Fine Telescope Image Analysis at La Silla

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With the arrival of the NTT at La Silla a new and powerful instrument for telescope testing was added to our telescope alignment facilities.

The automated Shack-Hartmann instrument mounted with a CCD detector was developed for the NTT quality analysis required for the prime mirror surface correction and secondary mirror movement of the active optics concept.

A portable version of the Shack-Hartmann has also been developed under the name of ANTARES.

During the last year, all La Silla imaging telescopes have been tested. The Antares software has been improved and it is possible now to obtain in only a few minutes the third order aberrations (spherical aberration, coma, astigmatism, . . .) of the telescope optics. A map representation of the higher order "aberrations" over the telescope pupil is also available and we commonly call it the map of residuals.

The telescope analysis power of Antares is very high and often complex to interpret. Antares results indicate all optical aberration effects occurring in the telescope light beam, including the pure aberrations of the optical system and the thermal (bubble or convection) high-order aberrations. Antares analysis gives a complex and accurate average of the optics and the light beam aberrations.

With a large number of analyses, Antares results may be more easily divided into the two separated aberration effects, the telescope optics (mirror deformations and collimation errors) and the thermal activity (bubbles and convection effects in the light beam).

The experience gained over the past year has confirmed the importance of the Antares analysis; not only can the telescope be better aligned, but precise information about the thermal effects has also become available.

The light beam thermal activity depends on three effects: the external seeing (normally averaged with as correct integration time of the star image exposure), the dome seeing and the local air effect or mirror seeing. With appropriate, precise temperature measurements performed during the Antares analysis, a measure of the dome seeing becomes available and improvements are then possible. We already note a dramatic decrease of the high frequency aberration residuals for the classical dome when the dome slit is turned towards the wind direction (ventilation effect of the heating source in the dome). A minimum of 5 m/s is required to ventilate correctly the dome. A wind stronger than 15 m/s increases the telescope instability and produces oscillations. With no wind the telescope quality is dominated completely by the thermal contribution.

On a few occasions, stable thermal effects attributed to local air motions disturbed the telescope aberrations over a period of more than 30 minutes. Spherical aberration, astigmatism and coma can be affected strongly by the local air (air bubbles). Convection of a warm main mirror surrounded by cold air increases drastically the high frequency aberrations and the rms residual can rise to a bad value close to 1 arcsec. The residual maps performed for each sequential analysis show inconsistency in this case. Averaging of all residual maps shows the stable local defects over the telescope pupil attributed to mirror figuring errors (although there is no information about which of the mirrors).

Almost all telescopes tested suffered from spherical aberration. The Antares analysis allows a correction of the spherical effect by a modification of the instrument position along the telescope axis. Discrepancies between theoretical and real matching of primary and secondary mirrors produced the spherical errors. Antares is the best tool to adjust properly the primary-secondary mirror separation, thereby determining the nominal telescope focus position where the entrance reference surface of all instruments must be located. The principle of telescope focusing for different instrument positions by moving the secondary mirror is wrong. Telescope focusing should be used only for compensation of small mechanical changes of the telescope structure due to temperature variations.

Telescope quality testing has also been performed successfully with Antares at other Observatories.

The basic telescope quality is generally good (except for the too large spherical aberration); 80 % energy is concentrated within subarcsec values and the thermal effect dominates mostly the final telescope quality.

It is now fundamental to avoid too much thermal activity in the telescope area if high imaging quality is wanted. All heat sources must be removed and a good dome ventilation (with air fans) will improve the air exchange between the exterior and the dome. NTT analysis experience has shown how it is possible to improve the dome design.

However, it would be best to use the telescope without any dome at all!

The Dust War

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Telescopes on terrestrial sites suffer of an unavoidable phenomenon disturbing high-quality astronomical observations: Dust pollution.

By the term dust we include all different kinds and sizes of organic and mineral particles. Effects on astronomical observations can be really critical. A great deal of progress has been made recently to improve the optical quality of modern ground-based telescopes and it is quite easy to keep the telescope performances at a consistent level of high optical quality. We must preserve high signal throughput and low noise level. Regular cleaning will increase the lifetime of the coating and optical surfaces, thus improving safety by reducing also the frequency of handling.

Past experience at La Silla shows that the average loss of mirror reflectivity is of the order of 10 % per surface and per year. Our present recoating periodicity is of the order of 2 to 2½ years. A loss of reflectivity of 35 % after two years also means that even with very good seeing conditions the dust contamination becomes the main factor reducing the performance. Image contrast is also reduced by optical surface diffusion and the surface emissivity produces serious contrast and sensitivity limitations on IR observations.

A monthly cleaning procedure will remove 90 % of all the limiting effects above listed. Recoating frequency will be decreased to four-year intervals. The longer interval is also fundamental in maintaining the quality of polish, which is inevitably reduced by cleaning for aluminization.

Dust deposition is not only a direct effect from our atmosphere, contamination rates increase also drastically with human activity on the telescope area. Dust lies on the optical surface and, after a period of months with varying climatic conditions, the dust adheres to the surface by either physisorption or chemisorption. Adherence force may reach more than 100 g with physisorbed submicron-sized particles. Organic or even mineral dust may become glued to the surface by chemisorption with water or condensation solution droplets. Severe localized mirror corrosion may occur producing the spots, transparent to light, classically seen on old aluminium mirror coatings. Then the dust removal becomes impossible by air blowing only and washing (with mechanical action) is required to overcome the sticking forces of the dust particles.

Two directions must be pursued to limit dust contamination: We must first try to decrease the dust rate deposition by avoiding unnecessary dirt-producing activities in the telescope and instrumentation areas. Then a periodical cleaning of optics must be scheduled to remove the direct dust contamination before either physisorption or chemisorption have fixed the particles on the surface.

It is an easy matter to obtain rapidly a growing awareness of the importance of keeping telescope and instrumentation areas as clean as possible. Opticians will have the important task to survey the dust contamination and to perform careful optical part cleaning.

Figure 1: *CO_2 cleaning.*

Systematic and thorough cleaning of the dome and telescope structures have been operating for half a year with the help of all the La Silla team. Awareness of cleanliness requirements of all people involved in telescope work will be the major challenge of high-performance optics.

Two optical surface cleaning techniques will be used at La Silla: The pure carbon dioxide snowflake jet is used on a monthly basis to remove the dust accumulation over the surface. This method is a rapid and easy-to-use technique; only a few minutes are required to clean a four-metre-telescope mirror. Time is consumed only during the cleaning preparation (CO_2 bottle with adequate pipe length to reach the mirror). CO_2 liquid is throttled through a nozzle and expanded at atmospheric pressure into a special plastic tube oriented with around 45° inclination towards the mirror surface. The resulting snowflake jet removes dust without any damage of the aluminium surface, the flakes slide over the surface on a cushion of CO_2 gas and leave no residues behind. Dust is removed with different physical effects from those of a gas blowing and particles sticking over snowflakes crystals. The procedure is applied on an inclined mirror (telescope orientation greater than 45° Zenithal distance) and gravity allows dust and residual snow to move down and out of the mirror surface. Figure 1 shows the cleaning method. Some dust residuals remain on the surface (physisorbed submicron-sized particles with the strongest sticking forces), the CO_2 cleaning allows a reflectivity increase to 90% of the fresh coating.

The peeling technique allows an almost complete reflectivity recuperation. However, application on large surfaces is delicate and time consuming. We foresee a peeling cleaning every year or every six months, depending on future

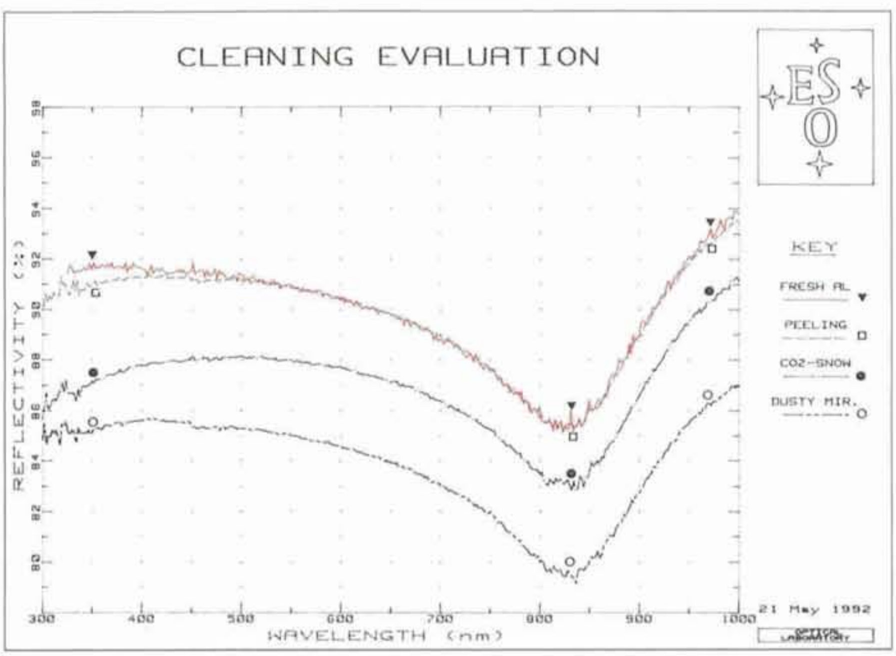

Figure 2: *Comparison of cleaning techniques.*

experience. Fortunately, lacquer products are now available in spray cans which will simplify the application.

Various cleaning tests have been performed either at La Silla or Garching. Figure 2 shows the cleaning efficiency of the CO_2 snowflake and peeling technique on a mirror exposed to dust contamination. Recent scattering and reflectivity measurements have been performed on test mirror samples with four conditions of the mirror surfaces, the original coating being protected with a cover to obtain the reflectivity and scattering reference of data, half the dirty surface then cleaned with CO_2 jet and peel-off-lacquer. The results confirm the efficiency of the two procedures.

A project for an automated pilot CO_2 cleaning device for the NTT main mirror is at the stage of a call for tender at the ESO Headquarters. Mirror cleaning will be performed with CO_2 snowflake jets on a rotating arm.

Cooperation concerning the cleanliness of the observatory, telescopes and instruments will be greatly appreciated. Maximum efficiency in astronomical observations make these efforts mandatory.

Adaptive Filtering of Long Slit Spectra of Extended Objects

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1. Introduction

In both galactic and extragalactic astronomy, long-slit spectroscopy has proven to be a useful tool to study the physical properties of extended objects.

In the last two decades, CCD detectors coupled to spectrographs, while on the one hand simplifying some aspects of the processing of 2-D spectra – such as, for instance, the need for correcting the S-distorsion introduced by the image tubes –, on the other hand have allowed to reach fainter light levels thus arising the need for a careful removal of all sources of noise.

One of the most extreme examples is the study of the kinematical properties of the stellar component in early type

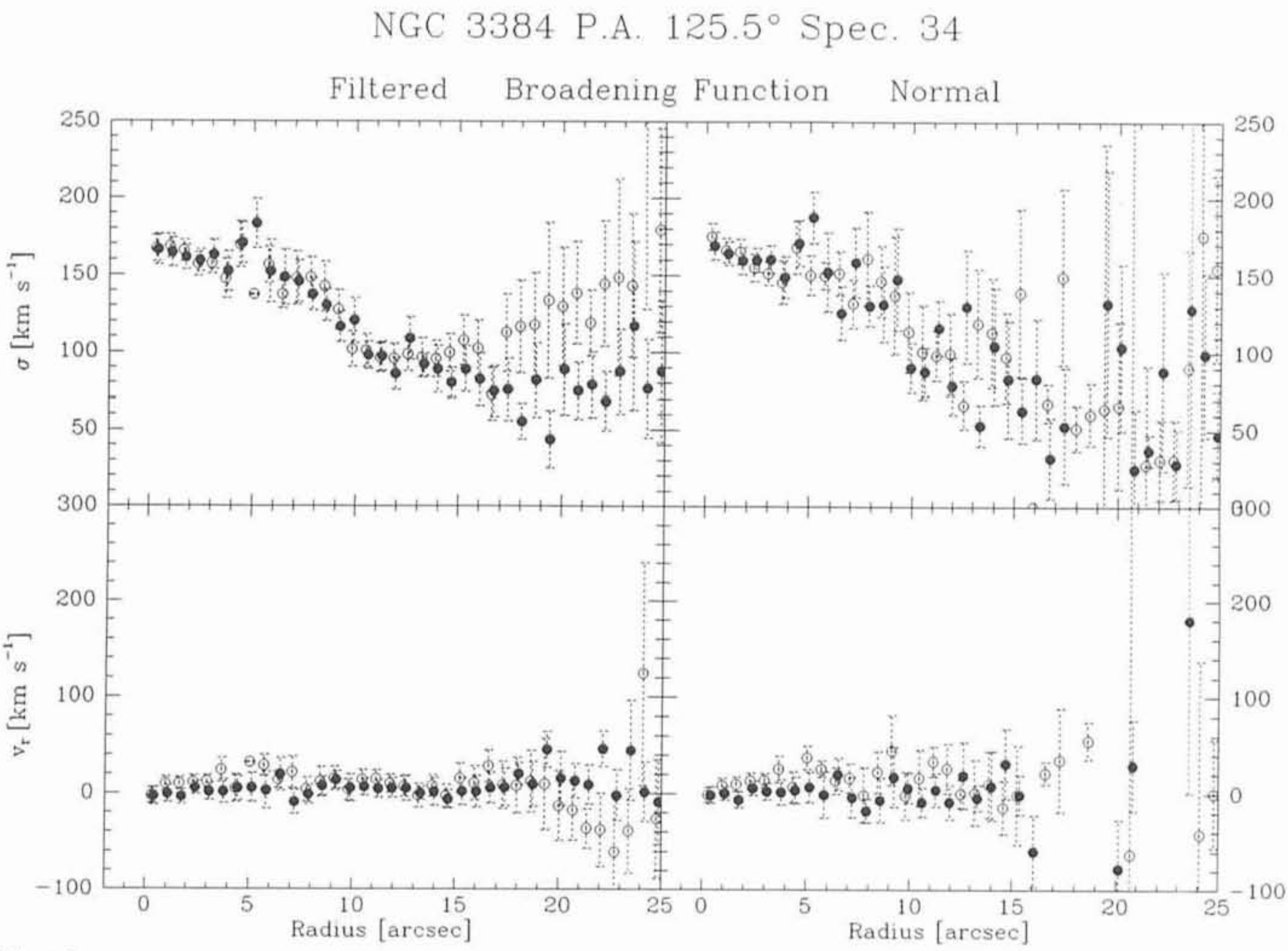

Figure 1.