Recent Improvements in the Optical Quality of the La Silla Telescopes

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Last spring the Director-General of ESO, Professor Woltjer, asked the Optics Section in Geneva to investigate systematically the optical quality of all the La Silla telescopes and make any necessary improvements to bring all instruments up to the maximum of their potential. Of course, we have been concerned with the 3.6 m telescope throughout its construction and installation, but the extension to the other telescopes was a major new commitment, requiring considerable time and effort as well as the understanding and cooperation of our colleagues in Chile.

The more stable a telescope, the better it will perform and the less maintenance it will require to keep it "optically" in good condition. Thus the new 1.54 m Danish telescope should be a very favourable case with its single Cassegrain configuration, whereas the 3.6 m telescope with its three observing stations and multiplicity of inevitably complex equipment is clearly a much more difficult instrument to maintain.

We have put the word "optically" in inverted commas above for a quite specific reason. The "optics" of a telescope are intrinsically quite stable elements: unless they are scratched, chipped or broken, the elastic properties of the materials of which they are made *guarantee* that they retain the same intrinsic characteristics they had when leaving the optical manufacturer. But the intrinsic optical quality, which is determined by the optical design and the manufacturer's skill, will only be realized in practice if the telescope mechanics are functioning correctly where they impinge on the optics, namely in support systems and mechanics affecting the relative centering of elements. The sort of errors that can be induced by such *mechanical* defects as distinct from intrinsic optical defects are discussed in detail in ESO Technical Report No. 8. Maintenance of telescope optics is, in fact, simply a specialized form of *mechanical* maintenance to prevent the occurrence of these defects, mainly coma, astigmatism and image tilt.

3.6 m Telescope

At the beginning of 1978 there were complaints from users that the earlier excellent optical quality at the prime focus had deteriorated. This was not altogether surprising in view of the volume of work and frequent changes inevitable with the commissioning of the telescope for routine observation. Plates showed a variable situation indicating mixtures of image tilt (tilt of the plateholder to the beam), astigmatism and coma. This situation was investigated last April.

The astigmatism and coma were found to be due to leaks in the air feeds to about a third of the lateral support cushions of the prime mirror. This had three effects. First, the mirror was incorrectly supported, particularly in certain azimuths, in inclined telescope positions, leading to astigmatism in such inclinations. Secondly, the inadequate support caused the mirror to slip sideways on inclination of the telescope which produced massive asymmetrical forces at the lateral fixed points. This also produced astigmatism which, since the mirror did not necessarily slip back when the telescope was restored to the vertical position, was often also present in the zenith position. Thirdly, the lateral side slip produced decentering coma of variable amounts. After correction of these leaks and application of a suitable preload to the lateral fixed points, there has been no further evidence of prime mirror slippage. Careful measurements have been done here with probes, also at the top unit. Another possible source of slippage—of the PM cell at the flexion bars—has also been dealt with.

The image tilt error was caused by a mechanical defect in the pedestal (the unit supporting the PF adapter) of the top unit. It was known that a basic error existed in the focusing system causing a tilt and this had been provisionally corrected by a wedge spacer which had not been mounted with the intended orientation. Last October, this tilt error was corrected at its source in the focusing system and all flanges checked, the temporary spacer wedge being removed. The final result was very satisfactory—a maximum tilt error of less than $2\frac{1}{2}$ arcmin for the least favourable pedestal rotation. This was measured by a sighting telescope mounted below the Cassegrain adapter and a plane mirror in the plateholder. This tilt error is below the tolerance (3 arcmin) even for the larger field of the triplet corrector, soon to be installed.

Such operations require much mechanical handling and are very time-consuming. By comparison, centering of the telescope in the prime focus is a relatively simple matter in which we now have much experience. The centering is performed by translating the pedestal, which includes the corrector whose optical axis must be brought into coincidence with that of the prime mirror, by the "x-y movement". The amount and direction of the movement necessary is determined by what we call "pupil plates" to distinguish them from "focus plates". The principle of this method has been known for at least as long as high-quality Cassegrain telescopes have existed, but its precision when applied photographically is surprisingly good. It is essentially the same as a Hartmann test but the "screen" is simply the two concentric circles defining the outside of the pupil and its central obstruction. If the image is defocused to give an image of about 2 mm (this seems about the optimum in the prime focus), the form of the pupil can easily be measured in a projection device. Coma displaces the inner circle relative to

Fig. 1 (ESO 3.6 m telescope): *(Pl. 1 p) "Pupil plate" for the 3.6 m telescope showing 0.6 arcsec of decentering coma. A corrector translation of 1.4 mm was required to correct this. (Original image diameter ca. 1.5 mm.)*

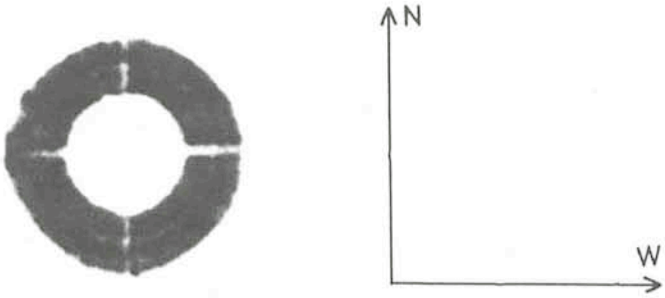

Fig. 2 (ESO 3.6 m telescope): *(Pl. 3 p) "Pupil plate" for 3.6 m telescope after centering to <0.3 arcsec of coma. The judgment of symmetry of the pupil was made at 45° to the spider to avoid local turbulence disturbance. (Original image diameter ca. 1.5 mm.)*

the outer one. By applying certain conversion factors, the coma and the necessary shift of the corrector can be deduced from this asymmetry. It is also possible to determine other defects from such pupil plates, notably astigmatism and spherical aberration. The precision obtainable depends on the seeing, particularly the "internal" dome seeing which gives pupil distortions which cannot be integrated out by longer exposures.

Figure 1 (Pl. 1p) shows a typical pupil plate before recentering, corresponding to 0.6 arcsec of coma and requiring a shift of 1.4 mm of the corrector. *Figure 2* (Pl. 3p) shows the result after final centering—the residual error here is < 0.3 arcsec and is near the limit of detectability with the moderate seeing at the time.

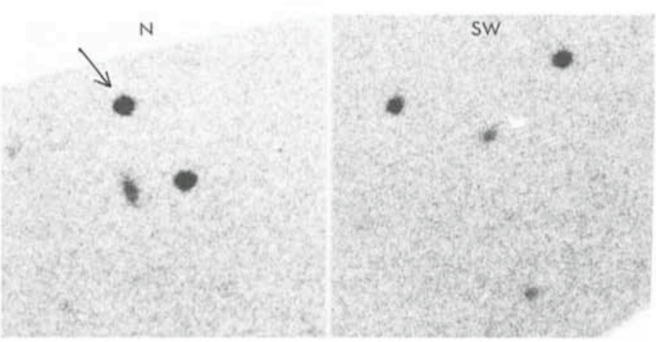

Fig. 3: *Two fields from the extreme edge of a plate taken with the 3.6 m telescope at the prime focus by Hans Schuster of NGC 55 (45 min on baked IIIa-J with filter GG 385). At the extreme edge of the field in the N direction (left field), slight asymmetry of star images is detectable on the original where the theoretical edge field coma (ca. 0.25 arcsec) has vectorially approximately* added *to the small decentering coma residual (ca. 0.25 arcsec uniform over the whole field). The second field in the SW direction shows no detectable asymmetry on the original because the coma vectors have approximately* subtracted.

Figure 3 (Pl. 8p) shows a test photo of NGC 55 kindly taken and guided by our colleague Hans Schuster using a baked IIIa-J plate with filter GG 385. The exposure time was 45 mm and the zenith distance about 20°–25°. The seeing estimate was about 2 arcsec and the smallest images are about $1\frac{1}{2}$ arcsec. At the edge marked with the arrow, it is possible on the original to detect a slight asymmetry due to coma. This corresponds to the side of the field where the residual decentering coma (about $\frac{1}{4}$ arcsec, and constant in amount and direction over the whole field) adds up vectorially with the theoretical residual of the corrector field coma (about $\frac{1}{4}$ arcsec at the edge of the field and radially directed towards the centre of the field). This demonstrates that, even with moderate seeing, very high centering precision is worthwhile if top-quality results are desired.

Centering in the Cassegrain focus must be done by tilting the secondary until coma compensation is achieved. We found that the tilt necessary was slightly beyond the tilt range provided. This is a sign that the "collimation error" (angle between the normal to the δ-axis and the sighting direction of the telescope) exceeded considerably the original tolerance. This was not surprising since the basic alignment to the δ-axis had not been repeated because of lack of time. But the result was that we had to leave 0.45 arcsec of uncorrected decentering coma in the Cassegrain—not a large amount but more than the tolerance for optimum performance with good seeing. It is intended to repeat the basic alignment and centering next July to correct this, an operation anyway essential for the subsequent coudé installation.

Apart from this small residual centering defect in the Cassegrain system, the optical performance of the telescope is excellent.

Danish 1.54 m Telescope

The optics for this telescope was figured by Grubb-Parsons under most exacting test procedures. It was therefore with considerable confidence that we set about the basic adjustment of the optics last November, with excellent cooperation from our Danish colleague, Johannes Andersen. The result of a detailed alignment procedure was a final collimation error of the centered telescope of < 0.25 arcmin.

Centering was then performed by "pupil plates". *Figure 4* shows a pupil plate for the zenith after centering to a coma of < 0.3 arcsec and similar plates for inclinations of about 45° in the S, N, E und W directions. The negligible variation of coma proves the excellent mechanical rigidity of the telescope.

The qualitative evidence of the image quality (under moderate to indifferent seeing conditions) indicated that it was very good. Hartmann tests were intended but could not be

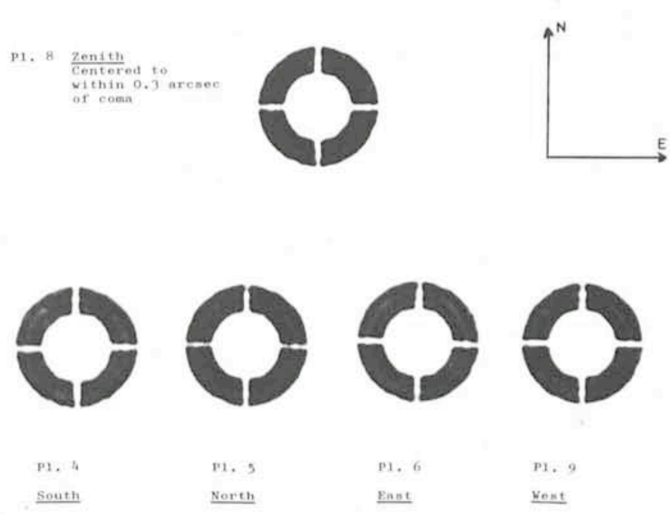

Fig. 4 (Danish 1.54 m telescope): *After centering in the zenith to the quality shown in Pl. 8, the telescope was inclined at about 45° in all four directions. The pupil plates show a negligible variation proving the excellent mechanical stability of the telescope. (Original image diameter ca. 2.5 mm.)*

carried out because of more pressing work on the autoguider. They will be performed later. Subsequent photos with the McMullan camera, printed elsewhere in this *Messenger,* have confirmed that this is a telescope of first-rate quality.

1 m Photometric Telescope

The 1 m telescope has been the subject of complaints for a long time regarding image quality and stability. Above all, its performance was erratic and alignment was not maintained. We suspected that most, if not all, these problems were attributable to the state of the prime mirror cell. We were most fortunate in having with us last November Jan van der Ven who had designed this cell fifteen years ago while working at Rademakers in Holland! With his help, it was found that the prime mirror had probably never been correctly mounted in the cell and that certain minor mechanical modifications were necessary to facilitate correct mounting. After 3 days of hard work (including weighing the mirror on a wonderful balance constructed by Jan, to make sure the support loads were set to an optimum) the primary was correctly mounted in its cell and the telescope ready for test during the one available night. Unfortunately, the seeing was rather poor, particularly within the dome due to the disturbance of the day-time work. The centering was done, as before, with pupil plates, but the quality of the pupil plates, even integrated for 4 m, was poor. Also, the judgment of the plates was made more difficult in the N-S direction by a small mechanical vignetting of the pupil whose origin we had no time to trace. Nevertheless, centering within about 0.3 arcsec was still possible. *Figure 5* shows the results. Pl. 3 shows the final centering state after two iterations of correction. Pl. 4 to 7 show results with the telescope inclined in various directions. There is evidence of coma variation in the W plate (zenith distance ~ 50°) indicating a small error in the performance of the tube (Serrurier truss); but the astigmatism of about 1.2 arcsec is more serious. The present evidence is that astigmatism appears in a constant direction (independent of telescope azimuth) following the spider on inclining the telescope, but the *amount* increases with telescope inclination. The evidence suggests the cause is in the secondary support but there was no time to investigate this further—we hope to do so next August.

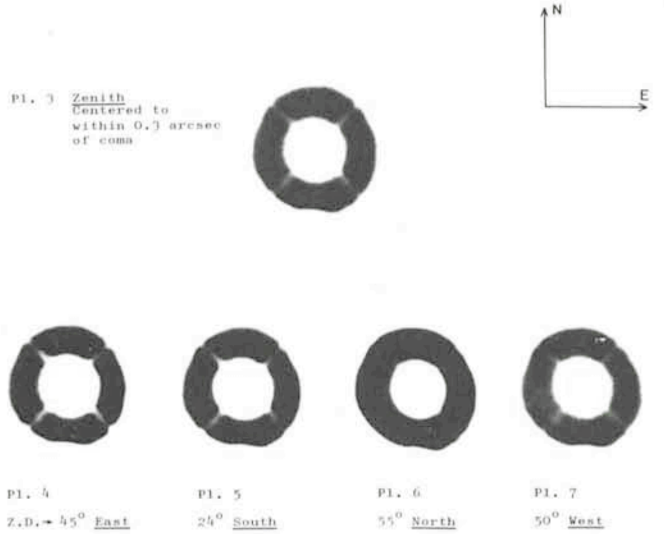

Fig. 5 (ESO 1 m photometric telescope): *After centering in the zenith to the quality shown in Pl. 3, the telescope was inclined at the zenith distances shown in the four directions. The pupil plates in the inclined positions show astigmatism up to 1.2 arcsec in the N and W positions and some coma in the W position (Serrurier truss error). (Original image diameter ca. 2.5 mm). Note that both dome turbulence and external seeing were very bad, giving poor quality pupil image. Note, too, the vignetting at the south edge of the pupil.*

ANNOUNCEMENT

ESO Workshop on Two-Dimensional Photometry

Subjects include microdensitometry of photographic and electronographic plates, panoramic detectors, calibration and data-acquisition problems.

The workshop will take place on 21–23 November 1979 in Leiden (the Netherlands). It is organized by Prof. H. van der Laan (Leiden) and Prof. P. O. Lindblad (ESO-Geneva). Participation by invitation.

Interested persons may contact Prof. Lindblad.

The reproducibility of centering between Pl. 3 and Pl. 8 seems to confirm that the telescope is at last *stable* and maintaining its adjustment. Stability is obviously a sine qua non of satisfactory telescope performance.

1.5 m REOSC Telescope

We had been asked to look at this telescope as well. Unfortunately, the time allotted was in parallel with our 3.6 m time, so we could hardly devote any time or effort to the 1.5 m. Our colleague in Chile, Paul Giordano, did some excellent work checking and readjusting the axial support system of the primary. Some thought was put into improvement possibilities for the unsatisfactory radial support system. There was no time available to mount and try out a new support for the secondary mirrors, intended to provide easier adjustment.

Examination of the image in and out of focus revealed a clear triangular error probably due to the primary radial support and a decentering error apparently varying with focus. The performance seemed stable.

Considerably more time and effort will be needed to get this telescope into an optimum opto-mechanical state.

Conclusion

We have attempted here to give an idea of the work programme for the maintenance and improvement of the optical quality of some of the La Silla telescopes. Our most grateful thanks are due to many colleagues on La Silla who helped us, in particular Paul Giordano and Jan van der Ven, as well as Jan's colleagues in the Mechanical Group. What has been done so far is only a modest beginning: one of us (R.W.) is going to spend a whole year in Chile from next June to pursue the matter with all the telescopes in a more concentrated effort. But it should be remembered that this improvement is only possible if the necessary telescope time is made available. A modest investment in telescope time *now* should save this time many times over in the future by ensuring that astronomers have telescopes functioning as they can and should, giving maximum efficiency use. In general, unreliability of performance or poor quality images cost far more observing time than their systematic correction would require.

Finally, an appeal to our friends, the user astronomers. It will be an immense help and always greatly appreciated if you will contact us directly in Geneva with any comments, suggestions or questions regarding the optical quality of the telescopes on La Silla: you will be helping us to help you!