in the future. The requirements and implications of this service are currently being studied by ESO.

Current NTT Status

In the last issue of *The Messenger*, I reported the emergence of a few new technical problems as a result of the installation in January of the latest version of the NTT common software at the NTT. The two new problems with the highest rate of occurrence in the weeks following the software upgrade, and with the most damageable impact on operations (or, in other words, those responsible for the largest amount of technical downtime), were the spontaneous reboots of LCUs and the random failures of technical CCDs. The origin of both was found to be related to inaccuracies in the time distribution protocol. While the technical CCD control software was successfully modified to handle properly such inaccuracies and avoid further failures, the exact mechanism by which the time inaccuracies trigger the LCU reboots has not been identified yet. As a provisional workaround, LCUs are now running on their internal clock rather than on a centrally distributed time. Although the internal LCU time is considerably less accurate, so that the currently adopted option is not conceptually satisfactory, it does not have any significant negative impact on the operation of the telescope and of the instruments, and it effectively solves the annoying problem of the LCU self-reboots. Therefore, it is quite acceptable until a “cleaner”, more permanent solution has been worked out and is implemented. With it, and with the above-mentioned modified technical CCD software, the reliability of the NTT control system has now come back to the excellent level achieved in the last months of 1997.

From the point of view of the visiting astronomers, the end of the NTT Upgrade Project and the return of the telescope fully within the La Silla operational context should, in practice, be a very smooth transition, since classical observing at the NTT will continue to follow the scheme set up during the last year. After the completion of the major technical works of the December 1997 – March 1998 period, time and resources have been, and will in coming months be, available to refine and to consolidate a stable operational model, in which emphasis will be laid especially on an improved service to observers. In particular, we hope to be able to provide NTT users with a few new auxiliary tools, which should allow them to have a better interaction with the system and with their data. One such product that has been put into service on the astronomer’s workstation is the File Handling Tool, which provides the observer with a number of features allowing him, for instance, to examine the headers of his FITS files, to have a quick look at his data, or to take advantage of various options for easy saving of his data to tape.

Staff Movements

End of March, Domingo Gojak, an electronic engineer who was in the NTT Team since the beginning of the Upgrade Project, was transferred to the team in charge of the 3.6-m telescope to support the upgrade of the latter. Domingo had been one of the key players in the success of the technical upgrade of the NTT, and he will undoubtedly play an equally important role in the upgrade of the other La Silla major telescope. I have enjoyed to work in the same team as Domingo during more than 4 years and I wish him all the best in his new assignment.

At about the same time, Olivier Hainaut, a former fellow from the Medium-size Telescope Team, passed to the NTT Team as a new senior staff astronomer. Olivier, a very experienced observer specialised in the study of small bodies of the solar system, has been designated as the future Leader of the NTT Team, a responsibility that he will take over from the author of these lines in July, after a period of overlap which will allow him to integrate himself in the team and to become familiar with his future task.

Two new fellows have also joined the NTT Team, at the end of April and the beginning of May: Vanessa Doublier, a former student at ESO in Garching, and Leonardo Vanzi, who comes from Arcetri (Italy). Both have experience in IR observations, and they will accordingly, at least in part, be assigned to the support of SOFI.

It is a pleasure to welcome these newcomers, with whom I am looking forward to collaborating in the last months of my involvement with the NTT and to whom I shall be pleased to hand over the responsibility of this telescope, trusting that they will maintain it as a world leading 4-metre-class telescope for the greatest benefit of the ESO astronomical community.

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Tuning of the NTT Alignment

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1. Introduction

Since the end of the NTT upgrade project it has been known that the alignment of the secondary mirror (M2) was only marginally within specification. When the atmospheric seeing was greater than one arcsecond, the misalignment had no noticeable effect on the image quality. But, under better seeing conditions, it was a limiting factor for the image quality. Therefore, it was decided to tune the position of the M2 unit. We used the NTT wave front sensors, which are part of the Active Optics system, in a novel way to measure the required realignment of M2.

2. Effects of a Telescope Misalignment on the Image Quality

2.1 The NTT optics

The NTT is an aplanatic telescope of the Ritchey-Chretien type. Aplanatic means that the telescope, if it is properly tuned and aligned, is free of spherical aberration and coma in the field. A proper alignment requires that the distance between the primary mirror and the secondary mirror is correct and that the optical axes of the two mirrors coincide. The by far most important aberration remaining in the field is then astigmatism, which is zero at the centre of the field and increases quadratically with the field angle. The aberration is therefore rotationally symmetric with respect to the centre of the field.

In reality, any telescope is to some extent misaligned. Such a misalignment will introduce additional optical aberrations, first of all the so-called decentring coma. At the NTT, a wave-front sensor is used to measure the aberrations affecting the telescope. The detected coma is corrected by tilting M2 around its centre of curvature.

Since coma is not field dependent, the telescope will then, despite the misalignment, be free of coma over the whole field. But this coma correction is not sufficient for a complete alignment, since the axes of the two mirrors are not yet necessarily coincident. In this optical configuration, the axes of M1 and M2 will actually intersect at the coma-free point (CFP), forming an angle α (Fig. 1). The name

CFP stems from the fact that a rotation of M2 around this point will not change the coma of the telescope. In the NTT, the coma-free point is 1676 mm above the vertex of M2 (which has a radius of curvature of 4417 mm).

The residual misalignment of the two axes will destroy the rotational symmetry of the field astigmatism. This can approximately be described as a shift of the rotationally symmetric pattern of astigmatism away from the centre of the field. The measured astigmatism may then be smaller than in the aligned configuration at some position at the edge of the field, but it will be significantly larger at the opposite side. This will lead, at least in some areas of the field and under good seeing conditions, to a noticeable image degradation compared with the aligned configuration.

2.2 Image quality problems reported at the NTT

Strong asymmetric variations of the image quality under very good seeing conditions were reported for the detector in the red arm of the EMMI instrument where the diameter of the field of view is close to 10 arcmin. The pattern of image degradation was actually fixed with respect to the telescope (and therefore apparently rotated on the scientific detector as the instruments were mounted at the Nasmyth foci).The problem was therefore due to the telescope optics and not to the instrument itself. Any dynamic cause (telescope tracking, vibration, ...) could also be ruled out as the effect on the images was not uniform across the field. This led us to question again the alignment of the M2 mirror. Indeed it had been reported during the Big Bang that the alignment of this element was only marginally within specification (see "News from the NTT" by J. Spyromilio in *The Messenger* No. 87). Most convincing was the fact that such a misalignment would introduce similar effects as the ones measured with EMMI.

2.3 Consequences for the image quality

2.3.1 PSF across the chip

As mentioned earlier, the PSF is quite inhomogeneous across the field which makes any attempt of deconvolution very difficult. This was clearly a strong limitation for astronomers looking for high resolution.

2.3.2 High PSF sensitivity to focus errors

Even in the presence of astigmatism, the images are round when the telescope is at best focus. However, even with a small amount of defocus, image elongations will appear. For a given defocus, the ellipticity will grow with the amount of astigmatism. This means that at the side of the field with the large astigmatism the image elongations will be stronger than in an aligned telescope.

2.3.3 Focus variation measured by the wave-front sensor

The NTT wave-front sensor measures six modes of aberrations (defocus, decentring coma, spherical aberration, astigmatism, triangular coma and quadratic astigmatism). The measurement of defocus is also affected by the misalignment of M2. Indeed the field curvature is corrected under the assumption that the incoming optical beam is centred on the axis of the adapter. This is not true in the case of a misaligned M2 and, therefore, the amount of defocus was not correctly calculated. Therefore, a specific focus sequence had to be executed (either a thorough focus sequence or the use of the focus wedge).

2.3.4 Inaccurate calculation of the on-axis astigmatism

In order not to interfere with the observations, the measurements performed by the wave-front sensor are normally done off axis although the astigmatism to be corrected is the one affecting the centre of the field. To get the corresponding value of astigmatism at the centre, one has to subtract the field contribution from the value measured off axis. A model assuming a rotationally symmetric field astigmatism therefore gave inaccurate results for the on-axis astigmatism.

2.3.5 Out of specification condition for the field lens

The field lens is located between the f/5.3 EMMI red camera and the CCD detector. Its purpose is to compensate the field curvature such that the focal plane is flat over the whole field at the level of the detector. With a misaligned

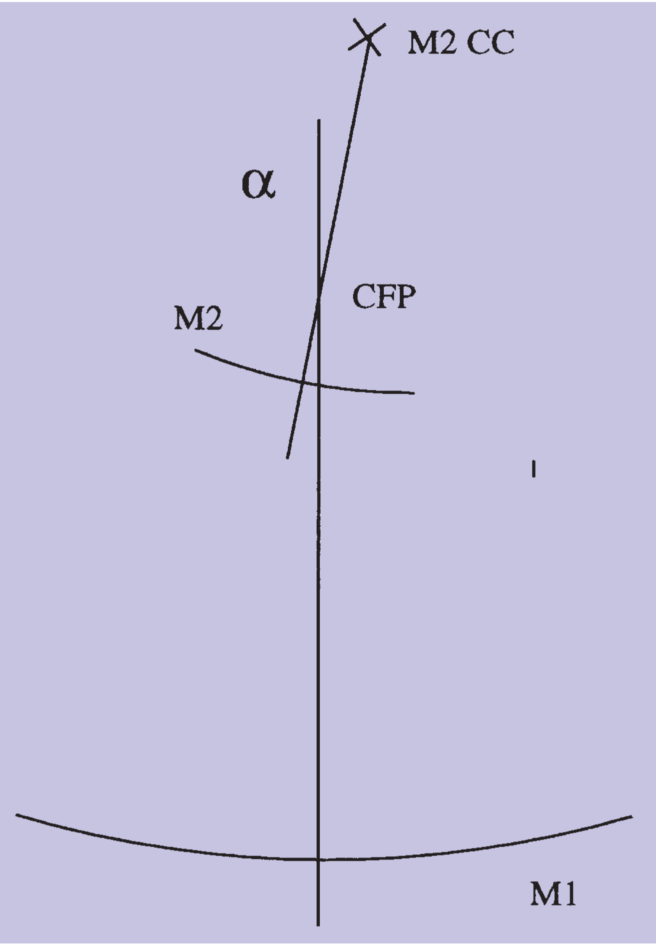

Figure 1: Telescope configuration after removal of coma.

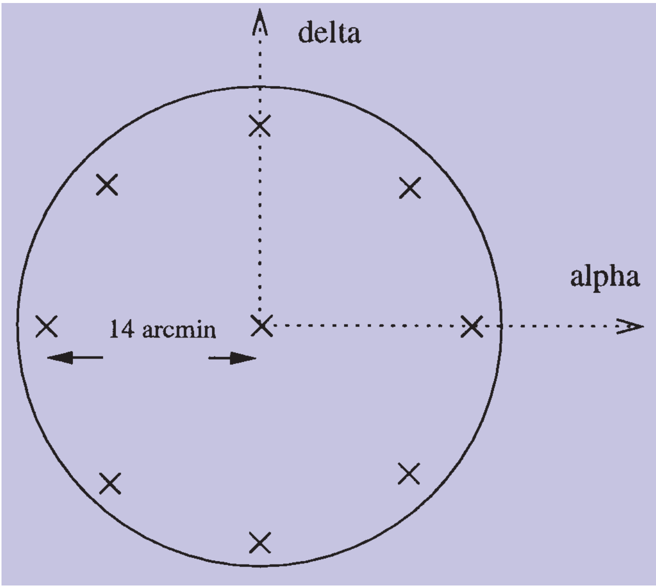

Figure 2: Measurement points for astigmatism mapping.

M2 the field lens did not give the desired result.

3. Wave-Front Sensor as an Alignment Tool

A method presented by B. McLeod [1] uses the measured field astigmatism to calculate the angle by which M2 has to be rotated around the CFP. The original method deduces first the field astigmatism and then the telescope misalignment from the ellipticities and elongation angles of images in the field. In the case of the NTT, this can be greatly simplified by using directly the output data of the wave-front sensor.

3.1 Theoretical basis

In his article, B. McLeod gives an expression relating the astigmatism components (Z_4,Z_5) to the field angle (θ_x,θ_y) for a secondary mirror tilted by an angle (α_x, α_y) around the CFP.

$$Z_4 = A_x + B_0(\theta_x^2 - \theta_y^2) + B_1(\theta_x\alpha_x - \theta_y\alpha_y) + B_2(\alpha_x^2 - \alpha_y^2) \quad (1)$$

$$Z_5 = A_y + 2B_0\theta_x\theta_y + B_1(\theta_x\alpha_y + \theta_y\alpha_x) + 2B_2(\alpha_x\alpha_y) \quad (2)$$

The (A_x,A_y) terms correspond to the residual astigmatism introduced by the M1 support on the primary mirror. The coefficients B_0, B_1 and B_2 are constants depending on the geometry of the telescope. Using the optical parameters of the NTT we get:

$$B_0 = -24.3679\ \mu\text{m/degree}^2$$
$$B_1 = 30.0719\ \mu\text{m/degree}^2$$
$$B_2 = 0.1768\ \mu\text{m/degree}^2$$

3.2 The measurement procedure

In our case, the wave-front sensor allows a direct measurement of the astigmatism vector (Z_4,Z_5) at any position in the field just by moving the guide probe. As shown by formulae (1) and (2), the difference between an aligned and misaligned telescope is larger at the edge of the field due to the linear terms in θ_x and θ_y. In these equations, there are only 4 unknowns (α_x,α_y,A_x,A_y). Theoretically, two astigmatism measurements should be sufficient to deduce the misalignment parameters. Nevertheless, we preferred to perform 9 measurements distributed over the field as shown in Figure 2.

The results of the field astigmatism mapping have then been fitted using a least squares algorithm. The computation is done completely automatically using as input the log file produced by the Active Optics system. Here are the steps performed successively by the programme:

- retrieve guide probe positions and astigmatism measurements (Z_4,Z_5) from AO log file
- convert guide probe positions to field offsets (θ_x,θ_y) in telescope reference frame
- Compute M2 misalignment (α_x,α_y) via a least squares fit.

3.3 Misalignment data

The mapping of the astigmatism was done at both foci. The results are presented in Table 1. σ_{fit} is the residual r.m.s. after the least squares fit. There is a reasonable agreement between the two foci. The averaged misalignment angle is 0.090 degrees. Using equation (1), one can calculate the resulting highest value c_{ast} of the coefficient of astigmatism and the corresponding diameter d_{80} containing 80% of the geometrical energy both at the edge of the detector in the EMMI red arm and at the edge of the field of the NTT (15 arcmin). The value of d_{80} can directly be compared with the *FWHM* values for the atmospheric seeing. The values for c_{ast} and d_{80} are shown and compared with the corresponding values for a perfectly aligned telescope in Table 2.

TABLE 1: Initial misalignment parameters

Nasmyth focus	date	σ_{fit}(nm)	α_x (deg)	α_y (deg)
A	18/01/98	366	0.052	0.074
B	18/01/98	173	0.089	0.087

TABLE 2: Initial astigmatism parameters

	EMMI	EMMI	NTT	NTT
Case considered	c_{ast}	d_{80}	c_{ast}	d_{80}
Perfectly aligned M2	286 nm	0.121″	1520 nm	0.641″
Misaligned M2	632 nm	0.266″	2230 nm	0.940″

3.4 Method for the correction of the misalignment

The active optics system allows to correct the astigmatism affecting the telescope by deforming the primary mirror. Such a correction of astigmatism is uniform over the whole field while the deviation of the astigmatism from an aligned telescope is field dependent. The NTT active optics system is therefore not capable of restoring the optimum rotationally symmetric pattern of the field astigmatism.

Therefore, the only possibility to correct the effects of the misalignment was a realignment of M2, that is a rotation around the CFP. At the NTT, the computer-controlled lateral motions of the secondary mirror are limited to rotations around the centre of curvature of M2. Therefore, the rotation around the coma free point had to be achieved by a combined rotation around the centre of curvature and a tilt of M2 around its pole. The second action could most easily be performed by a rotation of the whole support structure of M2, that is by moving the spiders at the connection points to the top ring.

4. Realignment and Results

The realignment has been performed in February just before the installation of SUSI2 with the help of Francis Franza and Stephane Guisard. Two opposite spider arms were moved in opposite direction at the top ring by 1.3 mm.

New astigmatism mappings have been performed just after the realignment. They gave very good results as shown in Table 3. Overall, the misalignment of the M2 is now 0.018 deg which is 5 times smaller than the previous value. Table 4 shows for this new configuration the astigmatism values at the edge

TABLE 3: Final alignment parameters

Nasmyth focus	date	(σ_{fit} (nm)	α_x (deg)	α_y(deg)
A	12/02/98	157	0.002	0.016
B	12/02/98	77	–0.003	0.021

TABLE 4: Final astigmatism parameters

Case considered	EMMI c_{ast}	EMMI d_{80}	NTT c_{ast}	NTT d_{80}
Perfectly aligned M2	286 nm	0.121″	1520 nm	0.641″
Realigned M2	350 nm	0.148″	1666 nm	0.702″

of the detector in the EMMI red arm and at the edge of the field of the NTT. The small differences both in the coefficients and the d_{80} values at the edge of the EMMI detector between the corrected and a perfectly aligned NTT will be virtually undetectable. Therefore, for all practical purposes, the NTT can now be regarded as a perfectly aligned telescope. The improved optical quality of the NTT has been confirmed by subsequent observers.

Reference

[1] Collimation of Fast Wide-Field Telescopes, McLeod, B.A., 1996, *PASP* **108**, 217–219.

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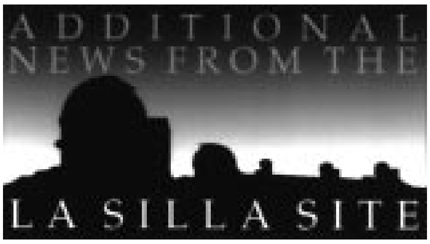

The La Silla News Page

The editors of the La Silla News Page would like to welcome readers of the tenth edition of a page devoted to reporting on technical updates and observational achievements at La Silla. We would like this page to inform the astronomical community of changes made to telescopes, instruments, operations, and of instrumental performances that cannot be reported conveniently elsewhere. Contributions and inquiries to this page from the community are most welcome.
(R. Gredel, C. Lidman)

CES Very Long Camera Installed

M. KÜRSTER, ESO, Chile

After a general overhaul of the Coudé Echelle Spectrometer (CES), its new Very Long Camera was successfully installed between April 9 and 20. It consists of a new f/12.5 camera mirror that was mounted in the frame of the old scanner mirror and an x-y table on new pillars which hold a new 45° folding mirror and the CCD mount. The new Very Long Camera was jointly built by Uppsala Astronomical Observatory (optics) and the University of Liège (mechanics). It replaces the previous Long Camera (f/4.7) which was decommissioned.

During a first series of test measurements with the thorium-argon lamp, resolving powers of R = 235,000 were obtained at different wavelengths. At this resolving power the sampling was determined to be $\approx$ 2.45 pixels/FWHM.

The Very Long Camera will be commissioned during May 14–20 together with the new fibre link to the Cassegrain focus of the 3.6-m telescope and image slicers built by ESO Garching (optics) and ESO La Silla (mechanics). A sliding carriage with housings for up to four different image slicers has already been installed. The slit unit was also integrated on this sledge. The weeks before the commissioning will see the installation of the fibre in the Cassegrain adapter, and the installation of the fibre exit unit in the CES pre-slit area. The latter unit will be movable (with very accurate repositioning capabilities) to permit the continued use of the CAT telescope with the CES.

Improving Image Quality at the Danish 1.54-m Telescope

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The image quality achieved at a telescope depends on many factors, not the least of which is the thermal environment of the dome, telescope, and mirror. During the daytime, the dome, telescope and mirror heat up; at night this heat is released, causing air turbulence which degrades the seeing by causing the starlight to be diffracted along different paths. As part of the seeing improvement campaign at the major La Silla telescopes, it has been decided to address these problems also at the Danish 1.54-m telescope, which was once known for its excellent images (e.g. *The Messenger* No. 17, p. 14, 1979).

After a lengthy period of measurements and analysis by Danish and ESO staff (in particular M.I. Andersen and A. Gilliotte), it was concluded that both charge diffusion effects in the (thinned Loral 2K) CCD and thermal problems near the mirror and in the dome and building were responsible for the currently observed image degradation. Considering that the contract between ESO and Copenhagen University on the operation of the telescope had been extended for a ten-year period from 1996, a substantial investment in reducing daytime heating of the dome, telescope and mirror was found justified.

There are two ways to address this problem. One solution is to estimate the nighttime temperature and to maintain the dome, telescope and mirror at this temperature during the daytime by use of a cooling system. The other solution is to increase the natural ventilation in the