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Adaptive Optics: status and perspectives in the 4..100m range telescopes

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Abstract. The status of Adaptive Optics development for telescopes in the range of 4 to 100m class is reviewed, especially in an Italian perspective.

1. Introduction

Adaptive Optics (AO) is not an easy job but, in the end, it can be very rewarding. The gain is strongly dependent upon the diameter of the telescope: it can increase with a power as large as D^4 for the detection of background–limited objects. This fact makes AO a frustrating exercise or a very productive tool (the choice depending upon the psychological condition in which one places himself) for a $D = 4$m class telescope, and a unique technique with potentialities that we are only starting to explore, thanks for instance to the Naos–Conica system aboard VLT, when it is applied to a $D = 8$m class telescope. The difference should not be a surprise, if one considers that the gain can be as large as a factor of 16: more than an order of magnitude.

Growing in diameter the gain offered by AO becomes more and more important, so that several people consider it as a condition for the existence of the next generation Extremely Large Telescopes, ELTs (Ardeberg et al. 2001, Gilmozzi 2000, Nelson 2000). At the same time AO has the potential to become a show–stopper for such giants, once they cannot be realized with the due capabilities.

In the following I will briefly describe the AO–related activities in which Italy is involved, giving a very short outline of the developments under way in other countries. The resulting list is, by necessity, inaccurate and incomplete but, I believe, it provides a sample of the current situation.

2. The Italian role in the Astronomical Adaptive Optics business

As long as Adaptive Optics is intended to be a system with correction capability higher than the simpler tip–tilt correction (a realm where several experiences can be recorded in several Observatories) and other real–time or post–processing high angular resolution techniques (essentially speckle interferometry and deconvolution), we can list hereafter the projects where the Italian contribution to the technological development of Adaptive Optics is significant.

– *AdOpt@TNG: a 4m NIR system*
  This is a 97 actuators, Near InfraRed system, which is characterized by

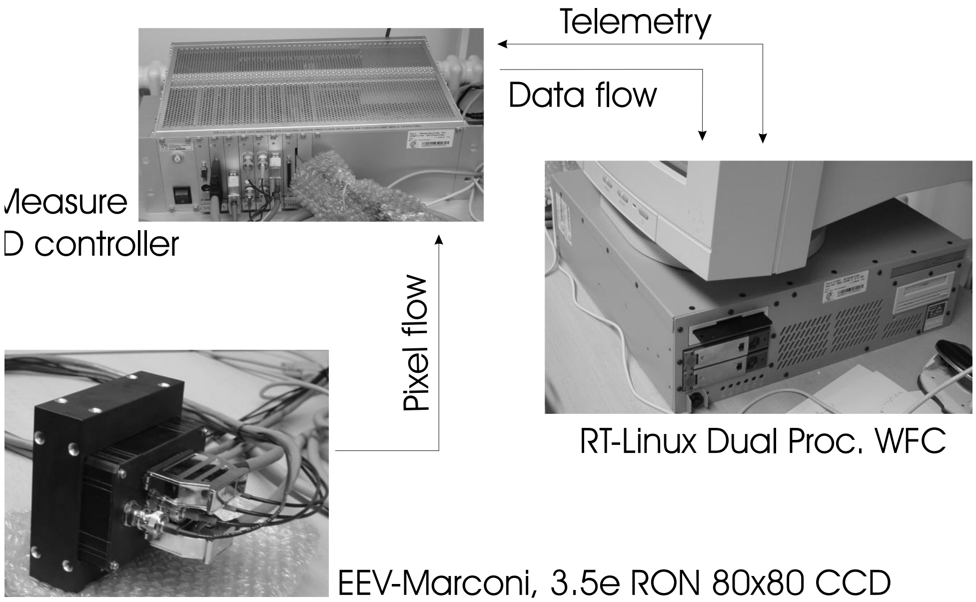

Fig. 1. The new components for the AdOpt@TNG system along with a simplified data–flow between these components. These are going to replace the almost 7 years old components aboard the Nasmith interface on one foci of the $D = 3.5$m currently largest Italian telescope, located atop LaPalma, on the Canary Islands. Although improvement in noise levels and latency time are foreseen, the real boost is expected to come from the augmented reliability and easiness of use of such components. These are scaled down prototypes for the MultiConjugated Adaptive Optics system that will equip NIRVANA, an interferometric instrument to be mounted on the 2×8.4m telescope being erected on Mount Graham, Arizona.

a pyramid WFS (Ragazzoni 1996, Ragazzoni & Farinato 1999, Esposito, Feeney & Riccardi 2000). This system is currently undergoing a vigorous refurbishment plan. The existing CCD, achieving in the lab a RON of about 7 electrons, is being replaced by a SciMeasure CCD of the same format, achieving an equivalent RON of about 3 electrons. The WaveFront Computer, a component that along the whole lifetime of the system has given so many troubles, is going to be replaced by a dual–processor PC running a Real–Time Linux operating system (see also Fig.1). Moreover a failed actuator on the Deformable Mirror (DM) has been fixed (this required shipping to the US company who built it) and re–coated, along wit almost all of the other reflective optics. Furthermore it is worth to point out that the NIR camera fed by this module has been recently refurbished as well.

– *MMT secondary mirror*
The Monolitic Mirror Telescope (former Multiple Mirror) secondary adaptive mirror is more than a single project, as it clearly represents for the whole LBT (Hill & Salinari, 2000) community on the two sides of the Atlantic a test–bench for this novel technology. It is a 2mm thick 642mm diameter mirror with 336 force–actuators realized by means of voice coils actuating on permanent magnets glued on

the back of the thin shell (Brusa & Del Vecchio 1998, Riccardi *et al.* 2001). The secondary adaptive mirror has been mounted on the telescope and closed loop observations have been successfully carried out in the Mid–IR obtaining almost diffraction limited images.

– *AGW and secondary mirror aboard LBT*
The complete first–light AO–loop for LBT is, as expected, mostly an Italian business (Esposito *et al.*, 2002). The WFS is a pyramid one equipped with a low–noise SciMeasure camera, with provisions for a L^3CCD one, with a pupil–plane modulator to achieve linearity on a wide range of conditions. The secondary adaptive mirror is an evolved version of the successful MMT one. A downscaled version, using exactly the components that will be adopted in the final design, is now undergoing performance tests in the lab. The system commissioning in Arizona is now foreseen around the end of 2004.

– *A WFS for MAD on VLT*
ESO is pursuing the project of a MultiConjugated Adaptive Optics (MCAO) Demonstrator to be mounted for experimental purposes on one focus of VLT. In this context Italy has designed and is currently building a complete layer–oriented WFS, that will be delivered soon. The layer–oriented approach, it may be interesting to recall it here, is a technology that reconstructs optically the shape to be applied to a DM conjugated to a certain layer altitude (Ragazzoni 1999, Ragazzoni, Farinato & Marchetti 2000, Diolaiti, Ragazzoni & Tordi 2001). It is also a real closed–loop system, different from other possible kinds of MCAO modules, characterized by some non–closed–loop behaviour which may introduce non–linearity problems on the WFS, an issue not discussed here.

– *PIGS: an experiment at WHT*
This is a sort of *quick and dirty* experiment to be carried out in collaboration with the WHT in Canary, equipped with a Rayleigh laser beacon facility. It essentially envisages the on–sky testing of some sort of z–invariant WFS that potentially can scale up to 100m class telescopes AO.

– *NIRVANA: a 24m facility?*
NIRVANA stands for Near InfraRed and Visible Adaptive iNterferometer for Astronomy and it is equipped with a couple of Multiple FoV MCAO systems (Ragazzoni et al. 2003). These can search for natural reference stars over an anular FoV of 6 arcmin in diameter for the correction of the ground turbulence and over the central 2 arcmin FoV (also the maximum achievable FoV in the scientific train) for the correction of the second and possibly a third layer, prior to feed a NIR interferometric camera (Carbillet et al. 2002, Herbst et al. 2003). It is interesting to point out that, although in the current design it essentially includes two complete but distinct MCAO systems for each arm, prior to their recombination in the interferometric camera, in an early phase of the project an almost complete optomechanical design was carried out for the wavefront sensing in the recombined path. The latter option, in fact, is a study of a WFS for a 24m–class telescope. We have seen that this is doable with the current technology, although requiring off–the–shelf components on the edge of their target performances (see also Fig.2).

– *Participation to Planet Finder*
In response to a Call for Second Generation Instrumentation by ESO, two consortia led by France and Germany respectively replied proposing different approaches for a high–order AO system, followed by some sort of coronographs, polarimeters, integral field spectrographs, with the aim to identify, study and characterize extrasolar planets. Italy is participating to the second consortium with a leading role in the diffraction–limited integral field

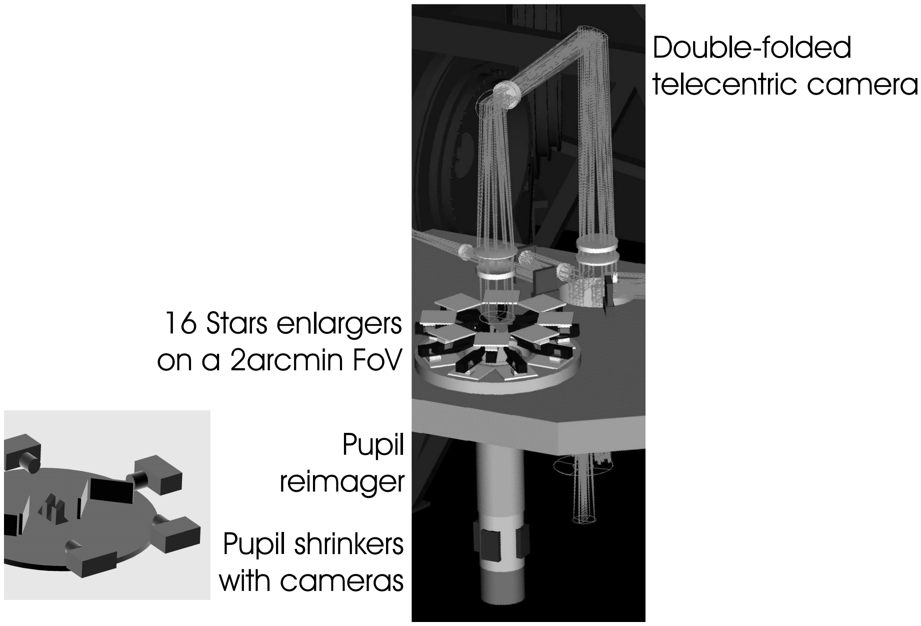

Fig. 2. A 24m–class wavefront sensor for MultiConjugated Adaptive Optics able to exploit a full 2 arcmin FoV. The two exit pupil of the LBT telescope are recombined in the lower right part of the central picture. From this point the beam is treated as if it were a single 24m diameter beam. The camera is folded twice and the light reaches the stars enlargers before going to the pupil imager. In the latter the original pupils of the telescope are then disassembled by means of the system of lenses and prisms shown in the lower left picture.

spectroscopy. The adopted WFS for this kind of project should be a pyramidic one.

– *FP6/100m studies*
  In the European Union FP6 framework a specific study for the development of Extremely Large Telescopes is going to be led by ESO, also in the framework of the OWL project. Italy contributes significantly in the AO area. In particular an experiment for the simultaneous WFSensing from more than one VLT unit should allow the measurement of turbulent layers at a range of several Kms over a contiguous, although irregular, area with a size comparable to the one typical of an ELT. In this way, for instance, several of the discussions under way regarding the effect of outer scale and/or the predictability of the wavefront will be investigated in an unambiguous way.

3. Conclusions

The development of Adaptive Optics is involving a wide range of telescope apertures: 4m–class telescopes await a reliable system to exploit the potential niches of science, like the search of brown dwarfs, and act as a test–bench for novel technologies, like wavefront–computers, or novel concepts, like Rayleigh laser beacons. On 8m–class telescopes, on the other hand, forefront science is today achievable on telescopes accessible from the Italian astronomical community, like Naos–Conica aboard VLT, and they are nevertheless subject of forefront technological studies like the implementation of wide field correction AO (namely MCAO). On larger apertures Italy and LBT are exploiting one of the most ambitious interferometric instruments, while our country is running together with other European partners and in competition/collaboration with our colleagues on the other side of the Atlantic. The effectiveness of these efforts is to be measured on the long term range with astrophysical achievements, this is sure, but both the technological and the astrophysical communities should be aware of the unique possibilities that can have at their hands.

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