La Silla Telescope Status, a Great Achievement on Image Quality Performances

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Nowadays almost all La Silla telescopes deliver very good image quality, routinely achieving sub-arcsec images. In some cases, the theoretically predicted performances of the telescope is matched, or the limitations are at least understood.

The image quality, however, is not only a function of the telescope optical set-up, it is also highly dependent on the cleanliness of the optical surfaces.

Main Mirror Maintenance

Five years ago, systematic cleaning of the primary mirrors using CO_2 was implemented on the major telescopes: the NTT, 3.6-m, 2.2-m and Danish 1.54-m. Main mirror cleaning is now carried out by the telescope team as part of the routine maintenance operation. The only restriction with this process is that the humidity cannot be too high. Indeed, high humidity causes the condensed water surrounding each cold CO_2 particle to stick the dust to the mirror surface, resulting in an accumulation of dust on the mirror.

A mirror water washing operation, performed by the opticians, was also implemented about three years ago. The best period to wash the mirrors is the end of the summer, when the high humidity is decreasing and hence the frequency of the CO_2 cleaning was disrupted. The mirror washing was first implemented on the NTT, whose mirror cell was designed for such a process, then on the 3.6-m and is soon to be carried out on the 2.2-m as well.

The optimal frequency of the CO_2 cleaning, resulting in clean mirrors without too much time spent on the operation, was found to be one week. The NTT was the test bench for the process with the mirror surface maintaining good reflectivity for a three-year period with the regular CO_2 cleaning and four "in-situ" washings (Fig.1).

Aphotograph of the washing operation at the NTTis also presented in Figure 2.

All the above-mentioned telescopes were realuminised during the year 2000 and the reflectivity is still above 88% at 670 nm with low roughness. The 2.2-m main mirror suffered some water contamination during the bad winter period and a first washing is scheduled for the near future. Recently, the 3.6-m main mirror also suffered water contamination from cooling liquid, and the washing is already scheduled end of March.

The status of the mirror is verified on a monthly basis with a measure of the R% and roughness. A database of the mirror status for the main telescopes will soon be available on the La Silla web site.

Telescope Image Quality

About nine years ago, the awareness of the observer towards the image quality increased and the quality delivered by the 3.6-m was found insufficient because the improvements in the performance and dynamic range of the detectors showed more accurately the image quality achieved by the telescope. With the availability of wavefront sensors – the first one available was a Shack-Hartmann type called Antares – the optical quality of the telescope was measured more often, and more precise aberration information was obtained. On several occasions, large aberrations were identified. The spherical aberration, often mistaken for seeing quality, appeared clearly and only the decentring coma was adjusted after measurements performed only on zenith. It was found that almost all third-order aberrations were affecting the telescope. The most critical issue concerned the instability of the aberrations at different telescope orientations as well as with changes in temperature. A dedicated study with eventual periods of closed telescope was really compulsory. In 1994, a complete study of the 3.6-m with a contracted optical engineer on La Silla was initiated to determine the status of the telescope and to find a way of improving it.

During this process, we gathered considerable experience in solving problems with the telescope, but also a deeper knowledge of the limitations of the telescope was reached. The 2.2-m, Danish 1.54-m and the NTT have all benefited from this exercise. Of course, the active optics concept, greatly demonstrated with the NTT, allowed a better understanding of the local thermal contribution.

The contributions of dome and mirror seeing were identified and a solution to decrease both has been found.

Thanks to all the La Silla staff for their ongoing interest and success in improving the image quality at the telescopes on site.

The NTT Status

This telescope delivers the best image quality on La Silla with the active optics system fulfilling all expectations. Initially, the limiting factor for this telescope was found to be the image quality of the La Silla site. Now, after a long period of operation, more image quality limitations have appeared. To monitor the image quality, the NTT has a distinct advantage over the other telescopes as repeated image analysis is made during the observations. All re-

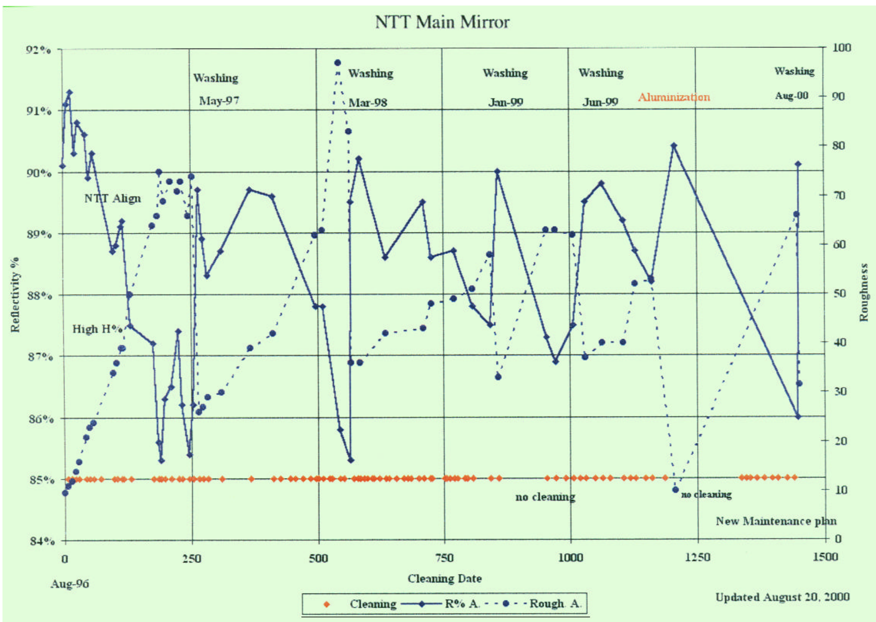

Figure 1: The variation of the reflectivity (R%) and roughness of the NTT main mirror during the period from August 1996 to August 2000.

Figure 2: The NTT main mirror being rinsed with distilled water. The last washing step before drying the mirror surface.

sults are logged in a database, and statistics can be performed with respect to external meteorological conditions or other parameters. The image quality generally becomes poorer when the wind speed is below 5 m/s or if the temperature is dropping rapidly as demonstrated by Figure 3a.

Several recommendations were made to the NTT team to improve the image quality:

– Install high flux fans to produce artificial wind to reduce mirror seeing.

– Install a new M2 baffle with open shade to avoid warm bubble formation.

– Improve the air conditioning in the instrument room to avoid a positive gradient.

– Install a Nasmyth shutter to close the optical path not in operation.

The new baffle and fans have been installed and the new results already show a substantial improvement in the image quality (cf. Fig. 3b).

The air-conditioning of the instrument rooms was slightly improved but an optimal solution could not be implemented because of high cost.

The timing of a complete image analysis and mirror correction cycle is unfortunately long in comparison with the VLT active optics system. On some occasions, more frequently than before, the active optics is not converging properly. Hence the telescope does not always operate in closed-loop correction. Some efforts should be undertaken to reach the same operational mode as used on the VLT.

A complete maintenance of the astatic levers is underway to recalibrate and readjust each lever. For perfect imaging quality at the zenith, each lever must be adjusted to the medium range of the counterweight move, and the spring compensation tuned to compensate the spherical aberration constant term. This time-consuming operation will be performed during 2001.

The possible upgrade of the active optics will also include a standardisation of the present software to comply with the latest version at the VLT.

The 3.6-m Status

Excellent work at the 3.6-m has resulted in improved image quality due to the minimisation of the spherical aberration, triangular and astigmatism contributions, even when the telescope is inclined. In addition, the dome and mirror seeing contributions are now almost negligible. The main limitations affecting image quality are the coma instability when moving the telescope far from the zenith. Astigmatism is still slightly high, with a contribution coming from the axial fixed points. A new design of the axial fixed point contact on the mirror back side is compulsory to reduce a lateral stress applied on the mirror.

A new support for the M2 unit is currently under study. It will mainly be a copy of the present NTT M2 adjusting support. The improvement to image quality will be significant, with the coma variation kept under control at a low value. We are still awaiting the green light to build and implement this new unit.

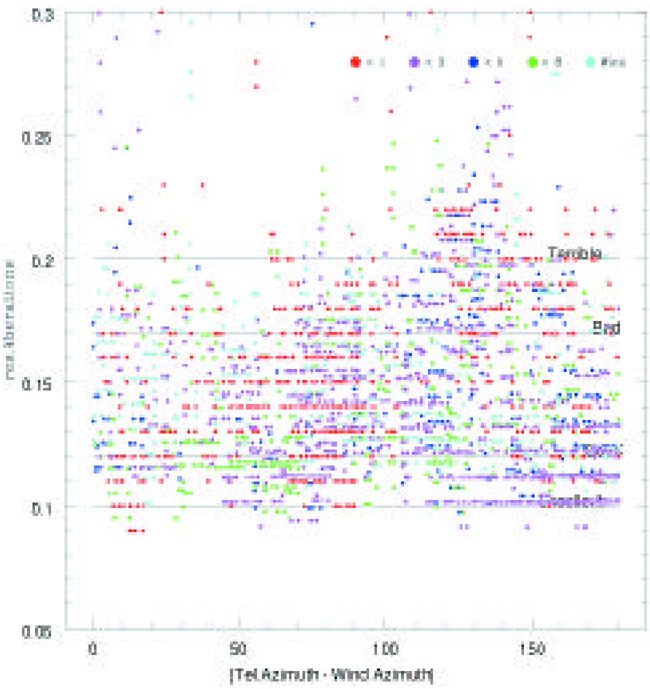

Figure 3a represents the "fitting" residual variations (non-modelised 7 first aberrations) of the image quality with NTT dome position relative to the wind direction as well as the wind speed. Colour code of wind speed is at top of figure in m/s.

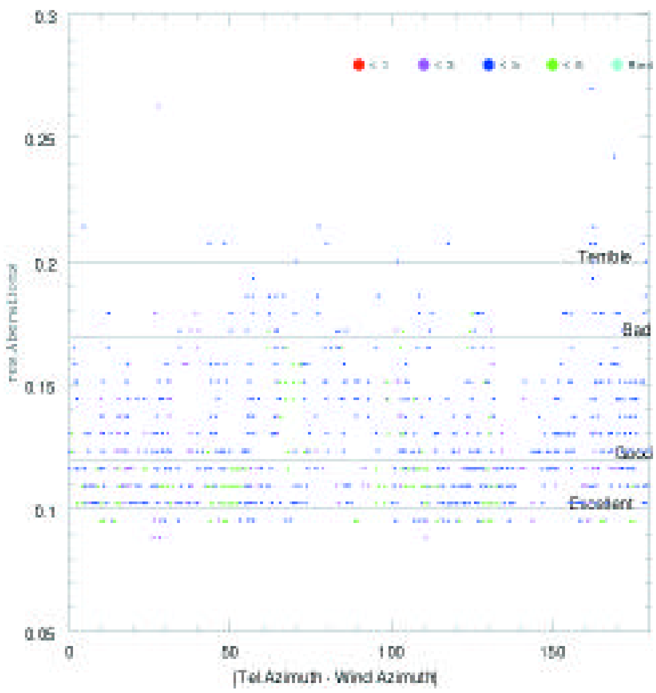

Figure 3b corresponds to the same layout as Figure 3a, after installation of the new baffle and fans.

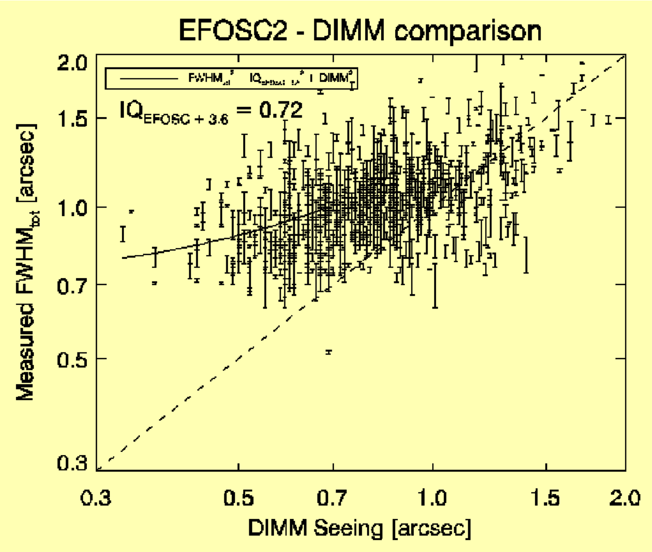

Figure 4 shows that the image quality is, on several occasions, better than that measured by the Dimm monitor. Local site effects and the mirror fans are most likely the reason for the better seeing measured at EFOSC2 on these occasions. Image quality can be as good as 0.6 arcsec and ranges up to 1.5 arcsec, with the coma variation being the main reason for the measured spread in EFOSC2 seeing quality.

coma terms are almost stable and below 0.2 arcsec.

The telescope focus has been shifted to compensate the high constant term of the spherical aberration. However, the variability of this aberration was not confirmed at the time when the amount by which to shift the focus was decided. Although the right correction may not have been applied, observers are not reporting poor image quality. The main limitation of image quality at the Danish 1.54-m is still the instrument detector sampling. Even after the recent detector changes (October 2000), the sampling of 0.81 arcsec (2 pixels of 0.015 mm with a scale of 27 arcsec/mm) is often reached when the night seeing conditions are around or below 0.6 arcsec. (The previous CCD suffered from diffusion transfer increasing in fact the pixel size.)

The present status of the image quality at the 3.6-m, despite the two remaining limitations, is already within the objectives fixed at the beginning of the study. We have achieved the goal of 0.9 arcsec within 60 deg Zenithal Distance and image quality as good as 0.6 arcsec has been measured with EFOSC2. The EFOSC2 sampling limit of two pixels is now often attained.

For the last few months, the EFOSC2 image quality is logged together with the external seeing. Figure 4 speaks for itself about the present quality of images. The EFOSC2 image quality is already acknowledged by the ESO community.

The Infrared mode of the telescope with the F/35 chopping M2 mirror has also been improved. The image quality obtained at 10 and 20 microns with the new TIMMI2 is diffraction limited.

The 2.2-m Status

During 2000, the telescope has been greatly improved with the large decrease in the contribution from astigmatism. A separate article describes these activities.

Observers often report the image quality as very good, and sub-arcsec images are often obtained when the outside seeing is good. The limiting resolution of the Wide Field Imager pixel size is often reached when the seeing is below 0.5 arcsec and the mirror colder than the outside air.

Image quality limitations still exist but are more related to thermal contributions rather than opto-mechanical features.

The Danish 1.54-m Status

The ongoing problem of the spherical aberration varying with the temperature has been studied again. Experience gained on the 3.6-m, NTT and 2.2-m presented a possible explanation of this challenging feature. Again, the opto-mechanical mirror support seems to be guilty and the behaviour of the axial fixed points with temperature variations is the most probable explanation. A bending effect at the mirror edge, where the spherical aberration is more sensitive, could produce the 0.3 arcsec variable term of this aberration. The defocus, astigmatism, quadratic and

Pending Issues

A further step on improving the image quality of the telescopes will be considered this year. A large part of the stray light level affecting the depth of the image, is related to the telescope baffling quality as well as the cleanliness of the optical surface. At least three cases must be considered, the first case is when there is a high density of bright stars in the field, the second when there are very bright objects close to the target and the last case when there is a bright star almost alone in the field. The improvement of the telescope baffling will reduce at least the second case. The others depend primarily on the light diffusion by the optical surfaces. Of course, the mirror polishing quality improved dramatically between the construction of the 3.6-m and the VLT, but this benefit could be easily lost if the cleanliness of the mirror surface is not ensured.

The baffling status of the 2.2-m, the NTT and the 3.6-m telescopes must be verified and recommendations will be issued.

Image Quality Improvement of the 2.2-m

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Historical Overview

On the very first period of operation of the 2.2-m telescope, a direct CCD camera was offered to the community. With a pixel size of 0.35 arcsec and a small field of 3 arcmin, the telescope image quality was never reported as being bad or showing asymmetric, elliptical images. In the mid-1990s, a new imaging instrument called EFOSC2 was installed at the telescope. Observers soon began seeing variable image elongations across the full field, which were later identified as coming from the instrument and not the telescope. Meanwhile, the optical quality of the telescope was measured to be as good as 0.35 arcsec d80% close to zenith, using our portable Shack-Hartmann called Antares. The optical quality of the EFOSC instrument was strongly dependent on the precision with which focus had been achieved, and subsequent variations with temperature. The EFOSC camera focus did not include temperature compensation as was the case with EFOSC1 on the 3.6-m. The focus degradation introduced field curvature and increasing