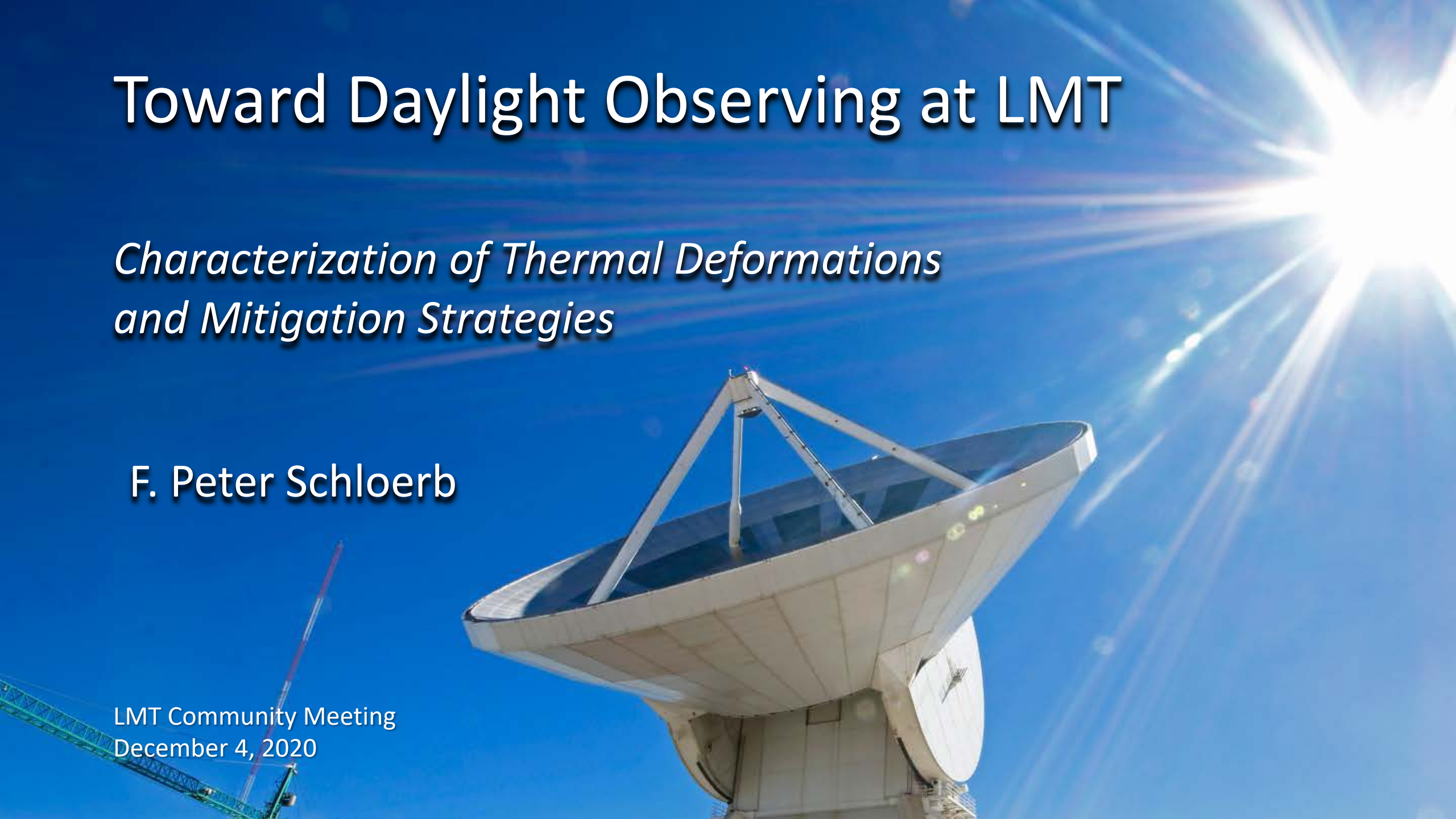
Toward Daylight Observing at LMT

Characterization of Thermal Deformations and Mitigation Strategies

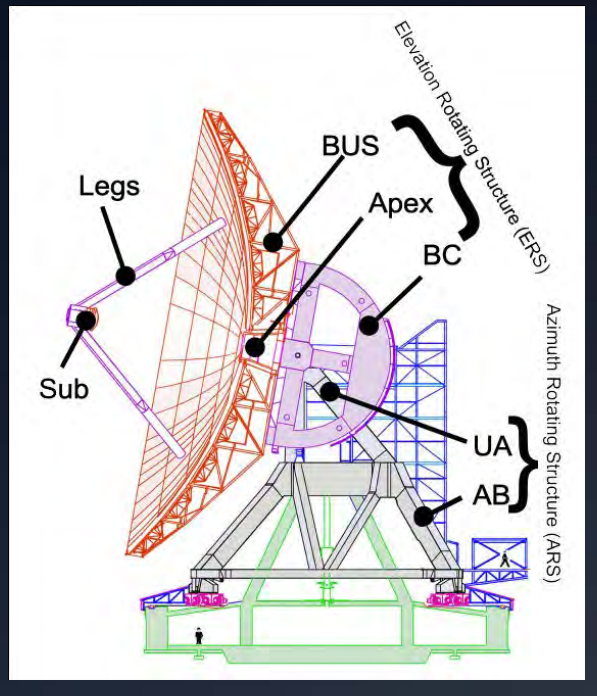
F. Peter Schloerb

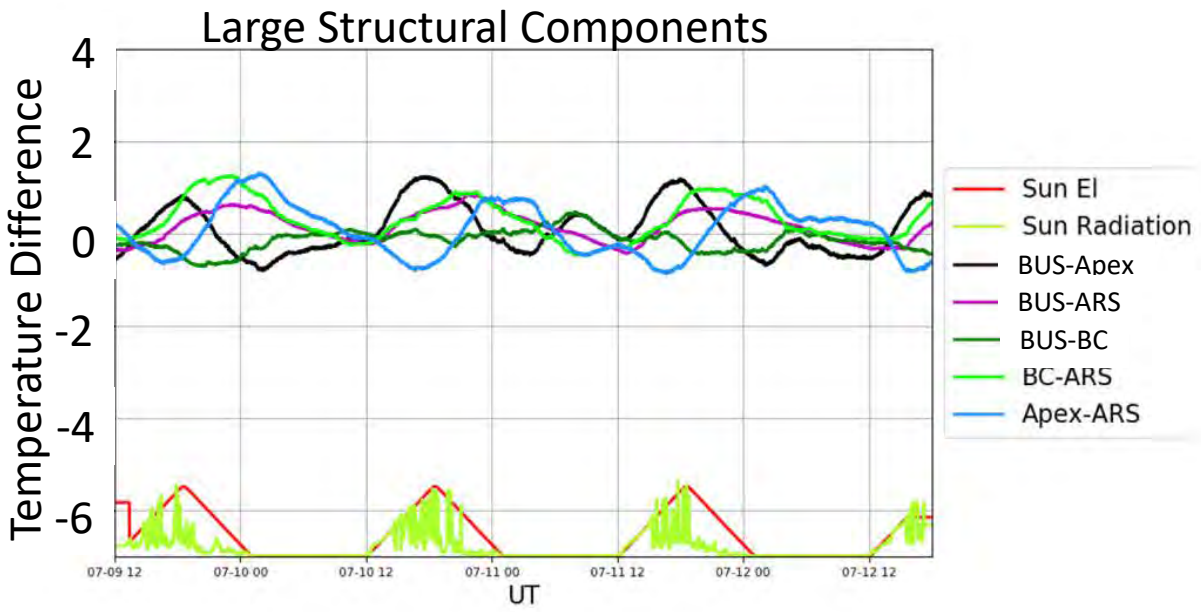


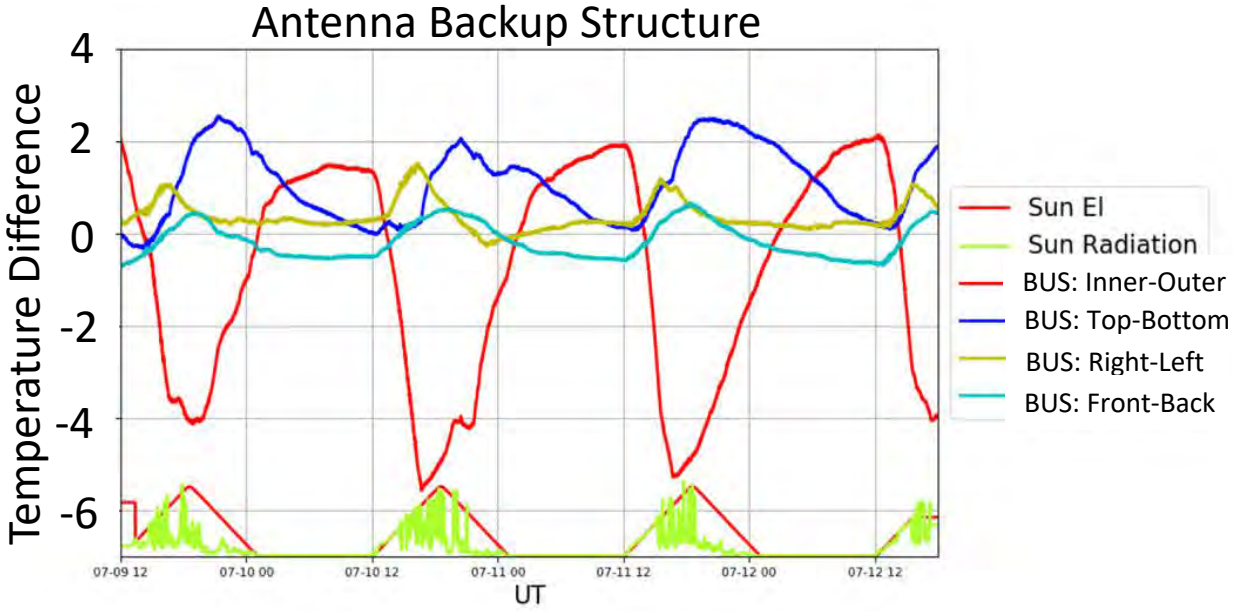
LMT Community Meeting
December 4, 2020

Characterization

Daily Temperature Differences within the LMT structure

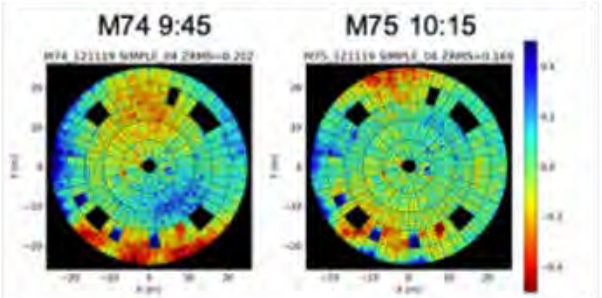


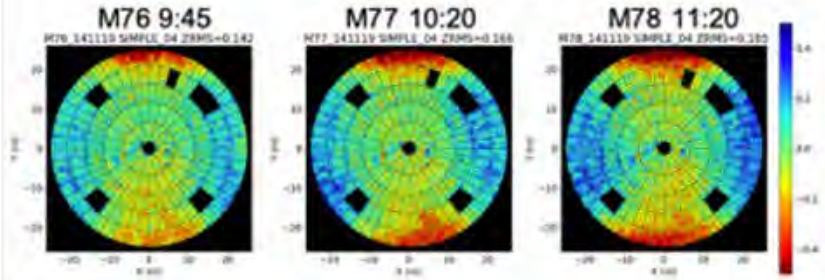




Photogrammetry Maps

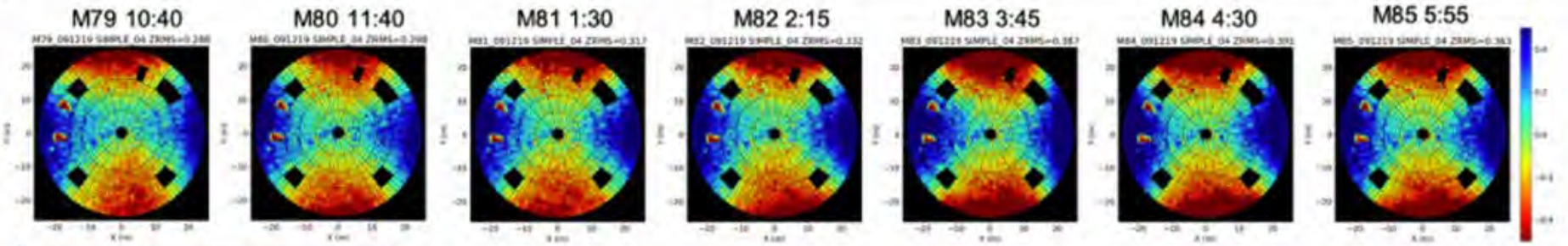
Best parabola removed

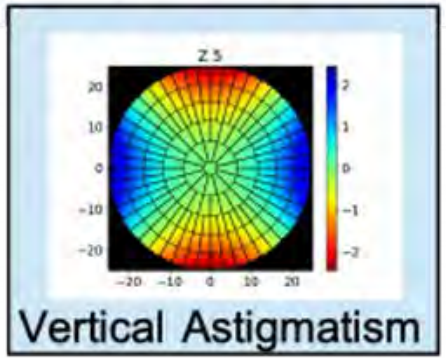


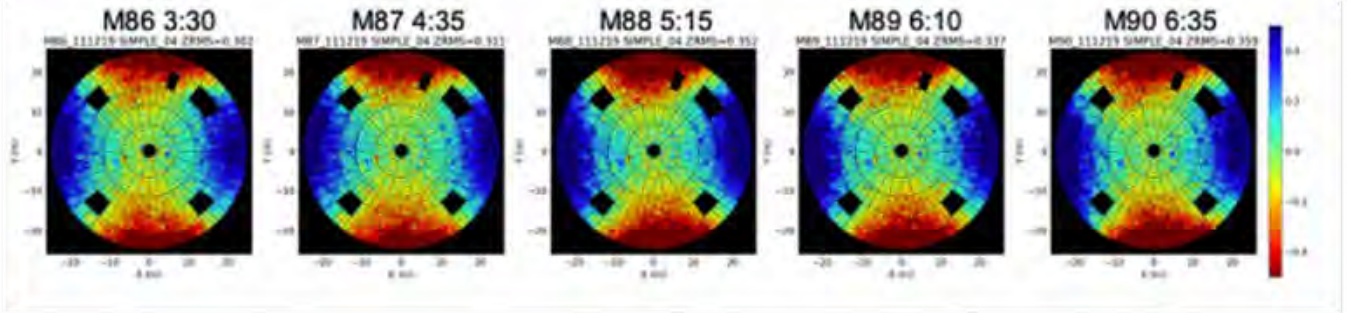


Temperature Gradients

MAP	Dish	I-O	T-B	R-L	F-B	D-UA	D-BC
74	3.08	0.97	0.48	0.41	-0.19	-0.21	-0.08
75	2.74	1.43	0.35	0.45	-0.25	-0.25	-0.17
76	1.06	1.31	0.11	0.00	0.11	-0.05	0.30
77	0.94	1.48	0.04	0.04	0.07	-0.03	0.37
78	0.77	1.73	-0.06	0.09	0.02	-0.08	0.40
79	3.75	1.75	0.64	0.26	-0.25	-0.68	-0.43
80	3.39	2.18	0.50	0.29	-0.28	-0.86	-0.55
81	2.86	2.60	0.26	0.18	-0.28	-0.95	-0.52
82	2.69	2.72	0.20	0.17	-0.27	-0.97	-0.54
83	2.37	2.94	0.07	0.18	-0.29	-1.05	-0.53
84	2.23	3.02	0.02	0.14	-0.30	-1.05	-0.51
85	1.94	3.16	-0.07	0.15	-0.30	-1.01	-0.50
86	0.44	1.94	-0.39	-0.03	-0.21	-0.73	-0.24
87	0.34	2.07	-0.41	-0.05	-0.25	-0.56	-0.15
88	0.26	2.17	-0.40	-0.05	-0.26	-0.58	-0.15
89	0.17	2.28	-0.40	-0.05	-0.27	-0.68	-0.20
90	0.13	2.32	-0.41	-0.07	-0.28	-0.72	-0.23

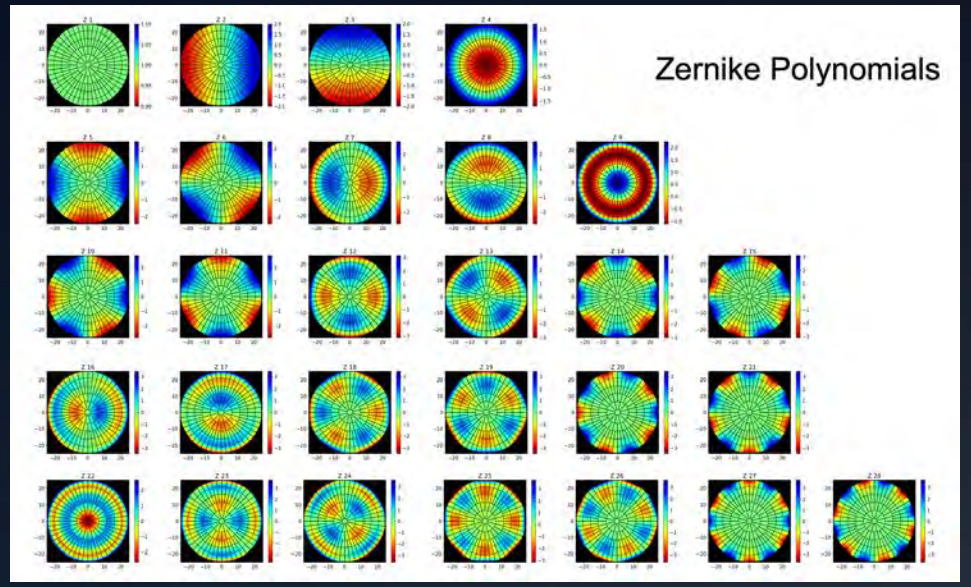


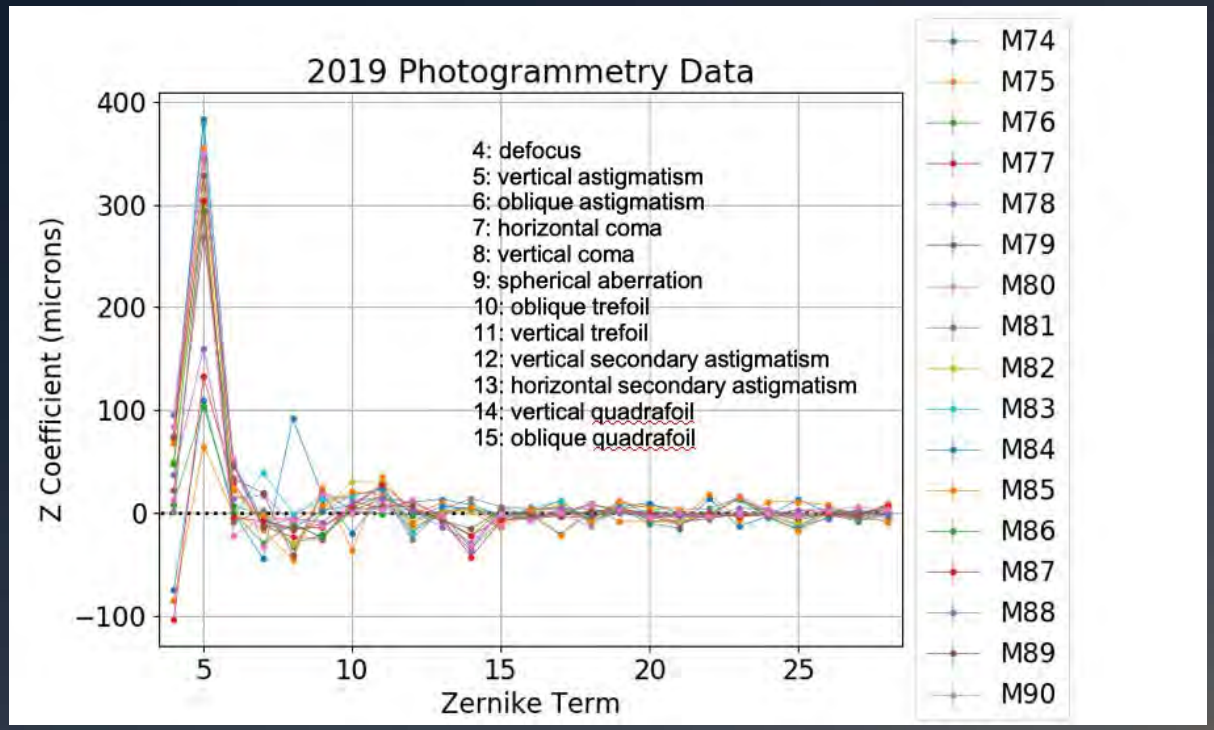


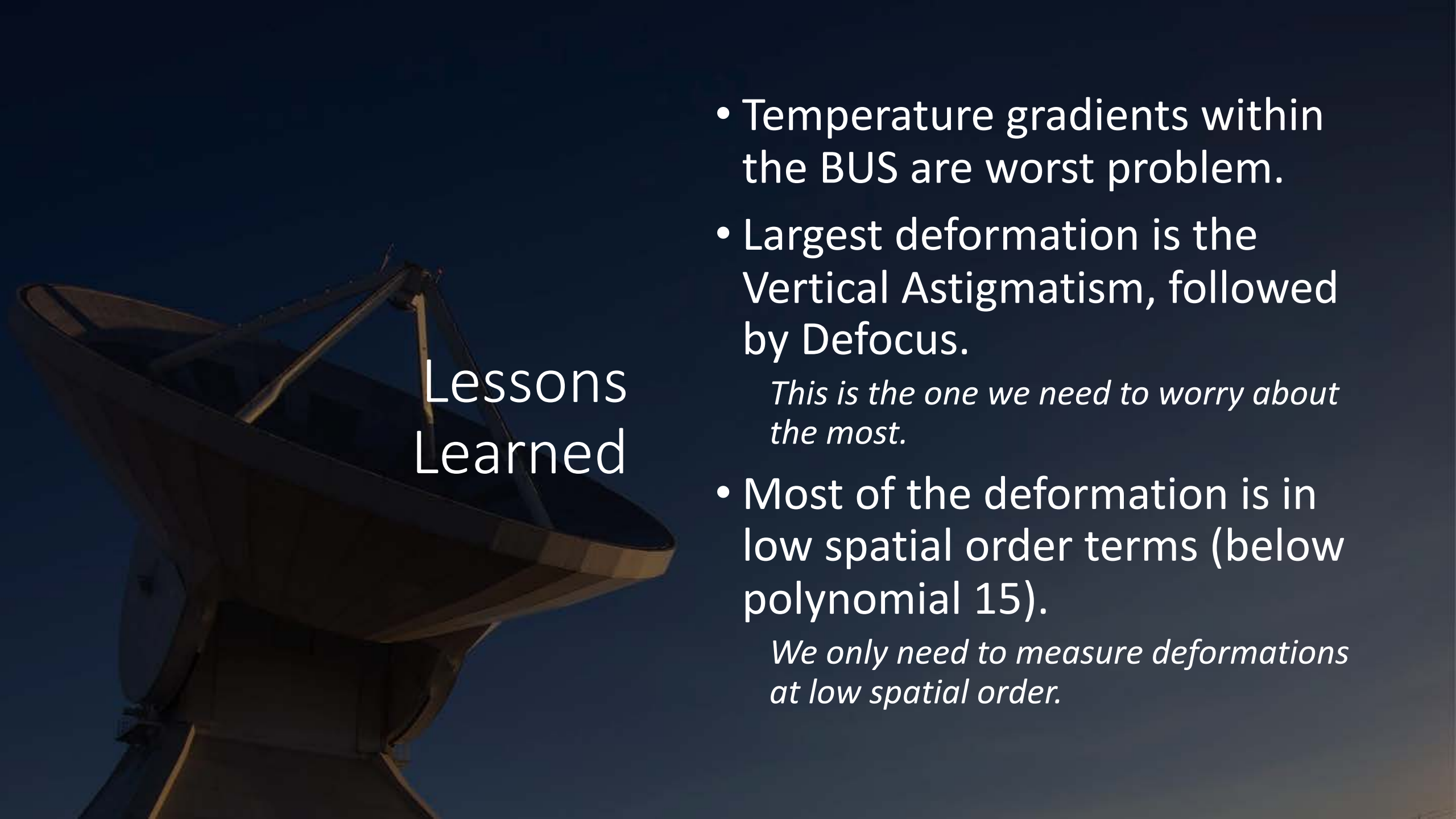


Analysis of Maps

Major contribution from Vertical Astigmatism Term





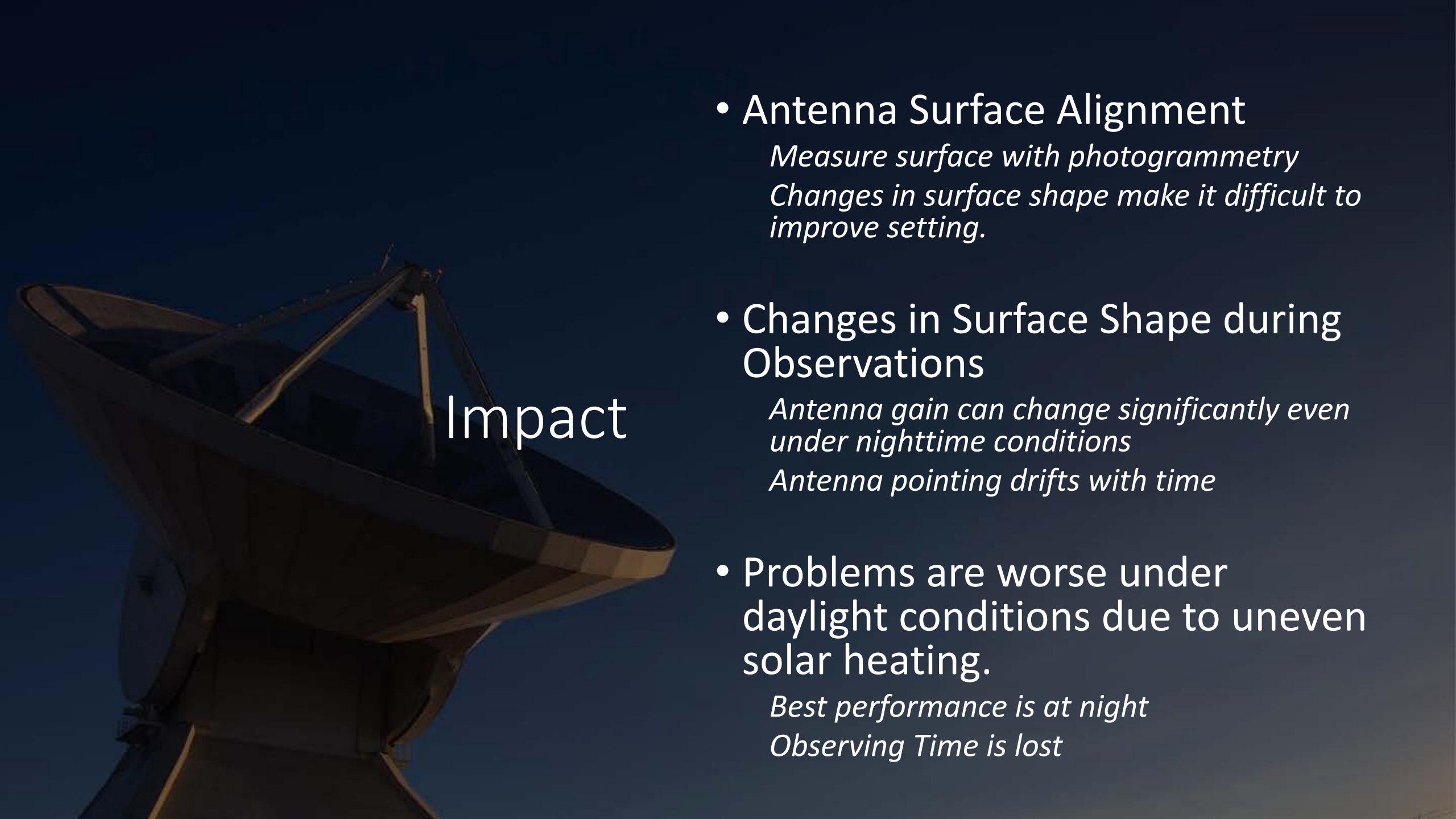


Lessons Learned

- Temperature gradients within the BUS are worst problem.
- Largest deformation is the Vertical Astigmatism, followed by Defocus.

  This is the one we need to worry about the most.
- Most of the deformation is in low spatial order terms (below polynomial 15).

  We only need to measure deformations at low spatial order.



Impact

- Antenna Surface Alignment
  - *Measure surface with photogrammetry*
  - *Changes in surface shape make it difficult to improve setting.*
- Changes in Surface Shape during Observations
  - *Antenna gain can change significantly even under nighttime conditions*
  - *Antenna pointing drifts with time*
- Problems are worse under daylight conditions due to uneven solar heating.
  - *Best performance is at night*
  - *Observing Time is lost*

Mitigation Strategy 1

Minimize structural temperature differences

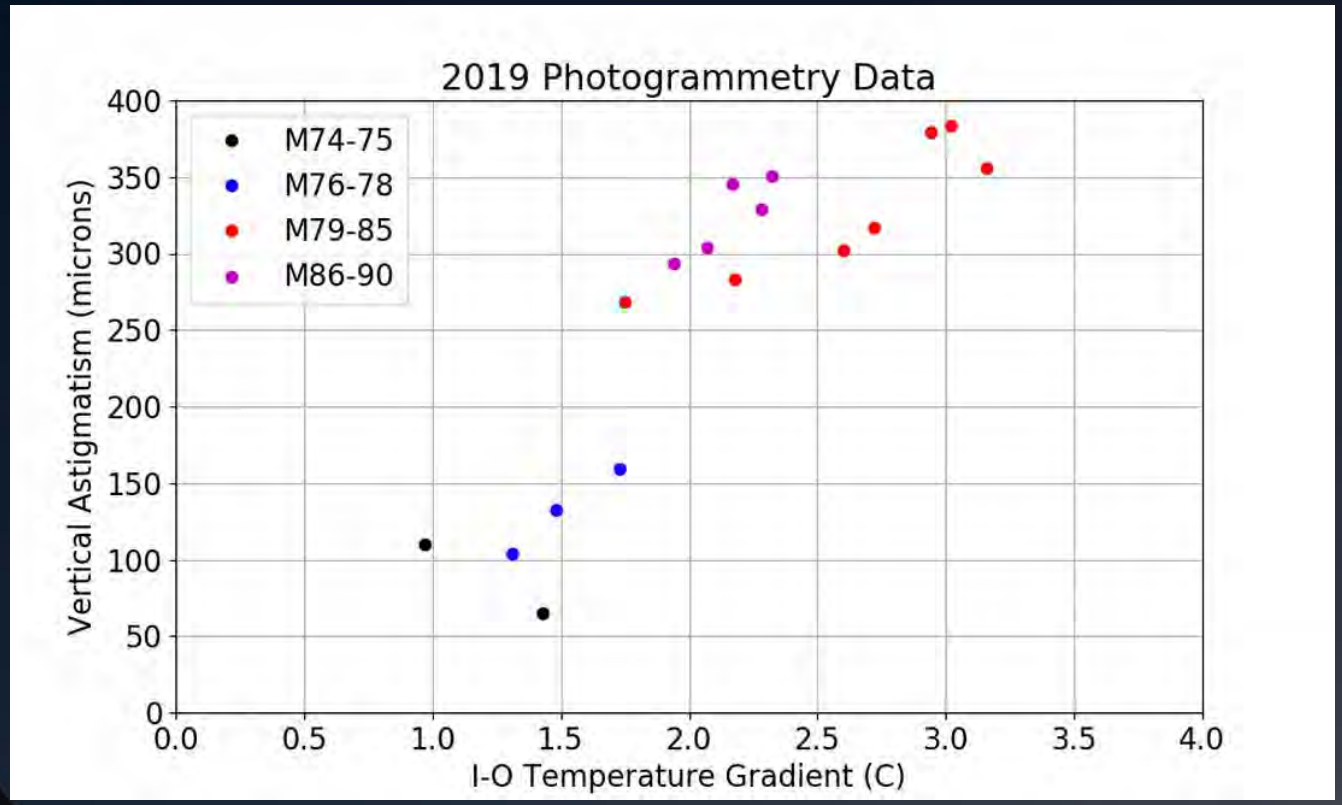
- Follow recommendations of antenna designer…
- Thermal Cladding - *Antenna is covered with insulating material*
  - *No direct sunlight*
  - *Slows structural response*
  - *But isolates antenna BUS from ambient air, so hot air is retained.*
- BUS Ventilation
  - *A feature of all large antennas*
  - *Need to install system of fans to circulate air within the BUS.*
  - *Project underway – now in design phase.*

Mitigation Strategy 2

Real-time Correction

- Approach:
  - Measure (or infer) surface deformation.
  - Use LMT Active Surface to make corrections.
- Measurement Techniques
  - Infer deformations from structural temperatures.
  - Infer deformations from astronomical measurements
  - Measure deformations in real time
- LMT is pursuing all approaches.

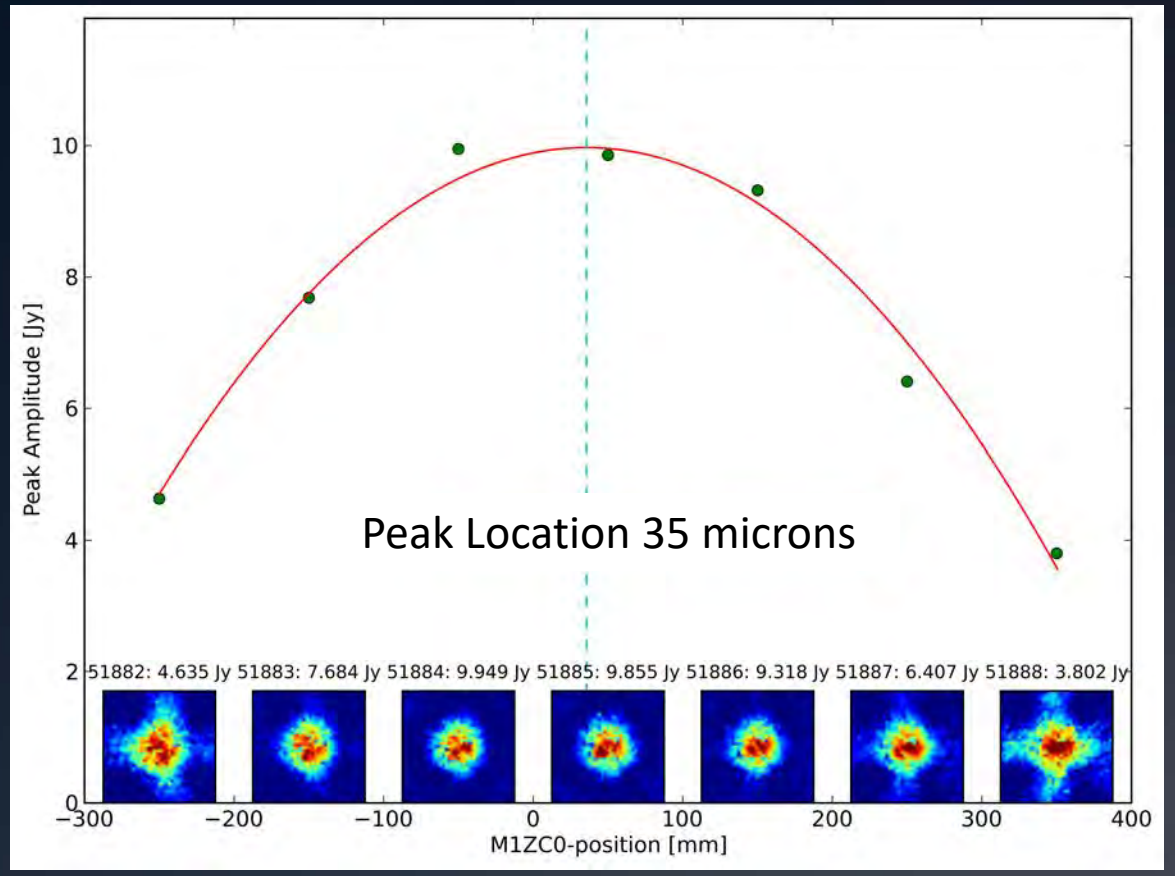
Deformation correlated with Temperature Gradients



Experience at other antennas suggests that we need measurements at ~200 positions on the structure to infer deformations accurately.

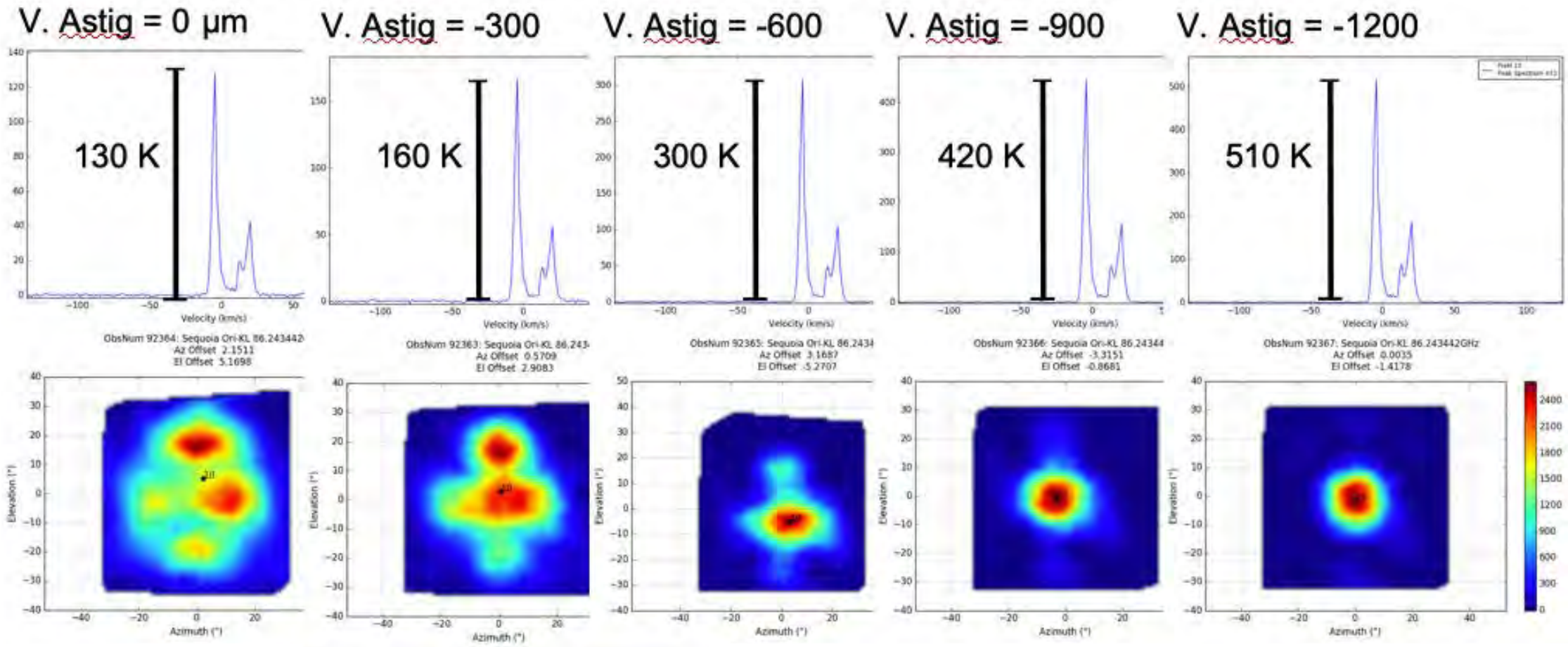
LMT program to install 256 temperature sensors is underway.

Real time measurements of Vertical Astigmatism at LMT



LMT makes regular measurements of this effect during observations

Example of Daytime Observation



LMT is conducting daytime tests to characterize behavior

Real-time Measurements

A concept for LMT

Precision Distance Measurements within Structures

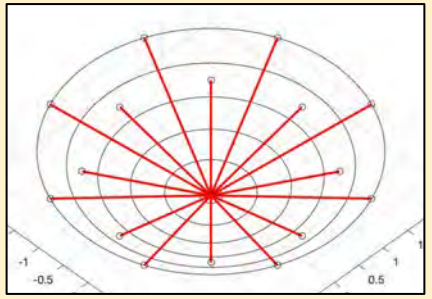
Etalon Absolute Multiline Technology

Length Error:

$$\frac{\Delta L}{L} = 5 \times 10^{-7}$$

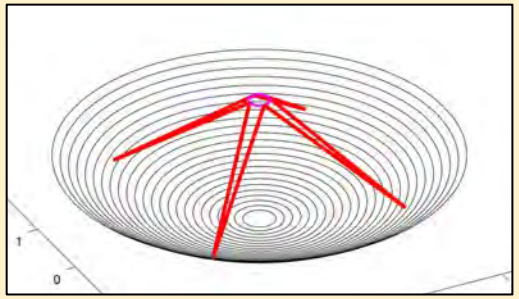
Testing at VLT

LMT Concept



Surface Measurement

- Estimate Zernike Coefficients through polynomial 15
- Surface Reconstruction Error: 30 microns RMS



Secondary Measurement

- Estimate 6 degrees of freedom
- Residual pointing error due to secondary misalignment: 0.25” RMS

Summary

- Studies of LMT Thermal Deformations have characterized the problem.
- Strategies have been developed to mitigate problems and work is underway
  - *Minimize Temperature Gradients*
  - *Measure Deformations and Correct*
- Expected Improvements
  - *Better surface alignment.*
  - *Better nighttime performance.*
  - *Useful scientific observing during daylight hours.*