



Jet Propulsion Laboratory
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CGI HOWFSC Model Validation in TVAC

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- Part of CGI diffraction modeling: provide ***credible raw contrast prediction*** (TB, CGI ground & IOC)
- Provide SE support for engineering decision making, risk assessment, etc., throughout the CGI development cycles
- Use the ***same/similar CGI HOWFSC control algorithm/model***, procedure, regularization strategy, constraints, etc.

(Modified for TVAC)

- Propagation Model** (PROPER) == Full (Fresnel propagation), contrast ***truth model*** + Compact (FFT propagation), ***control model***

Input to models (mostly measurement based):

- Individual surface aberration (CVS+CGI optics); mask fabrication errors
- (CVS) Pupil & DM alignment calibration info; DM gain calibration maps
- PR as measured (to imitate post-flattening Epup or WFE residual)
- No add'l uncertainty items (omit for quicker run time)



- Mask fabrication errors
- DM gain calibration maps; pupil & DM alignment calibration info
- PR as measured

- WFSC Model:** standard PWP +EFC
 - PWP: use as-built detector model to generate images over finite BW using ***truth model***, and E field estimation w/ ***control model***
 - EFC: Jacobian (by ***control model***) relinearization as needed; ***truth model*** for contrast scoring
- Detector Model:**
 - As-built detector parameter settings
 - EETC calculator to determine camera operating parameters w/ CVS light source spectrum

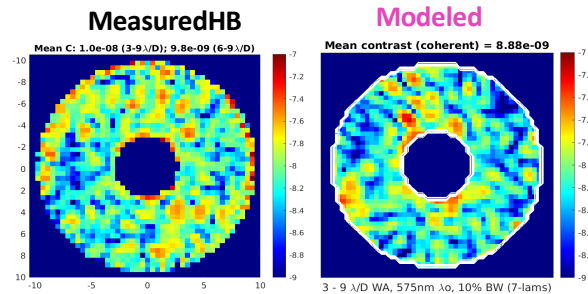
➤ First opportunity for HOWFSC model's validation w/ CGI

1. As-built pre-test prediction (w/ key TVAC calib info of components & alignments):

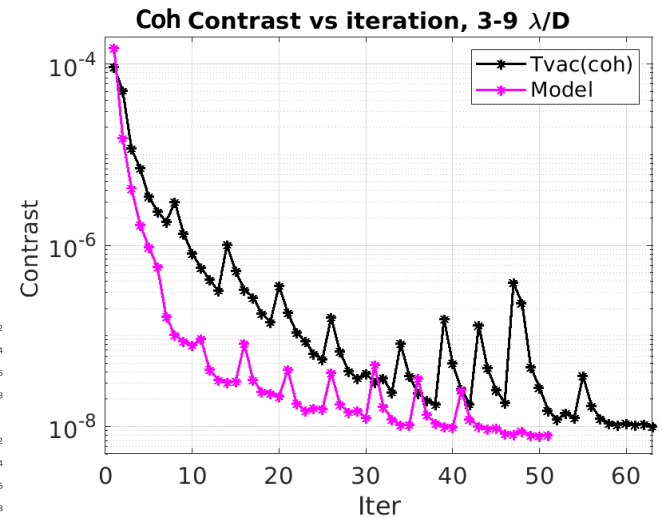
- **Good agreement on mean raw coherent contrast:** <25% err ($|p/m-1|$)
- Total number of iterations **in the same ballpark of x10s** (first time!)
 - Starting from HLC dsgn DM solution a success!

Note:

- Beta bump not in sync, as model was run before the TVAC test, while during TVAC they were adjusted on the fly by (perceived) need
- Recommendations from model greatly helped TVAC HOWFSC execution (esp. the 1st run)



(Model validation not required or planned)



(2nd from-scratch TVAC HOWFSC run; ID# 187~250)

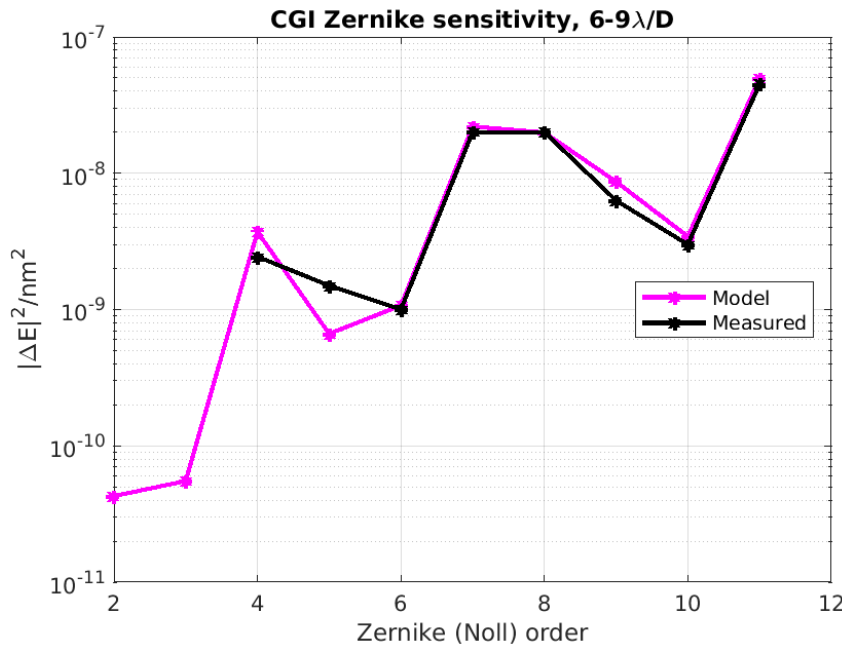
2. Monte Carlo prediction (w/ CGI Req. as uncertainty ranges, no flight unit calibrations):

- TVAC raw coherent contrast **right at the predicted max** (or ~14% over of 95th %) **Unexpected over-the-requirement imperfections related to DMs** (dead actuators, gain cross coupling, relative grid offsets) are among the main drivers for the TVAC contrast to max of predicted range

Raw coherent contrast (ppb), 6-9 λ/D

TVAC mears'd	1. As-built pre-test pred.	2. MC pred (MUF=2) Mean; 95 th %; max
9.8	7.6	6.1; 8.4; 9.8

- Z4~Z11, from Zernike internal step input test (via DM1, Test #3, in Joon's slides)
 - Good model vs measurement agreement (except Z5)
- Separate Z2~Z4 sensitivities test data taken, but not yet analyzed



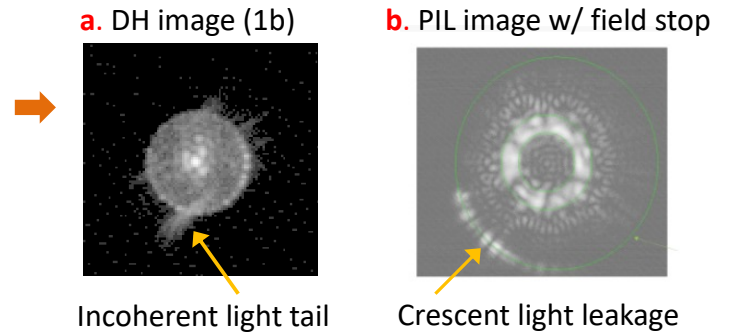
Z4~Z11 *perdition* vs measurement, in %

Zs	%	$ p/m-1 $	$ m/p-1 $
Z4		52	34
Z5		55.7	125.9
Z6		7	6.5
Z7		10	9.1
Z8		0.5	0.5
Z9		37.6	27.3
Z10		14.7	12.8
Z11		10	9.2
mean		23	28

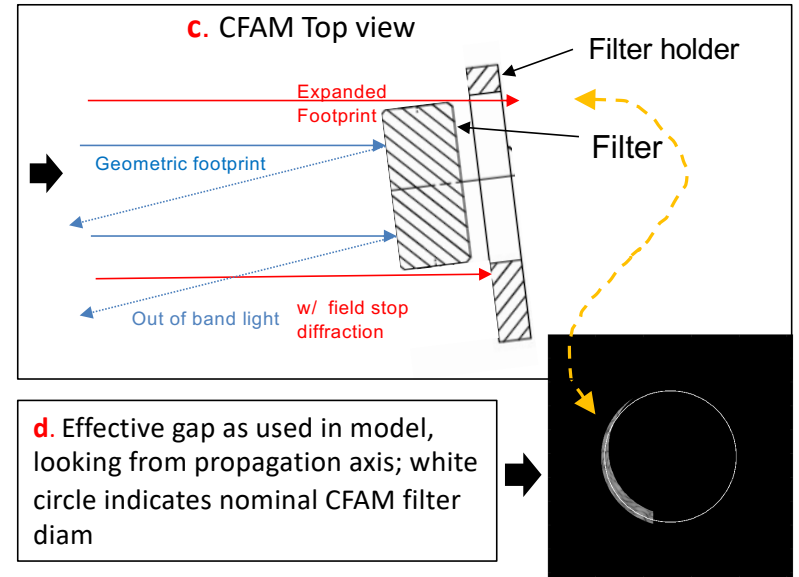
TVAC Anomaly: CFAM Stray Light Diffraction Modeling



- Toward the end of TV-30, an anomaly discovered:
 - a. Incoherent light tails in some of DH subband images
 - b. Crescent feature in pupil images taken w/ PIL mode, FS, & DH solution
- Preliminary analysis (Brian K, Gary K.) points to FS diffraction from out-of-band spectrum through a gap around CFAM

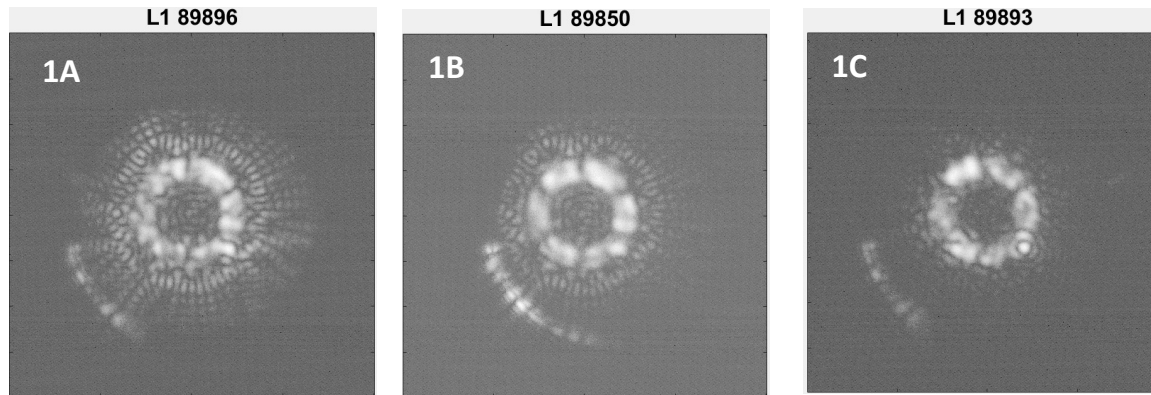


- Modeling to confirm, assess the impact in orbit & effectiveness of mitigation, & exercise as a model verification/validation test:
 - Based on the best understanding of the CFAM gap geometry (c. & d.)
 - **Run beam propagation twice, and then added incoherently:**
 1. wavelengths w/n CFAM BW pass through the nominal CFAM aperture
 2. wavelengths outside CFAM BW pass through the gap only

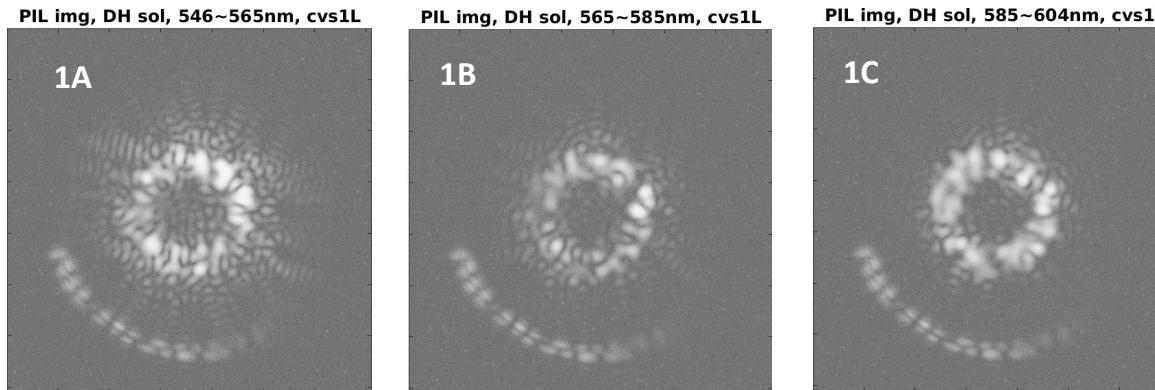


CFAM = color filter alignment mechanism

Measured

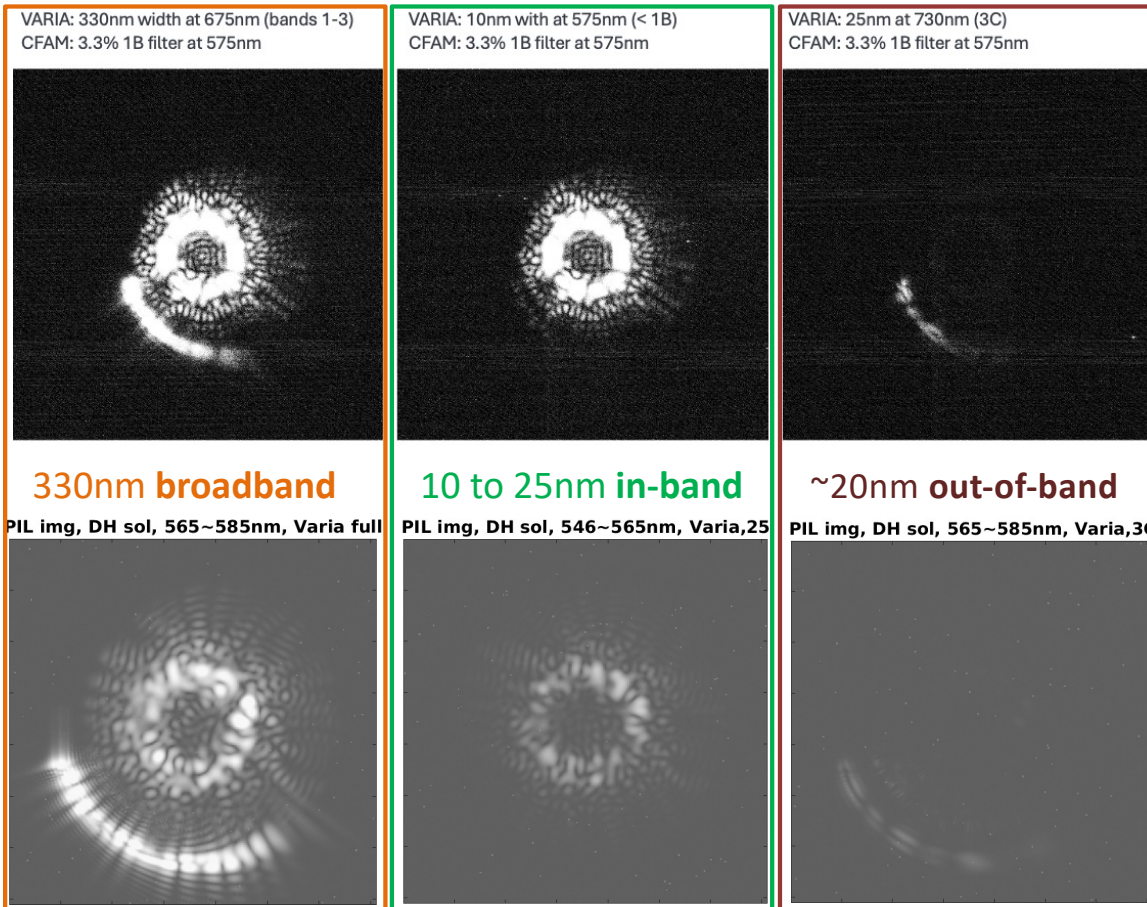


Modeled

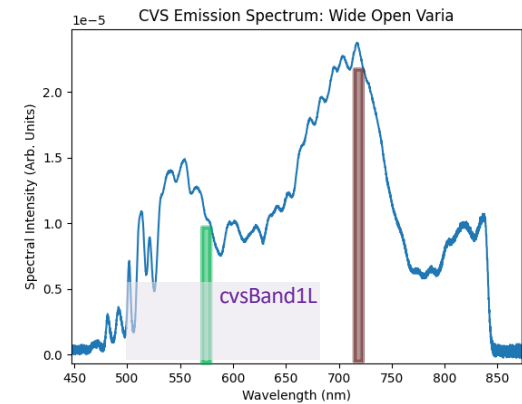


- Model reproduces PIL images w/ similar features & relative strength between leakage and nominal signal as observed
- Crescent arcs are all longer in model than in measured

Meas'd



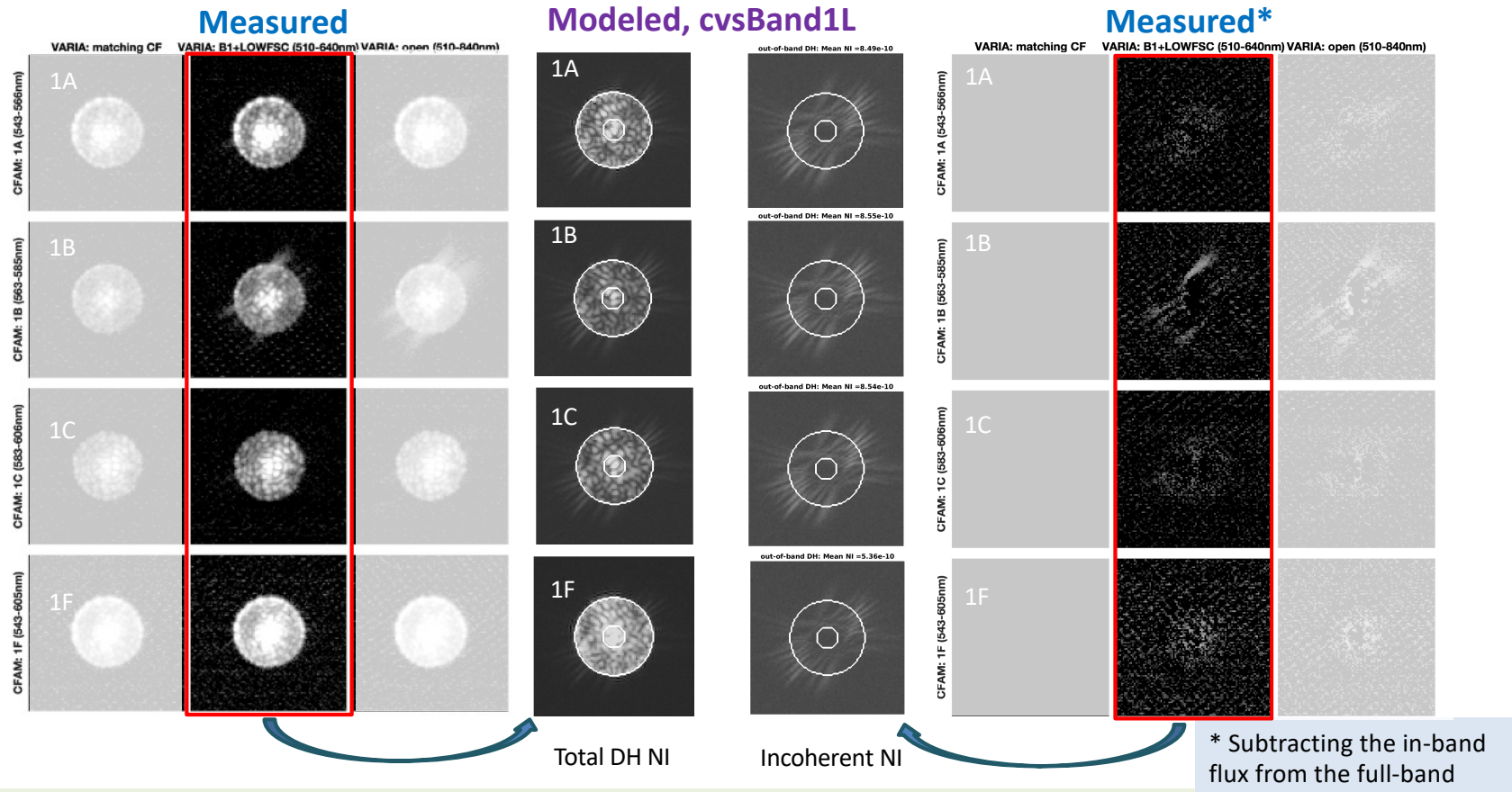
Modeled



(Same CFAM filter, green in plot)

- Model reproduces PIL images as observed *w/ similar features & relative strength* for leakage (the crescent) vs nominal signal
- Both model and measured results show leakage comes from out-of-band diffraction through CFAM filter gap

Model Verification of TVAC Stray Light – DH Images

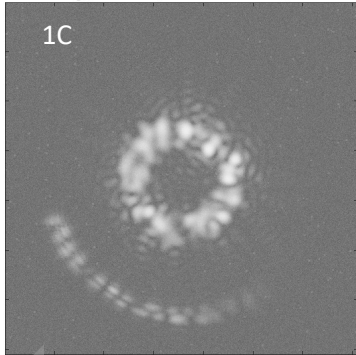


Model & measured are consistent: small incoherent contribution for TVAC (<10% of total incoh)

Would have much higher incoh contribution w/ stellar spectrums in orbit if no mitigation

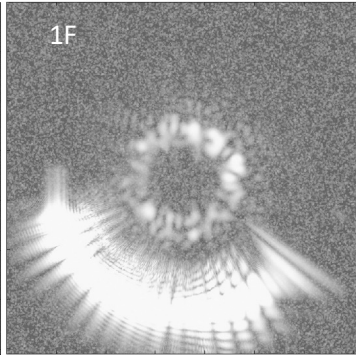
TVAC CVS Band 1L, ND =2

PIL img, DH sol, 585~604nm, cvs1L



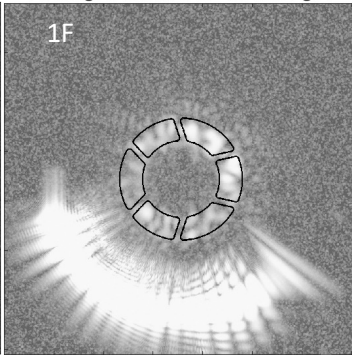
B3V spectrum, Vmag 2.25

PIL img, DH sol, 546~604nm, b3v



G5V spectrum, Vmag 2.25

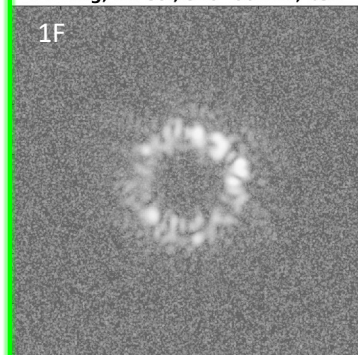
PIL img, DH sol, 546~604nm, g5v



PIL
Image
w/ FS

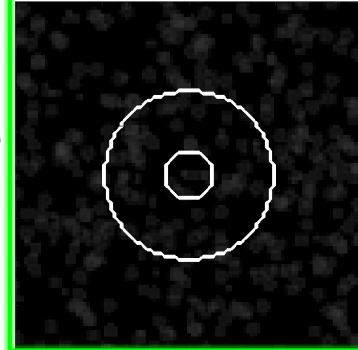
B3v spectrum, Vmag 2.25

PIL img, DH sol, 546~604nm, b3v



w/ 7.5mm baffle, pred.

out-of-band DH: Mean NI =1.35e-09



Leakage
to DH

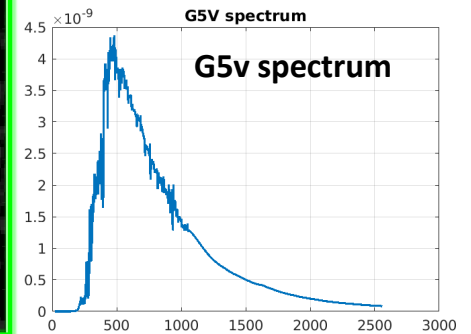
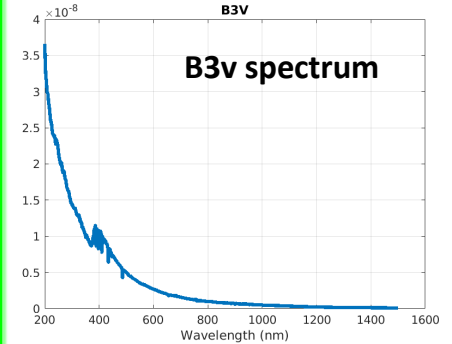
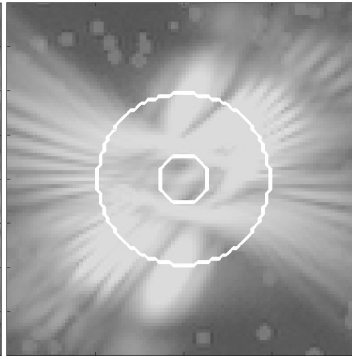
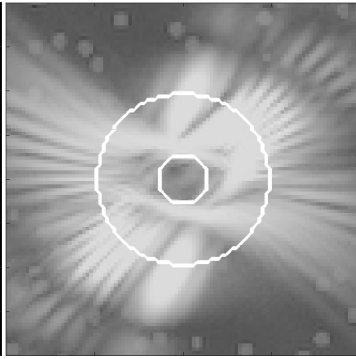
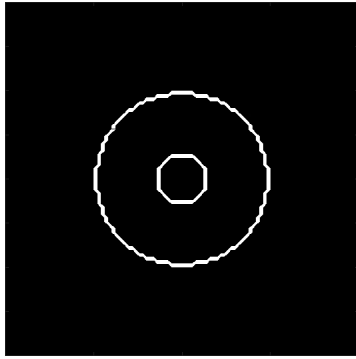
- Shorter end of out-of-band stellar light has stronger leakage at DH OWA (than longer end at IWA)
- $\Delta C \sim 1e-6$ for B3V, G5V stars

No Baffle, prediction

out-of-band DH: Mean NI =5.37e-10

out-of-band DH: Mean NI =1.63e-06

out-of-band DH: Mean NI =1.92e-06



- TVAC: first opportunity for HOWFSC performance model's validation w/ CGI
 - Calibration based as-built pre-test prediction **agrees well** w/ the actual TVAC performance
 - Extend our track record on good model validation result of as-built coronagraph system:
Raw coherent contrast, contrast convergence, and key sensitivities
 - Uncertainty based Monte Carlo predicted max goes w/ the actual TVAC performance
 - Under the circumstance of (unexpected) unmet requirements
 - Model verified a major TVAC performance anomaly (CFAM stray light)