Exposure Time Calculator for the Roman Coronagraph Instrument

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With support from: Vanessa Bailey, John Debes, Dean Keithly, Brian Kern, Bijan Nemati, Dmitry Savransky, Leah Sheldon

Roman Coronagraph Info Sessions
Day 2. 10/28/2021

CGI Perf: overview

- Excel spreadsheet[1,2,3] to calculate exposure time to reach SNR accounting for
  - Contrast stability
  - Coronagraph performance
  - Throughput
  - Detector QE
  - Albedo
  - Stray light
  - Exozodi
  - Observing scenario

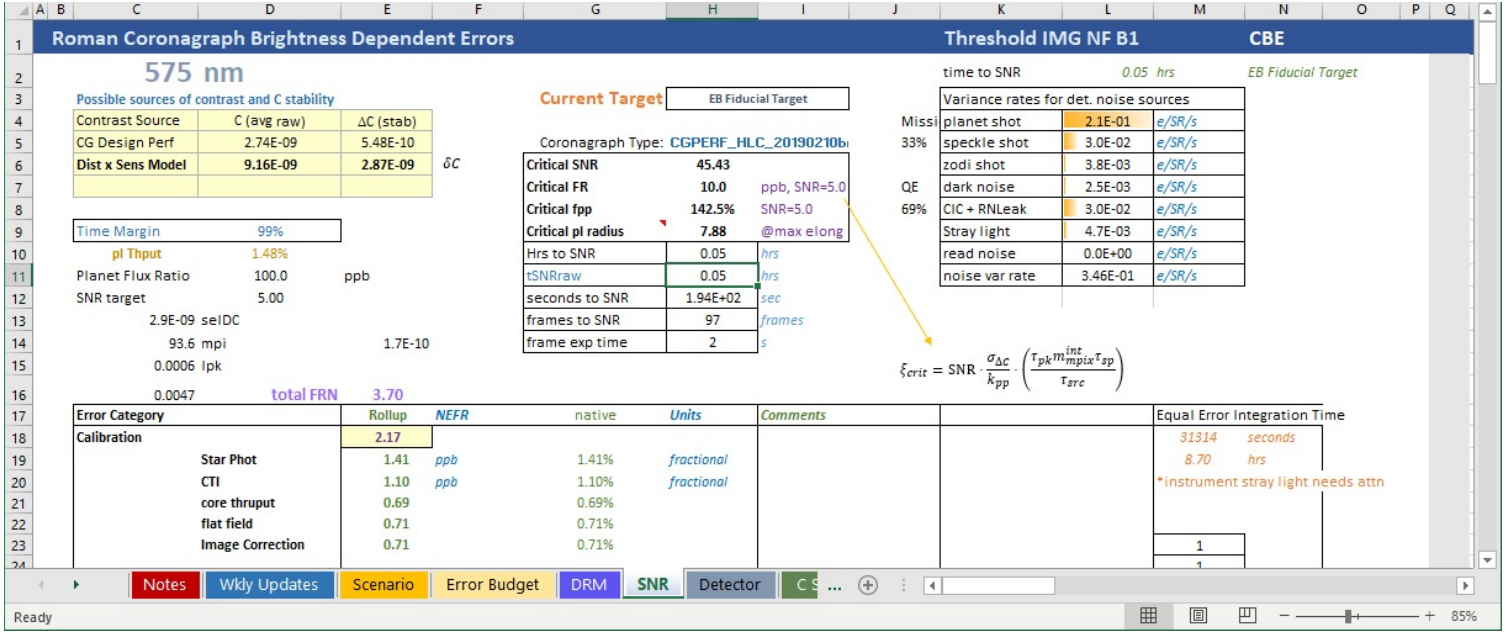
$$t = \frac{\mathrm{SNR}^2 C_b}{C_p^2 - \mathrm{SNR}^2 C_{sp}^2}$$

- t – Exposure time
- SNR –Signal to noise ratio
- C_b – Background electron noise count rate
- C_p – Planet signal electron count rate
- C_{sp} – Residual speckle count rate

[1] Bijan Nemati (2020) doi: 10.1117/12.2575983; [2] Bijan Nemati, H. Philip Stahl, Mark T. Stahl, Garreth J. J. Ruane, Leah J. Sheldon (2020) doi:10.1117/1.JATIS.6.3.039002 [3] Roman Coronagraph Instrument private repository

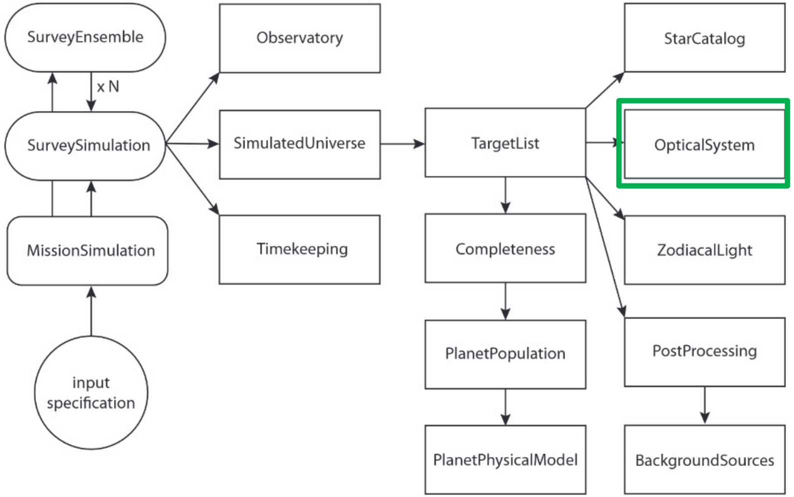
CGI Perf: overview

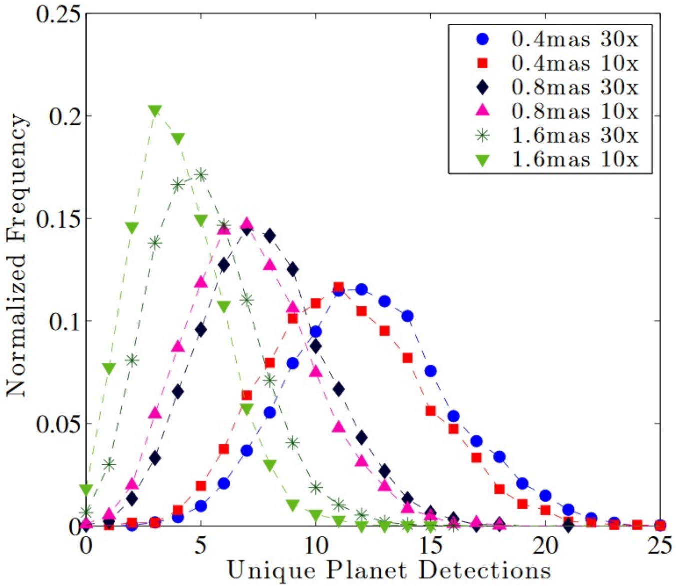
- Great for testing, but not very extensible



EXOSIMS: overview

- End-to-end simulations of space-based exoplanet imaging missions written in Python[1,2,3]
- Estimate detection and characterization yield by simulating hundreds of missions
- Extensible, modular, and open source





[1] Dmitry Savransky, C. Delacroix, D. Garrett (2017) 2017ascl.soft0610S [2] Dean Keithly, D. Savransky, D. Garrett, C. Delacroix, G. Soto (2020) doi:10.1117/1/JATIS.6.2.027001 [3] https://github.com/dsavransky/EXOSIMS

CGI Perf in EXOSIMS

- Goal: Calculate exposure times quickly for a many targets and many observing scenarios
- OpticalSystem module written that can calculate the CGI Perf exposure time calculations
- Works directly from CGI Perf csv inputs
- Methods[1,2,3]:
  - Calculate background, speckle, and planet count rates
  - Calculate integration time
  - Calculate Δmag for an integration time via numerical inversion

[1] Bijan Nemati (2020) doi: 10.1117/12.2575983; [2] Bijan Nemati, H. Philip Stahl, Mark T. Stahl, Garreth J. J. Ruane, Leah J. Sheldon (2020) doi:10.1117/1.JATIS.6.3.039002 [3] Roman Coronagraph Instrument private repository

EXOSIMS input

- A JSON file
  - Telescope and Coronagraph information[1]
  - Specify which EXOSIMS modules to use
  - Hard coded parameters such as planet orbital parameter ranges
  - For each starlight suppression system we load the csv files from the CG_Perf spreadsheet
- For more info see https://exosims.readthedocs.io/en/latest/userparams.html
- To create and use planets in code, use the TargetList module
- EXOSIMS uses the TimeKeeping module to track time

```
  starlightSuppressionSystems : [
   {  name :  HLC-565 ,
      lam : 575,
      BW : 0.10,
      Rs : 0,
      IWA : 0.13049,
      OWA : 0.45,
      Nlensl : 5.0,
      lenslSamp : 2.0,
      occ_trans :  $HOME/Documents/github/WFIRST-CGI-
      core_thruput :  $HOME/Documents/github/WFIRST-C
      core_mean_intensity :  $HOME/Documents/github/W
      core_area :  $HOME/Documents/github/WFIRST-CGI-
      core_contrast :  $HOME/Documents/github/WFIRST-
      core_platescale : 0.30,
          core_stability :  $HOME/Documents/github/WF
          core_stability_setting :  MCBE ,
          CG_Perf :  $HOME/Documents/github/WFIRST-CG
   }
 ],
  observingModes : [
   {  instName :  imager ,
      systName :  HLC-565 ,
      detectionMode : true,
          ContrastScenario :  2019_PDR_Update ,
      SNR : 5,
          tau_pol : 1,
          GCRFlux : 5,
          photons_per_relativistic_event : 250,
          luminescingOpticalArea : 0.7854,
          OpticalThickness : 4,
          luminescingOpticalDistance : 0.1,
          s_baffling : 0.001
   }
 ],
  modules : {
    PlanetPopulation :  KnownRVPlanets ,
    StarCatalog :   ,
    OpticalSystem :  Nemati_2019 ,
    ZodiacalLight :  Stark ,
    BackgroundSources :  GalaxiesFaintStars ,
    PlanetPhysicalModel :  ForecasterMod ,
    Observatory :  WFIRSTObservatoryL2 ,
    TimeKeeping :   ,
    PostProcessing :   ,
    Completeness :   ,
    TargetList :  KnownRVPlanetsTargetList ,
    SimulatedUniverse :  KnownRVPlanetsUniverse ,
    SurveySimulation :   ,
    SurveyEnsemble :
```

[1] https://roman.ipac.caltech.edu/sims/Param_db.html

Roman Coronagraph Exposure Time Calculator

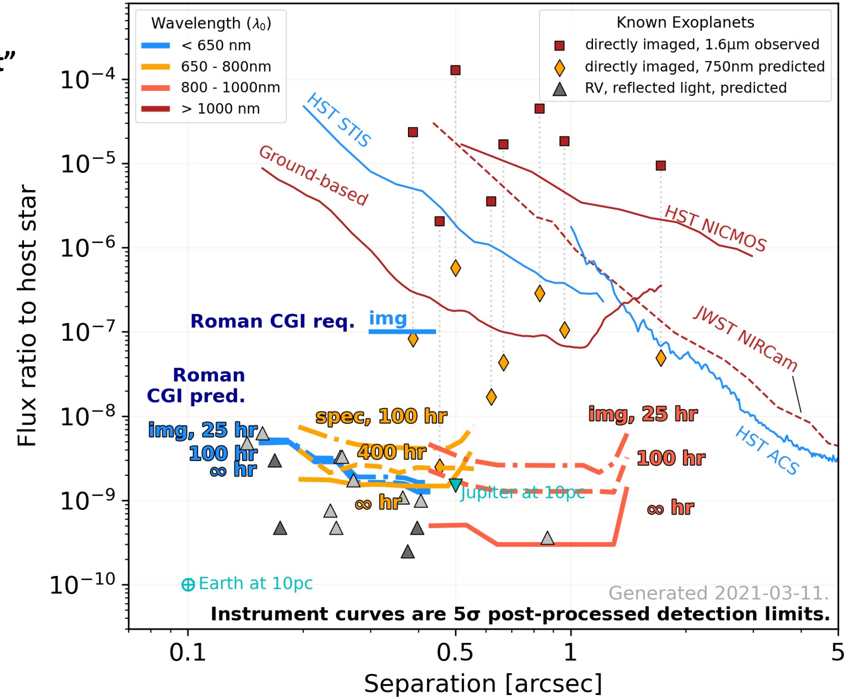
github.com/nasavbailey/DI-flux-ratio-plot/

See “**Observing with the Coronagraph Instrument**” talk on Day 1

Predicted detection limits are strongly speckle-limited at shorter wavelengths

Based on lab demonstrations as inputs to high-fidelity, end-to-end thermal, mechanical, optical models.

Most Model Uncertainty Factors set to ~1



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Sergi Hildebrandt Rafels (JPL)

Roman Coronagraph Exposure Time Calculator

Allows the user to derive integration times for:

- Three types of **targets**:
  - Self luminous exoplanets
  - Reflected light exoplanets
  - Exodust
- Three different **observing modes**:
  - Narrow Field of View Imager (575 nm, 10% bandwidth)
  - Single Slit, Prism-based Spectroscopy (730 nm, 15% bandwidth, R=50)
  - Wide Field of View Imager (825 nm, 10% bandwidth)
- Two Instrumental and Mission **performance** levels:
  - **Optimistic**: most model uncertainty factors are set to 1
  - **Conservative**: current best estimates of model uncertainty factors (will be updated as ground tests happen)
- Fully **documented**
- Public repository on **GitHub**
- Written in python

https://github.com/hsergi/Roman_Coronagraph_ETC

SHR: acknowledges support by the Turnbull Roman CGI Science Investigation

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Deep Dive Info Session on November 18, 2021, 9 am PT: Link

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Questions