

Monday 15 April 2024, CO2 cleaning of WHT Primary mirror, with analysis of CT7 Reflectometer measurements

This is the first cleaning following the October 2023 water wash, and was carried out one day after calima had dispersed.

The mirror did not appear very dusty, nor was it uniform in oblique light, but varies in a pattern likely left by sponges after water washing.

Despite nonuniformity, the Std Deviations on reflectivity are small. Notably, DI (Scattering) increased by 8 - 10% since Washing in Oct 2023.

Unusually, scattering also increased following CO2 cleaning in both average and maximum values. It is now is double that of 5 months ago.

Adjustment was made in Reflectivity for upward drift in Reference values of about 1% upwards since October 2023. Scattering reference is stable.

A new sample a week later confirms the condition of the mirror is highly variable: Range of 12% in Scattering. 4% decrease in Reflectivity.

In contrast to newly aluminised INT, water washing of WHT M1 may have increased adhesion of calima during the many episodes of past winter.

Measurements before CO2			wavelength of band (nm)								"Dust Indices"					
location		Tempr. °C	365	404	464	522	624	760	970	365	404	464	522	624	760	970
150	15/04/2024 10:40	right 1	21.13	84.98	82.46	82.01	82.49	83.84	80.73	87.54	18	18.7	8.3	8.4	7.6	8.7
151	15/04/2024 10:41	right 2	21.44	84.86	81.91	81.97	81.50	84.09	80.48	86.86	18.1	19.3	19.4	18.8	14.5	17.4
152	15/04/2024 10:42	bottom 1	21.81	85.90	83.51	83.67	84.14	85.64	82.58	88.87	14.3	14.6	19.6	20.3	13.7	17.4
153	15/04/2024 10:43	bottom 2	22.16	88.53	86.00	85.54	85.90	86.78	83.64	89.65	9.6	9.6	14	13	9.3	11.2
154	15/04/2024 10:44	left 1	22.16	87.05	84.86	84.60	85.10	86.05	83.28	89.27	12.8	12.2	9.5	8.9	7.1	8.6
155	15/04/2024 10:44	left 2	22.53	88.24	85.91	85.50	85.76	86.68	83.62	89.52	9.1	9.1	12.1	11.2	8.8	9.9
157	15/04/2024 10:47	top 1	22.66	85.47	83.67	83.47	84.10	85.10	82.66	88.59	15.6	15	40.1	50.2	18.7	19.8
158	15/04/2024 10:47	top 2	23.03	86.54	84.54	83.90	84.96	85.68	82.97	89.11	13.5	12.6	14.9	13.6	10.7	11.6
Averages bef CO2				86.45	84.11	83.83	84.24	85.48	82.50	88.68	13.6	13.7	14.0	13.5	10.2	12.1
Std Deviations				1.41	1.50	1.38	1.55	1.09	1.23	0.99	3.6	4.1	4.4	4.6	2.9	3.8

Green highlights are the best values obtained. Compare with measurements after Water washing Oct 2023:

Note change in reference measurement in these 5 months is significant (1-2%) and is adjusted for below:

Change since Oct '23 wrt Best values	-2.49	-2.98	-2.96	-3.17	-2.82	-3.03	-3.48	1.9	2.4	4.8	5.5	4.7	6.5	6.1
Change since Oct '23 wrt Averages	-3.99	-4.46	-4.34	-4.51	-3.84	-4.05	-4.28	5.0	5.8	6.9	7.9	6.6	8.7	7.8

On average, the Scattering has increased by 5-8%, consistent with, or larger than, losses in %R. This is normal, but some DI readings are very high.

In these cases (see blue highlight) the sum %R + %DI exceeds 100%, seeming to confirm theory that DI > 15% is outside range of scattering model.

They do tell us that scattering is simply very high in places. The red highlight is probably invalid (moved sensor?) and is omitted from statistics.

Next page: measurements after CO2 cleaning.

Measurements after CO2

location	Tempr. °C	wavelength of band (nm)							"Dust Indices"						
		365	404	464	522	624	760	970	365	404	464	522	624	760	970
159 15/04/2024 14:19 right 1	21.78	85.83	84.94	84.75	85.31	85.45	83.89	89.22	16.70	15.60	14.70	14.20	11.30	11.60	10.00
160 15/04/2024 14:19 right 2	22.53	85.37	83.97	83.67	84.78	85.35	83.75	90.06	20.10	20.00	18.80	16.80	12.50	13.00	8.90
161 15/04/2024 14:20 right 3	22.88	86.73	85.06	85.55	85.11	86.62	84.44	89.70	15.40	15.30	14.10	14.70	9.30	10.70	8.80
162 15/04/2024 14:21 bottom 1	23.09	86.91	85.35	85.46	85.99	87.05	84.70	90.69	15.00	14.30	13.50	12.70	8.10	9.80	7.00
163 15/04/2024 14:21 bottom 2	23.47	88.93	86.97	86.28	87.01	87.03	84.77	90.23	9.80	9.50	9.30	8.90	7.10	8.70	7.30
164 15/04/2024 14:22 bottom 3	23.81	88.98	87.13	86.78	87.49	87.86	85.59	91.34	10.40	10.10	9.30	8.70	6.20	7.30	5.70
165 15/04/2024 14:23 left 1	23.81	83.49	81.99	82.21	83.15	84.01	82.29	88.49	22.50	22.40	21.80	20.40	15.00	16.70	12.20
166 15/04/2024 14:23 left 2	24.06	87.92	86.08	85.61	85.82	86.73	83.93	89.97	11.10	10.70	10.90	10.30	7.60	9.30	7.50
167 15/04/2024 14:24 left 3	24.31	82.61	81.09	81.98	82.26	84.57	82.22	88.46	26.40	24.30	22.70	22.80	14.90	15.70	12.40
168 15/04/2024 14:24 top 1	24.19	85.89	84.18	83.89	85.13	85.73	83.79	90.29	18.20	17.90	17.70	15.40	11.50	11.90	7.80
169 15/04/2024 14:25 top 2	24.59	85.15	83.61	84.05	84.52	85.76	83.83	89.67	19.10	18.80	17.20	16.40	11.20	11.70	9.00
170 15/04/2024 14:25 top 3	24.81	83.58	82.35	82.38	83.70	84.30	82.89	88.21	21.60	20.00	19.60	17.70	13.40	13.20	11.20
Averages post CO2		85.95	84.39	84.38	85.02	85.87	83.84	89.69	17.2	16.6	15.8	14.9	10.7	11.6	9.0
Std Deviations		2.07	1.91	1.62	1.50	1.21	1.00	0.95	5.1	4.8	4.6	4.3	3.0	2.8	2.1
Averages omitting red values		86.86	85.25	85.12	85.68	86.40	84.30	90.13	14.5	14.0	13.3	12.7	9.0	10.1	7.9

The 3 red %R series are worse than any obtained prior to CO2 cleaning and may be due to stains, measured by chance.

Comparison before v after CO2

change in averages (omit red) 0.41 | 1.15 | 1.28 | 1.44 | 0.92 | 1.80 | 1.45 | 0.8 | 0.3 | -0.6 | -0.8 | -1.2 | -2.0 | -2.2 |

Note the very small improvement in average %R, with some increases in Scattering, even when supposed stains are ignored.

Given the large number of unusually high measurements, a new sample of these was taken a week later.

Repeat measurements of M1, 1 week later

216 25/04/2024 09:48 right 1	17.34	84.31	83.82	83.00	84.32	84.13	82.66	88.68	19.4	18.7	19.1	17.4	13.9	14.7	11.3
217 25/04/2024 09:49 right 2	18.13	87.89	87.12	86.37	87.13	86.97	85.02	90.60	11.6	11.0	10.6	10.3	7.6	8.3	7.1
218 25/04/2024 09:49 right 3	18.59	84.56	84.13	83.11	85.08	83.23	83.16	88.09	17.6	16.8	17.5	14.5	14.6	13.2	12.0
219 25/04/2024 09:50 bottom 1	18.75	86.47	85.63	85.30	85.98	86.60	84.29	90.13	14.1	14.2	13.0	12.0	8.4	9.8	7.6
220 25/04/2024 09:51 bottom 2	19.31	88.80	87.70	87.04	87.44	87.76	85.16	90.65	9.2	9.2	9.0	8.3	6.1	7.7	6.5
221 25/04/2024 09:52 left 1	19.44	84.58	84.06	83.57	84.85	85.49	83.76	89.49	19.2	18.8	17.9	16.7	11.3	12.4	9.2
222 25/04/2024 09:52 left 2	19.94	88.50	87.31	86.63	87.27	87.88	85.04	90.99	10.1	9.8	10.0	8.8	6.1	8.1	5.9
223 25/04/2024 09:53 left 3	20.19	86.07	85.28	84.87	85.68	85.88	83.91	89.27	14.2	13.9	13.0	12.3	9.3	10.6	8.8

224	25/04/2024 09:54	top 1	20.34	88.20	87.49	87.18	87.92	88.10	86.20	91.69	11.4	10.5	9.1	8.1	5.6	5.6	4.3
225	25/04/2024 09:54	top 2	20.72	84.91	83.92	83.48	84.76	85.47	83.50	89.60	18.1	18.0	17.8	16.0	11.5	12.4	8.7
226	25/04/2024 09:54	top 3	20.94	82.94	81.95	82.07	82.59	84.06	81.72	87.51	21.4	22.2	20.6	20.3	13.8	16.3	12.8
227	25/04/2024 09:55	top 4	21.19	85.10	84.14	84.19	84.80	85.78	83.85	89.67	17.7	17.7	16.2	15.7	10.8	11.5	8.3
Averages				86.03	85.21	84.73	85.65	85.95	84.02	89.70	15.3	15.1	14.5	13.4	9.9	10.9	8.5
Std deviation				1.93	1.85	1.75	1.56	1.59	1.22	1.21	4.1	4.2	4.2	4.0	3.2	3.1	2.5
Range				5.86	5.75	5.11	5.33	4.87	4.48	4.18	12.2	13.0	11.6	12.2	9.0	10.7	8.5

Above averages are very similar to those from previous sample (omitting red values), except in 2 bands (affected by Reference drift in past week.)

Change in averages after 1 week?	0.08	0.82	0.35	0.63	0.07	0.18	0.00	-1.9	-1.5	-1.3	-1.6	-0.8	-0.8	-0.4
Change, adjusted for dirt in Refnce	0.66	0.50	0.25	0.61	0.25	0.59	-0.07							

The adjustments are not consistent with and do not resolve the measured changes. In any case all < std dev, so are probably insignificant.

Changes (after - before CO2) in Reflectivity and DI by Location:

location	wavelength of band (nm)							"Dust Indices"						
	365	404	464	522	624	760	970	365	404	464	522	624	760	970
right	1.16	2.86	2.70	3.49	1.56	3.45	2.33	-1.77	-3.26	1.29	0.50	0.01	-1.69	-1.39
bottom	0.80	1.80	1.57	1.76	1.05	1.79	1.35	-0.3	-0.6	-6.0	-6.5	-4.3	-5.6	-4.8
left	-0.88	0.30	0.12	0.47	0.13	0.71	0.53	2.7	2.7	2.2	2.0	0.6	0.9	0.0
top	-0.16	0.56	0.87	0.90	0.78	1.42	1.33	3.4	4.0	0.7	0.7	-0.6	-1.0	-2.2

Conclusion:

Even with extra measurements, the effects of cleaning are highly variable in location and wavelength, sometimes insignificant or even negative.

The mirror seems to have a good number of areas in poorer condition and needs another CO2 cleaning to see if scattering can be improved.

Calibration:

Gauge reference measurements taken after cleaning

15/04/2024 14:59	Gauge Ref	26.47	86.20	84.80	88.80	91.00	90.50	84.70	87.10								
148	22/11/2023 15:54	Gauge Ref	27.19	84.86	83.42	87.58	89.75	89.98	83.74	86.37							
Change in Ref in 5 months			1.34	1.38	1.22	1.25	0.52	0.96	0.73	Used to adjust new values wrt Oct 2023							
16/04/2024 09:45	Gauge DI	20.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.4	10.2	10.2	10.3	9.5	9.5	0.0	
26/04/2023	Gauge DI	25.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.2	10.2	10.3	10.3	9.6	9.6	8.9	
215	25/04/2024 09:39	Gauge %R	18.56	85.73	85.16	89.05	90.98	90.26	84.21	87.17	0.0	0.0	0.0	0.0	0.0	0.0	0.0

after M1 measurement.

228	25/04/2024 10:00	Gauge %R	19.84	85.54	85.15	88.80	91.05	90.37	84.35	87.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
229	25/04/2024 10:01	Gauge %R	20.59	85.58	85.06	88.85	91.02	90.35	84.31	87.16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
change from previous				-0.17	-0.05	-0.23	0.05	0.10	0.12	0.01	No significant drift. Take average of all 3.						
change since 15/4				-0.58	0.32	0.10	0.02	-0.17	-0.41	0.08	Use this adjustment to compare post-CO2 samples						

Values after Wash 10/2023				89.09	87.19	86.95	87.50	88.80	85.58	92.23	8.6	7.9	7.1	5.6	3.7	3.4	2.3
change since wash				-3.07	-1.97	-2.22	-1.85	-2.86	-1.56	-2.53	6.7	7.1	7.4	7.8	6.2	7.5	6.3

Tertiary mirror measurement:

156	15/04/2024 10:46	WHT M3	22.5	62.04	61.32	61.70	62.57	63.37	61.62	66.08	35.3	26	9.2	8.6	7.3	8.8	7.7
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