MCAO for the European Solar Telescope: first results

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EST

- 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

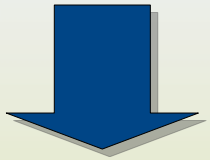
- UtoV partecipates in WP6000 – **Wavefront reconstruction** for the MCAO system

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

EST-MCAO

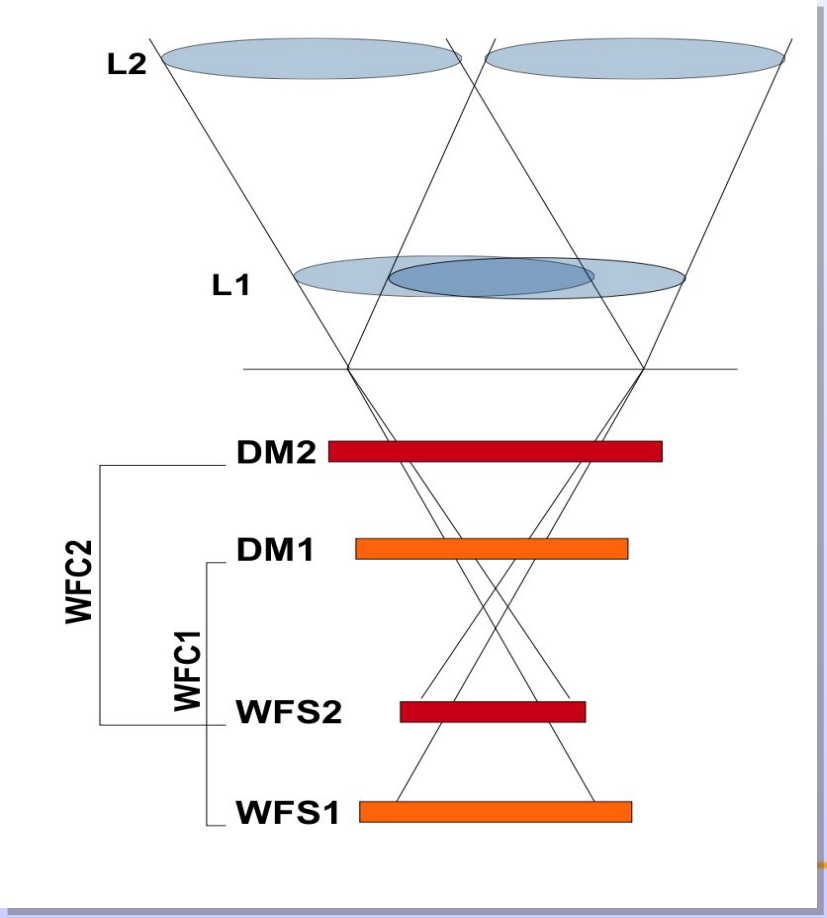
- DIFFICULTIES
  - Daytime turbulence
  - High speed wavefront analisys (less than 1 ms)
  - Low contrast target
  - Time delay error
  - Mirror seeing

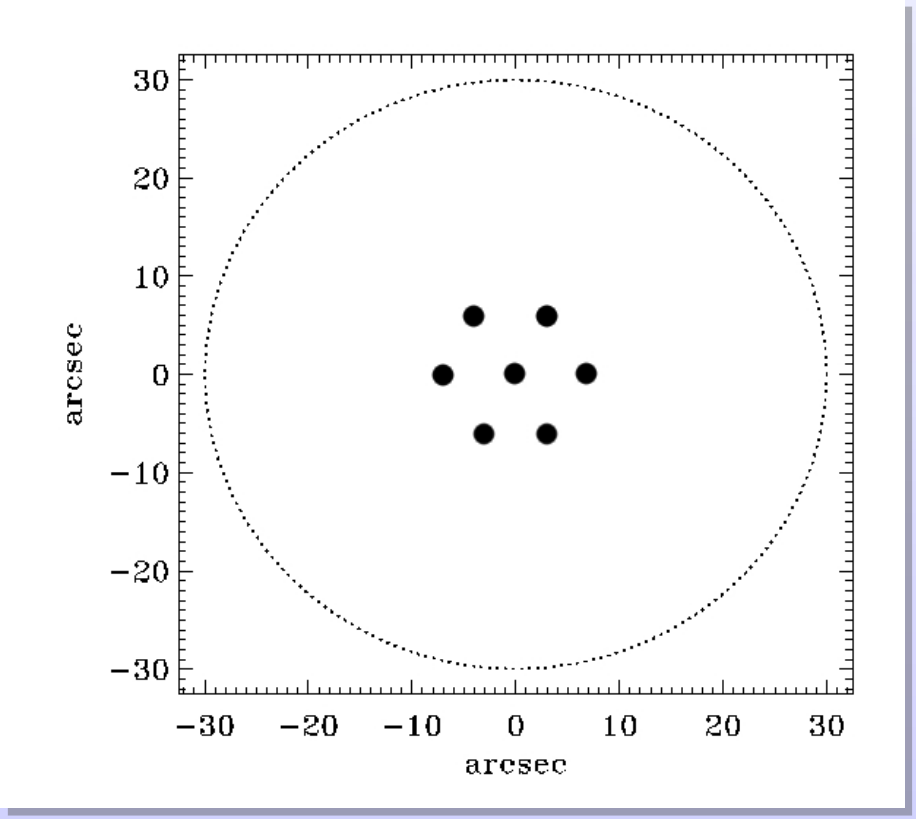


Need for detailed performance studies through simulations and tests

Layer Oriented MCAO

- We have investigated the layer oriented approach with a 7 points exagonal asterism





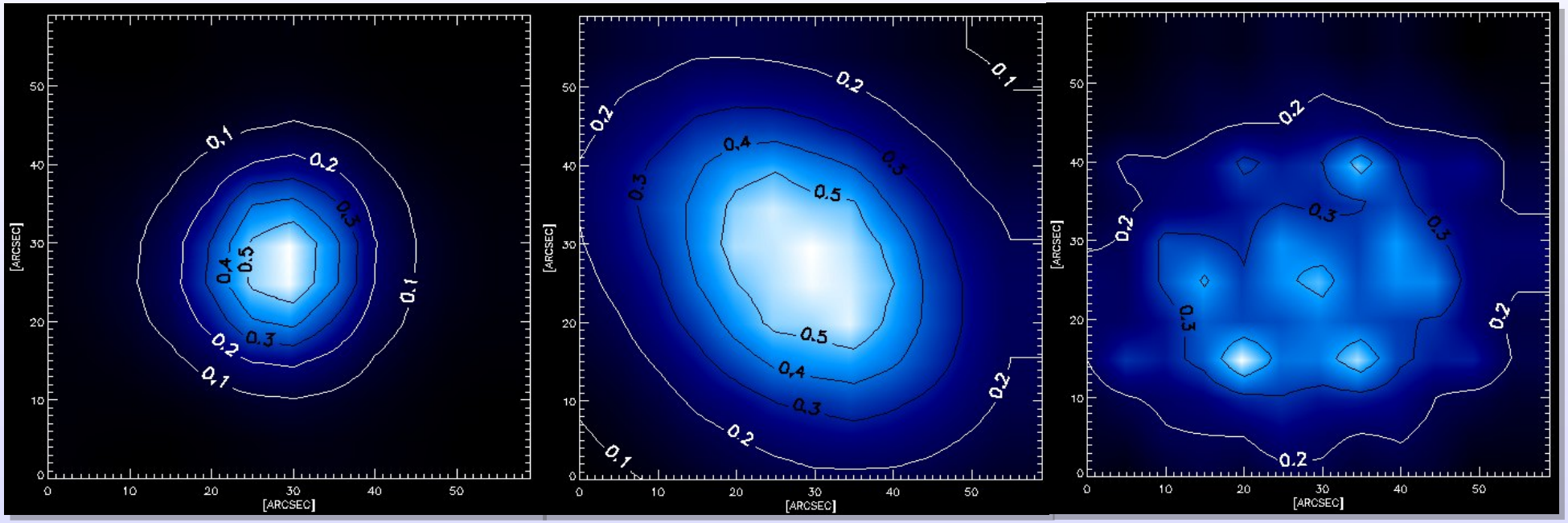
MCAO simulations

- 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

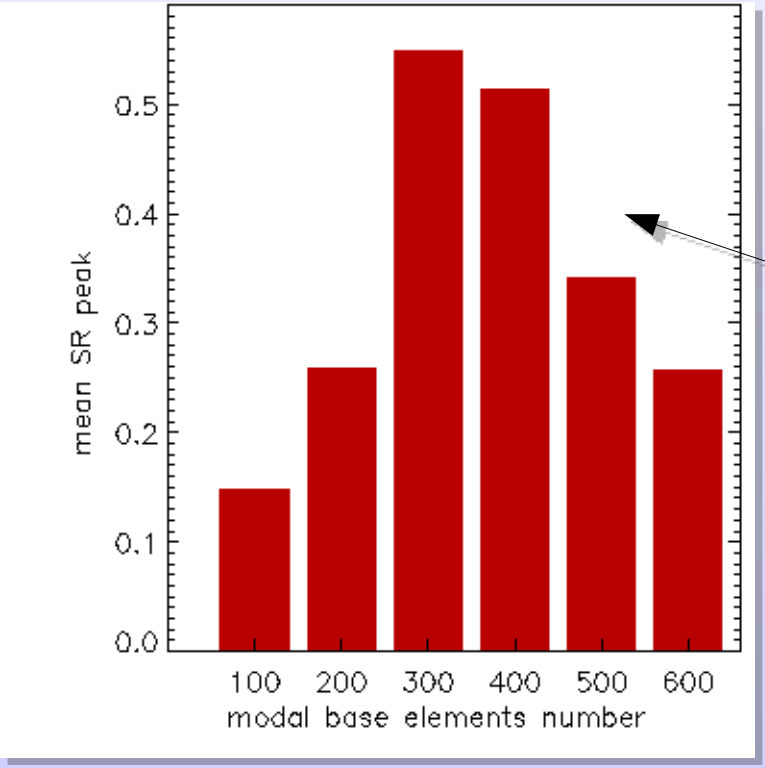


7” radius **10” radius** **15” radius**

(SR = PSF peak / diffraction limited PSF)

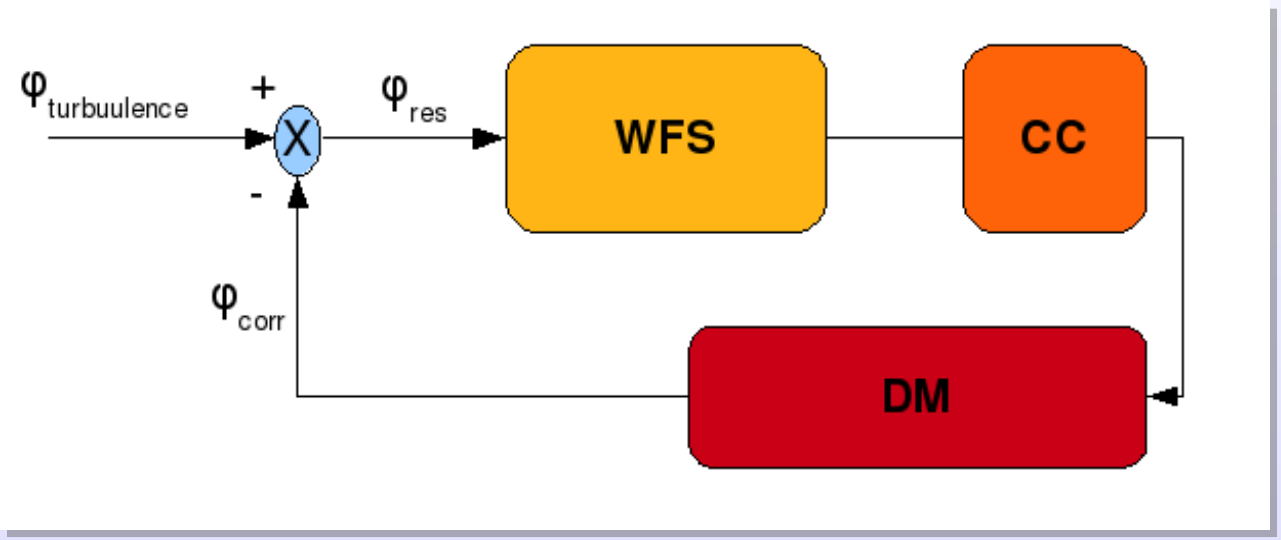
Modal approach

- 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



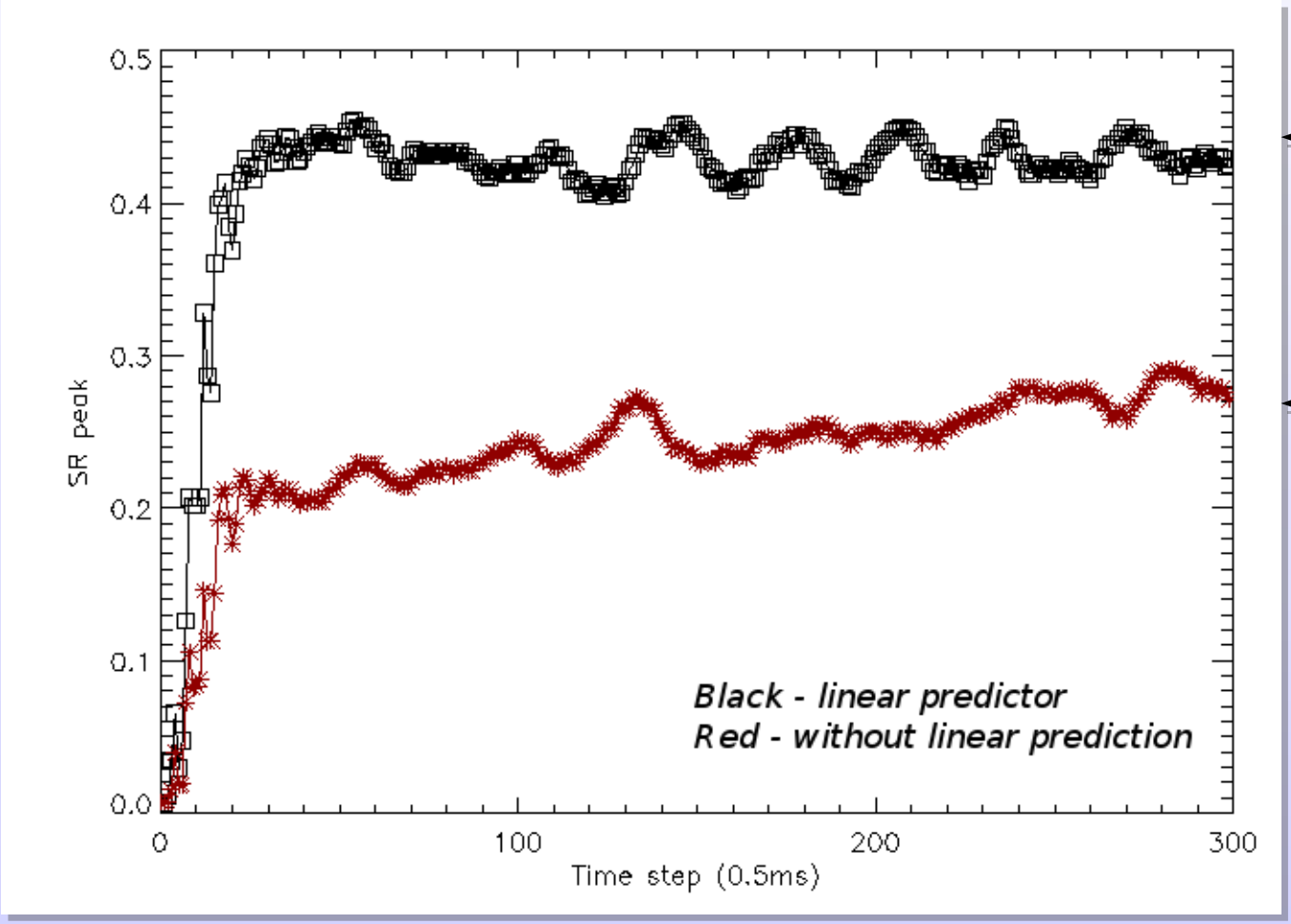
Finite sampling effects on modal reconstruction (30 x 30 WFS subapertures)

Time delay error



- **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

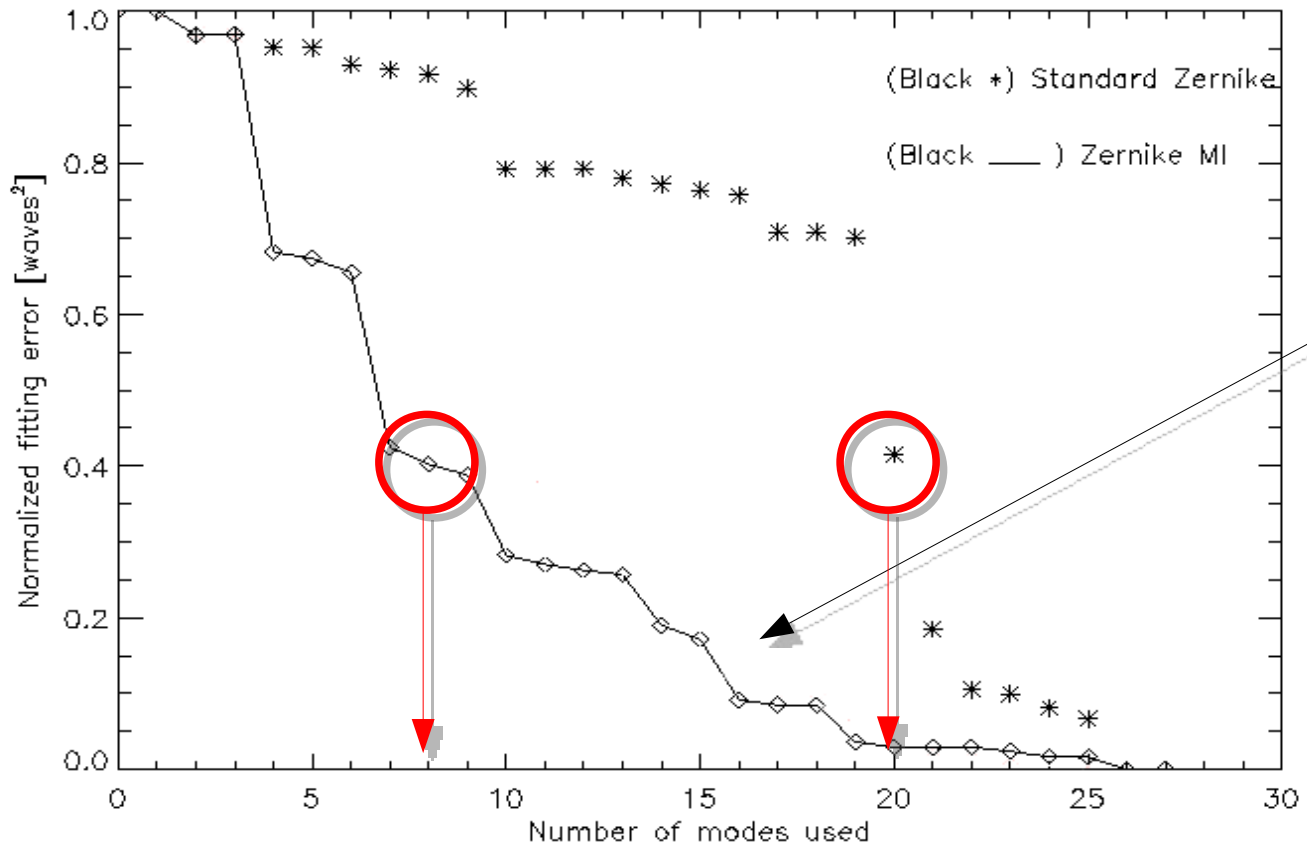


SR With linear prediction

SR Without linear prediction

Modal optimization

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...

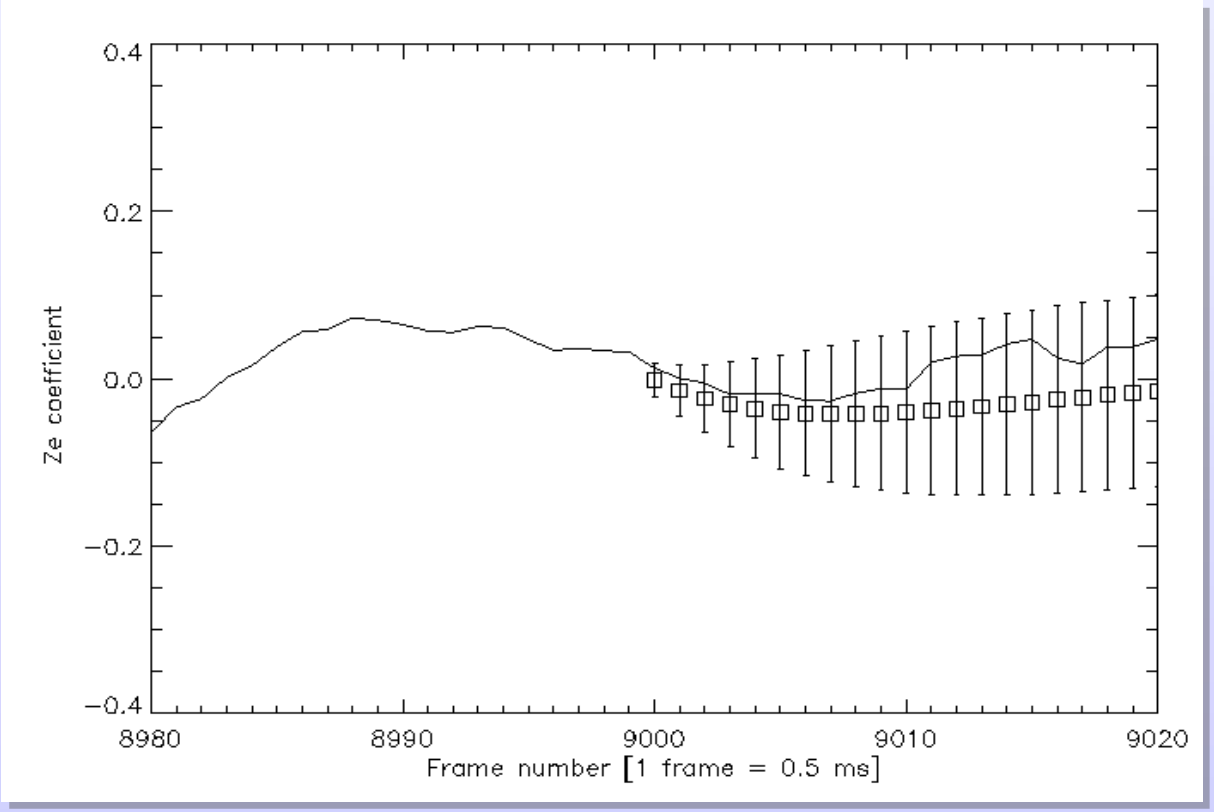
- New neural network learning algorithm for the Linear Predictor
- Mirror seeing treatment
- Shell models turbulence simulations
- Testing ARMA forecasting in closed loop conditions

References:

- *Arcidiacono, C., Diolaiti, E., Tordi, M., Ragazzoni, R., Farinato, J., Vernet, E., & Marchetti, E. 2004. Layer-oriented simulation tool. Applied optics, 43(22), 4288–4302.*
- *Ragazzoni, R., Diolaiti, E., Farinato, J., Fedrigo, E., Marchetti, E., Tordi, M., & Kirkman, D. 2002. Multiple field of view layer-oriented adaptive optics. A&A, 396, 731–744.*
- *EST-SRD, EST Scientific Board. 2008 (Dec.). Science Requirements document for EST v6d2. SRD.*

ARMA forecasting

- 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 sistems