The Habitable Exoplanet Imaging Mission (HabEx): Exploring our neighboring planetary systems.

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(Figures and slides stolen from Maggie Turnbull, Paul Hertz, Ty Robinson, Chris Stark, Paul Scowen, and probably others…)

The HabEx STDT.
(mostly)

HabEx STDT Meeting, May 16-17 2016, Washington, DC. Team members from left to right: Rachel Somerville, David Mouillet, Shawn Domagal-Goldman, Leslie Rogers, Martin Still, Olivier Guyon, Paul Scowen, Kerri Cahoy, Daniel Stern, Scott Gaudi, Bertrand Mennesson, Lee Feinberg, Karl Stapelfeldt, Sara Seager, Dimitri Mawet. Missing STDT members (unable to attend meeting in person): Jeremy Kasdin, Tyler Robinson and Margaret Turnbull.

HabEx General Goals.

- Highest-level goals:

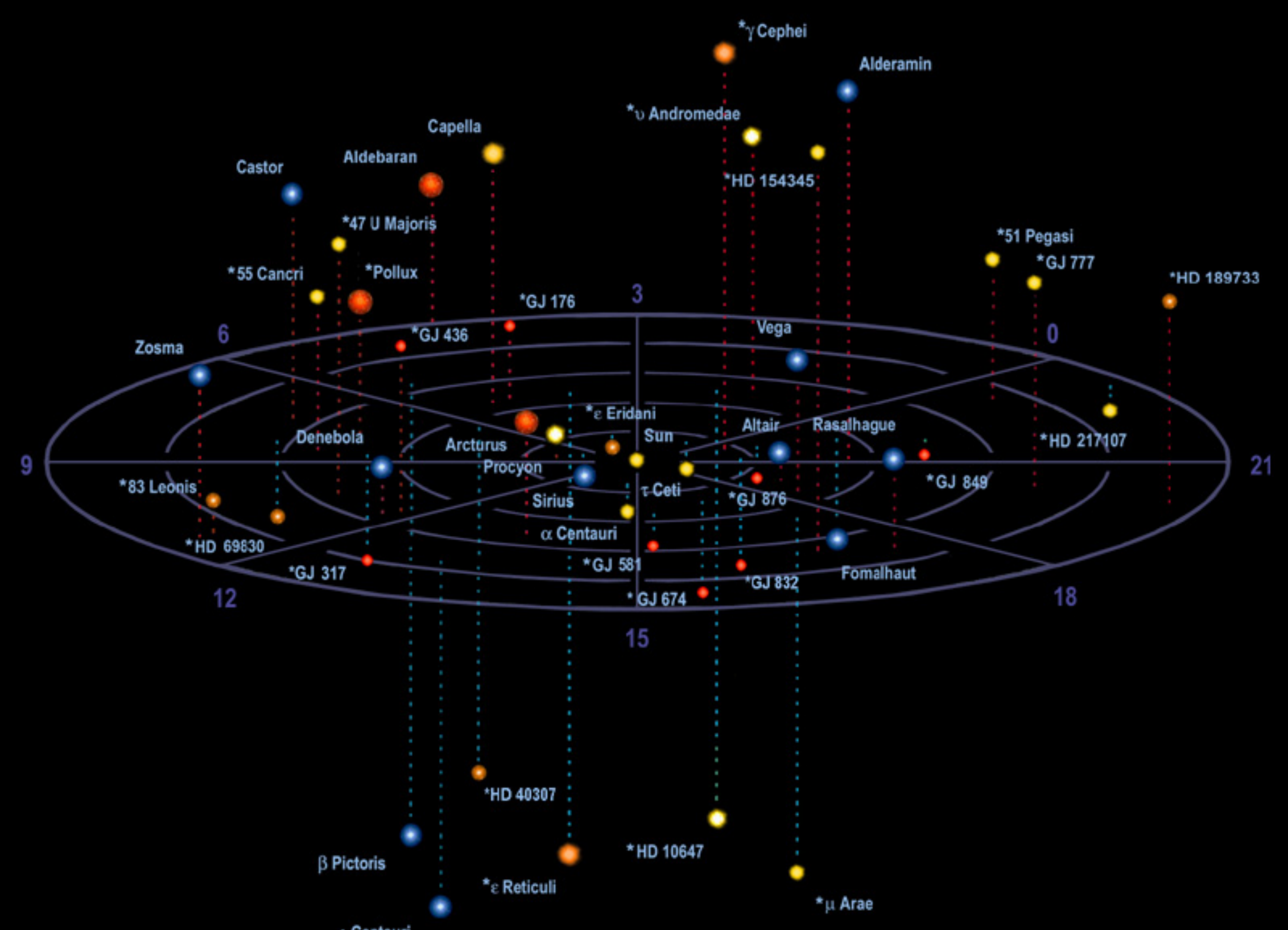
“Develop an optimal mission concept for characterizing the nearest planetary systems, and detecting and characterizing a handful of ExoEarths.”

“Given this optimal concept, maximize the general astrophysics sicence potential without sacrificing the primary exoplanet science goals.”

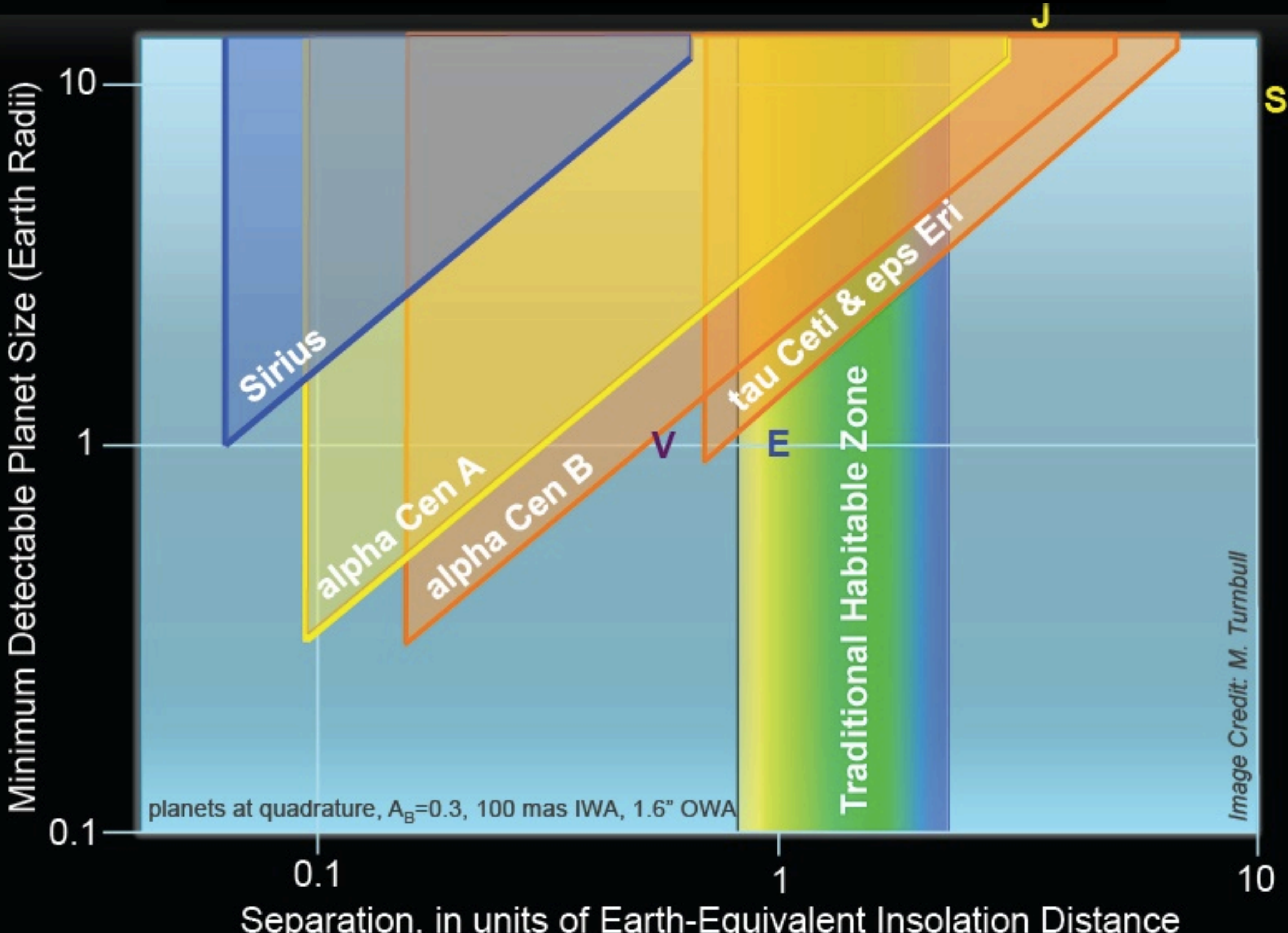
- Optimal means:
  - Maximizing the science yield while maintaining feasibility, i.e., adhering to to expected constraints.
- Constraints include:
  - Cost, technology (risk), time to develop mission.
- Thus some primary lower-level goals include:
  - Identify and quantify what science yields are desired and optimal.
  - Identify and quantify the range of potential constraints.

HabEx Science Goals.

- Exploration-based:
  - How many unique planetary systems can we explore in great detail, determine "their story", including finding and characterizing potential habitable worlds?
  - HabEx will explore XX systems as systematically and completely as possible.
  - Leverage abundant pre-existing knowledge about our nearest systems, acquire as much additional information as possible.
  - Take the first step into the unknown!
- Search for Potentially Habitable Worlds
  - Detect and characterize a handful of potentially habitable planets.
  - Search for signs of habitability and biosignatures.
- Optimized for exoplanet imaging, but will still enable unique capabilities to study a broad range of general astrophysics topics.



Random Internet Figure

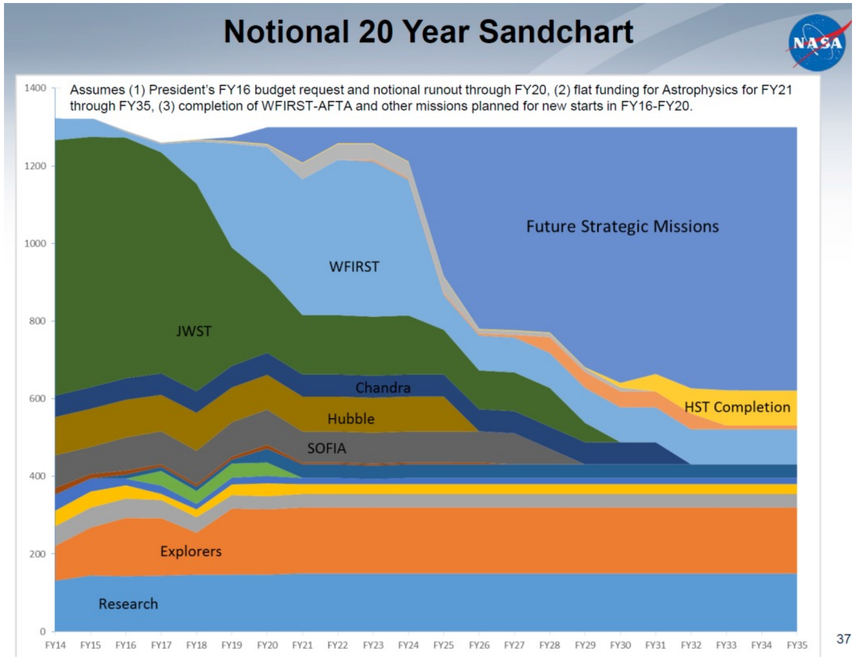


Maggie Turnbull

“Lashed to the Real Axis”

From Keith Warfield’s study of past decadal missions:

- “All past missions prioritized by the Decadal Survey were thought to be under $3B”
- Only allowed ~3 tooth fairies.

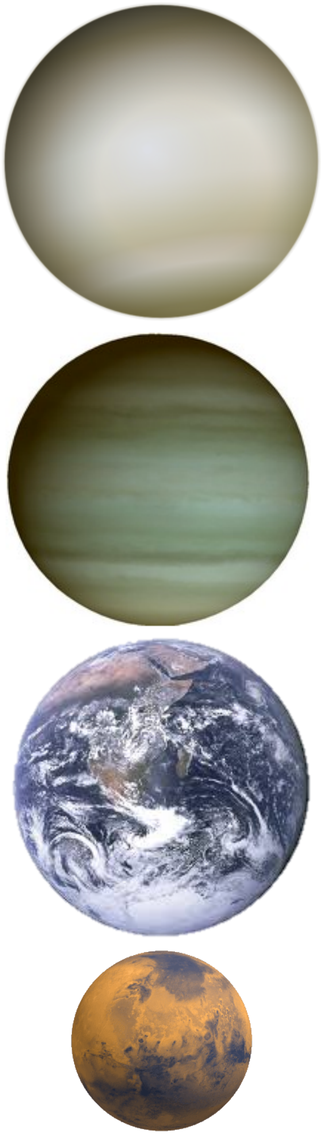


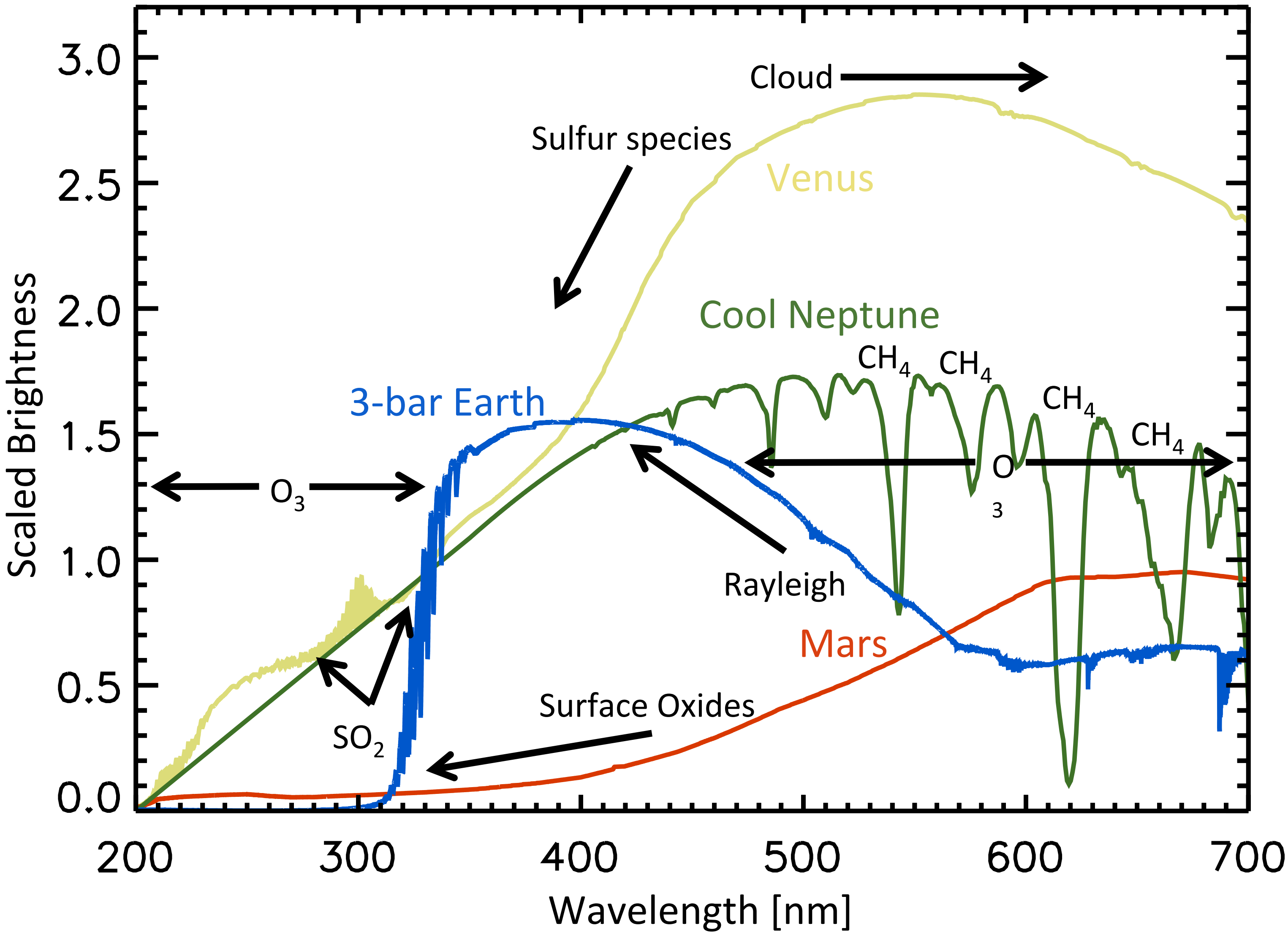
$7.0B by 2035

Paul Hertz

HabEx Science Cases

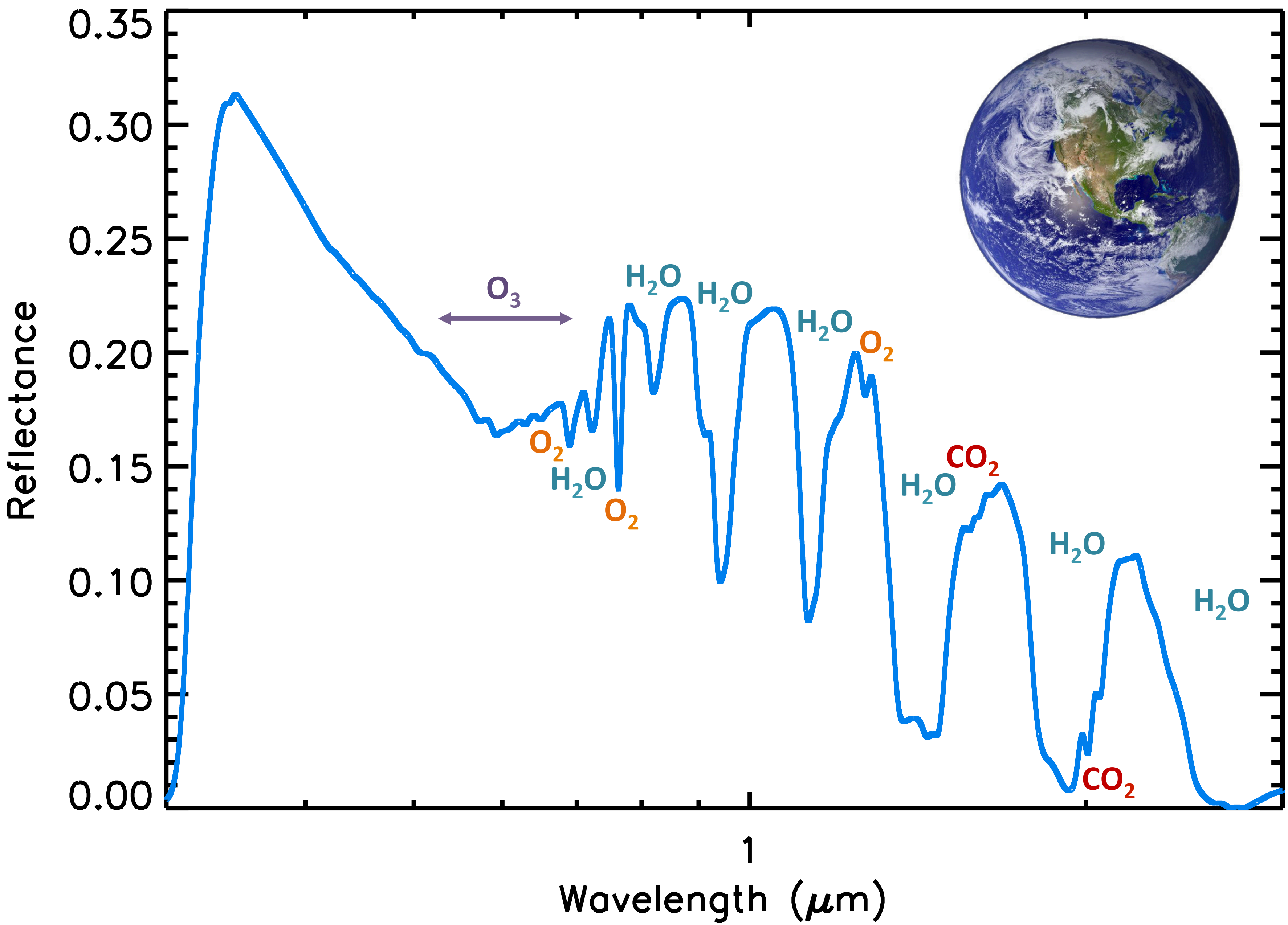
- Exploring our nearest planetary systems.
- Detect and characterize potentially habitable planets, search for signs of habitability and biosignatures.
- Enable a broad range of general astrophysics.





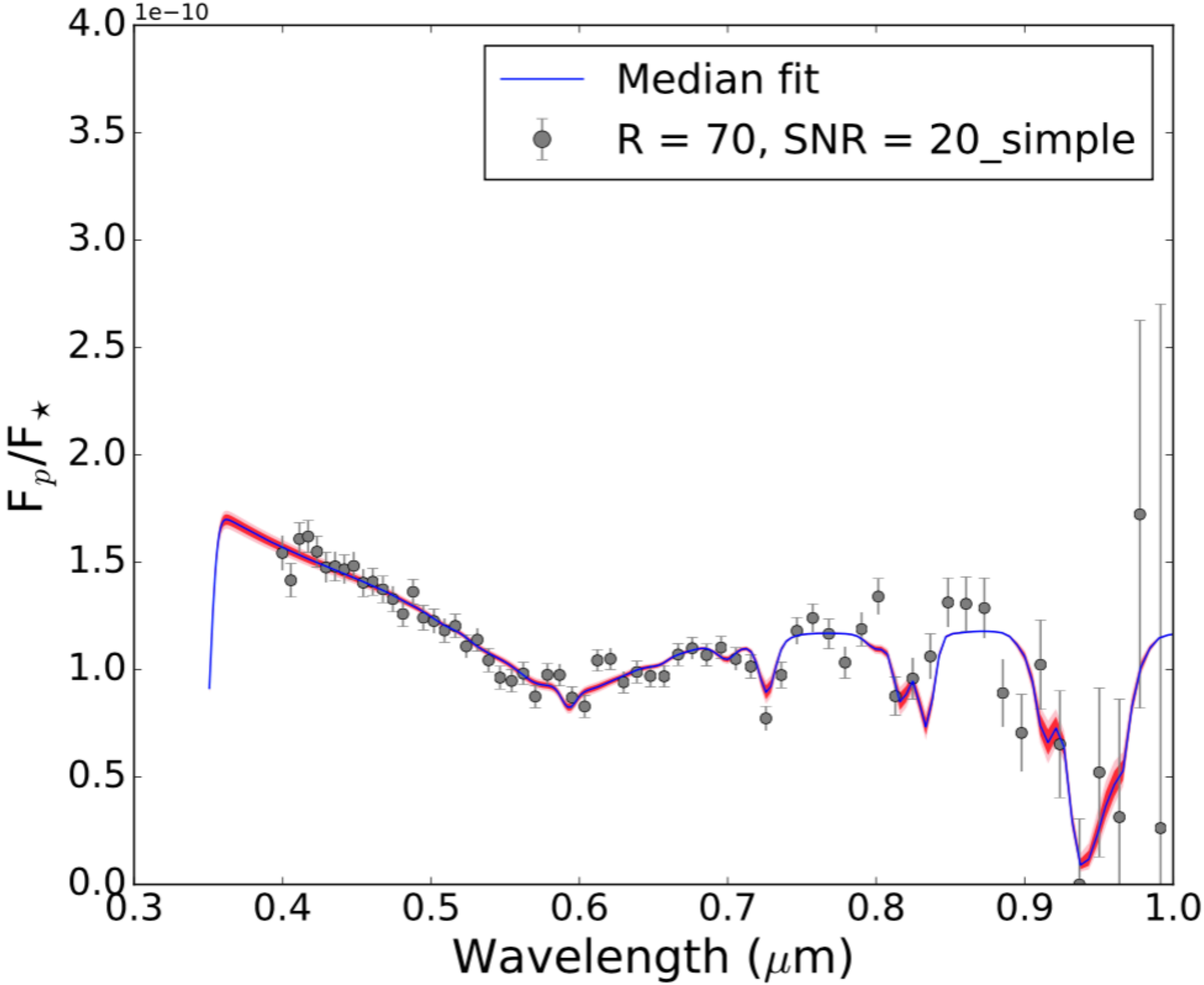
Cloud
Sulfur species
Venus
Cool Neptune
CH_4
CH_4
CH_4
CH_4
3-bar Earth
O_3
O_3
Rayleigh
Mars
SO_2
Surface Oxides
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Scaled Brightness
200
300
400
500
600
700
Wavelength [nm]

Ty Robinson

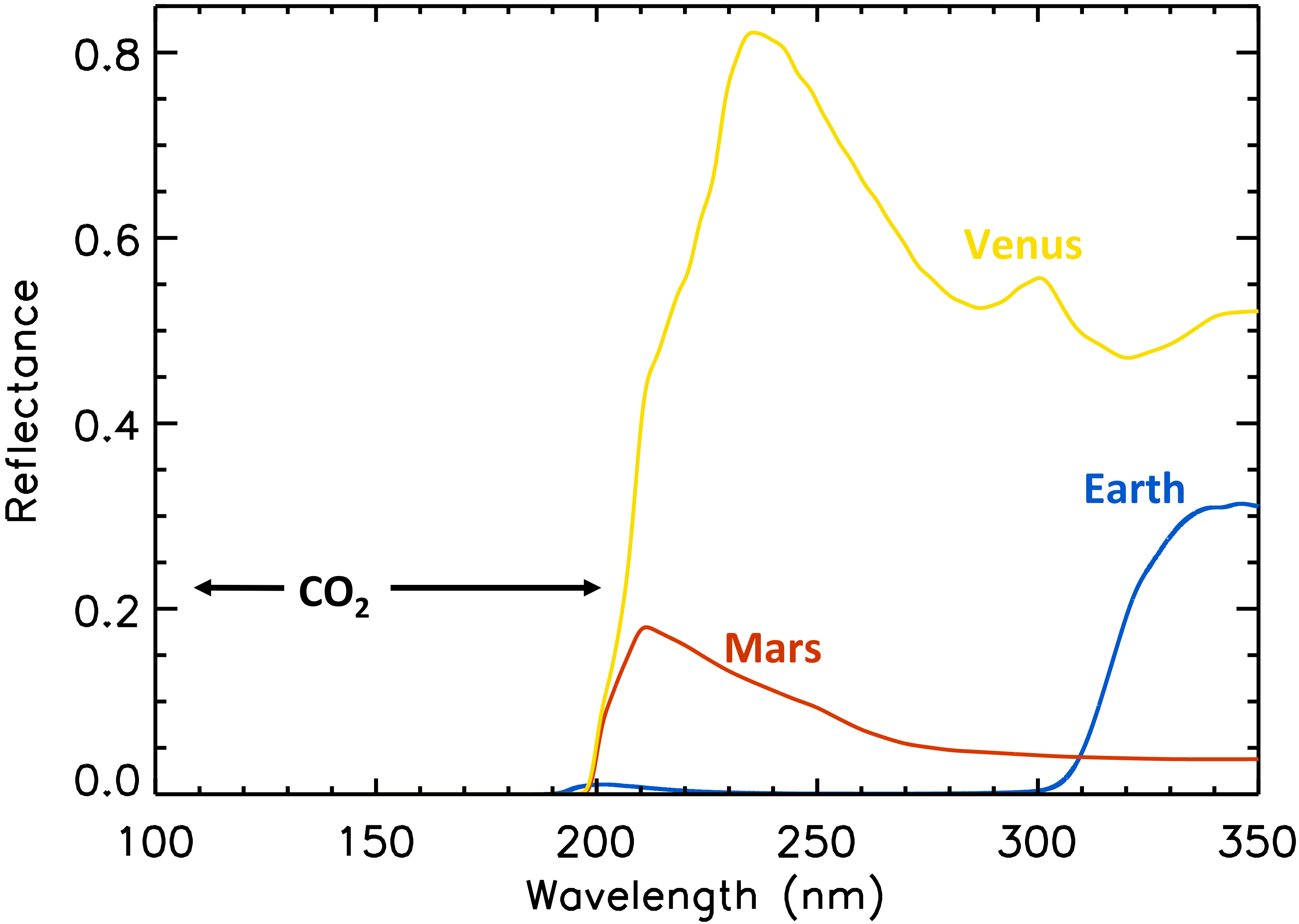


0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Reflectance
1
Wavelength (μm)
O3
O2
H2O
O2
H2O
H2O
H2O
O2
H2O
CO2
H2O
CO2
H2O

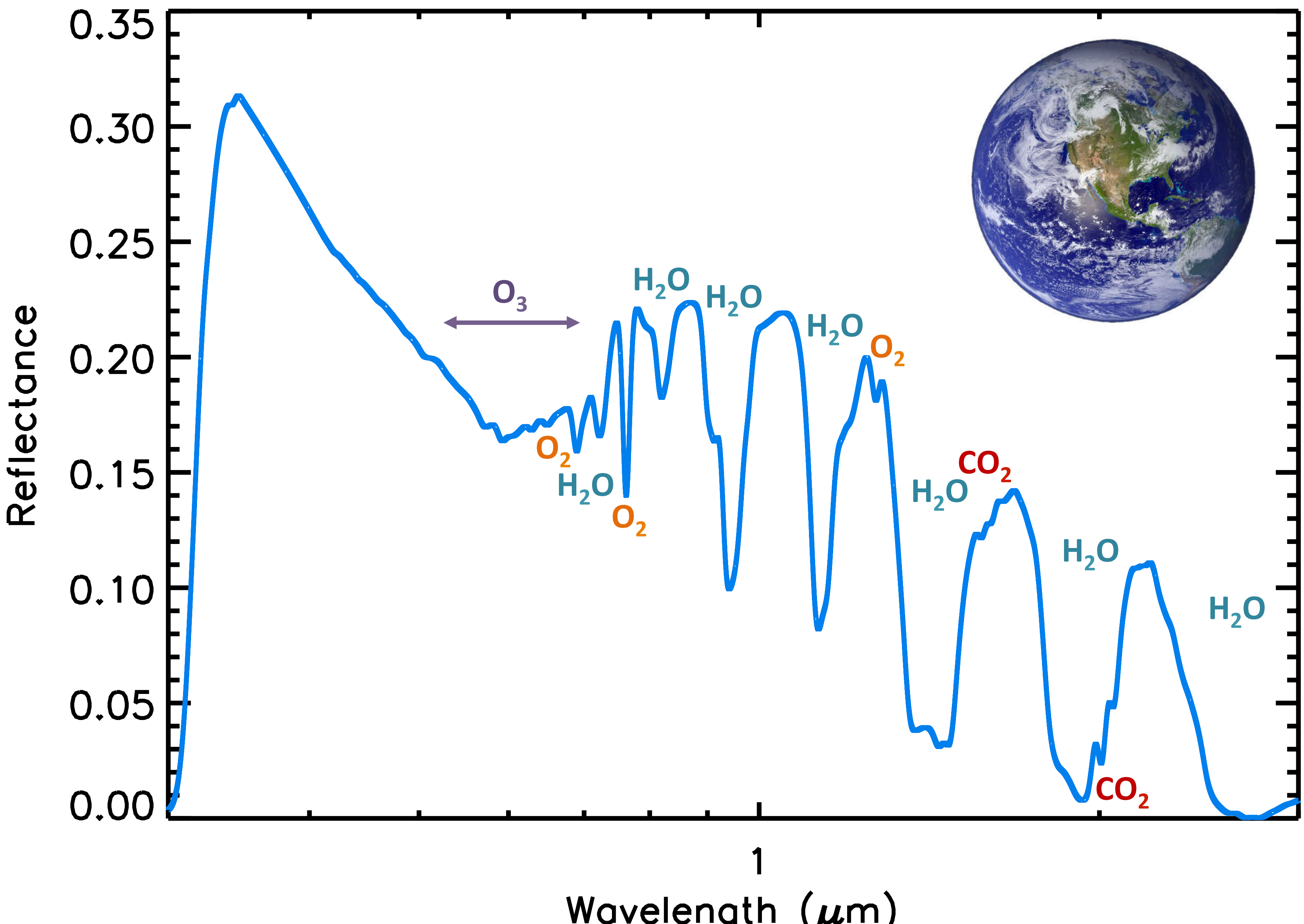
Ty Robinson



Feng, Robinson, et al. (in prep.)

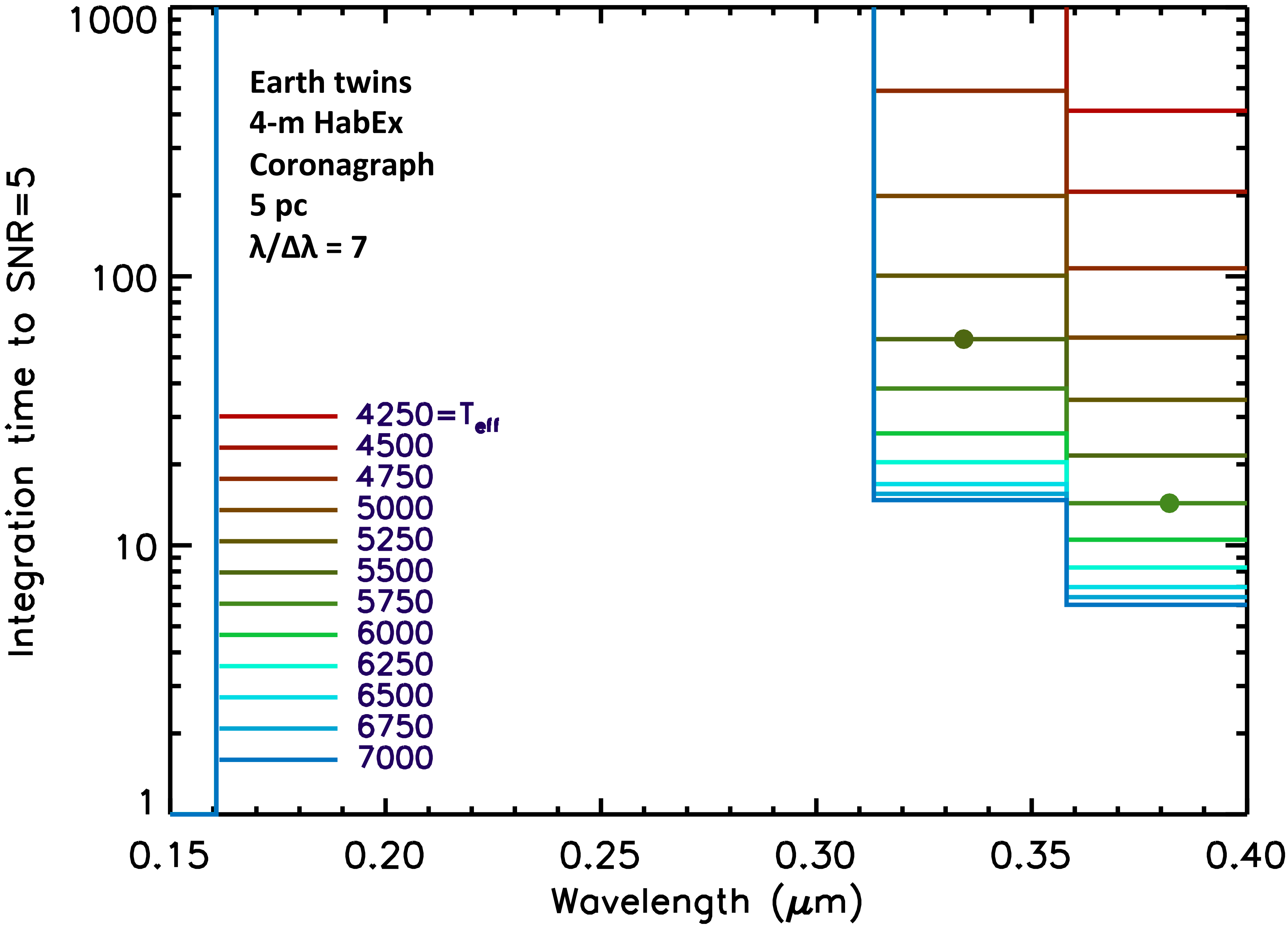

0.8
0.6
0.4
0.2
0.0
Reflectance
100
150
200
250
300
350
Wavelength (nm)
Venus
Earth
Mars
CO_2

Ty Robinson



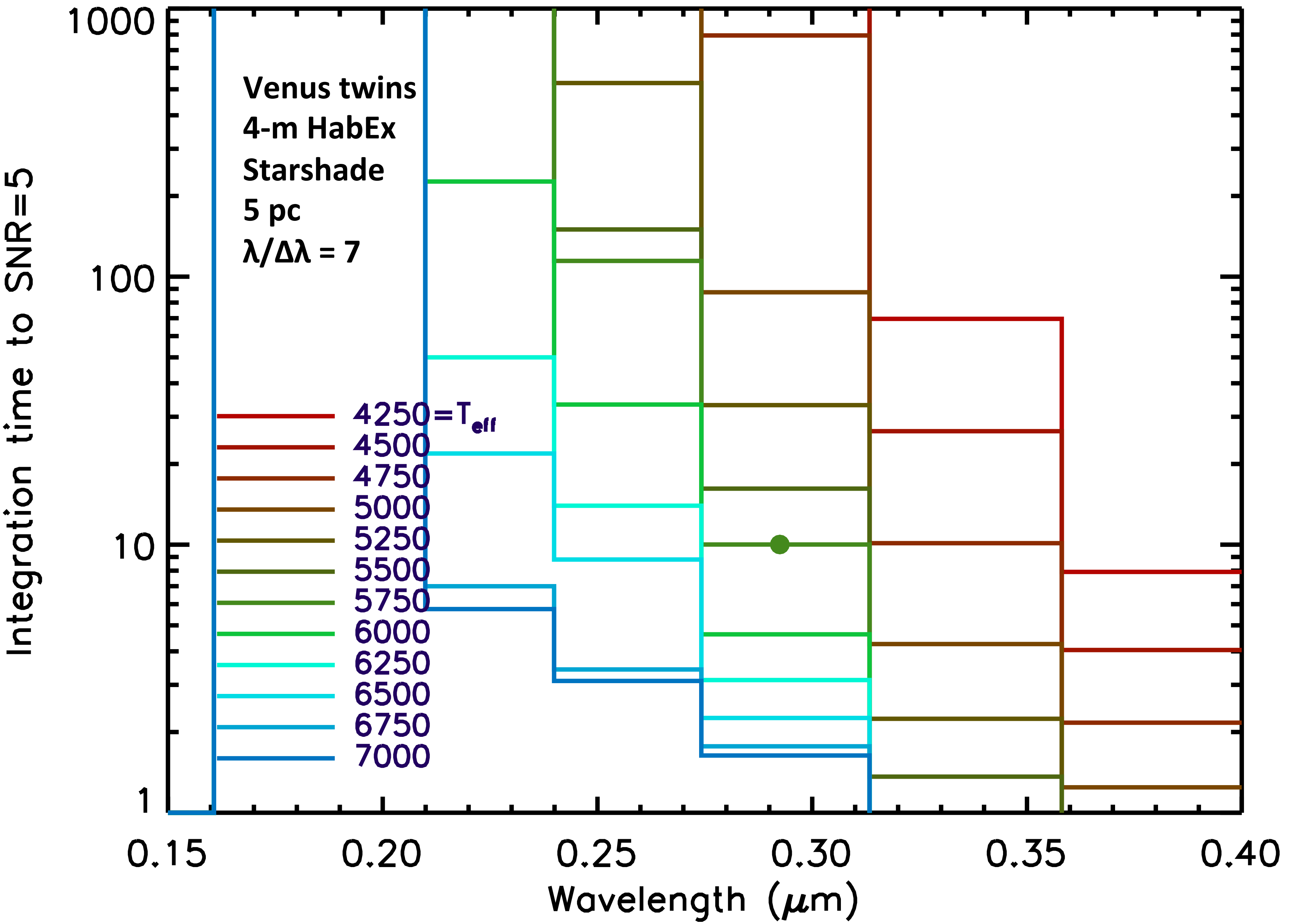
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Reflectance
1
Wavelength (μm)
O_3
O_2
H_2O
O_2
H_2O
H_2O
H_2O
O_2
H_2O
CO_2
H_2O
CO_2
H_2O

Ty Robinson



Earth twins
4-m HabEx
Coronagraph
5 pc
λ/Δλ = 7
4250=T_{eff}
4500
4750
5000
5250
5500
5750
6000
6250
6500
6750
7000
Integration time to SNR=5
1000
100
10
1
0.15
0.20
0.25
0.30
0.35
0.40
Wavelength (μm)

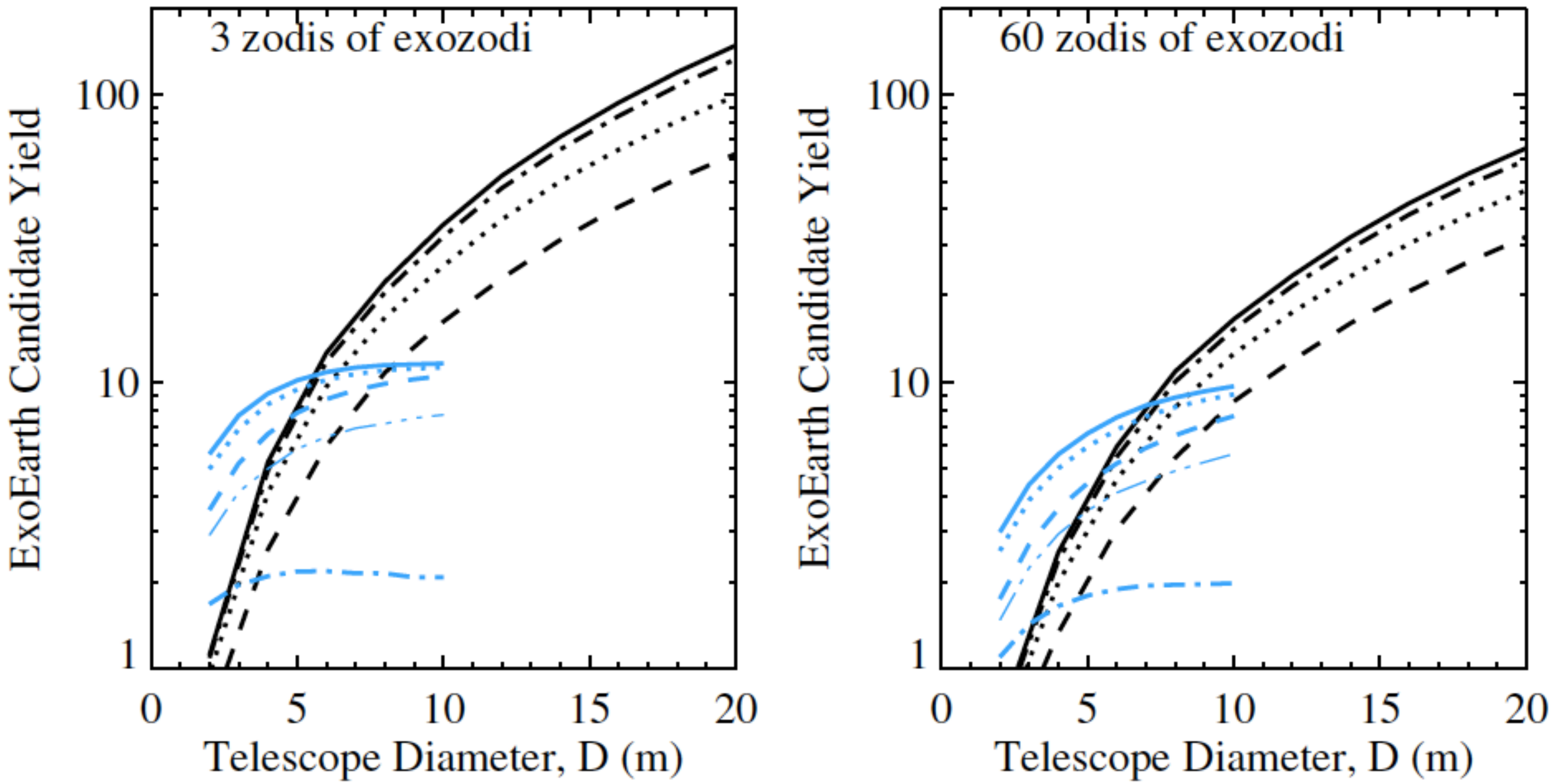
Ty Robinson



Venus twins
4-m HabEx
Starshade
5 pc
λ/Δλ = 7
4250=T_{eff}
4500
4750
5000
5250
5500
5750
6000
6250
6500
6750
7000
1000
100
10
1
Integration time to SNR=5
0.15
0.20
0.25
0.30
0.35
0.40
Wavelength (μm)

Ty Robinson

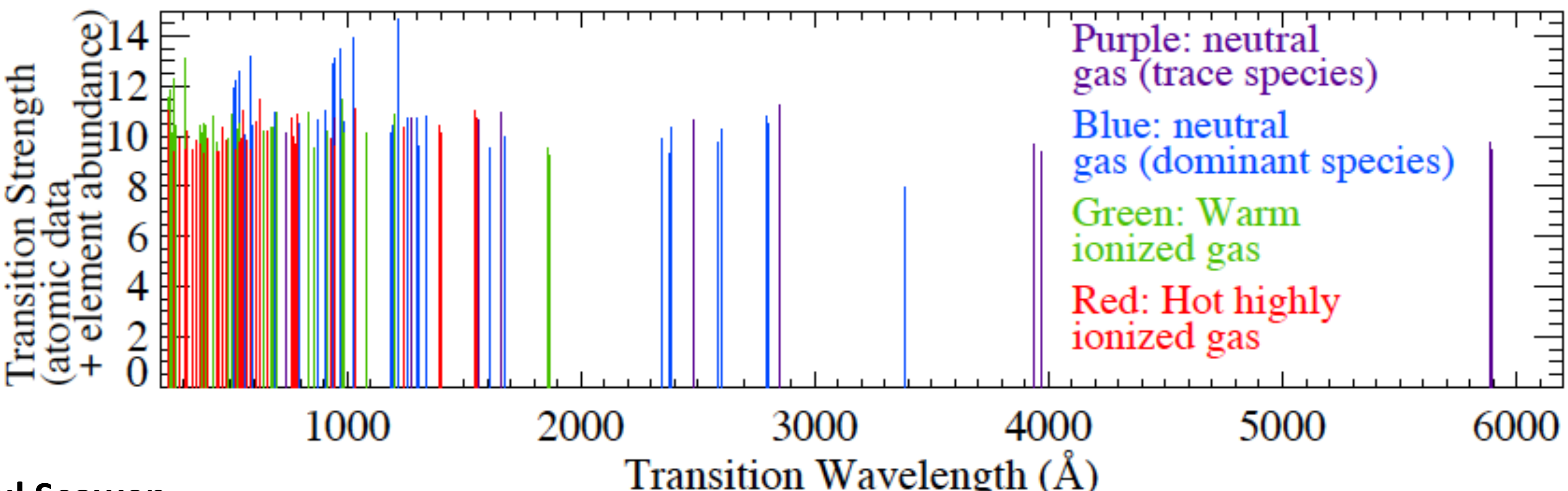
Yields: ExoEarths



Chris Stark

General Astrophysics

- Consider what will be or has been available:
  - HST
  - JWST
  - Ground-based ELTs
- UV for >2.5m provides a novel capability



Paul Scowen

General Astrophysics Themes.

- Hubble Constant
- Escape Fraction
- Cosmic Baryon Cycle
- Massive Stars & Feedback
- Stellar Archaeology
- Dark Matter

Capabilities Matrix.

Science driver	observation	wavelength	spatial resolution	spectral resolution	FOV	aperture	effective aperture	exp. time	other
Hubble Constant	image Cepheid variable stars in SN Ia host galaxies	optical-near-IR (!.6 micron)	diffraction limited	N/A	3'	>=4m		20 ks/galaxy	
Escape Fraction	UV imaging of star forming galaxies	UV, preferably down to 912A	diffraction limited preferred	R ~ 1000-3000	few arcmin	>=4m		few ks/galaxy	
Cosmic Baryon Cycle	spectroscopy of absorption lines in background QSO or galaxies; UV imaging	UV, imaging down to 115nm sufficient, spectroscopy down to 92nm preferred	10mas	R=1,000-40,000 (grating turret)	10'	>6m	>3x10^4 cm^2 in the UV - implies 10% (throughput + DQE) in the UV for a 6m telescope	300-2000s	MOS capabilities beneficial over a field as large as 20x20'
Massive Stars/Feedback	UV imaging and spectroscopy of massive stars in the Galaxy and nearby galaxies	UV, 120-160nm spectroscopy; 110-1000nm imaging	diffraction limited; 0.04" at 300nm	R=10,000	10-30'	>4m			large number of broad, medium and narrow filter bands; spectroscopic angular resolution 5 mas
Stellar Archaeology	resolved photometry of individual stars in nearby galaxies	optical (500-1000nm)	diffraction limited	N/A	10'	4-8m		100 hours/galaxy	this science can be done with smaller aperture telescopes, but a significant jump in capability occurs at around 8m
Dark Matter	integrated photometry + radial velocities and proper motions of stars in Local Group dwarf galaxies	optical (500-1000nm)	diffraction limited	?	10'	>=8m			astrometric accuracy of <40 m arcsec/yr

-> UV Spectrometer and UVOIR imager.

The Three Graces: Paul Scowen, Rachel Somerville, Dan Stern