The Adaptive Optics System for the Telescopio Nazionale Galileo

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Abstract

The Adaptive Optics System for the TNG is shown in its main guidelines. The development plan foresee three steps, namely tip–tilt, low–order and high–order correction. A number of additional features being implemented are discussed.

1 Introduction

The Telescopio Nazionale Galileo (TNG) is becoming a reality: the first light is foreseen by mid 1996, and one of the most important feature of such a telescope will be the permanent occupation of the two Nasmith focii with dedicated instruments. In the Nasmith focus dedicated essentially to the imaging in visible and near IR bands (with a moderate low resolution spectroscopic capability in the IR arm) an Adaptive Optics module is to be implemented (Bonaccini 1994, DiSerego *et al.*, 1995). This paper describes the plan for such a module that can be easily inserted in the optical beam, in order to zoom in the field at high resolution, providing diffraction limit image quality to feed the imaging cameras.

2 The Adaptive System

Three steps are essentially foreseen for the *Adaptive Optics at TNG* (AdOpt@TNG) module:

1. A tip–tilt correction system, APDs driven;
2. An 4×4 to 8×8 variable, full aperture system, with possibly a low brightness Rayleigh star;
3. An higher order (up to 16×16) system, equipped with a mesospheric Sodium laser star.

For the first step a voice–coil actuated tip–tilt mirror is to be implemented. In the second step a piezo–driven Deformable Mirror will be adopted. For the last step is to be decided the final choice for the correcting device: a trade–off between a scaling–up of the piezo driven mirror, a liquid crystal device or a secondary or tertiary deformable mirror will take place in the next year; care is to be given to the fact that some of the involved technologies are still in their infancy and it is difficult to foresee the optimum choice even with a time scale of the order of a few years. Fundamental limitations, like the requirement of a nearby Natural Guide Star for the tilt determination in the LGS case are under study in order to overcome in some way this class

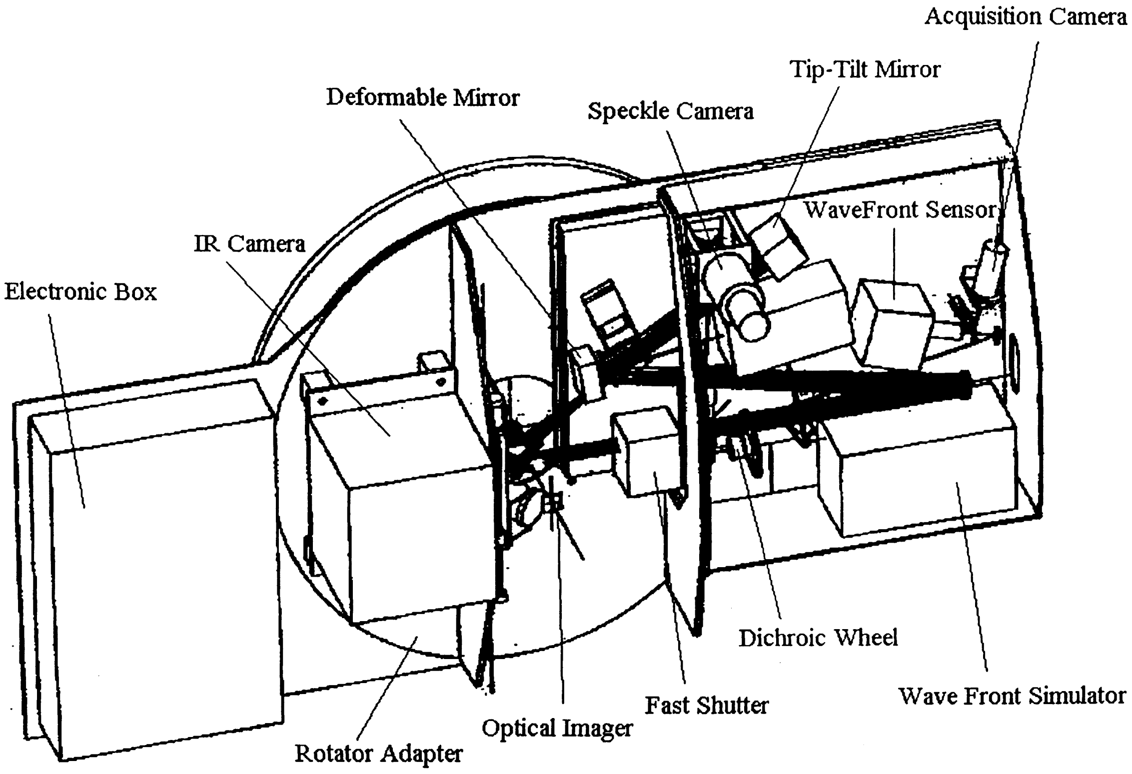

Figure 1: A three–dimensional CAD view of the AdOpt@TNG module. The Optical Imager is partially removed in order to show some internal details.

of problems (Ragazzoni & Marchetti, 1995; Ragazzoni, Esposito & Marchetti 1995; Ragazzoni 1995a).

Regarding the wavefront sensor a number of concepts and ideas has been developed and are entering int the realization phase:

- Avalanche PhotoDiodes (APDs) with dedicated quenching circuits have been developed and tested;
- Novel optical solutions for the image dissection in the tip–tilt sensor has been investigated and an optimal solution has been selected;
- A method to change the sampling over the pupil using different SH lenslet array has been outlined and a preliminary optical design has been worked out;
- A novel approach of wavefront sensing, giving variability on the gain and the sampling has been worked out (Ragazzoni 1995b).

The optical layout provides for a diffraction limited optical relay with a scale magnification larger than three, over a field of view up to one arcminut square. In Fig.1 the overall Adaptive Optics module is shown together with its main components.

3 LGS performances simulation

The currently top-end proposed AdOpt@TNG system is a 16×16 sampled/corrected subapertures. Its performance has been simulated, in a way that takes into account photon noise, readout noise of the sensors, time lag of the servo-loop, field and focus anisoplanatism effects. The simulated adaptive system has two separate servo-loops, one for the image motion correction (tip-tilt), and one for the image blur, with the remainder of the aberrations (high order).

The number of possible AO operating conditions is too large to be simulated. Therefore a thorough numerical analysis only for selected cases has been performed,

The simulated system has a CW sodium laser guide star (LGS), which produces an artificial reference star of $V = 10$. This requires CW laser powers between 5 and 10 W. The laser is propagated upward through a turbulent atmosphere, which has been simulated for La Palma on the basis of measured data and rescaled for the average seeing conditions of 0.7 arcsec. The used data have been obtained in summer, when the turbulence distributions seems to be more favourable for AO.

We are currently waiting for seeing characterization runs at the TNG site to further refine the model atmosphere and its turbulence temporal and spatial distributions.

The mesospheric layer sodium backscattered light produced by the LGS is propagated downward through the atmosphere to the TNG. At the TNG, the adaptive system is conjugating in real time the input wavefront phase with a deformable, continuous facesheet adaptive mirror, in order to give diffraction limit performance.

The tip-tilt and high order servo loops Modulation Transfer Function (MTF) have been calculated for the case where the tip-tilt natural guide star (NGS) and the LGS are superimposed, at the center of the field. A case of tip-tilt NGS magnitude $V = 17$ has been analyzed, in which the tip-tilt servo-loop -3dB frequency has been optimized at 23 Hz. The code can also treat the case of spatially separated tip-tilt NGS and LGS, but results are not reported here. MTFs have been evaluated within a 60" field, and the corresponding Point Spread Functions (PSF) have been obtained via FFT. PSFs have been evaluated for imaging in R, J and K bands. The details of the imaging camera (pixel size, optical capabilities, etc.) have also been implemented in the simulation.

In Figs.2 and 3 the expected performances for the R and J bands are shown. This is an indication that near diffraction limit performances would routinely obtained even at visible wavelengths.

4 Add–on

A number of additional features will be implemented in the AdOpt@TNG, possibly from the first implementation step:

- A fast shutter for image sharpening through best exposure selection;
- A speckle option with a dedicated *blue* detector: in this way the ultimate angular resolution of the telescope will be obtained: in a post–Adaptive Optics mode this add–on should be

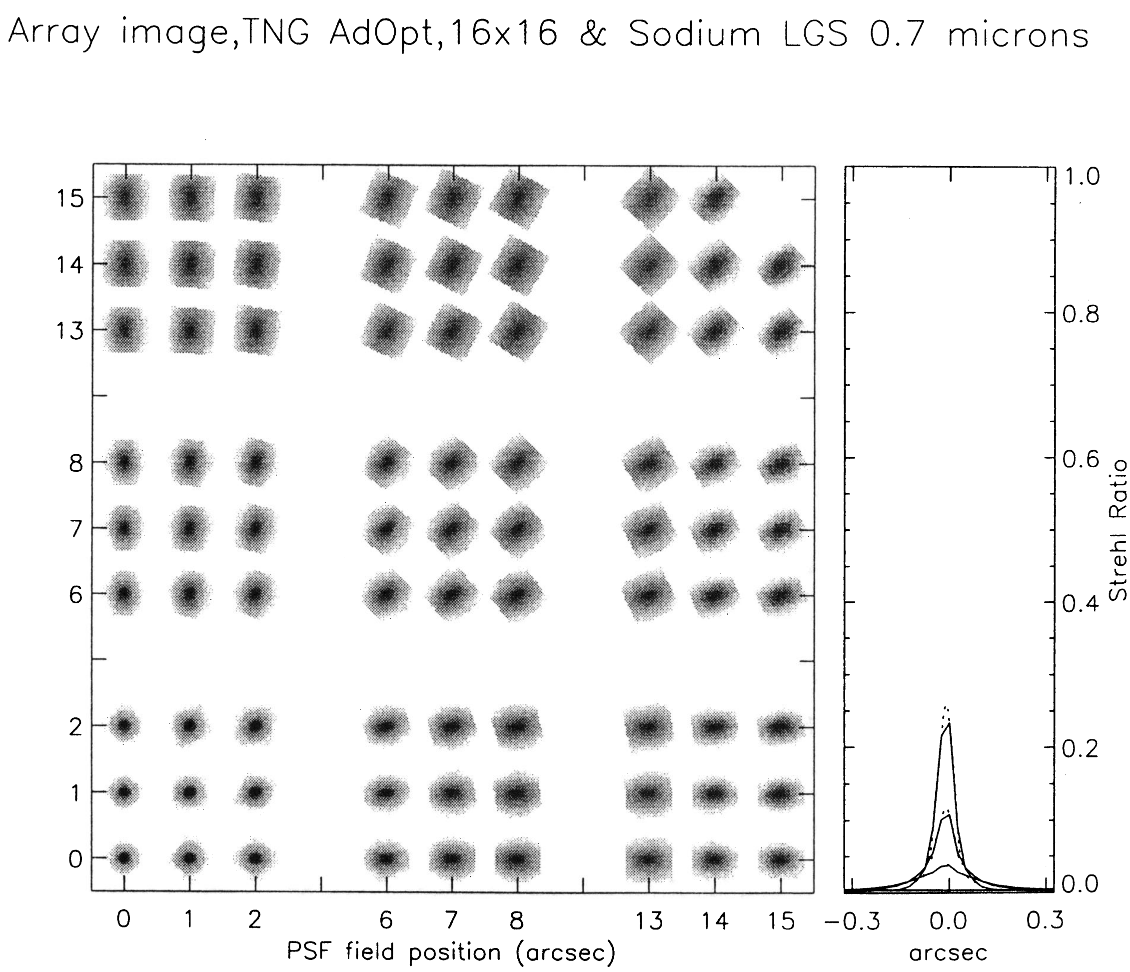

Figure 2: The expected performance of the final (third step) implementation of AdOpt@TNG, comprising a mesospheric LGS, imaging in the R band.

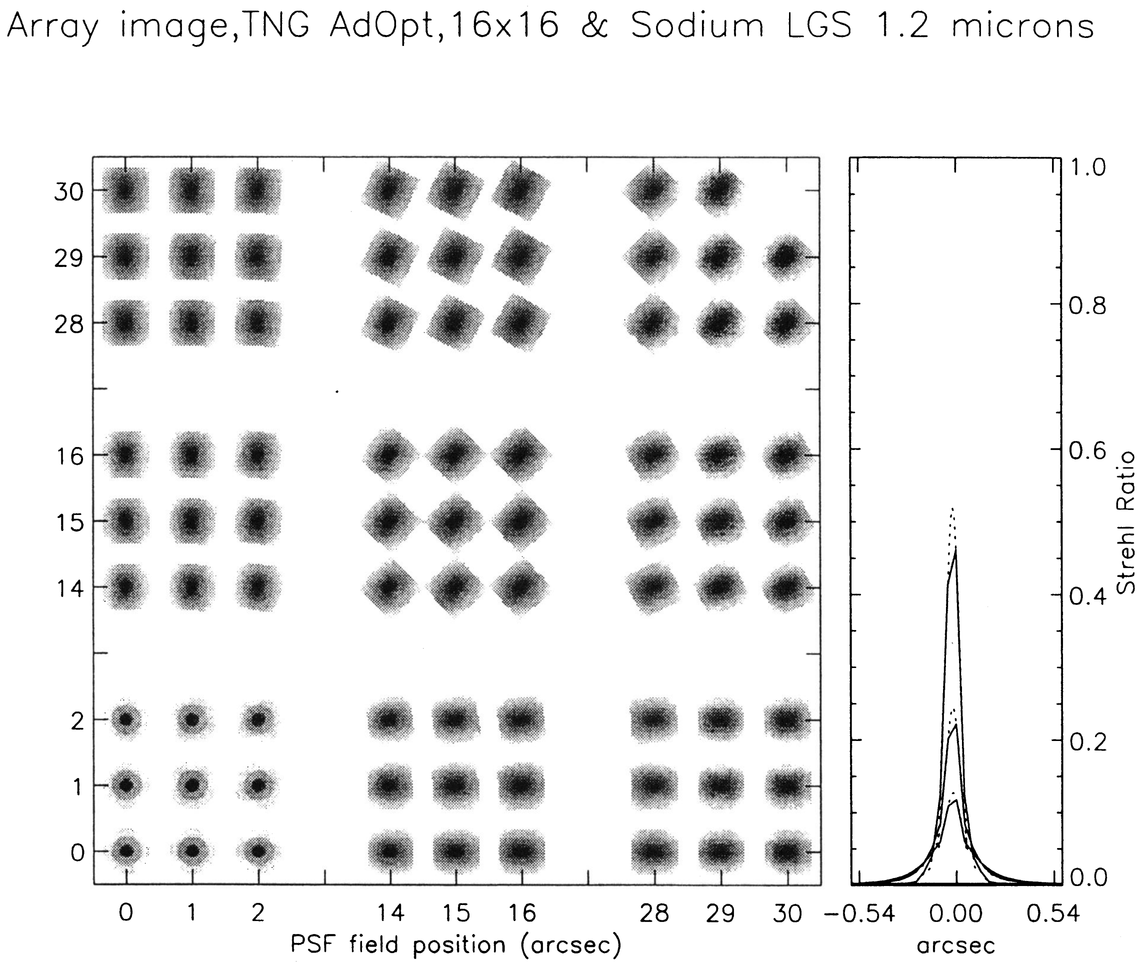

Figure 3: The expected performance of the final (third step) implementation of AdOpt@TNG, comprising a mesospheric LGS, imaging in the J band.

able to reach resolutions up to $\approx$ 20mas at least for the simplest astronomical objects (like double stars or moderate crowded clusters) up to very faint magnitudes;

- Acquisition devices able to improve the reliability of the acquisition of the star on the wavefront sensor.

Such Add–Ons will not drive the optical design of the AdOpt@TNG module; however they should represent a substantial improvement to the baseline performances. Sometimes these augmented performances are exploitable only with specially selected astronomical targets. They can be obtained at only a very limited cost (in terms of both money and work resources) and will be implemented from the early stages of operation.

5 Conclusions

The Adaptive Optics module suited to serve the Italian Astronomical Community is under its construction phase and care is given to phase this process with the TNG erection. The first and second step of this module, at least partially, will be operational in the first year of scientific operation of the telescope. We hope that this project will contribute to give to the Italian Astronomical Community an instrument for high angular resolution in the visible and IR band at the leading edge of the current developments in this field.

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