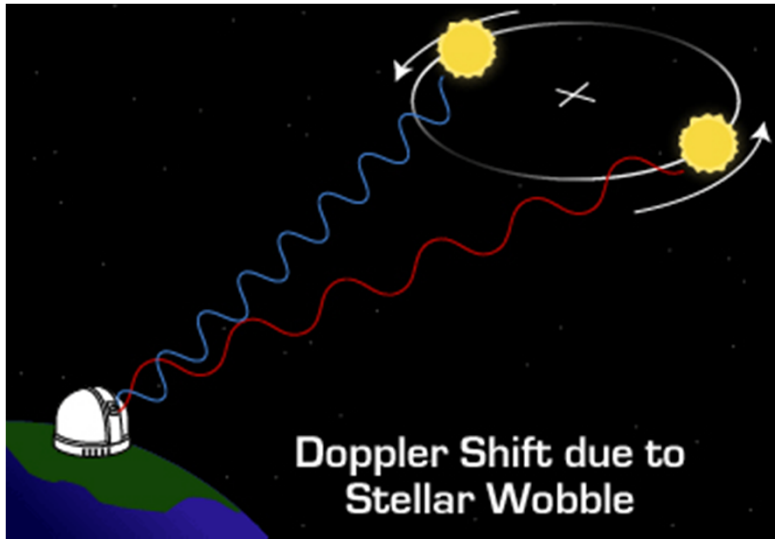
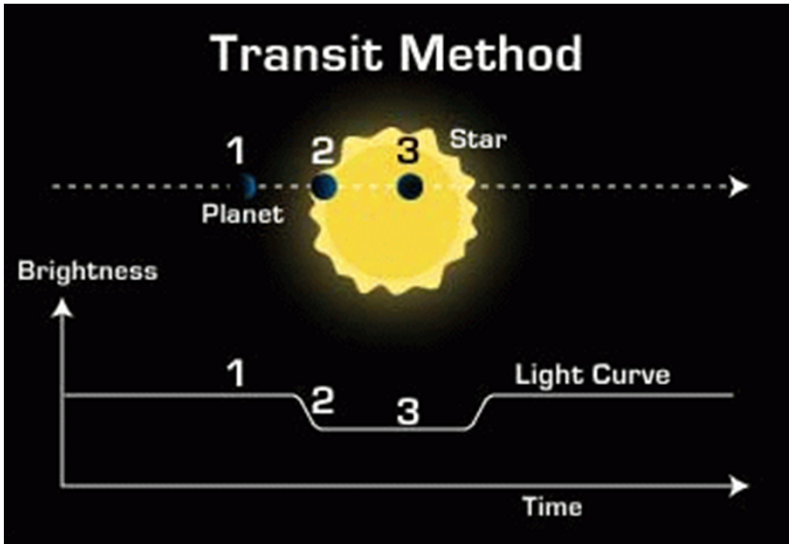
Sniffing Alien Atmospheres with JWST

David Charbonneau, Harvard University

219th Meeting of the AAS Meeting, JWST Town Hall, 9 January 2012

If you are interested in atmospheres, transiting exoplanets are the best kind of exoplanet, as they are the only ones for which the physical parameters are determined robustly.





Doppler Method

Determine Planet Mass

Transit Method

Determine Planet Diameter

Calculate Planet Density and Infer Composition:

Gas giant (Jupiter), Ice giant (Neptune), or Rocky planet (Earth)

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2011	**150**	***(but really 1300)***	**50**

Very Recent Progress

The first habitable-zone sub-Neptune?

The first Earth-sized exoplanets?

The first Earth-sized, habitable-zone planet?

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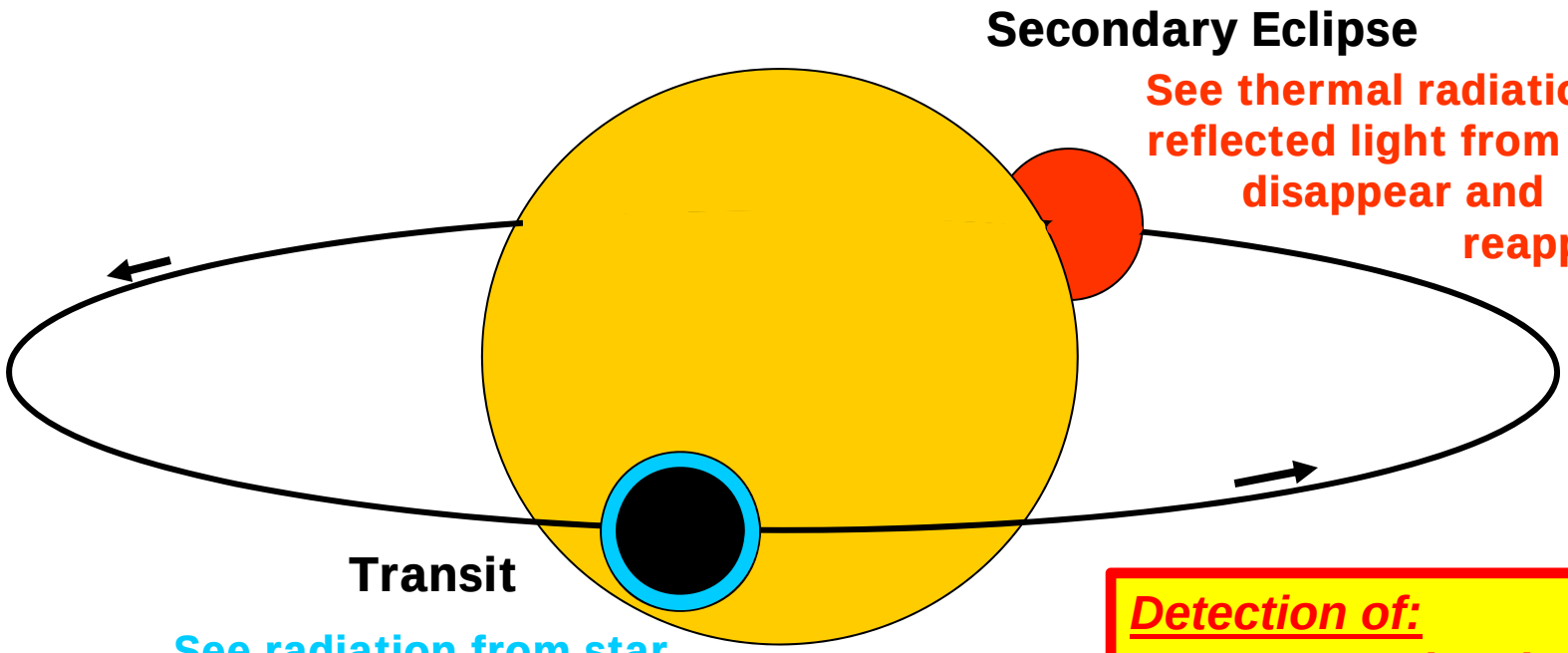
JWST will see first light perhaps 5 years after the discovery of the first exo-Earths.

Transits Allows Studies of the Atmospheres That Are Not Possible for Non-Transiting Planets



Detection of:

- Atoms & Molecules
- Stratospheres
- Clouds
- Winds

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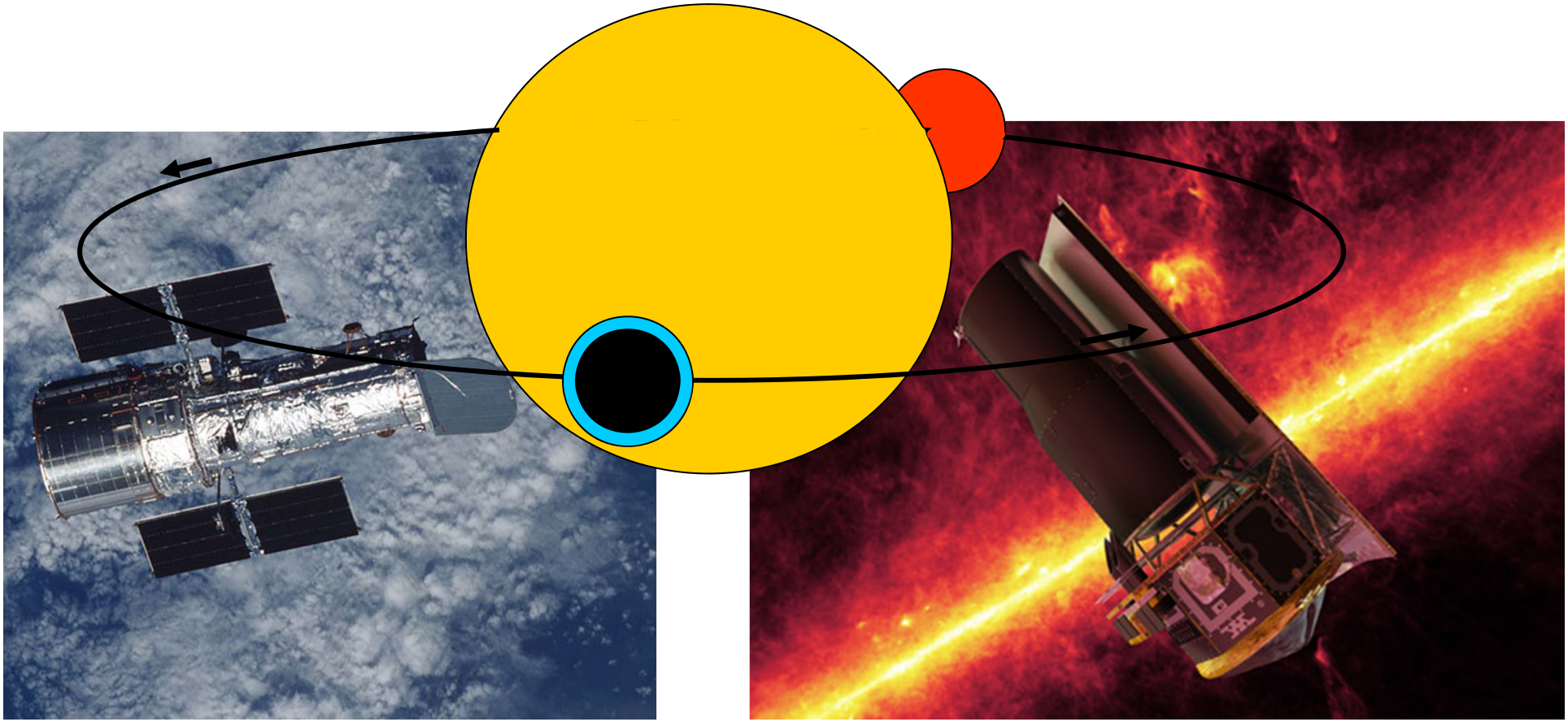

JWST Transit Science: The Best of Spitzer and Hubble

- My wish list for exoplanet spectroscopy platform:
  - Orbit that assures thermal stability and low background
  - Orbit that assures long dwell times
  - A stable PSF and excellent pointing
  - Infrared sensitivity (planetary temperatures; molecules)
  - Aperture sufficient to permit mod resolution spectroscopy

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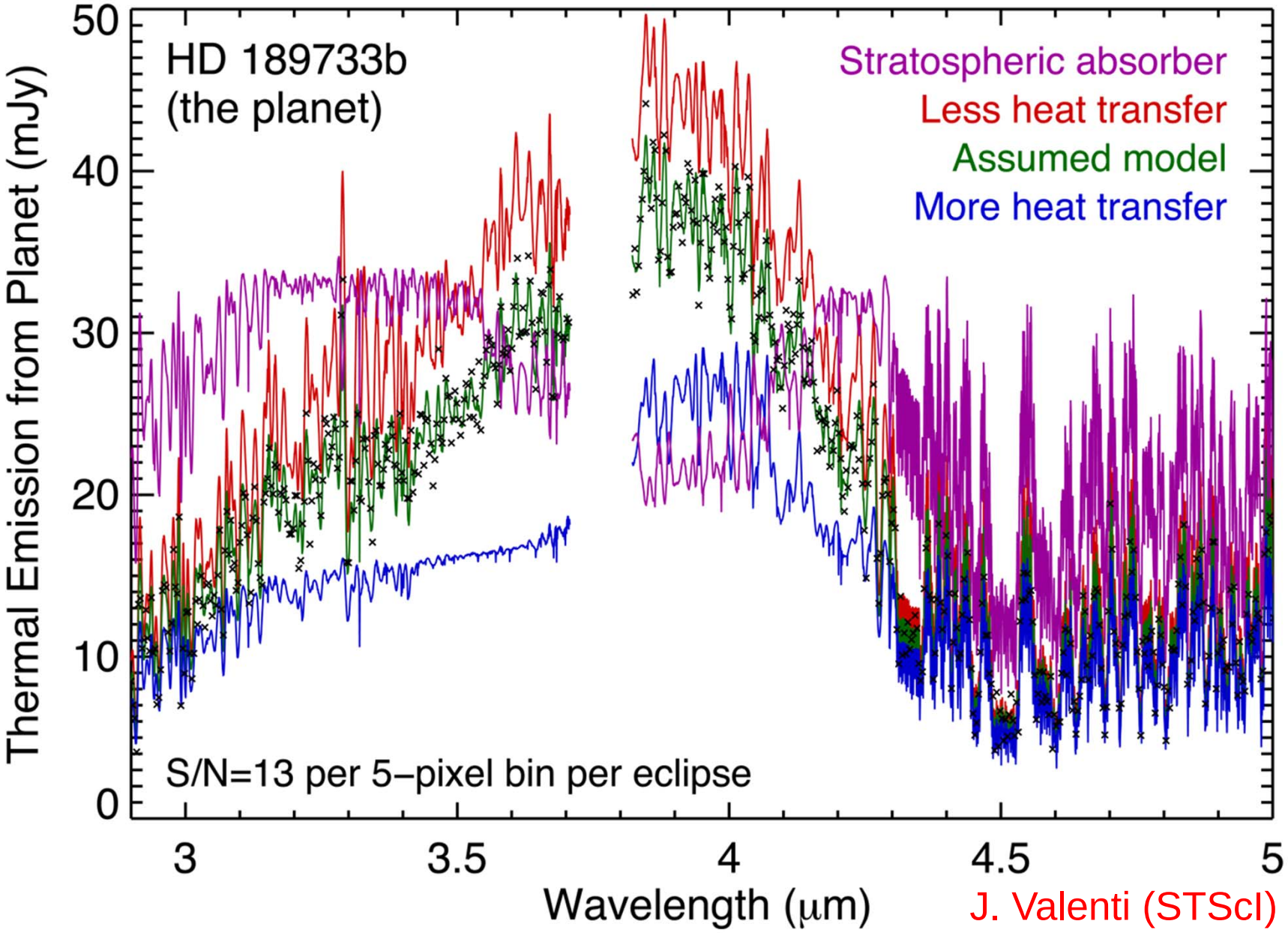
- **These are obtained with a large aperture, cryogenic telescope placed at L2, with a detailed error budget and careful instrument characterization prior to launch**
- JWST is an excellent platform for Exoplanet Spectroscopy

JWST Transit Capabilities

- **JWST offers a broad range of capabilities for transit observations**

	Instrument Mode	λ (μm)	R (δ/δλ)	FOV	Application
Imaging	NIRCam	0.6 - 2.3 2.4 - 5.0	4, 10 , 100 4, 10 , 100	2 x (2.2' x 2.2') 2 x (2.2' x 2.2')	Transit light curves of primary and secondary eclipses
	NIRCam (Defocused)	0.6 - 2.3	4, 10, 100	Defocused images 1) radius = 0.74" 2) radius = 1.42" 3) radius = 2.11"	High precision transit light curves of primary eclipses - defocusing of bright targets to avoid saturation
	MIRI	5.0 - 28.0	4 - 6	1.9' x 1.4'	Transit light curves of secondary eclipses
	NIRISS	0.6 - 5.0	4, 10	2.2' x 2.2'	Transit light curves of primary and secondary eclipses
Spectroscopy	NIRCam	2.4 - 5.0	1700	2 x (2.2' x 2.2')	Transmission and emission spectroscopy of transiting planets
	NIRSpec	1.0 -5.0	100, 1000, 2700	1.6" x 1.6"	Transmission and emission spectroscopy of transiting planets
	NIRISS	0.6 - 2.5	700	2.2' x 2.2'	Transmission spectroscopy of transiting planets - spatially defocused images to avoid saturation of bright targets
	MIRI-LRS	5 - 11	100	1.9' x 1.4' Slitless	Emission spectroscopy
	MIRI-HRS	5.9 - 7.7 7.4 - 11.8 11.4 - 18.2 17.5 - 28.8	3000 3000 3000 3000	3.7" x 3.7" 4.7" x 4.5" 6.2" x 6.1" 7.1" x 7.1"	Emission spectroscopy of transiting planets

Thermal Emission from a Hot Jupiter



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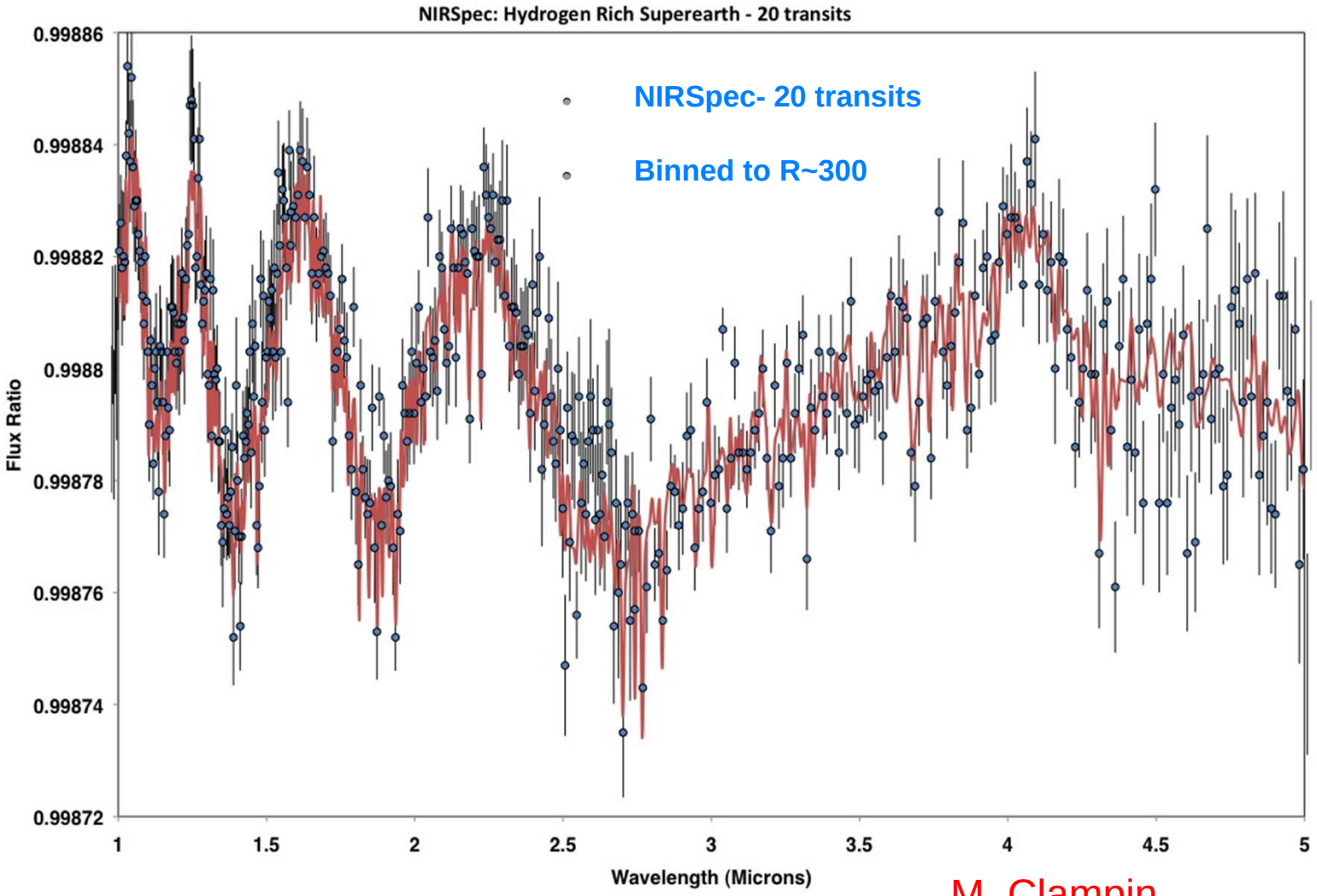
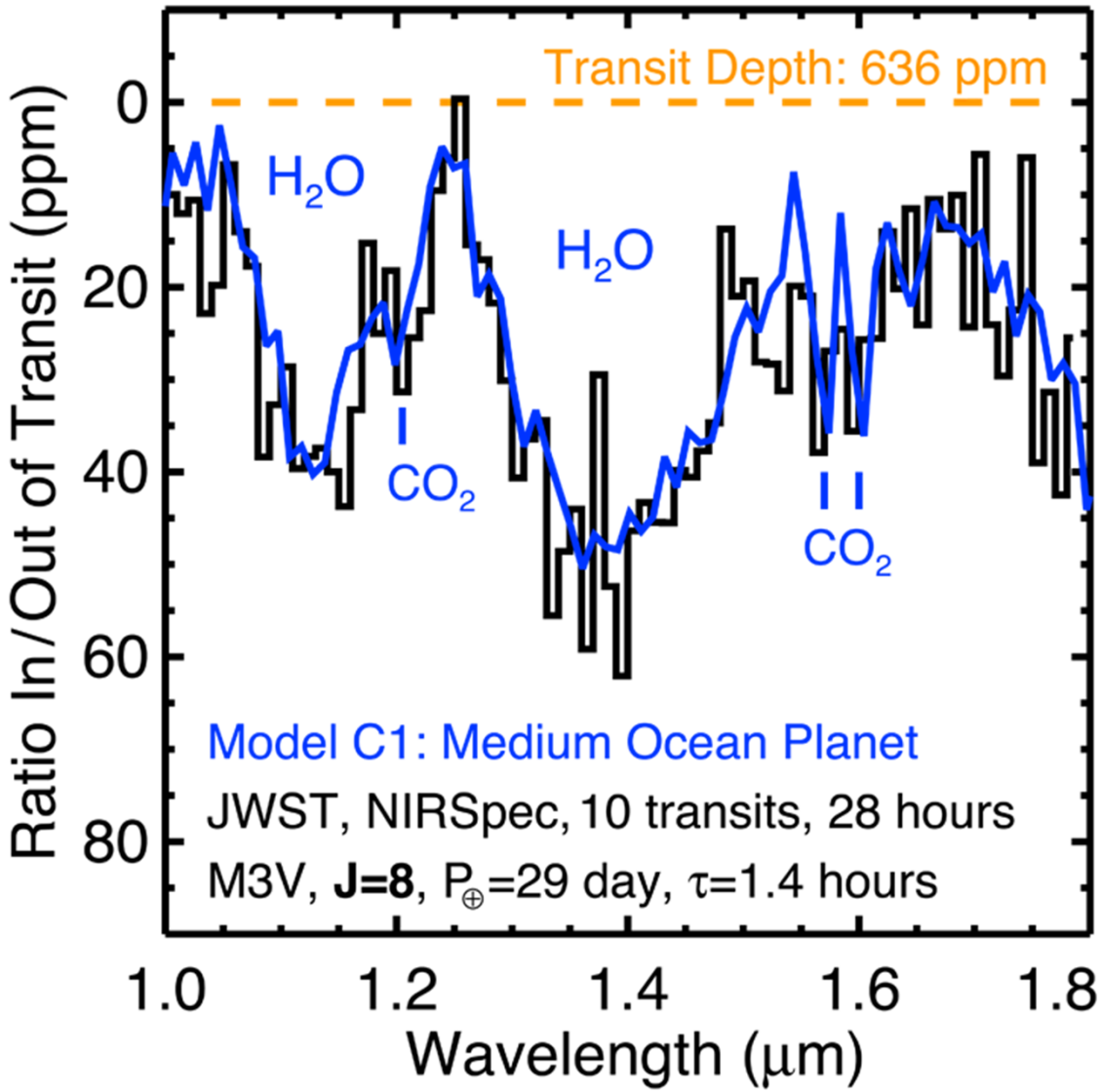
Hydrogen Rich Super-Earth (1.4 R_{Earth}, 5 M_{Earth})



M. Clampin
Model by E. Kempton

Transit Spectrum of Habitable-Zone Earth-size Ocean Planet (1 R_{Earth}, 0.5 M_{Earth})



Seager, Deming, & Valenti 2009

Model by Ehrenreich et al.

So, how will we identify the optimal targets to enable this JWST science?

TESS Science Goals and Drivers

MIT-led Mission: NASA, Orbital Sciences, Harvard-SAO

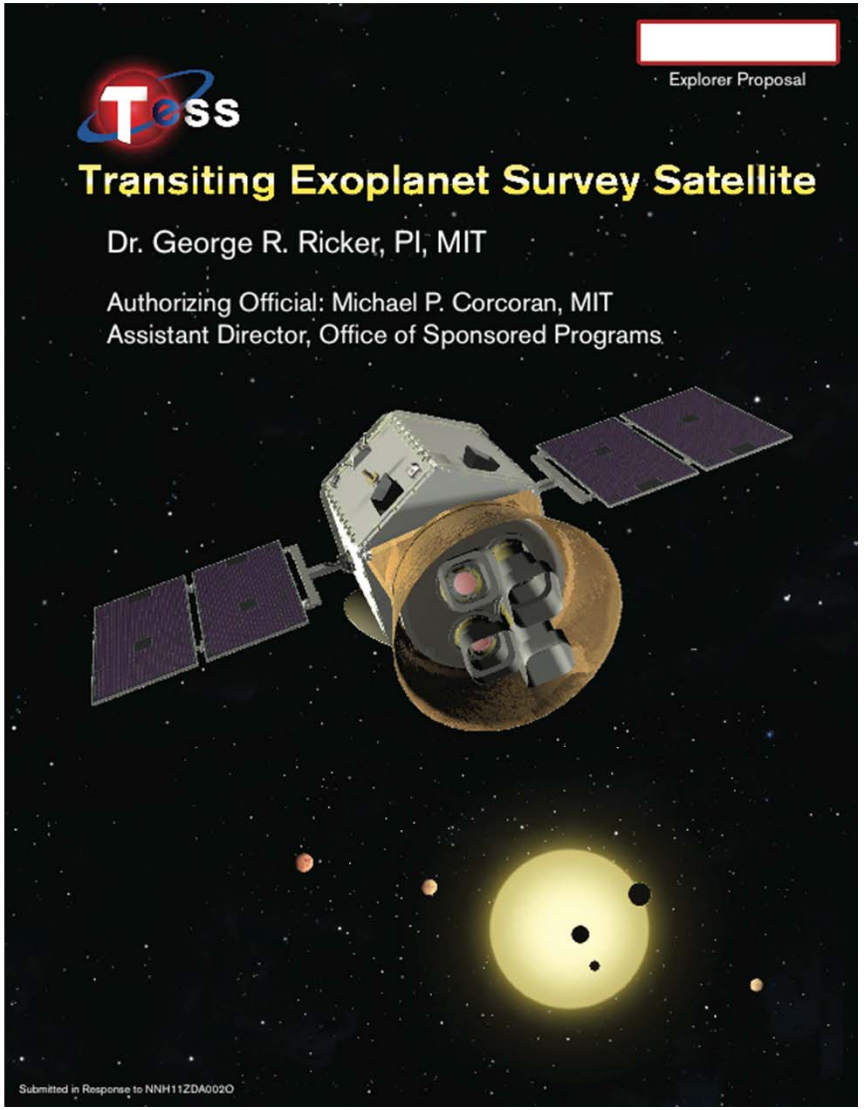
Discover Transiting Earths and SuperEarths around Bright, Nearby Stars

- Rocky planets
- Water worlds
- Habitable zone planets

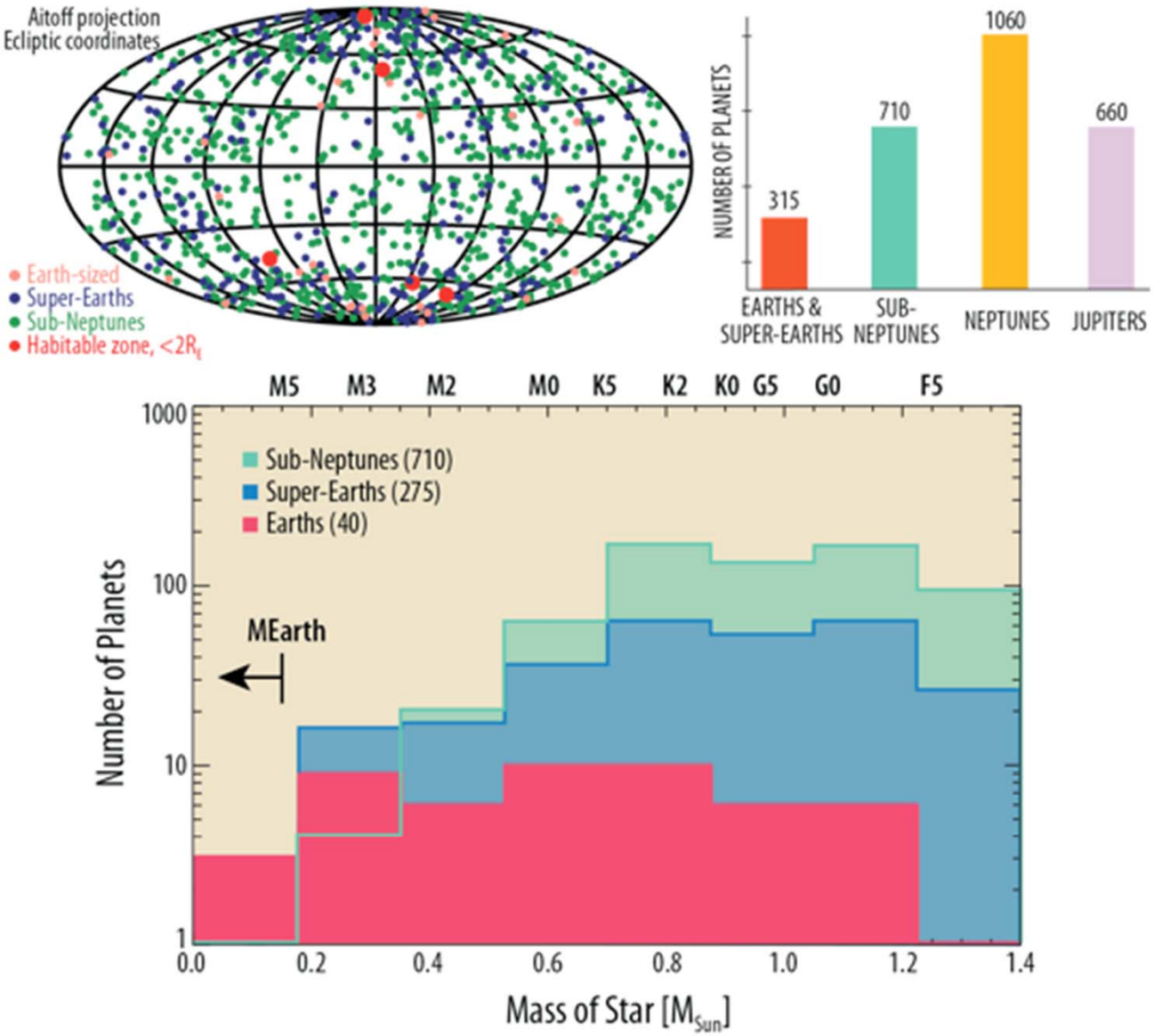
Discover 1000+ Exoplanets

All Sky Survey of Bright Stars

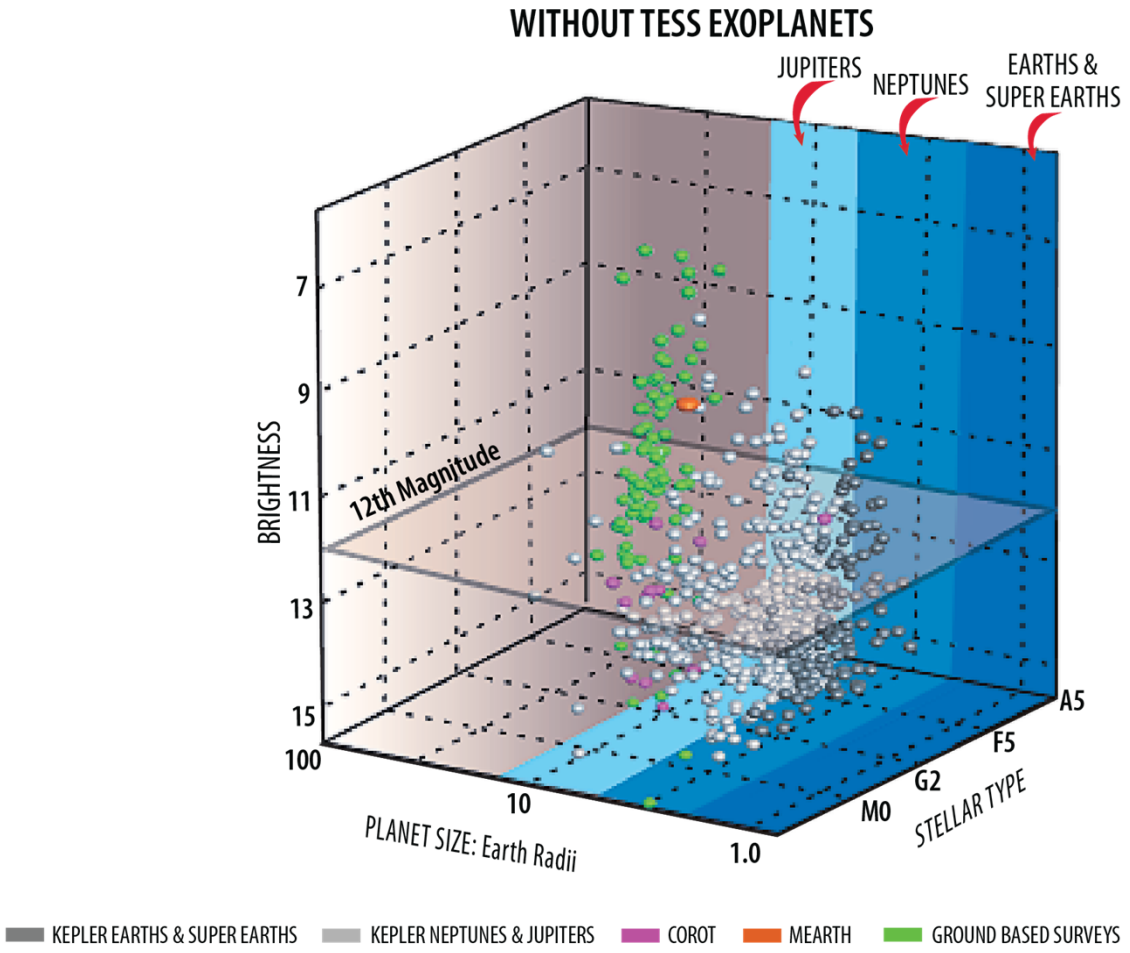
- ~40000 deg^2 (~400 x Kepler)
- F, G, K dwarf stars: 4.5 to 12 magnitude
- M stars known within 50 pc (= 150 l-yr)
- 500,000 stars in two years

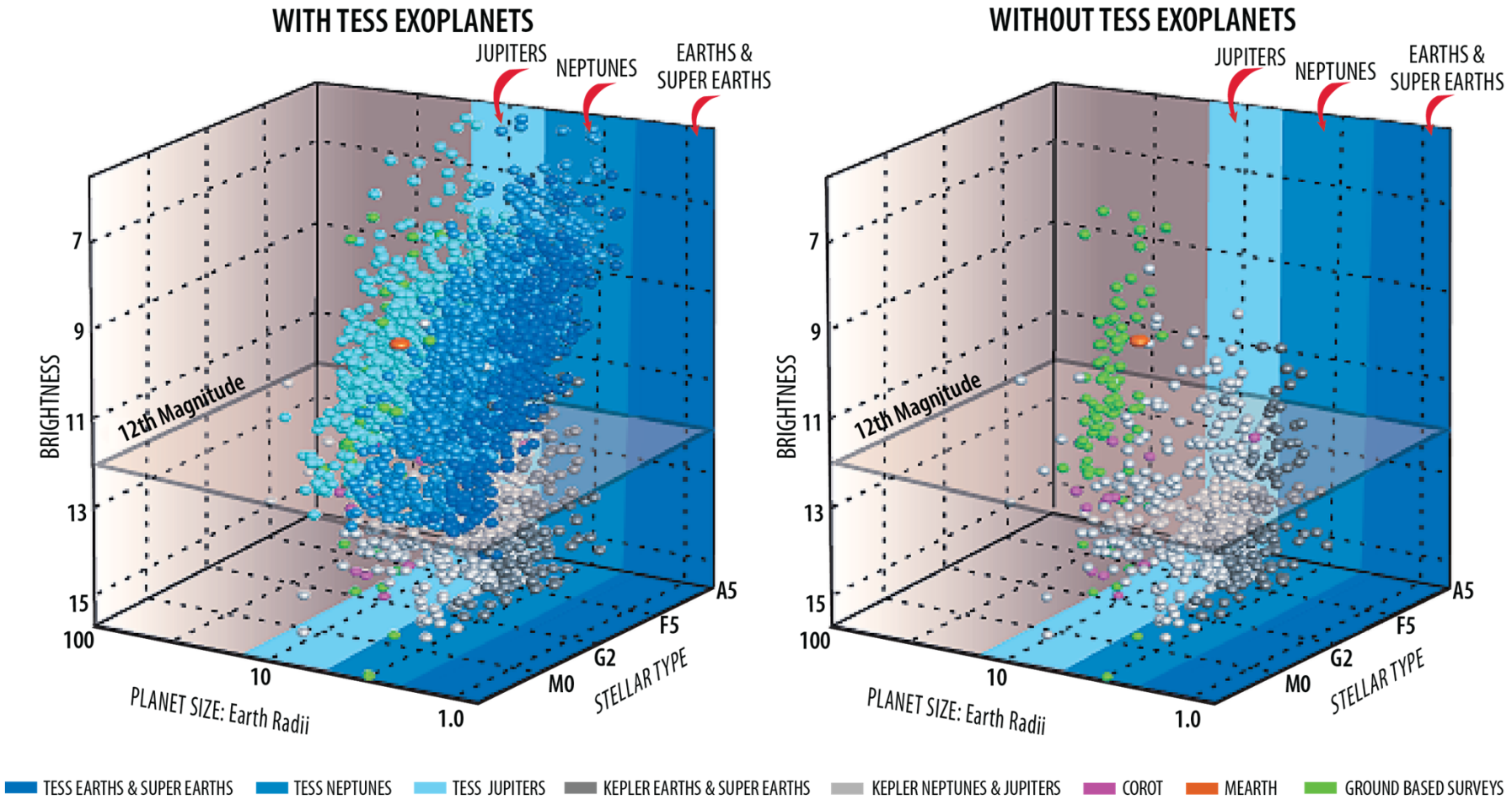


Predicted Science Yield from TESS Mission



TESS Will Discover ~300 Earths + SuperEarths


WITHOUT TESS EXOPLANETS
JUPITERS
NEPTUNES
EARTHS & SUPER EARTHS
BRIGHTNESS
7
9
11
13
15
12th Magnitude
100
10
1.0
PLANET SIZE: Earth Radii
A5
F5
G2
M0
STELLAR TYPE
KEPLER EARTHS & SUPER EARTHS
KEPLER NEPTUNES & JUPITERS
COROT
MEARTH
GROUND BASED SURVEYS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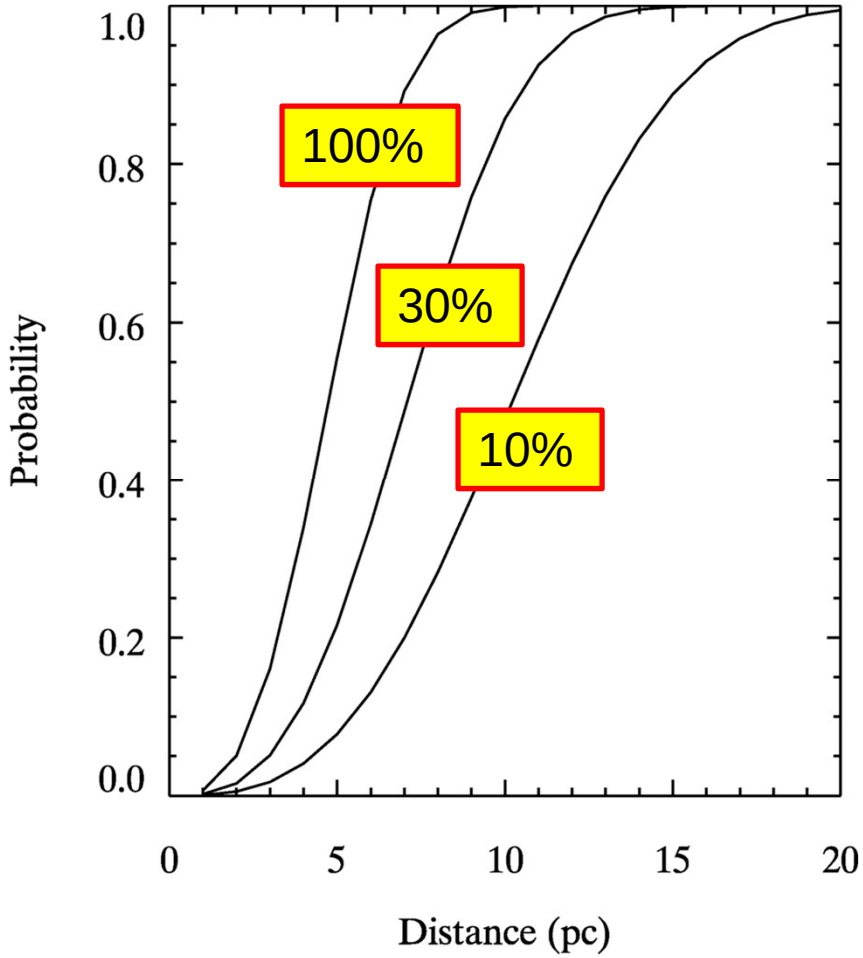
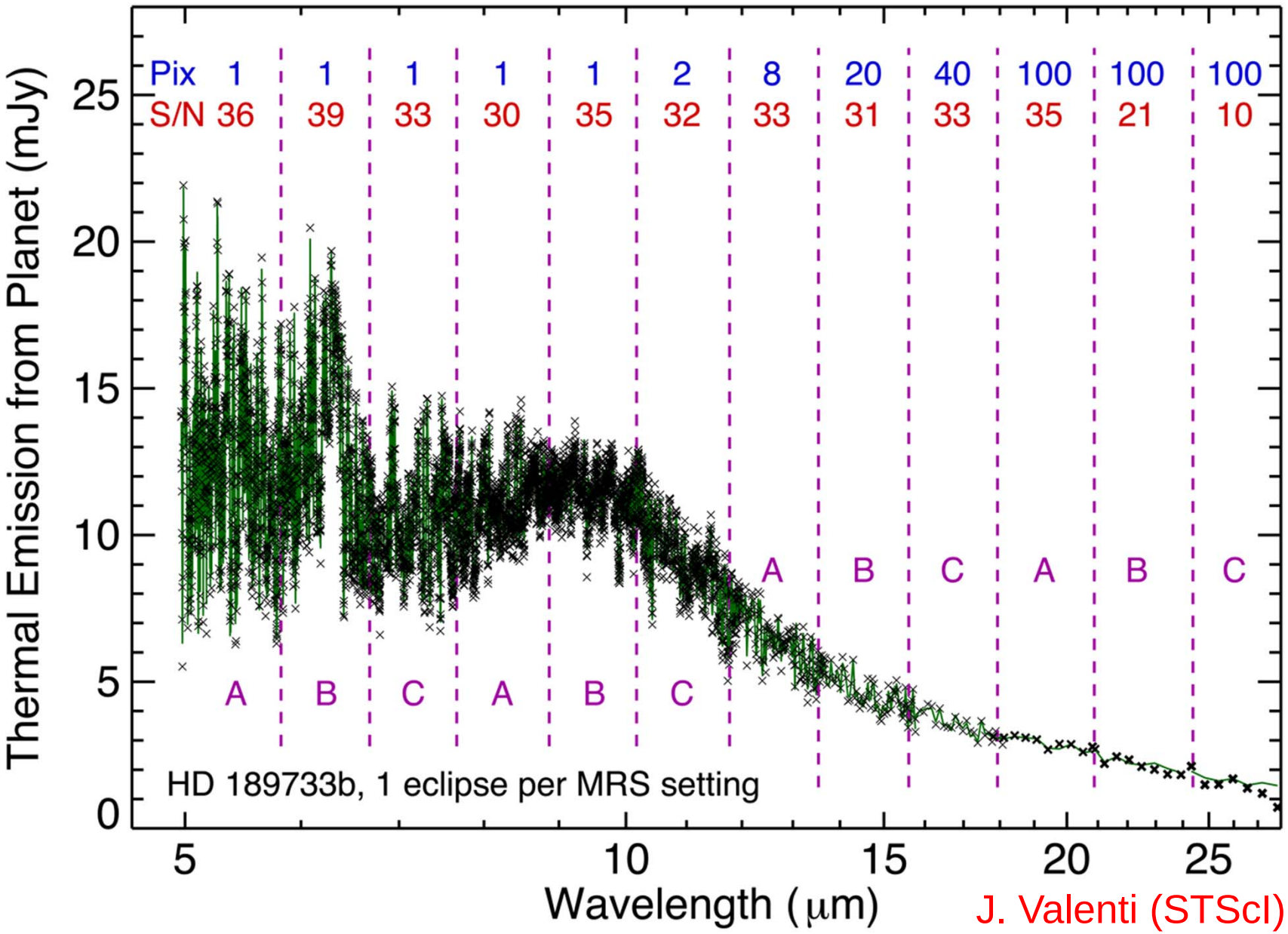
Probability of a Transiting Habitable-Zone Planet as a Function of Distance (in pc)



See Deming et al. (2009) for details

JWST will be an excellent platform for sniffing alien atmospheres

Simulated MIRI Observations of HD 189733b



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