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Toward the Interferometric First Light of LBT: LINC-NIRVANA

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Abstract.
Multi Conjugate Adaptive Optics (MCAO) allows one to obtain images close to the diffraction limit of a telescope on relatively large fields, at least when compared with the few arc–seconds of single star Adaptive Optics. This feature is fundamental to push to the limit the performance of the new generation of astronomical instruments, and this is why several 8–m class telescopes are designing and building MCAO systems. We are finishing the integration of one of the two MCAO wavefront sensor of MAD, a demonstrator that will be installed toward the end of the year at the Very Large Telescope (VLT). At the same time we are designing an instrument for the Large Binocular Telescope (LBT) based on the Layer–Oriented MCAO Technique, namely LINC-NIRVANA. Our contribution to this project, the first light of which is foreseen at the end of 2006, concerns the construction of four wavefront sensors for the double MCAO system (one for each telescope), with the aim of removing the atmospheric disturbance from the two beams which are going to be used in a Fizeau interferometric way. The status of these projects will be presented.

Key words. Multi Conjugate Adaptive Optics – Layer Oriented – Fizeau Interferometry

1. Introduction

NIRVANA stands for Near InfraRed and Visibile Adaptive iNterferometer for Astronomy. It is an instrument built by a consortium of Italian and German institutes. LINC is the infrared cryogenic camera where the beams coming from the 2 telescopes interfere, and it is made in Germany. The MCAO system is instead the part built by the italian partner, and it is a system based on the Layer–Oriented (LO) technique (Ragazzoni 1999; Ragazzoni et al. 2000), where two wavefront sensors per arm will sense the turbulence and consequently drive two deformable mirrors per arm. The MCAO system is designed in a way to be upgradable to three deformable mirrors per arm, by simply changing one flat mirror with a commercial deformable one and by adding in the wavefront sensor an additional group of optics with a CCD. In Fig. 1, an overall view of the LINC- NIRVANA system can be found.

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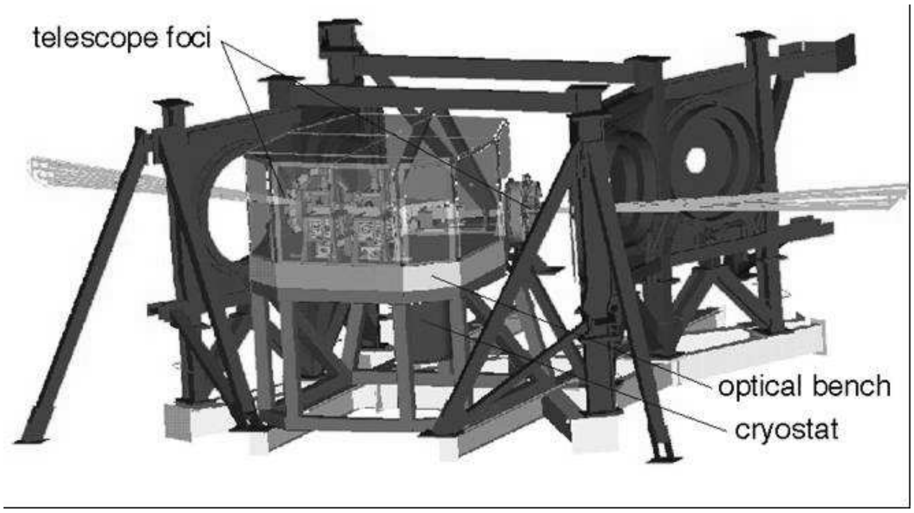

Fig. 1. An overall view of the LINC-NIRVANA system; the light collected from the folded gregorian foci of the two telescopes passes through the MCAO system, and it is then interferometrically collected at the LINC camera.

2. Instrument description

Nirvana (Herbst et al. 2001) is an instrument that, mounted on the Large binocular Telescope (LBT, Hill & Salinari 2000), will provide imaging and, potentially, spectroscopic capabilities, with a resolution equivalent to the longest baseline of the LBT telescope, that is about 24 m. The two mirrors of LBT are mounted on the same mechanical structure and NIRVANA will be rigid with respect to these. The main task of this instrument is to clear out the collected starlight from the aberrations introduced by the atmospheric turbulence and to combine interferometrically the two beams, making these form an interference fringe pattern inside a cryogenic camera.

The instrument is designed to take advantage of a unique features of LBT. In fact it will use the two secondary Adaptive Mirrors (Riccardi et al. 2003), that will introduce the compensation for the ground layer turbulence. A further correction for the high altitude turbulence will be introduced by two piezo-stack deformable mirrors (each with 672 actuators) mounted aboard the instrument.

Each of the two NIRVANA arms, in fact, will employ a so-called Multi- Conjugated Adaptive Optics system (MCAO) allowing for atmospheric turbulence compensation over a Field of View as large as nearly 2 arcmin in diameter. The two beams are then cophased by means of a fast recombination mirror, that takes into account the difference in pathlength (introduced by the atmosphere) that the starlight encounters in its journey to the telescope's mirrors. This provides a characteristic fringe pattern, equal for all the stars in the Field of View. This optical configuration, called Fizeau interferometer, is also unique in the realm of large (8m-class) telescopes, since usually other interferometers exhibit a Field of View that barely exceeds few arcseconds. In order to produce the above described compensation a combination of two wavefront sensing units, one for each arm, is foreseen (see Fig. 2). The Ground Layer Wavefront Sensor (GLWS), which is shown in Fig. 3, will drive the secondary adaptive mirror, that is conjugated to the telescope entrance pupil. The basic choice is to avoid the use of laser guide stars, both for budget and for technologycal reasons. The compensation will be made using a maximum number of references of 12 natural guide stars to be found in an annular Field of View of outer diameter of 6 arcmin, and inner diameter of 2 arcmin. Compensation of the

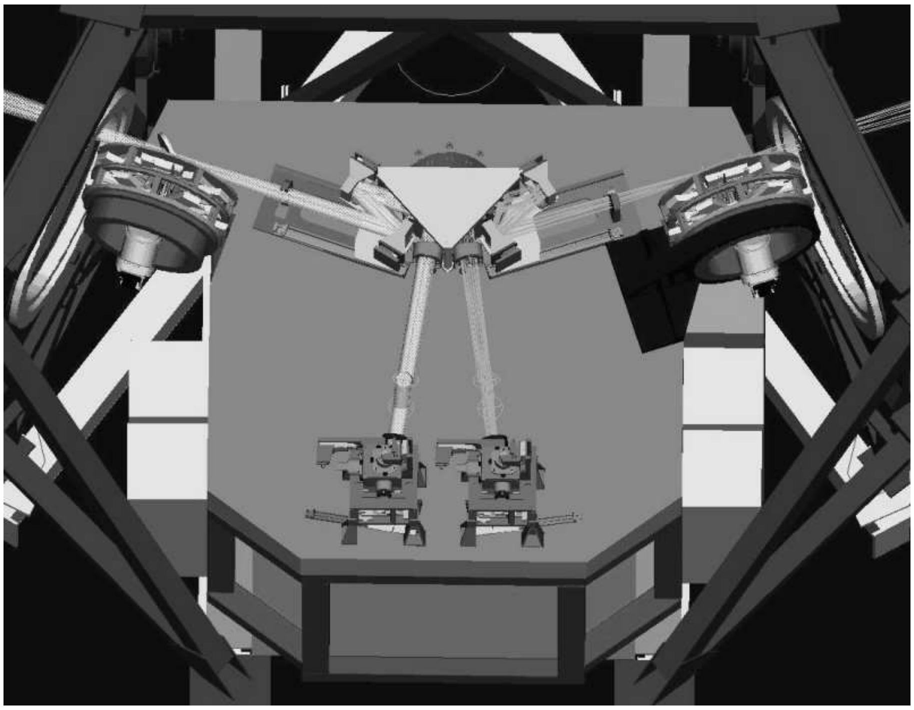

Fig. 2. The LINC-NIRVANA optical bench; clearly visible are the two mid- high altitude wavefront sensors (the two towers at the bottom) and the two ground layer wavefront sensors (on the top part of the drawing, left and right side) which are connected to two big bearings that operate the field de-rotation.

high altitude layers will be provided by two dedicated wavefront sensing units – the Mid High Wavefront Sensors (MHWS) – which are shown in Fig. 4. These units will use the central 2 arcminutes of the Field of View, where up to 8 reference stars can be used. Thus, the two wavefront sensors will use different field of views to look for suitable references, implementing a variation of the Layer Oriented Technique, which is called Multiple Field of View Layer–Oriented technique (Ragazzoni et al. 2002). These units are operated in a remote way, to keep the telescope environment unperturbed by all these complex operations. The co-phasing sensor will be located inside the cryogenic camera. In this way, differential flexures and/or thermal expansion, which are hard to trace down, will be easily controllable. The possibility is foreseen of implementing more than one way (for instance through a fiber-fed set of Integral Field Units), for an easy upgrade of the instrument with spectroscopic capabilities. Currently the instrument successfully passed the Preliminary Design Review Phase (early 2003) and is undergoing its Final Design Review phase in spring 2004.

3. Conclusions

As the instrument is a collaboration between Italy and Germany, the Italian responsibility is mostly focussed on the areas where its expertise is internationally recognized. In fact most of the Italian contribution is mainly concerned with the MCAO system and the opto-mechanics of the wavefront sensing parts. In particular the four units of Wavefront sensing (two per arms) are taking advantage of the conceptually similar system developed in collaboration with the European Southern Observatory for the Very Large Telescope.

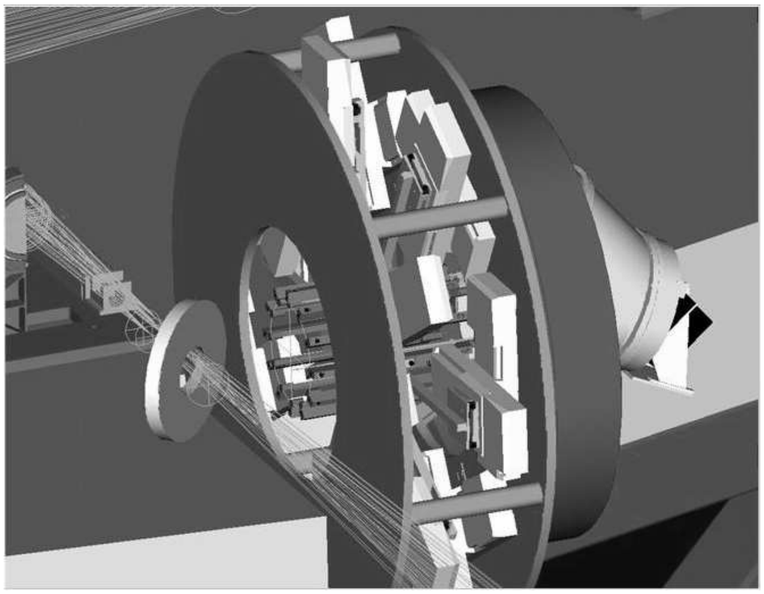

Fig. 3. The wavefront sensor conjugated to the ground layer (GLWS). The conjugation altitude is thus on the entrance pupil of the telescope. This WFS is driving the adaptive secondary mirror with 672 actuators.

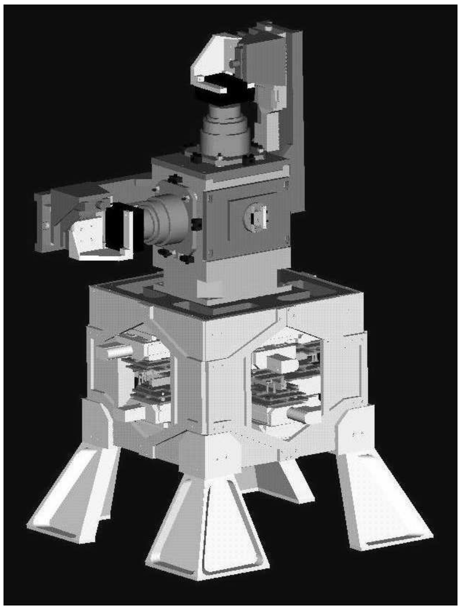

Fig. 4. The wavefront sensor conjugated to the high altitude layer (MHWS). The conjugation altitude can vary from ≈ 5 km to ≈ 15 km in order to maximise the correction and minimise the contribution of the layers above the ground one. This WFS is driving a commercial deformable mirror with 349 actuators.

This system is called MAD (Multi conjugate Adaptive optics Demonstrator, Marchetti et al. 2003) and has the purpose of demonstrating in the sky different techniques of wavefront sensing. We are finishing the integration in the Arcetri laboratory of one of the two wavefront sensors based on the Layer Oriented technique (Vernet Viard et al. 2002). In NIRVANA we have implemented a number of improvements based on the experience done while building this demonstrator for ESO, and furthermore we decided to design a system implementing an evolution of the Layer Oriented technique which is called Multiple Field of View, as already mentioned. In fact, the Italian contribution is pushing forward the technological development in this field, as, like in NIRVANA for example, the Field of View in which natural stars for atmospheric correction can be searched is enlarged in area by almost one order of magnitude. In addition the pupil sampling and the interferometric capabilities are explicitly considered in the design of these challenging sensing units.

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