Third MACAO-VLTI Curvature Adaptive Optics System now installed

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In July of this year the MACAO team returned to Paranal for the third time to install another MACAO-VLTI system. These are 4 identical 60 element curvature adaptive optics systems, located in the Coudé room of each UT whose aim is to feed a turbulence corrected wavefront to the VLTI Recombination Laboratory. This time the activities took place on Yepun (UT4). The naming convention has been to associate the MACAO-VLTI number to the UT number where it is installed. Therefore, although we speak here of MACAO#4, it is the third system installed in Paranal.

This short note will summarize the status of the MACAO-VLTI project, put forward a few results obtained recently and point out that with 3 operational MACAO-VLTI AO systems in Paranal, phase closure can now be attempted using AMBER fed with 3 AO corrected beams.

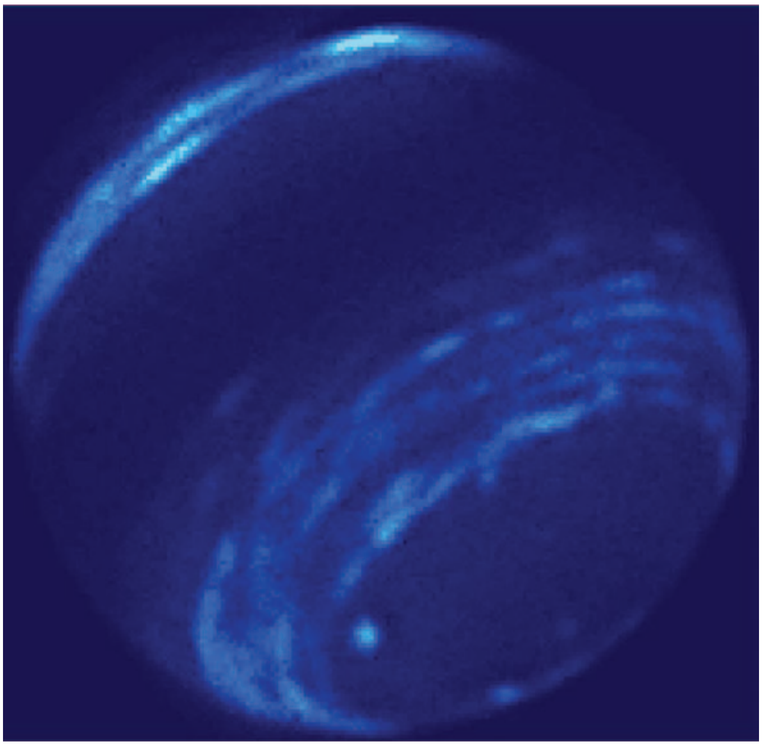

Figure 1: An impressive result of the August'03 commissioning; an image of Neptune in *H*-band (Van Cittert deconvolved). Besides the spectacular resolution of the atmospheric bands, this picture illustrates the capability of MACAO-VLTI to correct the wavefront on extended objects. The angular diameter of Neptune is 3 arcsec and the width (FWHM) of the narrowest bands is 67 mas.

The Advantages of Serial Production

The opportunity of producing a series of instruments is not given to all, and this is unfortunate. We could not emphasize enough the advantages of such strategy. MACAO benefited from this situation from the start of the project all the way to the end at the commissioning activities.

For the ESO Adaptive Optics Department the standardization of several instruments presented numerous advantages: four (4) MACAO-VLTIs plus one spare, SINFONI and CRIRES. To name a few of these advantages:

- Similar concepts for the design documents,
- Optimization of staff efforts,
- Single procurement and acceptance for all units (in general 7 units),
- Great flexibility and margin during acceptance and integration of first systems; if some of the 7 units are not acceptable, others are and allow to pursue the assembly/integration activities,
- Compatibility among MACAO, SINFONI, CRIRES allowing exchange of components (during the whole life of the project),
- Large flexibility for improving the system performance. Basic specifications/functionalities were fulfilled for the first systems and became better as the team acquired a deeper understanding of its functioning.
- Repeated and improved assembly/integration procedures, test procedures (PAE) and commissioning activities

Similar benefits, of course, came from the serial production of the VLT Unit Telescopes.

MACAO#4 (UT4) Commissioning

In 2003 the first and second MACAOs (UT2 and UT3) were commissioned in April and August respectively. A press release (ESO PR/11 03; 13 May 2003) was published to present the first light results. In November a joint effort between the AO dept. and VLTI used 3 nights on sky to characterize the gain

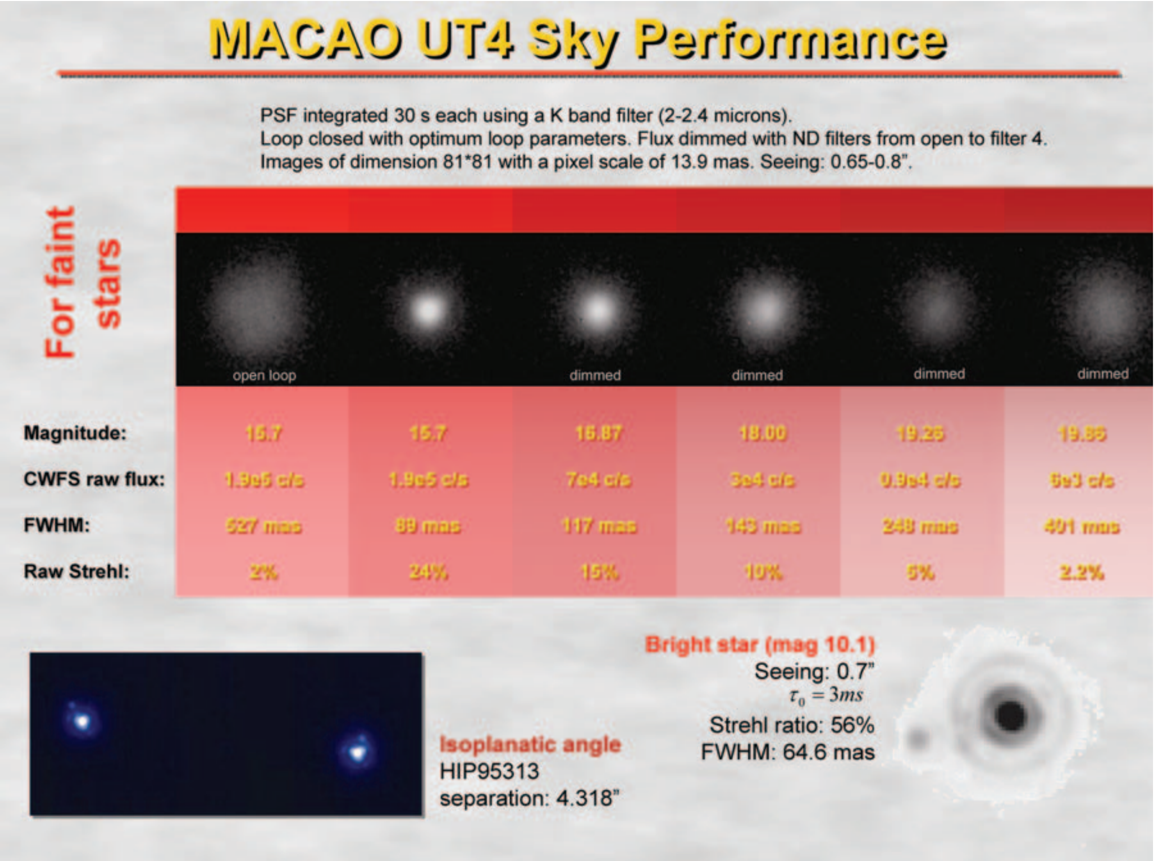

Figure 2: MACAO#4 (UT4) commissioning results (self-explanatory).

of using VINCI with the MACAO-VLTIs. Results of these various activities can be found in Arsenault et al. (2002, 2004a, 2004b), and Wittkowski et al. (2004). A general description is also provided in the Adaptive Department web pages at: http://www.eso.org/projects/aot/

The commissioning activities of this MACAO system were reduced to a minimum given the small number of nights on the sky (3) due to the busy UT schedules. Given the success of the previous commissioning on UT2 and UT3, this appeared to be a low risk strategy.

In July (2004) the Tip-Tilt Box on UT1 was decommissioned and some components re-used to integrate the UT4 MACAO-VLTI system. The commissioning went smoothly, especially the re-assembly/integration phase. It was completed early and the calibrations could start several days before the on-time sky.

The loop was closed on July 29th, approximately one half hour after the object was acquired. Usual verifications were performed: star acquisition, off-axis acquisition with XY table, atmospheric refraction compensation (for different guiding and scientific wavelength), chopping algorithm test, throughput of the system, performance on bright star etc.

Only after these tests were completed was the faint star performance of MACAO characterized. The results are summarized in Figure 2. A V~15.7 magnitude star was acquired, adaptive optics correction optimized and a K-narrow band image was taken. Strehl and FWHM were measured. The star was then dimmed artificially by inserting a neutral density filter in the beam. The faintest equivalent magnitude reached was V~19.8 (K-type star) but this value can vary depending on whether the star is red or blue. For a G-type star one should expect a similar performance for V~18 magnitude. The inconvenience of this method is that the sky background is also dimmed by the neutral density filter, but we believe that the fact that this test was carried out by full moon compensates for this effect.

During this particular run UT2 and UT3 systems went through a software upgrade in order to have similar configurations on all three MACAOs.

MACAO-VLTI Summary of Performance

The critical specifications for MACAO-VLTI are few: strehl ratio versus guide star magnitude, artificial piston over the pupil introduced by the deformable mirror.

The K-band strehl ratio specifications for MACAO-VLTI are 50% for stars V<11 and 25% for V=15.5 in seeing conditions of 0.65″. In 0.8″ seeing MACAO has obtained strehl ratios >50% for bright sources (V<11.5) even 60% if one corrects for the imperfect strehl of the test camera (typically ~90%). On fainter stars the strehl ratio remains larger than 25% until V~16; however performance can deteriorate for a blue object of V~16 (Avanlanche Photodiodes have a peak of sensitivity at ~0.7 µm).

The piston specification of 25 nm RMS in a 48 msec time window has always been very critical; progress has been made recently allowing us to fulfill this very challenging requirement. The improvements leading to this are:

- Control frequency of 420 Hz rather than 350 Hz; important decrease in the excitation of the deformable mirror main resonances
- Improvement in the control matrix and higher accuracy of the interaction matrix measurement
- Taking into account the non-linearity of the deformable mirror at large stroke.

In conclusion the MACAO VLTI installations and commissioning activities are proceeding according to schedule and the results are extremely encouraging showing performance better than expected and a high system robustness. The fourth and last MACAO will be installed in the course of 2005.

References

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