TMT
THIRTY METER TELESCOPE

High Contrast on Segmented Telescopes:

Contrast Sensitivity and Prediction

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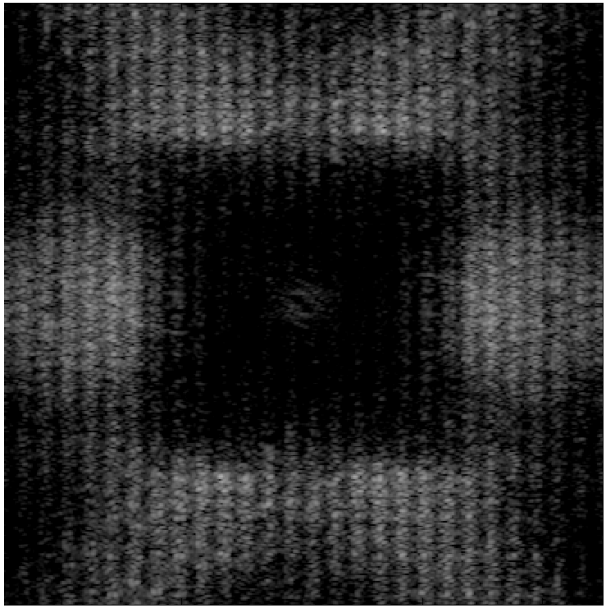
Overview

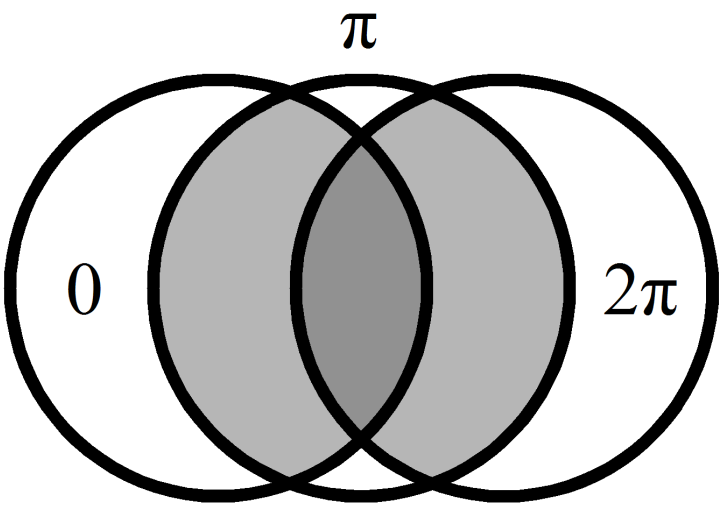
- Introduction to the Planet Formation Instrument
- Develop a set of parametric fits to predict contrast from segment aberrations

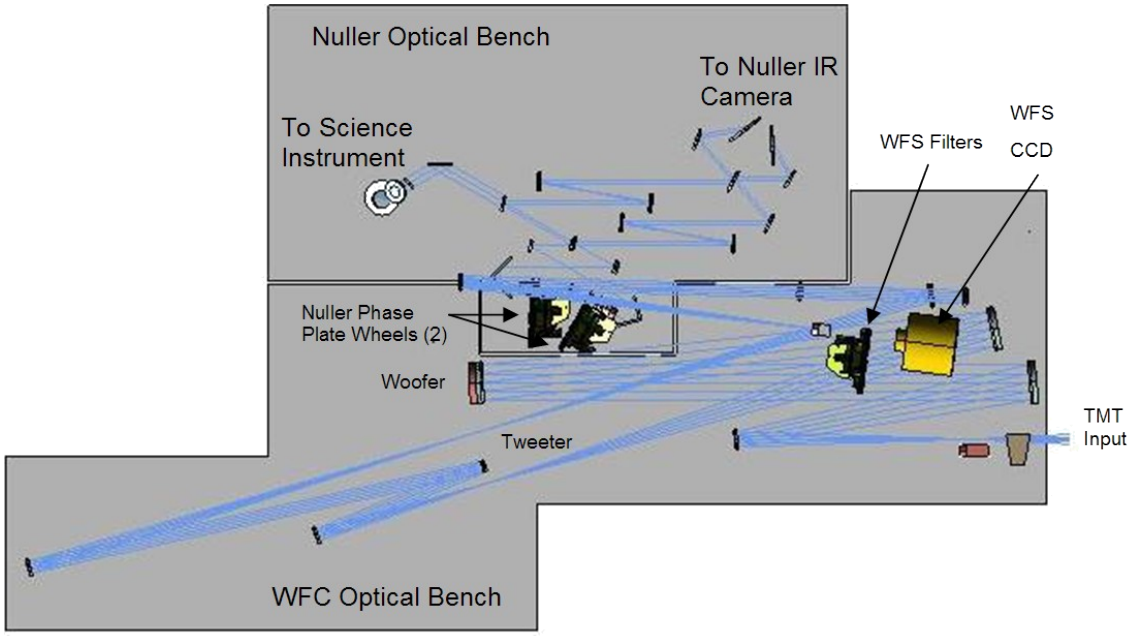
- Goal: A high-contrast predictor for the TMT Planet Formation Instrument (PFI)



Planet Formation Instrument

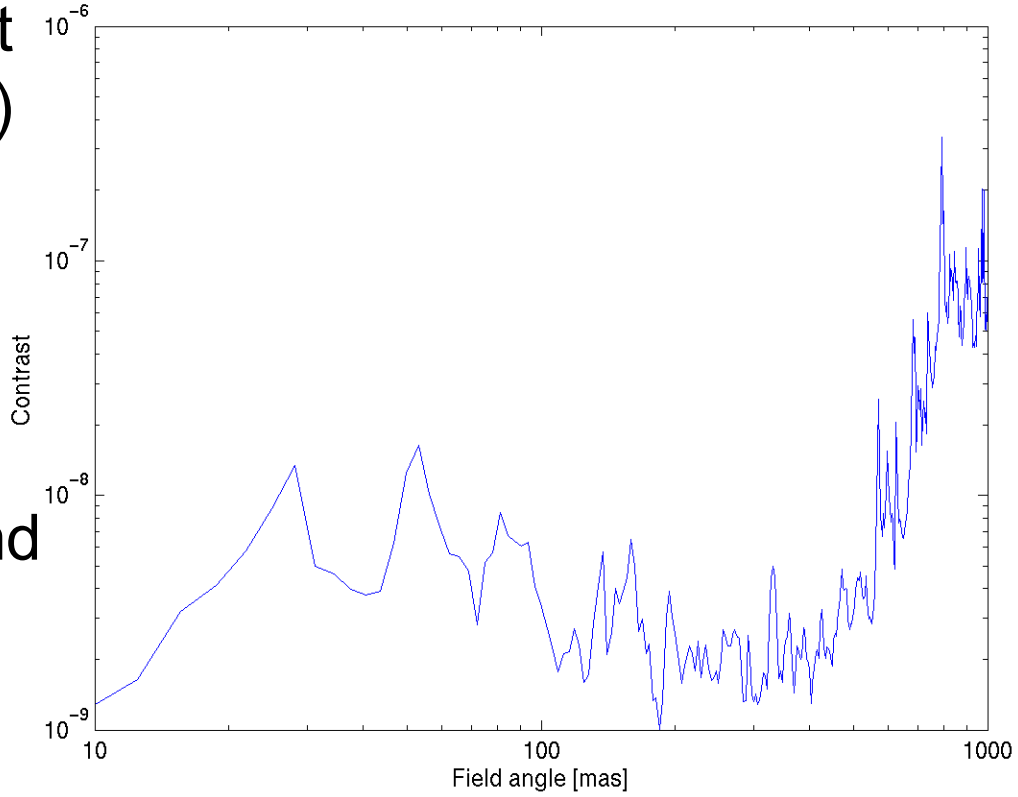
- The TMT's high-contrast imager
- Dual-shear nuller
- Integrated, high-order, multi-conjugate AO system





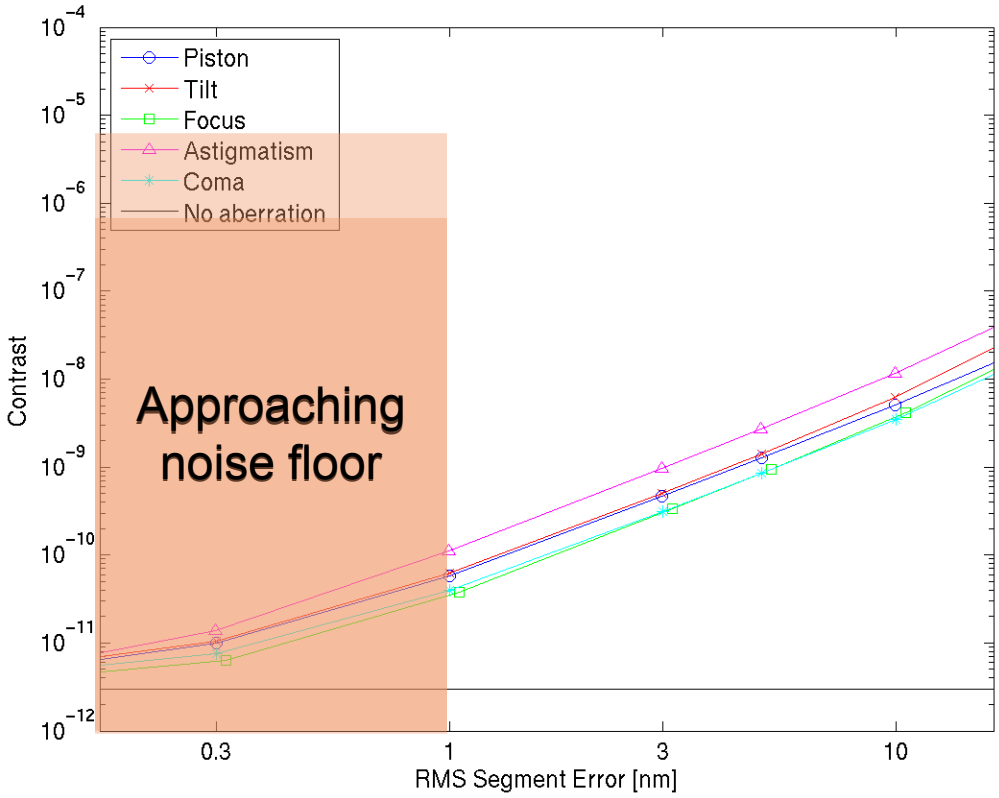
Simulation Procedure

- Apply a single segment aberration (e.g., piston)
- Correct the aberrated segmented wavefront
- Null the corrected wavefront
- Form H band image and measure contrast
- Rinse and repeat



Contrast Dependence

- Dependence of contrast on wavefront error
- Curve-fit
- Build a set of parametric fits for each aberration



Contrast Calculator Spreadsheet

$$C \approx \sum_{n=1}^{15} c_n \sigma_n^2$$

Noll Zernike	nm RMS	Contrast
Z1:	12	6.65E-09
Z2:	6	1.29E-09
Z3	6	2.13E-09
Z4	8	1.96E-09
Z5	8	6.65E-09
Z6	8	4.25E-09
Z7	4	4.77E-10
Z8	4	3.23E-10
Z9	4	2.36E-09
Z10	4	8.74E-10
Z11	3	7.17E-10
Z12	3	6.40E-10
Z13	3	4.20E-10
Z14	3	1.65E-09
Z15	3	1.15E-09
		3.16E-08

Measured: 5.6×10^{-8}

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Contrast Predictions

	Contrast Predictor	End-to-end simulation	Error Factor
Unwarped segments	1.2×10^{-7}	2.5×10^{-7}	0.48
Warped segments	2.0×10^{-8}	4.5×10^{-8}	0.44
Alignment errors	1.0×10^{-8}	1.3×10^{-8}	0.77
Combined	3.0×10^{-8}	5.6×10^{-8}	0.54

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Conclusions

- We have developed a Systems Engineering tool that can quickly calculate the tradeoffs between segment aberrations and PFI achievable contrast
- Comparing to previous results shows that we successfully estimate contrast to within a factor of two
- Future work:
  - Wavefront Correction calculator
  - Redo using updated TMT design
  - Publish

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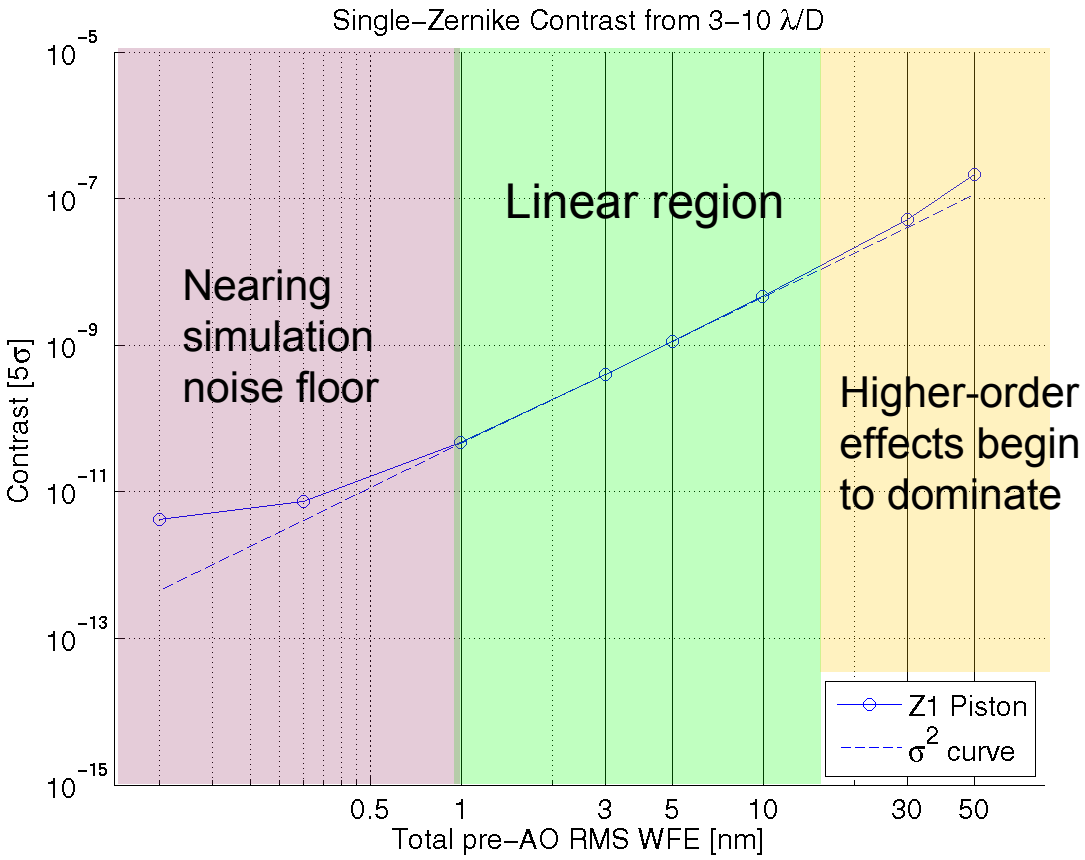
Backup

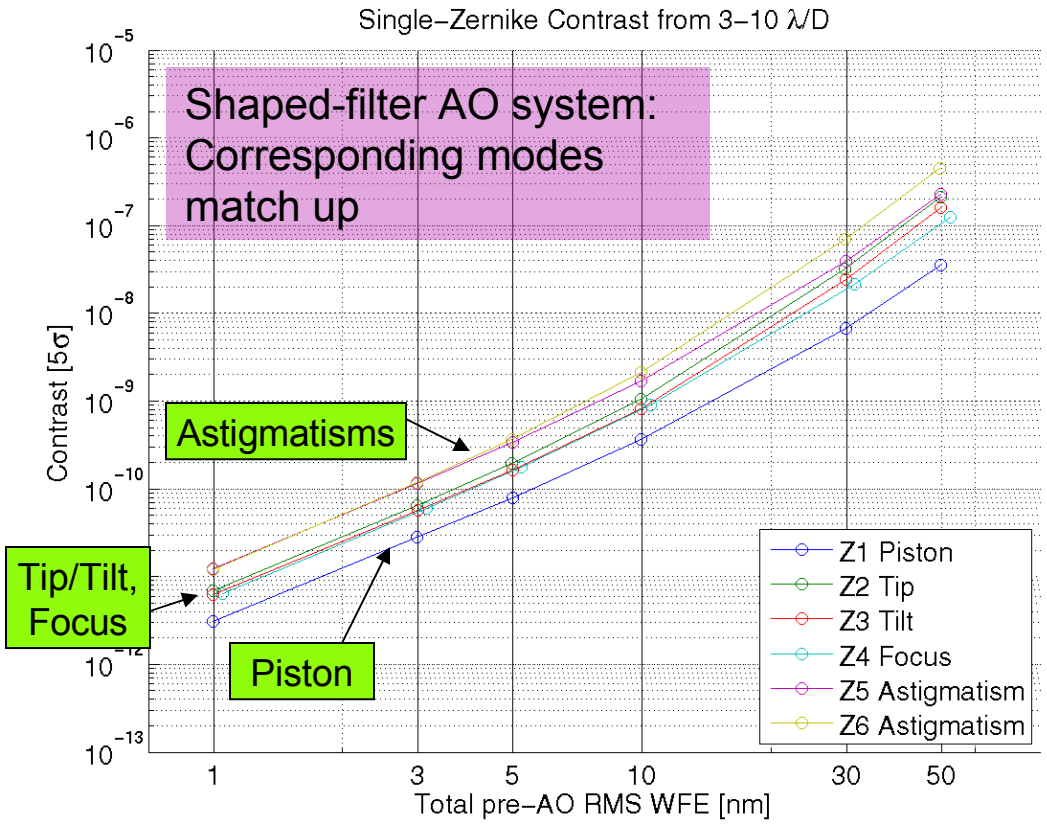
Contrast Dependence



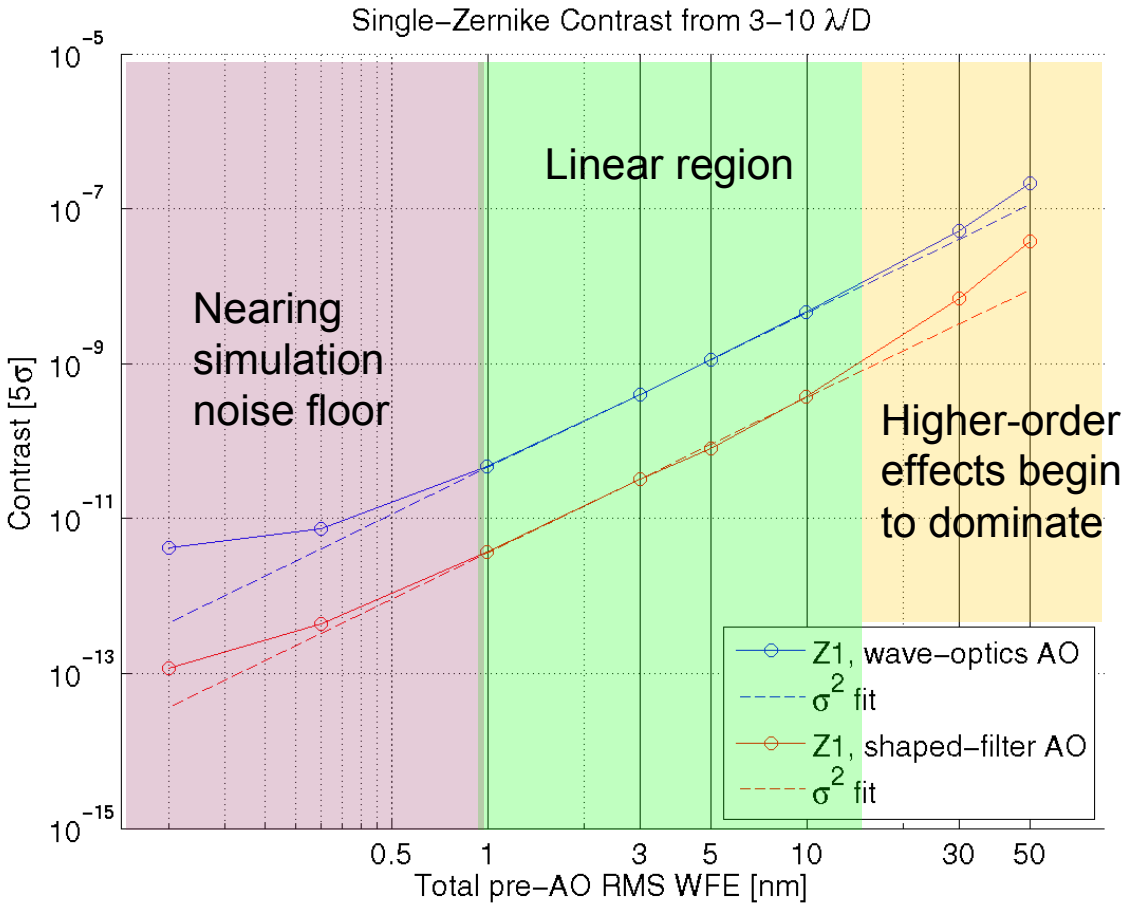
- Plot dependence of final contrast on initial WFE
- "Region of linearity" (shaded region) includes segment aberrations with WFE of 1 – 20 nm RMS
- This is the linear region in our simulation
- We compute a single-parameter σ^2 fit to the data in this region, which matches extremely well
- The fit curves have the form:
  $C = \exp[P] * \sigma^2$ *or*
  $\log[C] = P + 2\sigma$

Similar-Zernike Discrepancy

- Contrary to expectations, the contrast dependencies of similar segment aberrations (tip/tilt, astigmatisms) do not match up
- Using an idealized filtering AO system (removes all aberrations up to the AO's controllable bandpass) eliminates this discrepancy in the linear regime (see figure at right)
- Suggestion: difference is due to AO system, either
  - Wavefront Sensing
  - Wavefront Control
- Conclusion: while we would like to understand this effect, it does not prevent us from making effective contrast predictions



Comparison of AO Effects



Contrast Calculator Spreadsheet

$$C \sqrt{\sum_{n=1}^{15} |\square_n \square_n|^2}$$

Noll Zernike	Initial RMS	Corrected RMS
Z1:	10	3.99
Z2:	10	4.89
Z3	10	4.88
Z4	10	4.69
Z5	10	5.64
Z6	10	6.13
Z7	10	4.50
Z8	10	4.70
Z9	10	6.74
Z10	10	6.55
Z11	10	5.04
Z12	10	5.06
Z13	10	4.71
Z14	10	7.49
Z15	10	7.33
	38.73	**21.65**

Wavefront Correction Factors