Publication Year	2016
Acceptance in OA	2023-02-03T14:37:22Z
Title	Reflectivity of the ASTRI-SST-2M telescope prototype
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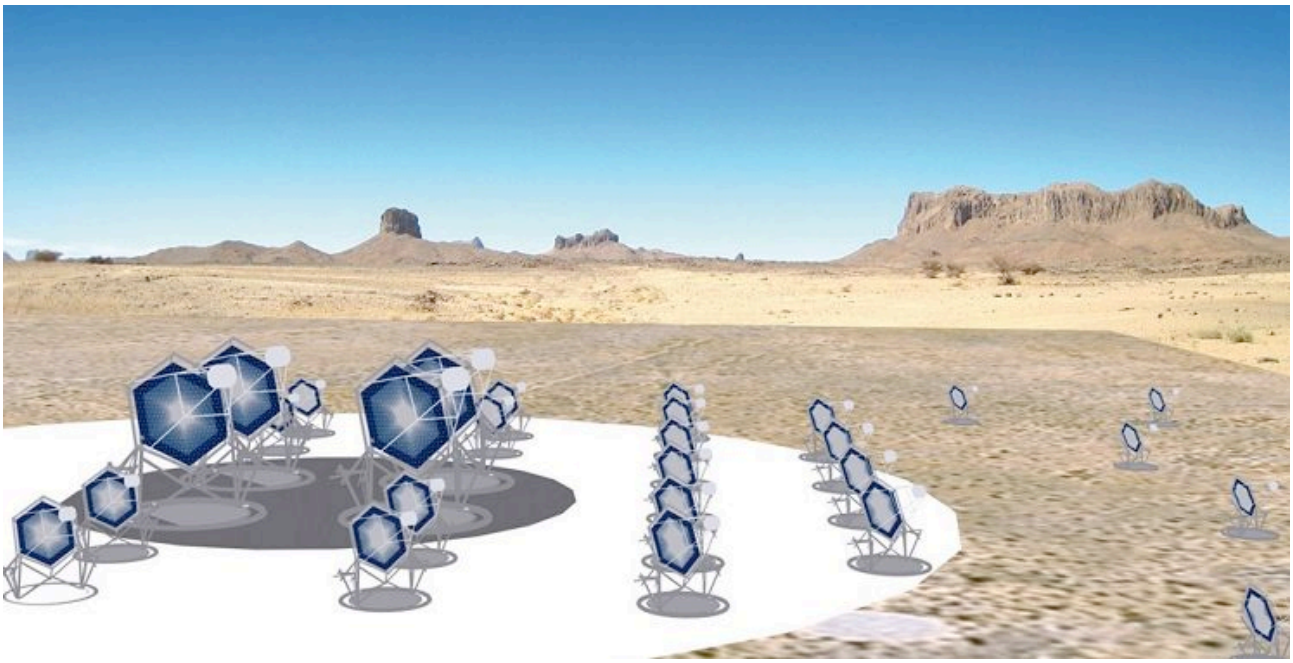
Handle	http://hdl.handle.net/20.500.12386/33142
Volume	ASTRI-IR-OAB-3500-066

Reflectivity of the ASTRI-SST-2M telescope prototype



Prepared by: Name: **Rodolfo Canestrari** Signature: Date: 12-04-2016

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DOCUMENT HISTORY

Version	Date	Modification
1.0	12-04-2016	first version

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LIST OF ACRONYMS

APPLICABLE DOCUMENTS

[AD1]

REFERENCE DOCUMENTS

[RD1]

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1. Introduction

This document reports about the specular reflectivity of the optical surfaces of the ASTRI telescope, namely the primary mirror M1 and the secondary mirror M2. It reports a short description of measurement and data analysis methods, the instruments used and the reflectivity of the mirrors as manufactured.

This document is intended to be a living document. In fact, it will be updated during the lifetime of the prototype with the new measurements taken.

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2. Instrumentation used

The reflectivity measurements have been taken with two different spectrophotometers. The measurements after the manufacturing have been taken using an Ocean Optics borrowed from the Observatory of Padova, while all the other measurements taken in situ after the telescope installation have been performed with a Filmetrics device from the Observatory of Brera.

2.1 Ocean Optics

This device is the model USB2000+ VIS-NIR equipped with an ISP-REF integrating sphere head. Reflectance measurements have been taken in the spectral range 357-900 nm. Unfortunately, the measurements taken below 470 nm are underestimated because of a strong non-linearity of the detector gain at low photons fluxes. The data have been truncated at 470 nm.

2.2 Filmetrics

This device is the model F20-UVX equipped with an external light source model LS-DT2 (with a Tungsten-Halogen lamp) and a CP-1 contact probe. The CP-1 head is specifically for curved surfaces. Reflectance measurements have been taken in the spectral range 250-1700 nm.

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3. Data taking

The surface of each mirror segments of M1 has been sampled with 9 measuring points over 3 diagonals, three points on three diagonals (15 points are used for the dielectric mirrors).

Concerning M2, the surface is sampled over 4 diagonals. Each diagonal has 9 measuring points.

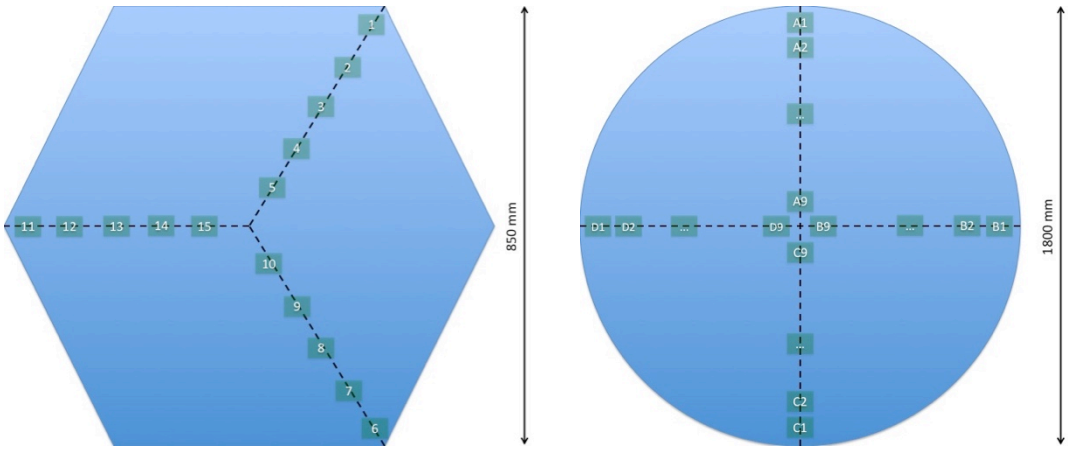
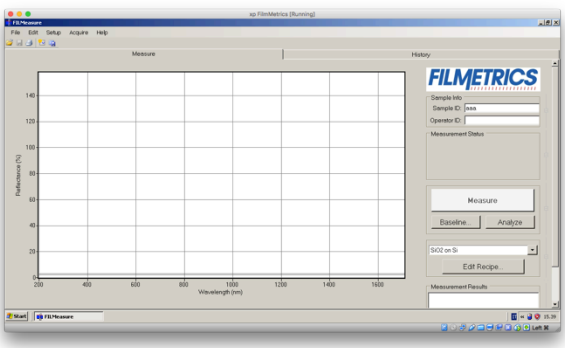


Figure 1 Distribution of the acquisition points over the segments of M1 and over the M2.

For the Filmetrics device, the procedure to be used for the acquisition of the measurements of each mirror segment (or each diagonal if referred to M2) is as follow. Allow about 30 minutes or more to heat and gain stability of the light flux. In a cold environment it could take even more.

Than open the acquisition software and follow these steps.

Acquire the Baseline.	

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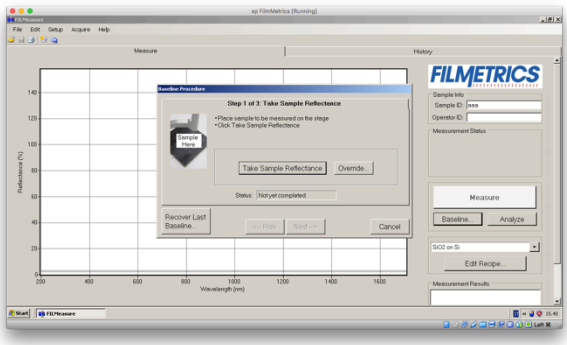
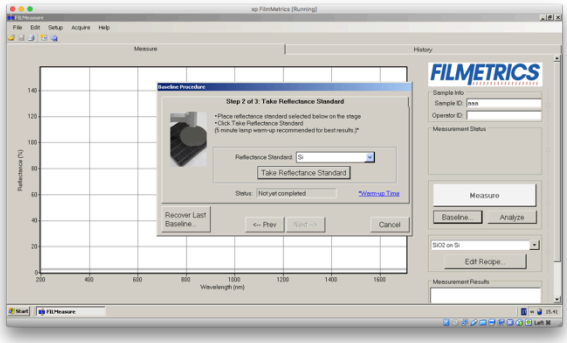
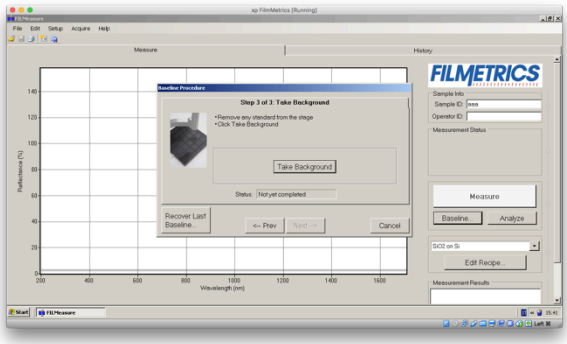
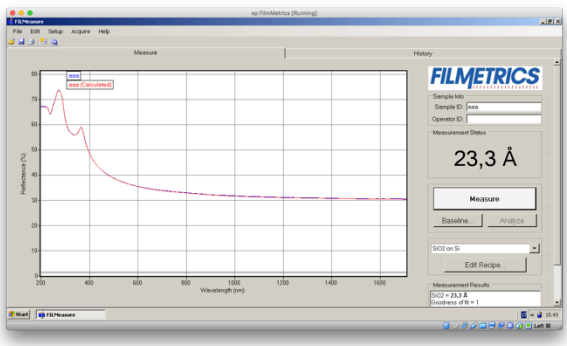
Take Sample Reflectance using an $AlSiO_2$ sample.	
Take Reflectance Standard using the Si wafer provided by Filmetrics.	
Take Background pointing the probe head toward the environment (take care to avoid pointing to direct light sources).	
Acquire the Si wafer (Ctrl-E) and save it as <specchio>_siref_1.fmspe (Ctrl-S)	

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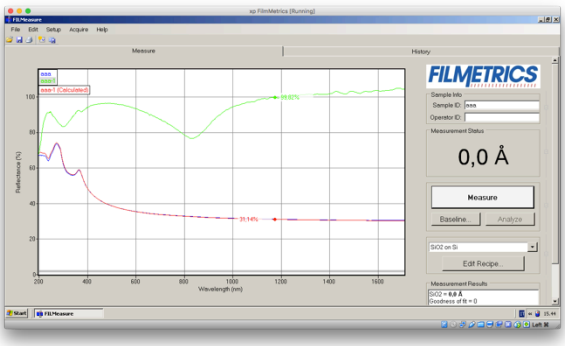
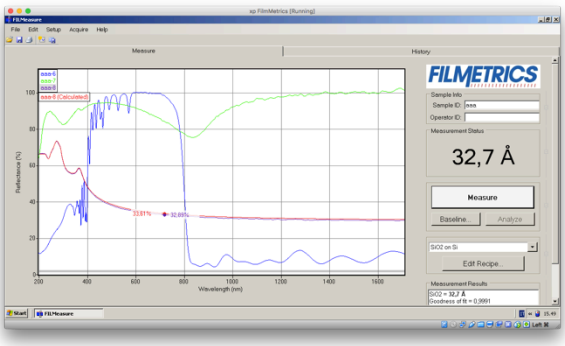
Acquire the $AlSiO_2$ sample (Ctrl-E) and save it as <specchio>_alsio_1.fmspe (Ctrl-S)	
Acquire the SiO_2TiO_2 sample (Ctrl-E) and save it as <specchio>_siti_1.fmspe (Ctrl-S). This will be used to calibrate the maximum reflectivity (plateau at 100%)	
Acquire all the data points on the mirror under test (e.g. 1-3-5-6-8-10-11-13-15) (Ctrl-E) and save it as <specchio>M-<numero>.fmspe (Ctrl-S)	
Repeat the acquisition of the Si wafer, the $AlSiO_2$ sample and the SiO_2TiO_2. This will be used to check the stability during the data-taking run.	

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4. Data analysis

The data are treated as follow.

The reflectivity curve acquired, at the beginning of the run, from the SiO_2TiO_2 sample is used to calibrate the maximum reflectivity. In fact the SiO_2TiO_2 sample shows a reflectivity plateau that reach 100%. This has been checked using different measuring instruments. However, this cannot be considered a real absolute calibration since the SiO_2TiO_2 sample has not been certified.

$$calibration\_factor = \frac{max\left(Refl_{SiO2TiO2}^{begin}\right)}{100}$$

The stability of the data-taking run is evaluated by comparing the curves of the SiO_2TiO_2 sample acquired at the beginning and at the end of the run (one run corresponds to one mirror). Instability up to 2% is tolerated.

$$stability = abs\left(mean\left(Refl_{SiO2TiO2}^{begin}[300{:}550] - Refl_{SiO2TiO2}^{end}[300{:}550]\right)\right)$$

All the reflectivity curves acquired during the data-taking run (including the one of the SiO_2TiO_2 sample) undergo a chromatic correction to take into account the response of the measuring system (spectrophotometer and optical head) to the wavelengths. This chromatic factor has been obtained thorough the measurement of a calibrated mirror sample done in the laboratory. This chromatic factor has the mean value equal to 1 within the wavelength range 300-550 nm. The chromatic factor is shown in Figure 2.

$$\begin{cases} Refl = \dfrac{Refl_{raw} * chromatic\_factor}{calibration\_factor} \\ mean(Refl_{raw}[300{:}550]) = mean(Refl_{raw}[300{:}550] * chromatic\_factor[300{:}550]) \end{cases}$$

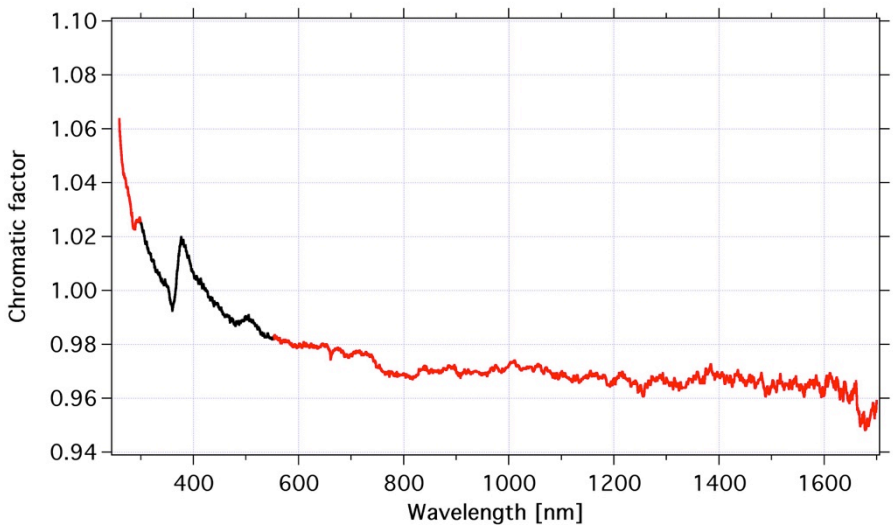

Figure 2 Chromatic factor used to compensate for the response of the measuring system to the wavelengths. We underline that this factor has a mean value equal to 1 in the range 300-550 nm (black part of the curve).

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The data are averaged between those at equal radial distance. With reference to Figure 1, the group of points (1, 6, 11) samples the external part of the mirror, the group (3, 8, 13) samples the middle part and the group (5, 10, 15) samples the inner part of the mirror. The standard deviation of the mean reflectivity values (evaluated in the range 300-550 nm) in each group is also calculated.

$$\begin{cases} Refl_{ext} = \dfrac{Refl_1 + Refl_6 + Refl_{11}}{3} \\ Refl_{mid} = \dfrac{Refl_3 + Refl_8 + Refl_{13}}{3} \\ Refl_{int} = \dfrac{Refl_5 + Refl_{10} + Refl_{15}}{3} \end{cases}$$

The total reflectivity of each mirror is then calculated by weighting the reflectivity of the three groups for the surface area subtended by each one. Based on the layout shown in Figure 1 the external part has a relative weight of 67.3%, the middle part has a weight of 24.5% and the inner part weights for the remaining 8.2%.

$$Refl_{mir} = 67.3\% Refl_{ext} + 24.5\% Refl_{mid} + 8.1\% Refl_{int}$$

The total reflectivity of the whole primary mirror of the ASTRI-SST-2M telescope prototype is computed as the average of the 18 mirrors.

$$Refl_{tot} = \frac{1}{18}\sum_{i=1}^{18} Refl_{mir}^{i}$$

The data analyses for the dielectric segments of the primary mirror and for the secondary mirror undergo the same mathematical treatment apart from obvious adaptations (number of data points, weights[1]).

[1] For dielectric, the weights are: 58.7%, 16.3%, 12.2%, 8.2% and 4.6%.

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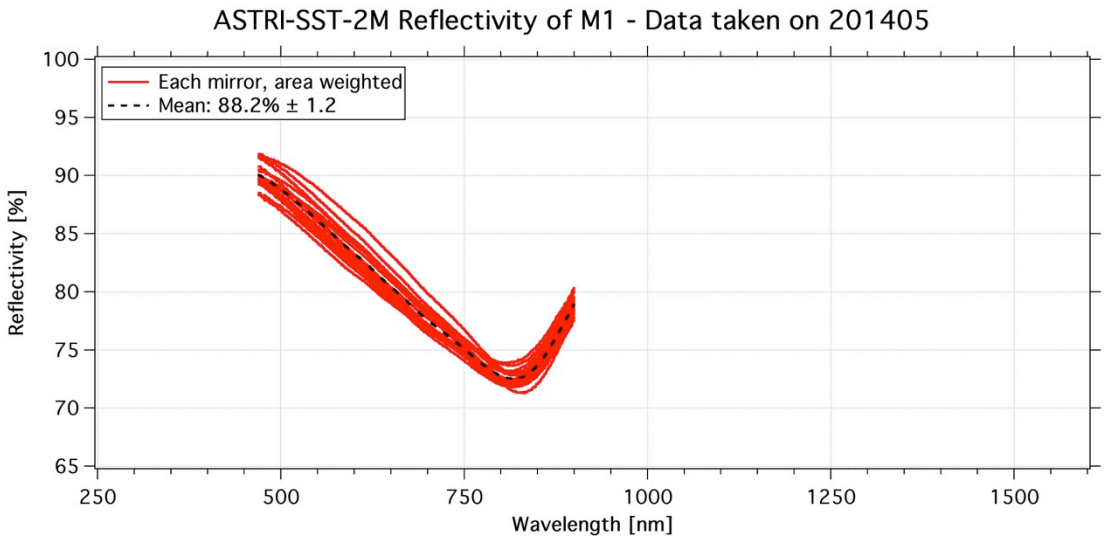
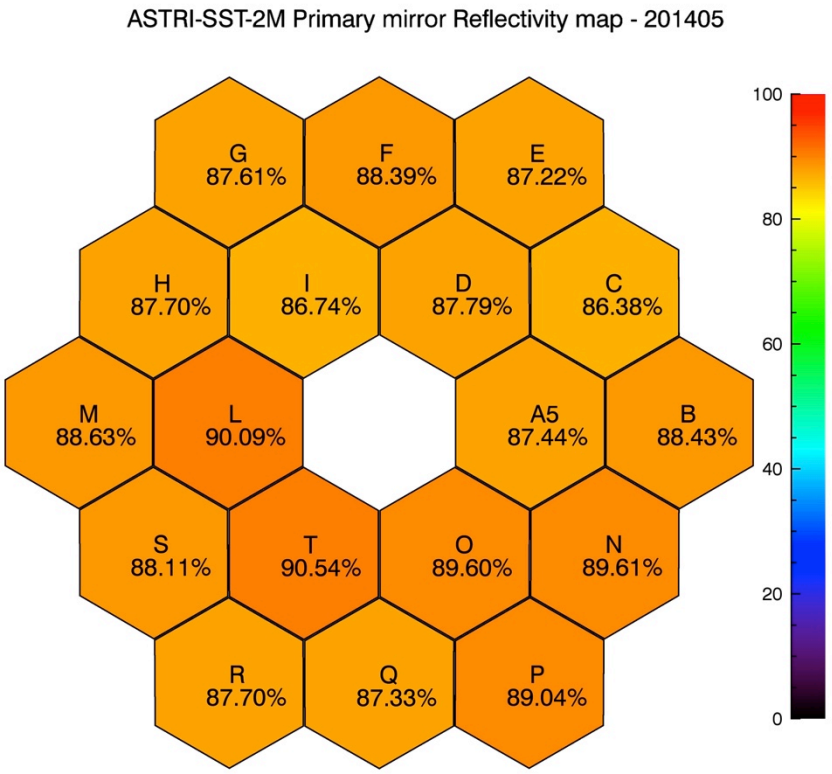
5. Reflectivity results for M1 – $AlSiO_2$ coating

5.1 Reflectivity at the manufacturing (May 2014)





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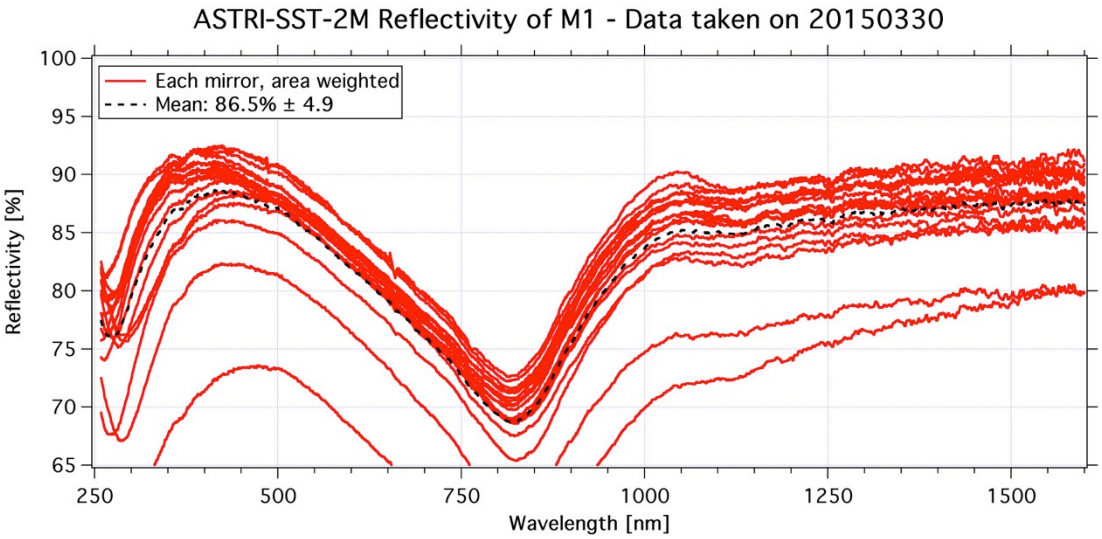
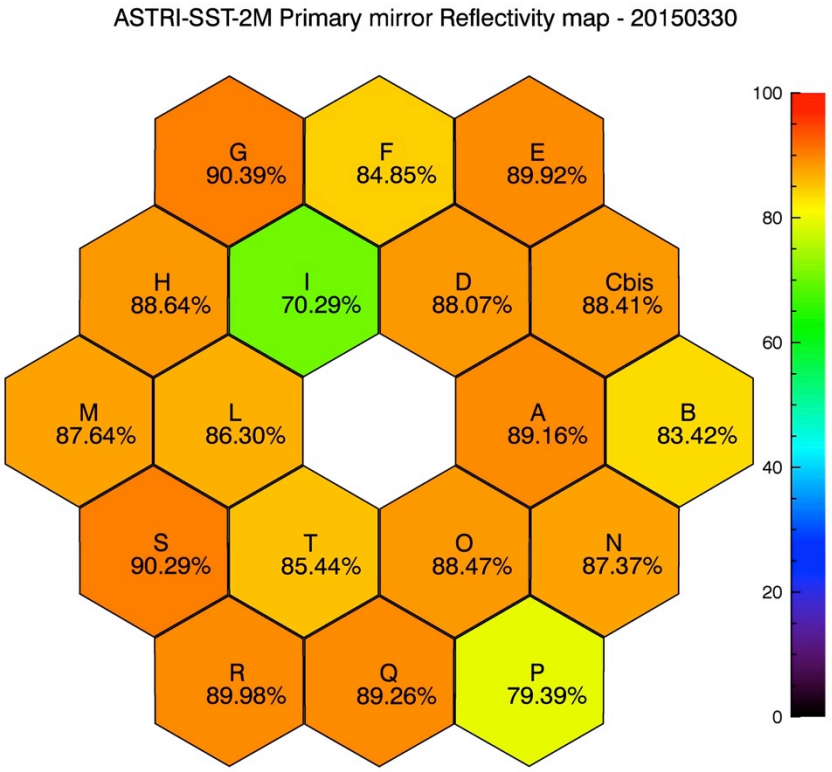
5.2 Reflectivity after 6 months from installation (March 2015)





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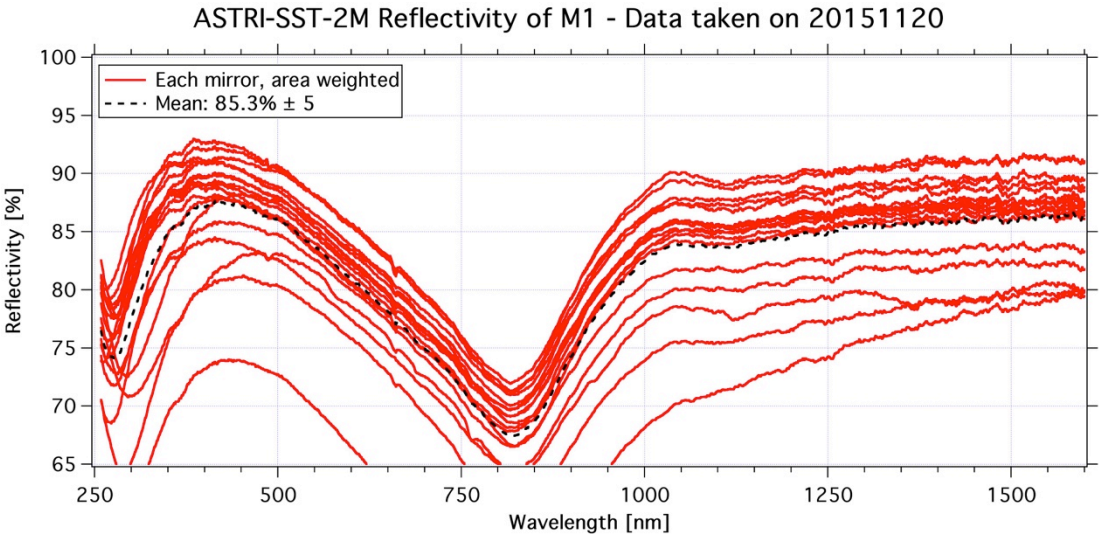
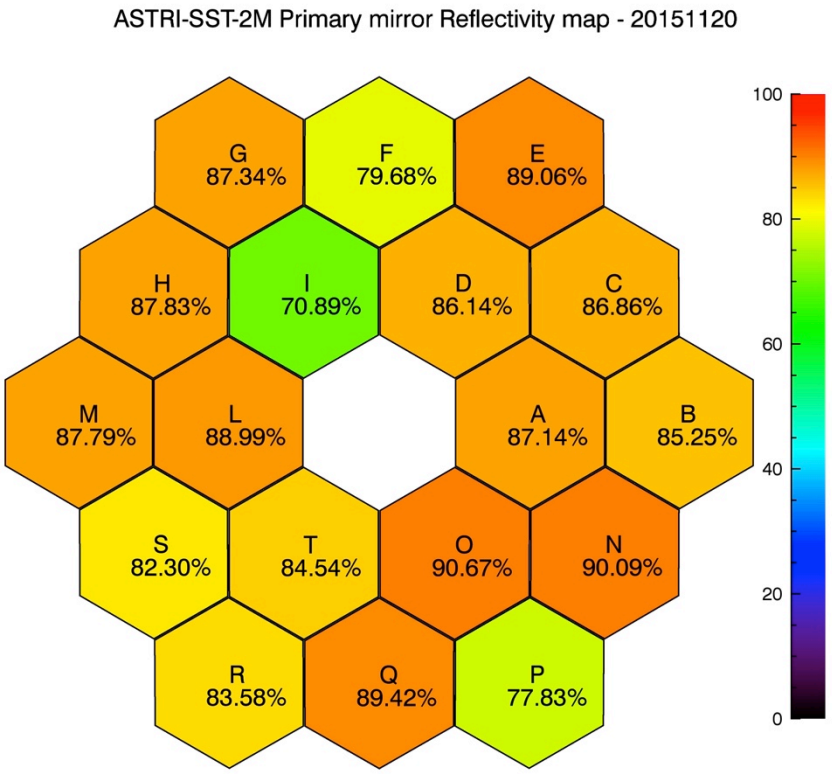
5.3 Reflectivity after 14 months from installation (November 2015)





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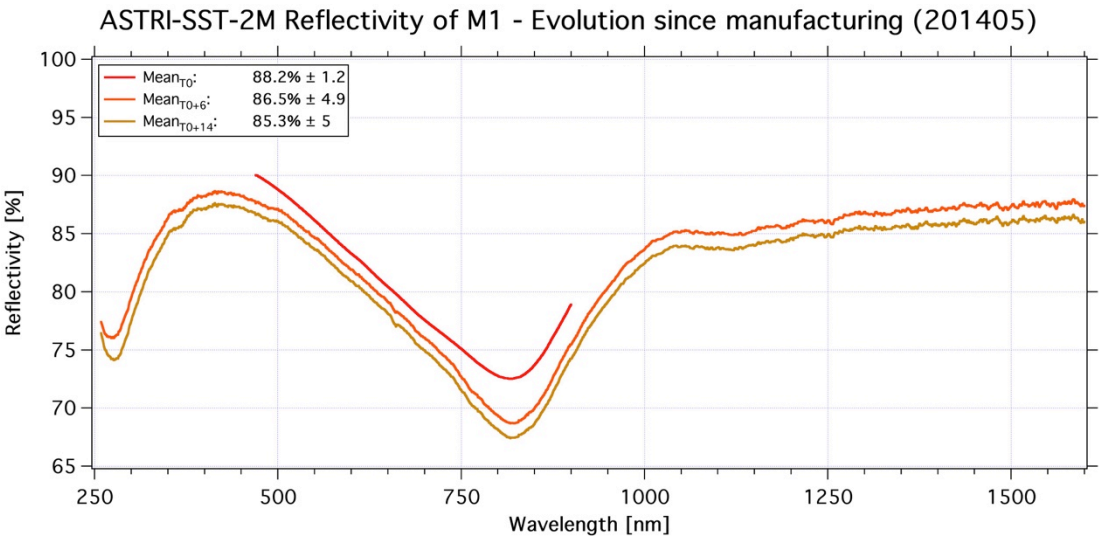
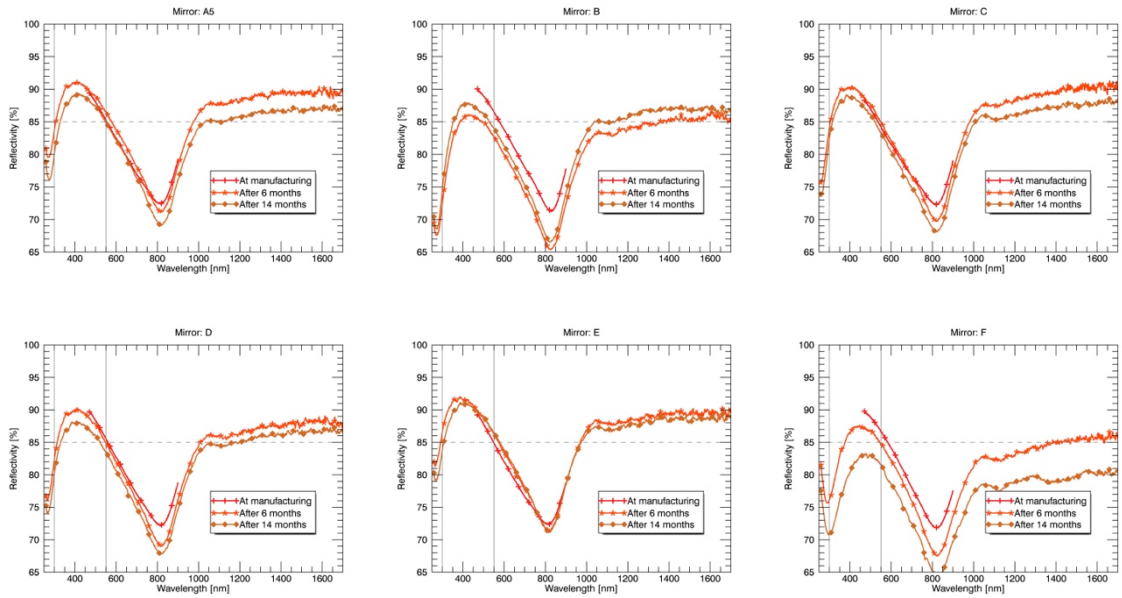
5.4 Reflectivity after 20 months from installation (May 2016)

TBD

5.5 Evolution of the reflectivity

T_0 is the date of the inauguration of the telescope (September 2014). Since that date the mirrors have been exposed to the environment.





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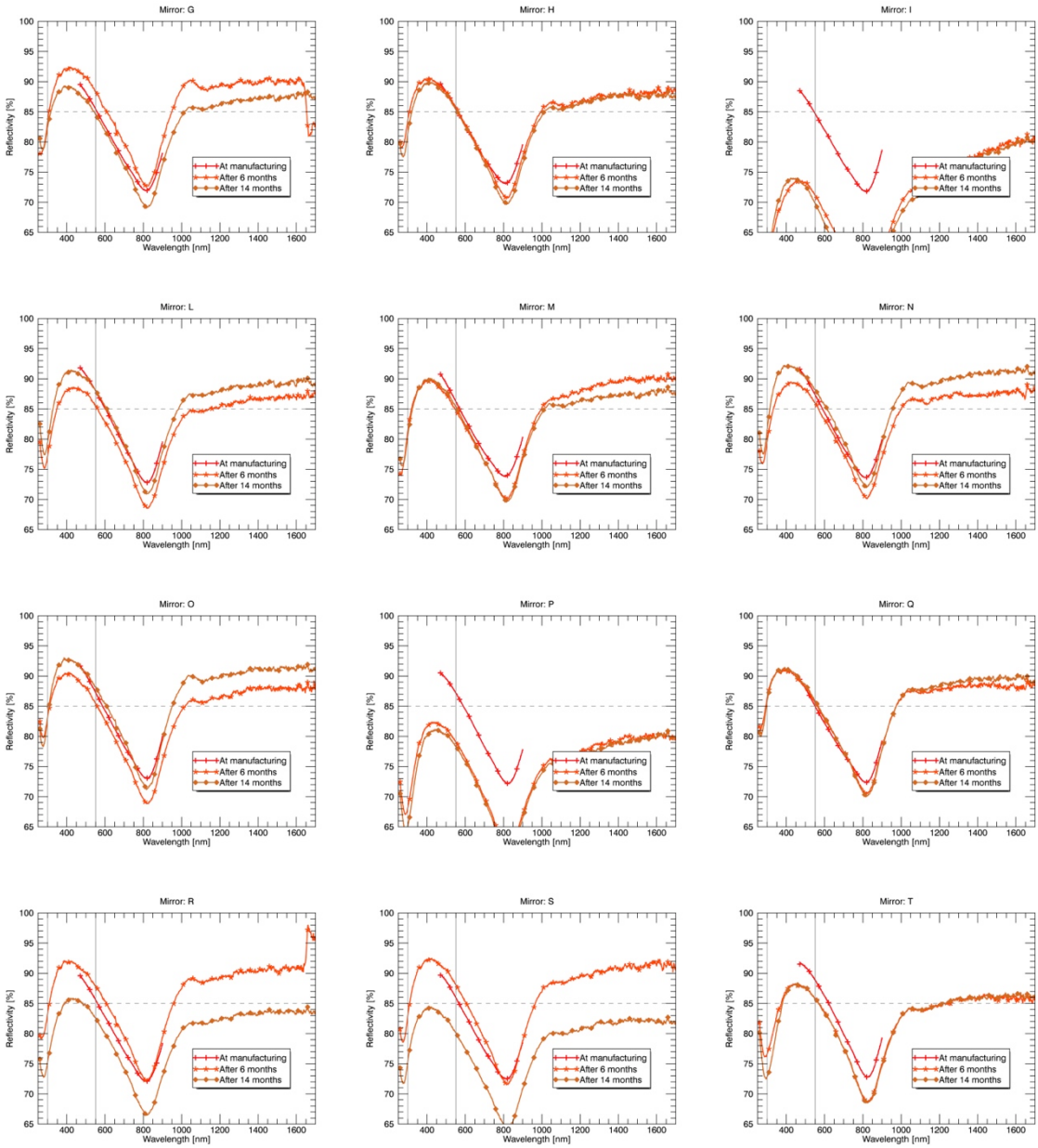

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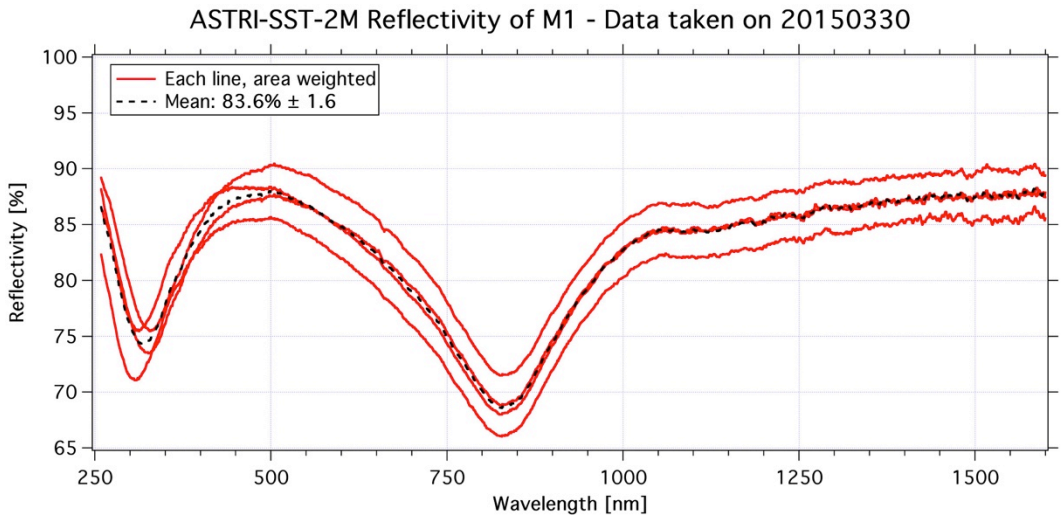
6. Reflectivity results for M2 – $AlSiO_2$ coating

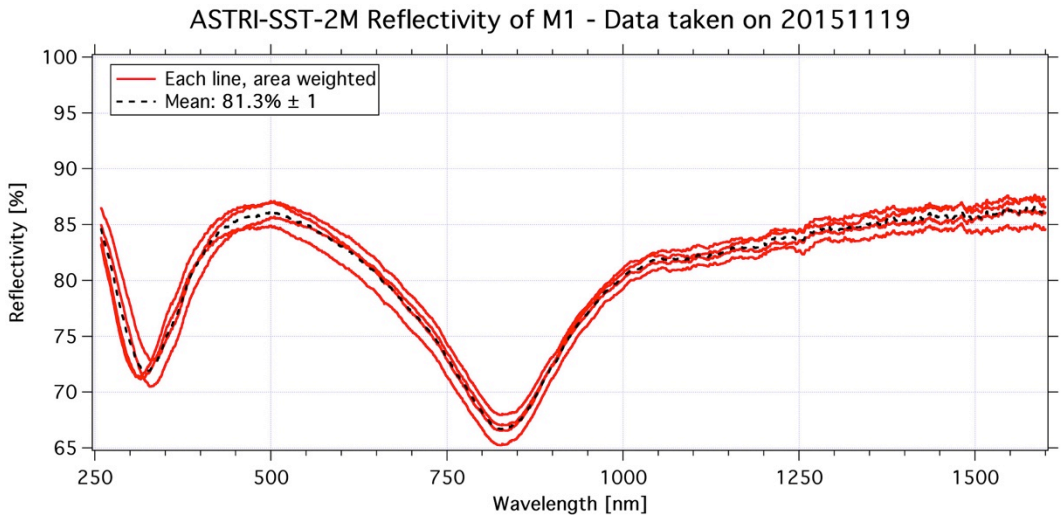
6.1 Reflectivity at the manufacturing (May 2014)

TBW

6.2 Reflectivity after 6 months from installation (March 2015)



6.3 Reflectivity after 14 months from installation (November 2015)



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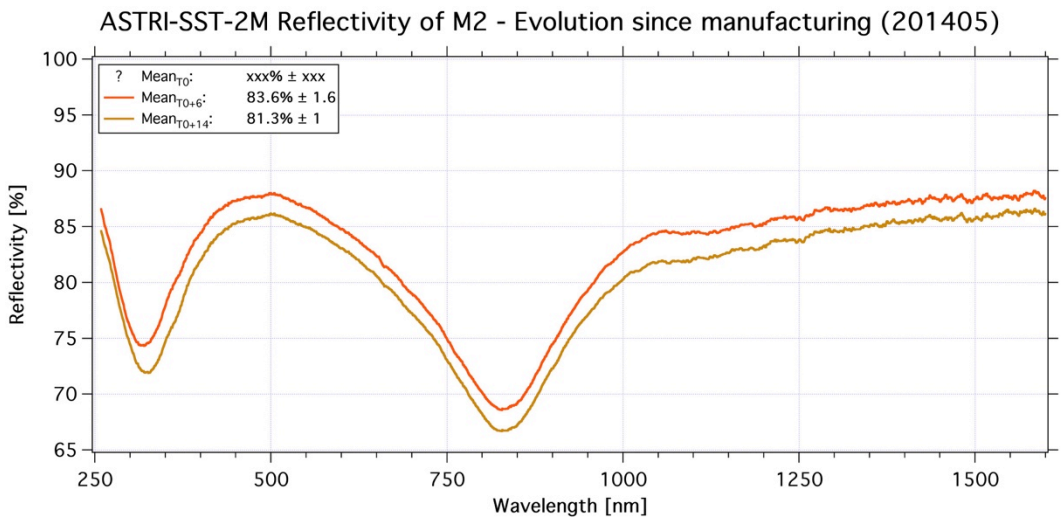
6.4 Reflectivity after 20 months from installation (May 2016)

TBW

6.5 Evolution of the reflectivity



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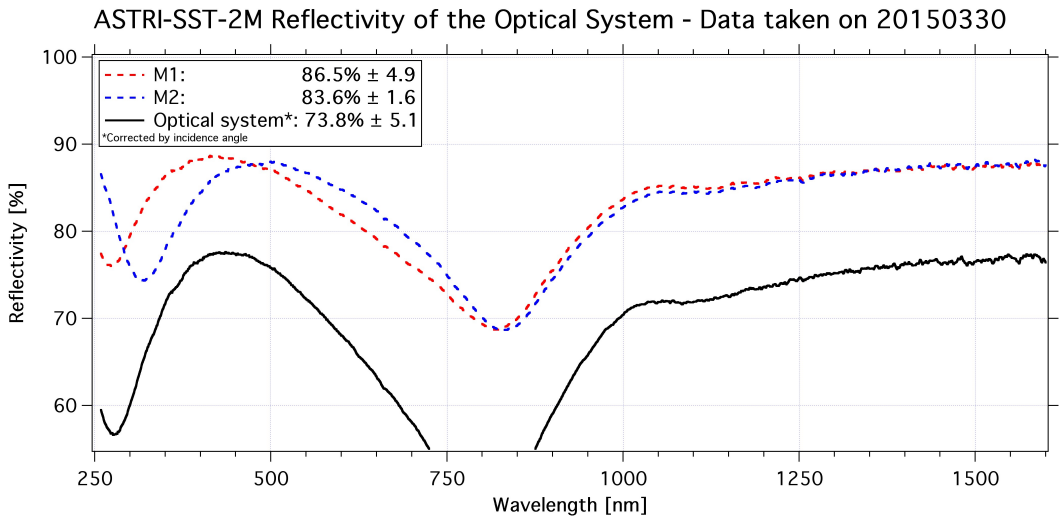
7. Reflectivity results of the optical system – $AlSiO_2$ coating

The reflectivity of the entire optical system has been calculated by multiplying the reflectivity of the primary mirror for the reflectivity of the secondary mirror[2]. This operation, if applied tout court, introduces an error in the effective reflectivity of the system. In fact, because of the optical system layout the light rays impinge on the secondary mirror with a mean incident angle of about 46°. However, all the reflectivity curves shown in this document are measured in normal incident. This error has been evaluated through simulations and the corrective factor has been implemented. The corrective factor is a simple shift of the reflectivity curve of M2 of 36 nm toward the shortest wavelength.

7.1 Reflectivity at the manufacturing (May 2014)

TBW

7.2 Reflectivity after 6 months from installation (March 2015)



[2] Following the CTA requirements, the entire optical system should have a mean reflectivity above 72.25% (i.e. 0.85*0.85=0.7225).

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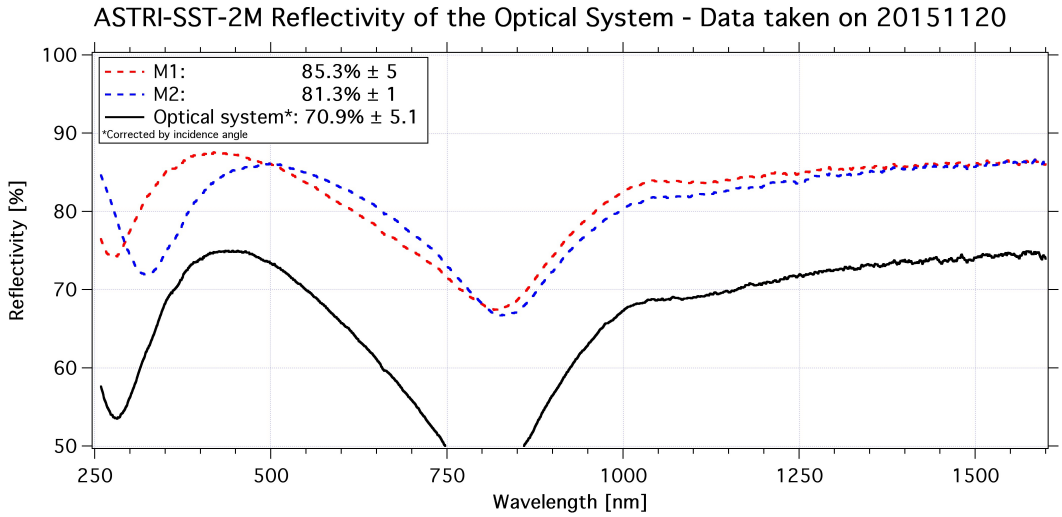
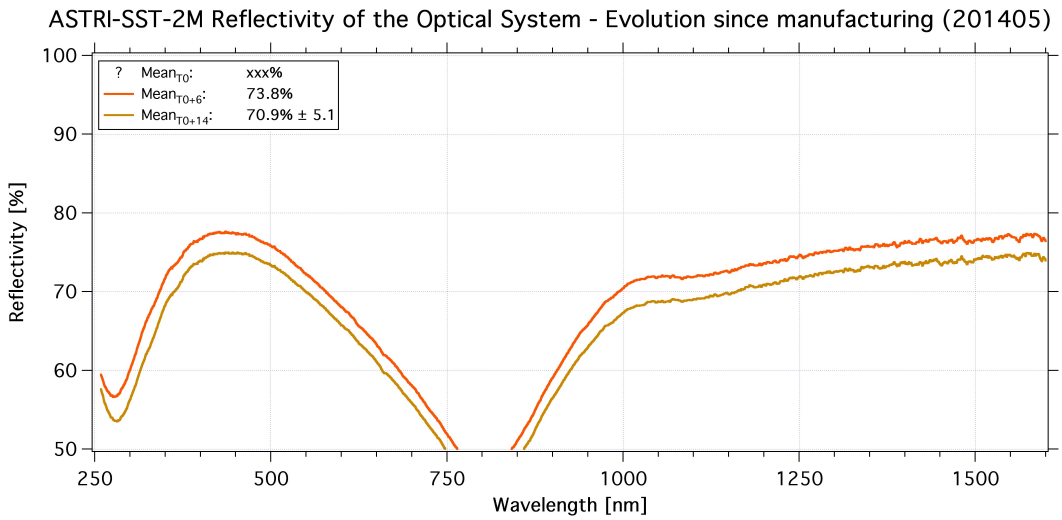
7.3 Reflectivity after 14 months from installation (November 2015)



7.4 Reflectivity after 20 months from installation (May 2016)

TBW

7.5 Evolution of the reflectivity



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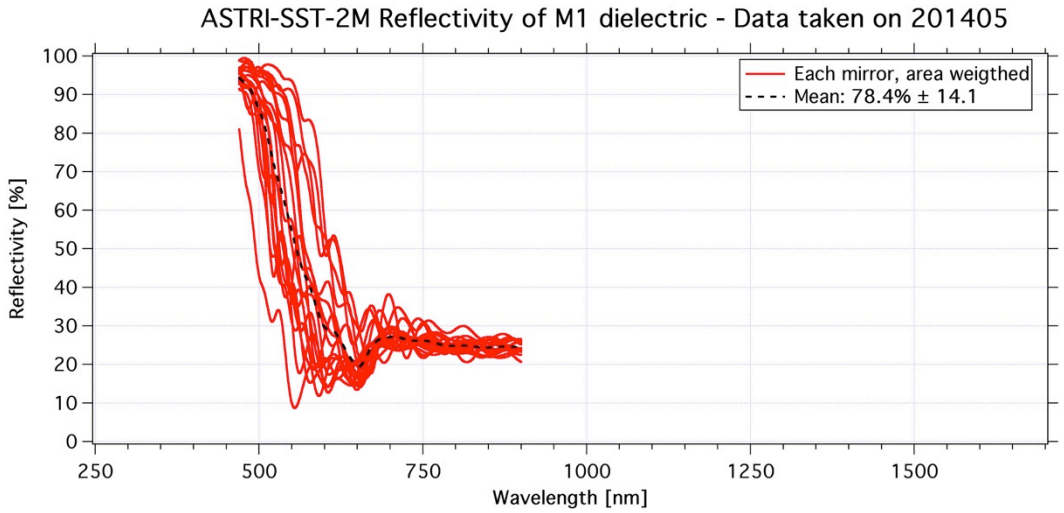
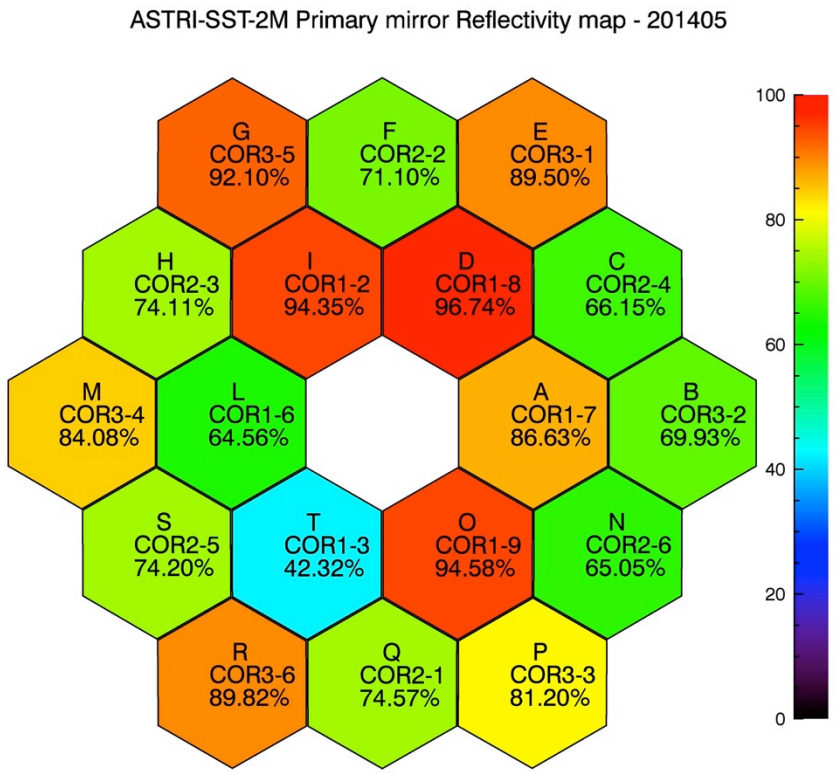
APPENDIX 1 - Reflectivity results for M1 – Dielectric coating

Reflectivity at the manufacturing (May 2014)





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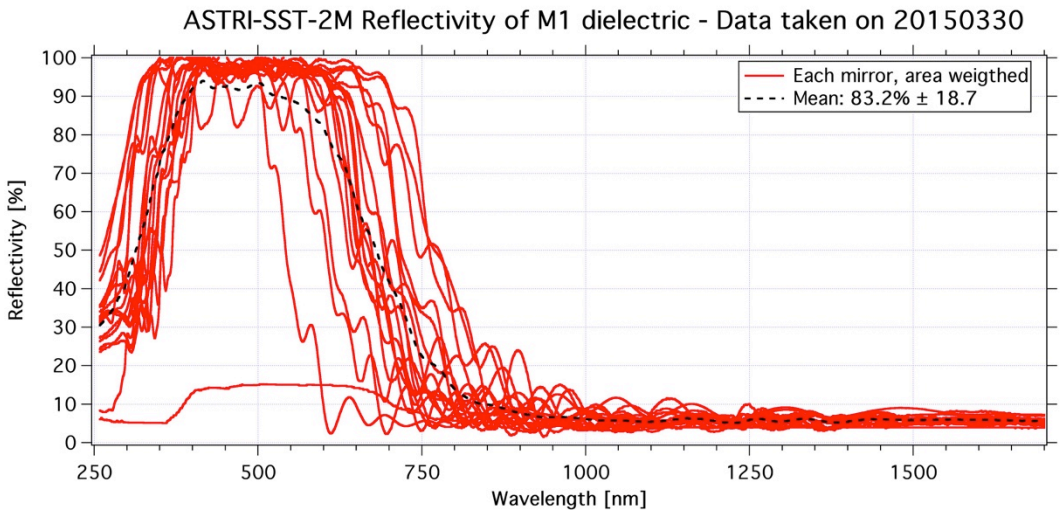
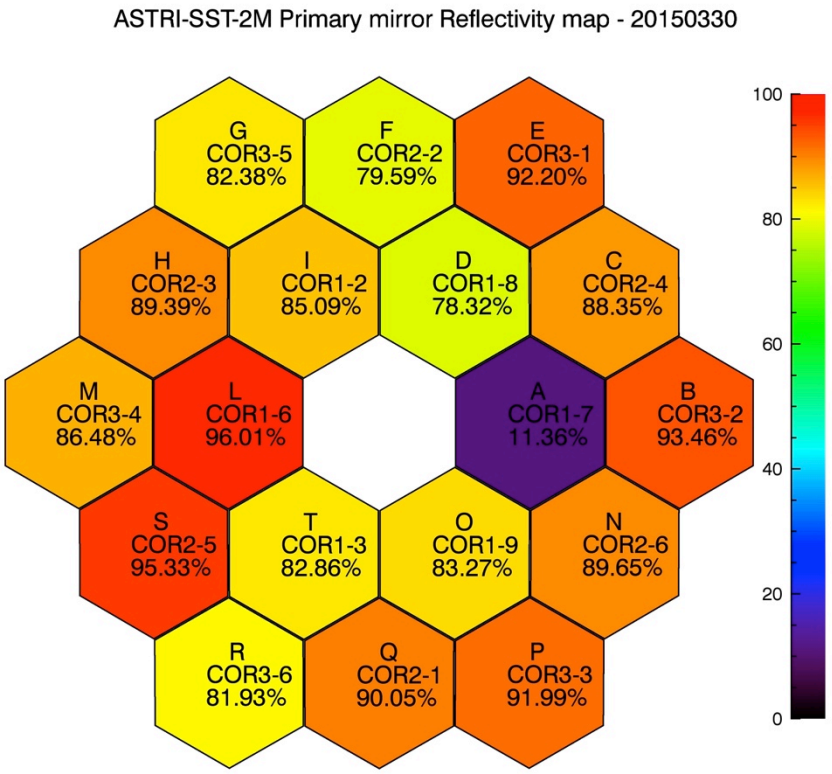
Re-measure with Filmetrics after 6 months from inauguration (March 2015)





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