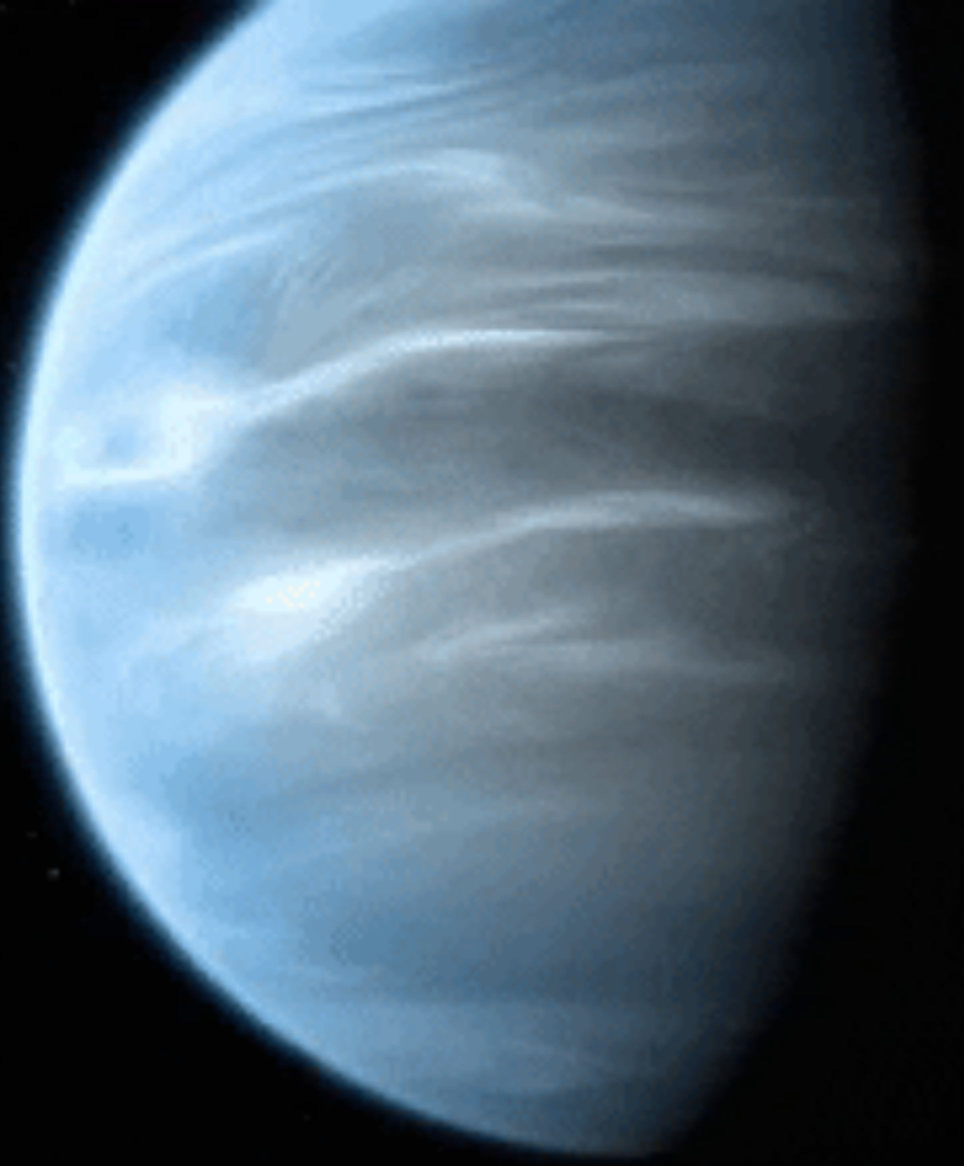
# Detecting Biosignatures In Gas Dwarf Planet Atmospheres With JWST



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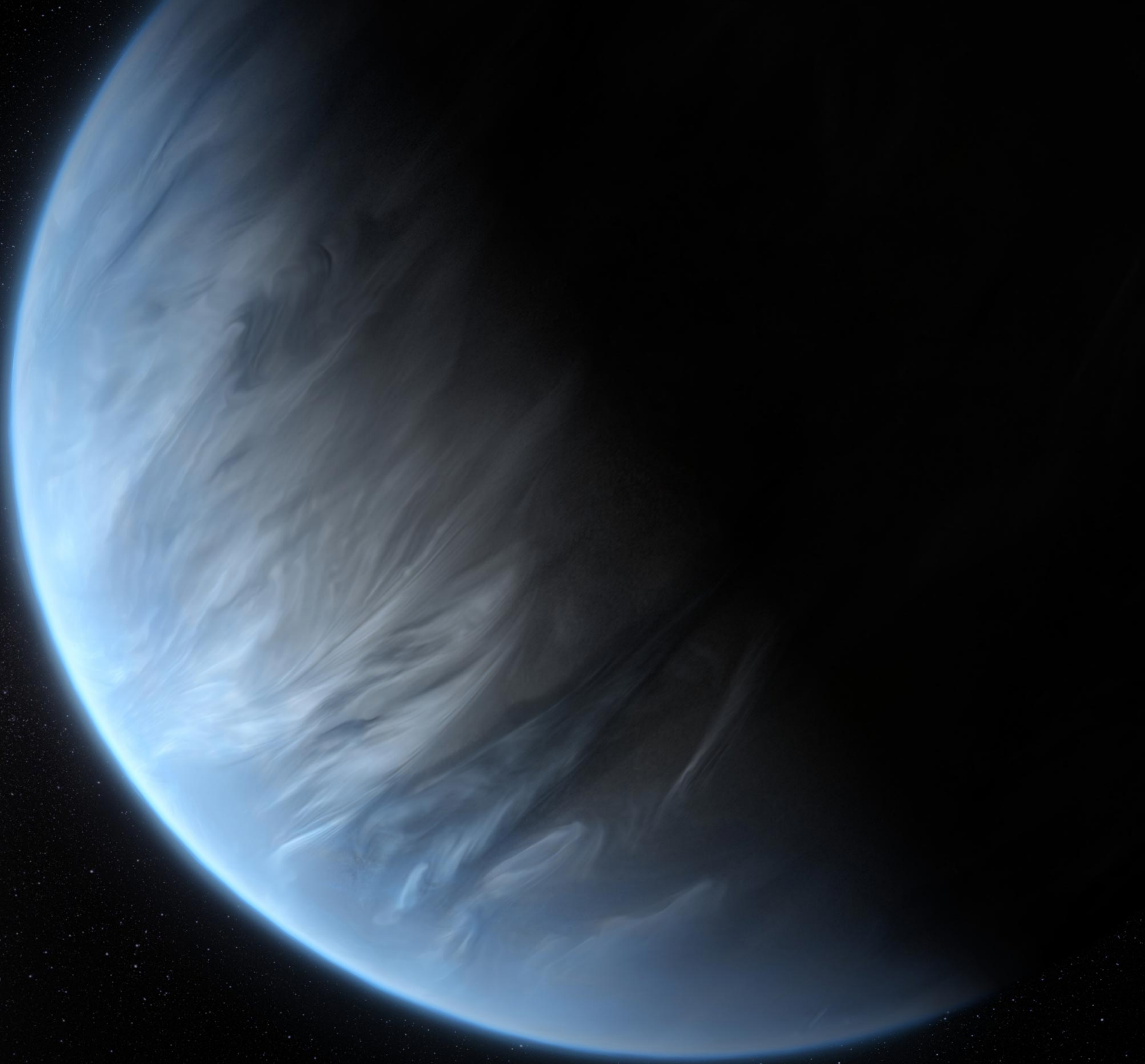
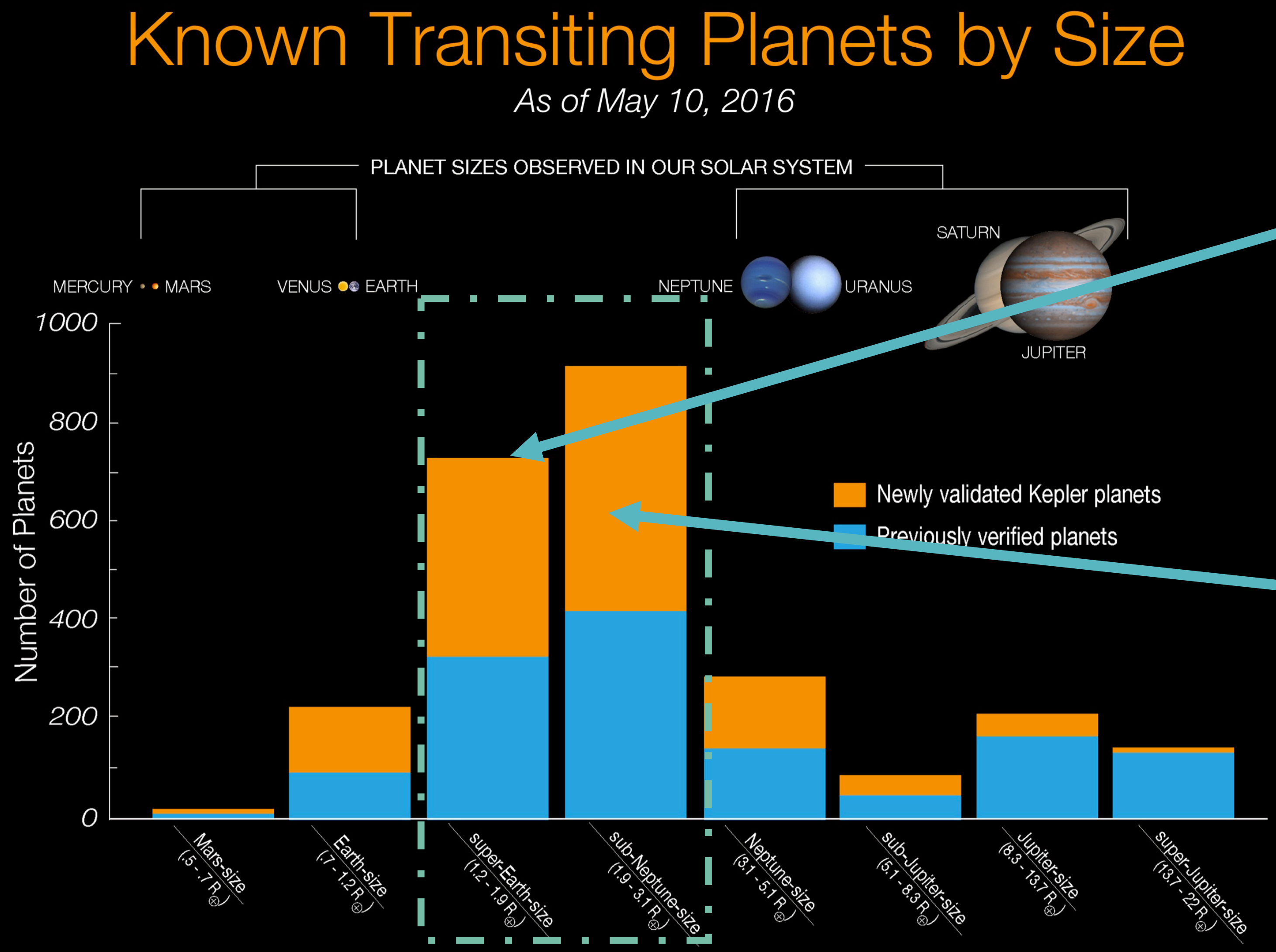
# Talk Outline

- ⭐Background of Gas Dwarfs Planets
- ⭐Atmospheric Biosignatures
- ⭐Gas Dwarfs atmospheres
- ⭐Ammonia as a Biosignature
- ⭐Detection of ammonia in the atmospheres of Gas Dwarf Planets
- ⭐Simulation of observations with JWST



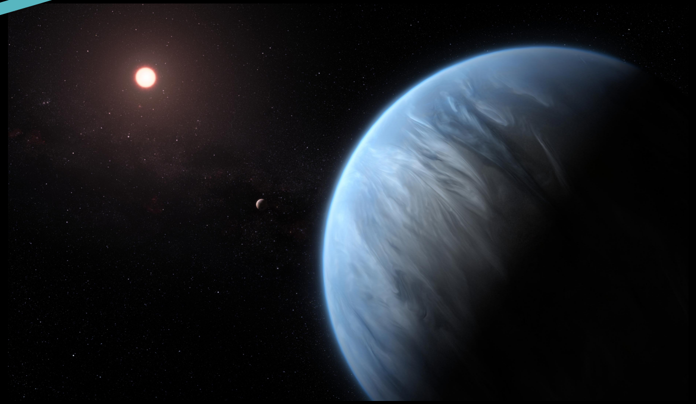
# Gas Dwarfs Are Amongst The Most Abundant Type Of Planet

Buchhave et al. 2014




Gas dwarf planets with rocky cores and hydrogen–helium envelopes.

**Super-Earths**



**Mini-Neptunes**

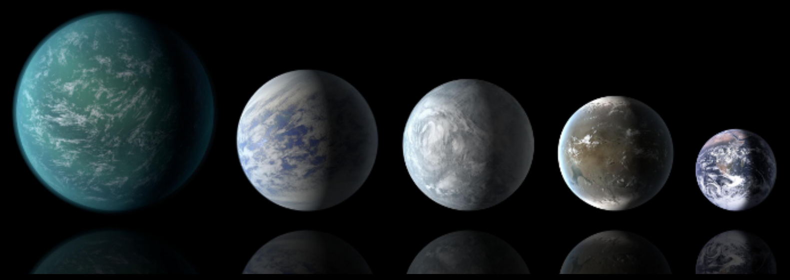
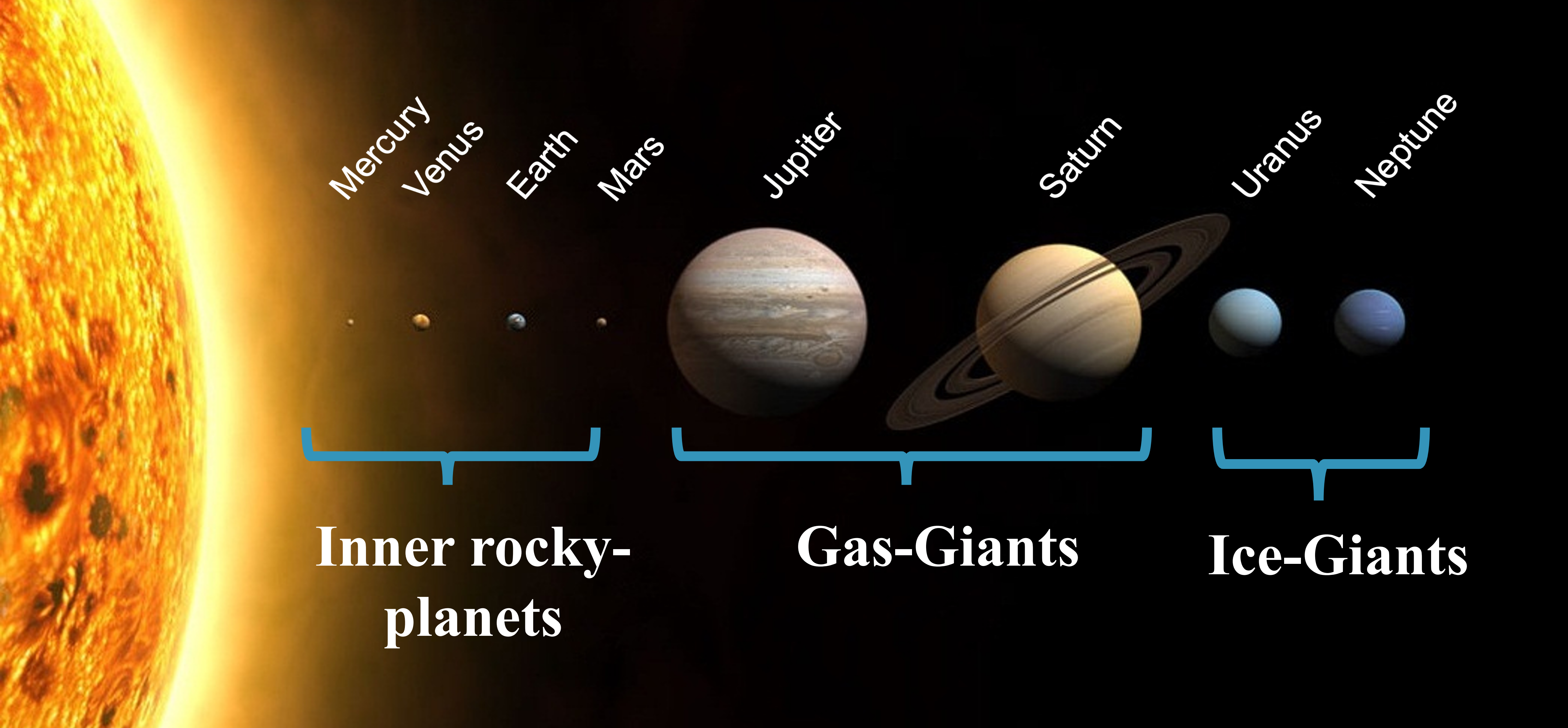
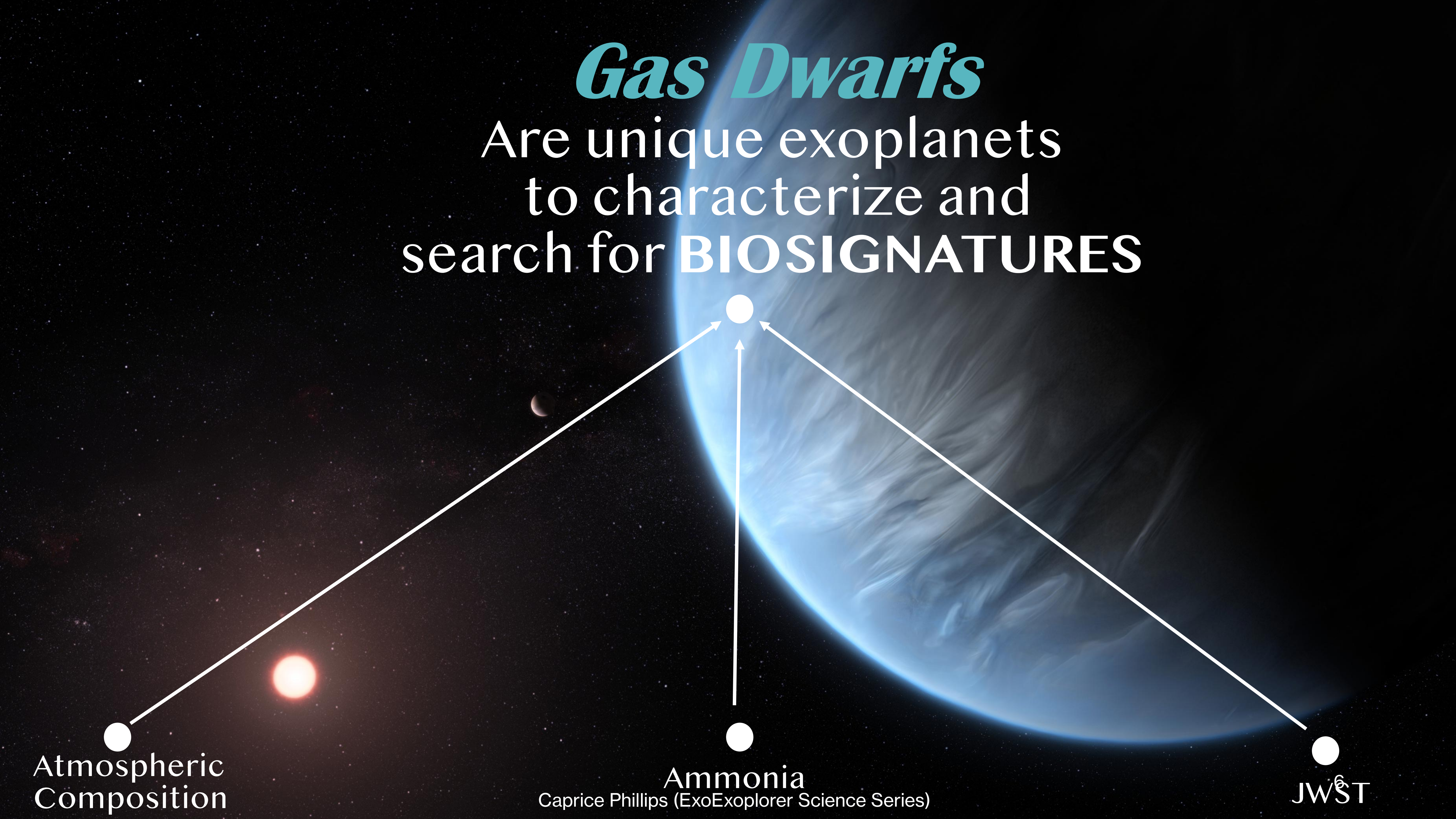


Image Credit: *NASA Ames / W. Stenzel*

# Gas Dwarfs Are Not Found In The Solar System




Gas Dwarfs
Are unique exoplanets
to characterize and
search for BIOSIGNATURES
Atmospheric
Composition
Ammonia
Caprice Phillips (ExoExplorer Science Series)
JWST

# TESS is Providing Targets for Follow-up Observations with JWST

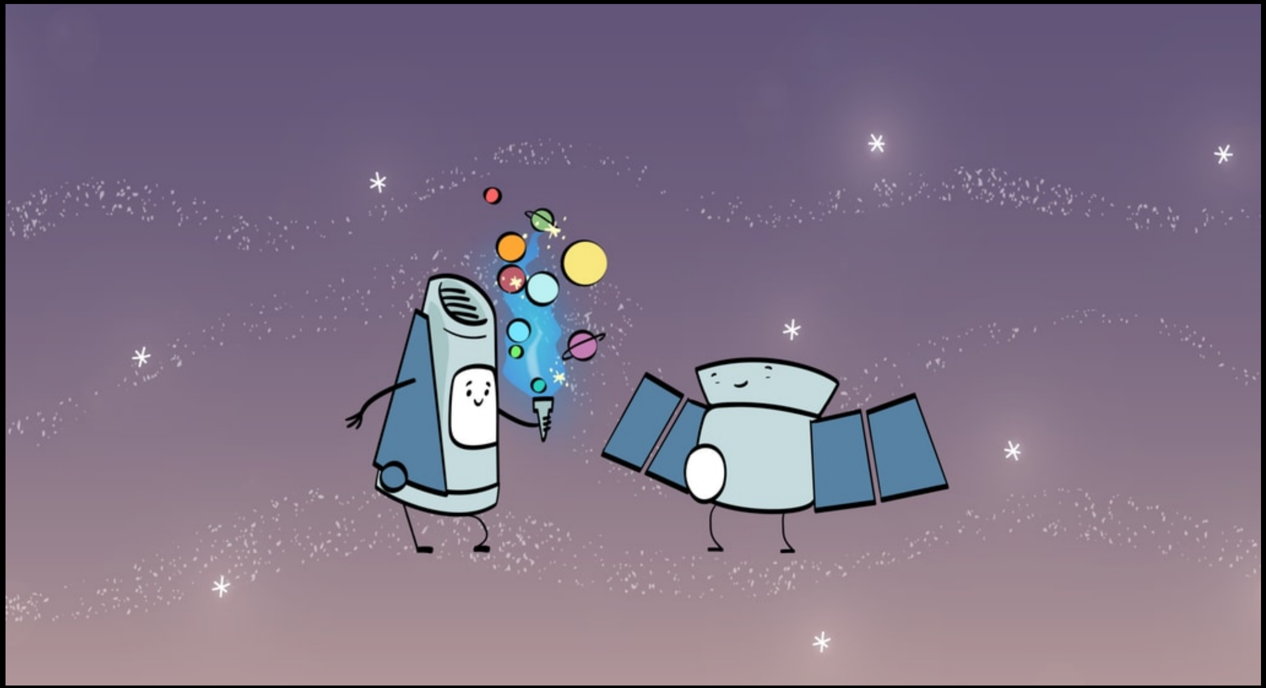
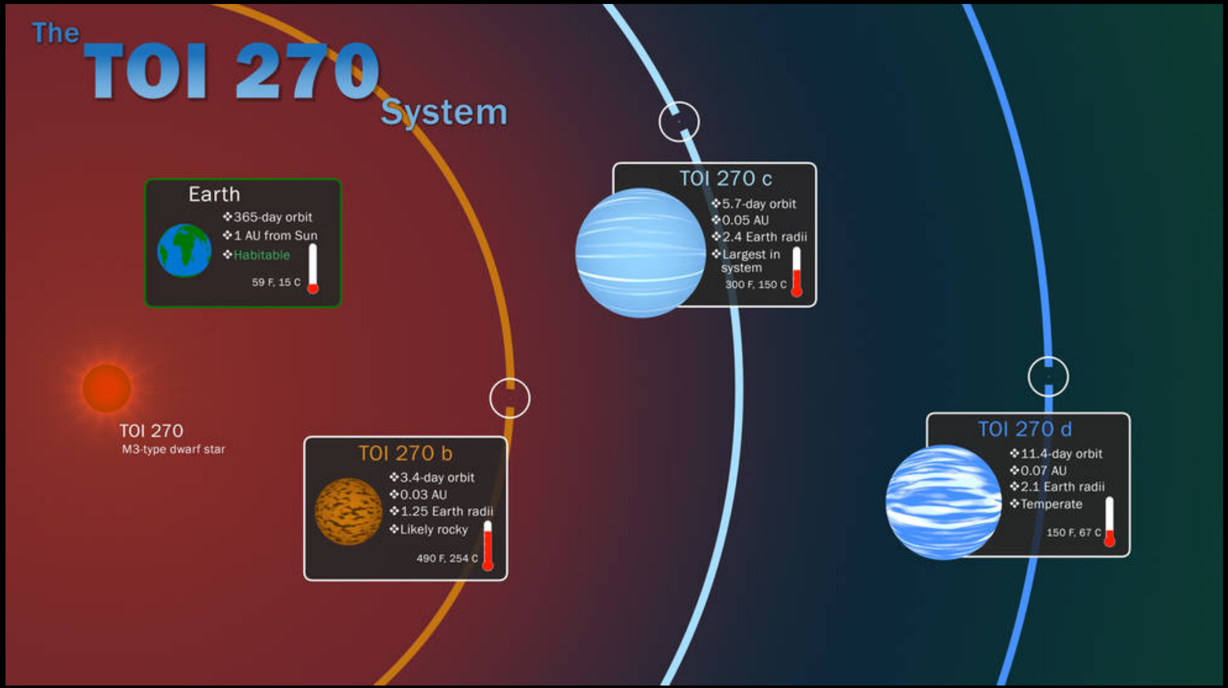


Image Credit: NASA's Goddard Space Flight Center Conceptual Image Lab

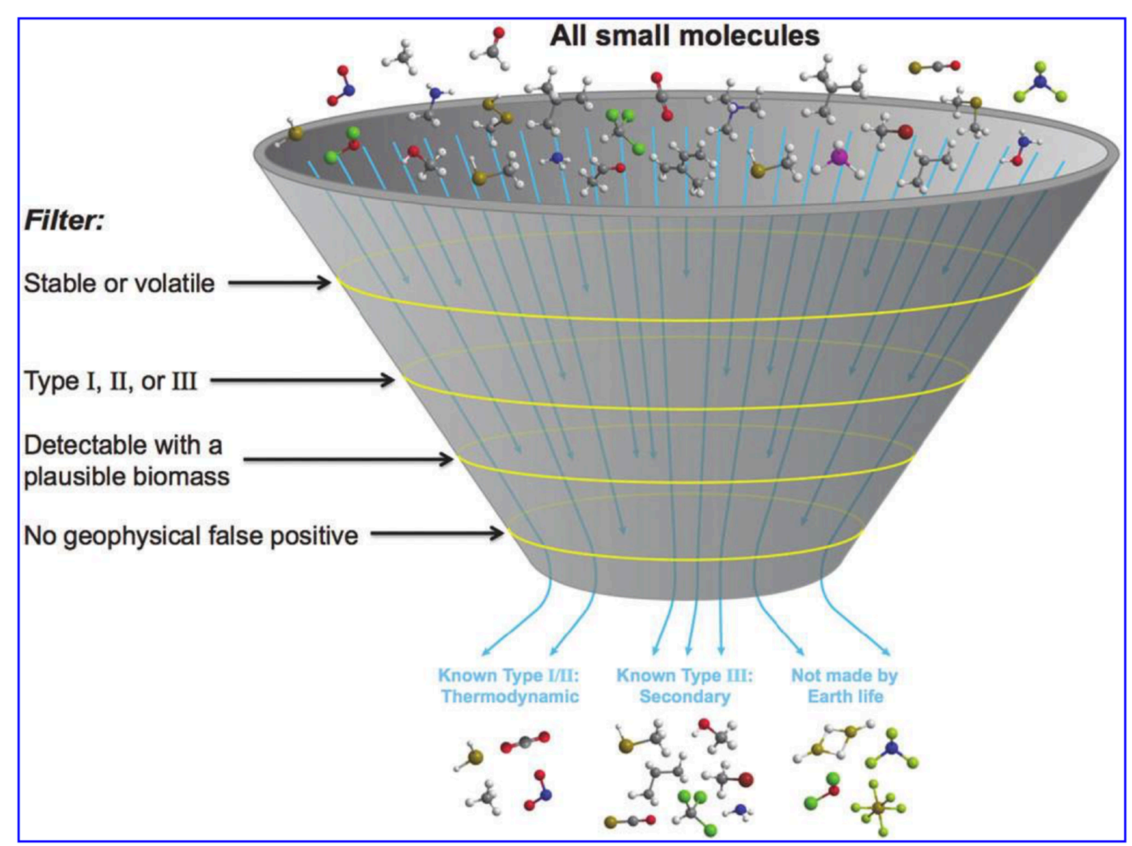


# What is a Biosignature?

- An atmospheric biosignature is a gas whose presence in a planetary atmosphere indicates that the planet likely harbors life

| Criteria |
| --- |
| • Generated by life |
| • Build up in planetary atmosphere to be detectable |
| • Present/active in wavelength range being observed |

Meadows & Seager 2010

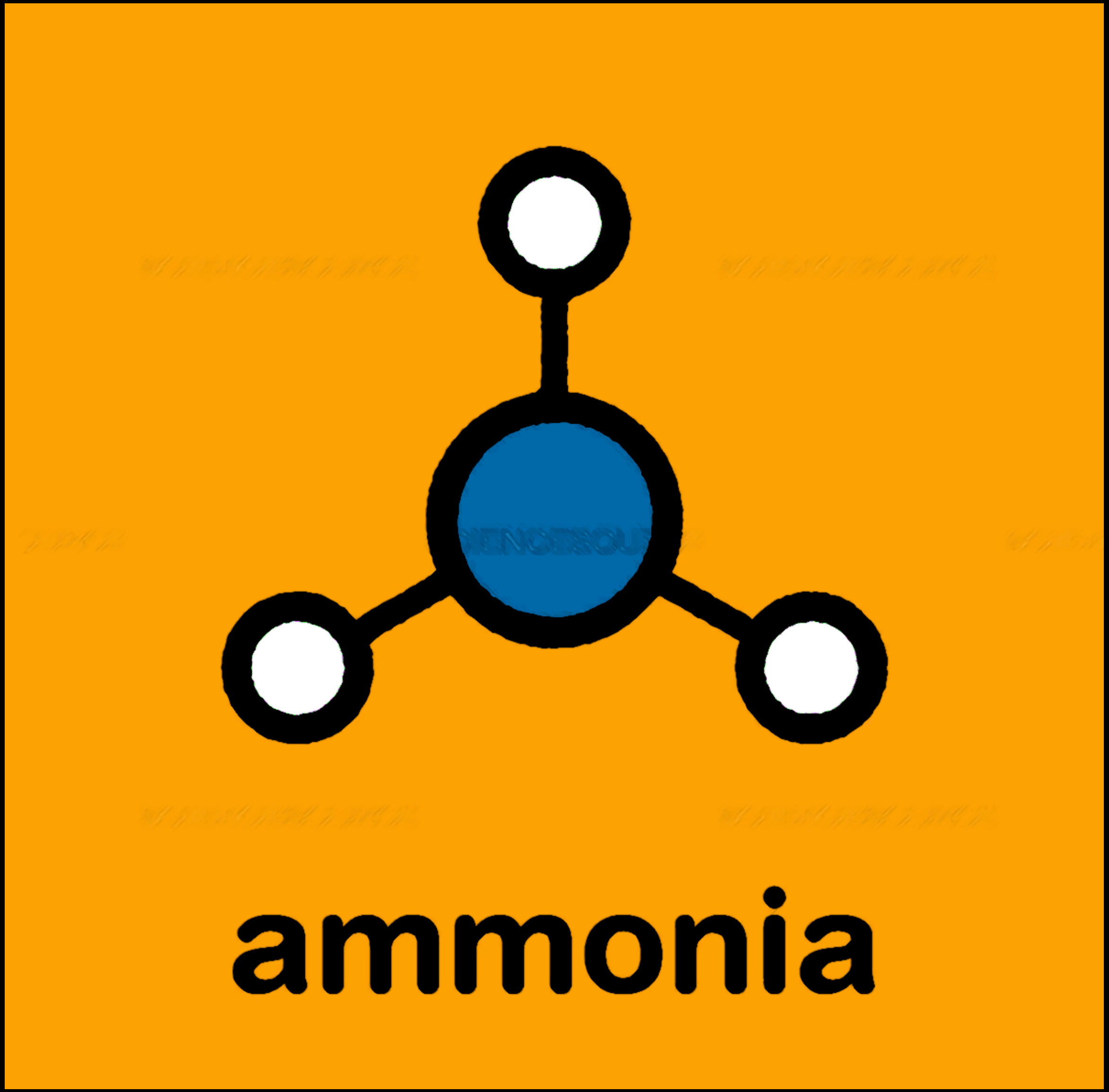



Seager et al. 2016

## What Makes A Biosignature Ideal?

- Does not exist naturally in the atmospheres at ambient temperatures & pressures
- Not created by geophysical processes
- Not produced by photochemistry
- Not significantly destroyed by photochemistry
- Have a strong spectral feature

Meadows & Seager 2010

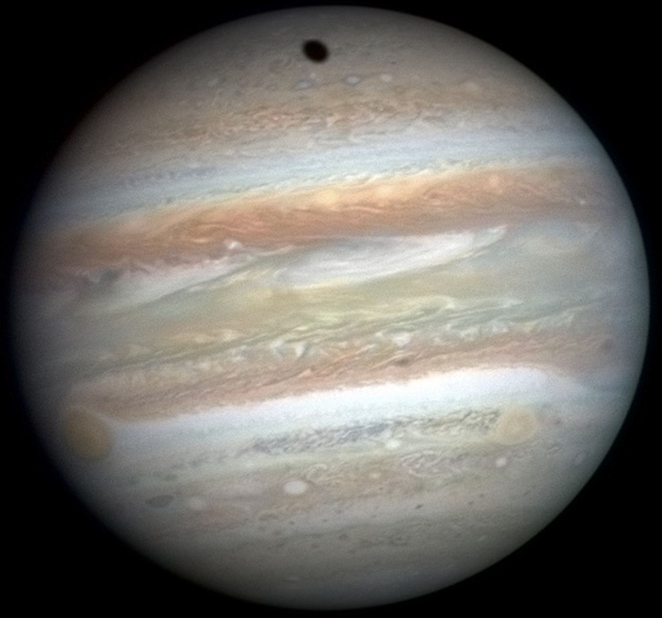


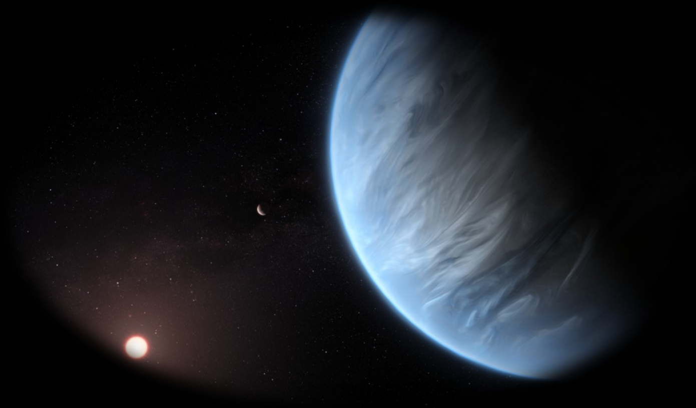

# Ammonia as a Biosignature

Microbial life can break apart bonds in Hydrogen and Nitrogen to produce Ammonia

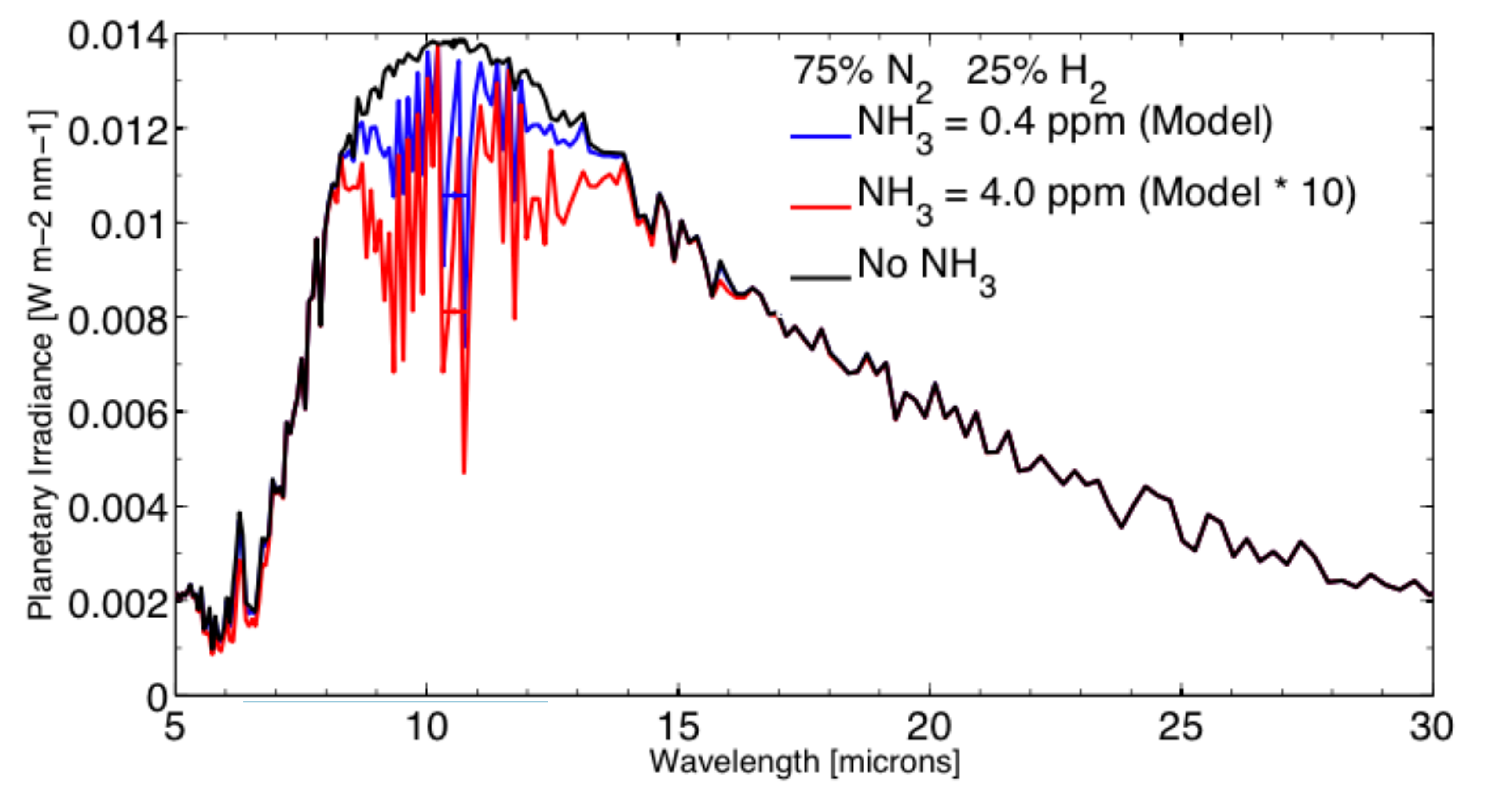
$$3H_2 + N_2 \rightarrow 2NH_3$$

# Brown Dwarfs, Gas Giants and Hydrogen-dominated atmospheres can have ammonia features



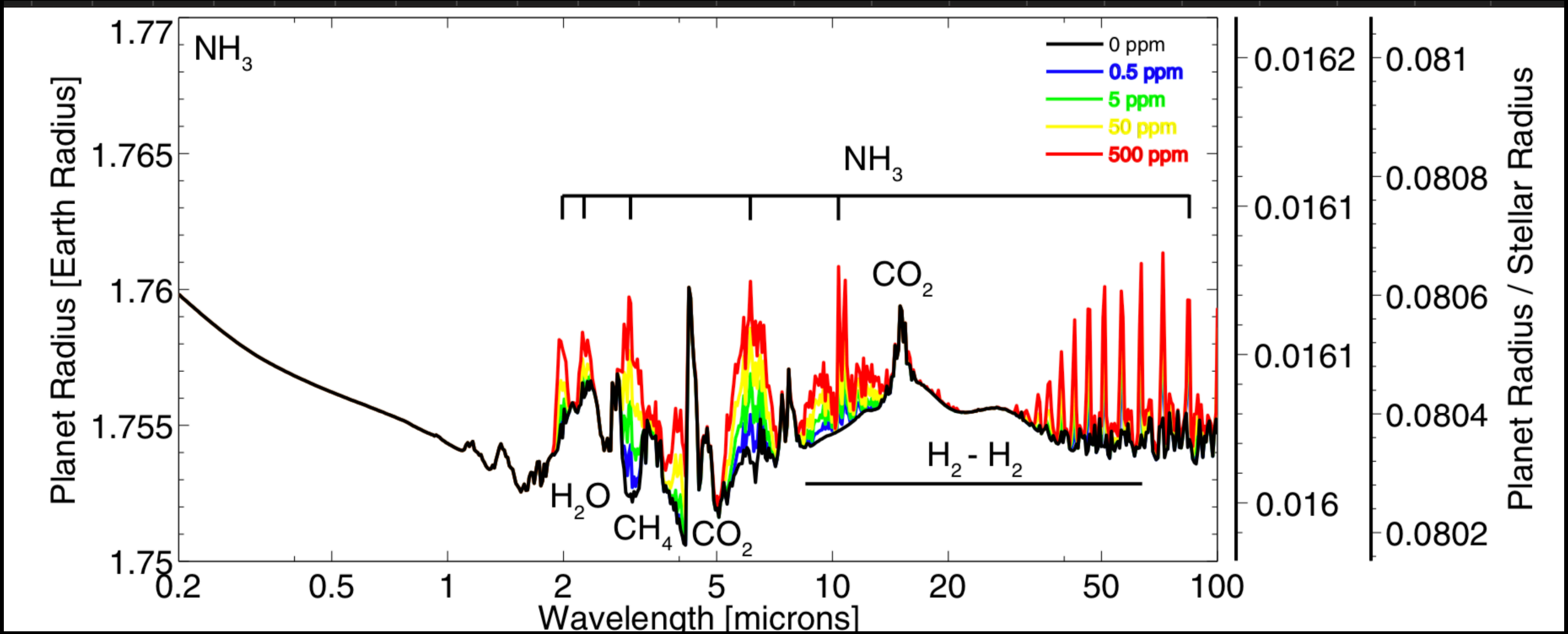


# Synthetic Thermal Emission Spectra For A "Cold Haber World."




Seager et al. 2013

# Theoretical Transmission Spectra For "Cold Haber World"

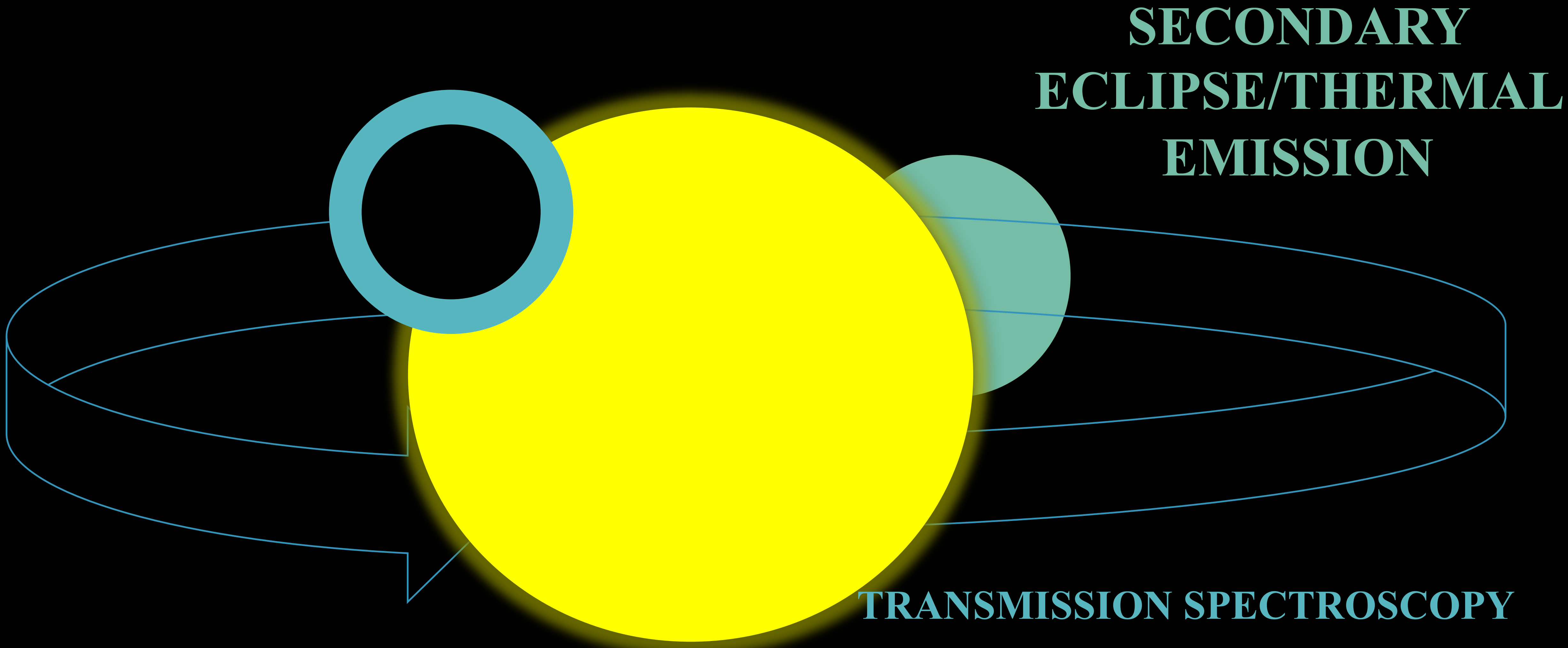



Seager et al. 2013

# Caution for False Positives for Ammonia

1. A rocky world with hot surface temperature of ~820 K
2. Naturally occurring NH3 in atmospheres of gas giant planets/mini Neptunes
3. Planets with outgassed NH3 during evolution

Seager et al. 2013


SECONDARY ECLIPSE/THERMAL EMISSION
TRANSMISSION SPECTROSCOPY

# JWST Will Provide Unprecedented Collection and Wavelength Coverage

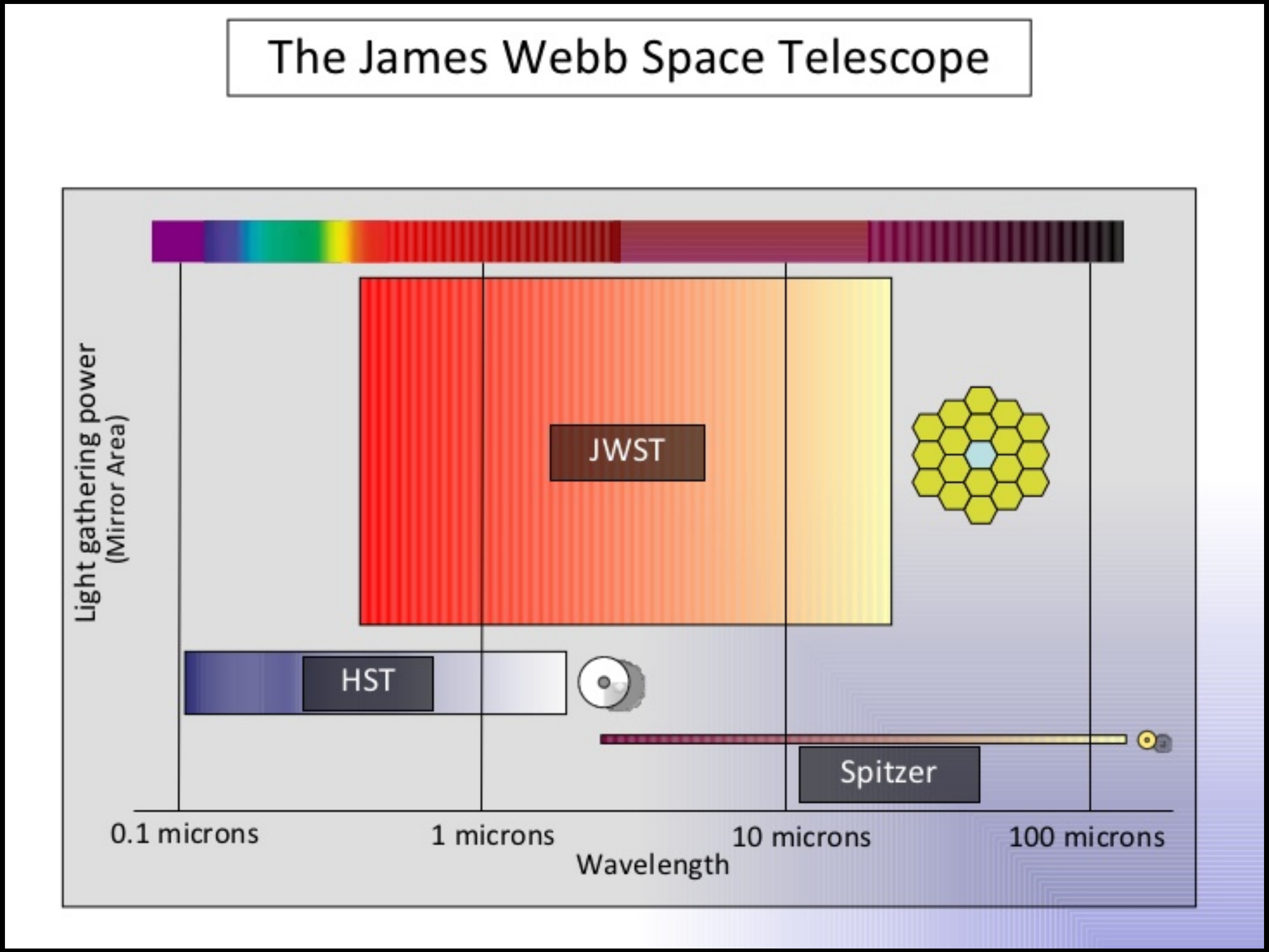
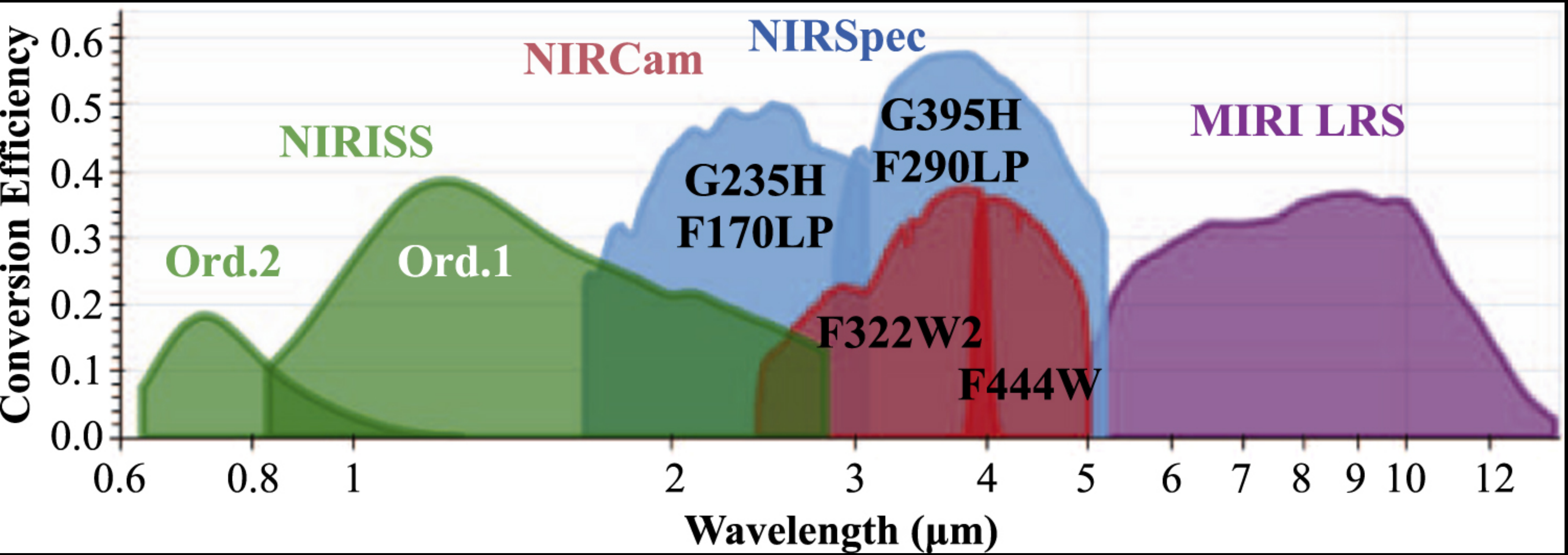



Image credit: STScI

- JWST's wavelength range will be from about 0.6 to 28 microns (visible to the mid-infrared light).
- Hubble Space Telescope observes at 0.1-2.5 microns (ultraviolet to the near infrared).

# NIRSpec and NIRISS instruments have higher efficiency than NIRCAM




Bean et al. 2018

1 Choose amount of ammonia in atmosphere

2 Choose instrument

3 Choose varying amount of hydrogen in atmosphere

4 Determine if ammonia can be detected

$NH_3$

4.0 ppm

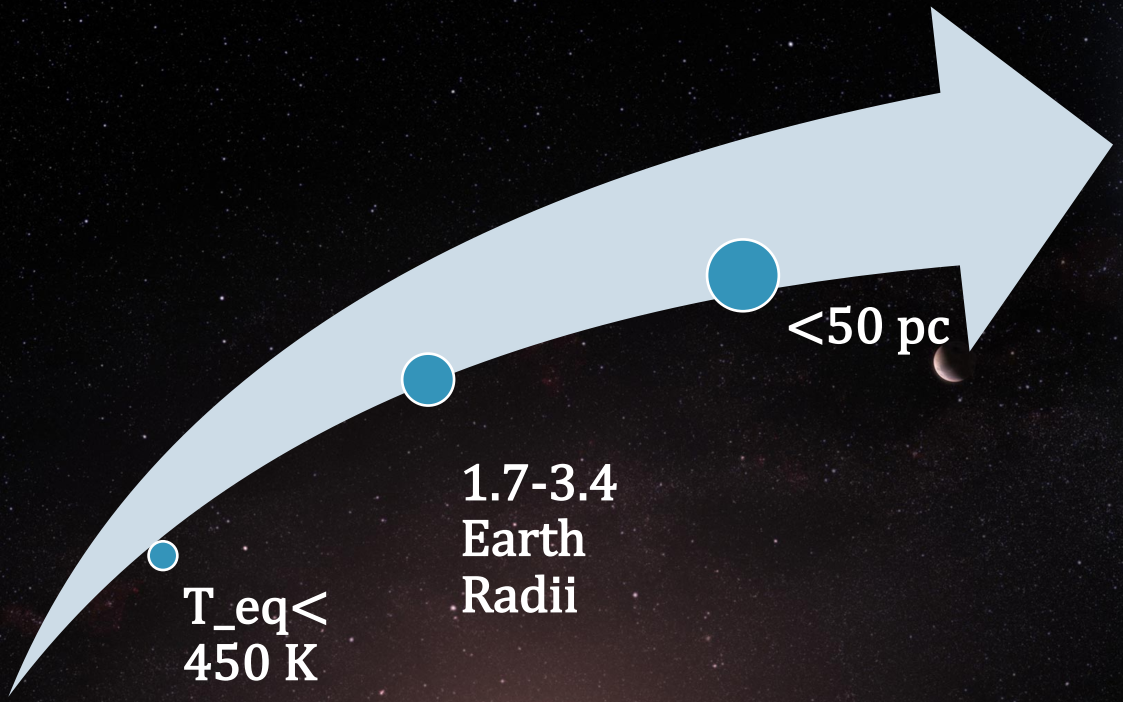
MIRI LRS

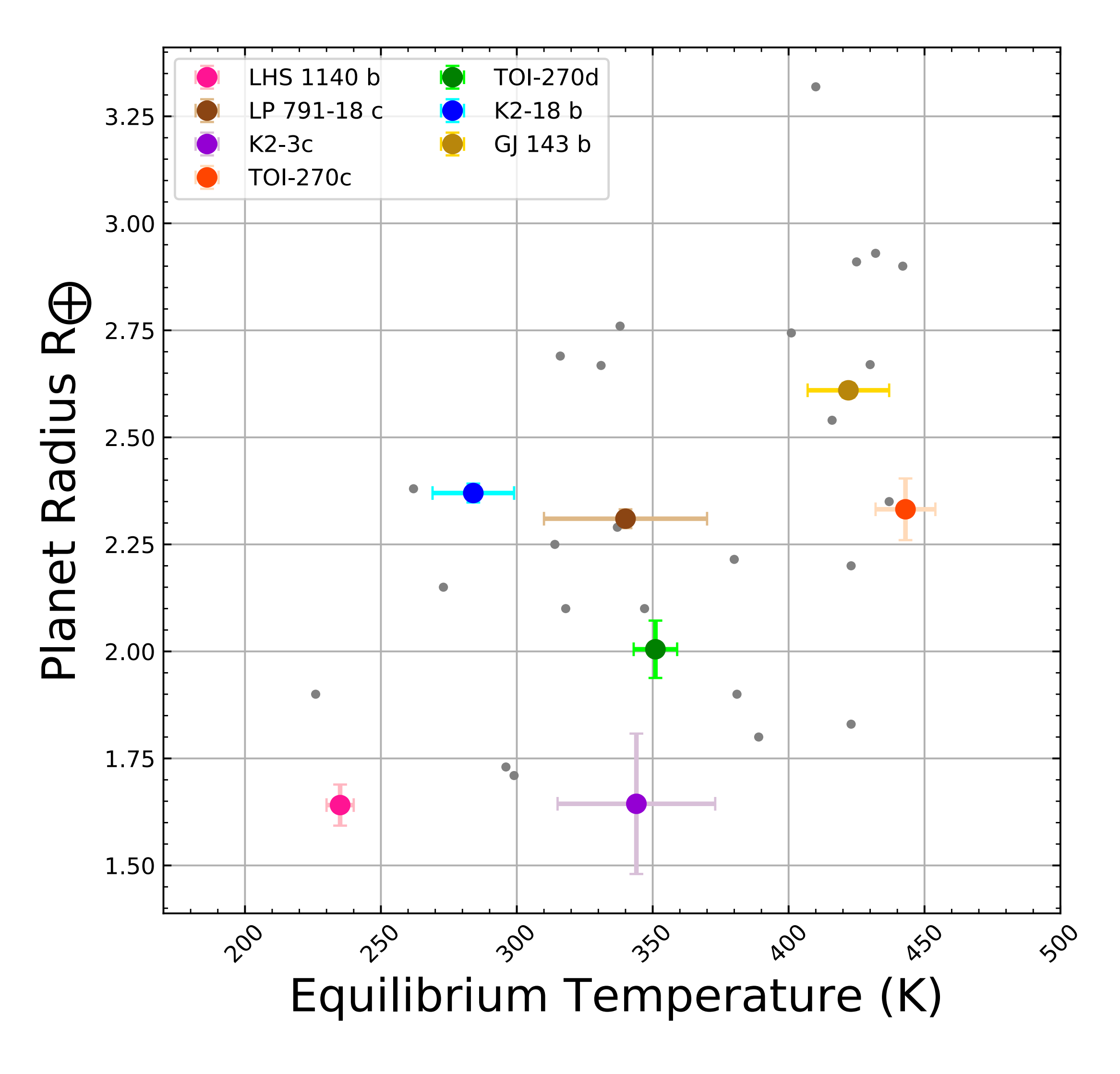
- Low MMW
- High MMW

NIRSpec

- Low MMW
  - No clouds
  - Cloud decks
- High MMW

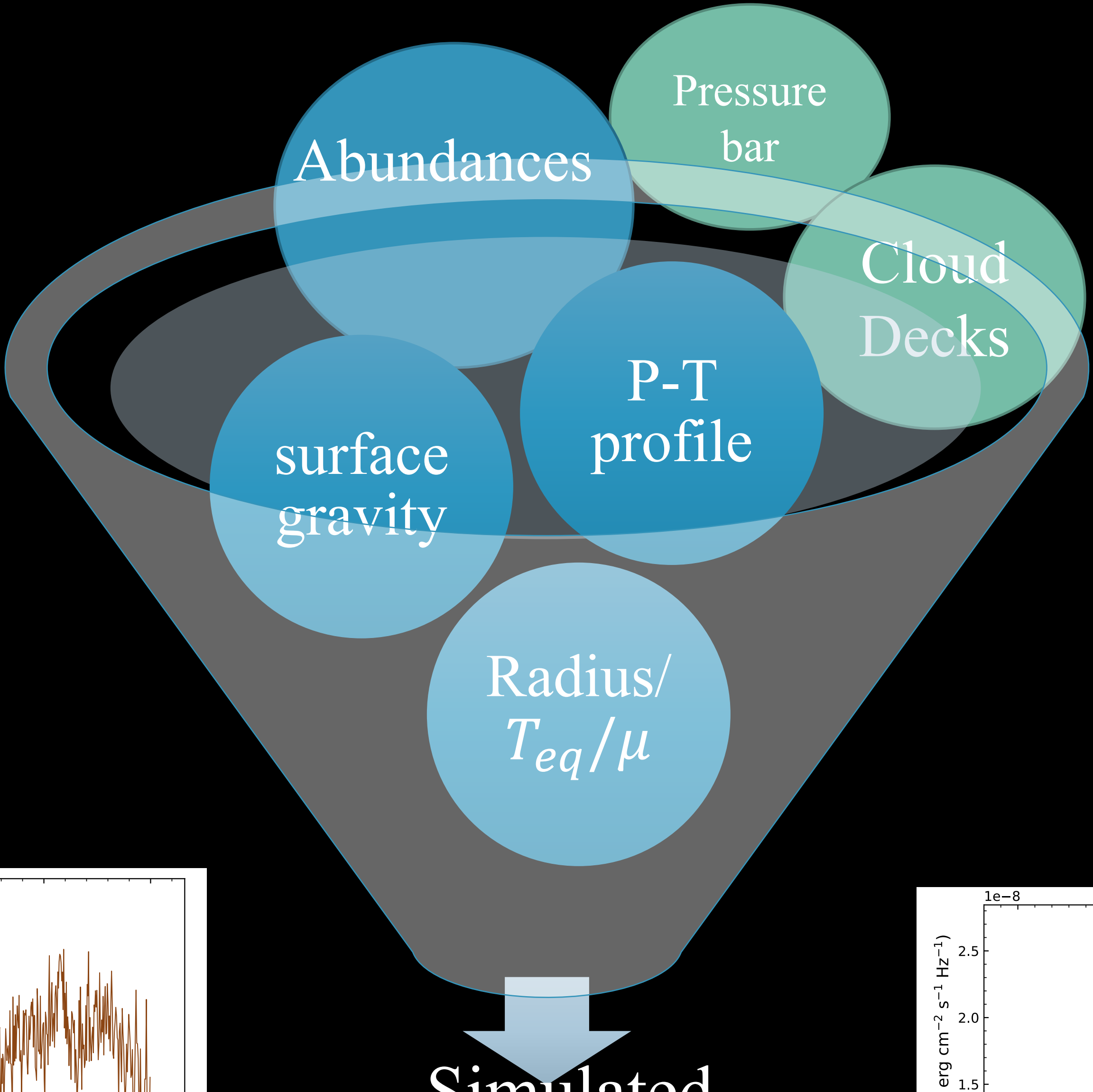
# Selection Criteria for Targets



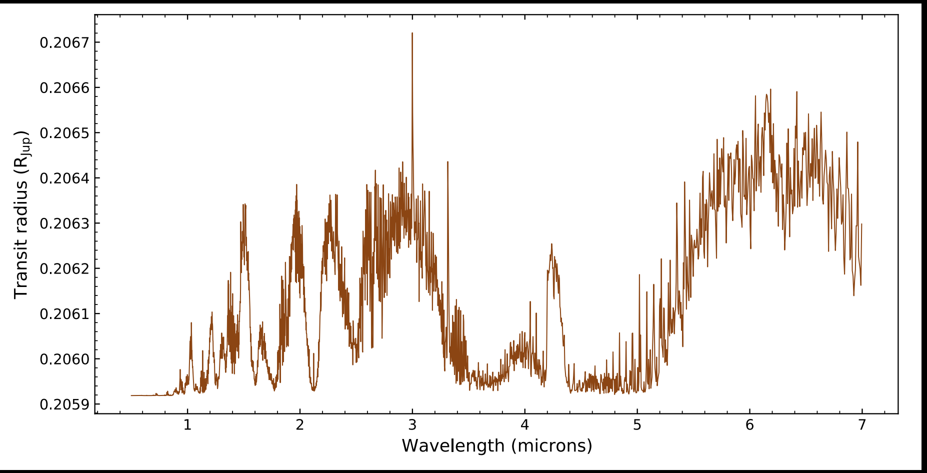



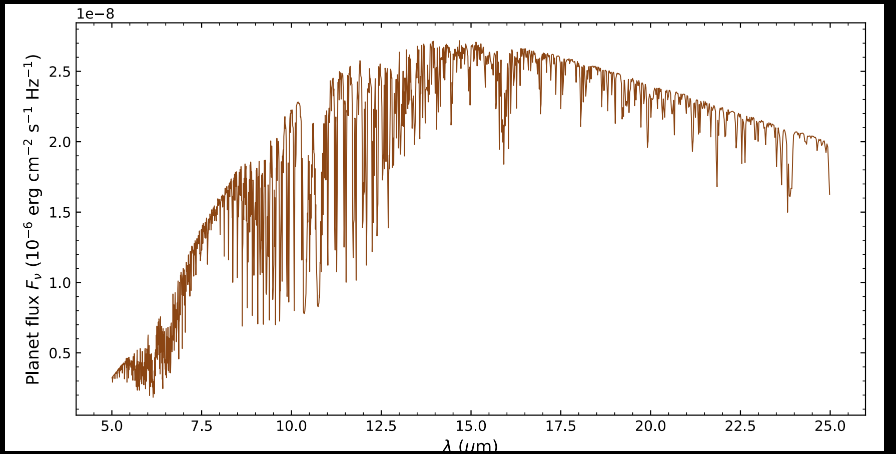

Phillips et al. in prep

Mollière et al. 2019



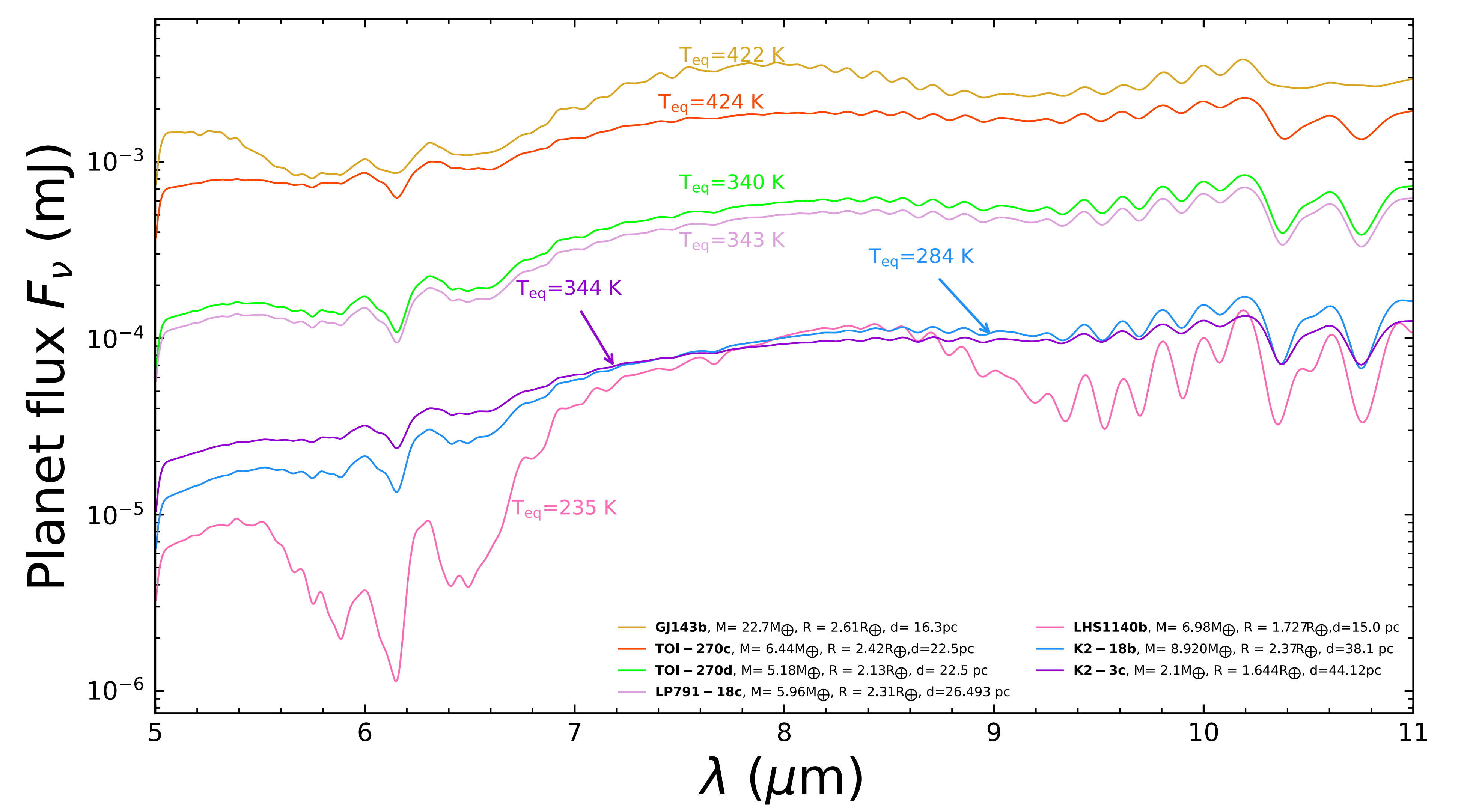

# Simulated Transmission/Emission Spectra



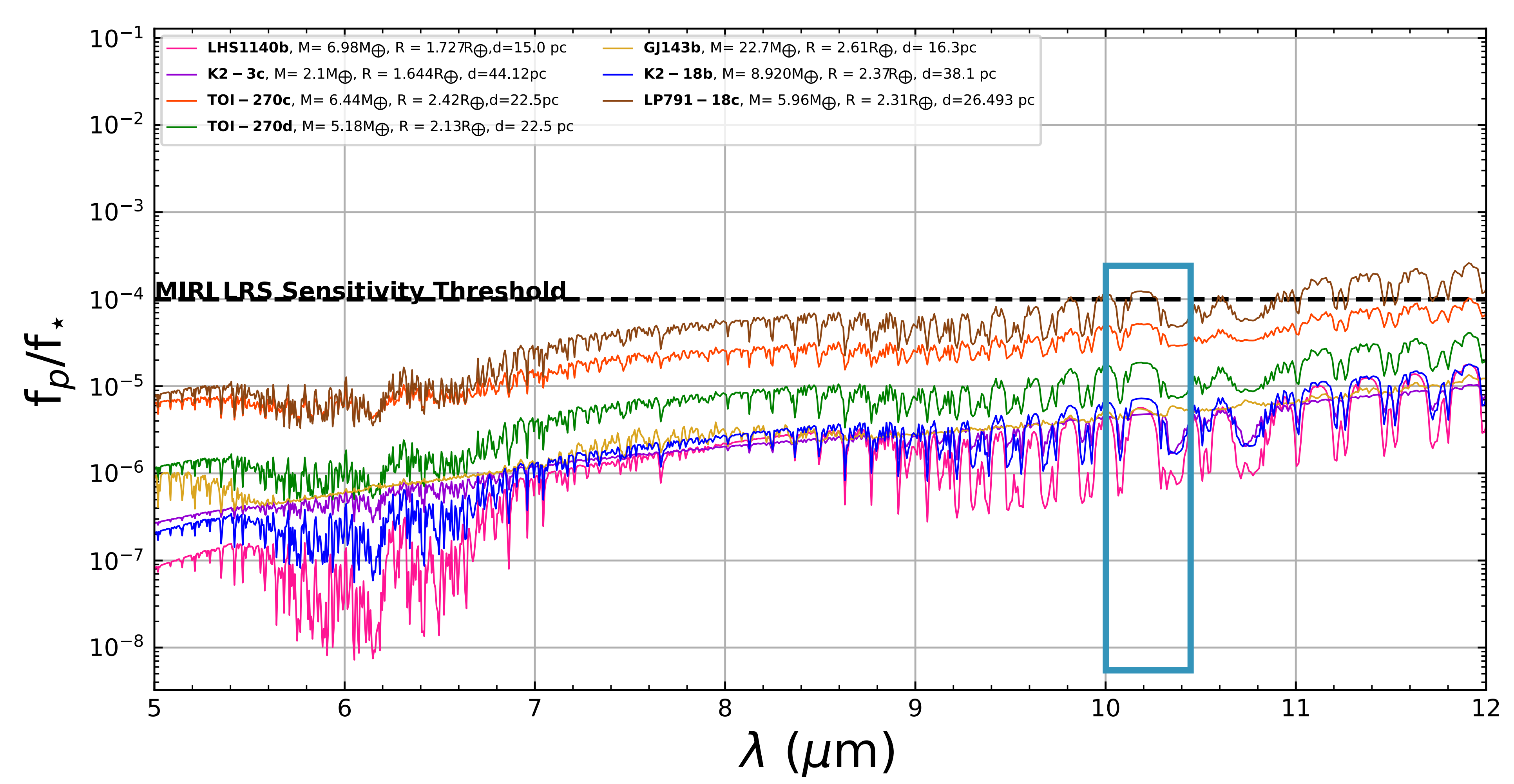

Caprice Phillips (ExoExplorer Science Series)

# Low Planetary Flux Makes Atmospheric Characterization Challenging




Phillips et al. in prep

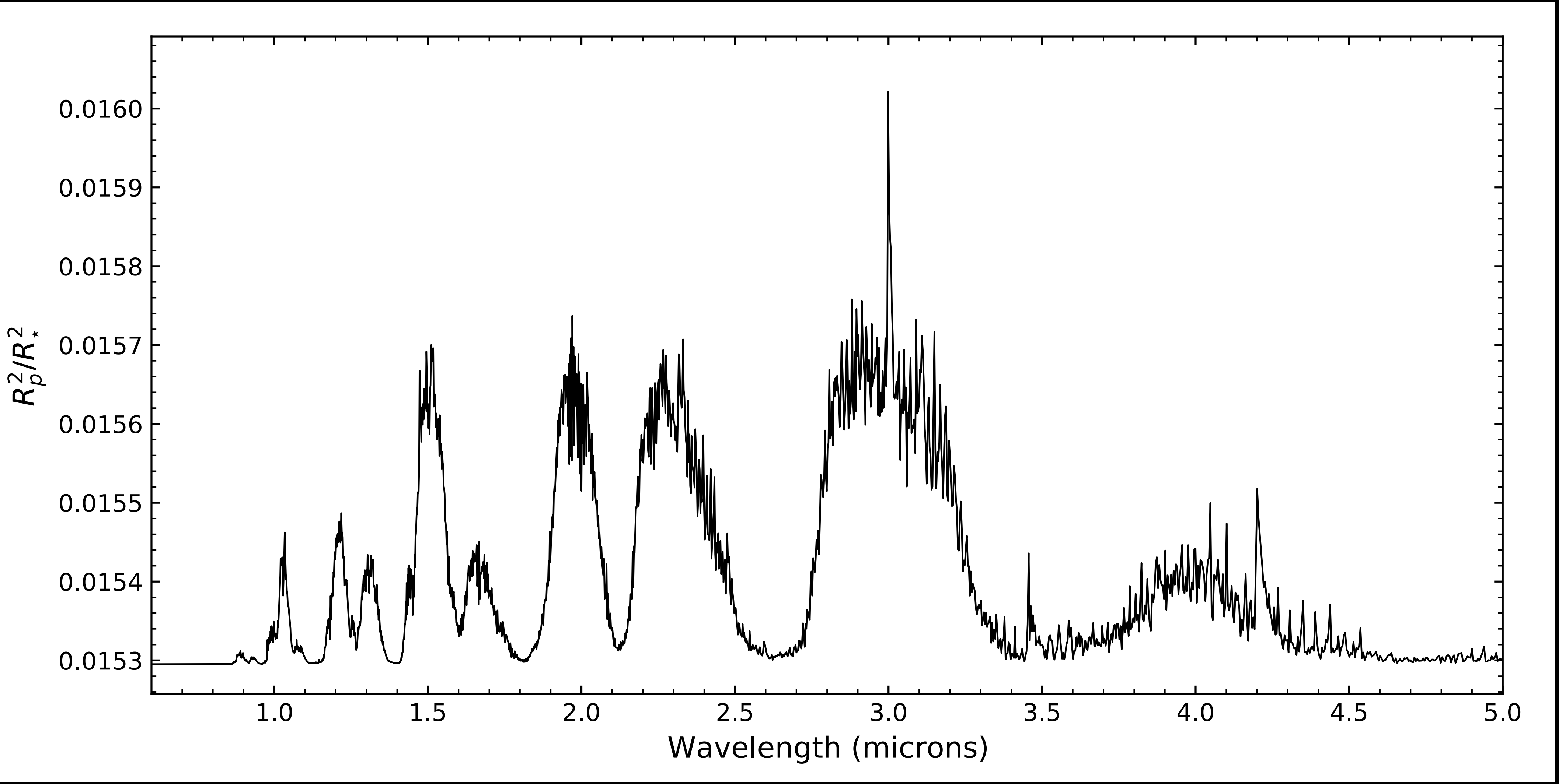
# 10$\mu$m Ammonia Feature Is Difficult To Detect With MIRI LRS



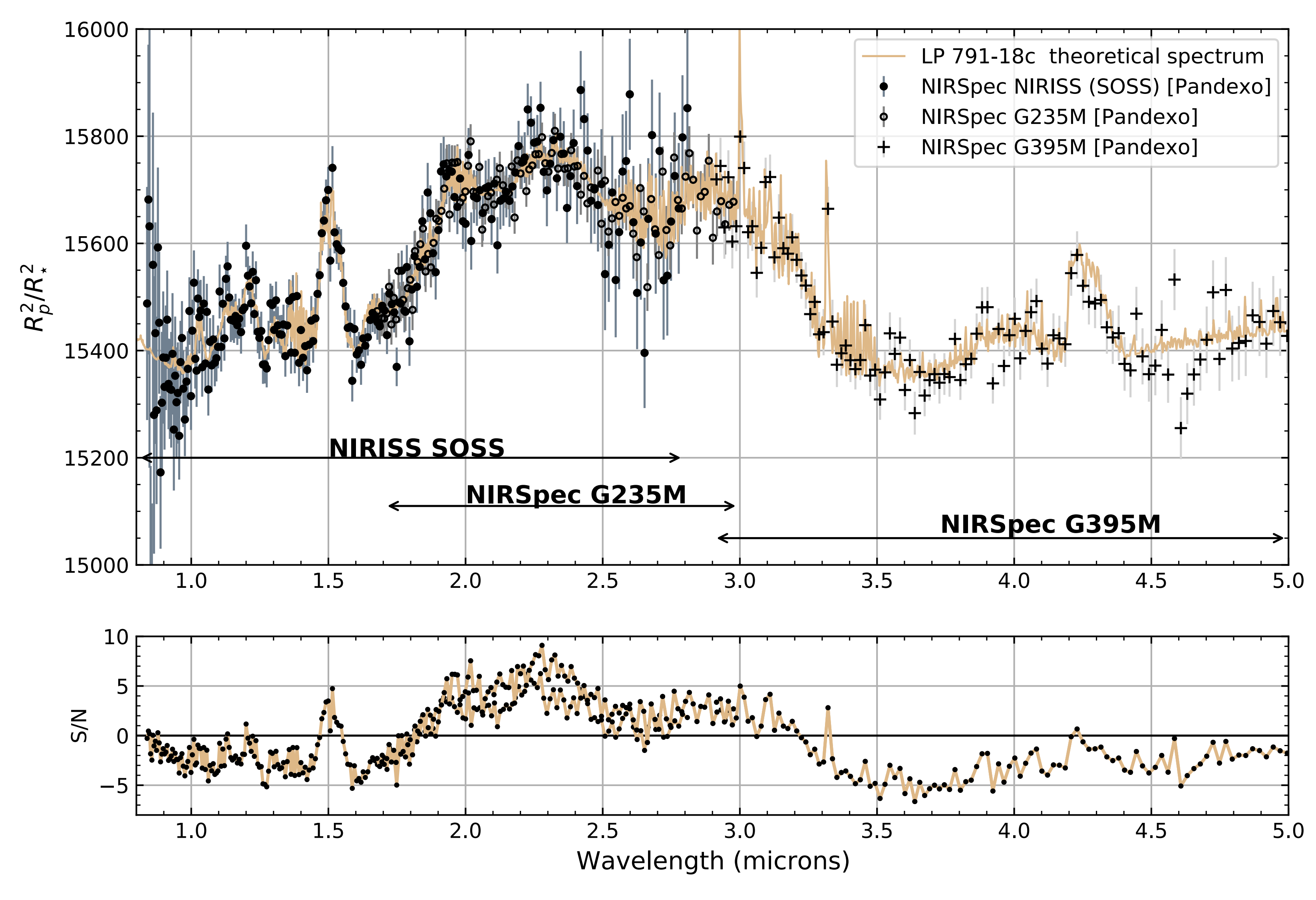



Phillips et al. in prep

# Ammonia Has Many Features In The NIR



# Signal-To-Noise Scales with $\frac{1}{\mu}$

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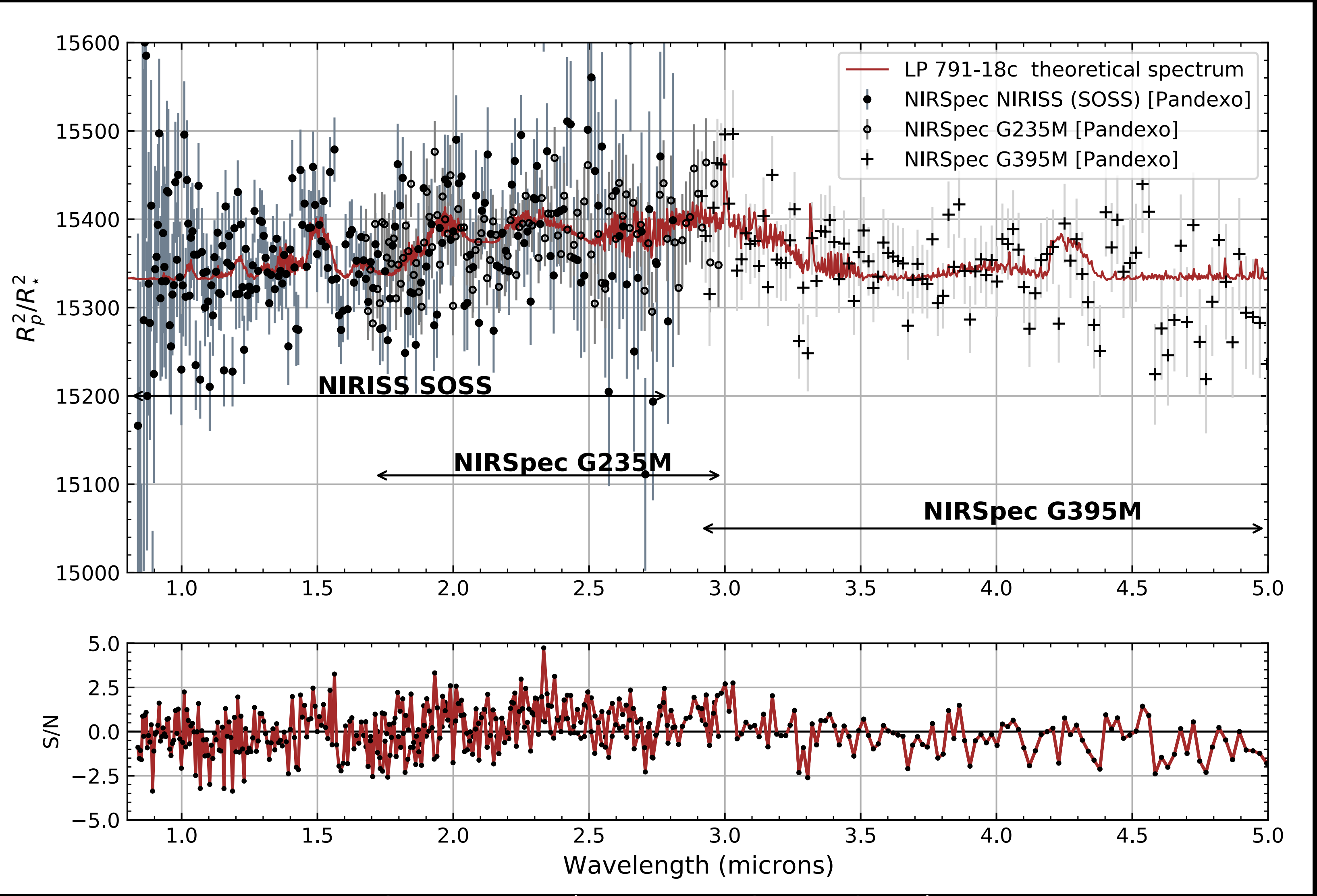
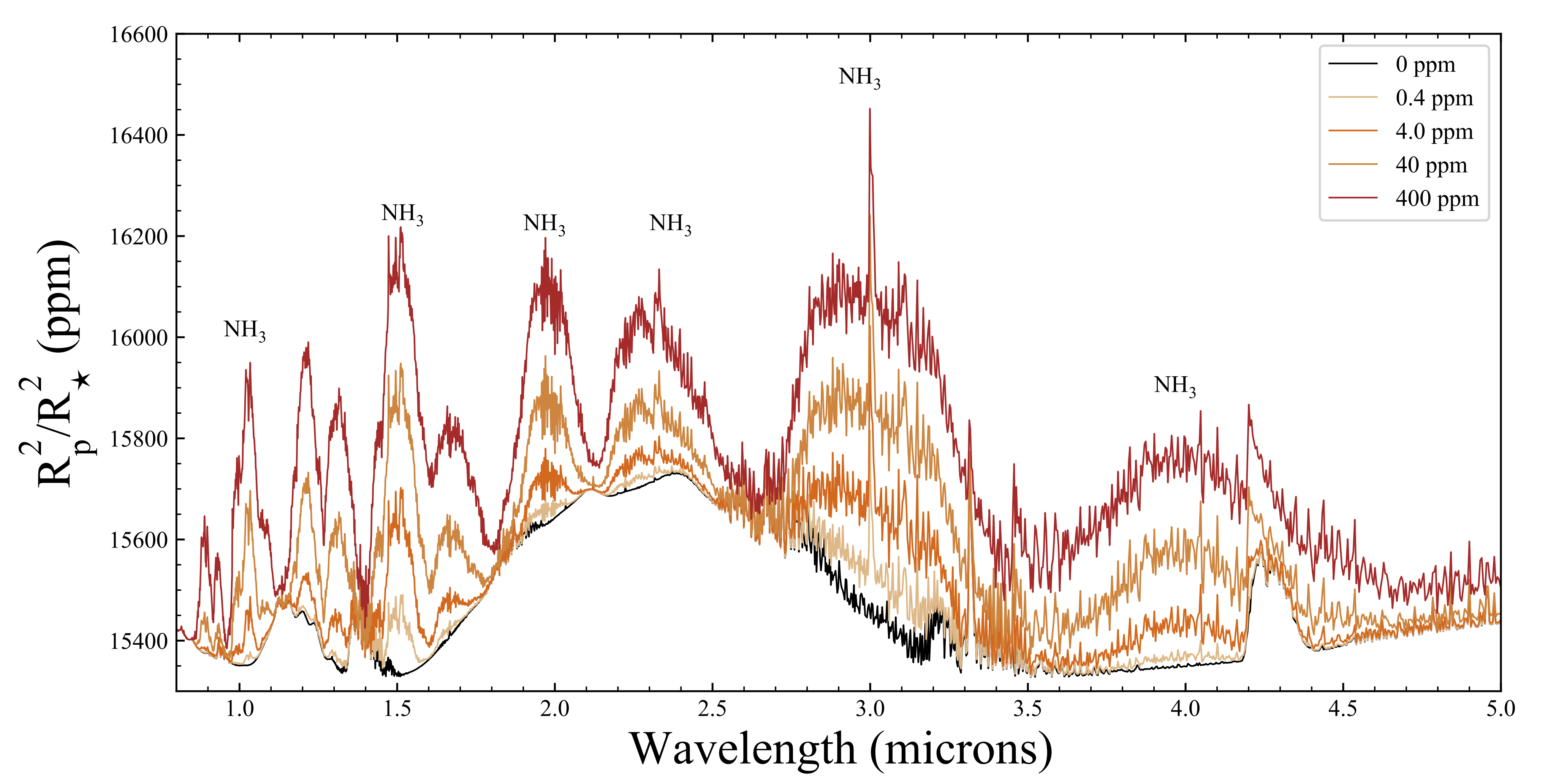
# 25% $H_2$ & 75% $N_2$ atmospheric composition produces weaker S/N




Phillips et al. in prep

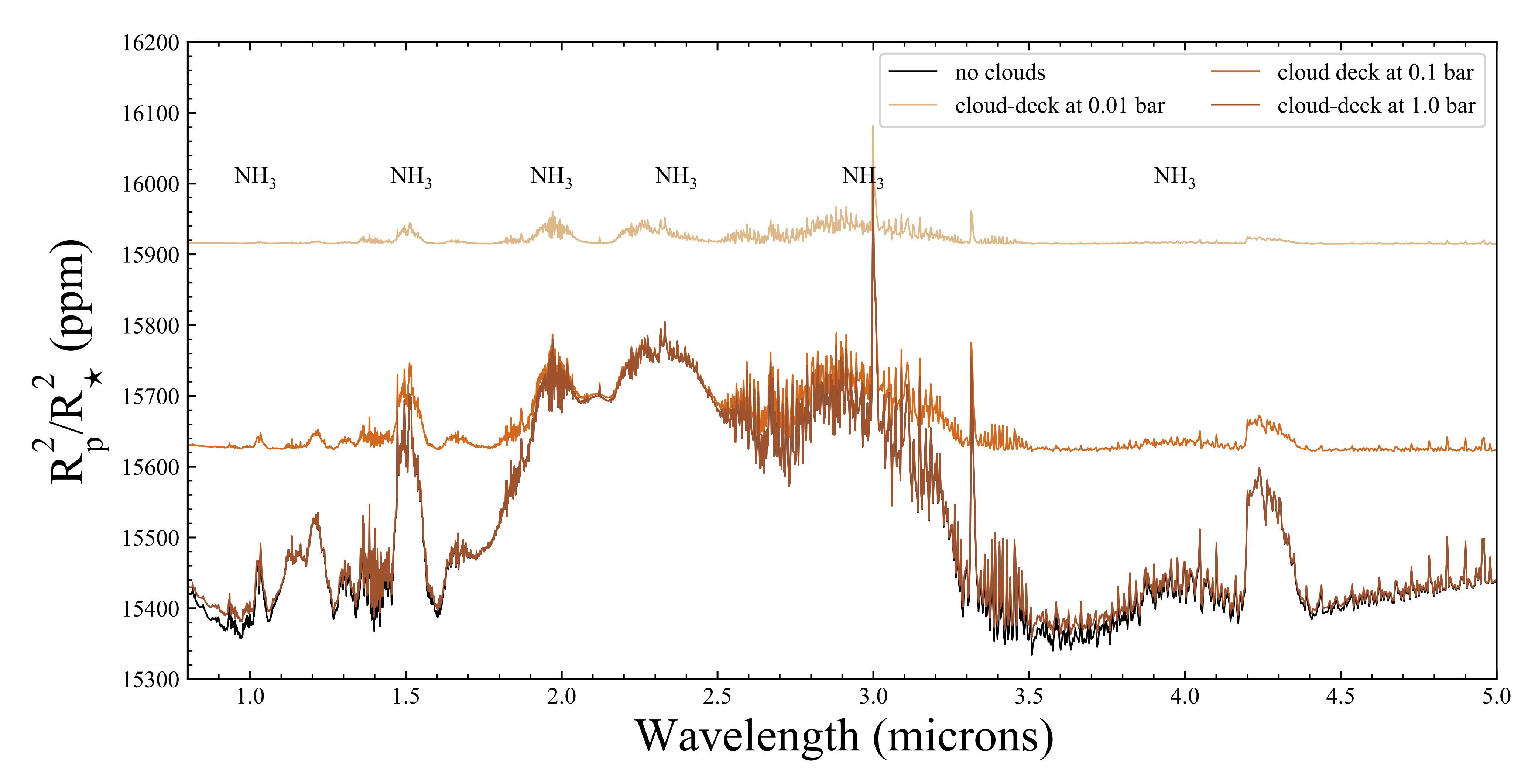
# Higher Concentration Of Ammonia Produces HIGHER Transmission Signal





Phillips et al. in prep

# Clouds Weaken Spectral Features

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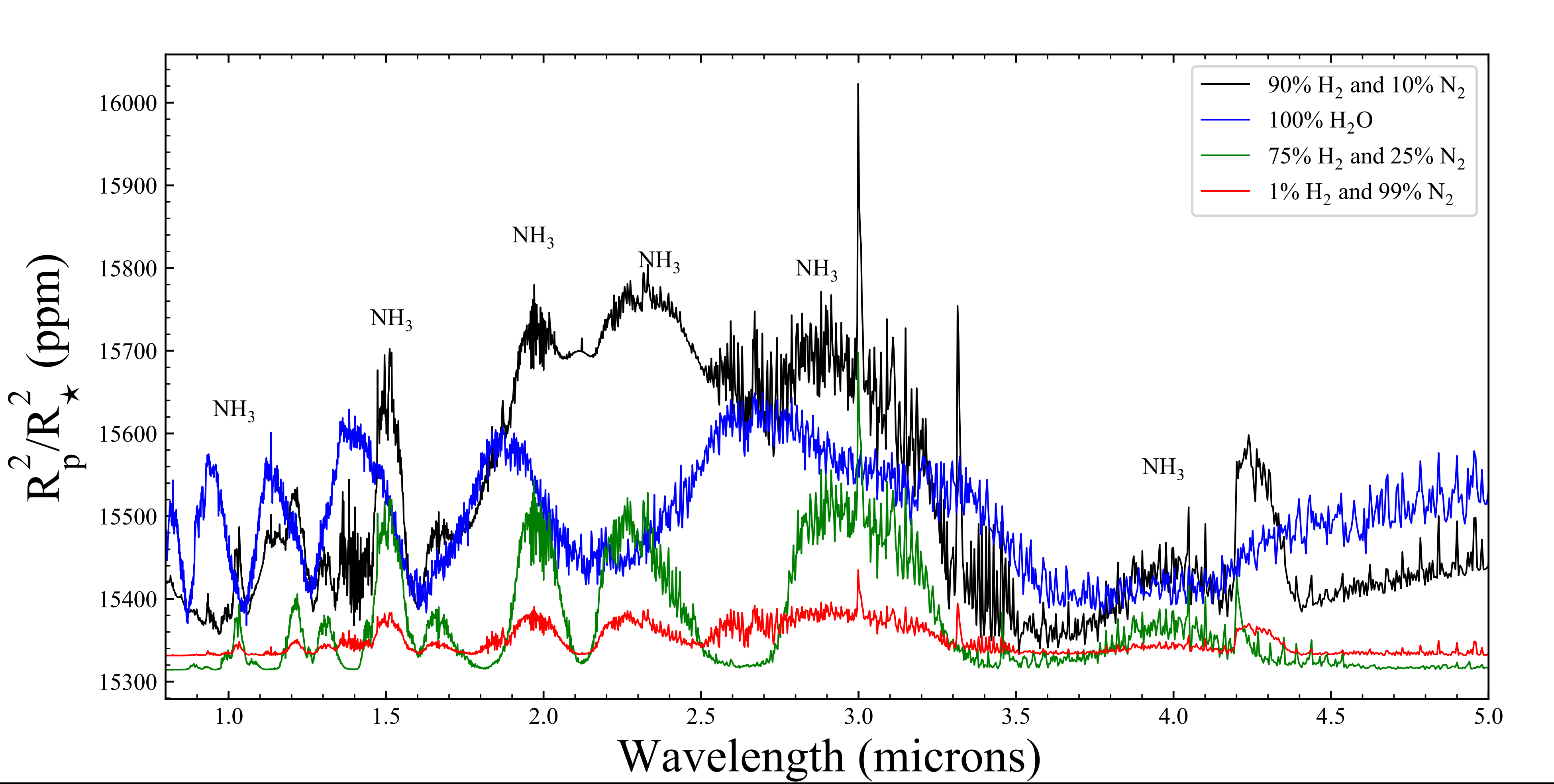
# Various Atmospheric Composition Affects Transmission Signal Strength

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# Rank List of Targets

1. LP 791-18 c

2 TOI-270 c

3. LHS 1140 b

4. GJ 143 b

5. TOI-270 d

6. K2-18 b

7. K2-3c

## *Gas Dwarfs*

Are more massive/common than Earth and are promising sites to look for SIGNS OF LIFE

## *Ammonia*

Is an exotic BIOSIGNATURE unique to hydrogen dominated atmospheres of gas dwarfs including super-Earths

## *NIRSpec*

Is a better instrument than MIRI LRS to DETECT AMMONIA

## *Detectability of Ammonia*

Is affected by CONCENTRATION OF AMMONIA in atmosphere, MEAN MOLECULAR WEIGHT, and presence of CLOUDS

# Thank you!

Website:
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