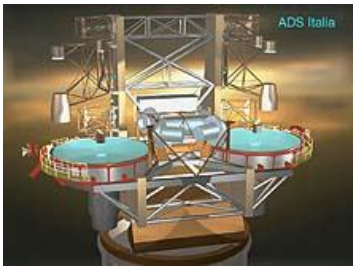

LBT PROJECT
2×8.4m TELESCOPE

Doc.No. : XXXsYYY
Issue : a
Date : 12 Jun 2012

LBT PROJECT

2 × 8.4m OPTICAL TELESCOPE

Astigmatism on the Adaptive Secondary

Testing the new Lookup Table (LUT)

	Signature	Date
Prepared	Konstantina Boutsia, Douglas Miller	June, 12, 2012
Reviewed		
Approved		

1. Revision History

Issue	Date	Changes	Responsible
a	12-Jun-12	First draft	KB, DM

2. Table Of Contents

3. About this document

3.1. Purpose

The purpose of this document is to present the process that was followed in order to better understand the problem of the elevation dependent astigmatism found on the Adaptive Secondary (AdSec). We present the analysis of archive data that allowed us to conclude that the original LUT is not working properly and led us to the creation of a new one. We also present the verification tests that took place during technical observing time and proved that the new LUT can be used for science operations.

3.2. Reference Documents

[RD1] CAN 485f032, F. Quirós-Pacheco, R. Briguglio, E. Pinna, A. Puglisi, A. Riccardi, and S. Esposito, "FLAO#1 commissioning report", December, 2011

4. Original Lookup Table

A known feature of the adaptive secondary mirror is the introduction of astigmatism when the elevation changes because of gravitational flexure of the reference body. This has been confirmed from lab results and an effort to characterize it was done by the FLAO group during daytime commissioning with the retroreflector [RD1].

According to those measurements, when the elevation changes between 90deg and 26deg the WFE of astigmatism variation is of the order of 10µm RMS Wavefront. Another feature is that this variation shows an evident hysteresis curve such that the amount of astigmatism present on the AdSec depends on the direction of the elevation change. The maximum width between the two paths was found to be of the order of 4-5µm WFE RMS (see Figure 1).

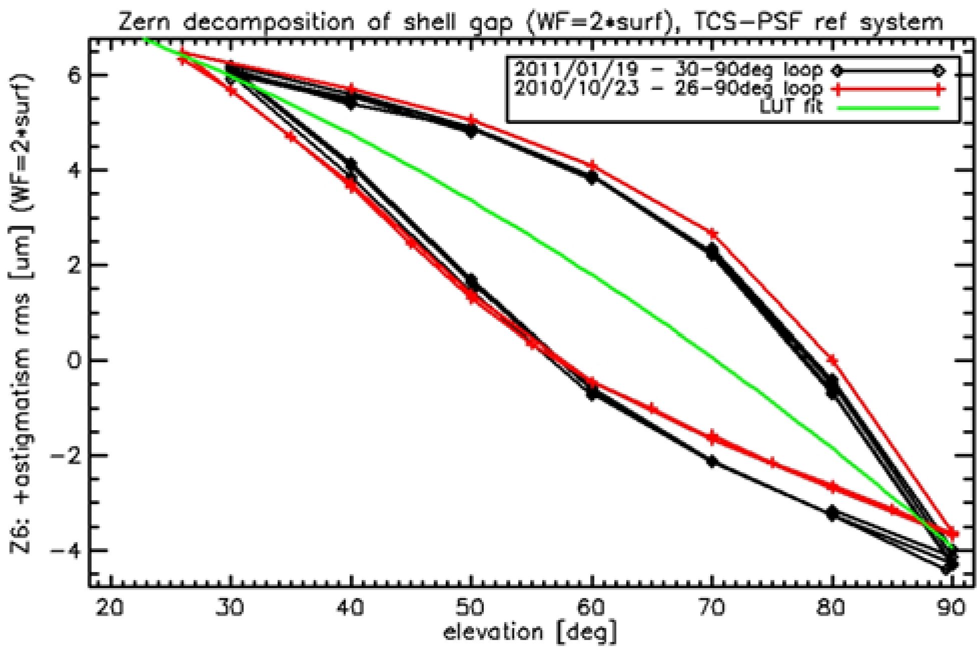

Figure 1: Red and black plots represent two samplings of Z6 astigmatism vs. elevation. The green line represents the fitting of the Z6 astigmatism with a 2nd order polynomial to be used for the LUT (plot taken from the FLAO commissioning report [RD1].

The original solution was to adopt a single valued look-up-table (LUT) of astigmatism versus elevation (green curve in Fig.1). This LUT is applied as an additive term to the position command for the low order Zernike modes (only Z6 for now) and it is refreshed to a new LUT value every 20 seconds. This procedure reduces the introduced error from 10µm to about 2-2.5µm WFE RMS, which proved to be only partially effective.

4.1. Archive data mining

For this reason, the IQ group has performed an analysis of more than 3 months of archive data to explore alternative solutions.

In order to have a homogeneous and consistent data sample as possible from the archive “pool”, it has been decided to use only data-points that fulfill the three following conditions:

1. Forces have been cleared, at least once at the beginning of the night. This way we are certain that all the astigmatism measurements depart from the LUT values.
2. The time between the current and the previous preset is less than 10min. This way we can exclude random telescope movements (going to zenith and back again for whatever reason) that could impact where on the hysteresis curve the current telescope elevation lays.
3. Only MODS and LUCI focal stations were selected, since they are mainly used during science operations, so that our sub-sample is as realistic as possible.

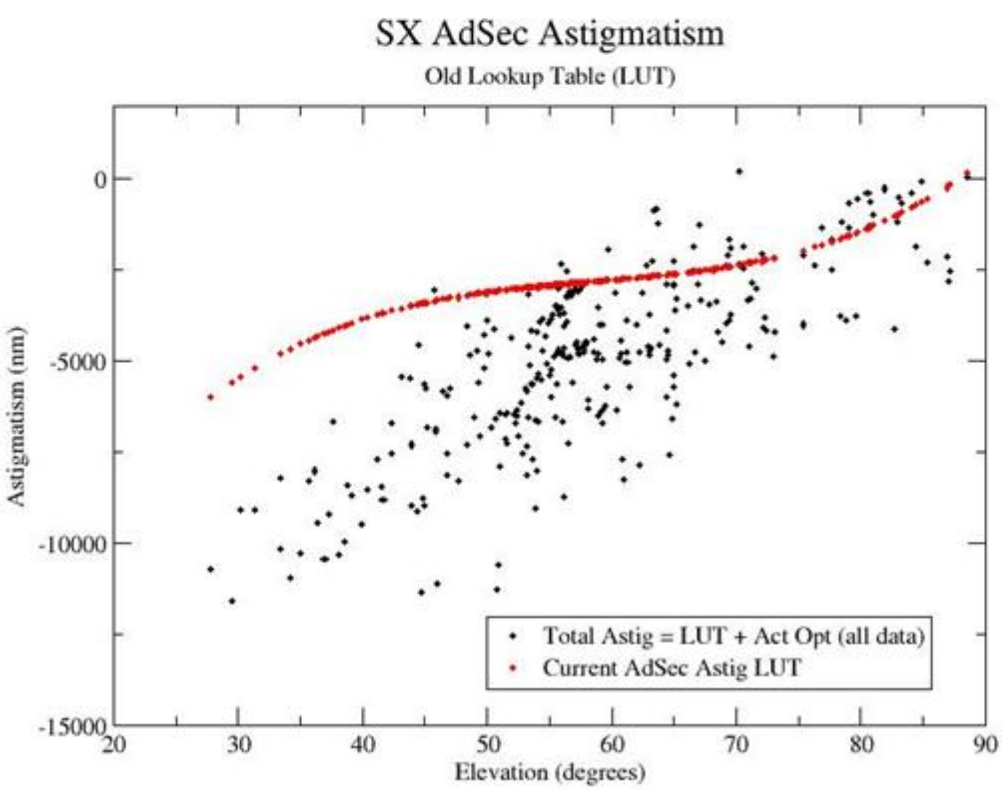

Figure 2: Astigmatism vs. elevation for the left adaptive secondary mirror (SX AdSec). Red points represent the original LUT values. Black points represent the total astigmatism that had to be applied to the AdSec for collimation. This total astigmatism is actually the sum of the LUT value and the additional Z6 correction applied by the Active Optics.

After this selection, we end up with 284 points obtained over the period between Feb. 22 and May 30. The result of this analysis has shown that there is an obvious mismatch between the values of the original LUT and the final total astigmatism applied, especially at low elevations (see Figure 2).

Since the data were obtained under various weather conditions, a first test was to see if there is any kind of dependence between total astigmatism and ambient temperature or fwhm. We separated the data points in bins of fwhm (see Figure 3, left) and bins of ambient temperature (see Figure 3, right). Each dataset bin has been fit with a linear curve. The slopes of those curves, although somewhat different, can account for less than 200nm of scatter. So we conclude that both these external factors do not have a significant effect to the astigmatism variation that we see. The change in elevation appears to be the main factor with the largest contribution to the astigmatism on the adaptive secondary.

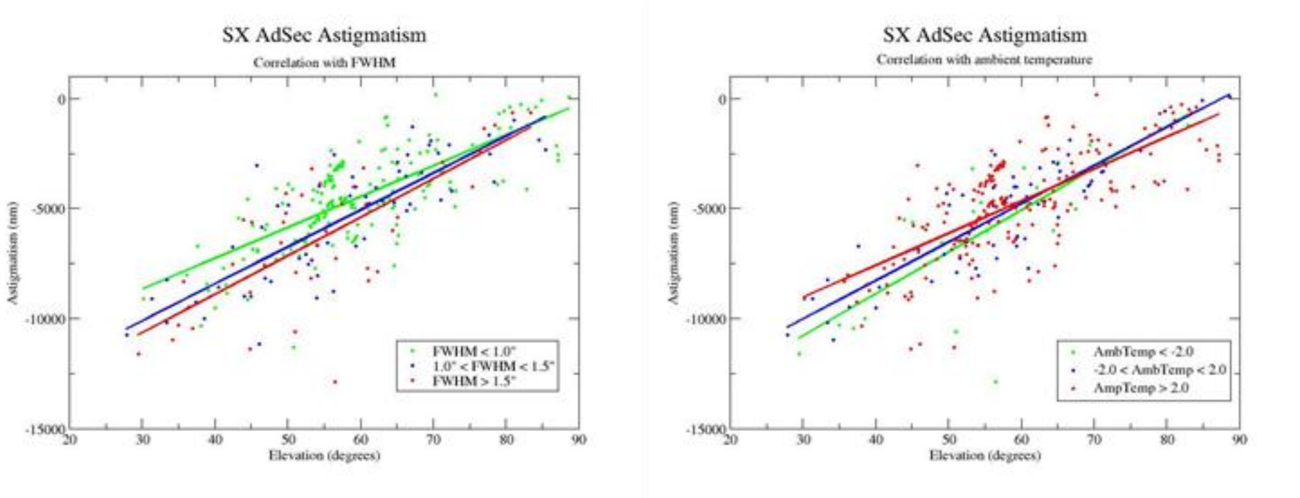

Figure 3: Total astigmatism vs. elevation, separated in bins of fwhm (left) and ambient temperature (right). The curves represent the linear fit of the data points in the various bins.

5. Creating a new LUT

Selecting only the data points that have been collected under best conditions (fwhm < 1.0”), we derive a new linear fit, which will serve as a benchmark for the new LUT (see Figure 4).

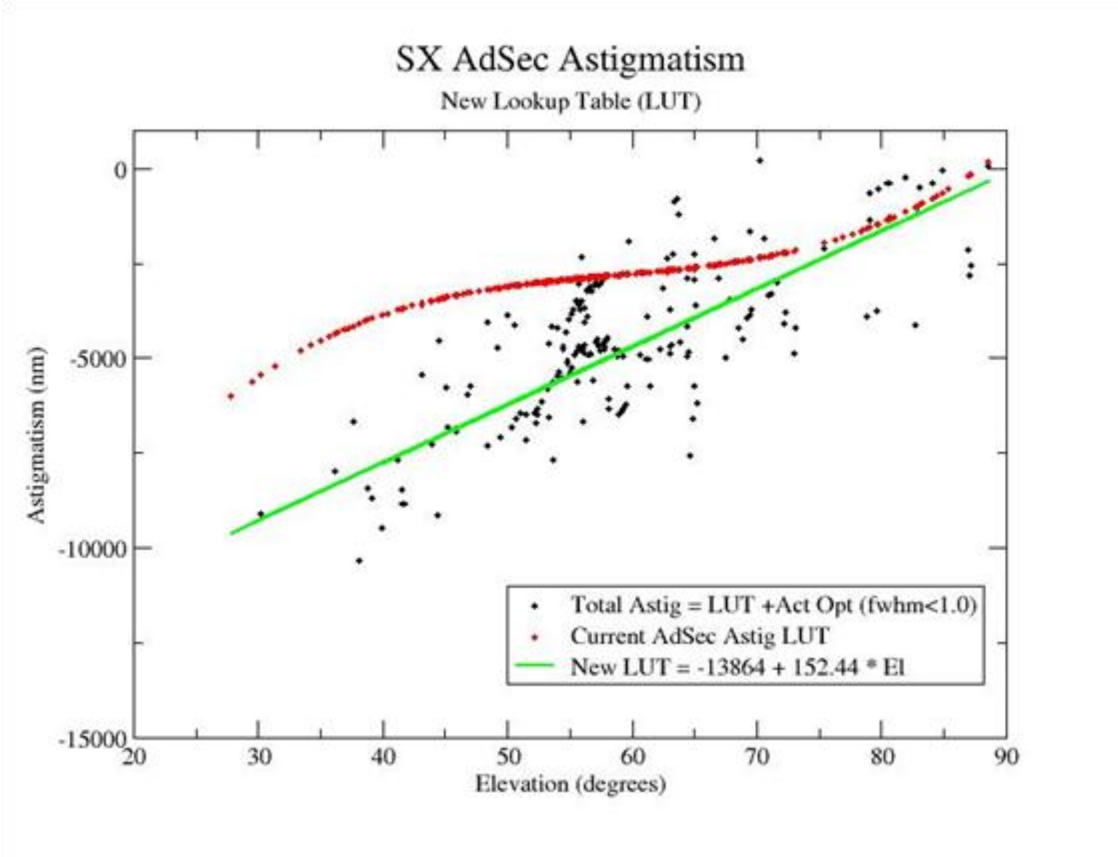

Figure 4: The black points represent the total astigmatism vs. elevation for all points obtained with good seeing conditions (fwhm<1.0"). The green curve is the linear fit to these points and will be used as the new LUT. The red points show the original LUT.

6. Verification of the new LUT

During the technical run that took place from the 30th of May to the 1st of June we obtained data to verify the quality of the new LUT. We collected three Adsec Astigmatism Hysteresis curves:

1. One with the LUT turned off, to measure the hysteresis curve and see if it has changed since it was measured last fall.
2. One with the new LUT turned on, to measure how well the new linear LUT compensates for the elevation dependent astigmatism.
3. One with the new LUT turned on and clearing C00 before each preset, so that we start with the LUT each time we collimate, instead of having the astigmatism of the last preset still on the primary.

Throughout this run, the seeing has been variable between 1.5” to 2”, with some hours of good seeing (~1” or less), that have been used though mainly for other tasks.

The change in elevation was from 81deg to 27deg and back to 86deg, for the dataset without Clear C00 and from 85deg to 29deg back to 83deg, for the dataset with Clear C00 after each preset. The two hysteresis curves can be seen in Figure 5, along with the new LUT fit determined form archive data, which appears to be right in the middle of the hysteresis loop, as expected. This means that when the elevation decreases between presets, the Active Optics add negative (-) Z6 to the primary, and on the contrary, when the elevation increases with the new preset, positive (+) Z6 is added. From this plot there is no straightforward indication whether it is best to clear or not C00 at each preset. Figure 5 does tell us that no mater the starting amount of Astigmatism, the Active Optics plus LUT converge to the same amount of total astigmatism.

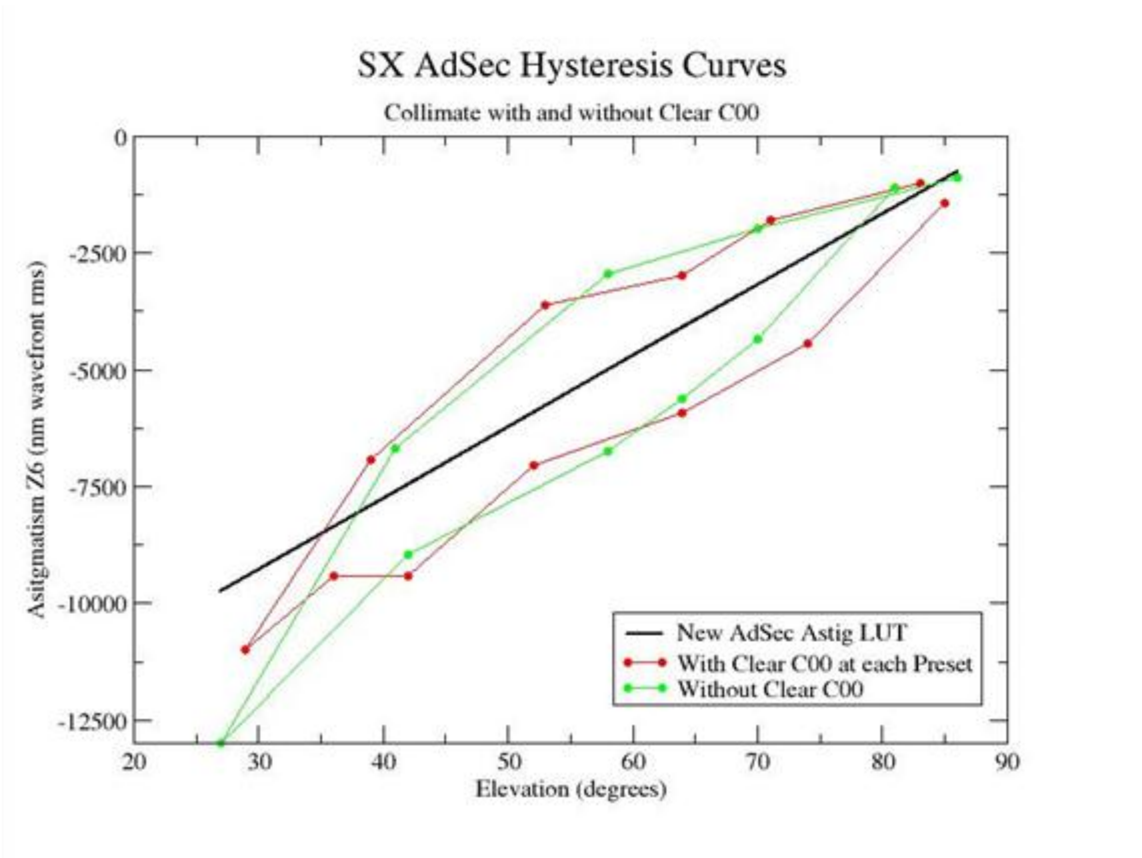

Figure 5: Here we show the hysteresis loop for the total astigmatism (Active Optics Z6 + new LUT) vs. elevation. For a set of points, there was a "clear C00" at each preset (red curve), while for the second set, the astigmatism on the primary was the one from the last preset (green curve).

We also notice that, for elevation <35deg, the two points in the hysteresis loops, show an offset from the LUT fit and with respect to the rest of the set. This is due to the fact that there is a software limit on the forces that can be applied by the LUT on the AdSec and at these low elevations, the new LUT requires values that are higher than this limit. In this case, the applied astigmatism from the LUT remains the same as the last preset, so the

Active Optics have to compensate for this discrepancy. There are two ways to deal with this issue. First we need to understand whether the margin to this limit can increase, in order to accommodate the requests of the new LUT. If this is not possible, then for elevations less than 35deg, the new LUT should have a constant value equal to the limit and Active Optics will have to apply the remaining astigmatism correction to the primary.

6.1. With or without Clear C00

In order to decide, whether it is best or not to clear C00 (or just Z6, when possible) at each preset, we look at the number of iterations it takes to collimate the AdSec (RMS WFE<500nm) in each case. In Figure 6, we plot the RMS WFE vs. # of iterations without Clear C00 (left panel) and with Clear C00 (right panel). In Table 1, we show the number of iterations needed to reach collimation after a preset for both cases (with and without C00).

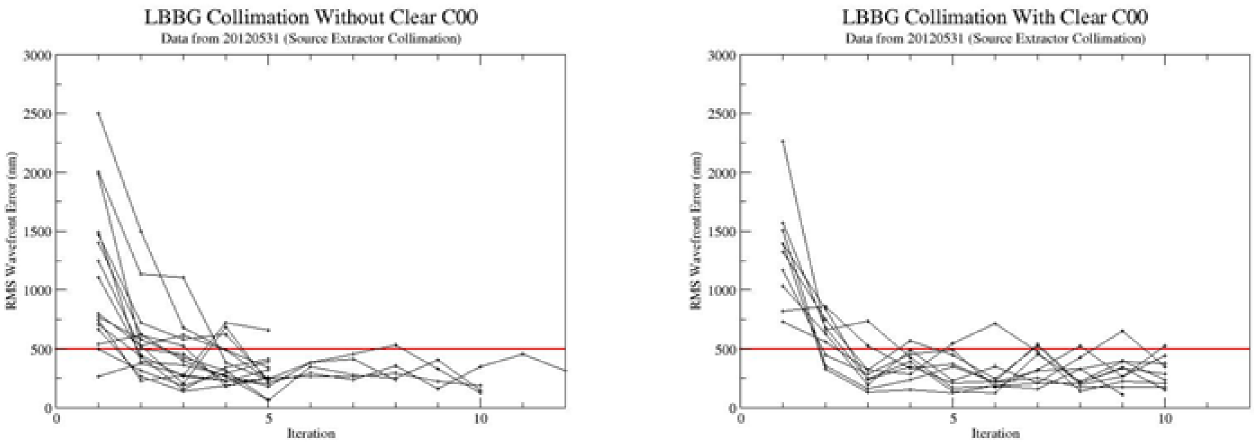

Figure 6: Collimation results for the two data sets: without "clear C00" (left) and with "clear C00" at each preset (right).

# of iterations	1	2	3	4	5
without clear C00	2/16 (13%)	7/16 (44%)	11/16 (69%)	13/16 (81%)	15/16 (94%)
with clear C00	0/10 (0%)	3/10 (30%)	8/10 (80%)	9/10 (90%)	9/10 (90%)

Table 1: Statistics on the number of iterations needed to reach collimation level after a new preset.

We see that although, at the 4th iteration 90% of presets have reached collimation when we clear C00, against the 81% of the presets without clear C00, we cannot clearly conclude that it is better to always clear C00, since this is a result based on small number statistics. Moreover, during these tests the elevation change was relatively small and usually at the same direction of the previous preset, which would benefit collimation without clear C00. In order to properly explore the effect of this parameter in the collimation, we should perform presets in random directions as it is usually the case during science operations.

6.2. Quadratic Fit

A final test was to try to fit a quadratic curve to the data points. As we see in Figure 7, apart from the low elevation end, where there is a 1000nm discrepancy, for the rest of the elevation range, the difference between the two fits is only some hundreds of nm, that should not have a considerable effect to science operations. In addition, we do know that at that lower end there is difficulty applying more astigmatism to the AdSec, as the quadratic fit requires. At this point, we believe that the linear fit is a good representation for the LUT and we will reconsider a quadratic fit when more data points will be available.

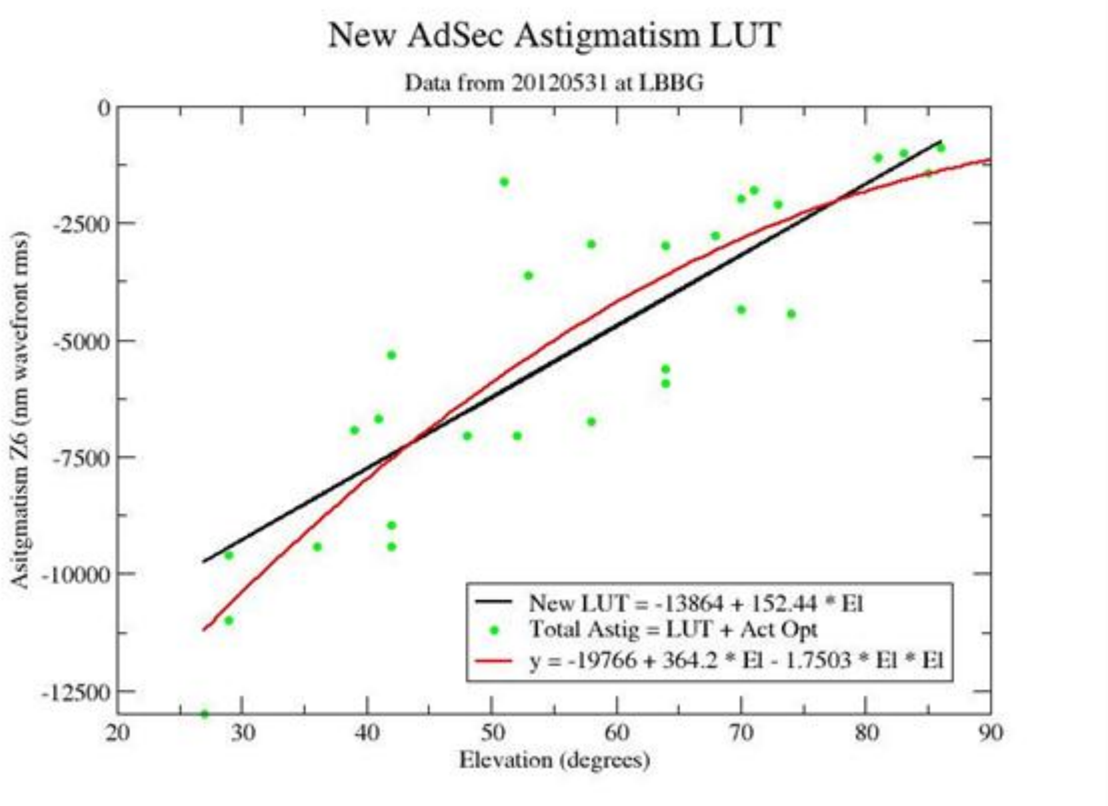

Figure 7: Total astigmatism vs. elevation for the data set obtained during the technical run for the verificatoin of the new LUT. Green points represent the measured values of the total astigmatism (new LUT + Z6 from Active Optics). The black line is the linear fit tha represents the new LUT and the red curve is a first quadratic fit of these same data, which could represent a future improved LUT.

7. Conclusions

As a final result of this analysis, we conclude that the new LUT is actually better that the original LUT and the new LUT has been implemented for use during science operations starting June 10th, 2012.

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