The Image Quality of the 3.6-m Telescope (Part IV) Better than 0.6″

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With this fourth article we will bring to a conclusion the first part of our study which started in September 1995. This part concerns the study and improvement of the image quality (IQ) at the Cassegrain focus of the 3.6-m telescope at Zenith. The second part, started a few months ago, studies the IQ at larger zenithal distance.

In this article we will explain how the IQ at zenith could be brought from 1.2″–1.3″ to less than 0.6″ during test time over the last twelve months. The goal was to obtain subarcsec images with good outside seeing (0.6″–0.7″) and to be able to go down to 0.8″ at the telescope during periods of outstandingly good external seeing (0.4″). Both objectives have been largely achieved. We first present the results of the August and October test nights. The parameters that contribute to the IQ in general have previously been detailed [1] and the most relevant ones with respect to the degradation of the IQ at the 3.6-m are reviewed here as well as the methods to minimise their effects. In the forthcoming months, changes will be made at the telescope to implement these improvements during regular observing time. The IQ that one can expect in the future is presented at the end of this article.

1. Results from the August and October Test Nights

For these nights (August 30, and October 8 and 18, 1996), the IQ measurements were made as usual [1] except that:

• the focal plane of the telescope was shifted 166 mm down to compensate for 0.6″ d80% (the diameter of the circle containing 80% of the light) of spherical aberration.

• forced ventilation on the mirror has been used.

The IQ values are summarised in Table 1. This table can be compared to the table published in an earlier article [1]. Of particular interest are the very good results obtained during the last October night, where images (30 to 120 seconds exposure) with IQ as good as 0.58″ were taken.

TABLE 1.

	30/08/1996	08/10/1996	18/10/1996 beginning	18/10/1996 end
Average outside seeing	0.40″	1.12″	0.75″	0.43″
Average 3.6-m	0.73″	1.16″	0.83″	0.66″
Best value 3.6-m	0.67″	0.99″	0.75″	0.58″
Worse value 3.6-m	0.81″	1.34″	0.90″	0.78″
Number of measurements	22	27	19	22
Optical quality	0.55″	0.40″	~0.40″	~0.40″

Calculations show that for all these nights the IQ was limited by outside seeing, remaining optical quality and pixel size, and not by dome and mirror seeing. Relative to the October nights, the degraded optical quality of the August night is explained by the aberration hysteresis which we are studying at the moment and which prevented us from getting the same results as the last night.

2. Optical Quality

2.1 Spherical Aberration

The existence of spherical aberration at the Cassegrain focus was hypothesised in the last article [2], but was still waiting for confirmation. The most recent set of tests (August and October 1996) were all done with the position of focal plane 166 mm lower than the usual one and confirms that spherical aberration was present at the old focus position.

Another concern was the variability in the spherical aberration values measured (see [2], Table 4) despite the fact that spherical aberration is a “strong” aberration. Part of this variability is caused by the M1 mirror cell but still needs further investigation (part of the IQ study at large zenithal distance). A second cause is mirror seeing. This idea was proposed by Ray Wilson and has now been proved. The proof is outlined below in the section discussing mirror seeing.

Nevertheless, these two effects do not appear to fully explain the long-term variability of the spherical aberration as measured by Antares since 1991 [2].

Antares (a Shack-Hartmann wavefront analyser) and curvature sensing (intra- and extrafocal image analysis) measurements show that the residual spherical aberration at the new focus position (166 mm below the old one) is less than 0.15″ (d80%), whereas it was measured to be between 0.6″ and 0.8″ by Antares at the old focus position. We therefore confirm that the spherical aberration is a limiting factor of the IQ at the actual instrument position.

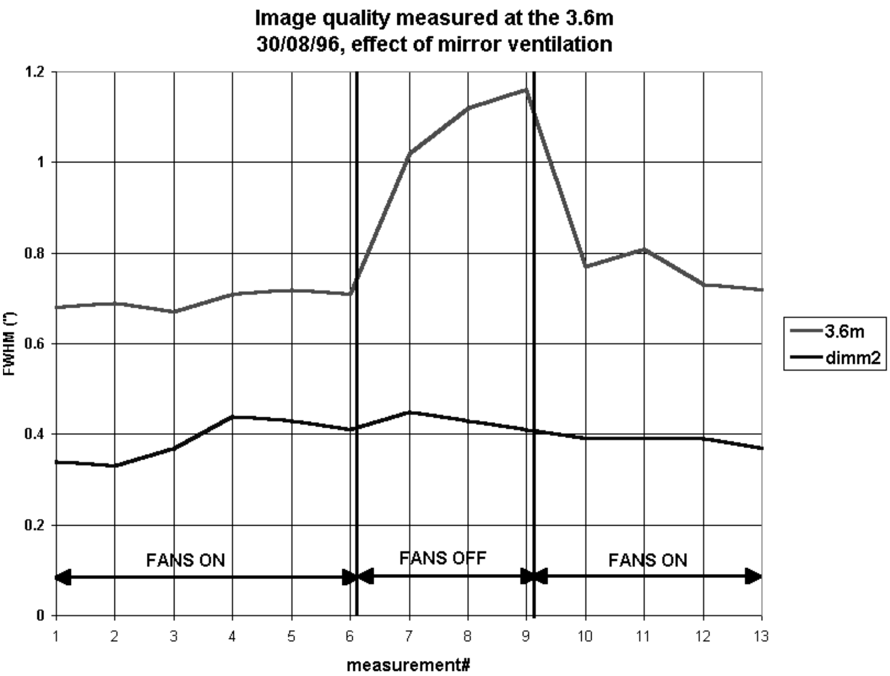

Figure 1.

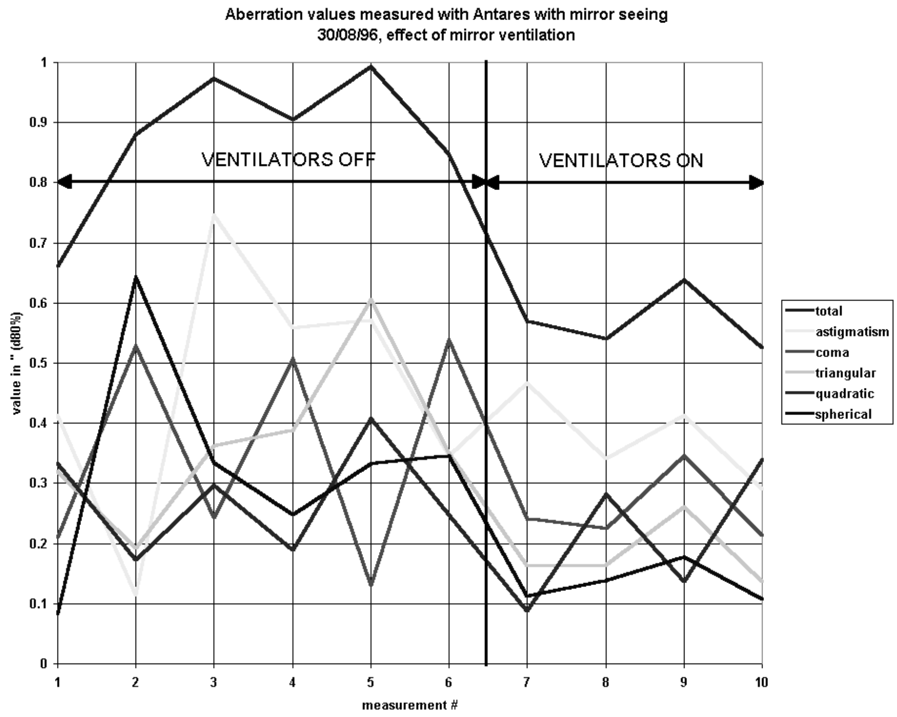

Figure 2.

2.2 Other Aberrations

As already written [2], triangular coma, astigmatism and quadratic astigmatism at zenith are now within the range of values we used to have before the October 1994 aluminisation (respectively <0.2″, <0.2″ and <0.1″ d80%). This improvement occurred after the June technical time. These aberration values have been confirmed with the curvature sensing method and Antares in August.

3. Mirror Seeing

3.1 Effect on IQ

For the first time it has been possible to prove the existence of mirror seeing, quantify its effect and remove it. This has only been possible thanks to the relocation of the mirror cover, done during June technical time [3]. This change allowed the installation of a very powerful ventilation system above the main mirror. This system was used for the first time during the August test night. Although the mirror temperature was 2 degrees higher than the ambient air, we were able to obtain good images (see Table 1). In fact the ventilation system eliminated all mirror seeing (estimated to 1.1″) during these nights. This was proved when the ventilation system was switched off (see Fig. 1). The IQ measured at the telescope increased from 0.7″ to 1.2″ in only a few minutes. It came back to 0.7″ a few minutes after the system was switched on again.

3.2 Effect on the Aberration Values Measured by Antares

The effect of mirror seeing is illustrated in Figure 2, and explains the variability and the size of the aberrations as measured by Antares. In the presence of mirror seeing, Antares gives high and noisy values. When the mirror seeing is removed (ventilation system on), the aberrations come back to the expected values and the noise in the measurements decreases.

4. Other Effects

• Dome seeing: a dome-seeing monitor was installed at the beginning of the year. Significant dome seeing has never been detected since then. The most recent test nights also showed no dome seeing, so we can say that we do not have a major dome-seeing problem at the 3.6-m. Previously, it was said that this was the major source of IQ loss. Recently, efforts to control the thermal environment of the telescope were initiated. This included a better floor cooling strategy, removal of heat sources, and the installation of cooled electronic racks [3], etc. Although we believe that dome seeing is not a problem, we will remain conscious of the thermal environment of the telescope. All temperature values will be available at any time via the new TCS–GUI (Telescope Control System – Graphical User Interface) system. The dome seeing monitor will remain installed so that dome-seeing measurements can be performed at any time.

• Guiding accuracy: a quick check of the guiding accuracy was done in August. A 5-minute exposure with 0.69″ IQ was obtained. In comparison with the 30-second images taken immediately before (0.69″ also), this demonstrates that the telescope guides accurately.

5. Expected IQ in the Future:

We have shown that during night tests we can obtain good images with the 3.6-m. In the coming months, two significant modifications to the telescope will occur so that the IQ obtained with the instruments also improves. These changes are:

• A special flange to lower the instruments to the new focal plane will be manufactured in order to remove spherical aberration. This implies that modifications to the instrument-handling tools and perhaps to the Cassegrain cage will be required.

• A ‘clean’ ventilation system shall be installed. The principal concern is that dust may quickly dirty the mirror and

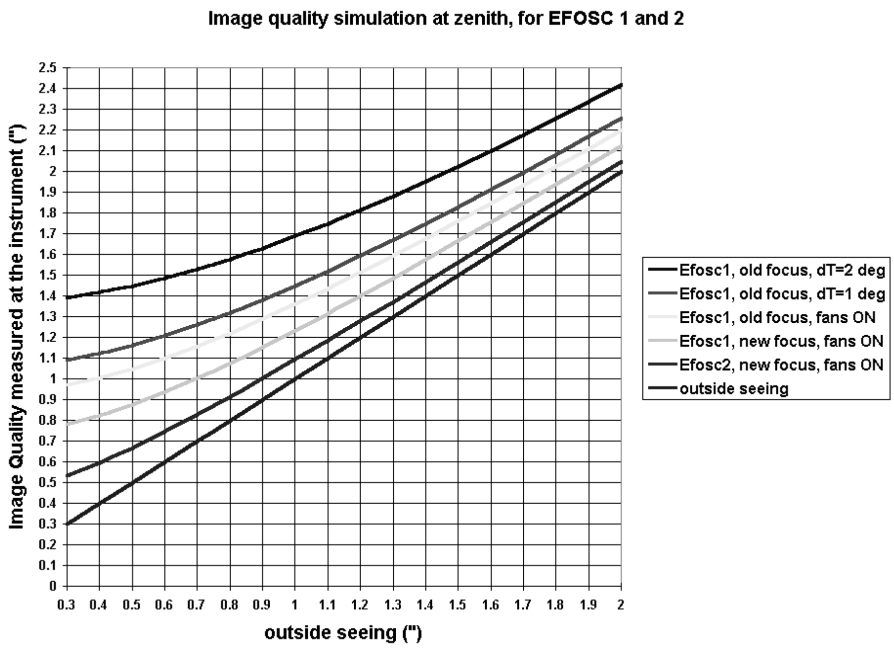

Figure 3.

may also fall down the Cassegrain hole onto the instrument optics or onto slits.

Figure 3 shows the expected IQ one should obtain with EFOSC 1 and 2 at zenith according to the outside seeing value, for different mirror-seeing conditions and focal-plane positions. The six curves represent, from top to bottom:

1. The IQ with EFOSC1 at the actual focus position, with the mirror 2 degrees hotter than the ambient air.

2. Same as 1 but with 1 degree mirror seeing only.

3. Same as 1 but without mirror seeing (or with the ventilation system on).

4. EFOSC 1 at the new focus position with the ventilation system on.

5. EFOSC 2 at the new focus position with the ventilation system on.

6. Outside seeing value.

The first two curves are in fact the IQ we now have. The ventilation system should bring down these curves close to the third one. Moving the instruments down shall also give a substantial improvement to the IQ of the order of 0.1″ to 0.2″ as demonstrated by curve 4. However, we see that the IQ will be mainly limited by EFOSC1 pixel size (0.6″). The installation of EFOSC 2 (0.19″/pixel) at the 3.6-m next year will improve further the IQ by 0.15″ to 0.25″, providing of course that the instrument does not degrade the images. This fifth curve is in fact the curve we measure now with the direct CCD (0.19″/pixel) at zenith during the night tests with the new focus position and the M1 ventilation system working.

6. The IQ Study Keeps On Going

Very good results have been obtained at zenith (Zd < 30 degrees). The second part of our study will now aim to achieve good image quality far from zenith (Zd $\sim$ 60 degrees). This includes work on activating M2 to compensate for telescope flexure and improvements to the support of M1.

In the meantime, the shift of the focal plane and the ventilation system will be implemented so as to give the expected IQ with the instruments at the Cassegrain focus.

References

[1] S. Guisard, "The Image Quality of the 3.6-m Telescope: Part II", *The Messenger* No. **83**, March 1996.

[2] S. Guisard, "The Image Quality of the 3.6-m Telescope: Part III", *The Messenger* No. **85**, September 1996.

[3] J. Fluxa, G. Ihle, S. Guisard "Report on the Technical Time in June 1996", *The Messenger* No. **85**, September 1996.

[4] S. Guisard, "Report on the night test, 29th and 30th August 1996", 3.6-m+CAT Upgrade 3P6-PLA-032-008, September 1996.

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