AFTA PIAACMC 2nd Generation (PIAACMC-20140719) Modeling Results

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Results Summary

- IWA = 1.3 λ/D, no defined OWA (λ = 550 nm)
- Can work over 20% bandpass
  - may be limited by polarization aberration changes over bandpass, even in single polarization channel
- Single DM (44 actuators across pupil) allow for single-sided OWA out to ~18 λ/D or small full dark hole (OWA ~5 λ/D)
- Relatively high throughput (core throughput is 50% of maximum theoretical)
- High jitter sensitivity (1 mag contrast degradation from 1.3-3.5 λ for 0.4 mas jitter)
  - jitter sensitivity means no significant differences between solutions with 9 or 18 λ/D OWAs for 0.4 mas jitter
- High low-order aberration sensitivity requires operation in a single polarization channel
- Results for 10%, 1-sided, 9 & 18 λ/D OWA dark holes submitted for science metrics

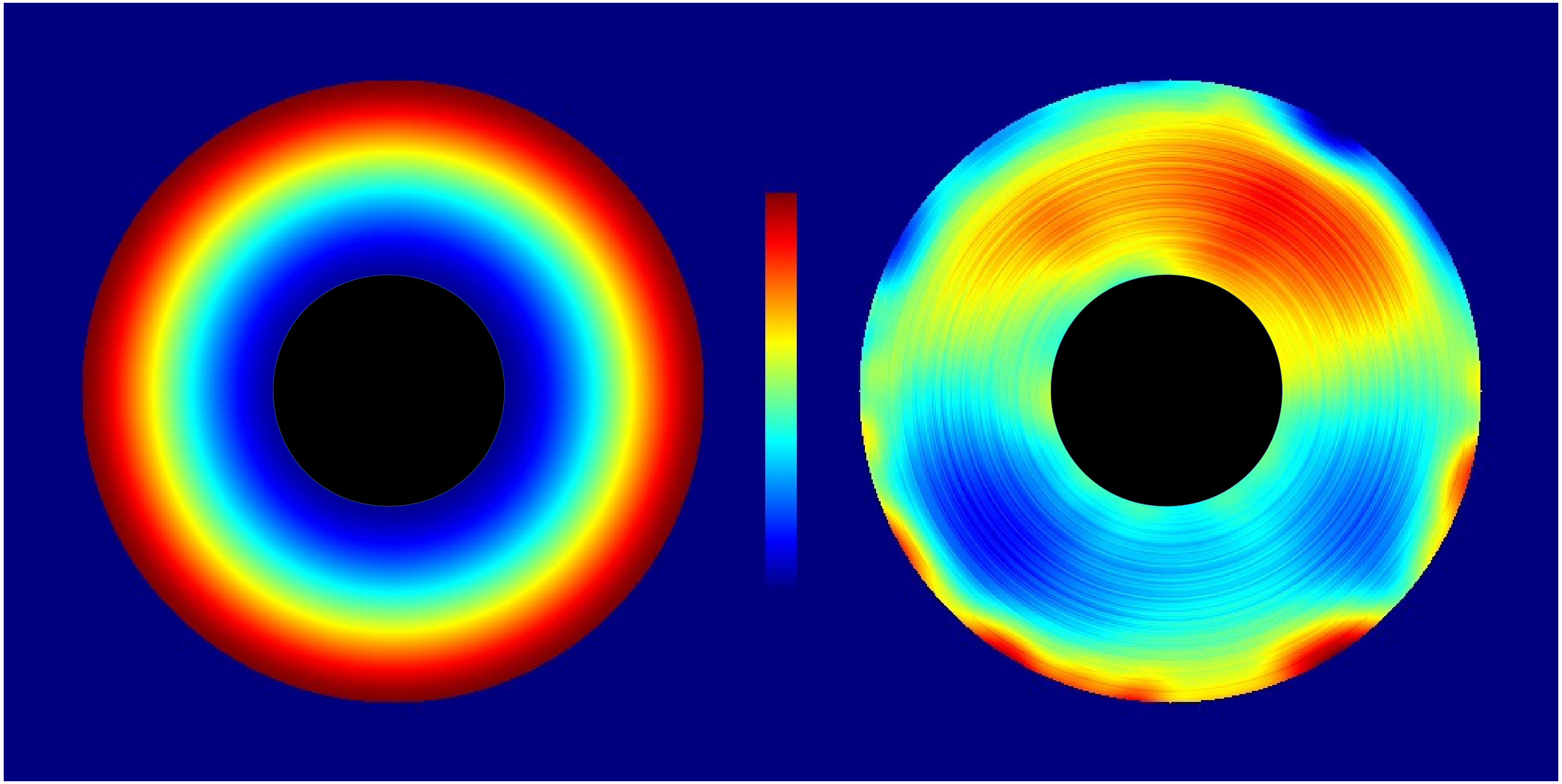
PIAACMC Modeling

- Inputs provided by Guyon
  - PIAA M1 & M2 optic 2-D surface profiles (not circularly symmetric)
    - 1.2x angular magnification
  - focal plane mask 2-D surface profile (reflective)
  - 4 Lyot stops
  - entrance beam diameter (44 mm), focal ratios, and Lyot stop separations
  - No inverse PIAA
  - no design-defined OWA
  - operating bandwidth is 20% centered at 550 nm
- Translated into PROPER
  - unfolded a new single DM (44 mm) PIAACMC prescription from Hong
  - tweaks to match up beam sizes, Lyot stop positions
  - high-res sampling at focal plane mask using DFT

PIAACMC M1 Surface

M1 Surface Map

Mean radial profile subtracted

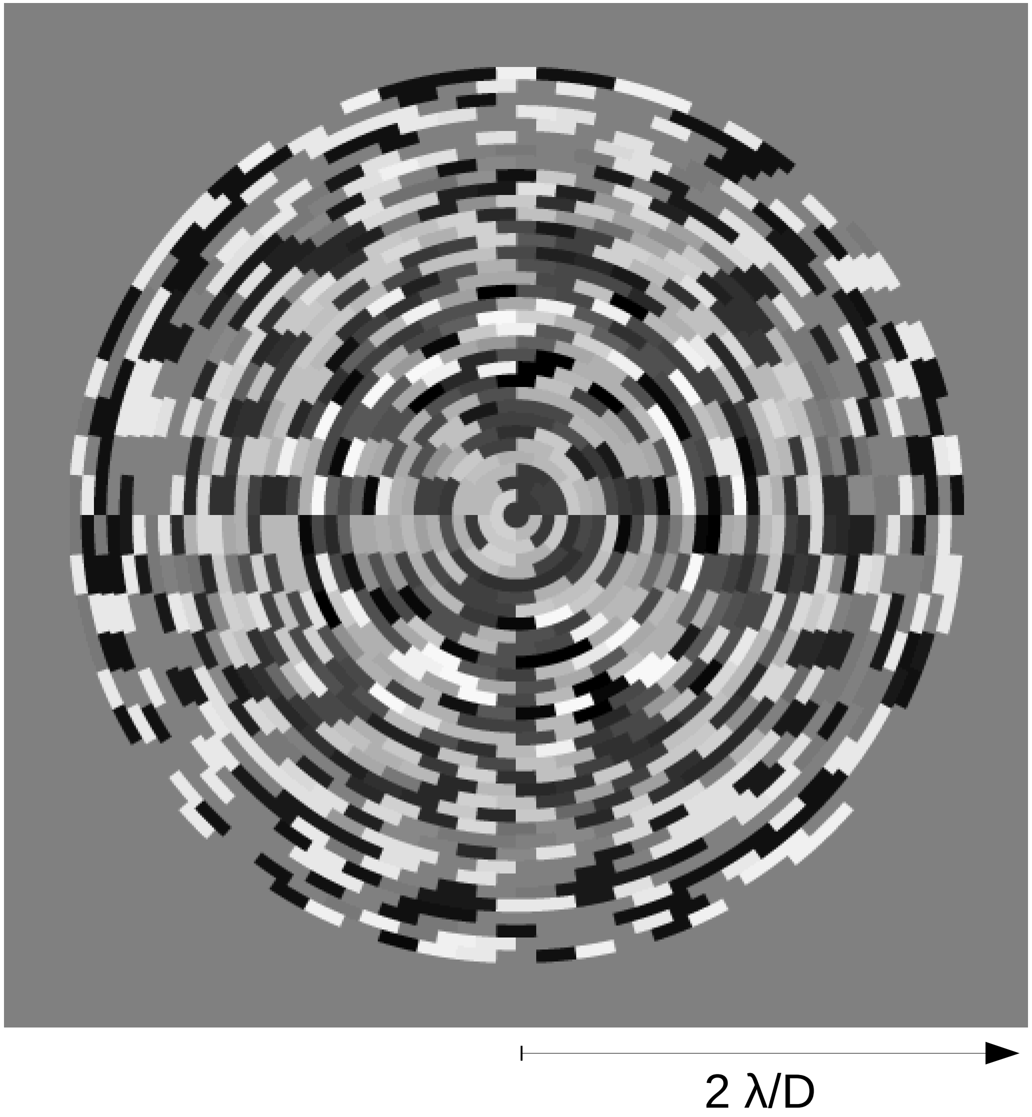


7695 nm surface deviation

11 nm surface deviation

(thin groves are
sampling artifacts)

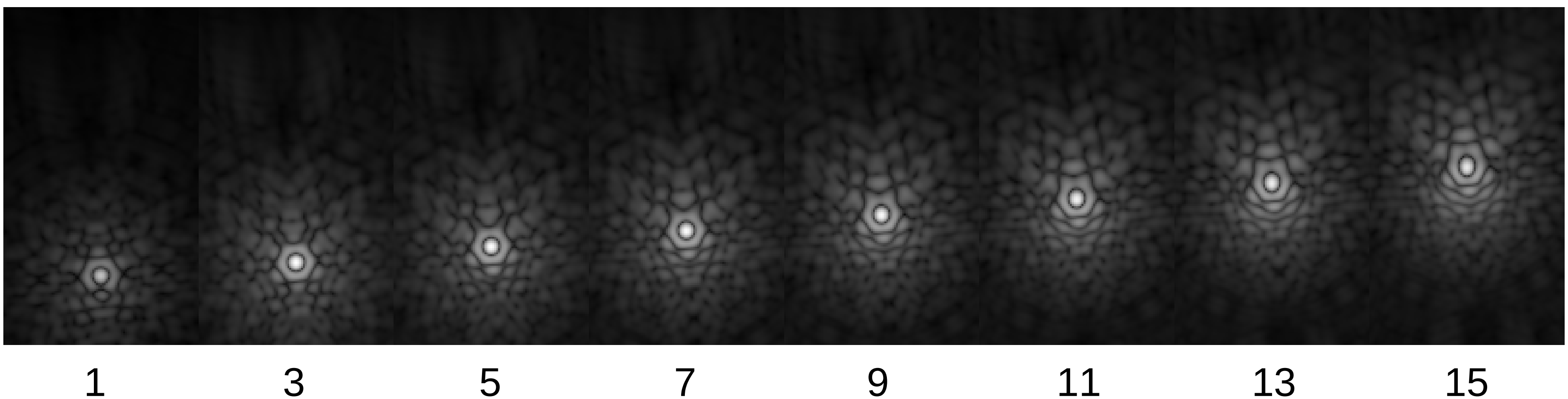
PIAACMC Focal Plane Mask



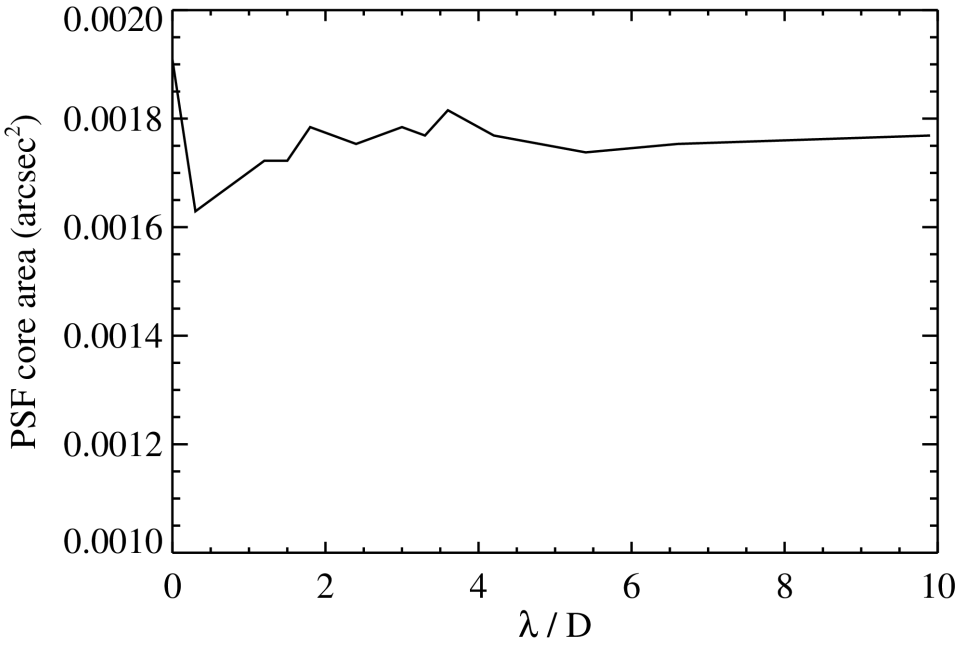
611 nm P-V surface (reflective)

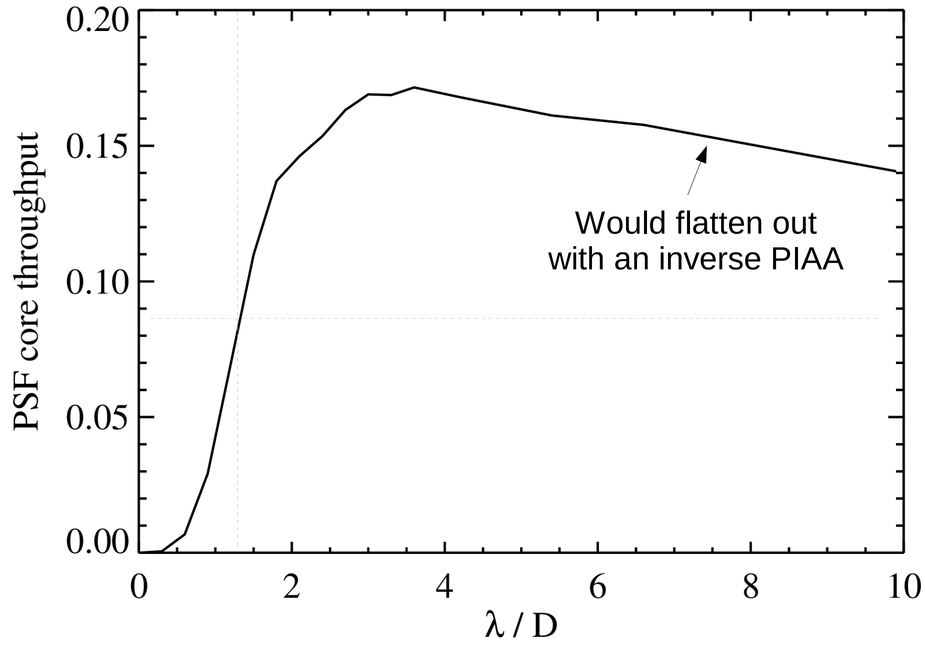
PIAACMC Off-axis PSFs

no-inverse PIAA but limited off-axis distortion due to weak PIAA optics



PIAACMC Throughput
(ignoring losses from reflections, filters, etc.)





PSF core throughput = flux inside planet FWHM region / flux at AFTA primary
(for AFTA without a coronagraph this is 0.34)
Peak relative throughput = 0.17 / 0.34 = 50%
PSF core area (FWHM area) ≈ 0.00175 arcsec^2
(for AFTA without a coronagraph this would be 0.00165 arcsec^2)
Coronagraph transmission = 67%

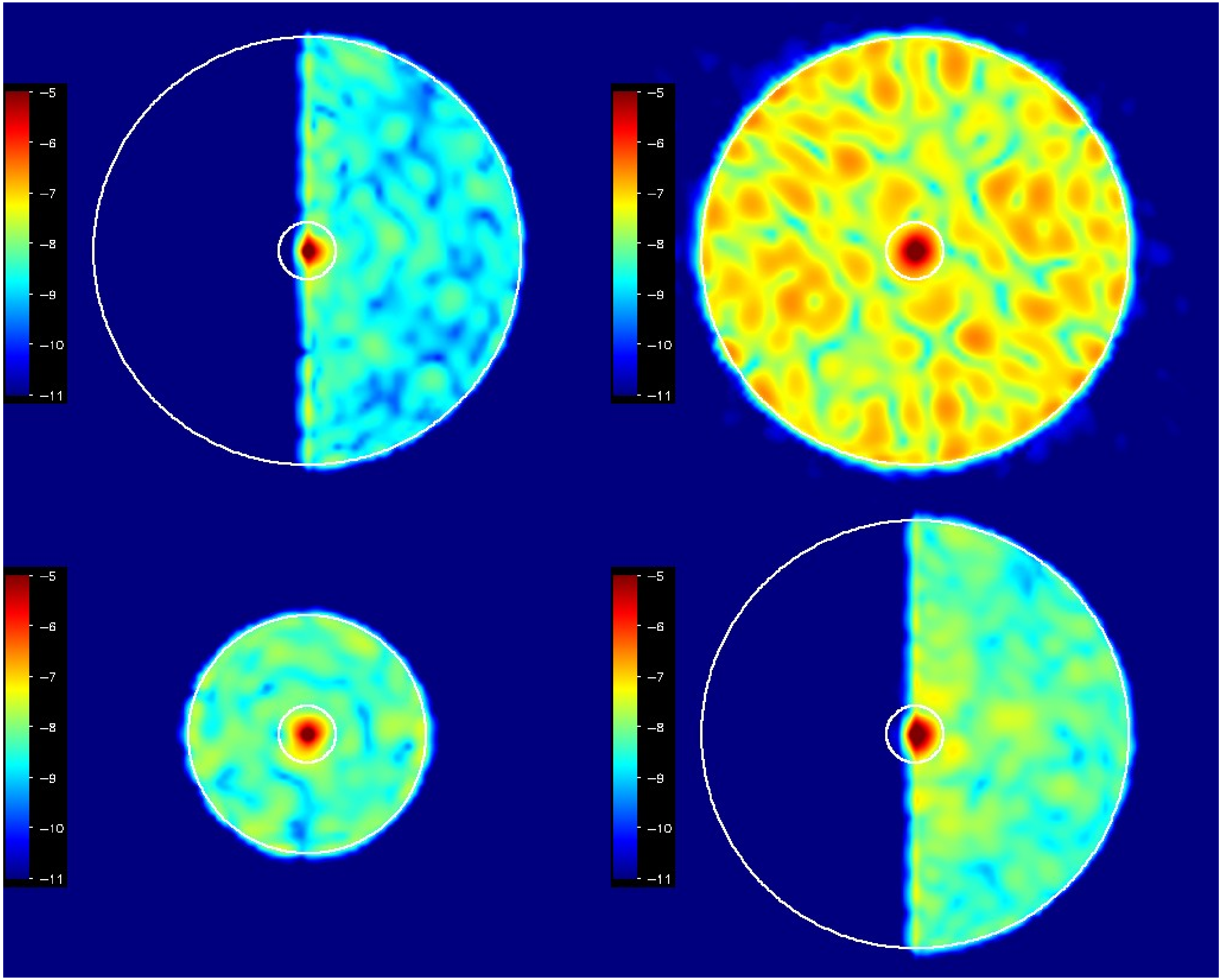
PIAACMC EFC Runs

- Since design does not impose a particular OWA, so different values were tried
- Single DM provides phase & amplitude control only over a half dark hole with a large OWA, but a full dark hole can be obtained using a very small OWA
  - the contrast limit in a full dark hole is strongly dependent on the assumed quality of the optical surfaces that generate phase-induced amplitude errors, since amplitude corrections are limited using 1 DM in this mode
- Design was for 20% bandpass but most evaluations were done at 10% to match other coronagraphs
  - Wavelength-dependent polarization aberration variation over a wide bandpass has not yet been included (don't have such information, yet), and would likely contribute to contrast limit over a 20% bandpass
  - Science team indicated a desire for 10% bandpasses in non-IFS modes for spectral distinction
- EFC was run using 10% (523-578 nm) and ~20% (500–600 nm) bandpasses using 9 wavelengths spanning each
  - “sensing” used computed complex-valued fields rather than DM probing
  - jitter added after a solution had been obtained

PIAACMC Post-EFC Results (no jitter)

10% one-side, r = 1.2 - 9 λ/D

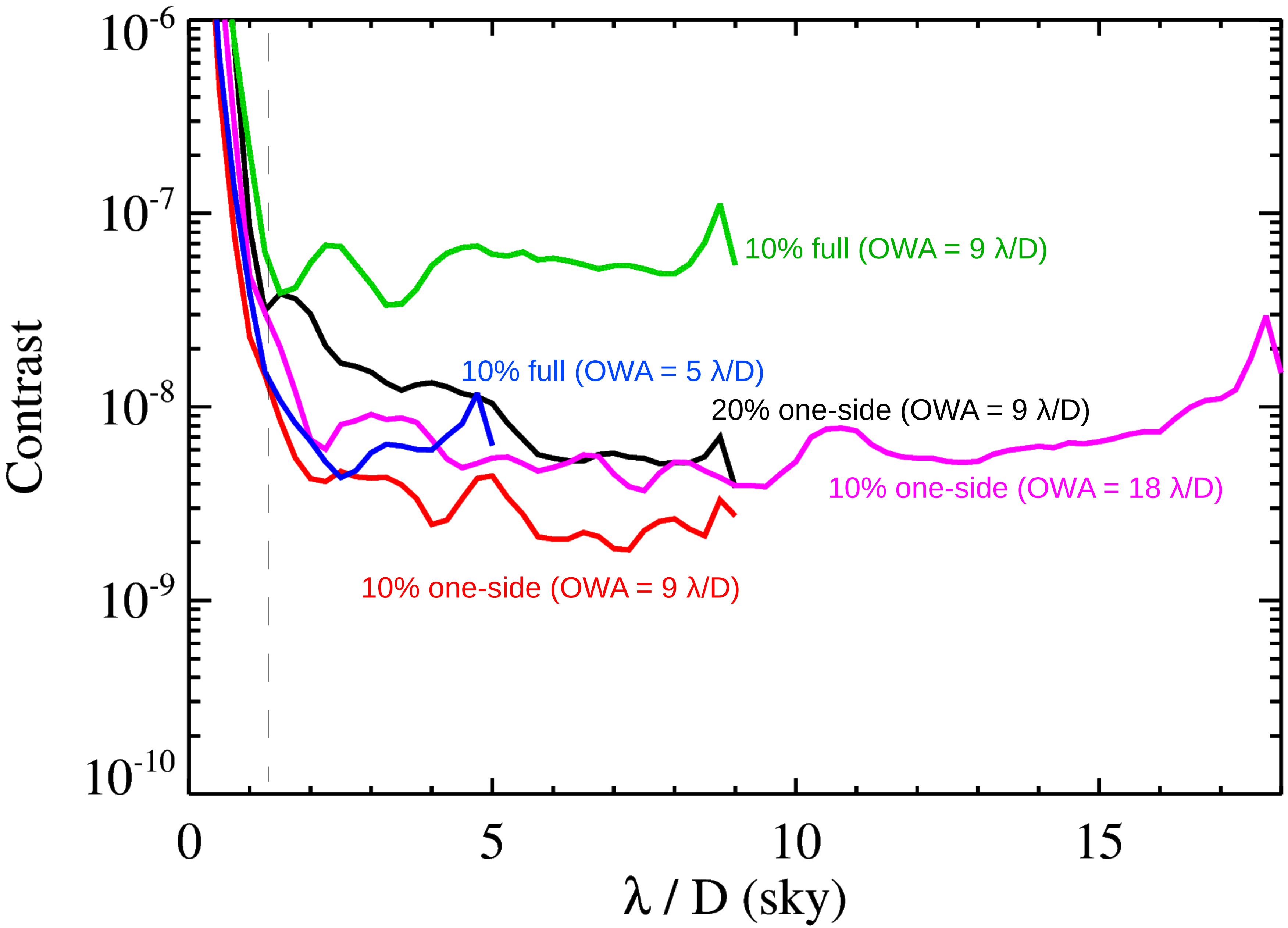
10% full, r = 1.2 - 9 λ/D



10% full, r = 1.2 - 5 λ/D

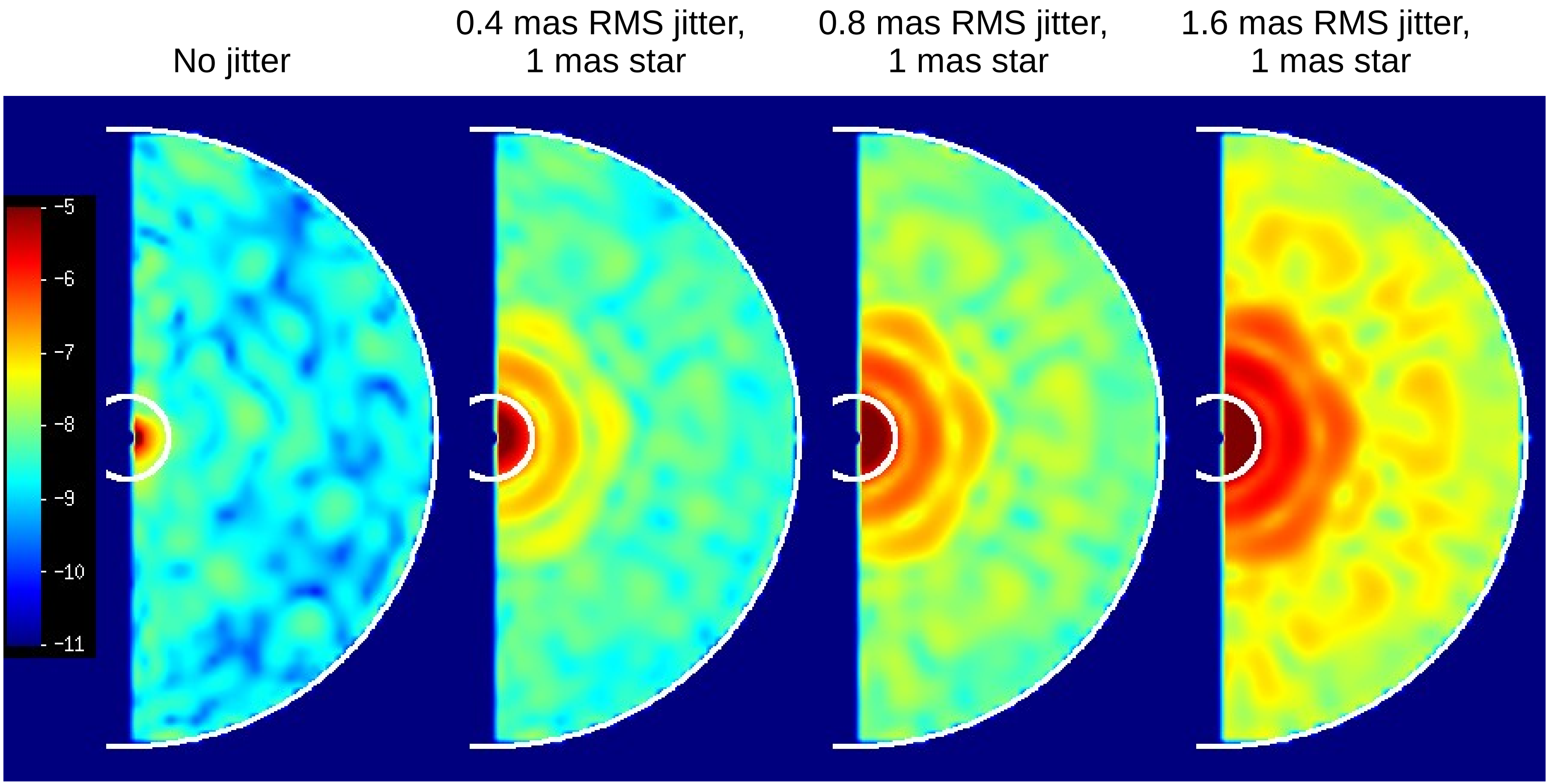
20% one-side, r = 1.2 - 9 λ/D

PIAACMC Post-EFC Results (no jitter)



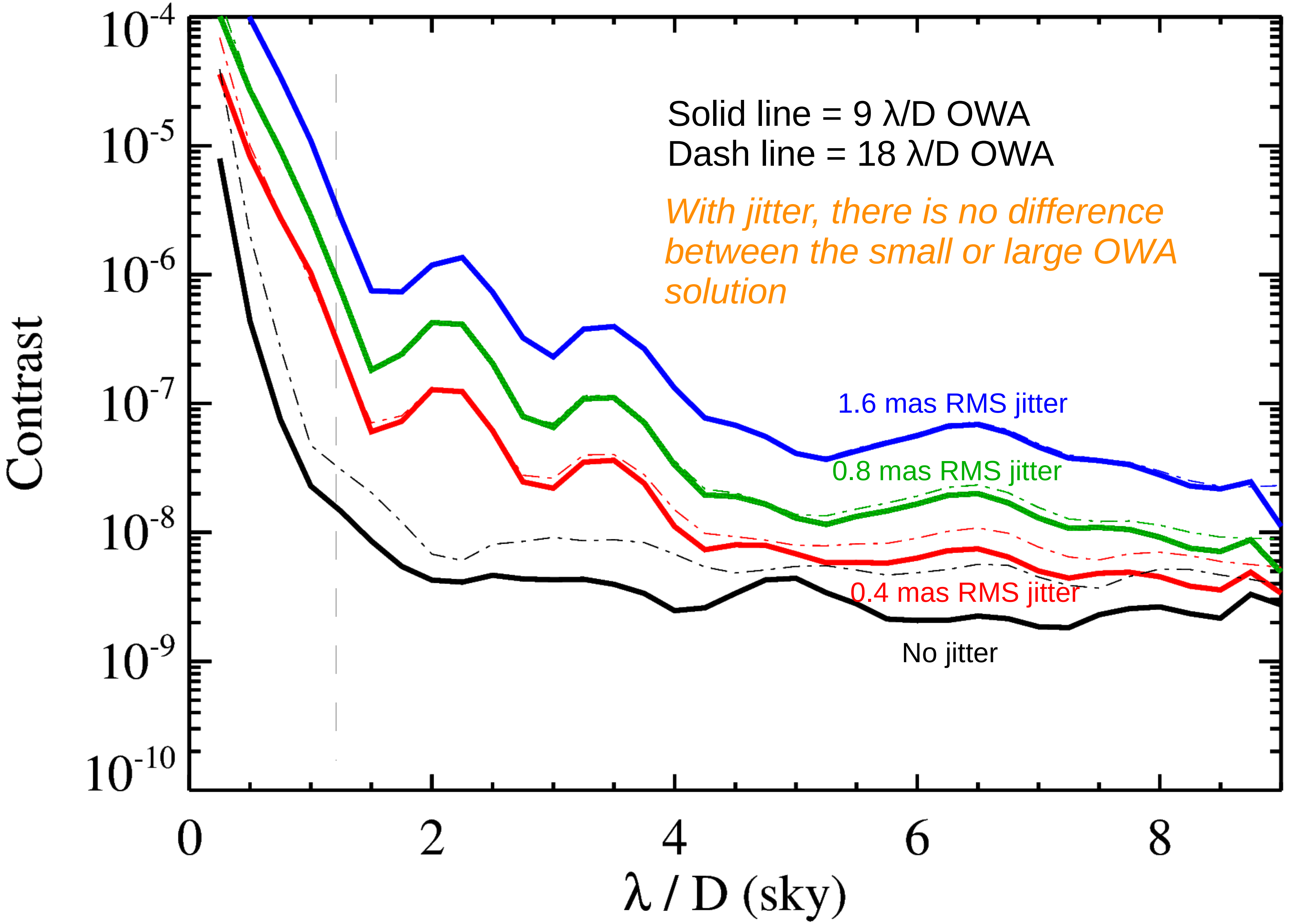
PIAACMC 10% bandpass

Half dark hole (r = 1.2 – 9 λ/D); jitter added after EFC solution



PIAACMC 10% bandpass

Half dark hole (r = 1.2 – 9 λ/D), jitter includes 1 mas star

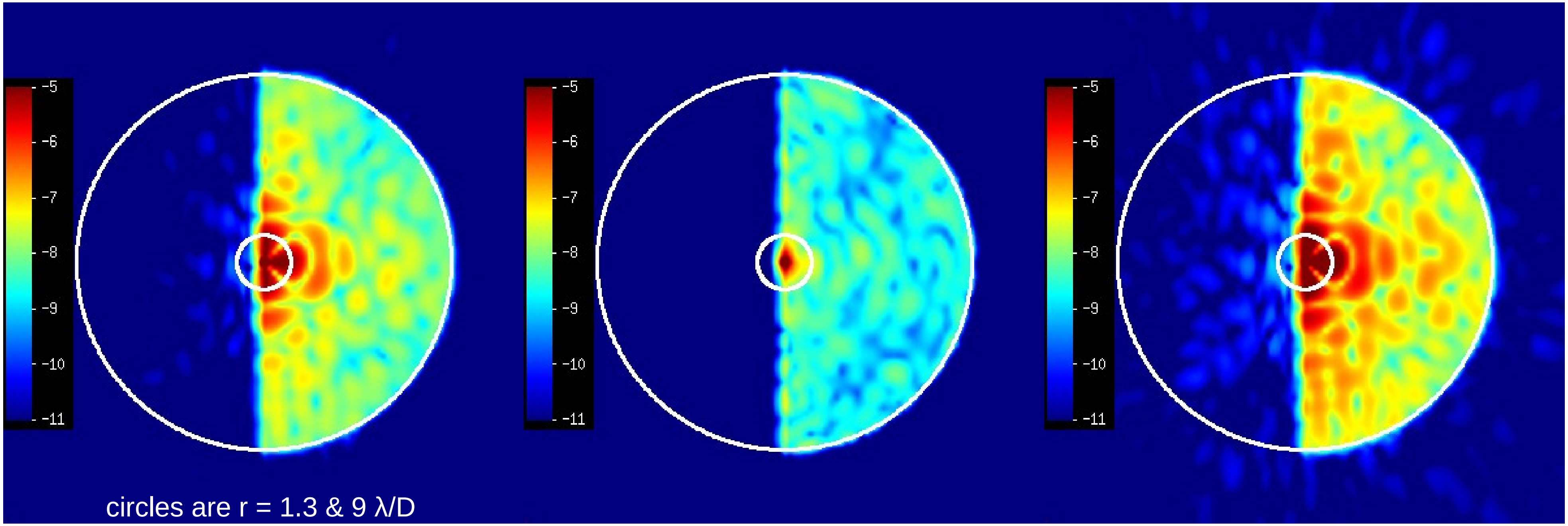


PIAACMC (Gen 2) Post-EFC (polarization, no jitter)
523 – 578 nm, half dark hole (r = 1.2 – 9 λ/D)

X+Y polarization
Optimized for both

X polarization
Optimized for X

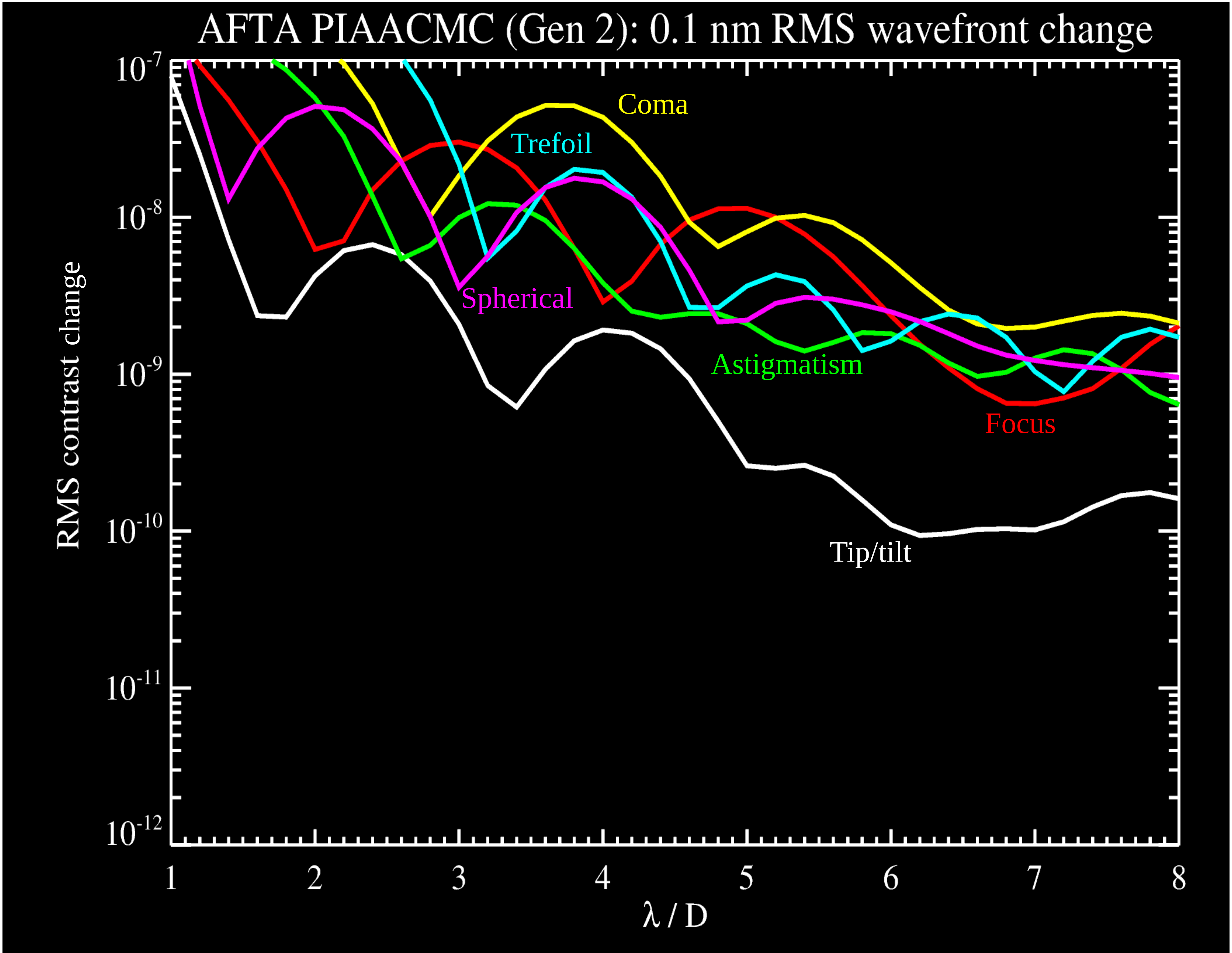
Y polarization
Optimized for X



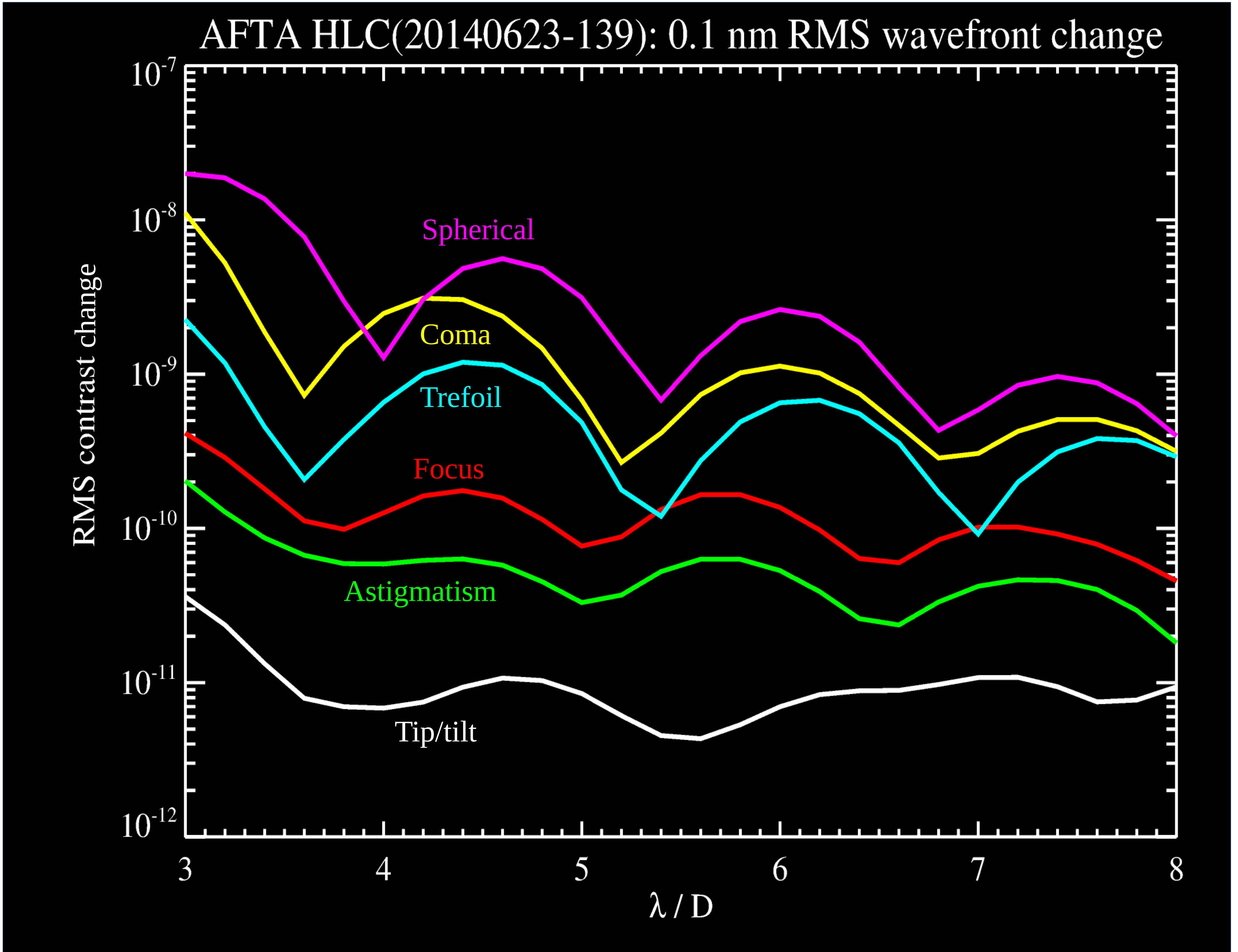
This PIAACMC design is only suitable for a single polarization.

Sensitivity Plots

- Plots for 550 nm (monochromatic)
- 100 pm of individual aberrations were inserted at the primary mirror and propagated through the system with no wavefront control
- The RMS of the difference between the aberrated and unaberrated intensity fields was computed in 0.4 λ/D-wide annuli of different radii
- Latest HLC design presented for comparison



AFTA PIAACMC (Gen 2): 0.1 nm RMS wavefront change
RMS contrast change
λ / D
Coma
Trefoil
Spherical
Astigmatism
Focus
Tip/tilt


AFTA HLC(20140623-139): 0.1 nm RMS wavefront change
RMS contrast change
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
3
4
5
6
7
8
λ / D
Spherical
Coma
Trefoil
Focus
Astigmatism
Tip/tilt