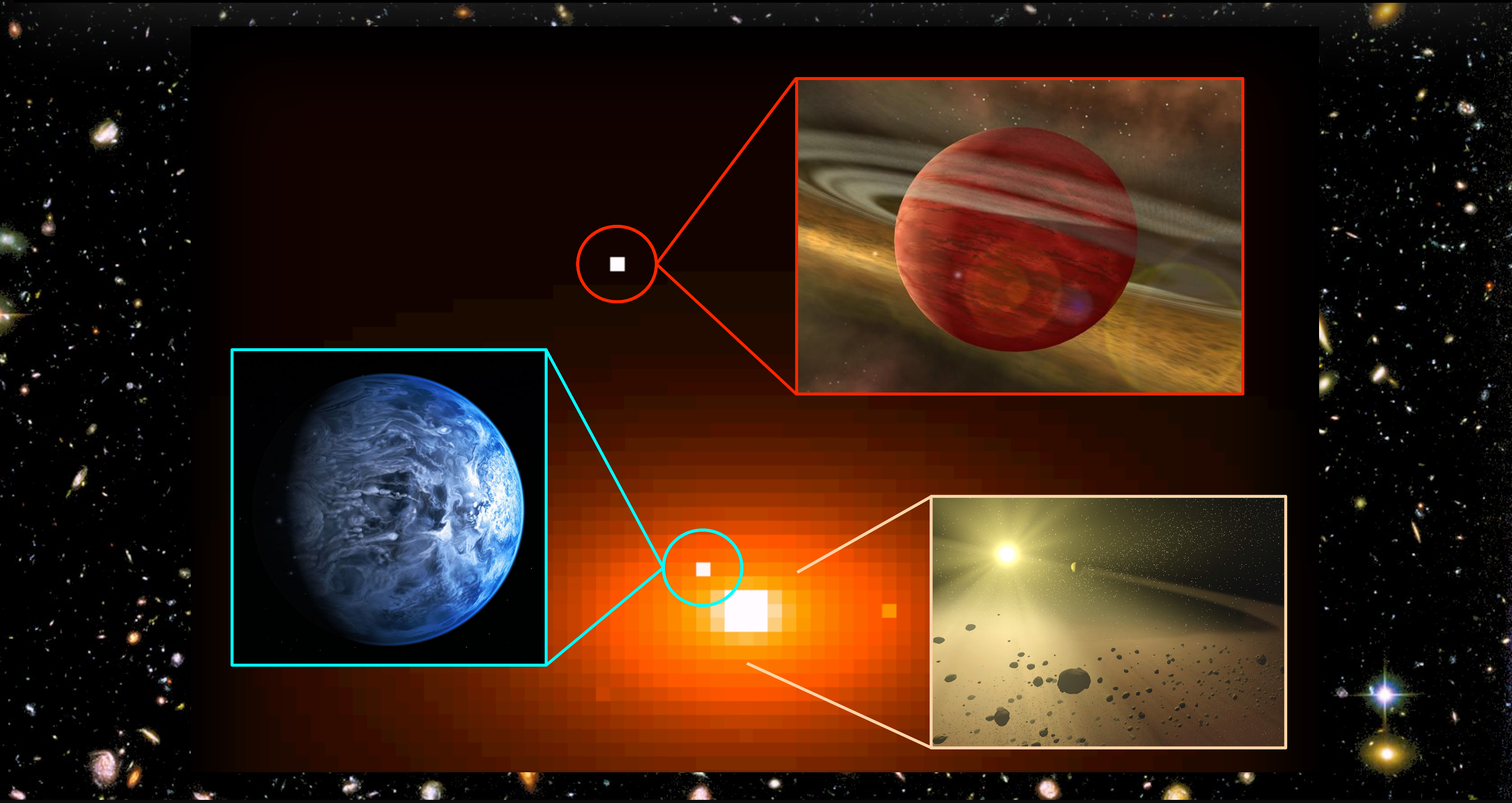
WFIRST CGI SIT:
Targets, Datacubes, and Data Challenges



Dr. Margaret Turnbull, SETI Institute
Carl Sagan Center for the Study of Life in the Universe

WFIRST Coronagraph SIT
Turnbull Team Members

Dr. Margaret Turnbull (SETI Institute)

David Ciardi (NExScI / Caltech)

Hannah Jang-Condell (Wyoming)

Stephen Kane (SFSU)

Nikku Madhusudhan (Cambridge)

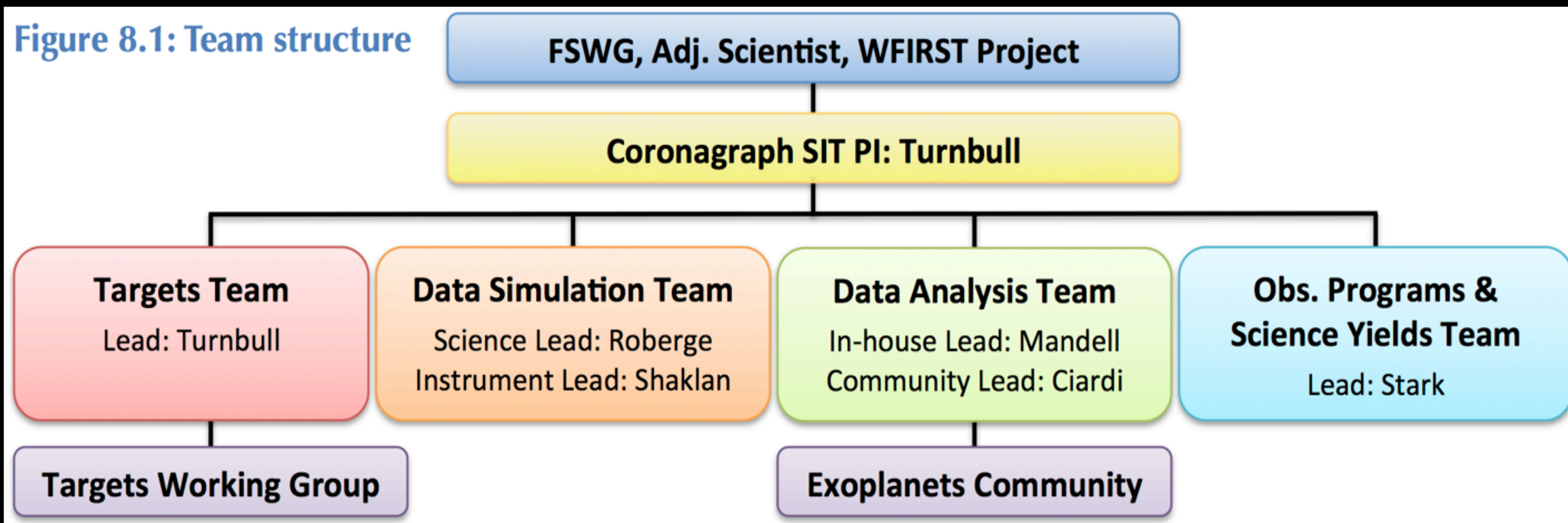
Aki Roberge, Avi Mandell, Michael McElwain (NASA GSFC)

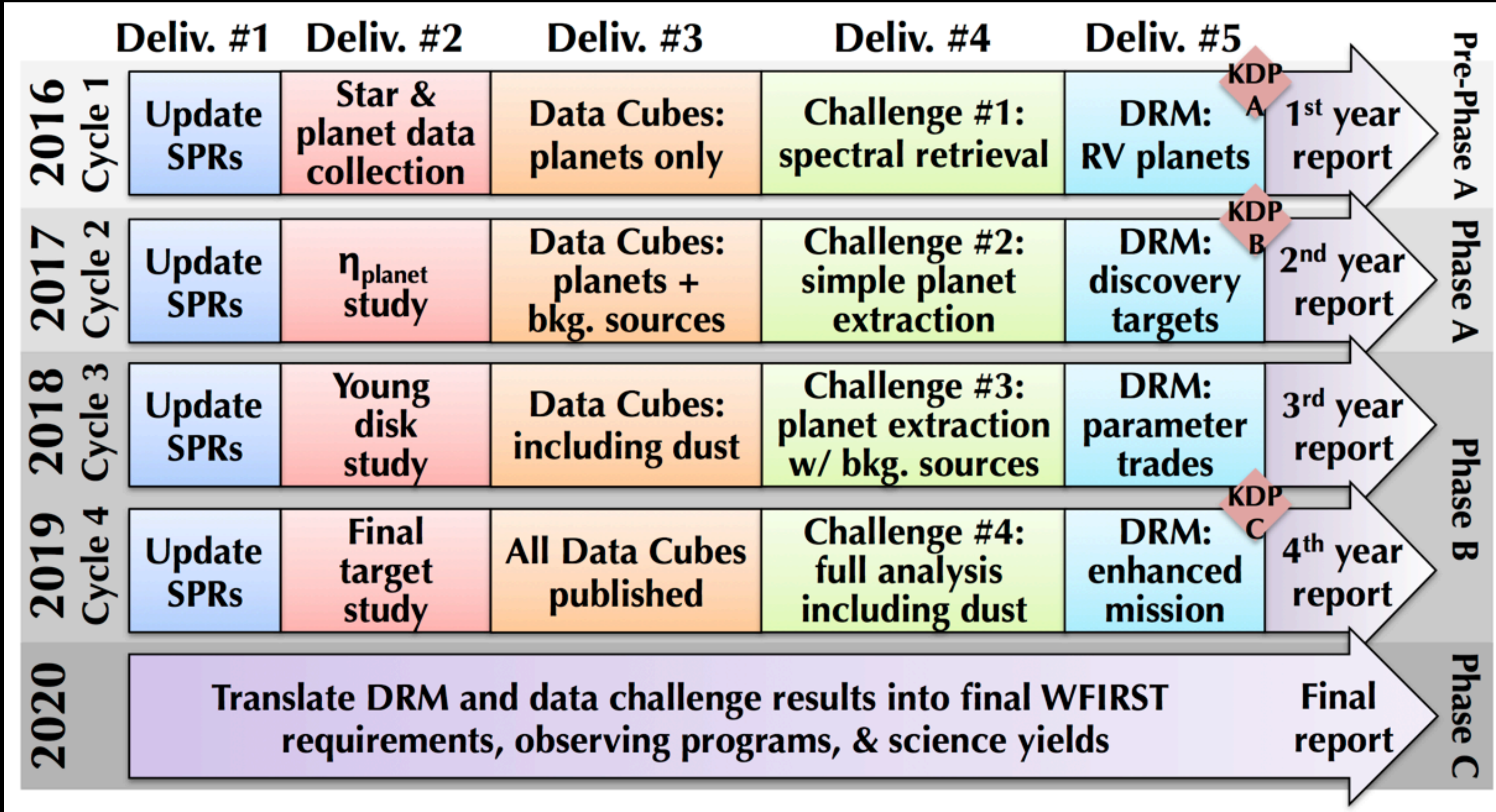
Stuart Shaklan, Renyu Hu (JPL)

Chris Stark, Laurent Pueyo, William Sparks (STScI)

Philip Hinz (Arizona)

WFIRST Coronagraph SIT
Turnbull Team Members





Caption: Plan for success of the WFIRST CGI. One full SIT Cycle occurs in each of Years 1–4. Scientific performance requirements (SPRs) tasks are shown in blue boxes (Deliverable #1), target characterization in red (Deliverable #2), data simulation in orange (Deliverable #3), data analysis in green (Deliverable #4), and design reference mission (DRM) tasks in aqua.

WFIRST Coronagraph SIT
Turnbull Team Deliverables

1. The WFIRST Science Requirements Document.

The considerations above lead to the following set of scientific requirements:

EDI 1: Survey ~200 nearby stars, including both those with and without known planets, spanning a range of spectral types. [Is this the right number, given the available observing time? Move spec on search depth from EDI 17,18 to here?]

EDI 2: Characterize a significant sample (10-20) of >4R_E planets in broadband reflected-light photometry, measuring the ratio of flux in a given filter to the peak flux with an accuracy of 10%, spanning ~5 bands that are sensitive to Rayleigh scattering to methane absorption.

EDI 3: Spectroscopically characterize a subset (6-10) of giant planets spanning a range of irradiances and determine the depth of methane, water, and other features to within 15%. Ideally, the planets to be characterized should have known masses.

EDI 4: Detect a sample (~4) of planets of less than 4 R_E in broadband photometry in at least three bands including Rayleigh and water features. It is a strong goal to characterize at least one planet below 2R_E.

EDI 5: Characterize the orbital semi-major axis (within 20%) and eccentricity (within 0.2) of all imaged planets, in conjunction with Doppler or astrometric measurements.

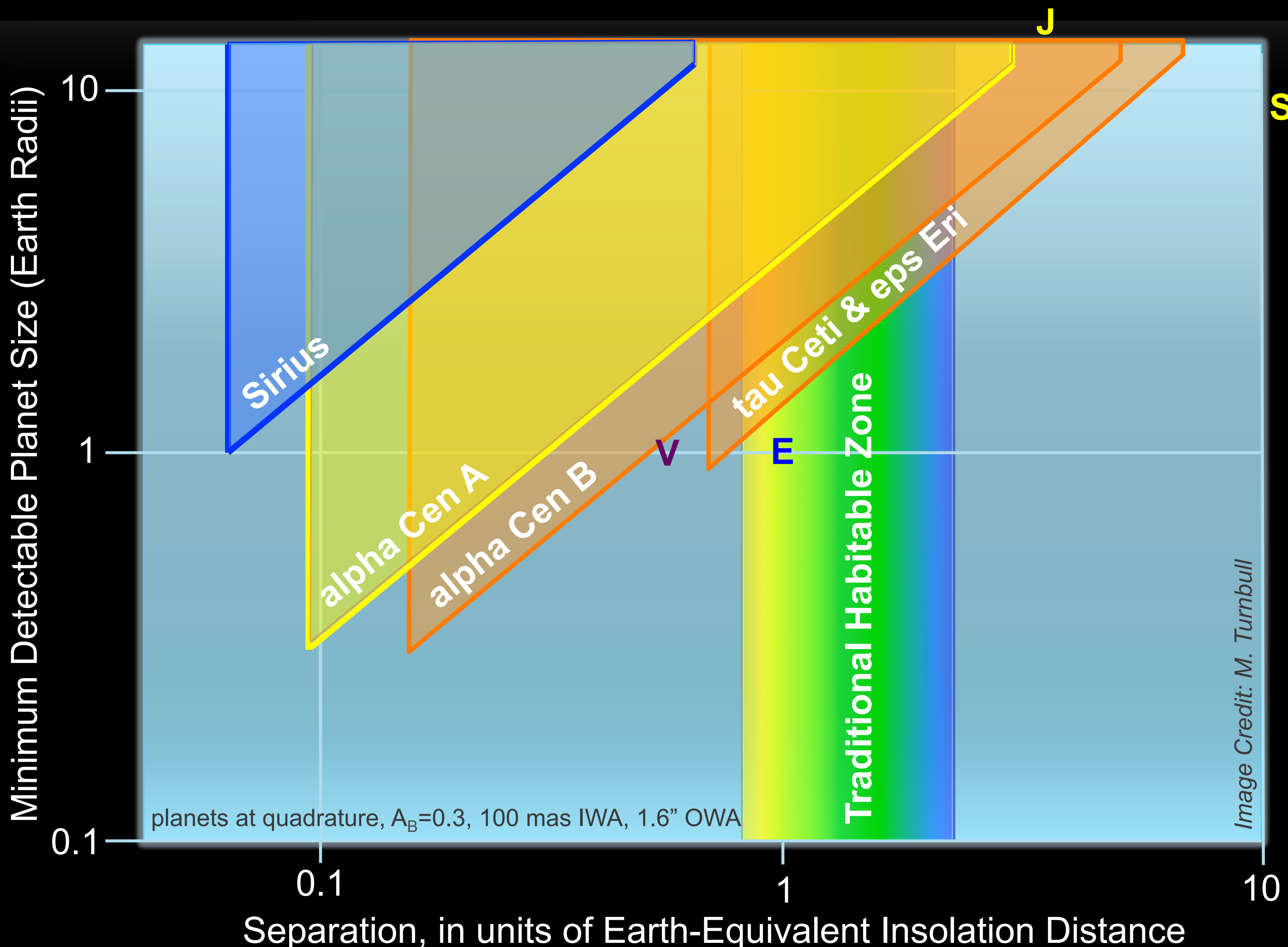
Turnbull Team Deliverables

2. *CGI Target Descriptions*: Known RV planets, Discovery target systems and Disk Systems.

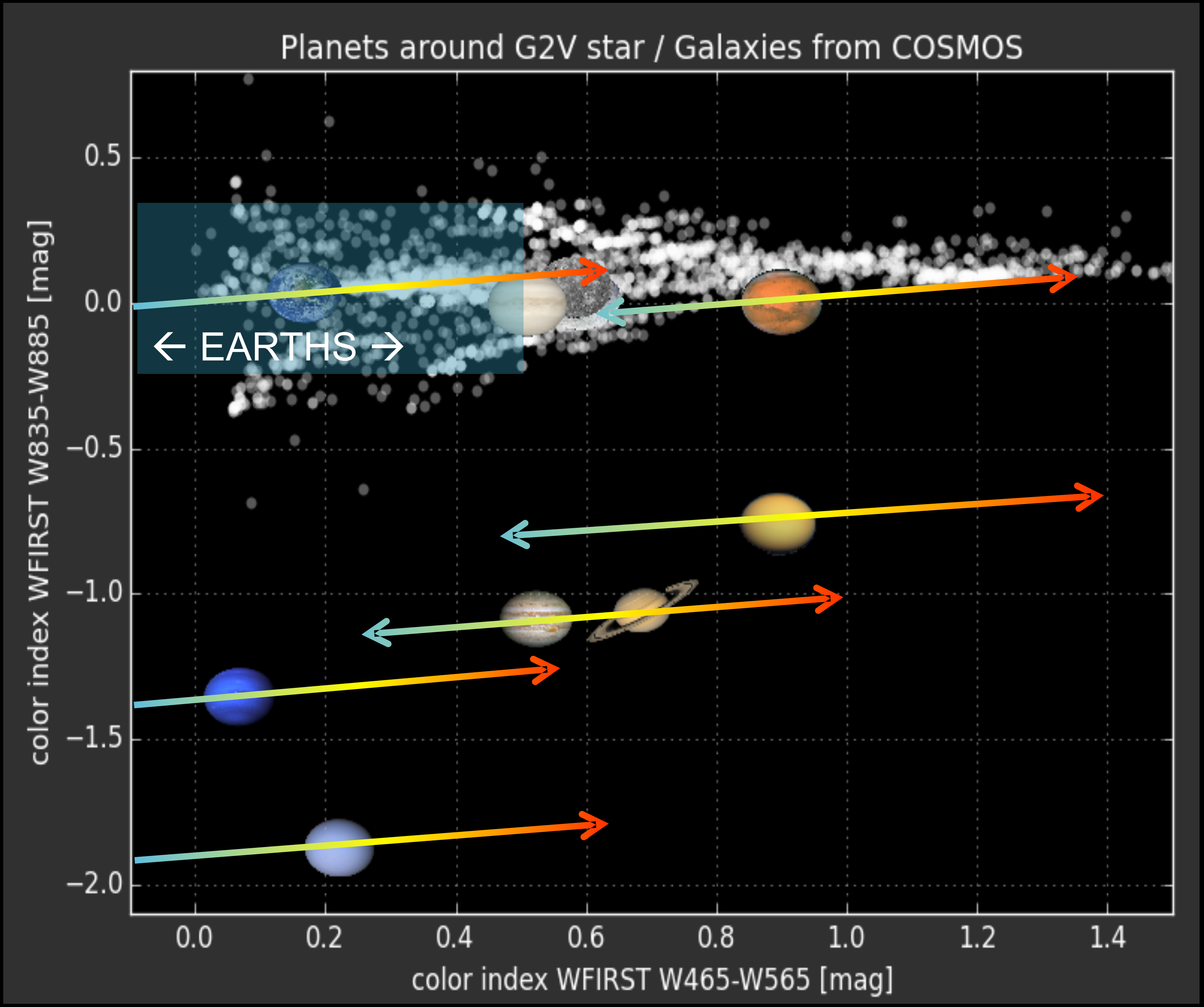
   - stellar characteristics: multiplicity, activity, ages, abundances, astrophysical background

   - detectable planet size-age-temperature/separation phase space for each individual target

Turnbull Team Deliverables



Planets in WFIRST Bands: What can we learn from color?

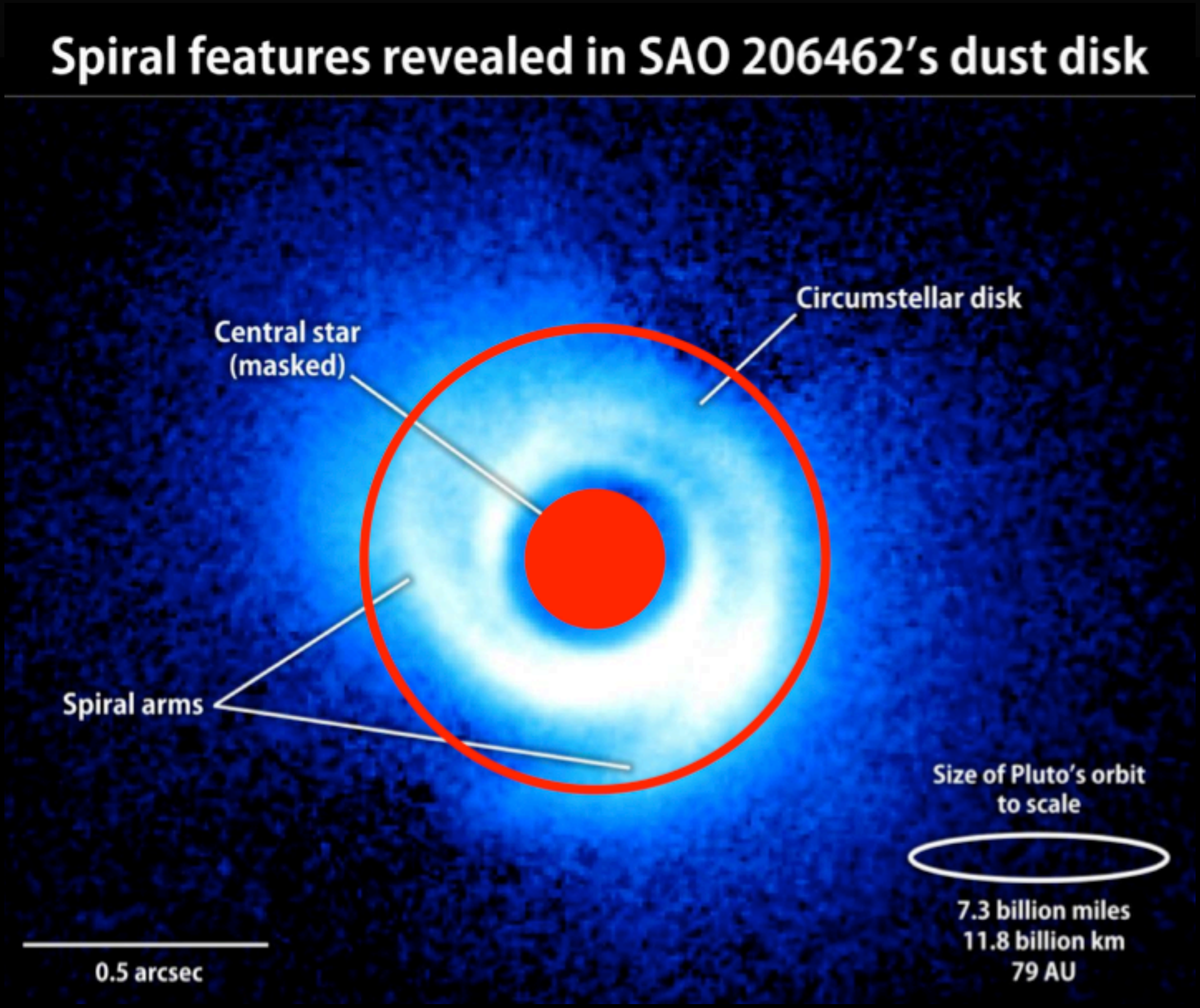


“R-I”

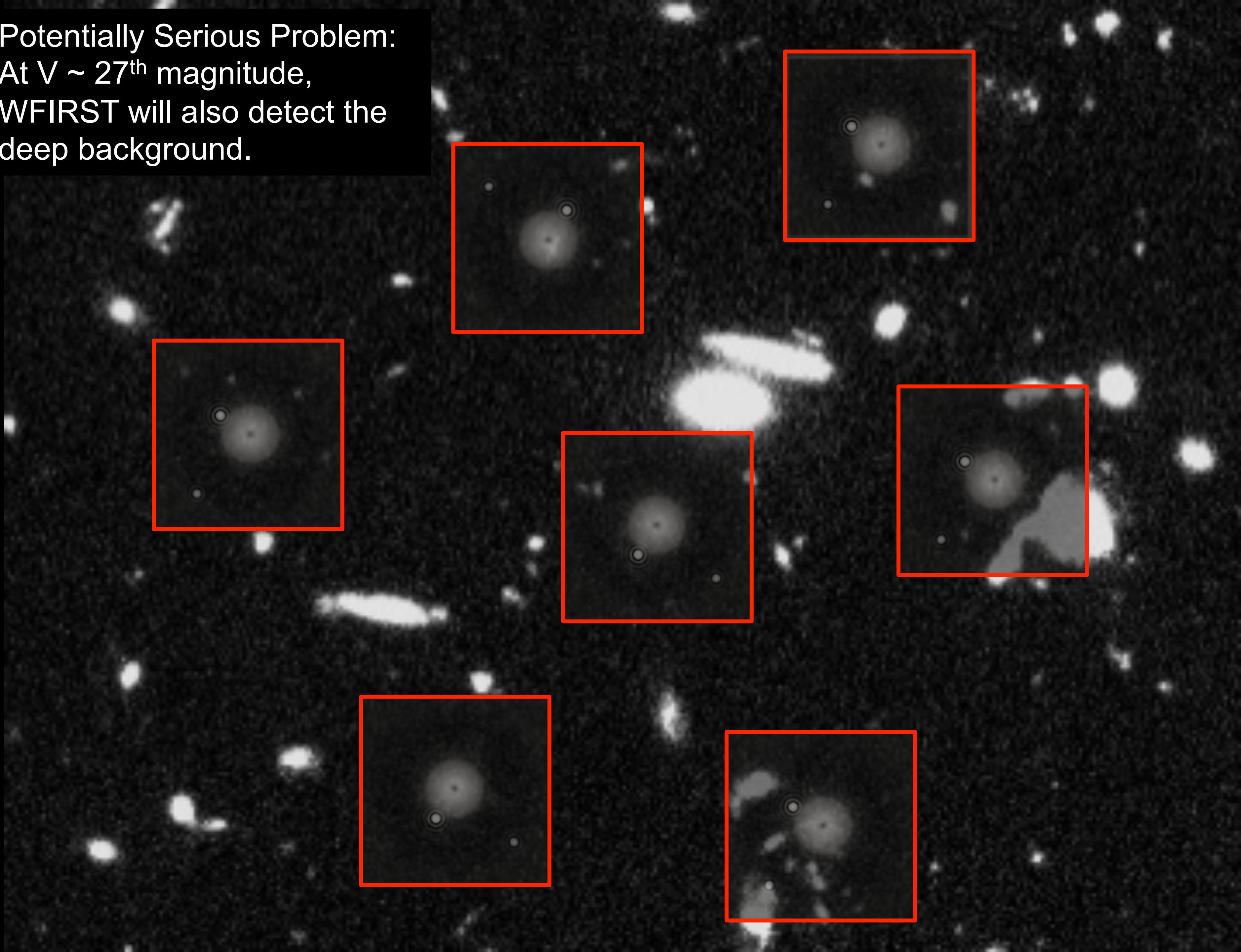
“B-V”

Turnbull Team Deliverables

2. *CGI Target Descriptions*: Identify most interesting disk systems and evaluate detectability of planet formation signatures

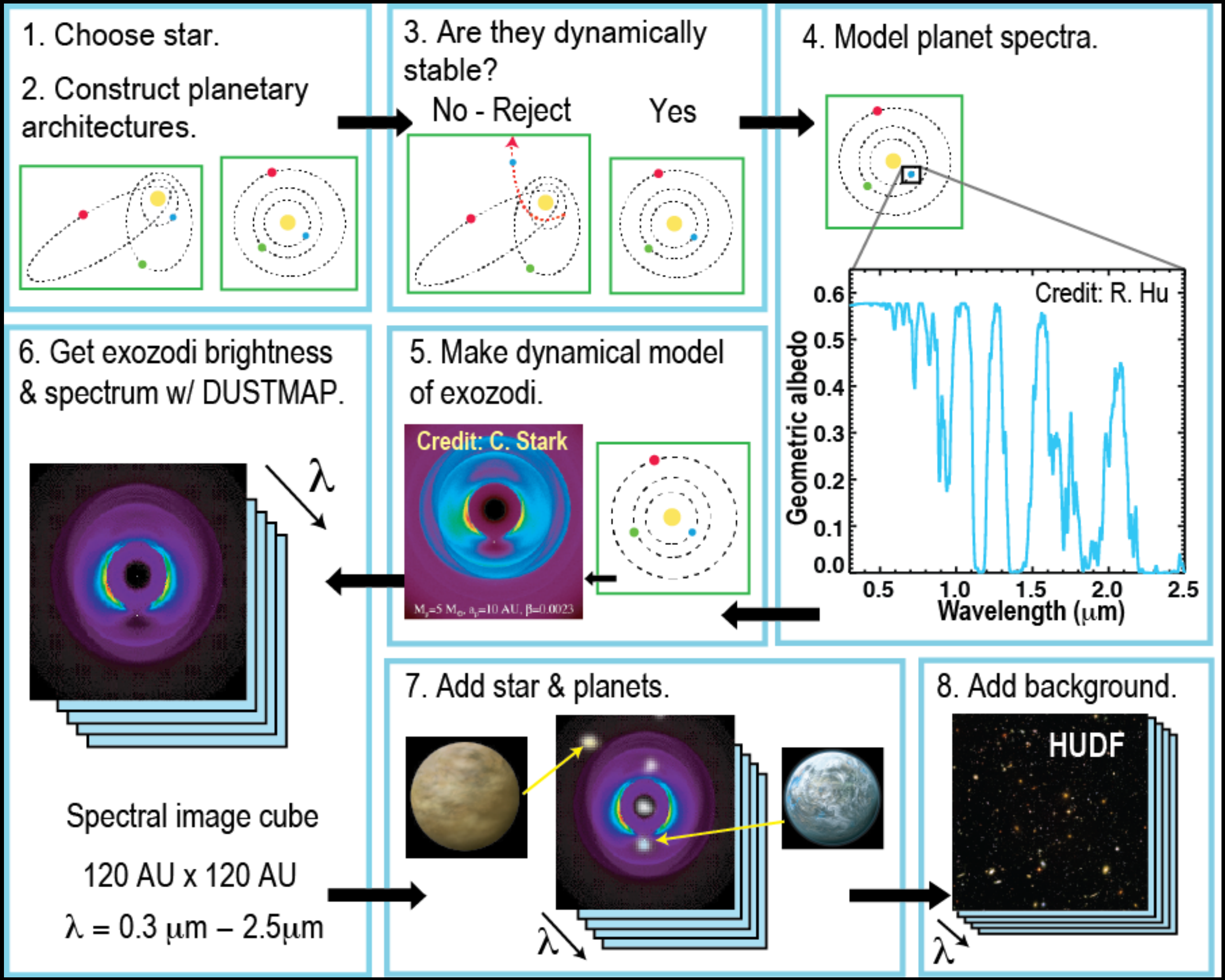


Potentially Serious Problem:
At V ~ 27th magnitude,
WFIRST will also detect the
deep background.



Turnbull Team Deliverables

3. *Spectral Data Cubes* for input to Instrument Simulator(s).

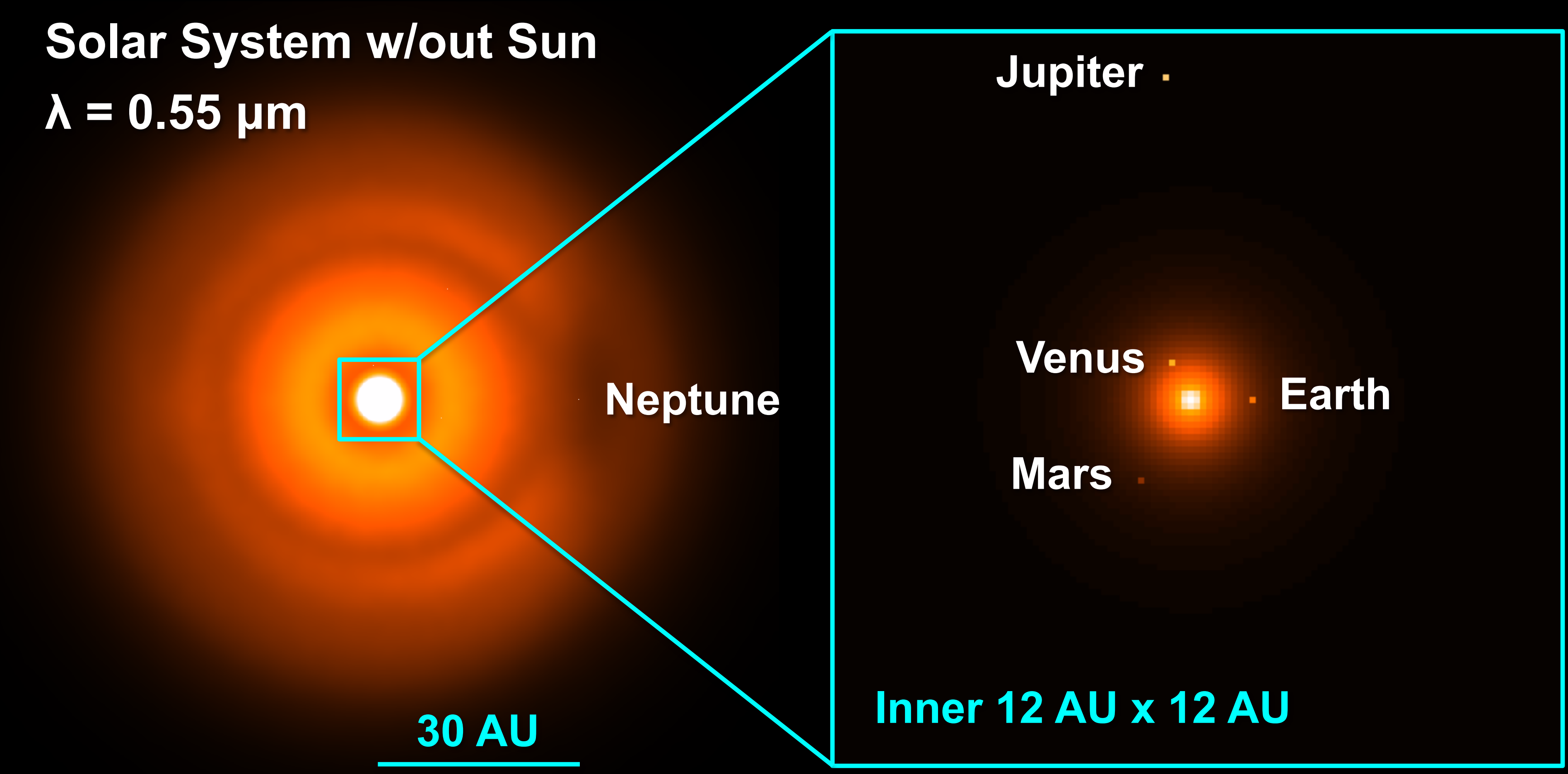


Turnbull Team Deliverables

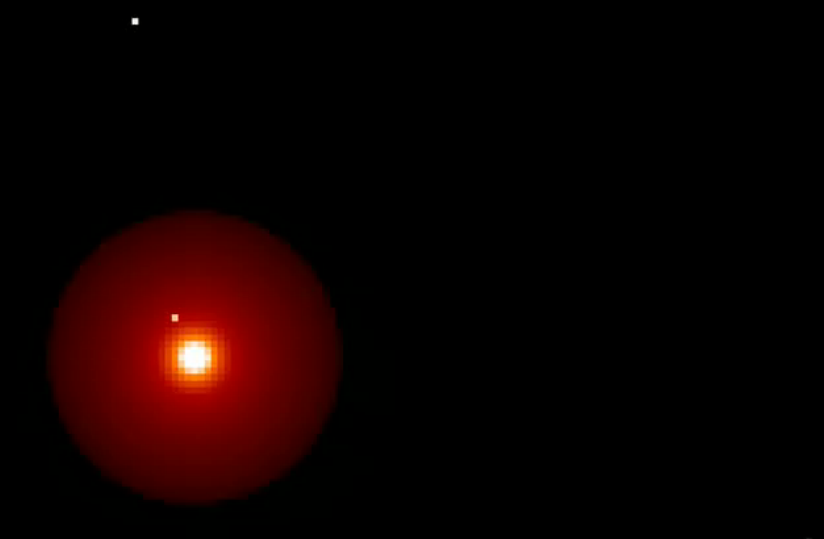
Spectral image cubes: 0.3 μm – 2.5 μm

Contain star, planets, consistent dust

Option to add galactic & extragalactic background sources



Credit: A. Roberge & the Haystacks team



$\lambda = 0.30\ \mu m$

WFIRST CGI: Preparing for Discovery

Stellar Target Data

\+

Known and Hypothetical Planets

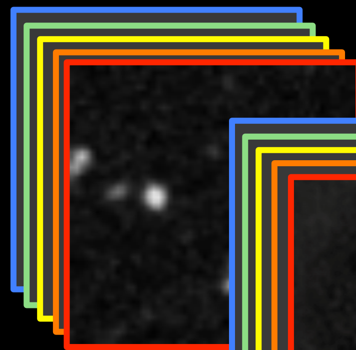
\+

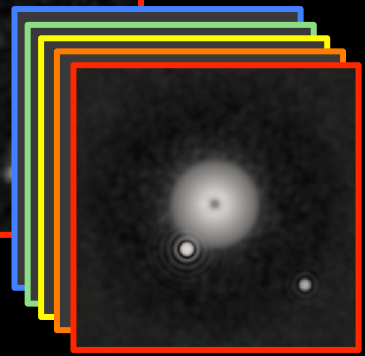
Dust

\+

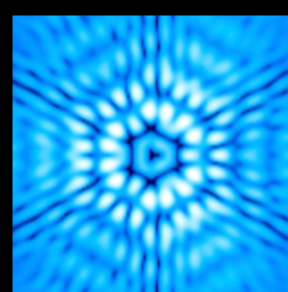
Astrophysical Background

Spectral Data Cubes

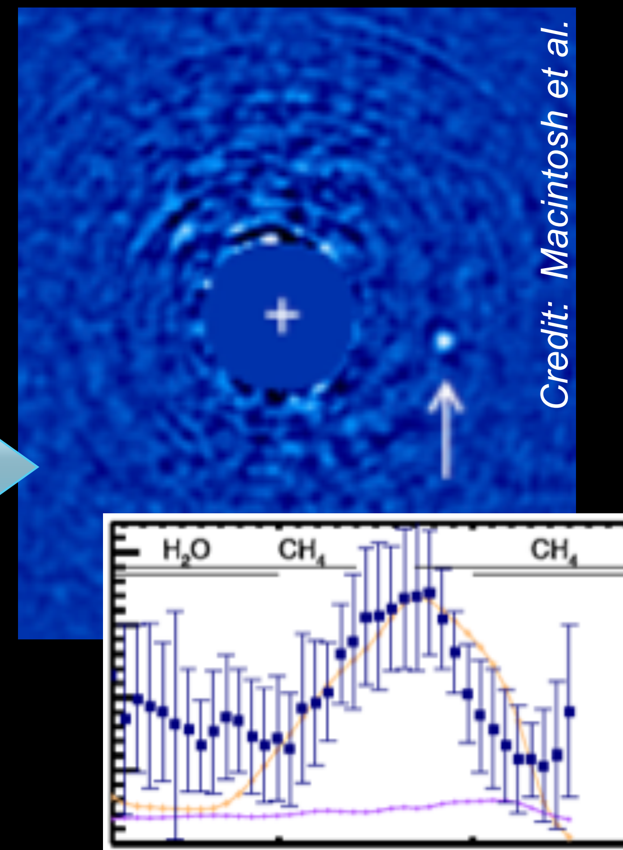




Instrument Response Simulator



Blind Retrieval Exercises: Community Challenges and In-House Studies



WFIRST Coronagraph SIT
Turnbull Team Deliverables

4. *Spectral Retrieval Studies*, including In-House and Community Data Challenges.

- use assembled spectra and cubes for "blind" studies
- test extraction algorithms to find everything
- test modelers' ability to retrieve own models
- test inter-team differences
- include placebos and non-planets
- map science yield vs spectral resolution and SNR
- start with noisey spectra and add complexity gradually

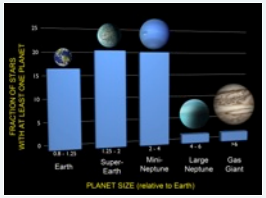
- FIRST DATA CHALLENGE: AUGUST 2016

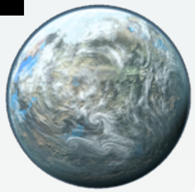
Turnbull Team Deliverables

5. Optimized *observing programs* and *science yields*.

Astrophysical Constraints

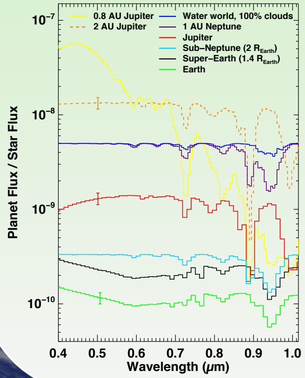
- η_{planet}
- $\eta_{exozodi}$
- Planet sizes
- Albedos
- Phase functions

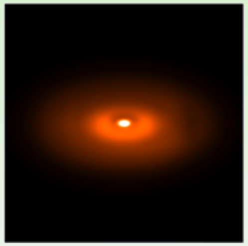




Observational Requirements

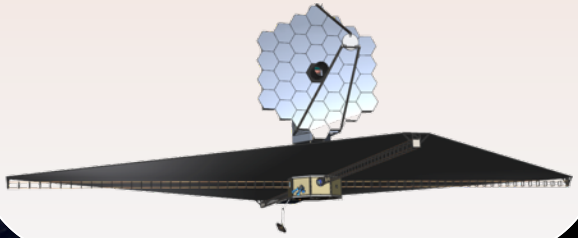
- Central wavelength
- Total bandpass
- Spectral resolution
- Signal-to-Noise
- Observing strategy





Technical Requirements

- Telescope diameter
- Contrast
- Contrast floor
- Inner working angle
- Outer working angle
- Total throughput
- Overheads



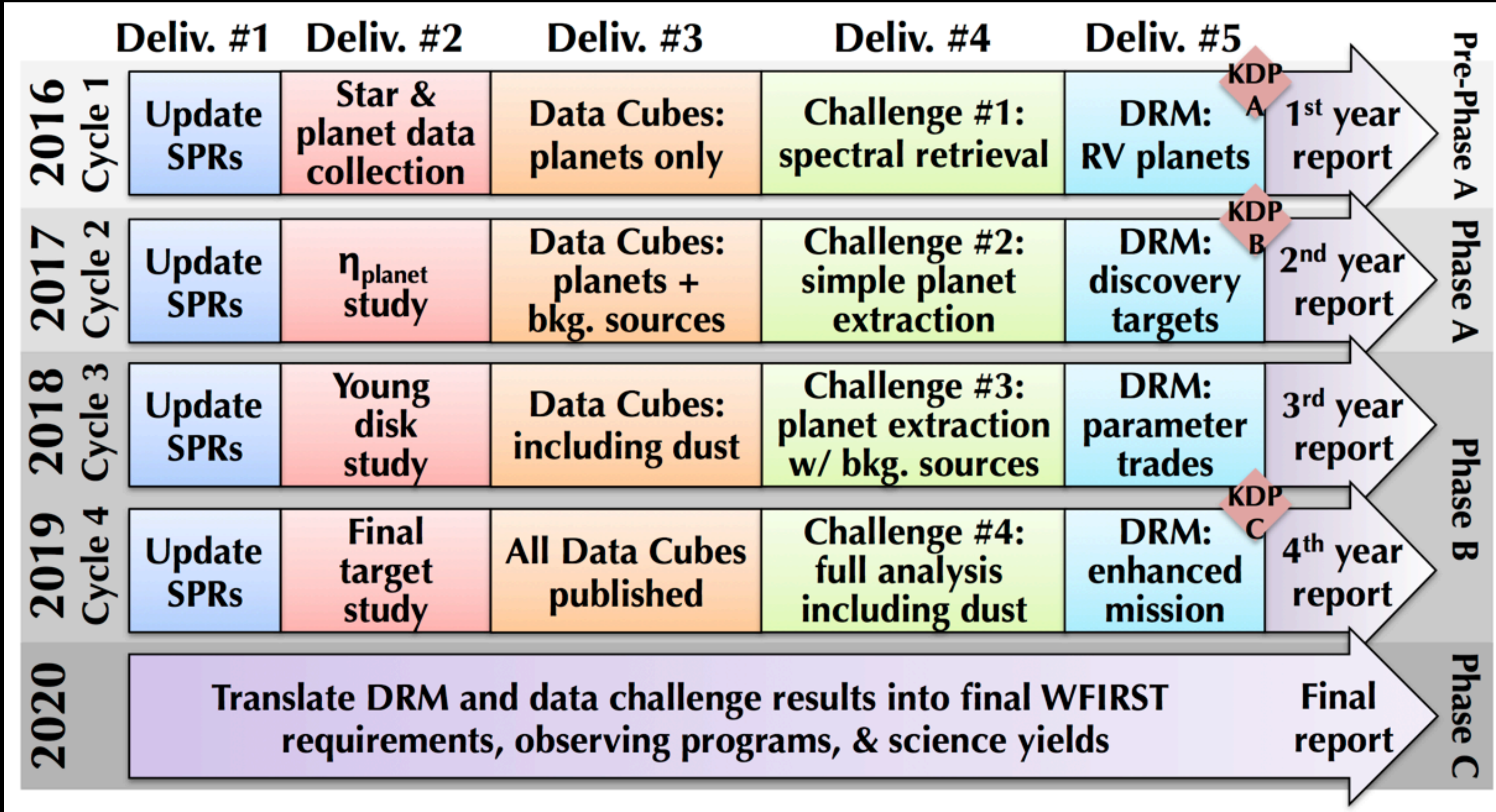
Stark et al. (2014) Stark et al. (2015)

Design reference mission (DRM)

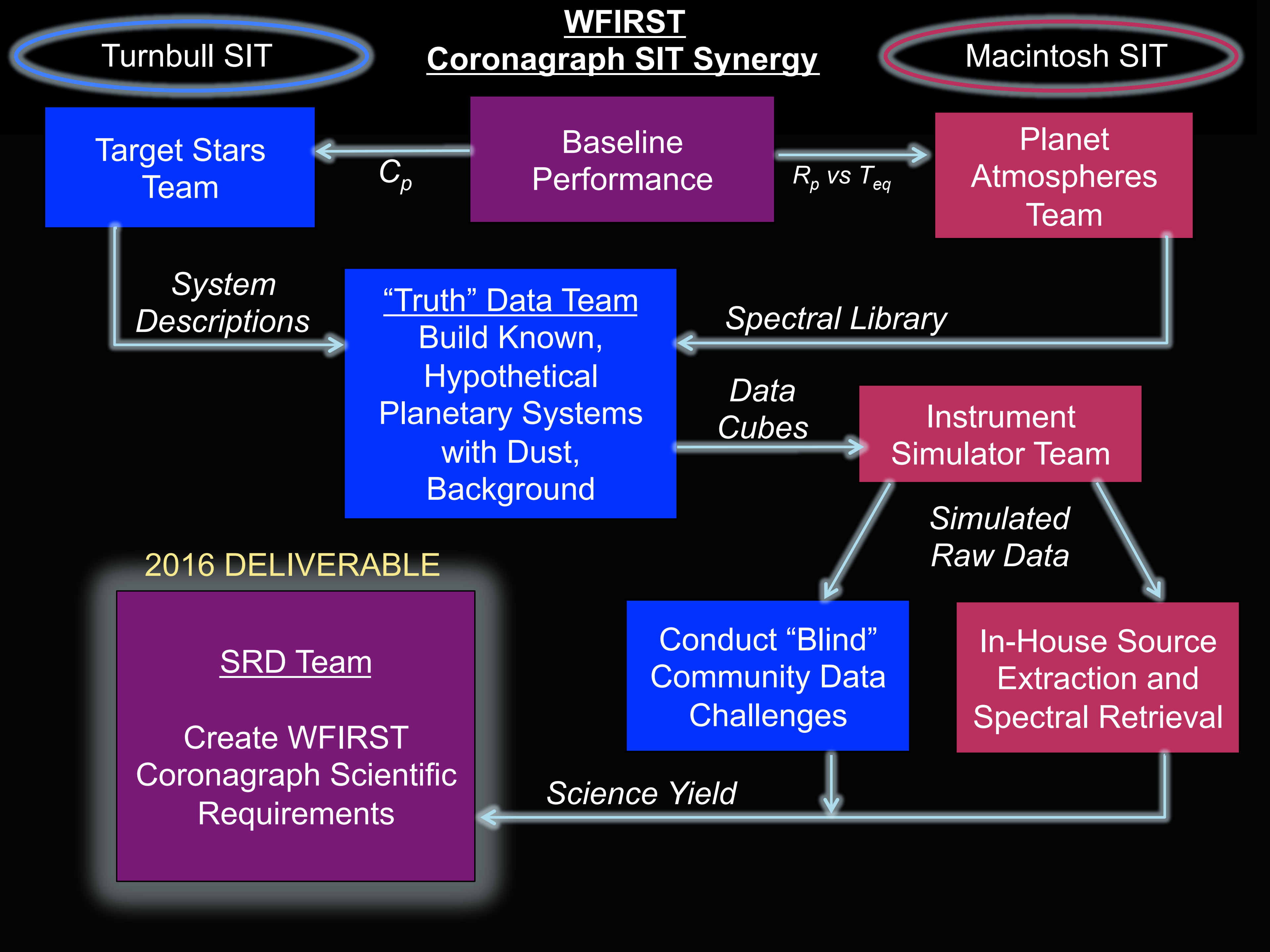
Turnbull Team Deliverables

5. Optimized *observing programs* and *science yields* (DRM output).

   - start with RV targets as "guaranteed science" including uncertainty in orbits
   - add in discovery targets
   - explore fast follow-up for confirmation of faintest planets in broadband
   - explore optimal follow-up timing for orbit determination
   - explore trades in dark hole size vs. depth
   - explore trades in contrast vs. bandwidth (impacts post-processing algorithms)
   - explore optimal observing strategy for target star subtraction vs. limiting contrast



Caption: Plan for success of the WFIRST CGI. One full SIT Cycle occurs in each of Years 1–4. Scientific performance requirements (SPRs) tasks are shown in blue boxes (Deliverable #1), target characterization in red (Deliverable #2), data simulation in orange (Deliverable #3), data analysis in green (Deliverable #4), and design reference mission (DRM) tasks in aqua.


WFIRST
Coronagraph SIT Synergy
Turnbull SIT
Macintosh SIT
Target Stars Team
Baseline Performance
Planet Atmospheres Team
C_p
R_p vs T_{eq}
System Descriptions
"Truth" Data Team
Build Known, Hypothetical Planetary Systems with Dust, Background
Spectral Library
Data Cubes
Instrument Simulator Team
Simulated Raw Data
2016 DELIVERABLE
SRD Team
Create WFIRST Coronagraph Scientific Requirements
Conduct "Blind" Community Data Challenges
In-House Source Extraction and Spectral Retrieval
Science Yield

Six Month (and Beyond) Plan

1. Identify relevant detectable planet size-temperature phase space for RV targets.
2. Assemble spectral models with range of possible planet parameters (abundance ratios, clouds, etc)
3. Add in some trickery
4. Assemble appropriate stellar spectra for division
5. Add noise
6. Recruit retrieval teams
7. Distribute to community retrieval teams via IPAC for Data Challenge #1: August 15 – November 15
8. Interpret findings in terms of parameters relevant to the SRD
9. Wash, rinse, repeat.