Progress Report May 2014

MCAO SIMULATIONS AND TESTS 1/2

Objective

The Multi-Conjugate Adaptive Optics (MCAO) system of EST combines a narrow field high order correlating WaveFront Sensor (WFS), providing the information to correct the ground layer, and a wide field lower order correlating WFS to control the higher altitude mirrors (4 DMs). Correlating sensors collect a wide field of view (FOV), which has several implications, i.e. averaging wavefront information from different sky directions, making the Strehl ratio to drop for low elevation observations.

End-to-end simulations of the EST MCAO system are in progress to analyze the performance for a large range of elevations and depending on the asterism geometry, number and height of DMs, in order to find the best system configuration.

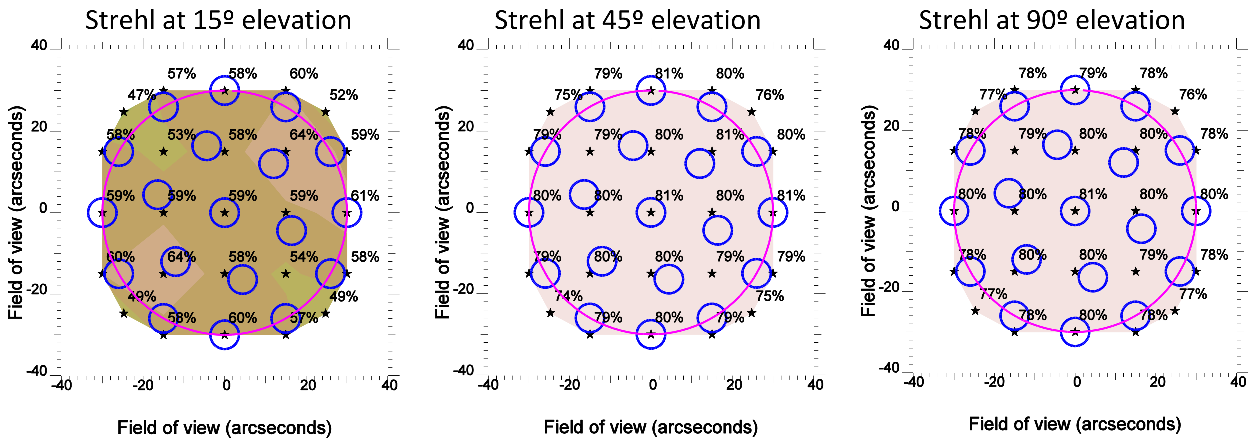
EST parameters	AO	MCAO	EST parameters	AO	MCAO
DM height (km)	0	0, 1.6, 6.6,10,23	Sensing field points	1	19
Spatial Sampling (cm)	8	8, 30, 30, 30, 30	Subapertures/pupil diameter	50	13

Simulations and Analysis

Intrinsic anisoplanatism associated to solar wavefront sensor

One of the challenges of solar AO is that the wavefront sensor has to work on extended and low contrast objects such as sunspots or solar granulation. A correlating Shack-Hartmann is used to sense the wavefront. The FOV has to be large enough to contain structure for the correlation algorithm to work robustly, but not too large, to avoid averaging of wavefront information from the upper layers of the atmosphere. Usually a FOV of 8-10 arcsec is used. With such FOV, the anisoplanatism affects the measurements of the correlating SHWFS, averaging the wavefront information over the field of view and thus decreasing the sensitivity to the wavefront distortions introduced at large heights above the telescope aperture. For low elevation observations, the increased line-of-sight distance to the turbulent layers leads to a wider wavefront area to be averaged for a given FOV. Therefore, the contribution of this anisoplanatism to the AO measurements must be taken into account in solar AO performance evaluation. The only way to estimate its effect is numerically, by including an end-to-end model of the wide field cross-correlation WFS in the simulations.

Open-loop simulations are performed for different telescope elevations with the Fractal Iterative Method (FrIM3D), a fast algorithm for tomographic wavefront reconstruction developed at CRAL. In this case layers at the altitude of the DMs are reconstructed (no projector was used). The simulations feature 10 realizations of a turbulent atmosphere with r_0=10 cm at 550 nm. The atmosphere includes 19 frozen layers distributed in altitude, representative of typical atmospheric conditions during solar observations. The atmospheric profile is the combined C^2_n profile from Rimmele (2010) [1]. Both narrow field HOWFS and wide field LOWFS are simulated. The correlating SHWFS is simulated providing an approximate average of the measurement over a 10 arcsec field of view, in order to include the anisoplanatism effect. Only the fitting error (due to the limited number of actuators) is considered. These simulations show the homogeneous correction over the 1 arcmin FOV. The reduction in the Strehl for low elevations is an effect of the intrinsic anisoplanatism associated to wide field WFSs and the generalized fitting error.



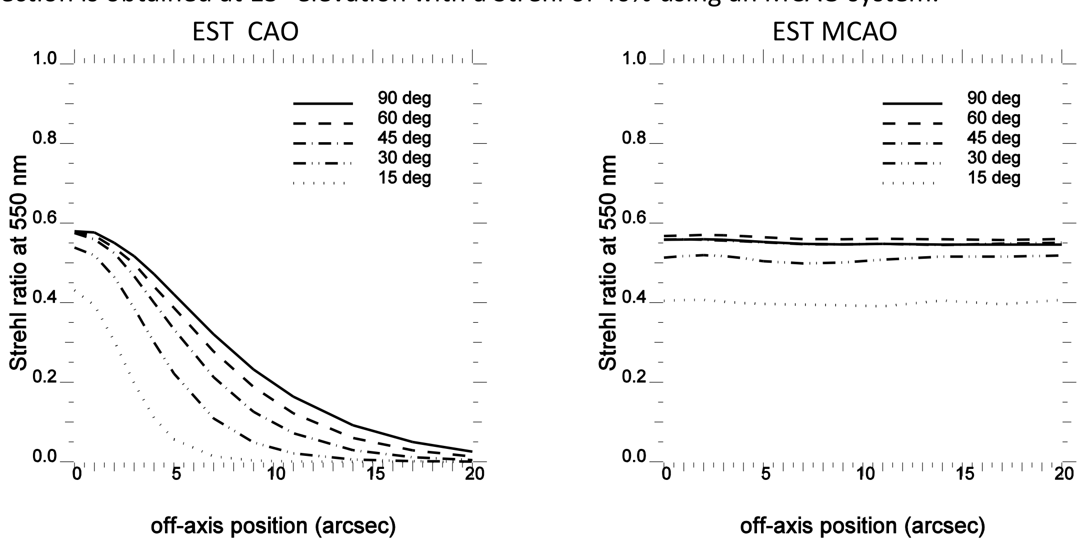
Blue circle: center of the WFWFS subfields – Pink circle is 1arcmin FOV- Stars are used to probe the Strehl

Estimated performance included error budget

Strehl ratio is estimated including the fitting, temporal delay, WFS measuring and bandwidth errors, using the values shown in the following table.

λ	τ_0	Frequency	SNR	contrast	f_S	f_G
550 nm	2 ms	2 kHZ	223	3%	1 kHz	213 Hz

In spite of the effect of the anisoplanatism of the 10 arcsec correlating SH, still a homogeneous correction is obtained at 15° elevation with a Strehl of 40% using an MCAO system.



Next step

Implementation of the projector in the MCAO reconstructor.

Ref. [1]: T. Rimmele, ATST Workshop (2010)