WFIRST Coronagraph
Optical Modeling
Update: Flight Configuration

John Krist &
The WFIRST Coronagraph Optical Modeling Group
Jet Propulsion Laboratory/Caltech
WFIRST Flight Coronagraph Models

• This is an update to prior presentations (SPIE, JATIS) that discussed WFIRST *flight* coronagraph modeling
  • Testbed modeling & modeling validation will be discussed in following talks by Zhou, Sidick, & Marx

• Flight modeling includes
  • Static performance
    • surface errors, polarization, static alignment errors, wavefront control (dark hole digging)
  • Dynamic performance
    • Pointing & wavefront jitter tolerance
    • Alignment stability tolerance
    • Low order sensing & control (LOWFS/C)
    • Deformable mirror actuator drifts
  • Observation simulations
    • Realistic observing scenarios with STOP modeling (see today’s talk by Saini et al.)
    • End-to-end diffraction modeling with wavefront control
    • Detector models
    • Inputs to exoplanet yield estimators (see today’s talk by Nemati et al.)
  • Optical modeling tool development (PROPER)
Realistic System Simulation with
Wavefront Sensing & Control
New Version of PROPER

• Wavefront propagation using Fresnel & angular spectrum algorithms, deformable mirror model, complex aperture drawing, Zernike & PSD-specified aberrations

• Version 3 of PROPER released this week!
• IDL, Python (v2.7 & v3.x), and Matlab versions
• Bug fixes, minor additions
• Available from proper-library.sourceforge.net
Current WFIRST CGI Flight Designs

HLC

DM 1  DM 2

Focal Plane Mask
Nickel Thickness  Dielectric Thickness

Lyot Stop

SPC

Pupil Mask  Focal Plane Mask  Lyot Stop
Contrast vs Wavelength: HLC
10% bandpass, polarization errors, after wavefront control

\[ \lambda_c = 470 \text{ nm} \quad 505 \text{ nm} \quad 575 \text{ nm} \quad 661 \text{ nm} \]

Circles are \( r = 3 \& 9 \frac{\lambda_c}{D} \)

NOTE: Previous claim by Breckinridge & Chipman (Proc. SPIE, 2016) that WFIRST coronagraphs are limited to \( 10^{-7} \) contrast due to polarization was in error. They have since retracted that claim and agree with our results.
Contrast vs Wavelength & Jitter: HLC
10% bandpass, after wavefront control

No jitter | 0.4 mas RMS | 0.8 mas RMS | 1.6 mas RMS

505 nm

575 nm

661 nm
Contrast vs Wavelength & Jitter: SPC
18% bandpass, after wavefront control

\[ \lambda_c = 660 \text{ nm} \]
No polarization errors
No jitter

\[ \lambda_c = 660 \text{ nm} \]
With polarization errors
No jitter

\[ \lambda_c = 660 \text{ nm} \]
With polarization errors
1.6 mas RMS jitter

\[ \lambda_c = 770 \text{ nm} \]
With polarization errors
No jitter

Circles are \( r = 3 \& 9 \lambda_c/D \)
Old vs New SPC Design: Dealing with Primary Mirror Edge Rollover

Pupil Mask

SPC 20170501 (no rollover tolerance)  SPC 20170714 (rollover tolerance)

Circles are $r = 3 \& 9 \lambda_c / D$

$HLC$ is unaffected by rollover
Dynamic Pupil Shear Sensitivity

10^{-10} contrast change with 0.45 μm of pupil shear at Fast Steering Mirror
WFIRST CGI Simulation Pipeline: Current

Observing Scenario → Thermal / Structural / Ray Trace → Wavefront vs. Time

LOWFS/C Optical Model

DM#1 settings

Focus Adjustment Mechanism

Speckles vs. Time

Coronagraph Optical Model
WFIRST CGI Simulation Pipeline: Upcoming

- Observing Scenario
- Thermal / Structural / Ray Trace
- LOWFS/C Optical Model
- DM#1 settings
- Focus Adjustment Mechanism
- Coronagraph Optical Model
- DM Drift
- Pupil offset vs. Time
- Wavefront vs. Time
- IFS
- Speckles vs. Time
- Detector Model (noise, CTE, cosmic rays)
- Pointing Jitter vs time
  - Wavefront Jitter vs time
- Wavefront Jitter vs time
Observing Scenarios

• OS5 (imaging mode)
  • Observe bright star (β UMa) for ~8 hours
    • Use to dig/restore dark hole and for RDI
  • Observe science target (47 UMa) for ~28 hours
    • 2 orientations (Δ=26°) for ADI

• OS6 (IFS mode)
  • Observe η UMa for 2 hours
  • Observe 47 UMa for 2 hours at each orientation (Δ=26°)
  • Observe 47 UMa again for 2 hours at each orientation
  • Repeat entire sequence for 13 iterations (~138 hours total)
  • Rapid switching allows better temporal matching between reference (bright star or other roll) and science targets to deal with DM actuator drift
Modeling Things to Do

• Run OS6
  • Speckle fields will be posted to wfirst.ipac.caltech.edu, where the OS5 results are currently available

• Implement additional instability sources
  • wavefront jitter
  • pupil shear
  • DM actuator drift

• Implement detector model
  • including traps, cosmic rays

• Add GSFC IFS simulator (see today’s talk by Rizzo et al.)