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Exploring the performance of a GMCAO-equipped ELT within the deep field surveys strategy

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ABSTRACT

As the deep field surveys strategy represents a well popular way to study the cosmology and the formation and evolution of galaxies, we investigated how the new generation of extremely large telescopes (ELTs) will perform in this field of research. Our simulations, which combine a number of technical, tomographic and astrophysical information, take advantages of the Global-MCAO approach, a well demonstrated method that can be applied in absence of laser guide stars because it exploits only natural references. A statistics of the expected performance in a sub-sample of 22 well-known surveys are presented here.

Keywords: Global-MCAO, E-ELT, Galaxies: general, Galaxies: high-redshift

1. INTRODUCTION

Sky surveys are one of the symbols of the modern astronomy because they can allow big collaborations, exploiting multiple facilities and shared knowledge. They have an important role for the entire astronomical community, covering a broad range of topics: from the study of our Galaxy and the Local group, stellar astrophysics, to galaxy evolution, cosmology and far universe. The synergies between instruments and facilities denotates the higher value: they collect data in a wide range of wavelengths, from optical to near-infrared and also radio observation and, not least, spectroscopic follow-up.

In this perspective, it is worth to point out that the new technologies can help the progress of the deep field surveys strategy, which are thought to merge cosmological theories and astrophysical observations in order to depict a common scenario that explains the formation and the evolution of galaxies. Therefore, we investigated how one of the new generation of extremely large telescopes (ELT, i.e. the European Extremely Large Telescope[1]) will perform in this field of research, as it will play a key role together with the Giant Magellan Telescope[2] and the Thirty Meter Telescope,[3] because of their angular resolution and their capability in collecting the light of faint sources.

Our simulations combine technical, tomographic and observational information, and exploit the Global-Multi Conjugate Adaptive Optics (GMCAO) approach,[4] a method that takes advantage of only Natural Guide Stars (NGSs) to correct the scientific field of view from the atmospheric turbulence. By simulating K-band observations of 6000 high redshift galaxies in the Chandra Deep Field South area, we have shown how an ELT can carry out photometric surveys successfully, recovering morphological and structural parameters.[5] Here we extend the results to more regions in the sky: the following sections describes the increased statistics of the expected performance of a GMCAO-equipped ELT.

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2. SURVEYS SIMULATIONS

GIUSTO (*GMCAO Interactive Data Language Unreleased Simulation TOol*[6]) is an IDL-based code that computes the atmosphere on the collected wavefronts and, using the GMCAO method, estimates the SR over a given field.

The same procedure was applied in our previous work,[5] where we performed the photometric analysis of 6000 early- and late-type galaxies up to redshift $z = 2.75$ successfully pointing at the *Chandra Deep Fields South*. In that case, we obtained a median SR of 0.127 over the field and from the SExtractor analysis[7] we were able to detect the 99.7% of early type galaxies and the 89.4% of late-type galaxies.

We extend this SR analysis to other 22 fields, chosen between the most famous deep field surveys, as listed in 8, where also a summary of the input parameters can be found. In Table 1 a sub-sample of the GMCAO surveys whose results are shown in this work are presented.

Table 1. List of a sub-sample of the simulated GMCAO surveys campaign. Column 1: Name of the GMCAO field. Column 2: Galactic longitude and latitude of the central pointing.

GMCAO field	l,b [°,°]
GMCAO #4	125.89 54.83
GMCAO #9	37.65 82.62
GMCAO #10	123.69 -50.30
GMCAO #12	255.51 -34.82

As the GMCAO technique accounts only for NGSs to correct the wavefront perturbations, for a preliminary study we run on all the selected fields TRILEGAL,[9] a population synthesis code that simulates the stellar photometry of the Milky Way. The magnitude limit we used is $R \leq 18$ and the considered technical Fov is 10×10 arcmin^2. Some results of this predictions are shown in Figure 1, for surveys #4, #9, #10, and #12 as a sub-sample of the 22 GMCAO selected surveys. They correspond to the *Hubble Deep Field*,[10] *Subaru Deep Field surveys*,[11] *Deep Lens Survey-1*,[12] and *Deep Lens Survey-3*,[12] respectively. The majority of the cases have less than 500 stars in 10 arcmin^2, being GMCAO #9 and #10 the star-poorest regions, while survey #12 one of the star-richest field. However, the GMCAO request of 6 NGSs does not seem to be an issue.

Moreover, GMCAO uses numerical entities called Virtual Deformable Mirrors (VDMs), which are conjugated to given altitudes, chosen conveniently knowing the positions of the NGSs used for the correction and the input atmosphere (35 layers in our case[13]). As discussed in 6, 6 VDMs can be a good compromise between depth of focus and quality of correction, therefore for each field GIUSTO optimizes the conjugation layer of each VDM, except for the first that is fixed to the ground. The results of this analysis for the considered surveys sub-sample are plotted in Figure 2.

Then, their measurements were projected onto the 3 real Deformable Mirrors (conjugated to 0, 4 and 12.7 km, as foreseen for the ELT), using as optimization criteria the performance in the Scientific FoV area (50×50 arcsec^2, matching the expected Fov of Micado, the first-light imager at ELT[14]). This performance, in key of SR over the field, is shown in Figure 3 for the considered surveys sub-sample and for 100 sectors around the pointing area. The discontinuities of SR inside the sectors are due to the adopted dithering technique: adjacent regions can have rich or poor asterism and this reflects in terms of performance.

Surveys #4 and #9 are fields with the lowest SRs, on average, being the first one a well-know "dark region" and the second one the most northern survey considered, while #10 is well placed on the average performance and #12 represents the highest SR result.

3. CONCLUSIONS

Imaging sky surveys represent one of the most powerful tools for the modern astronomy to investigate the nearby and far away universe, thus providing new insights in the understanding of the galaxy structure and assembly

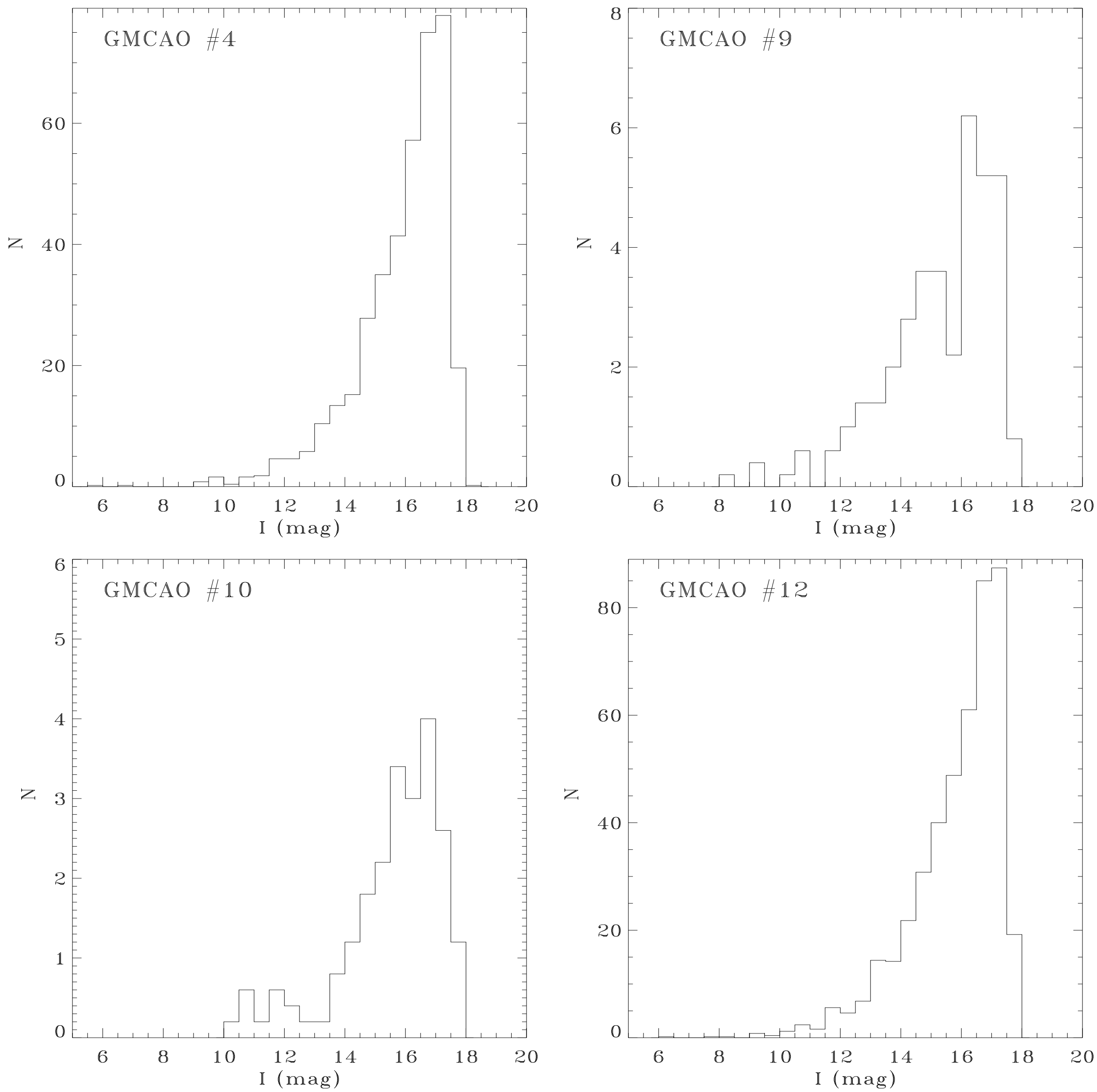

Figure 1. Statistical prediction for the sky coverage in a sub-sample of the GMCAO surveys using TRILEGAL. $R = 18$ is the magnitude limit of the sample. The area of investigation are the 100 technical FoV, for a total of 100 arcmin^2 each.

across time and the dark components of the universe, as well as of the history of our own galaxy. New generation telescopes will be used also for this kind of investigation, therefore a simulation of their performance is necessary.

Here we have presented a study of how an ELT-like telescope that benefits of the GMCAO technique, an innovative method that accounts of both well-accepted and new concepts, can perform if used for a campaign of deep field surveys. This simulation is given in terms of SR, using GIUSTO, the code we developed for such a purpose.[6] Comparing the results to what we have obtained in a previous work where we performed a full photometric analysis on mock images built for a GMCAO *Chandra Deep Fields South* survey, we point out to the fact that this method can be applied as an alternative to the baseline one, achieving good results in terms of SR, i.e. in quality of wavefront correction.

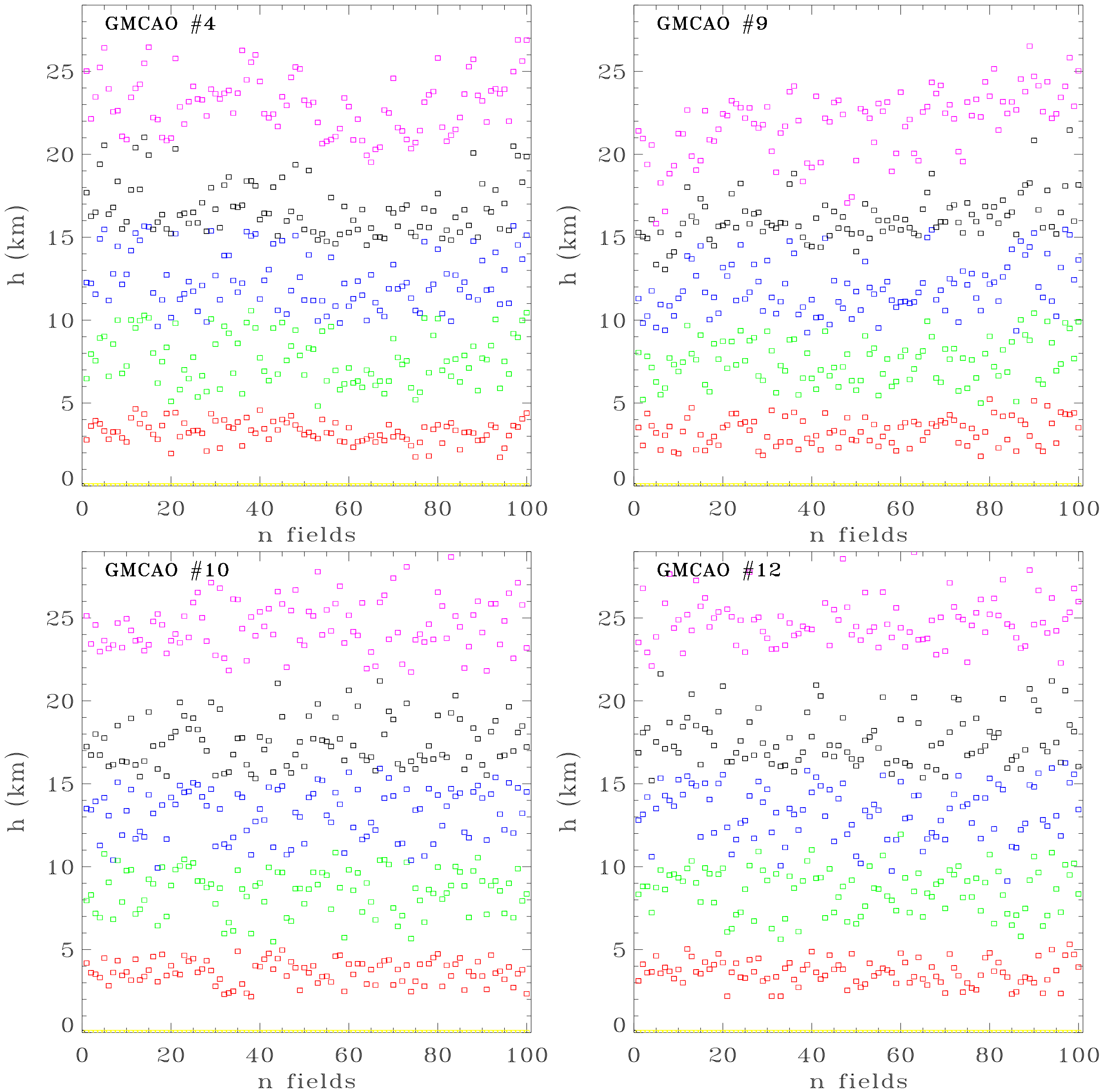

Figure 2. Computed altitude for VDMs for all the GMCAO surveys. The different colors correspond to each VDM: the yellow is for the one conjugated to the ground, then VDM #1 is red, VDM #2 is green, VDM #3 is blue, VDM #4 is black, and VDM #6 is magenta.

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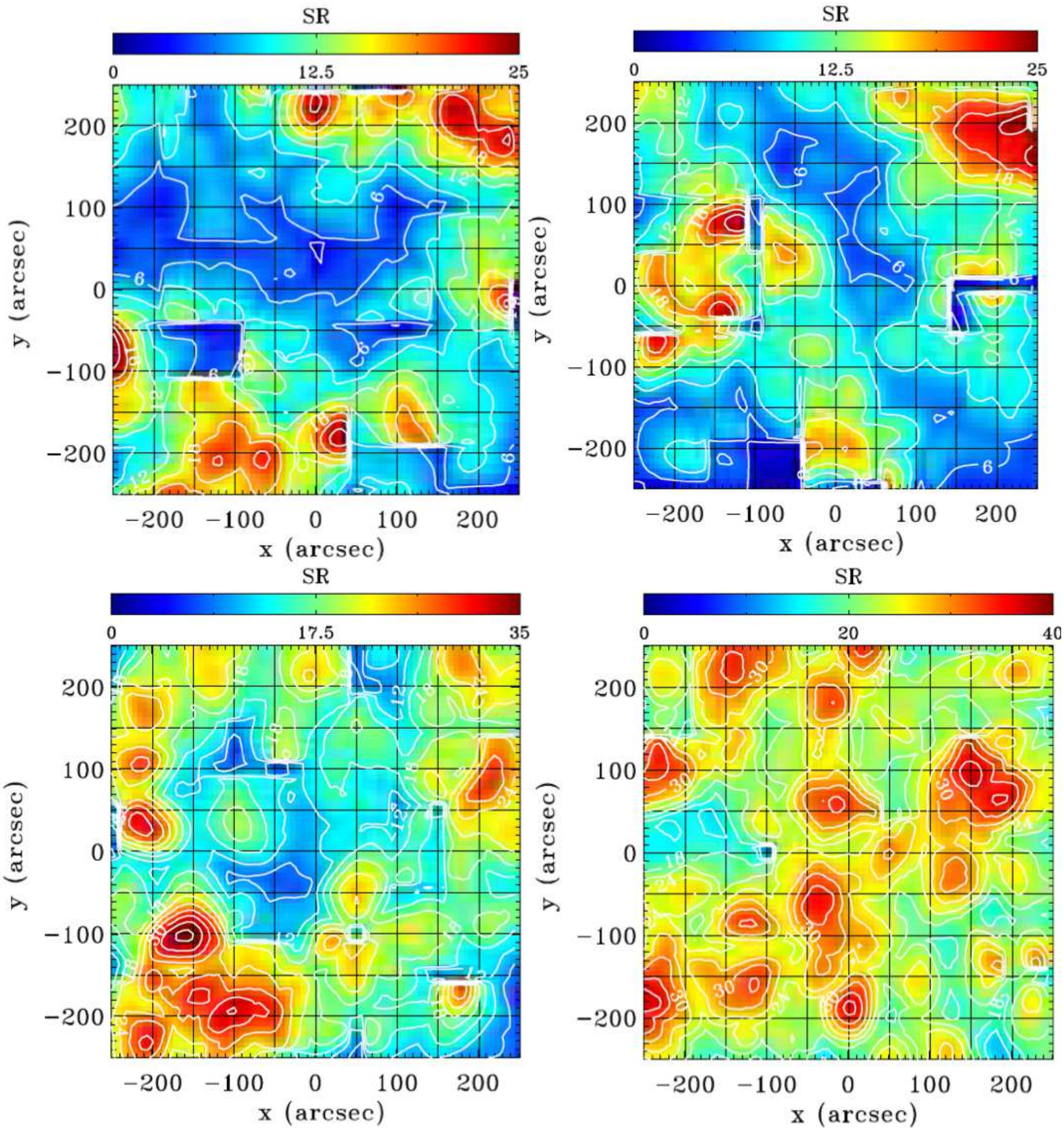

Figure 3. K-band SR map obtained with GIUSTO for a sub-sample of the 22 surveys: from left to right and top to bottom: GMCAO surveys #4, #9, #10, and #12. The image is divided into 100 sectors of 50×50 arcsec^2 each. The intensity contours of certain regions are shown. Color-bars indicate the scales of each panel.

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