Large Binocular Telescope

ARGOS

Advanced Rayleigh Ground layer adaptive Optics System

Vibration Measurements at LBT

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Prepared	D.Peter	2015/19/11
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Change Record

Issue	Date	Section/ Paragraph Affected	Reasons / Remarks	Name
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1 Scope

This document describes the measurements of the vibrations on the LBT during thenight of October 23 2015. Within the document the sources of vibrations on the laser as seen on the ARGOS WFS is investigated from OVMS data as well as ARGOS vibration system data.

2 Applicable documents

No.	Title	Number & Issue
AD 1		
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3 Introduction

During the night of October 23, 2015 the spots of the ARGOS lasers as seen on the WFS patrol cameras exhibited strong movements. At this time there was some wind with gusts and the telescope was pointing directly into the wind. The seeing was better than 2”. Later that night the seeing became worse but the wind ceased and the telescope did not point directly in to it. At this time the movement of the laser spots was significantly less. Thus the conclusion was that the movement was due to wind triggred vibrations.
As the use of the ARGOS vibration system did not significantly reduce the movement, the question came up, where the vibration takes place. In the following I will present ARGOS vibration system data as well as OVMS data to investigate into this question.

4 OVMS data

Fortunately there is OVMs data of the entire night.

4.1 Data reduction scheme

To derive the tilt movement of the mirrors from the accelerometer data, the following steps were performed:

1. Read the data
2. With a linear fit the constant and linear drifts of the data was removed
3. Any outlyer (larger than 5 * variance of the data) were set to the mean (= 0)
4. The data was filtered by a first order high pass filter with cut off at 4 Hz
5. The order of the data was reversed and it was again filtered (this is to remove any phase shift)
6. The data was integrated iteratively ($y(t) = y(t-\Delta t) + x(t)*\Delta t$, $x(t)$ = input at time t, $y(t)$ = integrated signal at time t, Δt sampling time)
7. The average was removed
8. The data was again integrated
9. The data was again filtered twice

Now we have position data in stead of accelration data.
To get to the tilt of the mirrors the accelerometer positions are needed:

Mirror	Accelerometer #	x-Position	y-Position
1	1	-4.206	0.013
1	2	1.766	-3.818
1	3	2.423	3.438
2	1	0	0.425
2	2	-0.368	-0.213
2	3	0.368	-0.213
3	1	0.163	-0.223
3	2	0.123	0.208
3	3	-0.272	-0.037

The tip and tilt were measured as rotations around the x- and y-axes.
The following notations are used: **SigMb_a** is the position signal from **accelerometer a** on **mirror b**.

Mb_ax is the **x-position** of the same accelerometer and **Mb_ay** its **y-position**.
Therefore:

M1_tip = [SigM1_1-{SigM1_2*(M1_3y-M1_1y)-SigM1_3*(M1_2y-M1_1y)}/(M1_3y-M1_2y)]/distM1x
With
distM1x = [M1_1y*(M1_3x-M1_2x)+M1_2x*M1_3y-M1_3x*M1_2y]/(M1_3y-M1_2y)-M1_1x
M1_tilt = (SigM1_2-SigM1_3)/(M1_2y-M1_3y)

M2_tip = (SigM2_3-SigM2_2)/(M2_3x-M2_2x)
M2_tilt = (SigM2_1-0.5*(SigM2_2+SigM2_3))/(M2_1y-M2_2y)

M3_Tip = [SigM3_3-{SigM3_1*(M3_2y-M3_3y)-SigM3_2*(M3_1y-M3_3y)}/(M3_2y-M3_1y)]/distM3x
With:
distM3x = [M3_3y*(M3_2x-M3_1x)+M3_1x*M3_2y-M3_2x*M3_1y]/(M3_2y-M3_1y)-M3_3x
M3_Tilt = (SigM3_1-SigM3_2)/(M3_1y-M3_2y)

4.2 Results

The following plots show the tip and tilt movement of the mirrors in arcseconds.
The angle given is the angle of the mirror tilt itself and **NOT on sky**.
In the plots we compare the data during the windy periode (internal_system_monitor_201510240123.txt, blue curve) with the data later that night (internal_system_monitor_201510240324.txt, red curve).

4.2.1 M1

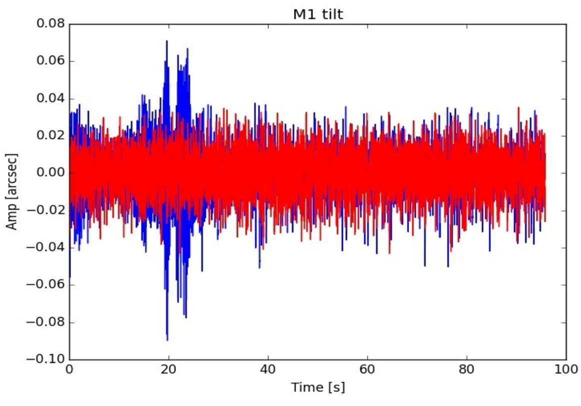

Figure 2: M1 mirror tilt. The blue curve represents the tilt for strong wind, the red curve the tilt for lower wind.

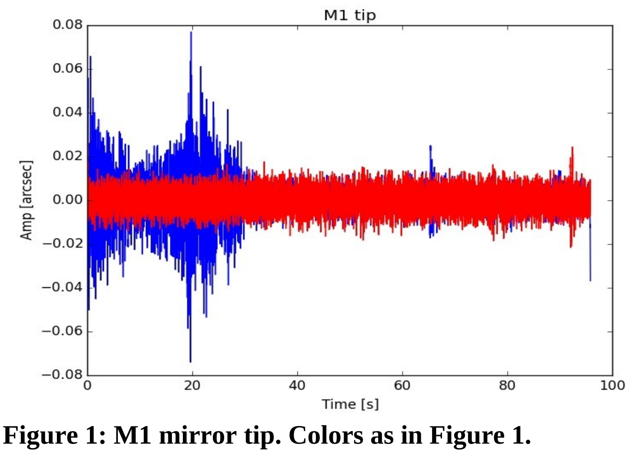

Figure 1: M1 mirror tip. Colors as in Figure 1.

The Peak to Valley tip and tilt of the M1 is below 0.2” even with strong winds. This is not so surprising as M1 is very heavy.

4.2.2 M2

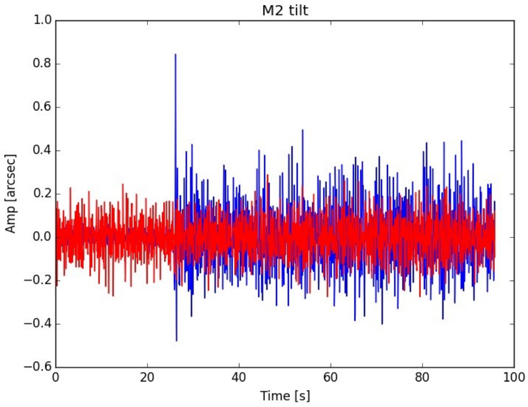

Figure 3: M2 mirror tilt. Colors as in Figure 1.

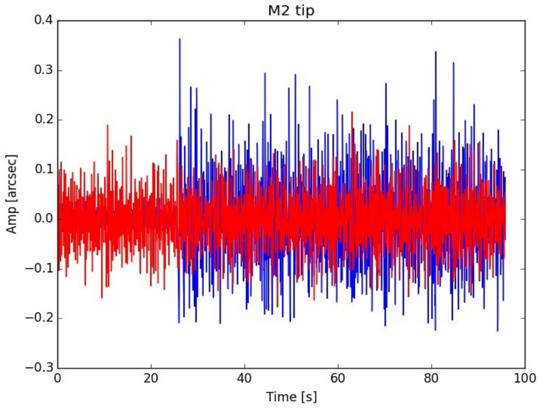

Figure 4: M2 mirror tip. Colors as in Figure 1.

The PV tip and tilt of M2 is about 0.6”. However it is not clear if the sudden change in amplitude at 25s after measurement start is real or artificially due to some loose contact. If so the data after 25s will probably be the real measurement.

4.2.3 M3

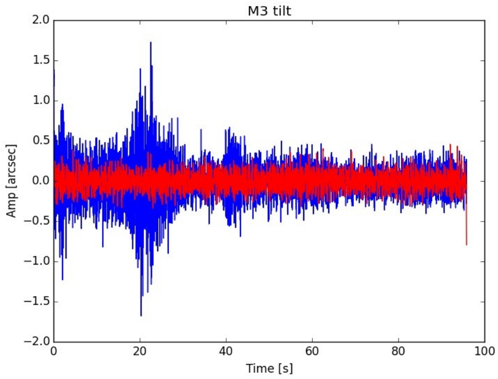

Figure 5: M3 mirror tilt. Colors as in Figure 1.

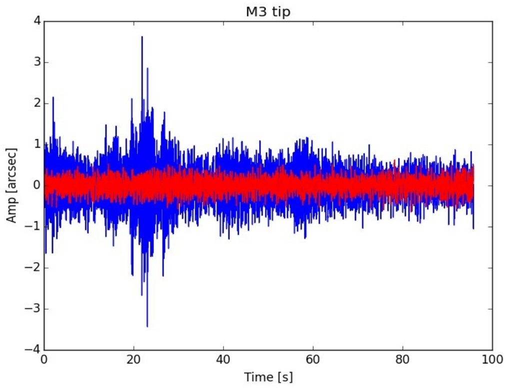

Figure 6: M3 mirror tip. Colors as in Figure 1.

The PV tip and tilt of M3 goes up to 7”/3.5” respectively. Thus M3 is a very good candidate for the origin of the large spot movements on the WFS patrol camera.

5 Vibration system data

From the vibration system the data was taken during the windy periode. It is not synchronized to the OVMS data however. Still it was made sure that there was significant spot movement on the ARGOS WFS while the data was taken.

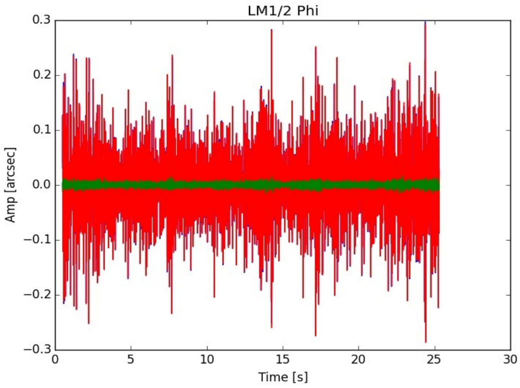

Figure 7: LM1+2 tilt in Phi direction. The blue curve represents the tilt calculated from the accelerometer data, the red curve represents the FSM movementwith optimized gain, and the green curve is the residuum.

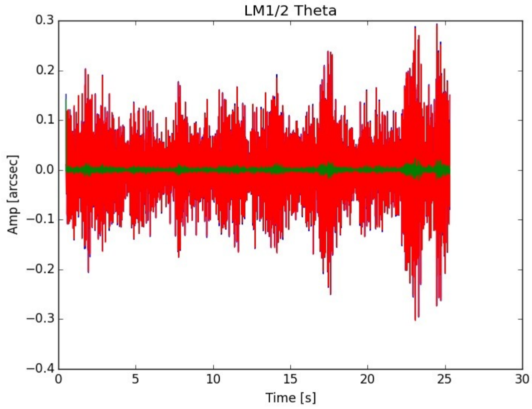

Figure 8: LM1+2 tilt inTheta direction. Colors as in Figure 7.

Two things are shown in each plot: The double integrated data from the accelerometers (integrated with the same procedure as the OVMS data but with a high pass filter with cut-off frequency of 8 Hz) and the output of the FSM. The FSM data is also filtered by the high pass filter the same way as the accelerometer data to make the results comparable.
As the projection of the axes of the FSM is clocked with respect to the axes on the LM1/2 mirrors and further on these axes are not orthogonal, the output of the NI-box needs to be multiplied by a matrix. Afterwards the data can be compared to the double integrated accelerometer signals.
In Figure.. and Figure.. the tip and tilt movement of the FSM is shown respectively.
The mirror tilt calculated from double integrated accelerometer data is shown as blue curve, the mirror tilt calculated from the NI-box output is shown as red curve and the difference is shown as green curve.
The PV tip/tilt (Theta,Phi) goes up to 0.6” uncompensated. After compensation this value is reduced to approximately 0.04”. Thus in uncompensated mode the tilt is of the same order as the one from M2 and much less than the tilt of M3. In compensated mode the tilt is much less than the M2 tilt.

6 Conclusions

There are a few conclusions which can be made from the data:

1. By far most of the vibrations come from M3
2. The vibration system removes more than 90% of the vibrations as measured on LM1/2

List of acronyms

AO	Adaptive optics
ARGOS	Advanced rayleigh guided ground layer adaptive optics system
ASAC	Argos swing arm cable
ASM	Adaptive secondary mirror
CPU	Central processing unit
CU	Calibration unit
HW	Hardware
I/O	Input / output
LGS	Laser guide star
NGS	Natural guide star
PFC	Prime focus camera
PLC	Programmable Logic Controller
PP	Park position
PUR	Polyurethane
SW	Software
TBD	To Be Defined
TBV	To Be Verified
WFS	Wave front sensor

End of document