RoPACS Network Workshop

Garching,10-11 May 2010

•I PART: Degree Work
The Adaptive Optics Group at Arcetri Observatory in Florence.
Topic :The close-loop perfomance optimization of The First Light Optics System for the Large Binocular Telescope (LBT).
Supervisor: S.Esposito

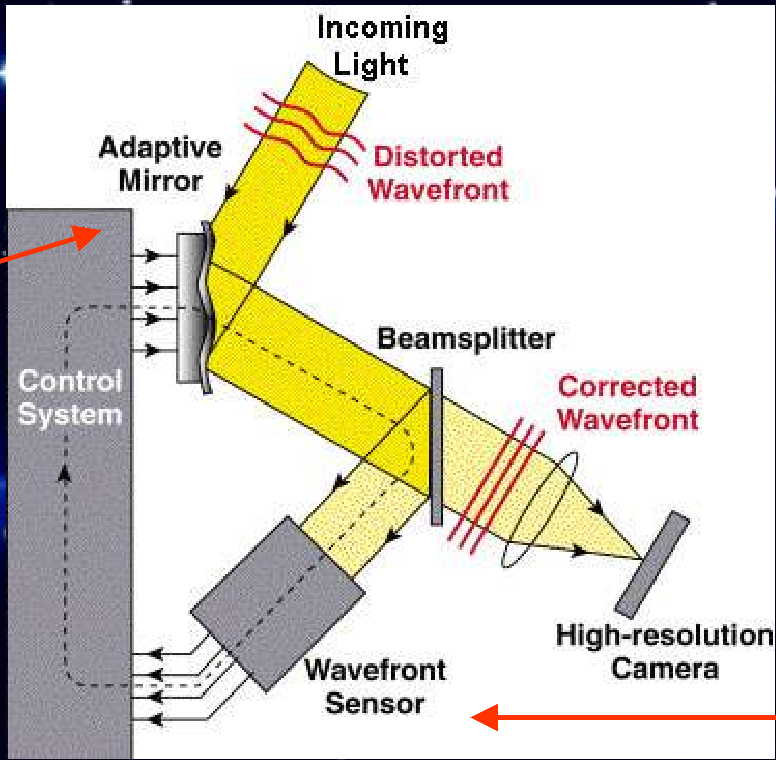
•II PART: Phd fellowship
MPE/ESO
Topic: Spectroscopic search for extrasolar planets
Supervisor: R. Saglia; L. Pasquini; F.Grupp

prepared by
Anna Brucalassi

ADAPTIVE OPTICS (AO)

Adaptive Optics (AO) is a technology for the real-time correction of the effects of light wavefront distortions induced by atmospheric turbulence (*seeing*) on astronomical images. The fundamental elements of this system are:

The wavefront corrector
A deformable mirror that corrects the phase fluctuation introducing different optical paths for different rays

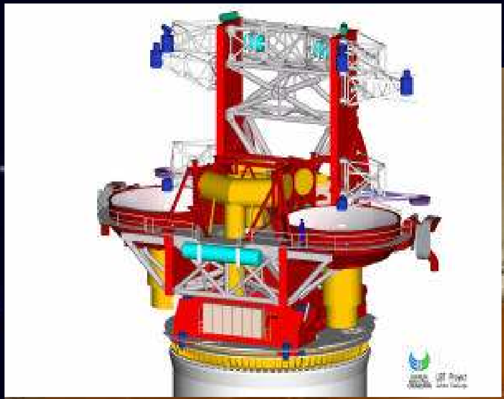


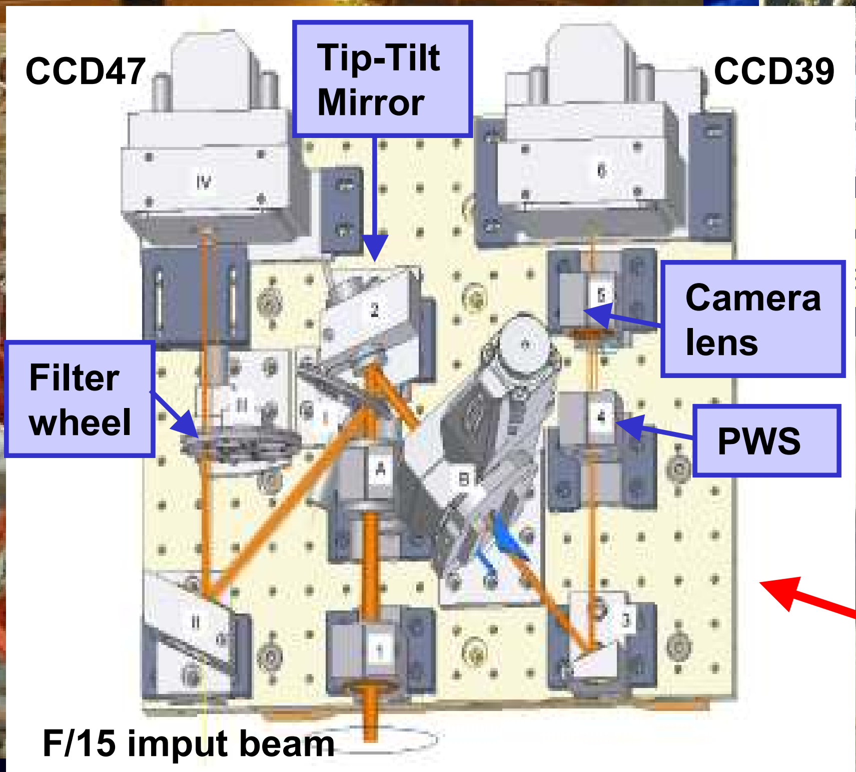
The wavefront sensor
A system that measures the instantaneous wavefront aberrations

The control system
A remote computer which computes the commands to be applied to the wavefront corrector from the wavefront sensor data.

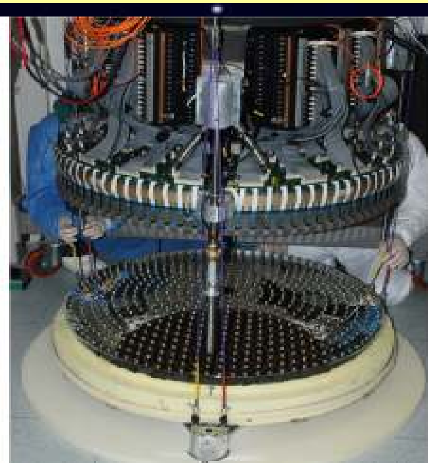
The Bent Gregorian Focus at LBT

The collocation of the AO system at the LBT telescope:





The Secondary Mirror is collocated on a interchangeable swing arm.

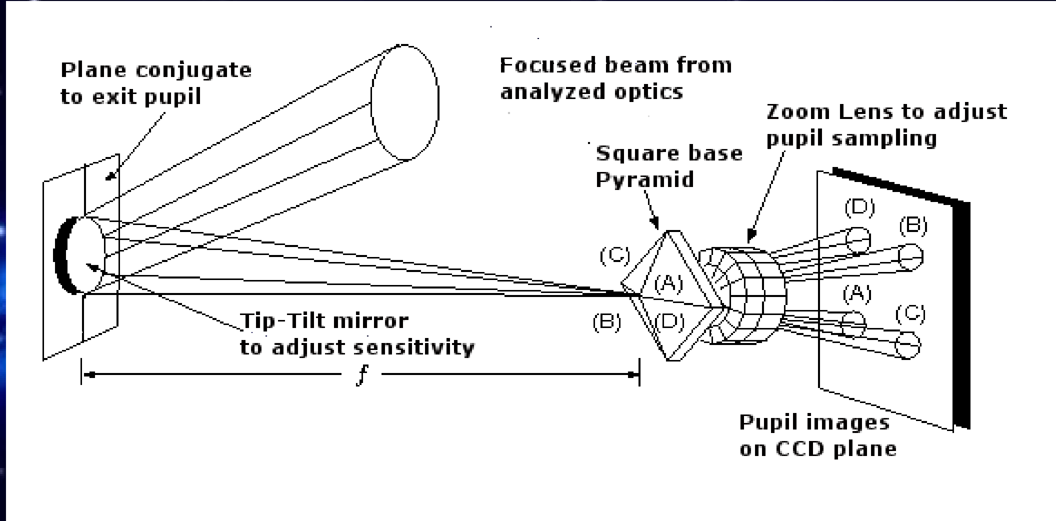


GW unit is bolted to the telescope
ator of the front bent Gregorian foci

The Pyramid Wavefront Sensor (PS)

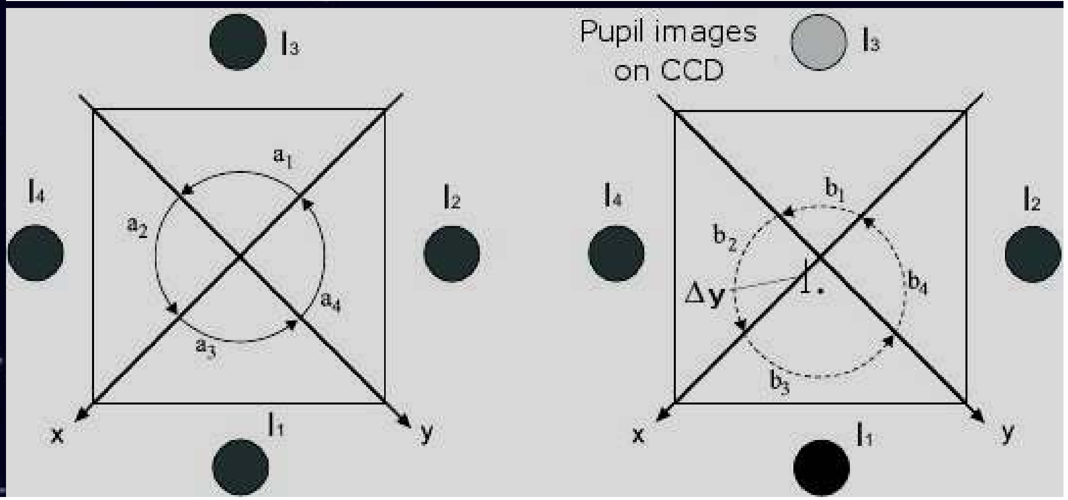
AIM: find the possibility to increased PS sensitivity as the wavefront correction progresses with an automatic algorithm to reach the linear range of the pyramid response as soon as possible.
This is a useful characteristic of PS when it used in closed-loop operation.

- The basic configuration of PWS :



Using the tip-tilt mirror, a periodic modulation is applied to the beam in order to distribute the light among the four surfaces of the pyramid.

When aberrations are present in the wavefront, the centre of the modulation circle is not on the pyramid vertex and the intensity distribution of each pupil image on the CCD is different.



The PS Sensitivity

Geometrical optics calculations show that the local WS slopes ($\partial W(x,y)/\partial x$, $\partial W(x,y)/\partial y$) are connected to the sensor signals (Sx, Sy) by the next relations:

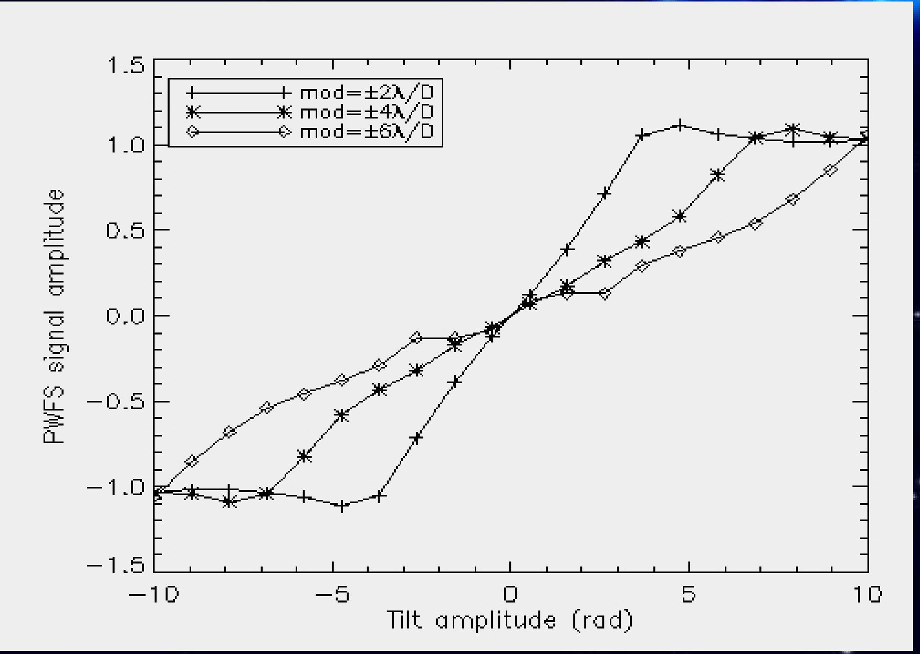
$$\partial W(x,y)/\partial x = R/f\,[\pi/2\ Sx]$$
$$\partial W(x,y)/\partial y = R/f\,[\pi/2\ Sy]$$

$$Sx = [(I_1+I_4)-(I_2+I_3)]/\sum I_i$$
$$Sy = [(I_1+I_2)-(I_3+I_4)]/\sum I_i$$

R=The linear Tip-Tilt modulation amplitude in the focal plane

I_i=Intensity patterns in the imaged pupils

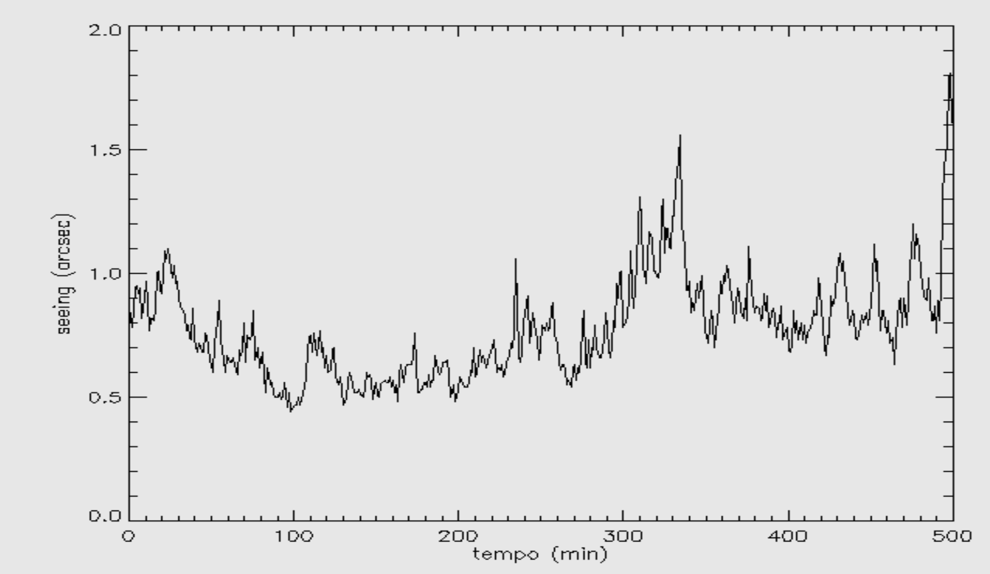
A graph of sensor response over a tilt amplitudeis :



A bigger modulation amplitude corresponds to a bigger linear interval but to a smaller correction.

With my alghoritm:
When partial correction is achieved (i.e. the aberrations are decreased) the modulation amplitude can also be decreased automatically , so that a small aberration will create a significative signal.

The seeing evolution

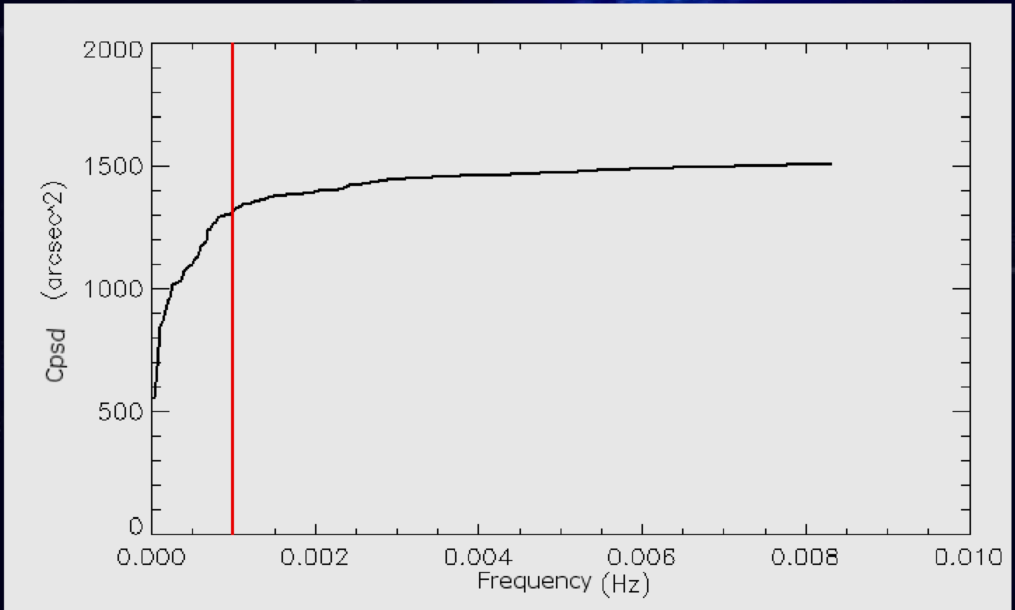


the turbulence seeing is not-stationary during an observation:

With a frequency analysis we could see that 90% of the seeing power spectral density is at low frequencies (under 0.001Hz).

The seeing changes with a time scale of a few minutes, while the observation time is usually longer.

The Cumulated PSD:



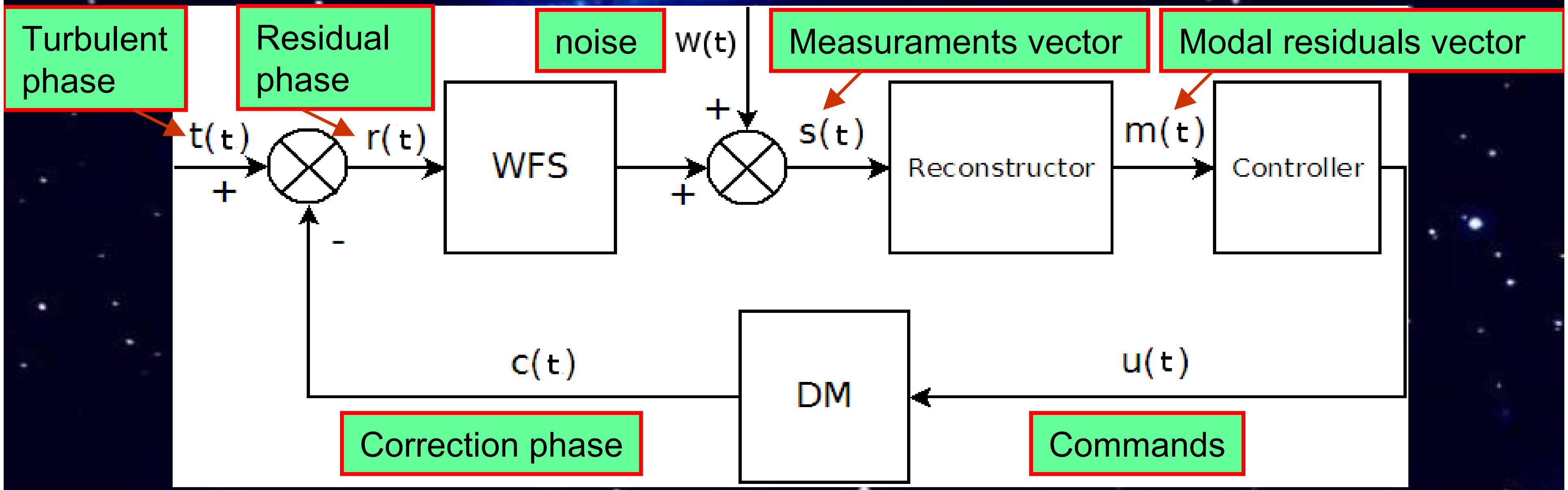
The system has to correct the instantaneous state of atmospheric turbulence and also its internal configuration has to be adaptive to the particular atmospheric conditions to obtain a better performance!

LBT AO Closed-Loop Control System

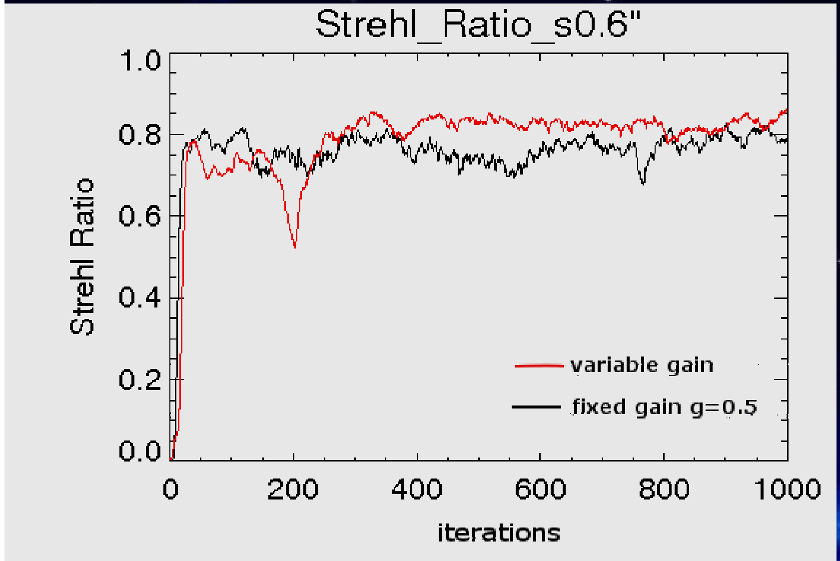
▪The performace of an Adaptive Optics (AO) system greatly relies on the synthesis of the controller parameters.
One of the most common control strategies is the modal integrator where each mode has a simple integrator controller with an adjustable gain.

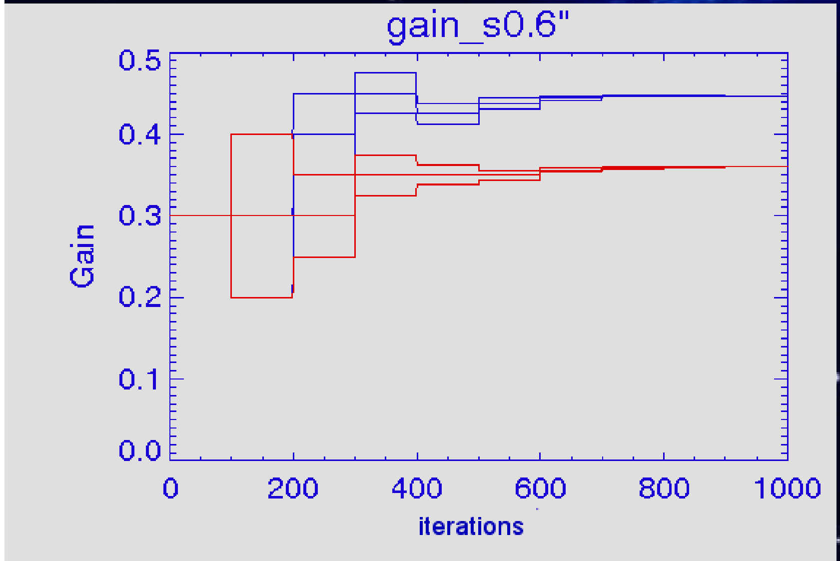
▪**To improve the performance of the LBT-AO system, I have found an automatic method to optimize in real-time the modal integrator gains.**
This technique can follow, in real-time, the evolution of the atmospheric turbulence during an observation and reach the optimal configuration of the system

The block diagram of the LBT closed-loop AO control system



Simulation results





In this section some numerical simulation results are shown. The performance is evaluated:

- in terms of Strehl Ratio (SR) at 1.65 μm
- for star magnitude M=10 and M=11
- In different seeing conditions (0.6”, 0.8”, 1.0”)

For ex. the data at Seeing 0.6” are presented :

Gain	Freq(Hz)	SRgfix	SRgvar
0.5	800	0.72±0.03	0.78±0.07
0.5	1000	0.71±0.03	0.76±0.07
0.5	600	0.70±0.04	0.73±0.09

➢**the optimal configuration of the system with a better performance than the one with the optimized fixed gain.**

➢ **The optimal configuration in less than a second with a generic initial condition and can be update when the atmospheric conditions change.**

➢**Each mode has an independent optimal gain**

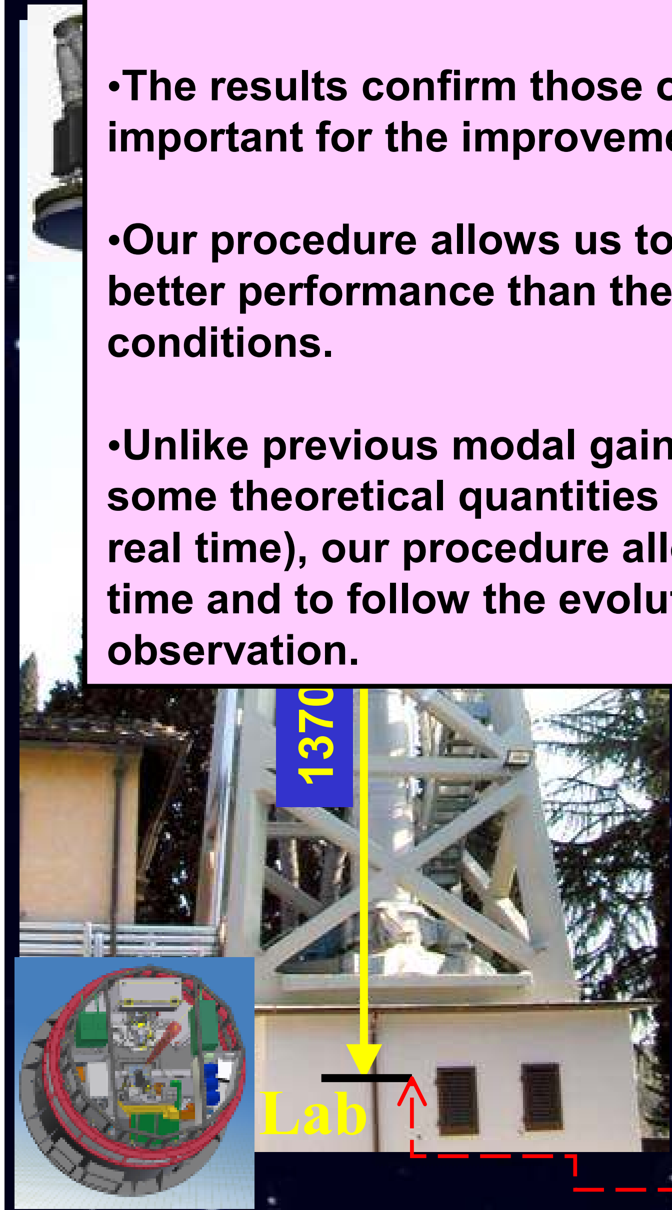
The Solar Tower

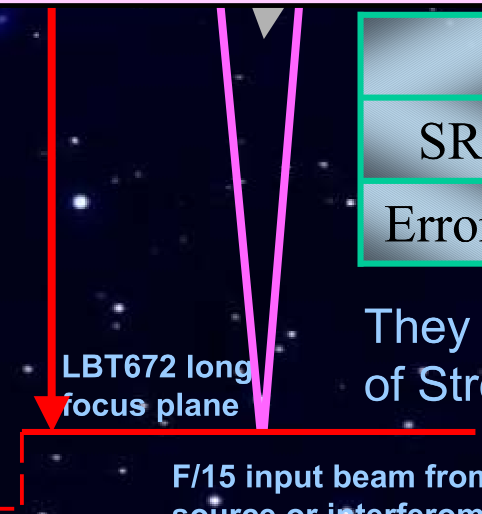
RESULTS:

•The results confirm those obtained in the numerical simulations and are very important for the improvement of the performance of the LBT AO system.

•Our procedure allows us to reach the optimal configuration of the system with a better performance than the one with the optimized fixed gain, regardless the initial conditions.

•Unlike previous modal gain optimization methods which need *a priori*-knowledge of some theoretical quantities and a great computational power (i.e. they can't work in real time), our procedure allows us to obtain an optimization of the system in real time and to follow the evolution of the atmospheric turbulence during an observation.





	g=0.4	g=0.6	g=0.8	galgor
SR	0.48	0.62	0.59	0.73
Errors	0.04	0.05	0.04	0.05

They are reported in terms of Strehl Ratio(SR).

FOCES

The FOCES is an échelle high-resolution spectrograph. It was at the 2.2m telescope of the Calar Alto Observatory and now it is under test at the Observatory of the Ludwig-Maximilians-University, Munich

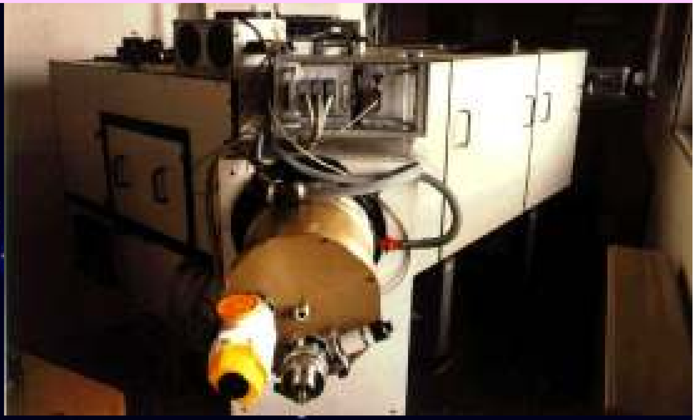
To improve the performance of the system my future work will include:

- Optical tests for stabilization
- Vacuum or pressure controls
- Temperature tests
- Measures on the fibre system scrambling
- .New arrangements for fix-movable parts

Calar Alto 2.2m	**Wendelstein** 2m
R= 46000/64000	R=70000
on 24/15 μm CCD	on 13.5 μm CCD
Moving parts (slit, grating,prisms)	No moving parts
Un-stabilized	P,T stabilized
S/N 100 for 10th mag G-star: 1h	S/N 100 for 10th mag G-star: 1h

FOCES will be re-installed at the Wendelstein 2m telescope In the next two years (see the Frank Grupp talk)

•First measures with FOCES at the Wendelstein telescope



Exo-planets in M67 :

THE AIMS are:

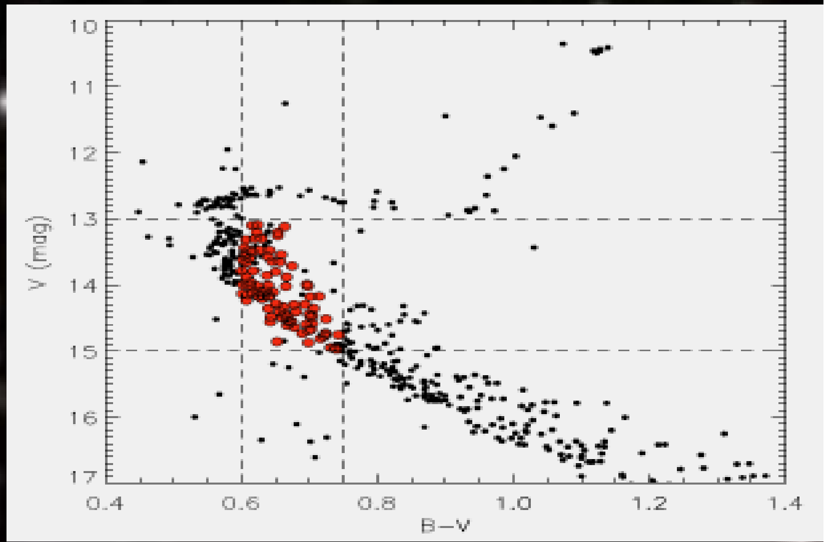
•to search for exo-planets in the old open cluster(OC) M67 in stars similar the Sun and more massive stars;

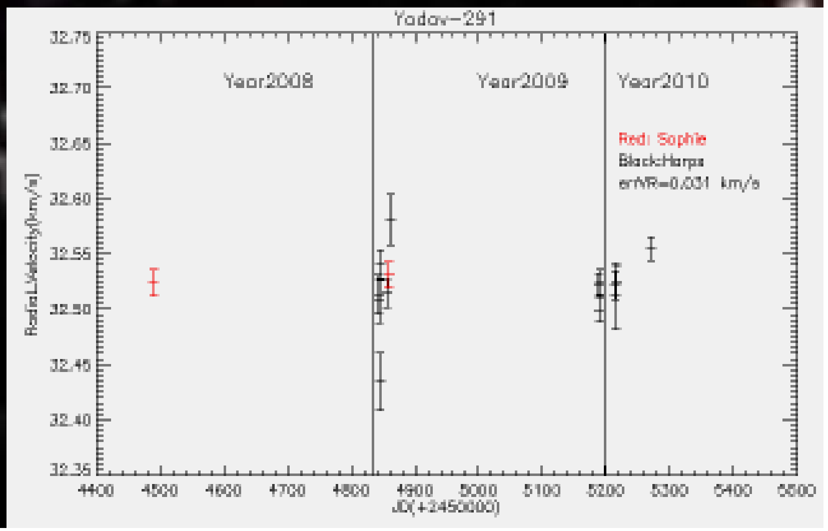
•to shed light on the role of stellar mass in the formation of planetary systems ;

•to find of the density and the orbital solutions for the planetary systems studied;

•to study the gravitational red-shift and the dynamical evolution of the cluster

Pasquini et al.(2008)





•Why M67:

M67 is a relatively rich cluster with a wide mass range which shows chemical composition, age, dynamical environment similar to the Sun and to the solar system.

•Method:

We'll analyse the spectra to get accurate radial velocities (RV) acquired by Harps@ESO (the fibre-fed high resolution echelle spectrograph at the ESO La Silla 3.6m telescope) and Sophie@OHP(the cross-dispersed échelle spectrograph permanently located in the OHP 1.93m telescope) for a sample of solar-type and turn-off/giants stars


Thanks for your attention!
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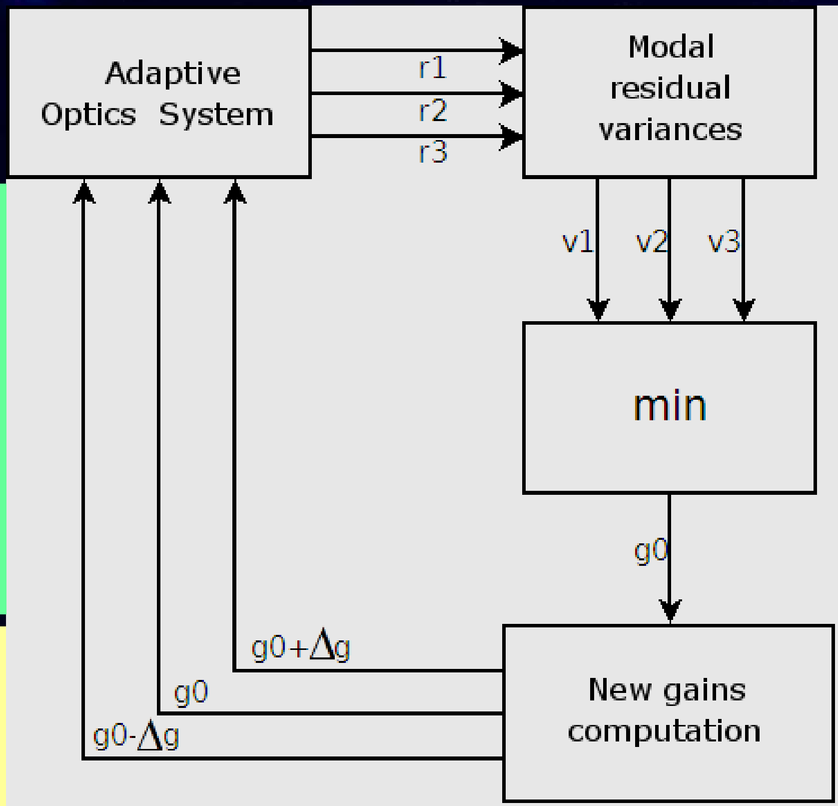
Automatic control gain

In this slide we present the software code implemented in the IDL language which was then included in the system software simulator

The algorithm selects sets of three groups of modes and assigns three different gains to these.



After a determined number of steps, it computes the variance of the modal residuals of each group

The smallest variance corresponds to the optimal gain g0 for the set of modes considered

It applies the optimal gain g0 to one group of the set

We obtain the convergency towards the optimal gain for each mode throught a more intensive sampling around the minimum of the plot σ^2, i.e. Δg is decreased every step

It determines new values of gain for the other group of the set. These are chosen as g0+/-Δg.