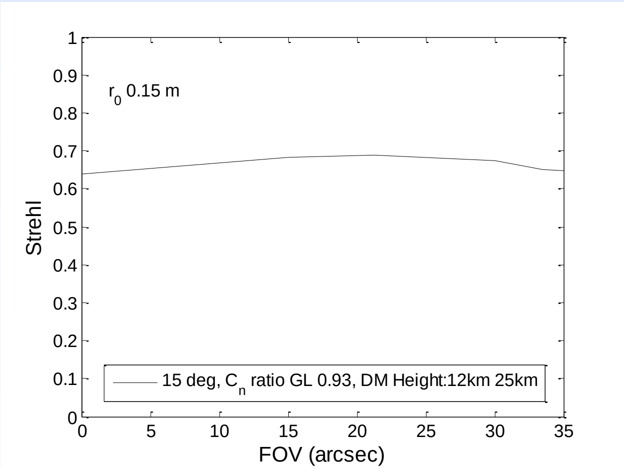
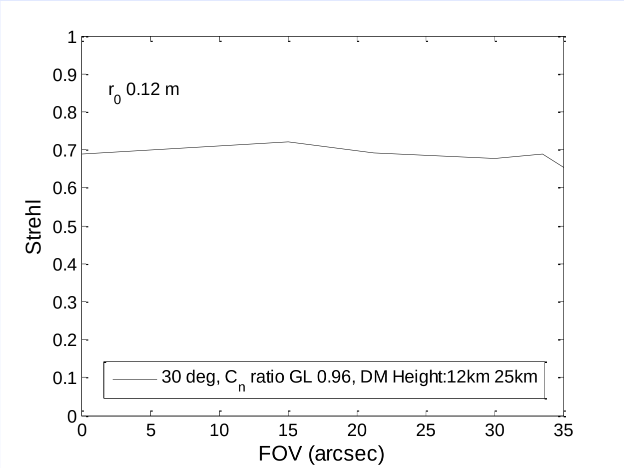
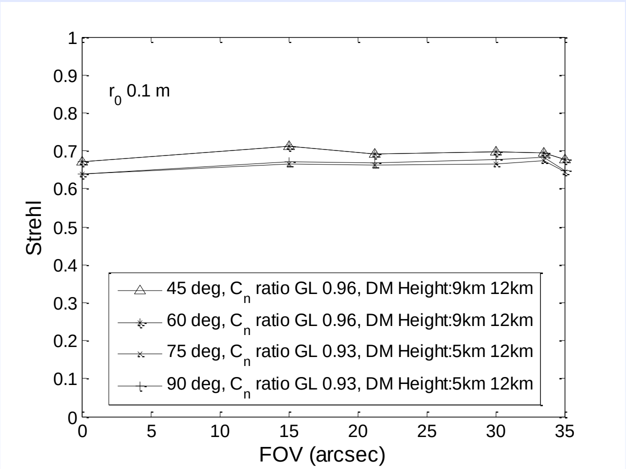
EST MCAO system performance simulations







5 DMs at 0, 5, 9, 12 and 25 kms are needed to have an homogeneous Strehl higher than 40% over the 1 arcmin FoV for all the elevation range.

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EST MCAO system preliminary error budget

With the equation for the generalized fitting we can estimate the error budget including the fitting and reconstruction, temporal delay, WFS measuring and bandwidth errors, for a 4 m telescope. We use the following atmosphere:

- integrated r_0=15 cm (conservative)
- 2 layers:
  - low elevation case: GL r_0=16 cm, altitude layer @ 25 km r_0=50 cm
  - high elevation case: GL r_0=16 cm, altitude layer @ 15 km r_0=50 cm
- 2 DMs; pupil DM d_0=8 cm, altitude DM@layer d_0=30 cm

The error budget for the low elevation case is

σ^2 (rad^2)	σ^2_{delay}	σ^2_{WFS}	σ^2_{BW}	$\sigma^2_{fitting\ th}$	$\sigma^2_{fitting\ sim}$
d_0@25 km	0.303	0.078	0.076	0.456	0.415

	Strehl (theoretical)	Strehl (simulated)
d_0@25 km	0.40	0.41
d_0@15 km	0.50	0.50

An homogeneous Strehl higher than 40% over the 1 arcmin FoV can be obtained even for low elevations and despite the intrinsic anisoplanatism of the WFWFS.

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Conclusions

- **Mainly two things limit solar AO performance: the extended FOV of the correlation SH WFS and the short visible wavelengths.**
  - Extended FOV: need to find a sensing method alternative to correlation tracking that could work on extended objects but with smaller FOVs (i.e. Mach-Zehnder) or alternative correlation algorithms (Durham) or neural networks approach (Oviedo).
  - Short visible wavelengths: Complexity.
- **FrIM end-to-end static numerical simulations:** 5 DMs at 0, 5, 9, 12 and 25 kms are needed to have an **homogeneous Strehl higher than 40% over the 1 arcmin** FoV for all the elevation range.
- **Analytical error budget:** an **homogeneous Strehl higher than 40% over the 1 arcmin** FoV can be obtained even for low elevations and despite the intrinsic anisoplanatism of the WFWFS.
- **DASP-solar (Durham collaboration) end-to-end dynamical simulations confirm FrIM static numerical simulations and analytical error budget results.**