



# *Roman Space Telescope* Coronagraph Image Time Series Simulations & Observing Scenarios

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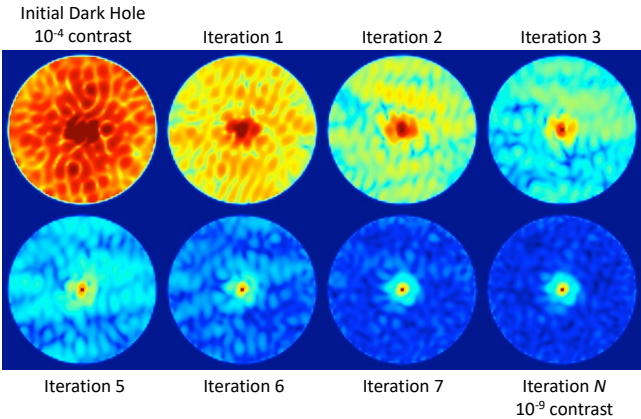
Jet Propulsion Laboratory/California Institute of Technology

26 October 2021

# The Dark Hole

## The “static” dark hole:

The dark hole immediately after running high-order wavefront control



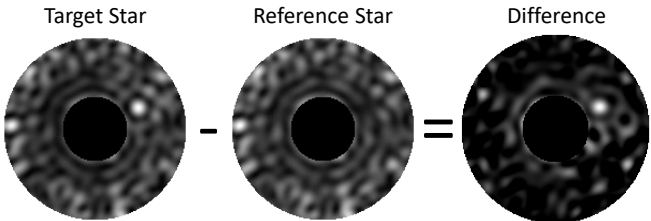
## Modeled using:

**Diffraction**

*aberrations, masks,  
fabrication errors,  
with wavefront control*

## The “dynamic” dark hole:

The dark hole as it varies over time due to thermal changes and pointing errors



## Modeled using:

**STOP** (structural, thermal,  
optical performance),  
dynamic (pointing), diffraction

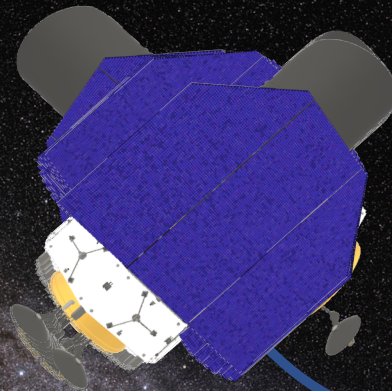
*structural & pointing changes*

# CGI Observing Sequence

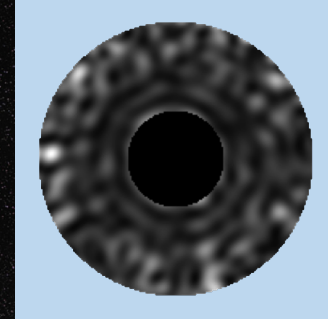
Bright Reference Star



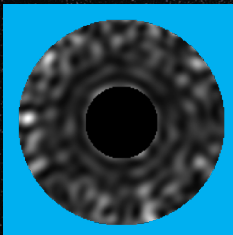
Target Star



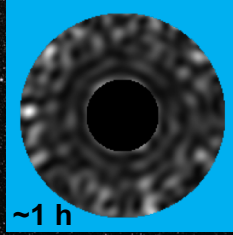
Reference star:  
TB 2010 Dark hole



Dark hole

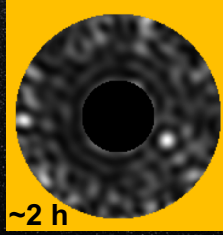


Reference image



~1 h

Target 0°



~2 h

Target 23°



~2 h

Target 0°



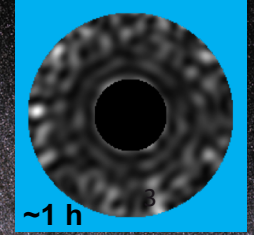
~2 h

Target 23°



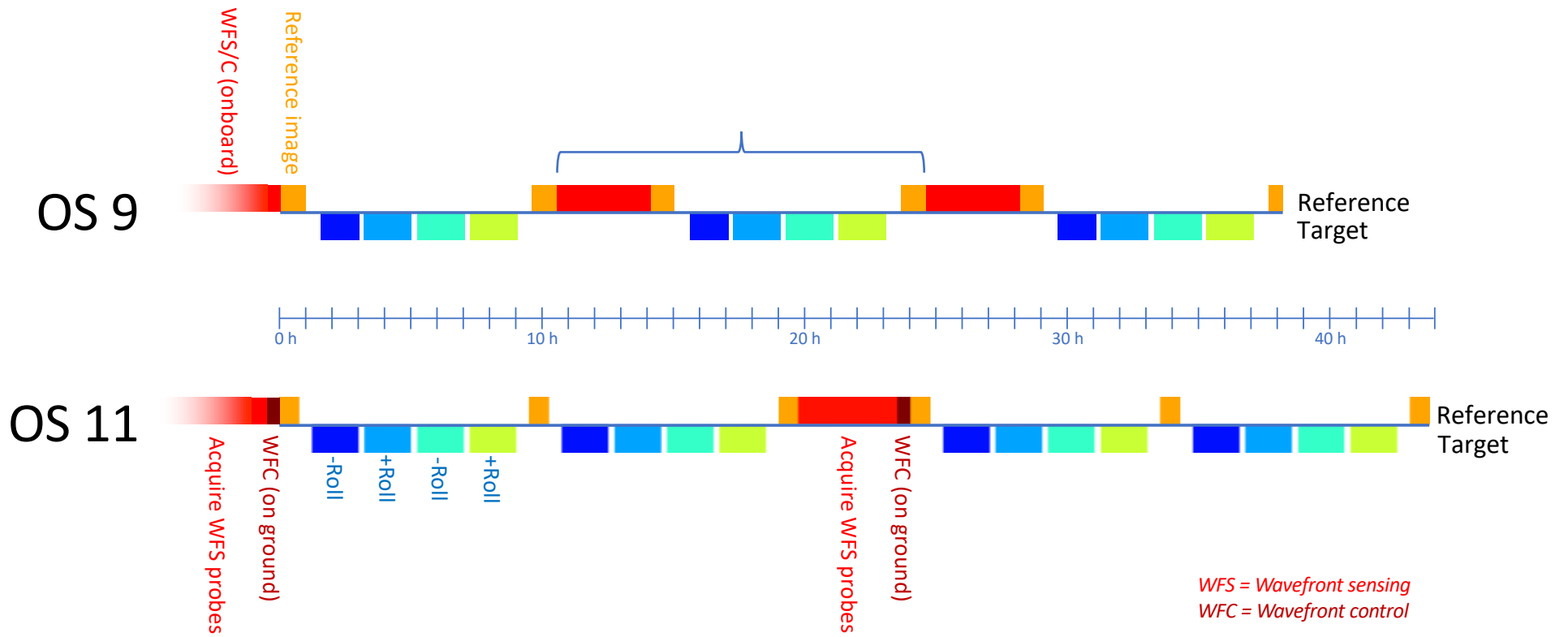
~2 h

Reference image

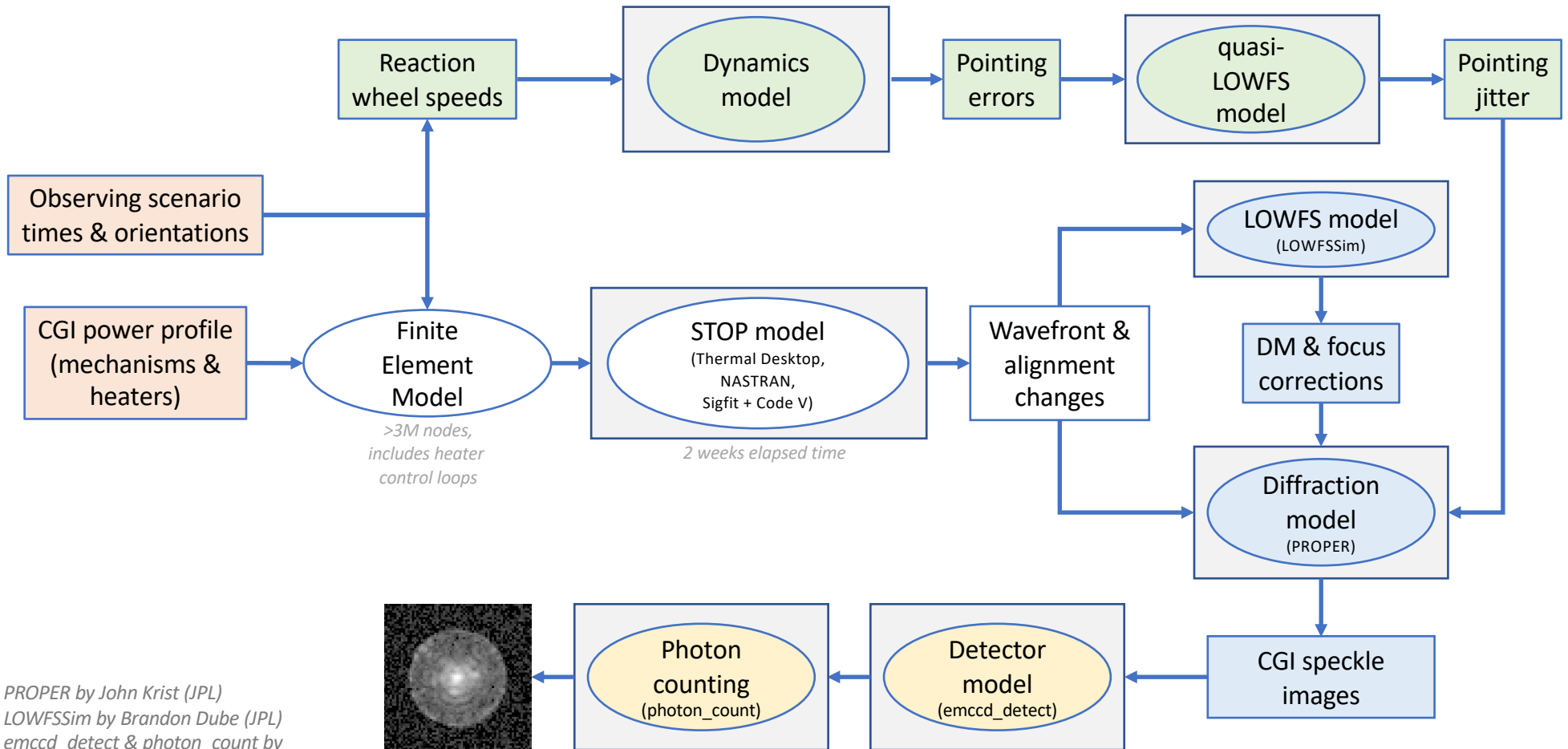


~1 h

# Observing Scenario (OS) Timelines



# Simulation Flow (OS 11)



PROPER by John Krist (JPL)  
 LOWFSSim by Brandon Dube (JPL)  
 emccd\_detect & photon\_count by  
 Bijan Nemati & Sam Miller (UAH)

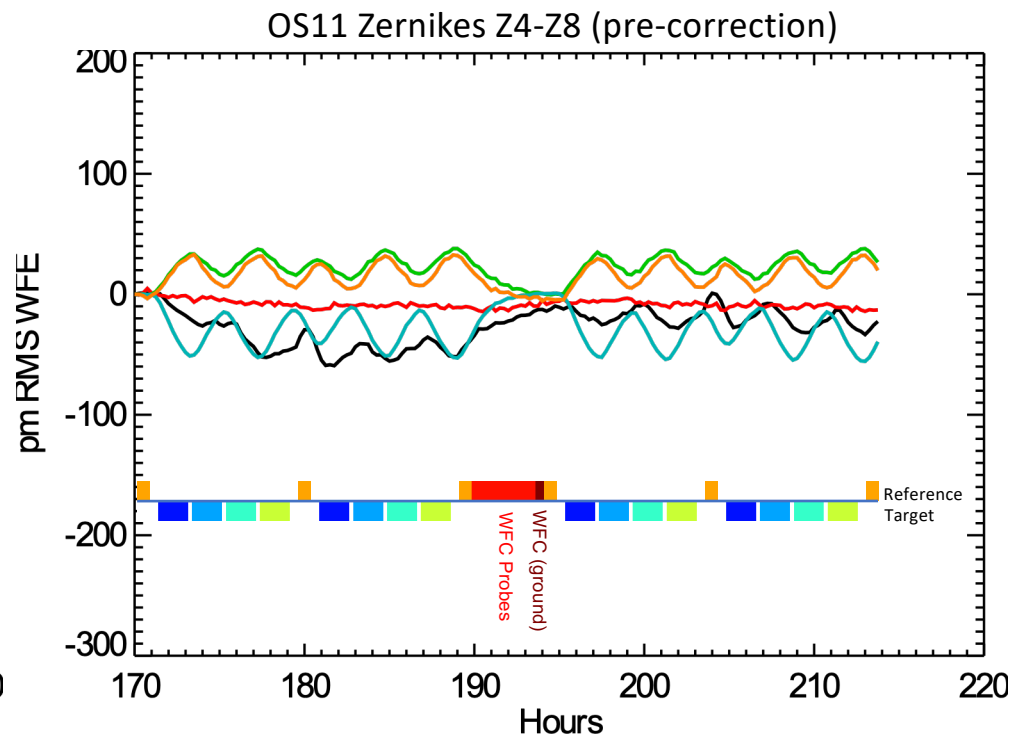
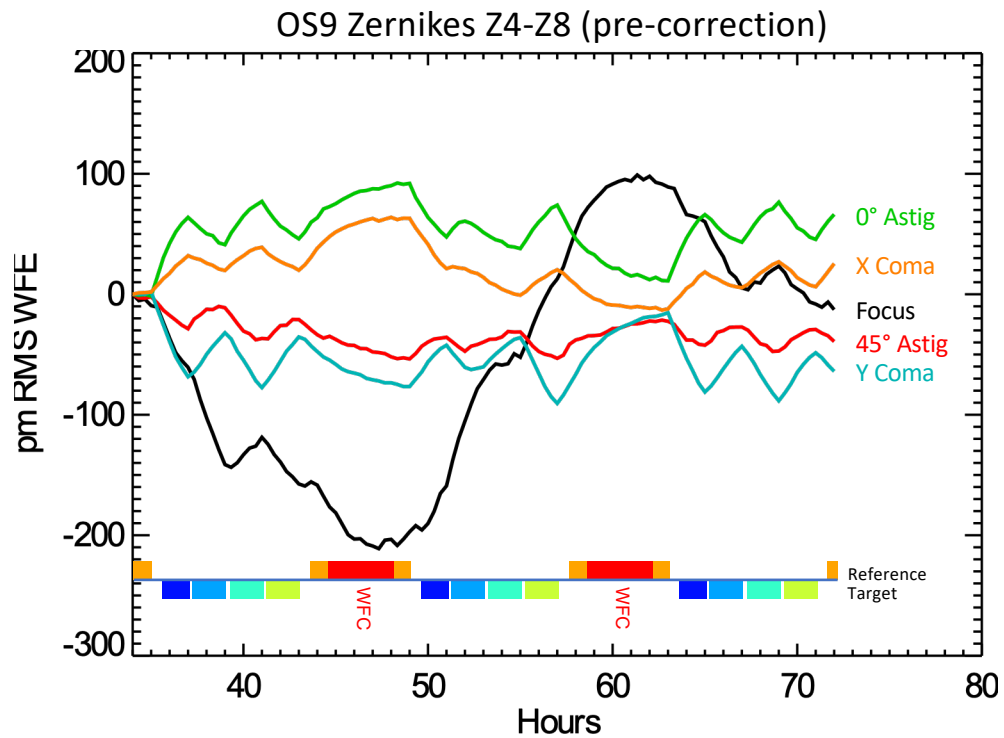
# Current Modeling Uncertainty Factors (MUFs)

Always included

- 2x structural deformation MUF
  - increases beam shear, wavefront error drift by 2x
- Frequency-dependent jitter MUFs
  - 3x (<20 Hz), 4.27x (40-100 Hz), 8x (>100 Hz)

Included only when specified

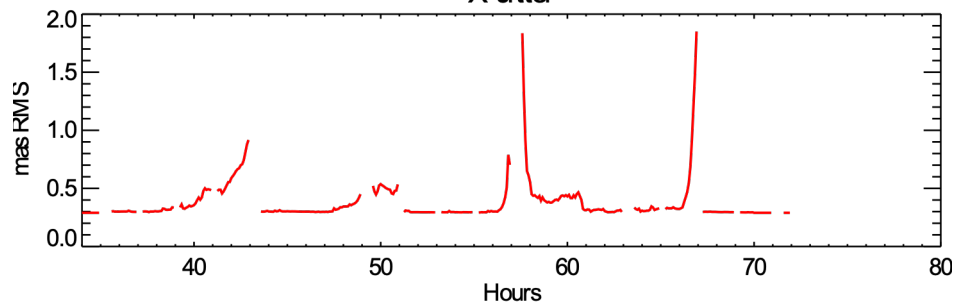
- CGI sensitivity MUFs
  - 2x contrast sensitivity to low-order errors (jitter, polarization)
  - 1.5x polarization aberrations
  - 2x initial contrast dark hole



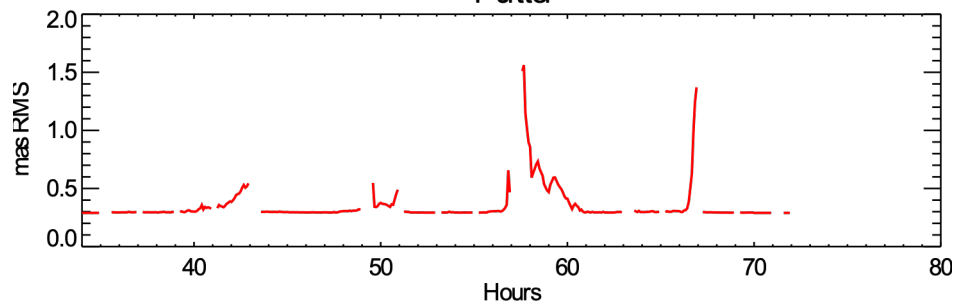
*Uncorrected values shown. Z2 – Z11 are corrected by LOWFS/C.*

OS9 FSM-corrected Jitter

X Jitter

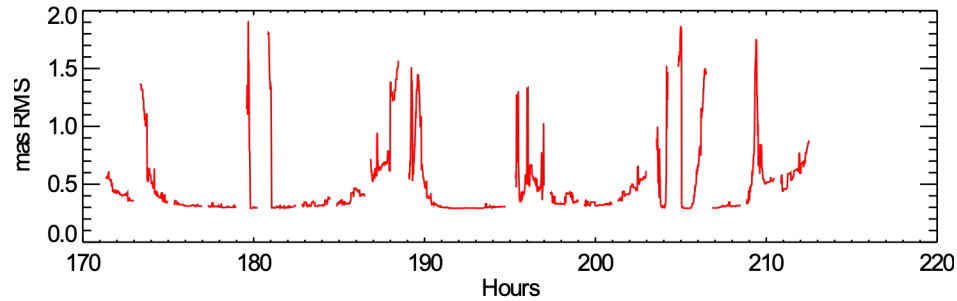


Y Jitter

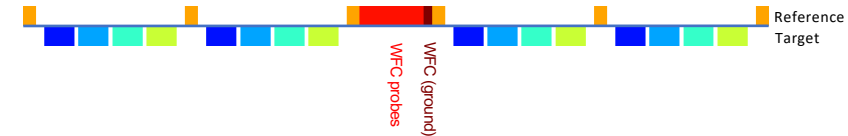
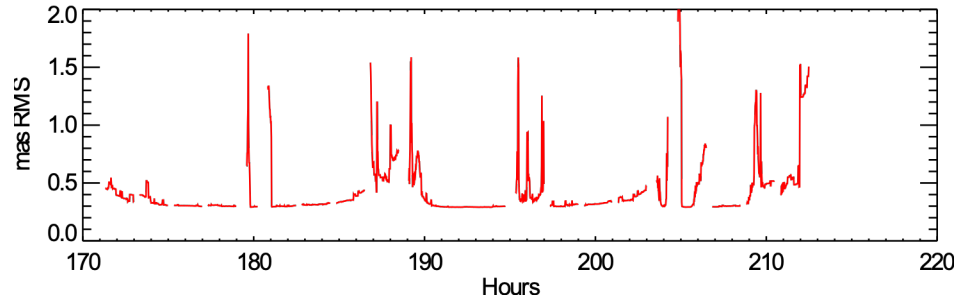


OS11 FSM-corrected Jitter

X Jitter



Y Jitter





# Errors Included in OS9 & OS11

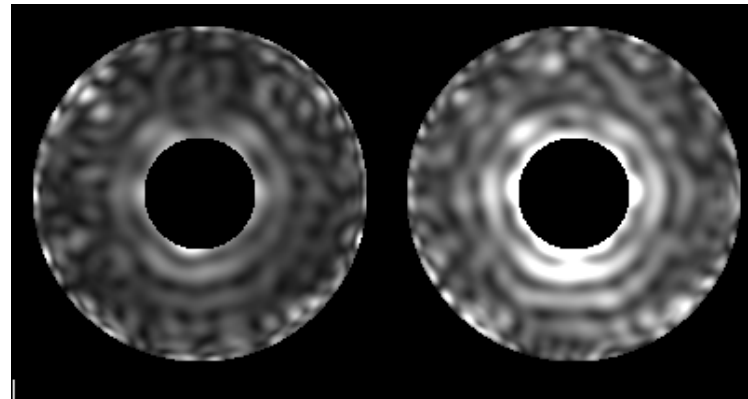
- Wavefront error thermal drift
  - Z4 – Z11 LOWFS sensed & corrected with measurement & DM errors
  - Internal CGI misalignments
- LOWFS/C
  - Star brightness-dependent measurement errors
  - 15 bit DM DAC with gain errors, FCM stroke error
- Beam shears
  - IC-CGI shear (from structural model)
  - CGI bench deformations due to power dissipation from PAM motions
    - Shears at at pupil masks & DMs
- DM thermal drift
  - Computed using separate CGI-only model for OS9
  - Computed in full model for OS11, with DM heaters
- Pointing (LOWFS-corrected) jitter
- All optical aberrations, including polarization & FPM fabrication errors
- EMCCD noise

# OS9 Time Series (HLC)

(noiseless, infinite signal, includes LOWFS/C)

No CGI MUFs

With MUFs



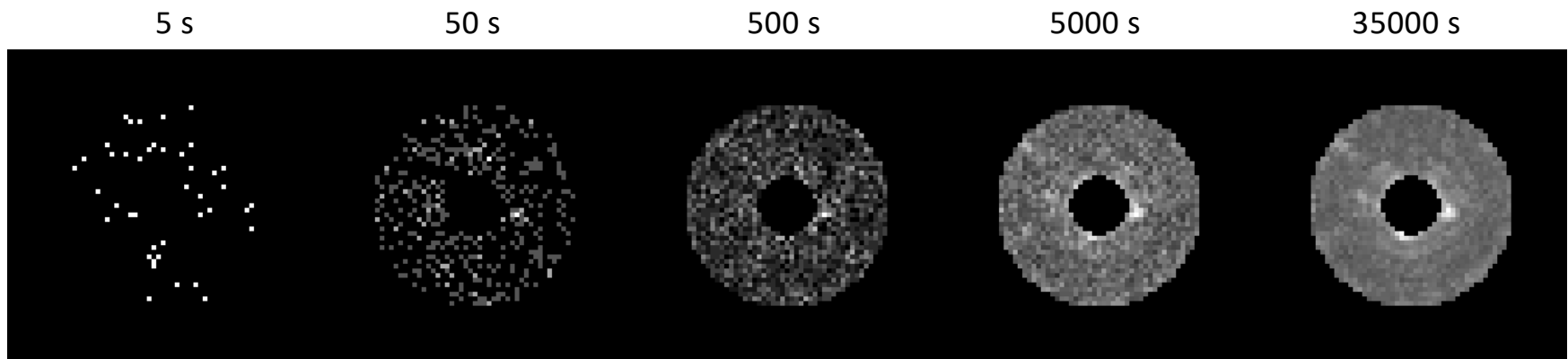
0 h

38 h

*MOVIE (play in presentation mode)*

# Target Star (47 UMa) Accumulated Exposures

HLC,  $V = 5.04$ , Photon-counted frames



# Current Public CGI Time Series

- OS5 (Cycle 6, 2016)
  - 8 h on reference star ( $\beta$  UMa), 2 x 14 h on 47 UMa (2 rolls)
  - Included thermal drift, LOWFS correction, shot noise only, no jitter, no CGI MUFs
- OS6 (Phase A, 2018)
  - 2 h on reference star ( $\eta$  UMa), 4 x 2 h on 47 UMa (repeat 2 rolls)
  - Repeat sequence 13 times
  - Included thermal drift, LOWFS correction (tip/tilt & Z4 only; no color terms), IC-CGI shear, DM thermal drift (bad implementation), LOS & WFE jitter, EMCCD model (non-photon-counted output images provided)
- OS9 (Phase B, 2020)
  - 4 h of WFC followed by 1 h imaging on reference star ( $\zeta$  Pup)
  - 4 x 2 h on 47 UMa (repeat 2 rolls)
  - 1 h of imaging on reference star
  - Repeat sequence 3 times (HLC), 15 (SPC)

[https://roman.ipac.caltech.edu/sims/Coronagraph\\_public\\_images.html](https://roman.ipac.caltech.edu/sims/Coronagraph_public_images.html)

## Next Step: OS 11

- Currently waiting on jitter model re-run and LOWFS/C model results
- Expect HLC time series by mid-December
- Posted on IPAC website, maybe mid-January
- **This is the last time series**

Questions to [john.krist@jpl.nasa.gov](mailto:john.krist@jpl.nasa.gov)