Toward AdOpt@TNG first light

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Abstract

The Adaptive Optics for the TNG telescope, at the time of the conference, will be under way to the Canary Islands where it will be mounted at one of the Nasmith Foci of the 3.5m TNG Telescope. Most of the instrument has been designed and built at the Asiago Astronomical Observatory. The module comprises an APD based Tip-Tilt Sensor and a four corner readable 80x80 CCD equipped with Shack-Hartmann and Pupil Plane Wavefront Sensor. In this paper we give a very brief summary of the science expectation from its commissioning phase that should finish in the first half of 1999.

1 Introduction

The currently largest Italian telescope, the Galileo National Telescope (TNG hereafter), based upon the ESO NTT design, had its first-light in April 1998 (Barbieri, 1997; Bortoletto *et al.*, 1998). At the two Nasmyth foci of this telescope six instruments will be permanently mounted. The Adaptive Optics module, namely AdOpt@TNG, is one of the two last instrument (along with the high resolution spectrograph) which realization (and related funding) has been decided (this happened February 2nd, 1996). At the moment of writing the instrument is approaching Canary Island aboard a container in a ship. The instrument will be mounted in a dedicated shift lasting with Tip-tilt compensation and Speckle channel implemented and tested on the sky. Astronomical return from an instrument is not only a matter of performances, depending also from strategies and culture of the astronomical community that is expected to deal with such a package. In the following the current situation is briefly outlined.

2 The AdOpt@TNG module

Full description of the AdOpt@TNG module (see also Fig.1) is beyond the limit of this paper and the interested reader is invited to consult the various references that describe the overall instrument (Ragazzoni & Bonaccini, 1995; Ragazzoni *et al.*, 1997, 1998), the optical relay (Ghedina & Ragazzoni, 1997; Ghedina, Ragazzoni & Marchetti, 1997), the wavefront sensing (Ragazzoni, 1996), the tip–tilt loop (Esposito, Fini & Ranfagni, 1995; Esposito *et al.*, 1998; Farinato *et al.*, 1997), the wavefront simulator (Marchetti & Ragazzoni, 1995; Marchetti *et al.*, 1997). Expected performances from the instrument in the first phase can be deduced from an IDL–based simulator that can be downloaded from the following URL: `http://www.tng.iac.es/html/instruments/adopts/adopt_2.html`.

3 The Italian Scientific Committe on Adaptive Optics

In January 1995 (di Serego Alighieri *et al.*, 1995), roughly one year before the funding of the module, a Scientific Committee reported the opinion and the interests of the Italian astronomical community about Adaptive Optics for the TNG. Programmes aimed to use Adaptive Optics to deal with several science problems have been drafted, ranging from Solar System objects up to High z Radio Galaxies. At that time the project foreseen a third phase of implementation with a Laser Guide Star and a 16×16 compensation module and, moreover, it was expected to have the instrument working at the telescope before or together with NICMOS aboard HST. Due to this expectation several programmes are by far too much ambitious with the current situation, however they represent a good sample of ideas to be investigated in the near future. The cited final report listed 28 programmes. It is interesting to note that these can be subdivided into classes of required angular resolution (in terms of FWHM):

- **Programs requiring FWHM better than 0.3 arcsec**
  Five out of 28 programs required only a very limited angular resolution improvement (I would say that, occasionally, normal seeing is capable of such a performance!), achievable even by just tip–tilt correction. Among the others the determination of the distance of galaxies from surface brightness fluctuations is to be mentioned here. The improved resolution, in fact, is needed to remove objects like globular cluster or field star that could affect the measurements. On the other hand this requires a somewhat good photometric accuracy of the order of 5% or better, maybe

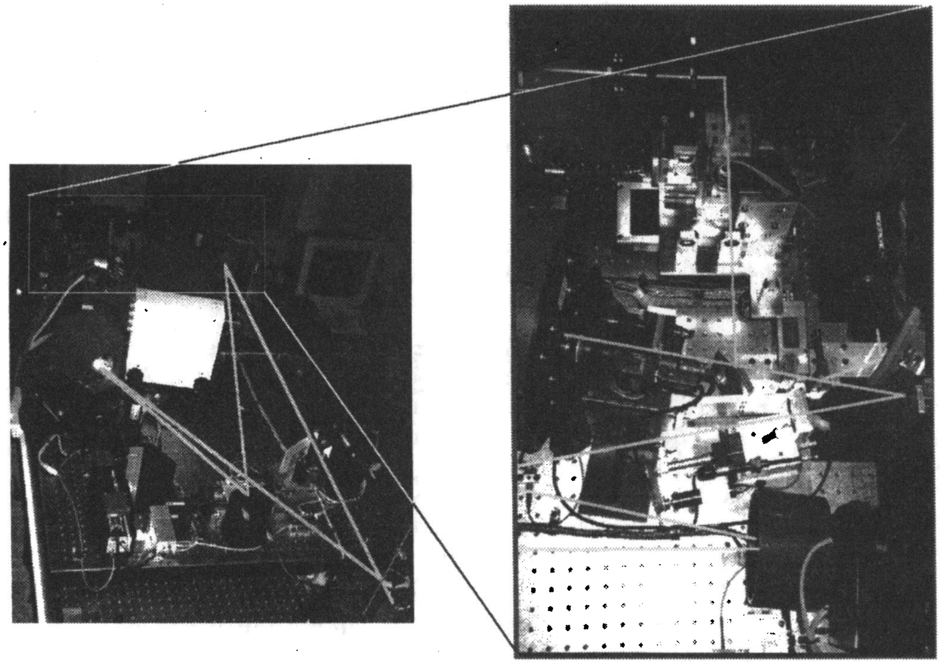

Figure 1: *Left side:* The AdOpt@TNG instrument as in the final configuration in the optical lab in Asiago. After extensive tests and alignment techniques check all of the components on the optical bench have been dismounted, packed and sent all together to the telescope site. *Right side:* An enlargement of the module is shown in a different perspective. The area under examination here is the wavefront sesning zone. Three different arms can be indivduated, namely for tip–tilt sensing, wavefront shape sensing, and for acquisition purposes. Three different detectors (four APDs, an EEV 80 × 80 CCd and an ICCD are used for the three different tasks.

difficult to achieve for various calibration problem. Morphology of AGN hosts and Radio Galaxies are to be cited also. It is curious that all these program are extragalactic ones, in spite of the low demand in term of angular resolution.

- **Programs requiring FWHM better than 0.2 arcsec**
  This is the most numerous class, with eleven out of 28 programs. These ranges from Solar System to high z objects. To be mentioned the comet morphology, the determination of the luminostiy function of the Planetary Nebulae to determine extragalactic distances and the search for gravitationally lensed objects around relatively bright quasars.

- **Programs requiring FWHM better than 0.1 arcsec**
  These programs (counting six out of 28) will be probably never be fully accomplished in their original form in the current adaptive optics implementation, with the exception of short very good seeing moments where AdOpt@TNG boost should be capable of peak perfromances. The study of the Galactic Center (already *attacked* by other 4m class adaptive optics facility) and the luminosity function of the faint end in globular clusters are among these. Others are viable only with some LGS aid and are beyond the limits of our current technical capability.

- **Programs requiring diffraction–limited capabilities**
  Six out of 28 programs required extreme performances. Four of these, moreover, required such performances at visible wavelengths. In spite of the fact that such performances are hopeless for AdOpt@TNG, it is to be mentioned that some of the required science can be recovered by the speckle channel. Routinely available autocorrelations for objects as dim as $V = 16$ are, in fact, expected from such a facility. Informations like duplicity, angular size and ellipticity can still be retrieved constraining the astrophysical diagnostic for objects ranging from nearby star clusters to quasars.

4 The Early Phase Science

More recently a Call for Proposal for the early phase of the TNG commissioning has been issued, open primarily to the Italian astronomical community and to the Spanish one. None of the programmes outlined in the preceeding section have been proposed. Six out of 41 proposals involves the Adaptive Optics module. Five have been proposed by people involved in the realization of the instrument, while the other, proposed by Spanish astronomers, involves AdOpt@TNG marginally. Athough we understand that this is a typical plot of any science community faced with new type of instrumentation, it is to be pointed out that a wide spread interest and, by conseguence, an high productivity for any adaptive optics system, is accomplished when some demonstrative programs have been succesfully accomplished. Of the seven people deeply involved in the realization of the module five are astronomers and only two engineer (but with a strong non–professional astronomy background) making this new task maybe slightly more easy than one could imagine. We outline in the following the two more challenging proposals.

- **Varying shape in reflection nebulae**
  In reflecting nebulae the variability of the illuminating star play a considerable role in the apparent shape of the nebula as seen from the ground. This has been subject of observations in seeing limited conditions (see for istance Lightfoot, 1989) and in diffraction or near–diffraction limited mode, using both HST and Adaptive Optics (see for istance Close *et al.*, 1997). Adaptive Optics is easier at near–infrared wavelengths, and it should be mentioned here that some contribution of the light from the nebula itself can be considered. However for the majoirity of reflection nebulae the reflected star–light is dominating up to $2.5\mu m$ wavelength (Sellgren *et al.*, 1996). Under the conditions of limited optical thickness of the nebula with respect to the distance the light is travelling during a period P of the variable illuminating star, the angular distance α between two consecutives *light rings* is given by:

  $$\alpha" \approx 173 \frac{P[\mathrm{days}]}{D[\mathrm{pc}]} \tag{1}$$

  We used this together with our simulation model for the AdOpt@TNG model to figure out a list of possible candidates to search for such an effect. It is to be pointed out that such light rings could exhibit a contrast significantly smaller than what can be predicted by a simple reflective–sheet model. In this case the optical depth of the nebula could play a significant role and the observer will receive light from the stars with different phases. This could constrain the optical thickness of the nebula and, under certain conditions, could place very strong constraints on a three–dimensional shape model of the nebula itself. Finally, it is to be mentioned that in the near–IR light amplitude of the illuminating stars can be very different with respect to the visible light. For istance such an amplitude will be smaller for Cepheids and larger for Miras. These are extra–constraints that are to be taken into account for the definition of the targets to be adopted.

- **Extragalactic objects imaging using asteroid as reference source**
  Ribak & Rigaut (1994) pointed out that a significant improvement in the sky coverage from NGS–based Adaptive Optics system can be obtained if one use asteroids as reference sources. AdOpt@TNG incorporates such a

suggestion. A dedicated tracking mirror is driven by two accurate piezo–controller and a dedicated electronic board can be programmed to gives to this mirror an equivalent offset between the observed scientific target and the sky region re–imaged onto the wavefront sensing zone that evolves with time in a well–specified manner. This is not a simple modification in the optical layout being necessary to have the pupil of the telescope reimaged onto such a mirror. Planning the early science phase of the AdOpt@TNG module we extensively used the Horizon's JPL astrometric codes to find out all of the interesting encounters observable under favourable conditions from Canary Island. A selection of the *easiest* cases (relatively bright target, bright asteroid, very close encounter and limited relative motion) still leads to several tens of possibilities for the six–months period taken into consideration. Most of the time such objects are poorly known and just a few cases relates with astronomical objects with a consistent literature. This poses, of course, problem of physical interpretation of the observation because, generally speaking, one is lacking of constraints at wavelengths other than the ones used for the Adaptive Optics observations. Nevertheless these objects are somewhat *unique* for the Adaptive Optics community. We have to mention here two aspects: *i:* the need for very accurate extragalactic object catalogs, sometime giving to both false results and missing result in our search, and *ii:* the need for a strategy when the object is to be observed, devoting the central time of the encounter, to the bands where isoplanicity is more important.

5 Conclusions

In our early science plan we are trying to merge the need for calibration data to tune and establish the performance of the system, with some scientific data production. Although the two things are not orthogonal a considerable efforts is to be spent in order to have an effective matchness between such two items. We hope, in the near future, to be able to express further opinion on this subject on the basys of some our succesful work atop the Roque de los Muchachos.

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