IMPROVEMENTS AT THE 3.6 M TELESCOPE

A summary of the 3.6 m image quality improvement is presented with the latest M2 upgrade and its results.

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In the early days of the 3.6 m the delivered image quality was not optimal. Image quality analysis was done almost always at the zenith using the "pupil plate", a photographic method with defocused images. The image quality was not verified systematically at positions far from the zenith. Coma aberration was corrected by a time consuming mechanical and manual re-collimation of the M2 tilt. Other aberrations were present but found to be unstable and with unclear origins at that time. Mechanical analysis of the telescope flexure performed during the 1980s showed incorrect behavior of the top unit with hysteresis pattern (Figure 1).

Observations at the Cassegrain focus using CCD detectors have brought to light further limitations on image quality. The use of a seeing monitor confirmed large differences between the atmospheric seeing and that of the 3.6 m. On average, by the early 1990s, the 3.6 m image quality was above 1 arcsec.

Using a portable wavefront sensor (Shack-Hartmann) with a CCD detector we started a systematic campaign to investigate the image quality. The first results obtained in 1991 confirmed the degradation of the image quality as a function of Zenith distance (Gilliotte, 2001).

Several concerns were identified as: (1) Thermal effects were clearly important to the image quality stability. Defocus, spherical aberration, tilt (image stability) and also astigmatism terms contributed, to the total image quality up to 1 arcsec when the telescope dome area was warmer than outside; (2) Coma, triangular and astigmatism aberrations changed, as a function of telescope position. Values up to 0.9, 0.5 and 0.6 arcsec were seen; (3) A constant value of spherical aberration was measured (around 0.5 arcsec).

The graph in Figure 1, prepared in 1991 by a mechanical engineer (J. Cheng), illustrates the different contributions to the total measured displacement of M2 with respect to M1. It was clear that the telescope image quality needed to be improved.

The 3.6 m Upgrades

In 1995 the goal of the 3.6 m upgrade project was to obtain a sub-arcsec image quality of 0.9 arcsec over 120 deg solid angle for the average site seeing. Following detailed studies almost all telescope parts and the dome were subject to this intervention. The dome and mirror seeing were reduced by minimization of heating sources in the dome, dome air cooling, and forced ventilation in front of the mirror. The spherical aberration was corrected by lowering the focal plane by 166 mm.

Triangular aberration (up to 0.4 arcsec at 60 deg zenith distance) was found to vary with telescope elevation and a modification of the M1 cell was made. This aberration was reduced below 0.2 arcsec by means of constant force components (springs) on the M1 axial astatic levers. A new wavefront sensing method was used by means of direct CCD observations (Curvature Sensing).

During the 1990s, all efforts were oriented towards the main mirror cell and the thermal environment problems (cf. Gilliotte, 2001). By 2000 the image quality of the telescope was still limited by the coma instabilities (up to 0.6 arcsec). Close to the zenith the telescope delivered an image quality of 0.7 arcsec at best.

New instruments (HARPS) and the increasing demand for high spatial resolution observations (0.16 arcsec for EFOSC2) provided the incentive for further image quality improvement. Upon completion of the M1 cell upgrade a new project to improve the M2 unit started in 2001.

The M2 Upgrade

The following goals defined the requirements: (1) Remote collimation of M2 for coma correction; (2) Coma must be better than 0.1 arcsec after applying the collimation correction; (3) Minimization of residual telescope flexures and related hysteresis; (4) Correction of the M2 focus instabilities.

The Coudé M2 unit support and the NTT M2 collimation concept were used as starting points. A new complete top ring was built. A pantograph design was used for the M2 support allowing the M2 to tilt around the center of curvature by means of an x, y translation table.

The new unit was installed in August 2004 and immediately gave an improvement in image quality and ease of focusing operation. However hysteresis on the coma variation was still observed, preventing a precise collimation correction. The M2 cell was then the last untouched part of the 3.6 m and possibly responsible for the residual behaviour. A complete maintenance of the cell including a realuminization of M2 was performed in November 2004. Additional unexpected sources of instability in coma and astigmatism were identified and corrected.

Optical Quality Results

The results obtained after the November 2004 intervention demonstrate that the 3.6 m telescope finally delivers an excellent image quality. Figure 2 illustrates the coma variation with respect to the S-N axis of the telescope. This axis has the strongest coma aberration. The residual coma hysteresis disappeared completely.

Figure 3 shows the total aberration variation on the full sequence S-N-W-E without M2 collimation correction. The final image quality in terms of classical optical aberrations is less than 0.4 arcsec, with a very small

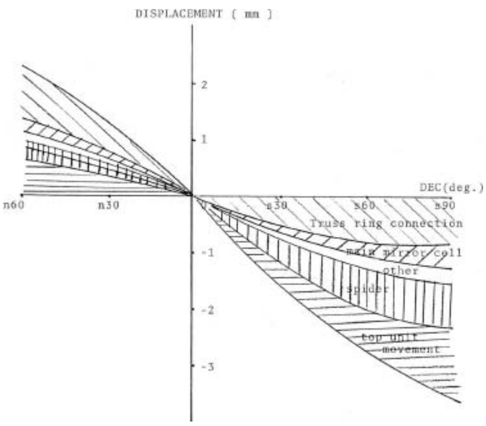

Figure 1: M1/M2 relative displacement with Declination.

amount of residual coma (< 0.2 arcsec) without collimation correction (< 0.1 arcsec with collimation correction). The main residual term is the astigmatism (as expected), contributing 0.35 arcsec when pointing far to the north.

Science Results

During the last months the improvement of the image quality of the telescope has been clearly noticed in EFOSC2, CES and HARPS observations.

The EFOSC2 seeing is measured in terms of image size and has been logged for several years. It includes telescope and instrument image quality and atmospheric seeing. In Figure 4 the evolution of the EFOSC2 seeing versus the corresponding measurements of the seeing monitor is presented. This graph covers several EFOSC2 runs. Each vertical band corresponds to one observing period. The red squares represent the seeing monitor value, while the blue squares correspond to the EFOSC2 image size in the y direction. During the most recent runs, the EFOSC2 measurements were comparable to the seeing monitor values down to 0.45 arcsec. Before the M2 upgrade the seeing as measured in EFOSC2 science images would not reach values lower than 0.7 arcsec, being limited by the telescope image quality.

HARPS observers have also noticed the improvement in image quality, gaining up to 40% more flux with respect to the pre-M2 upgrade times. In Figure 5 the gain in efficiency after the two M2 interventions (August 2004 and November 2004) is illustrated. Horizontal lines indicate average values.

The benefits of the new M2 unit are also noticed from the operational point of view: focusing operations are simpler and faster and coma aberrations can be corrected by remotely re-collimating the secondary mirror, although this option is only needed when observing to the extreme north. Since the November 2004 intervention, coma (< 0.2 arcsec) is independent of telescope pointing direction.

We look forward to many years of smooth operation and excellent image quality with the 3.6 m telescope.

Acknowledgments

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References

Gilliotte, A. 2001, The Messenger, 103, 2

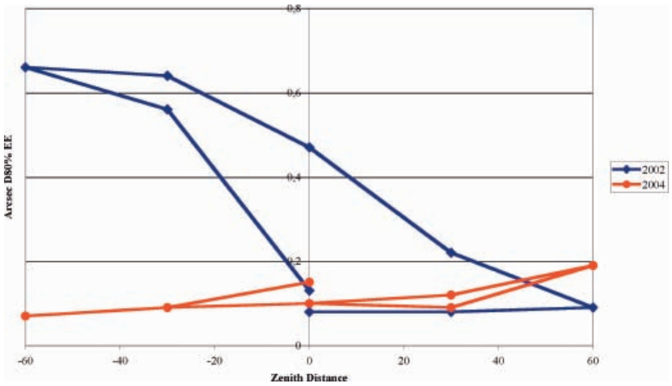

Figure 2: Coma Variation with Zenith Distance.

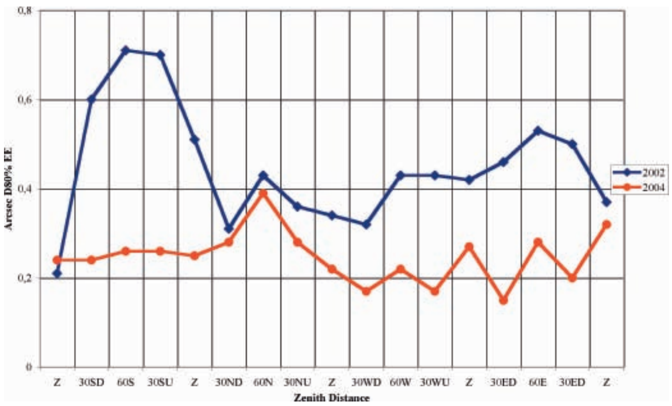

Figure 3: Image quality improvement: Optical Aberration variation with Zenith Distance.

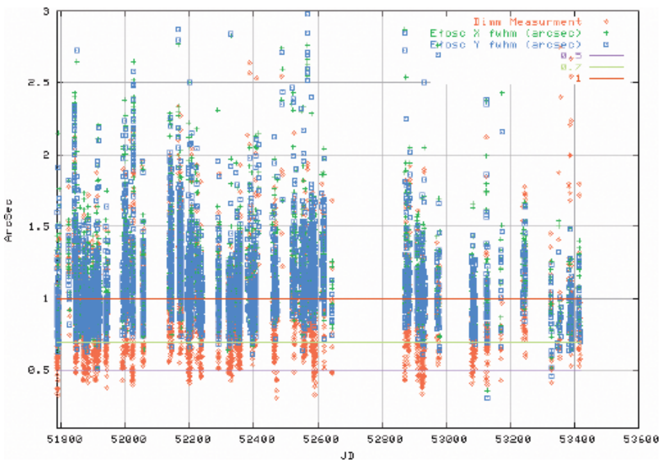

Figure 4: EFOSC2 seeing history (blue and green) compared with seeing monitor (red).

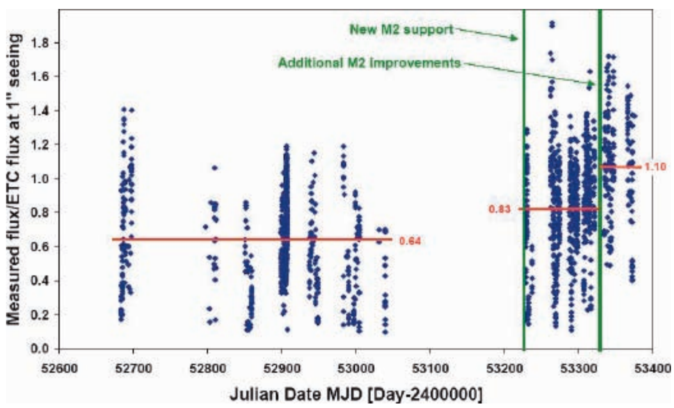

Figure 5: HARPS Efficiency variation with observing run.