# MAD Science Demonstration Proposal

## *Title: MAD Deep Extragalactic Field*


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**Abstract:**

We propose to use the unprecedented capabilities of MAD to perform a deep NIR (JHKs) observation in a patch of the sky close to one of the best studied area, the Chandra Deep Field South (CDF-S) where we have identified a star asterism that meets the requirements of the MAD AO system. The main purpose is to demonstrate the ability to reach in this observing mode extremely faint magnitudes for compact objects in a shorter amount of time than with seeing-limited imagers and at the same time to prove the effectiveness of the MCAO operation over long exposure times. We expect to be able to study the structure of galaxies in a range of redshifts (with a few detections at z>2) and to characterize their surface brightness distribution at unmatched spatial resolution at these wavelengths. The dataset will be made public and will be ideal as preparatory work for future MCAO-based VLT instruments and a critical reference for the science cases of the future E-ELT.


**Scientific Case:**

Work with MAD in the previous observing runs has concentrated on galactic fields (globular clusters, regions of star formations). We propose here to do deep imaging of a high latitude field, something which has never been done before at this angular resolution in the K band. The main scientific drivers of such a proposal are summarized below.

- This observation will be a test case on how deep one can actually go in AO-assisted imaging of extragalactic fields in the near-IR. Due to the set-up of MAD, which relies on three bright stars within a 2′ field, there are very few fields at high galactic latitude that can be observed. We have identified one such field at the periphery of the well-studied CDF-S. We have performed a simulation of the correction performance. Fig.1 shows the Strehl ratio map in K band, PSF shape variation in the field and associated FWHM (values besides the color bar). We can expect rather good image quality in the central ~80 arcsec within the asterism.

- From the existing studies in the CDF-S and deep NIR surveys, we expect to detect ~ 40 compact galaxies (or compact knots in galaxies) in our field down to $K_{AB}$ ~ 26. The region is at the outskirt of the Abell cluster 3141 at z=0.1 and includes 2 detected SWIRE sources from Spitzer.

We will get unique information on the structure of galaxies over a range of redshift to z~3. We will derive photometric redshifts initially from complementary observations in the B and I bands (see below). While the size of the field would not permit to get any statistically significant results, we will be able to test how deep AO data could be used to investigate how Galaxy structure correlate with physical properties (e.g. star formation rate, metallicity). Only recently using HST it has become possible to study such correlations at $z \sim 2$. We know from recent NIR observations at 8-10m telescopes the existence of a large population of $z > 1$ galaxies e.g *distant red galaxies* (DRGs, Franx et al. 2003) or *BzK* (Daddi et al. 2004). These selections are complementary to the Lyman break technique (Steidel & Hamilton 1993) that by construction is biased against objects obscured by gas or older and more quiescent systems that have formed the bulk of their stars at $z > 4$. Several analyses suggest that these NIR selected sources may make a substantial contribution to the stellar mass density at $z > 2$. Using the high spatial resolution of a deep MAD pointing, it will be possible to fit the 2D surface brightness distribution of galaxies at $z > 2$. This will allow to quantify the fraction of them that are best fitted by "exponential disk-like" surface brightness profiles or by "de Vaucouleurs-like" profiles. Further, estimating the effective radius ($r_e$) of such galaxies, one could derive the surface mass density ($M_{star}/\pi r^2$). This quantity will allow a meaningful comparison with classes of local galaxies in order to establish an evolutionary track between $z \sim 2.5$ and $z = 0$. Additionally, HST/NICMOS images of $2 < z < 3$ galaxies have shown that a relevant (~ 40%) fraction of them have close faint or bright companions or asymmetries which indicate they could be in the process of minor or major mergers. The rest-frame optical images of these galaxies with MAD will allow studying the morphological properties of these distant galaxies at these wavelengths in unmatched details.

- This public dataset will be very useful to optimize the performance of future MCAO systems planned for 8m class telescopes that will have a much larger sky coverage thanks to multiple Laser Guide Stars. They will also provide a very useful reference for the science cases for the future E-ELT, several of which deeply rely on NIR imaging assisted by AO.

If this proposal is approved we plan to apply for 9 hours of DDT time to observe the same field in the B band (FORS1, 1 hours) and I band (FORS2, 7 hours). We estimate to be able to reach the following limiting magnitudes (seeing ~0.6-0.7 arcsec): $B_{AB}$ (5σ, 1″ radius) = 26.3 and $I_{AB}$ (5σ, 1″ radius) = 26.7. Together with the NIR magnitudes they will be used to derive photometric redshifts for the galaxies.

## Targets and integration time

| Target | RA (2000) | DEC (2000) | Filter | Magnitudes | Total integration time (sec) | Field (arcmin) |
|---|---|---|---|---|---|---|
| MAD Deep Field | 3:37:00.5 | –28:08:23 | J | 25.0 | 21,600 | 1.1x1.1 |
| | | | H | 24.6 | 18,000 | |
| | | | Ks | 24.0 | 18,000 | |

The field has been selected in order to have three bright stars within a field of view of 2′ as required by the system to achieve an effective correction.

## Guide stars list and positions

| Target: MAD Deep Field | | | | | |
|---|---|---|---|---|---|
| Nr. | α(2000) | δ (2000) | mag (V) | $RA_{rel}''$ | $DEC_{rel}''$ |
| 1 | 3:36:56.489 | –28:08:13.34 | 11.01 | 44.8 | 9.7 |
| 2 | 3:36:58.102 | –28:07:53.26 | 8.96 | 22.2 | 29.7 |
| 3 | 3:37:03.586 | –28:08:54.42 | 11.32 | -43.1 | -31.4 |

## Time Justification:

Based on the limiting magnitudes derived from the April 2007 MAD observations (which appeared in relatively good agreement with the predictions of the ISAAC ETC adapted to the image quality and background estimate of MAD) we estimate that $K_{AB}$=26 can be achieved with 5 hours integration on an unresolved source. We will use dithered integrations of 200 sec each (DIT=10, NDIT=20). Integration times for J and H are 6 and 5 hours respectively to reach the same AB magnitude. In J this is based on the currently rather high background observed in this band. If this problem will be corrected (it is probably due to a light leakage in the filter mount) the J exposure time could be reduced. Overheads (acquisition and dithering) are estimated at 40 min per filter. Two additional hours are reserved to observation of flux calibrators. **The total amount of requested time is 20 hours.**

**Simulations DF with MAD – K band**

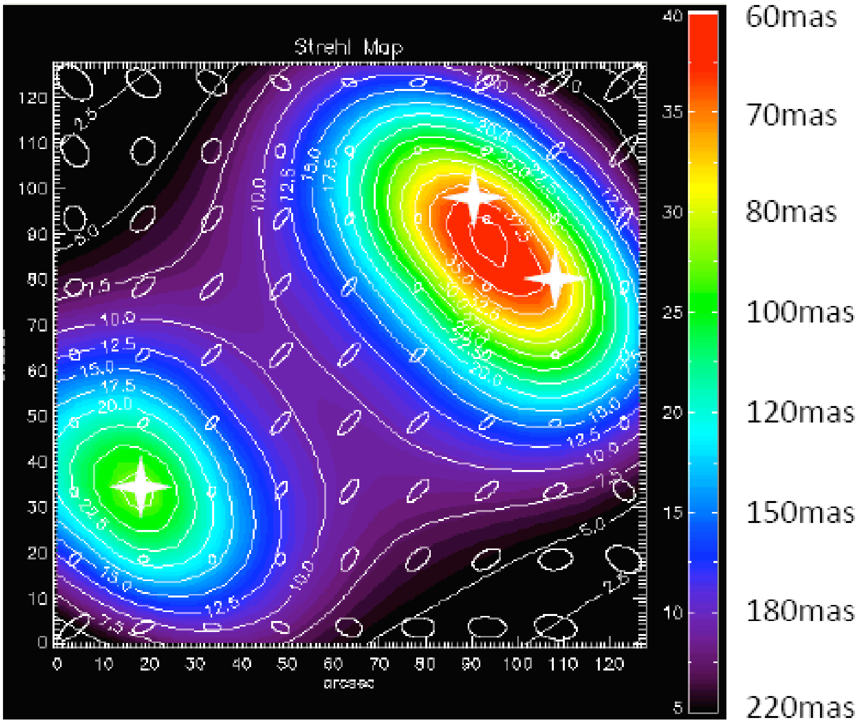


Figure 1. A preliminary correction performance estimate has been computed using the YAO simulation software adapted to the MAD optical configuration and to our field. The guide stars asterism has been reproduced with correct positions and magnitudes and closed loop simulations have been carried on for a correction frequency of 400Hz after a quick run of loop parameters optimization. The atmospheric model consist of 8 layers for a global seeing contribution of 0.8 arcseconds (at 0.55 um). The total simulation length is of 5000 iterations. The results shown consist of the Strehl ratio map in K band, PSF shape variation in the field and associated FWHM (values besides the color bar).