Abstracts Beyond MAD

Miska Le Louarn <lelouarn@eso.org>

Title: MCAO for Beginners : Principles and Limitations

Abstract: In this presentation, I will discuss the fundamental principles and limitations of Multi-Conjugate AO (MCAO). I will show how MCAO differs from other AO modes, like Single Conjugate AO and Ground Layer AO. I will discuss what limits the performance of MCAO systems, like number of deformable mirrors, guide stars and atmospheric turbulence profiles.

Enrico Marchetti <emarchet@eso.org>

Title: Lessons from MAD: On-Sky Performance Testing

Abstract: MAD has been initially installed at VLT UT3 early in 2007 to perform three technical runs aiming at validating the MCAO technique. The on-sky observations followed a long phase of integration and testing in the laboratory allowing to bring the system at a good level of reliability and robustness. Thanks to this preliminary work we did not wait too long to obtain the first successful results which encouraged us in offering the system for a campaign of science demonstration. In this talk I will briefly introduce the MAD system and I will present the main performance results obtained during the on-sky technical runs. I will also highlight the most important technical achievements in terms of MCAO correction obtained during the Science Demonstration runs.

Johan Kolb <jkolb@eso.org> / Paola Amico <pamico@eso.org>

Title: Lessons from MAD: From the Lab to the Sky

Abstract: A year before seeing the first star light, MAD was already closing MCAO loop in the optical laboratory of ESO HQ in Garching, and showing excellent performance. This will be the starting point of this presentation. It will be followed by a journey through some of the problems encountered when trying to maintain this performance in a real telescope environment, from hardware issues to performance optimization, from last minute discoveries to the instrument first light. The last step consisted in stopping “using MAD” as engineers and starting “operating MAD” as astronomers. We will describe MAD Operations on sky: The challenges, the issues and the accomplishments of the three science demonstration runs with particular emphasis on what we have learnt along the way and the future applications of these valuable lessons.

Roberto Ragazzoni <roberto.ragazzoni@oapd.inaf.it>

Title: Layers and Pyramids: Lessons learned and Future Perspectives

Abstract: The layer-oriented Wave Front Sensor onboard MAD had got successfull closed-loop operations and achieved science results into a dedicated run. In this talk I will review the experience achieved on the sky, especially in the framework of the ability to achieve closed loop operations with faint reference stars and will discuss which are the options for improving the layer-oriented approach in order to turn MCAO with solely NGSs a realistic and practical target.

Monika Petr-Gotzens <mpetr@eso.org>

Title: Review: Star Formation

Abstract: Understanding the process of star formation remains one of the most exciting challenges of modern astrophysics. The emergence of stars and planets from the cold dusty cores of molecular clouds is accompanied by a variety of complex powerful processes that can be witnessed with modern techniques over a large range of the electromagnetic spectrum. In this talk, I will discuss some recent progress as well as open issues related to star formation research, with a particular emphasis on the initial stellar and substellar mass function.

Herve Bouy <bouy@iac.es>

Title: A deep look into the cores of young nearby massive clusters

Abstract: We took advantage of the new possibilities offered by MAD to study the IMF and multiplicity over the entire mass spectrum in the core of young nearby massive clusters (sigma Orionis, lambda Orionis and Lupus).

Andreas Seifahrt <seifahrt@astro.physik.uni-goettingen.de>

Title: A MAD view of the M16 elephant trunks

Abstract: Results of the MAD SD and commissioning observations of M16 will be shown and compared to VLT/ ISAAC and GEMINI/ ALTAIR observations.

Boyke Rochau <rochau@mpia.de>

Title: A MAD visit of Trumpler 14

Abstract: The Carina Nebula (NGC 3372), at a distance of ~2.6 kpc, is an HII region with a particular star cluster population which comprises a large concentration of O-type stars. Trumpler 14 is one of the very young and populous clusters located in the central part of the Carina Nebula. It shows, in contrast to the nearby cluster Trumpler 16, no evolved stars but several O-type stars notably the O2If* star HD93129Aa. The proximity of the

Carina Nebula and the dense population of bright O- and B-type stars of Tr 14 offer an ideal environment for the use of a multi-conjugate adaptive optics system. The resolution power and the wide-field of view at VLT-MAD allow to resolve the dense central region of the cluster including its most massive stellar population. Analysis of the observations deliver information about image quality provided by the MCAO system (e.g. spatial distribution of Strehl values). They further provide the opportunity to construct deep color magnitude diagrams (CMD). Comparison of Pre-Main sequence stars in the CMD with theoretical isochrones yield distance, extinction and age of the low-mass cluster population. Results from both, the technical and scientific analysis will be presented.

Hugues Sana <hsana@eso.org>

Title: A MAD view of Tr 14

Abstract: We used MAD to target the core of the Trumpler 14 young open cluster in the Carina region, with the idea to constrain the close environment of the many massive stars in that cluster. The collected data constitute the deepest NIR photometry ever achieved on the cluster, allowing us to put some constraints on the duration of this recent star formation event. We will also discuss the multiplicity properties of the massive stars and how they compare with the properties of solar-type star in the cluster.

Silvia Vicente <svicente@rssd.esa.int>

Title: MAD observations of giant proplyd candidates in NGC 2244 and NGC 2264

Abstract: Externally illuminated protoplanetary disks or "proplyds" are a special class of YSOs found embedded within or near a HII region. They are usually identified as comet-shaped photoionized envelopes with bright ionization fronts facing the source of external UV radiation and extended tails pointing away from it, which are visible in optical emission lines (Halpha, [OIII], [SII]).

As a Science Demonstration program for MAD we proposed to observe, in H and Ks, a sample of 8 giant proplyd candidates detected in different cluster environments (age, distance, and number of OB stars) and located at different distances from their external ionizing sources. Different cluster ages, densities and UV radiation fields may strongly affect proplyd characteristics. Our goal was to resolve and to characterize with detail the morphology of these systems in the NIR and to make a direct comparison with existing HST optical images. We were expecting to test if the models for protoplanetary disk photoevaporation in Orion are applicable to more extreme regions. Only 2 candidates, of the proposed sample of 8, could be observed with MAD during the Science Demonstration program, and only in the Ks-band. They are located in NGC 2244 (1.5 kpc, O5 star, 4 Myr) and in NGC 2264 (800 pc, O7 star, 4 Myr) and were initially discovered in Spitzer 8 and 24 micron images (Balog et al. 2006). More recently these systems were also observed with HST/NICMOS (Balog et al. 2008). In this talk, I will present the preliminary results for the giant proplyd candidates in NGC 2244 and NGC 2264 derived from the MAD images in the Ks-band and from comparison with previous observations.

Nuria Huelamo <nhuelamo@laeff.inta.es>

Title: MAD observations of the young cluster NGC2362

Abstract: I will present MAD observations of NGC2362, a ~5 Myr cluster at ~1.5 Mpc. Its low interstellar and internal extinction, together with the lack of circumstellar disks, makes this cluster an ideal laboratory to study early stellar evolution.

Joao Alves <jalves@caha.es>

Title: MAD observations of local starburst NGC 3603

Abstract: We make use of the relatively large FOV and resolution of MAD to observe the Milky Way's starburst cluster NGC3603. We constraint its Initial Mass Function (IMF) and look for evidence of mass segregation. Unlike what is found in the literature we find that 1) the IMF of this cluster is Salpeter like and 2) there is no evidence for mass segregation.

Michael Campbell <mac@roe.ac.uk>

Title: MAD images of the dense stellar cluster R136

Abstract: We obtained H and K band MAD imaging of R136, the dense stellar cluster at the core of 30 Doradus in the LMC. Three MAD pointings were observed with impressive results - Strehl ratios as high as 30% and FWHMs as good as 0.08" were recorded, with relatively uniform corrections across two of the fields. I will give an overview of the performances in the three fields, discuss some of the difficulties of photometric calibration using different techniques, and mention some of the scientific applications we are now pursuing with the data.

Giuseppe Bono <bono@roma2.infn.it>

Title: Deep and accurate NIR photometry in crowded fields

Abstract: We plan to discuss both accuracy and precision of the photometry performed on NIR images collected with different detectors (NACO, MAD). We also plan to present preliminary results concerning the use of asymmetric analytical PSF and the comparison with canonical PSFs. Finally, we show their impact on the NIR CMD of Omega Centauri.

Francesco Ferraro <francesco.ferraro3@unibo.it>

Title: MAD and HST Observations of Terzan 5

Abstract: Terzan 5 is one of the most surprising globular clusters in the Galaxy. It is a quite extincted cluster in the direction of the Galactic Bulge and it harbors almost 25% of the known Millisecond Pulsar population of the entire Globular Cluster System. Indeed it has been considered for years the cluster with the highest stellar interaction rate of any GGC. By exploiting deep MAD-IR images combined with ACS-optical observations, we are

performing a proper investigation of the cluster structural parameters and stellar populations. A number of puzzling results are emerging from this investigation, suggesting that the stellar population of the cluster is much more complex than previously thought.

Felicia Troisi <Licia.Troisi@roma2.infn.it>

Title: Deep and accurate NIR photometry of the globular cluster 47 Tucanae

Abstract: We plan to present deep NIR color-magnitude diagrams (CMDs) of the globular cluster 47 Tuc. This cluster presents a very high central density and accurate photometry in the innermost regions is challenging even for optical space images. By taking advantage of J, K band images collected in very good seeing conditions with MAD@VLT, we obtained CMDs ranging from evolved red HB stars down to a few magnitudes below the turn-off region. We also plan to perform a detailed comparison with similar CMDs based on J and K images collected with SOFI@NTT and with HAWK-I@VLT.

Annalisa Calamida <acalamid@eso.org>

Title: Deep photometry of NGC3201

Abstract: We present accurate J,Ks-band photometry collected with both MAD/VLT and SOFI/NTT for the Galactic globular cluster (GGC) NGC~3201. Based on these data we devised a new method to estimate GC absolute ages by adopting the knee of the bending of the lower main-sequence (MS) in the Near-Infrared (NIR) J, J-Ks color-magnitude diagram. The color difference between this feature and the Turn-Off point is strongly correlated to the cluster age. This method is marginally affected by distance and reddening uncertainties, and by the possible occurrence of differential reddening. Furthermore, the knee location does not depend on the cluster age and it is a robust theoretical prediction.

Sergio Ortolani <sergio.ortolani@unipd.it>

Title: MAD observations of the galactic star clusters HP1 and FSR 1415

Abstract: The results of the MAD observations of the two galactic star clusters HP1 and FSR 1415 are presented. HP1 is a relatively metal poor globular cluster located in the galactic bulge.The comparison of its color-magnitude diagram morphology with the recent results from the spectroscopic analysis is discussed. This cluster could belong to a new cluster family in the bulge. FSR 1415 was found to be a new old open cluster. Only with MAD data this object could be studied in detail.

Elena Valenti <evalenti@eso.org>

Title: MAD OBSERVATIONS IN CROWDED AND REDDENED FIELDS: THE CASE OF NGC6441

Abstract: I will present the MCAO Infrared photometry of the moderately reddened

globular cluster NGC~6441. A study of the MAD performances and a comparison to HST data will be also briefly presented.

Giuliana Fiorentino <fiorentino@astro.rug.nl>

Title: Resolved Stellar Populations with MAD.

Abstract: A number of ELT science cases assume that accurate photometry can be carried out at very faint levels over relatively wide fields of view. It is very important to test this assumption as far as possible with currently available facilities. A useful generally applicable case is the photometry of point sources in crowded stellar fields, which provide natural, accurate probes of photometric sensitivity.

With this in mind, we proposed MAD observations of "classical targets" for resolved stellar populations: a Galactic Bulge Globular cluster, NGC6441, and a field in the Large Magellanic Cloud close to the Globular Cluster NGC1928. These two very crowded stellar fields push to the limit the capabilities of MAD, by testing simultaneously its sensitivity and spatial resolution. The Galactic globular cluster is relatively nearby (13.5 kpc) but behind a large amount of extinction. The LMC field is further away (48 kpc) but has an very well aligned, bright, asterism (all stars have V = 10-11mag).

Here we present the preliminary results we have obtained and the problems we have encountered in our analysis.

Mario Nonino <nonino@oats.inaf.it>

Title: The MAD Deep Field

Abstract: As part of a MAD Science Demonstration program, we have obtained deep Ks-band observations in a patch of the sky close to one of the best studied area, the Chandra Deep Field South (CDF-S). The patch include the outskirt of the Abell cluster 3141 and few Spitzer sources. I"ll present the imaging data set, the results of the spectroscopic follow-up and morphological analysis of extended sources in the MAD field. Potential application of improved MAD will also be presented.

Michael H. Wong <mikewong@astro.berkeley.edu>

Title: Outer Solar System Science with MCAO

Abstract: Studies of giant planets in the outer solar system require high angular resolution to distinguish fine details, including cloud features and ring structure. Conventional adaptive optics has been delivering high resolution Uranus and Neptune data, because these planets can be used directly for wavefront sensing. However, Jupiter and Saturn present unique challenges because they are too extended to serve as guide stars. Jupiter's large satellites have been used as natural guide stars for conventional AO systems as well as for MAD, with previous successful results at Keck and Gemini. However, these conventional AO observations can typically image only a fraction of Jupiter's disk for less than an hour, before the satellites drift too far from Jupiter.

MAD successfully demonstrated the advances possible in imaging of extended objects in the outer solar system. In particular, observations of Jupiter with Io and Europa as natural guide stars achieved a maximum resolution of about 0.09" while imaging the entire Jovian disk, during a continuous observing sequence of almost two hours.

Analysis of the images demonstrates that the MAD data has sufficiently high resolution to extract velocity fields from time-separated images. Serendipitously, the observations revealed a shift in Jupiter's equatorial haze distribution, possibly related to the global upheaval of 2006-2007 (a collection of atmospheric changes in both northern and southern hemispheres). The almost 2-hour duration of the MAD observations enhanced the reliability of the discovery by sampling ~220 deg of longitude as Jupiter rotated.

Enrico Marchetti <emarchet@eso.org>

Title: MAD MAX: Correction Performance

Abstract: One of the main limitations in the adaptive optics correction is due to the noise affecting the wavefront sensor detector. This noise transfers into the incapability to use faint stars as references for wavefront sensing, hence preventing to observe many astronomical targets of high scientific interest. In the recent years new technological developments (Electron Multiplying CCD, EMCCD) significantly improved the performance for fast read-out detectors achieving the ultimate goal of having negligible noise. The MAD upgrade will mainly consist of substituting the actual wavefront sensor detectors with EMCCD ones to increase the number of accessible astronomical targets for MCAO correction. In this talk I will introduce the concept for the upgrade and I will present the expected MCAO correction performance for several observing conditions.

Paola Amico <pamico@eso.org>

Title: MADMAX Operations concept

Abstract: The MAD upgrade will enable new exciting science at the VLT. We need to be prepared to go on sky, exploit the MADMAX capabilities and maximize the scientific return in the limited time window at our disposal. We propose an operations scheme which is tailored to MCAO observations with MADMAX and its science cases, and discuss its pros and cons with respect to the classical VLT operation scheme.

Paul Hickson <hickson@physics.ubc.ca>

Title: NFIRAOS@TMT

Abstract: The NFIRAOS (Narrow-Field InfraRed Adaptive Optics System) MCAO system will be the primary adaptive optics facility for the Thirty Meter Telescope for at least the first decade of operation. Feeding up to three instruments, it will be a dual-conjugate system employing multiple sodium laser guide stars. Operating in the 0.8 - 2.5 um wavelength range, NFIRAOS is designed to provide high Strehl-ratio images (S ~ 0.75 in the K band) over a 30 arcsec field of view, and partial AO correction over 2.3 arcmin. The entire system will be cooled to a temperature of -30C in order to reduce thermal emissivity.

Two instruments will be available for NFIRAOS at early light: IRIS, a near-infrared imager and integral field spectrometer, and IRMS, a multi-slit spectrophotometer. With a resolution of 7 mas (at 1 um) and a point-source sensitivity a hundred times greater than that of 8 to 10 metre telescopes, TMT/NFIRAOS will have tremendous scientific potential. The science programs are far reaching and include studies of first light, the formation of galaxies, reionization and evolution of the intergalactic medium, galaxy evolution, star formation, black holes, active galactic nuclei, gravitational lensing, stellar populations, star clusters, star formation, extrasolar planets and the outer solar system.

Richard Davies <davies@mpe.mpg.de>

Title: MICADO and MAORY: Science with MCAO on the E-ELT

Abstract: MICADO is the multi-AO imaging camera for the E-ELT, which has been designed and optimised to work with the MCAO system MAORY. In addition, for the initial operational phase at early light, it will have its own SCAO module; and in principle will also work with GLAO. In this contribution, we summarise the designs and performance of both MICADO and MAORY. We then present the science drivers for MICADO and show how these have shaped its design. The science drivers have led to a number of requirements on the AO system related to astrometry, photometry, and PSF uniformity. We discuss why these requirements have arisen and what might be done about them.