MCAO for the European Solar Telescope: first results

Marco Stangalini
Roberto Piazzesi
Dario Del Moro
Francesco Berrilli
Alberto Egidi

Università di Roma “Tor Vergata”

www.fisica.uniroma2.it/solare
• EST is a pan-european project, presently in its Conceptual Design Study financed by the European Commission

• It will be a **4-meter class solar telescope**, to be located in the Canary Islands

• **It will be optimised for studies of the magnetic coupling** between the deep photosphere and upper chromosphere

• multiple wavelength imaging

• 2D spectroscopy and spectropolarimetry

• high temporal resolution

• high spatial resolution
- sWP5300 led by UToV, provides the heat rejector/stop design in compliance with telescope optical design

- UtoV partecipates in WP6000 – Wavefront reconstruction for the MCAO system
EST-MCAO

- REQUIREMENTS
  - 1' corrected FoV
  - MCAO system
  - High servo loop stability
  - High order correction (300\(^{th}\)-400\(^{th}\) aberration order)
  - High efficiency wavefront reconstruction
DIFFICULTIES

- Daytime turbulence
- High speed wavefront analysis (less than 1 ms)
- Low contrast target
- Time delay error
- Mirror seeing

Need for detailed performance studies through simulations and tests
We have investigated the layer oriented approach with a 7 points exagonal asterism.
MCAO simulations

- **Layer Oriented approach** (Ragazzoni R. et al 2002):
  - FFT turbulence layers with WFS fine tuning
  - 7 wavefront sensors

- **LOST simulation tool** (Arcidiacono, C. et al. 2004)

- **Solar Package** plugin to fit solar case needs:
  - WFS noise treatment for extended sources
  - Time delay reduction with turbulence forecasting
Simulation setup

- Working wavelength: 555 nm
- 2 DMs
- Conjugation altitudes: 0 Km, 10 Km
- Integration times + loop delay: 1.5 ms
- 30x30 WFS sampling
- 2 Kolmogorov turbulence layers (FFT): 0 km, 10 km
- D/r0 : 26, 8
Strehl ratio maps

7” radius 10” radius 15” radius

(SR = PSF peak / diffraction limited PSF)
Modal approach

- We have tested a modal approach for wavefront reconstruction.
- The best results in terms of SR peak and sky coverage are achieved with a 300th order base dimension.

Finite sampling effects on modal reconstruction (30 x 30 WFS subapertures)
In order to reduce time delay effects we propose the use of some prediction tools:

- Modal coefficients forecasting with ARMA stationary processes
- Modal coefficients forecasting with linear predictor algorithm
Forecasting

SR With linear prediction
SR Without linear prediction

Black - linear predictor
Red - without linear prediction
We have studied modal base optimization using information theory on VTT (Vacuum Tower Telescope) real WFS data.

Mutual information reordering lets us shrink the base dimension while keeping the reconstruction error fixed.
To be done...

- New neural network learning algorithm for the Linear Predictor
- Mirror seeing treatment
- Shell models turbulence simulations
- Testing ARMA forecasting in closed loop conditions

References:

- EST-SRD, EST Scientific Board. 2008 (Dec.). Science Requirements document for EST v6d2. SRD.
Zernike forecasting using ARMA(2,3) process on real VTT (Vacuum Tower Telescope) WFS data

Coefficient prediction could play an important role in time delay reduction in the loop closure of AO systems.