# 5. The Image Quality of the 3.6-m Telescope: Part III

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In this report, in addition to the description of the work performed during the technical nights, a discussion of the current interpretation of the last measurements is given. Further investigation and confirmation is still required. Unfortunately, the nights scheduled at the beginning of August for this purposes have been lost due to inclement weather.

## 5.1 Checking the Lateral and Axial Mirror Supports

As highlighted in a previous report (Guisard, 1996, *The Messenger* No. 83), problems with the mirror support were discovered after the October 1994 aluminisation. This resulted in large aberrations (astigmatism, triangular and quadratic) even at zenith. All the forces of axial astatic levers were checked, they were found to be within 10 kg, except for three of the inner levers which were within 20 kg of the nominal values. The accuracy of the weighting method is about 10 kg, so that all the levers, except the three, have nominal values.

All levers have been moved several times, to ensure that any friction of the axis was eliminated, which could restrain the transmission of the force of the counterweight to the mirror.

The pneumatic lateral supports were also dismounted completely. It appeared that more than half of the supports (11 of 18) had rubber pads that were seriously damaged.

The rubber in the damaged pads was renewed. We now know that this rubber is too thick and too rigid. Problems had appeared after the October 1994 aluminisation when the rubber of all the pads were changed. More appropriate rubber has to be found. Time has been asked in November to replace the rubber on all the lateral supports.

## 5.2 Aberration at Zenith

At zenith, the telescope mirror is supported only by the axial supports. The lateral supports, although in contact with the mirror, should not apply any force to the mirror edge. Otherwise the mirror shape would be deformed and hence the image quality be degraded.

Abnormally high aberration at zenith has been recorded after the last aluminisation in October 1994.

In June 1996, a new set of measurements was made with the lateral supports completely loosened. For safety reasons, only the fixed points were touching the mirror edge but were not tightened. The data are summarised in Table 3 together with the results from October 1994. It can be seen that the resulting aberrations are much smaller.

*TABLE 3: Aberrations*

| | Oct. 1994 | June 1996 Loose | June 1996 Tight 0° | June 1996 10° | June 1996 20° |
|---|---|---|---|---|---|
| Astigmatism | 0.40″ | 0.20″ | 0.20″ | 0.35″ | 0.50″ |
| Triangular | 0.45″ | 0.20″ | 0.20″ | 0.25″ | 0.30″ |
| Quadratic | 0.20″ | 0.10″ | 0.10″ | 0.10″ | 0.10″ |
| Total | 0.65″ | 0.30″ | 0.30″ | 0.45″ | 0.60″ |

After these measurements, the following steps were taken to re-establish the lateral support:

• tightening the lateral fixed points to 50 Nm and then to 70 Nm

• putting the lateral pads in contact with the mirror edge without air

• applying air pressure to the pads

Tightening the lateral fix points or pressurising the pads did not degrade the image at zenith; however, the aberration increases with larger zenith distances, as shown in Table 3. Clearly the telescope suffers from degradation and in addition the aberrations do not always return to the initial value when returning to zenith.

If the lateral supports do not keep the mirror correctly nor push it back into its normal position, stress at the contact points between the glass and the support (lateral and axial) will de-figure the mirror shape. Time has been requested at the end of November to change the rubber of the lateral pads and check the proper operation of the REOSC system.

## 5.3 Measuring the Spherical Aberration at the Cassegrain Focus

In the technical nights in June, measurements of the spherical aberration of the 3.6-m telescope were also performed, by using both, Antares and the Curvature Sensing method (Roddier, 1993). These preliminary data show that the correct focal plane of the telescope is 12 cm below the actual focal plane.

The idea of the presence of spherical aberration at the 3.6-m telescope came out from the analysis of the Antares data, taken after 1991, whose results are summarised in Table 4. A spherical term is present, although with variable amount.

At first, noise and imprecision in the Antares measurements were suspected, but now we know that there are several reasons to believe that the Antares measurements are reliable:

1. Measurements made with Antares on other telescopes like the NTT and the 2.2-m show that the spherical aberration is smaller than 0.1″. We know the quality of the images these telescopes can provide.

2. On February 9, 1996, the spherical aberration was 0.5″ with Antares, a direct CCD gave a FWHM of 0.73″. A seeing monitor inside the dome measured 0.5″ of combined site and dome seeing. If we consider the Antares value (0.5″), the dome and outside seeing (0.5″), and the usual residual aberrations at zenith (0.3″) we come up with a total image quality of about 0.7″, which is what was measured with the direct CCD.

3. During June 29, 1996, intra- and extra-focal images were taken and analysed, using curvature sensing software. The analysis gave an average value of

*TABLE 4: Spherical Aberration*

| Date | Value in nm | d80 in % | # of Measurements |
|---|---|---|---|
| 21.07.91 | 5700 | 1.10″ | 14 |
| 22.07.91 | 4900 | 0.93″ | 19 |
| 24.08.93 | 4600 | 0.87″ | 52 |
| 19.10.94 | 6300 | 1.20″ | 10 |
| 21.10.94 | 4800 | 0.91″ | 30 |
| 24.10.94 | 6000 | 1.14″ | 32 |
| 21.01.95 | 6300 | 1.20″ | 11 |
| 22.01.95 | 6600 | 1.25″ | 20 |
| 23.01.95 | 4900 | 0.93″ | 21 |
| 09.02.95 | 2700 | 0.51″ | 8 |
| 06.04.96 | 4200 | 0.78″ | 23 |
| 28.06.96 | 3800 | 0.72″ | 48 |
| 29.06.96 | 2800 | 0.53″ | 34 |
| 30.06.96 | 2000 | 0.38″ | 18 |
| 01.07.96 | 3200 | 0.61″ | 9 |

0.56″ of spherical aberration, similar to the 0.53″ given by Antares.

4. Measurements made during May 1996 with ADONIS by P. Prado and E. Prieto showed that the spherical aberration was between 0.5″ and 0.6″.

In addition, during the June nights, the following measurements were done with Antares:

At the nominal focus, 0.56″ of spherical aberration was found, 30 cm below the nominal position, 1.0″ was measured and at 10 cm below the nominal focus, a negligible spherical was found (0.11″). Both 3rd-order calculations and computer simulations showed that, to remove 0.5″ spherical at this telescope, one has to move the focal plane down by 120 mm. This coefficient (240 mm/″) corresponds to what was measured by Antares in June and also corresponds to the coefficient given by Ray Wilson (237 mm/″). We know now how much we have to move the focal plane to correct a given spherical aberration. But first we have to confirm the value of the residual spherical aberration. F. Franza and B. Delabre measured 0.27″ in 1982, however, we do not know the exact conditions under which this value has been obtained. Since February 1996 we have measured spherical aberrations of the order of 0.5″.

Although we can now trust the Antares measurements, the apparent variability of the spherical term (see Table 4) has still to be understood. Ray Wilson suggested that this could be produced by mirror seeing. This interpretation is very appealing, but it is not easy to understand how this can be produced in practice, because these layers would be required to have the size of the pupil, and in addition, remain stable over one night. There are at least two possibilities:

(a) The mirror is enclosed in the centre piece. Stable layers of air could be formed more easily above the mirror, inducing a spherical term.

(B) There is a direct influence on the beam, at the level of the Cassegrain adapter. One year ago, a heat source (rotator encoder) was spotted only 30 cm away from the beam inside the adapter. This source could have been a cause of “variable” spherical term. The Cassegrain hole is now insulated to shield off this heat source.

In addition, during the last months, mirror cooling has been applied, and this could explain why the “spherical” term never reached very high values. Substantially, Ray Wilson’s interpretation seems very attractive; in this case the spherical aberration would be the product of a misplacement of the focal plane, combined with a (variable) component induced by mirror seeing or air instabilities along the light path. Of course we have to confirm this by carrying out much more measurements and simulations.

There is still a lot of work to do, however the goals should be achievable. Of all the traditional 4-m-class telescopes, the 3.6-m has certainly the best intrinsic optical quality, but it does not give the best images – not yet.

## 6. Pointing Model

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The pointing of the 3.6-m has been erratic for a long time: pointing models were repeated quite often and an individual model was needed for each instrument. What was more worrying, the model was not stable in time.

In the last two years, several changes occurred, both from the operational and from the physical point of view. The models are now performed by starting from scratch (and are not anymore incremental); stiffening of the spider has been applied, and the new TPOINT (Wallace, 1995) software has been made available. Several pointing models have been repeated during the last year, as frequently as possible, with all instruments and top-end configurations. The results are summarised in a report (available in the WWW page of the 3.6-m+CAT TT).

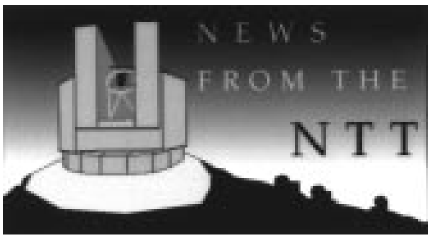
Substantially, the behaviour of the telescope is quite regular, and pointing models with an RMS of less than 10″ are obtained by using only a limited number of physical parameters (14), without the need of polynomial terms.

Models performed before and after the June 1996 intervention, of course, are different, but they remain stable with time, largely independent of instrument and top-end exchanges. The parameters used are indeed the same for the 3 instruments at F/8.

Although these performances are not yet comparable with the best pointing telescopes, they are satisfactory for the instrumentation presently available at the 3.6-m telescope. Some physical limitations exist at the moment on the telescope (i.e. hysteresis in the secondary unit); however, we think that these performances can still be improved by refining the measurement technique, and by collecting enough data to search for second-order terms.

### 7. Acknowledgement

During this technical time at the 3.6-m telescope both shifts of the Mechanics Support Team have been involved at the same time, together with the staff of the Telescope Team, putting in a lot of effort to accomplish the mission and to cope with all the unpredictable. Special thanks shall be given here to both teams!




*The NTT upgrade project has the following goals:*

1. *Establish a robust operating procedure for the telescope to minimise down time and maximise the scientific output.*
2. *Test the VLT control system in real operations prior to installation on UT1.*
3. *Test the VLT operations scheme and the data flow from proposal preparation to final product.*

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This article is being written at the end of August during the second phase of the NTT upgrade project. I am pleased to be able to describe some of the activities undertaken while the NTT has been off-line. For those not wishing to read much further, the short news is that we are progressing according to the detailed daily schedule with some tasks running one or two days ahead of time. In the context of the overall aims of the project and the critical question of “when will the NTT be back on-line?” such minor variations do not have any significant impact. However, the adherence to the schedule during the hectic first couple of months suggests that we have correctly budgeted for the time needed.