Science yield modeling with the Exoplanet Open-Source Imaging Mission Simulator (EXOSIMS)

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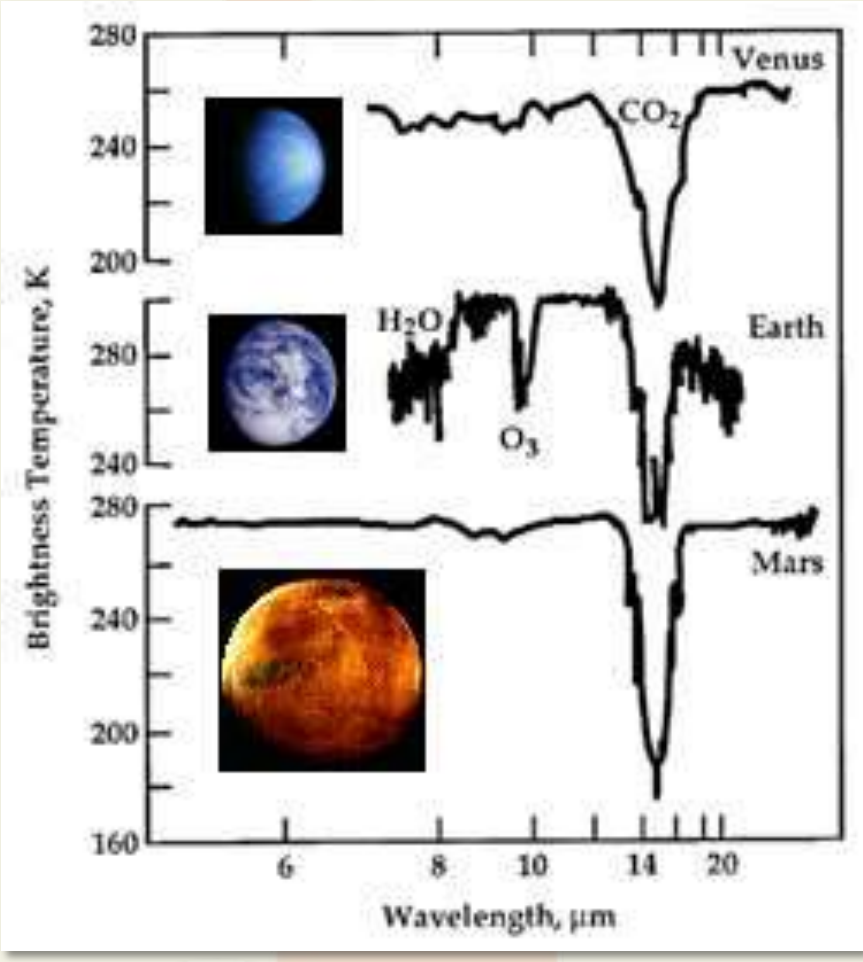
Direct imaging is extremely challenging

- Pure detection
- Astrometry, orbital parameters
- Photometry, spectroscopy
- Detection of life

But…

- Small angular separation:
  1AU @ 10pc = 0.1arcsec
- High contrast scenes:
  10^6 (IR) – 10^9 (visible)
- **Speckle noise** due to wavefront deformation (atmosphere, optics)



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High contrast and resolution, speckle discrimination and control

Direct imaging requires:

- Coronagraphy
- Wavefront sensing and control
- Pointing jitter control
- Post-processing algorithms

So far: imaged a few dozen of large bright planets, around young and nearby stars, on long-period orbits

Future **space observatories** will extend the parameter space (e.g. WFIRST ~2024)

Ultimate goal: imaging Earth-like planets

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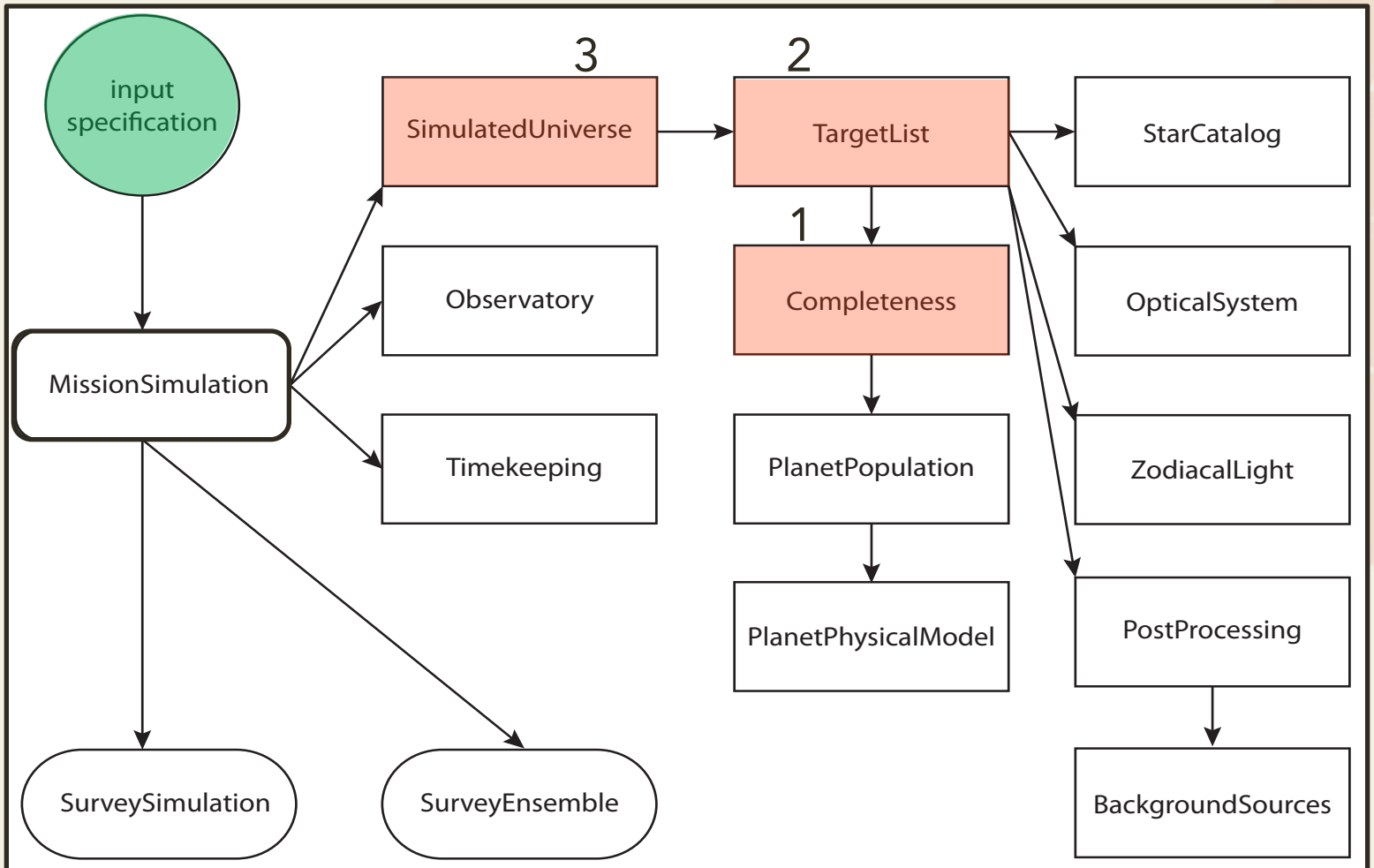
EXoplanet Open-Source Imaging Mission Simulator

- EXOSIMS - developed as part of WFIRST Preparatory Science
- Performs ensembles of simulations to determine science yield distributions
- Modular architecture, allows multiple mission designs
- https://github.com/dsavransky/EXOSIMS



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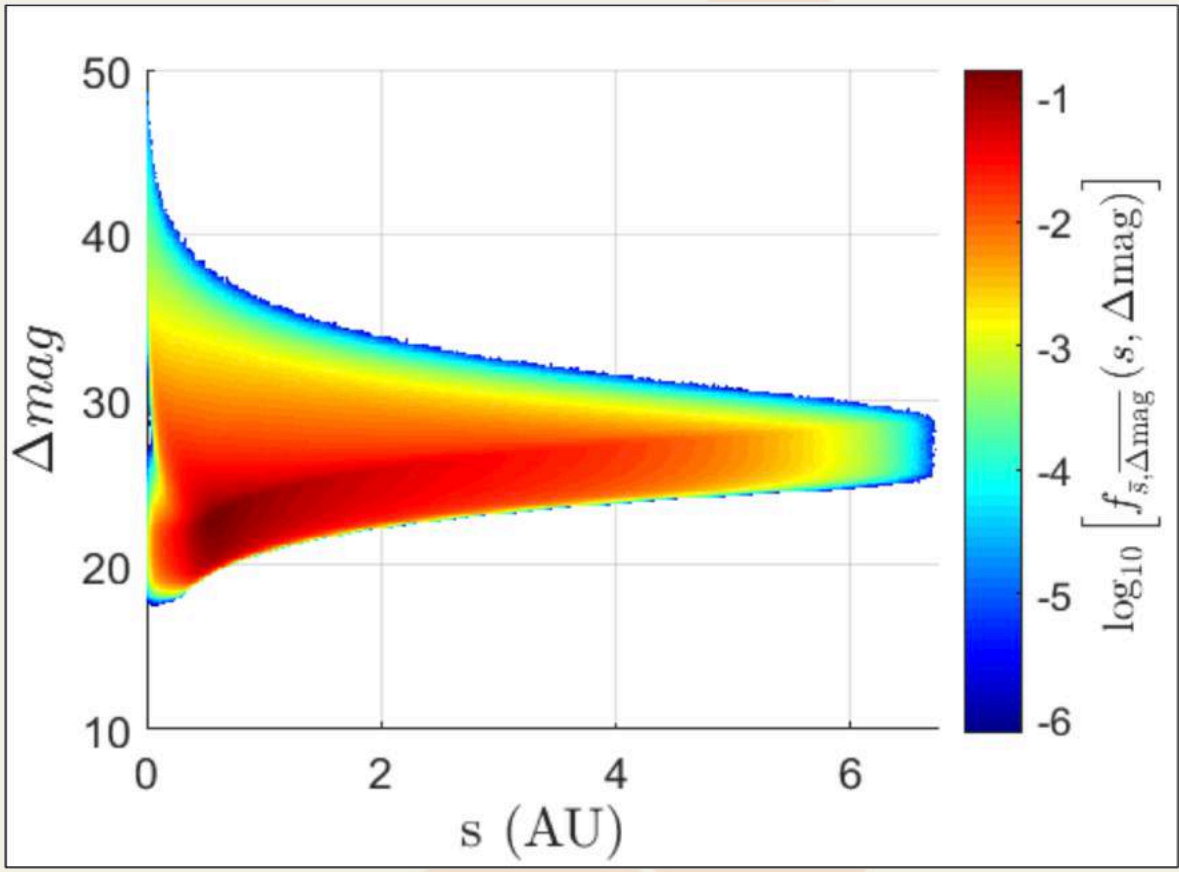
Example of completeness joint probability density function

Fig. from Daniel Garrett

- Planet apparent separation vs. difference in brightness
- Data → model → statistic generated from specific PDF of planet orbital and physical properties
- Updates completeness values for systems previously observed



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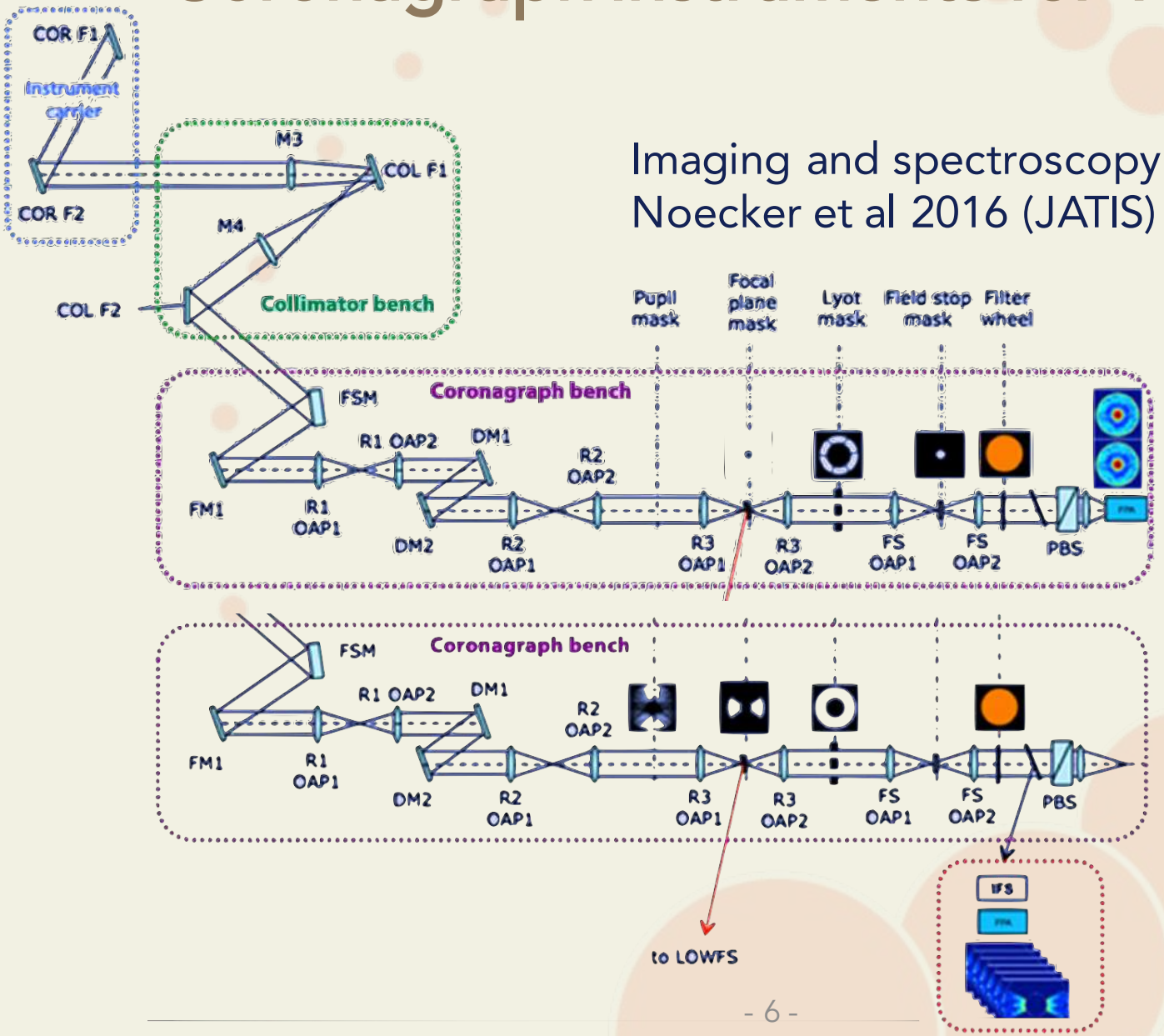
Optical System Module
Coronagraph instruments for WFIRST



Imaging and spectroscopy modes
Noecker et al 2016 (JATIS)

Hybrid Lyot Coronagraph

Shaped Pupil Coronagraph

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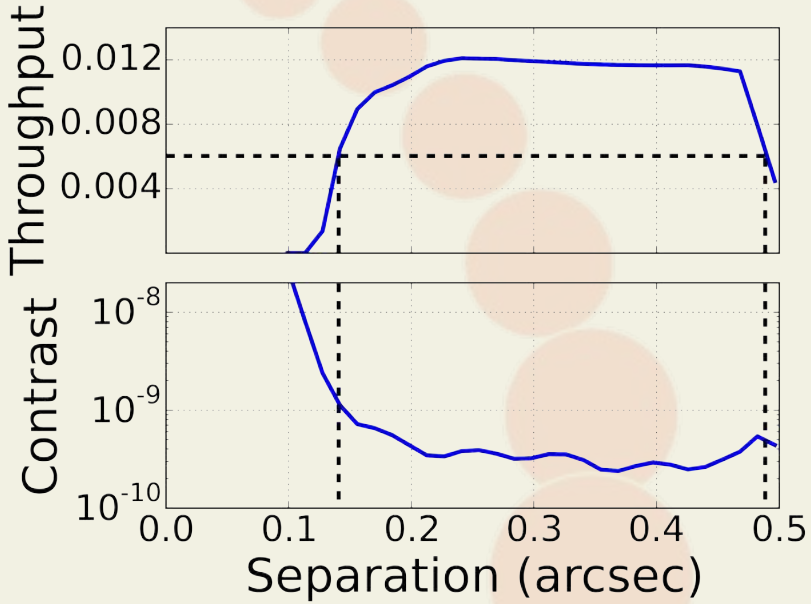
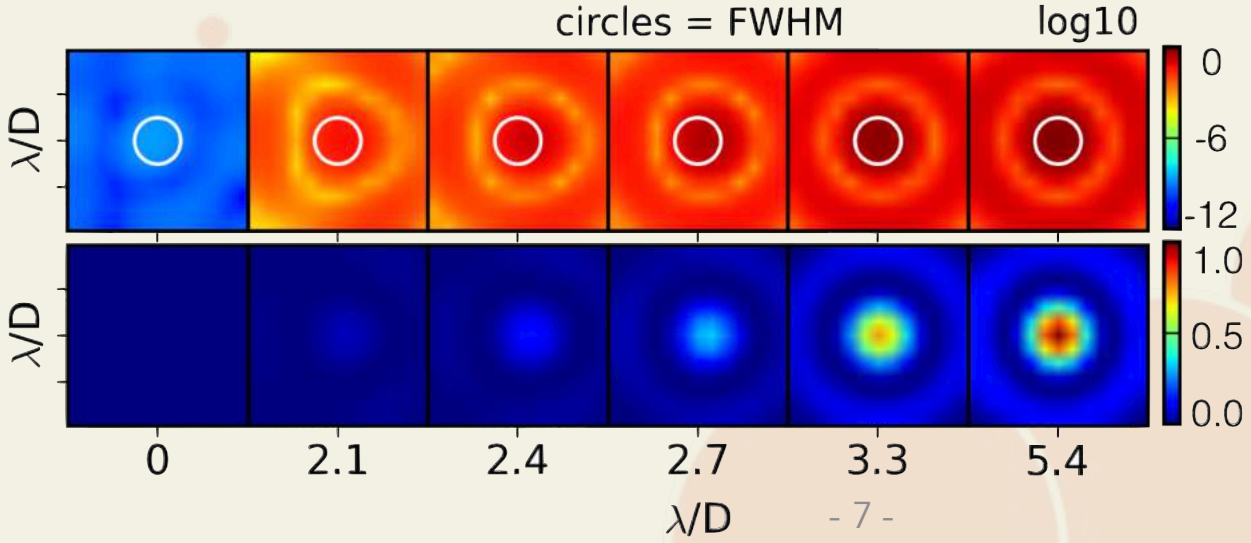
Target List Module Filtering

Filters out (from star catalog):

- Binary stars
- Too long integration times
- Unreached completeness threshold
- **Stars with planets within the IWA** → calculated based on throughput, contrast, and off-axis PSF





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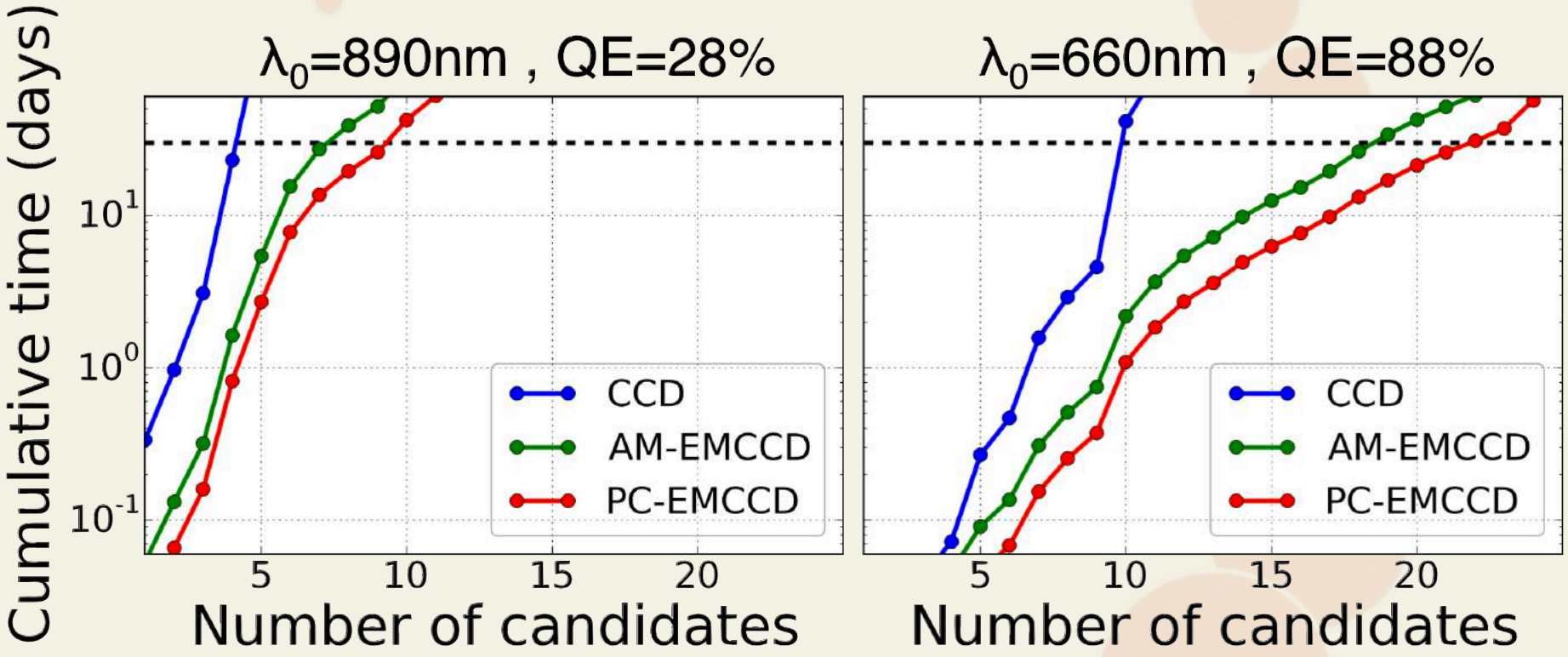
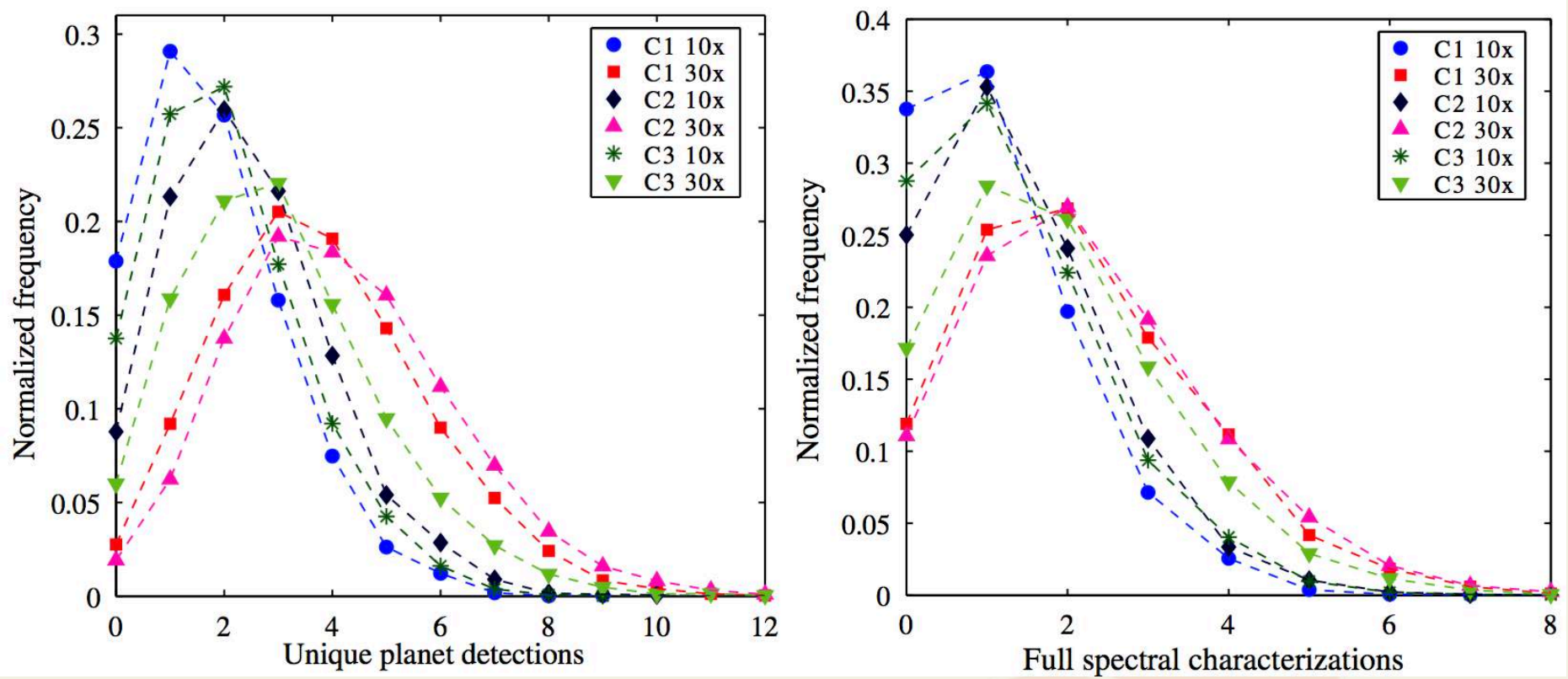
Mission yield comparison of different science instruments (cameras)



Mission yield comparison of pre-downselect Coronagraph Designs

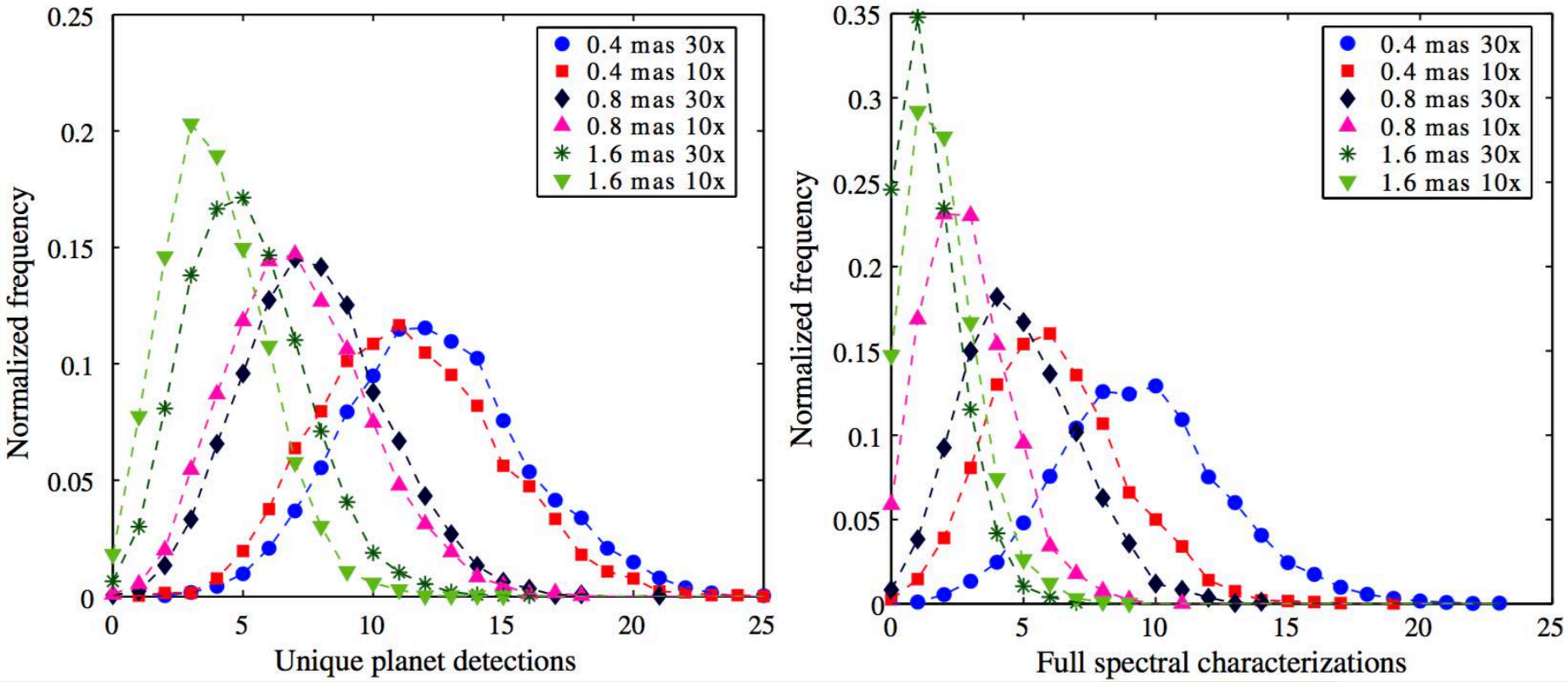
PDF obtained from mission ensemble simulation (~5000)



Savransky et al 2016 (JATIS)

Mission yield comparison of post-processing gains and telescope jitter values

PDF obtained from mission ensemble simulation (~5000)



Savransky et al 2016 (JATIS)

Conclusions and future development

- EXOSIMS — a modular, open-source software
- Compare different cameras, coronagraphs, post-processing gains, jitter values, etc.
- Alpha release: February 2016
- Continued updates through 2017, as a community-driven project
- Code and documentation publicly available: https://github.com/dsavransky/EXOSIMS