A New Lenslet Array for the NACO Laser Guide Star Wavefront Sensor

Markus Kasper[1]
Gerard Zins[2]
Philippe Feautrier[2]
Jared O'Neal[1]
Laurence Michaud[2]
Patrick Rabou[2]
Eric Stadler[2]
Julien Charton[2]
Claudio Cumani[1]
Alain Delboulbe[2]
Christoph Geimer[1]
Gordon Gillet[1]
Julien Girard[1]
Nicolas Huerta[1]
Pierre Kern[2]
Jean-Louis Lizon[1]
Christian Lucuix[1]
David Mouillet[2]
Thibaut Moulin[2]
Sylvain Rochat[2]
Christian Sönke[1]

[1] ESO
[2] Laboratoire d' AstrOphysique de Grenoble, France

In February 2010, a new 14 × 14 lenslet array was installed in the NAOS–CONICA (NACO) visible wavefront sensor. Compared to the previously available array, this new array has a shorter focal length and hence a field of view that is large enough for the extended laser guide star (LGS) spot. This successful upgrade results in improved adaptive optics correction delivered by NACO with the LGS.

Since 2007 NACO and SINFONI have regularly operated using a laser guide star on the VLT Unit Telescope 4 (UT4) (see Organisation Release eso0727). Theoretically, the performance of NAOS with an LGS should be close to the performance with a bright natural guide star (NGS), reduced by the unavoidable cone-effect of about 20 % loss in *K*-band Strehl ratio. Considering a NACO–NGS peak performance of 50–60 % *K*-band Strehl ratio in good observing conditions, one could expect Strehl ratios around 40 % with the LGS. However, the Strehl ratios obtained so far were around 20–25 % with the 7 × 7 lenslet array.

Figure 1. *JHK* composite image of the globular cluster Omega Cen with a field of view of 27 × 27 arcseconds and containing about 3000 stars.

One reason for this deficiency is that the LGS effective magnitude (NGS photon noise equivalent) corresponds to a star with $V \sim 12$ mag. Hence, the adaptive optics (AO) no longer operates in the regime where it is limited by fitting error, but rather in the photon and detector noise-limited regime, thus hampering the achievable Strehl ratios. Even in favourable seeing conditions, the previously available 14 × 14 lenslet array could not be used because of its small field of view (FoV) of 2.3 arcseconds per sub-aperture. This small FoV cuts the edges of the LGS spots and the corresponding truncation errors led to poor correction performance.

In May 2009, a contract for the replacement of the current visible wavefront sensor (WFS) 14 × 14 lenslet array by one that has a shorter focal length, and hence larger field of view, was commenced by ESO and the Laboratoire d'AstrOphysique de Grenoble (LAOG), the institute that was in charge of building the original NAOS visible WFS. This new array has a FoV that is twice as large, with 4.6 arcseconds per sub-aperture, and was expected to significantly improve the correction performance in good observing conditions when accurate wavefront sensing can be obtained with the LGS.

A major challenge for this project was to disturb regular observation with NACO as little as possible. So the installation and alignment of the new array at ESO Headquarters in Garching had to strictly follow a short and well-defined schedule that made the upgraded visible WFS available again in February 2010, only one and a half months after it had been dismounted and shipped to Garching just before Christmas 2009. Re-installation at UT4 started in the last days of January 2010, and the first night available for commissioning was 5 February.

During the commissioning nights, it quickly became clear that the new lenslet array brought the expected gain in performance, with the achievement of *K*-band Strehl ratios up to 35 % and image quality around 80 milliarcseconds (mas) full width at half maximum (FWHM) in good observing conditions. Also, the operation with the new lenslet array is virtually identical to that with the previous arrays, so the upgrade is largely transparent for the users. The globular cluster Omega Centauri was observed for five

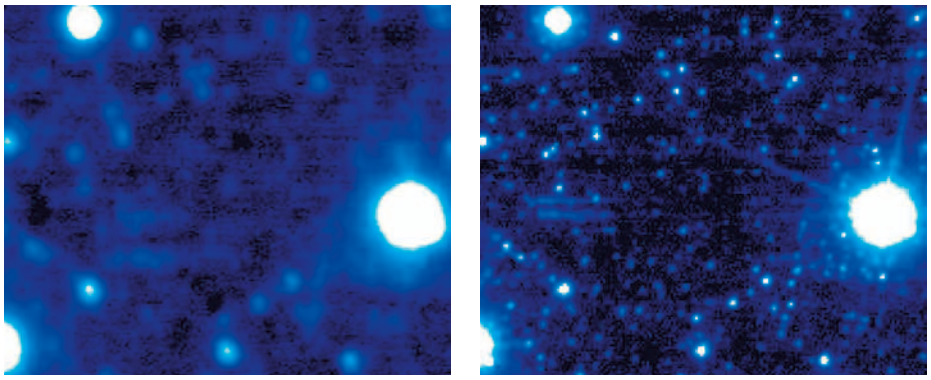

Figure 2. *K*-band close-up of the centre of Omega Cen, demonstrating the gain in sensitivity of the LGS AO (right) over the seeing-limited image (left).

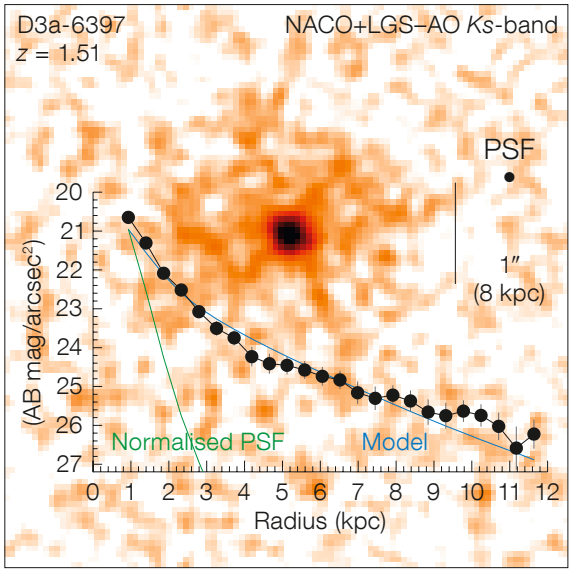

Figure 3. *Ks*-band map of the $z = 1.51$ galaxy D3a-6397. The surface brightness profile of the galaxy is shown as inset and compared to a stellar PSF and a model fit. Image and data processing by Natascha Förster Schreiber, Ric Davies (both MPE) and Giovanni Cresci (Arcetri).

minutes in each of the *J*-, *H*- and *K*-bands; Figure 1 shows a *JHK* colour composite and Figure 2 demonstrates the gain in resolution and sensitivity (about 3 magnitudes in that case) provided by the LGS AO. The angular resolution is better than 100-mas FWHM over the whole 27-arcsecond FoV. The Strehl ratio in the image centre is better than 30 % in the *K*-band, and better than 17 % and 12 % in the *H*- and *J*-bands respectively. The bright star in the centre was used as a tip-tilt guide star.

In order to test the sensitivity of the new mode, the high-*z* galaxy D3a-6397 was observed for 78 minutes total in the *Ks* filter. The FWHM of the point spread function of the data, as determined from two stars within the NACO FoV, is approximately 0.15–0.19 arcseconds, and the variations across the FoV are consistent with anisoplanatism. The image quality at the location of the science target (on-axis) could therefore be very close to, or indeed diffraction-limited (FWHM of about 0.11 arcseconds). This corresponds to a linear physical resolution of about 1 kpc at the redshift of the D3a-6397 of $z = 1.5$. The 3σ limiting magnitude in a point-source aperture of diameter 0.26 arcseconds in *Ks* (AB) is ~ 24.8 mag. The NACO *Ks*-band image clearly reveals a steep inner light profile and fainter emission is detected out to radii ~ 10 kiloparsec (kpc). The surface brightness distribution can be well represented by a central unresolved (point-like) component and an underlying exponential disc component of effective radius of ~ 7 kpc.

Acknowledgements

This intervention was successful thanks to the efficient planning and professional expertise provided by the LAOG project team as well as a high level of dedication from ESO staff during the critical period early in 2010. The authors would like to thank the UT4 telescope and instrument operator Cristian Herrera, and the Paranal laser specialists Juan Beltran and Jose-Luis Alvarez who made sure the laser was working at high power during the whole commissioning, as well as Natascha Förster Schreiber, Ric Davies (both MPE) and Giovanni Cresci (Arcetri) for the reduction and analysis of the D3a-6397 data.