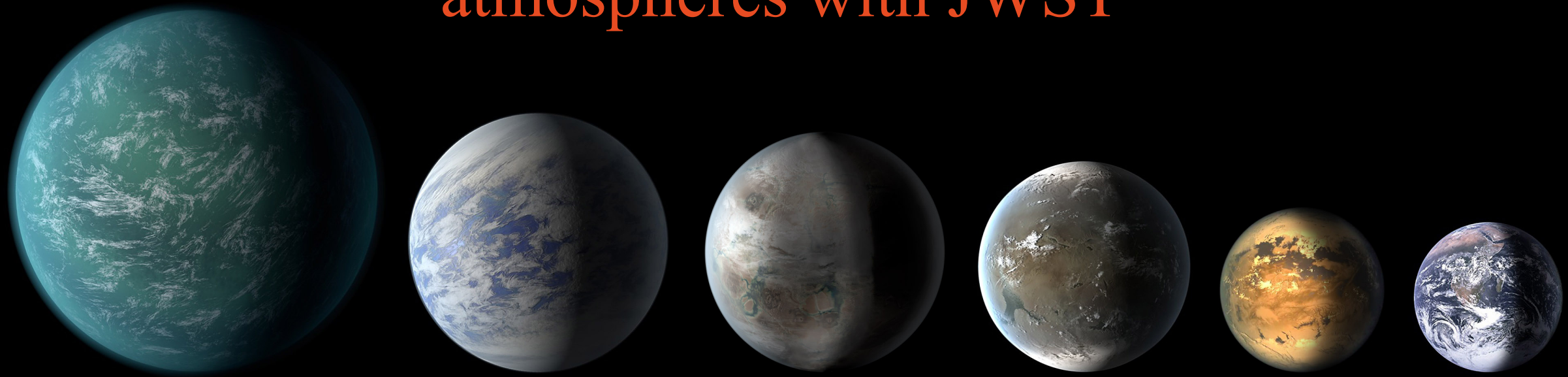
Detecting Potential Biosignatures in super-Earth atmospheres with JWST



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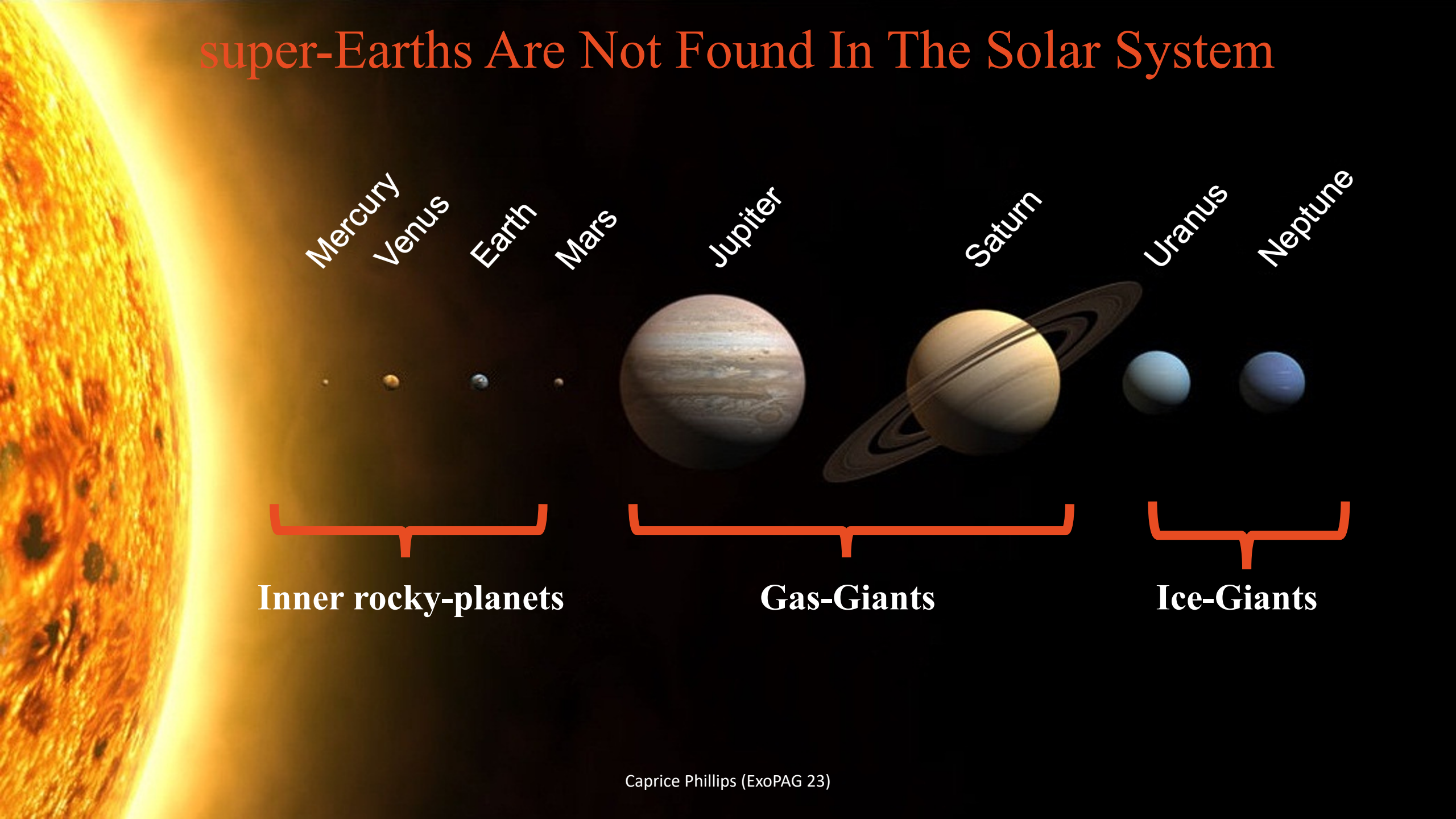
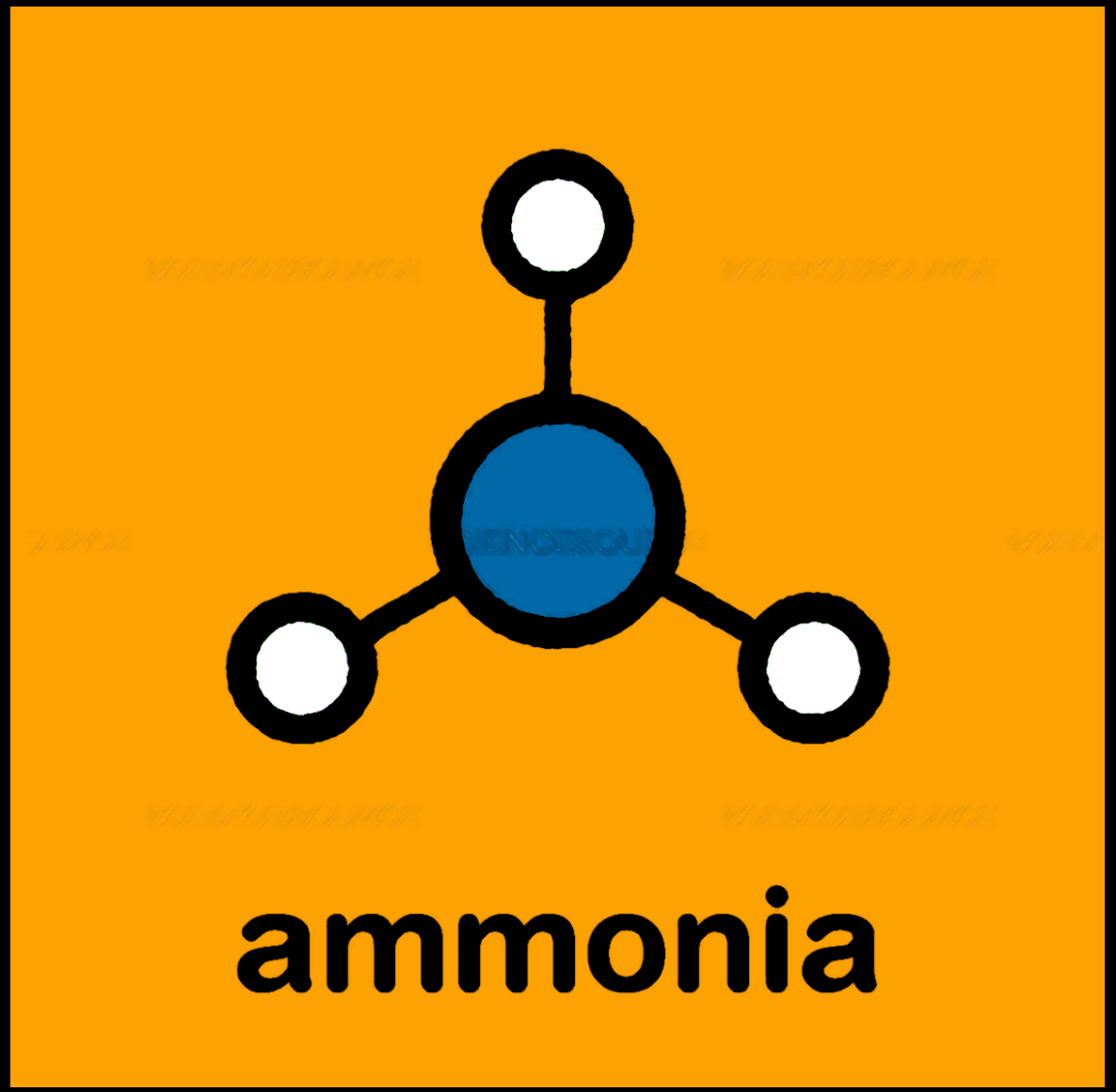
super-Earths Are Not Found In The Solar System





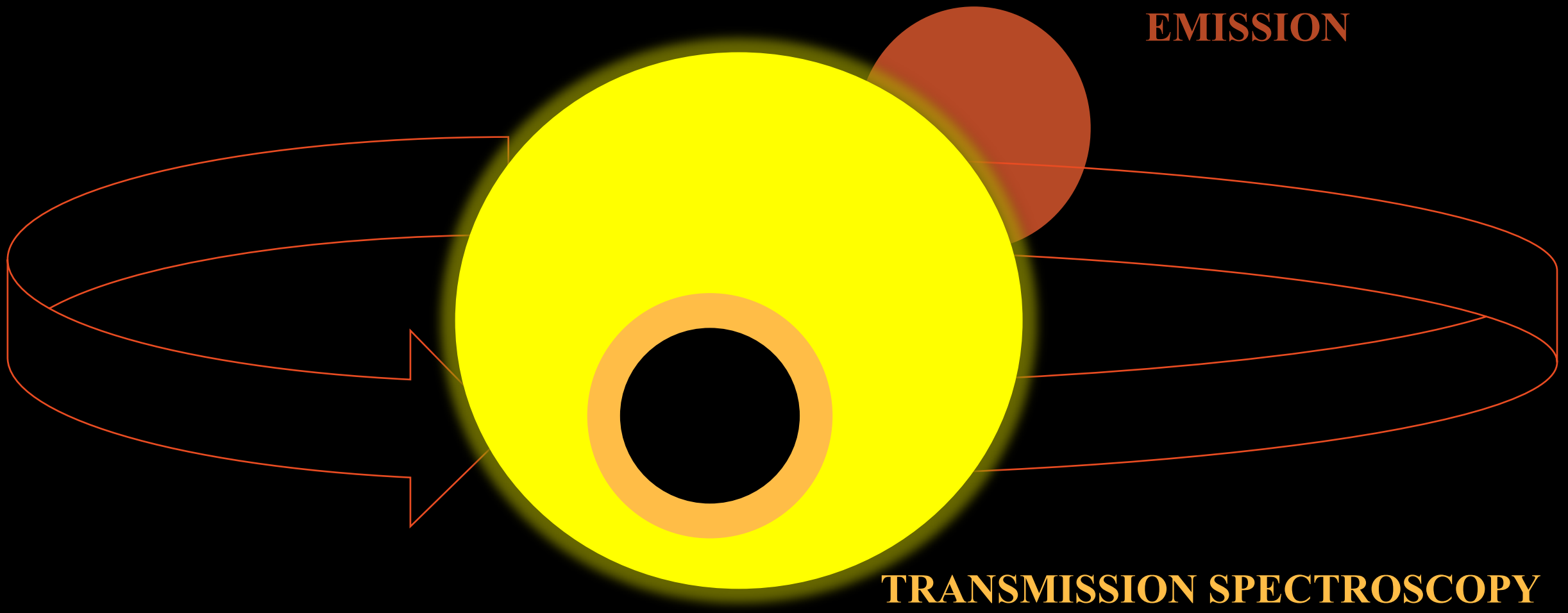
Ammonia as a Biosignature

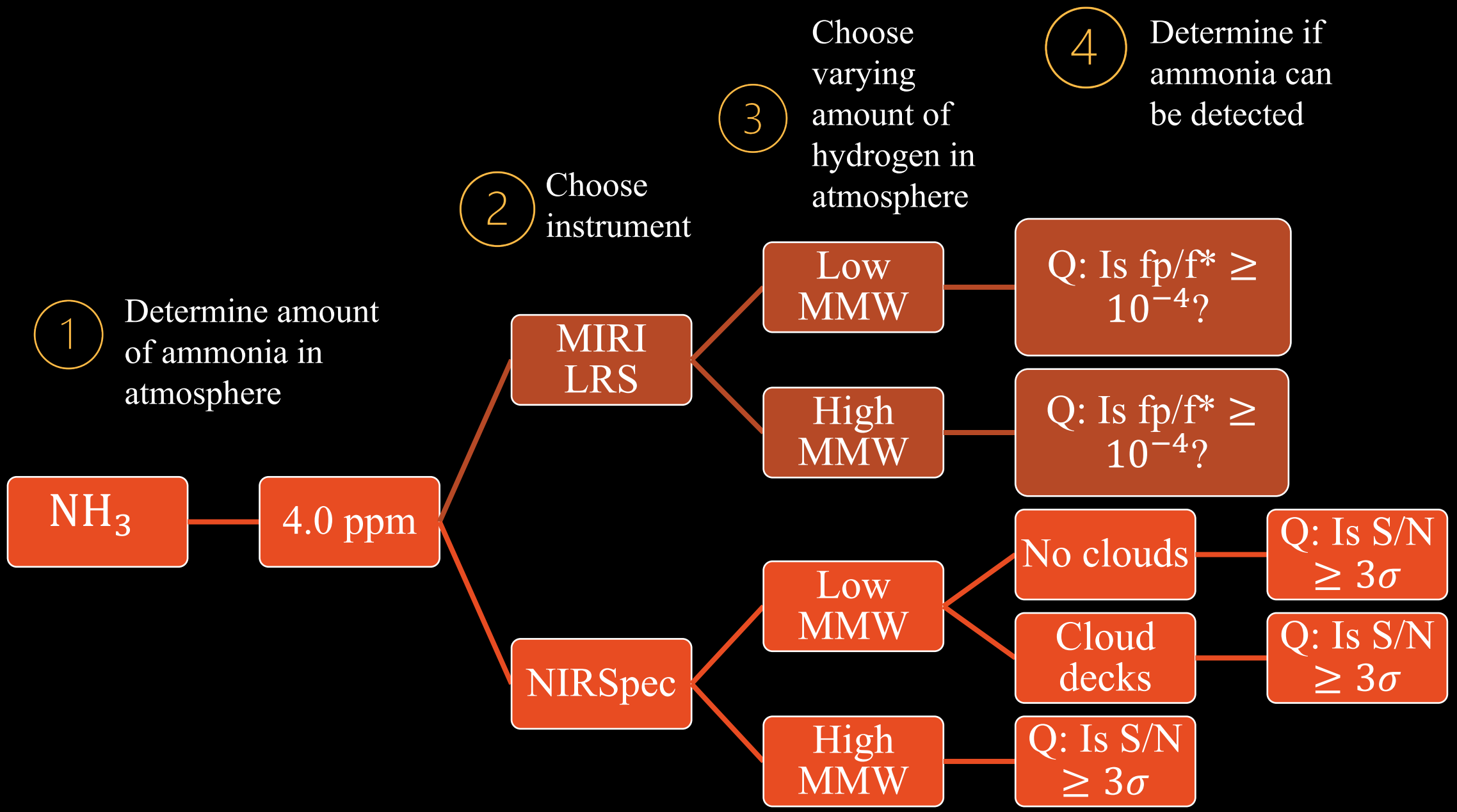
Microbial life can break apart bonds in hydrogen and nitrogen to produce ammonia

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

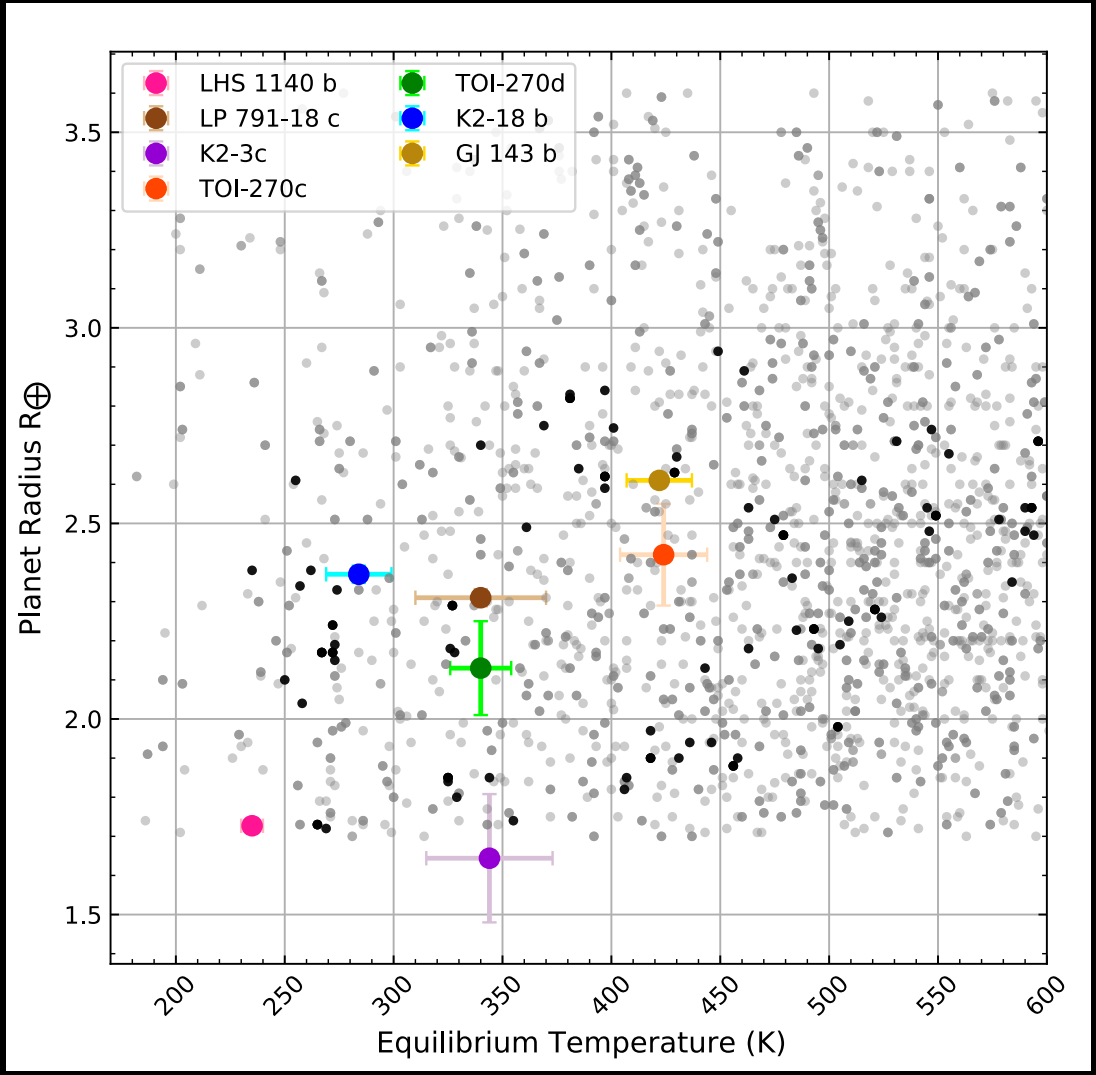
Seager et al. 2013

JWST Will Probe super-Earth Atmospheres




1
Determine 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
NIRSpec
Low MMW
High MMW
Low MMW
High MMW
Q: Is fp/f* ≥ 10^{-4}?
Q: Is fp/f* ≥ 10^{-4}?
No clouds
Cloud decks
Q: Is S/N ≥ 3σ
Q: Is S/N ≥ 3σ
Q: Is S/N ≥ 3σ

Selection Criteria for Targets



- Planet radii between 1.7 and 3.4 $R_\oplus$
- Equilibrium temperature below 450 K
- Distance within 50 pc

Targets for Study

- LHS 1140 b
- LP 791-18 c
- K2-3c
- TOI-270 c
- TOI-270 d
- K2-18 b
- K2-3c
- GJ 143 b

petit RADTRANS

Mollière et al. 2019

Abundances

Pressure Bar

Cloud Decks

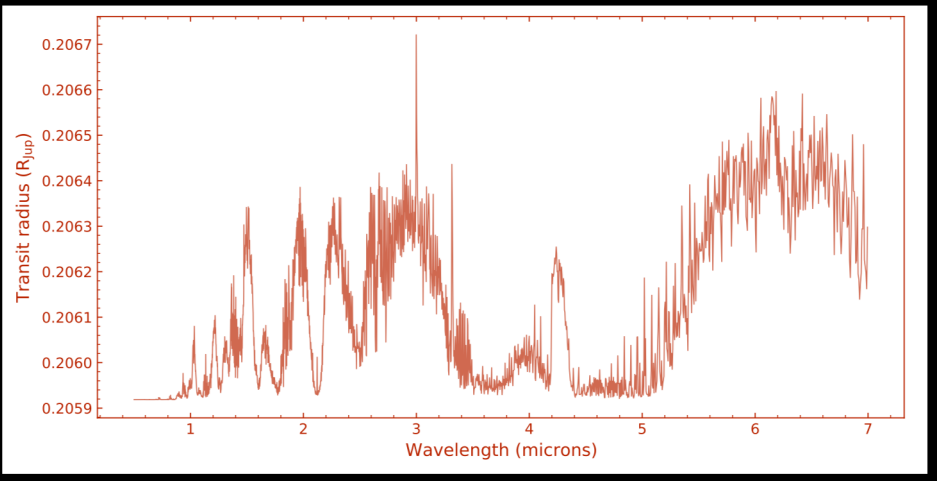
surface gravity

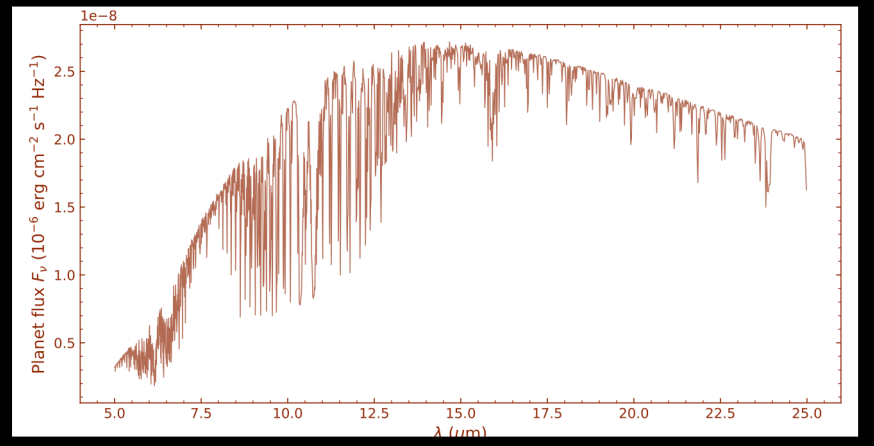
P-T Profile

Radius/ T_{eq}/μ

Simulated Transmission/Emission Spectra

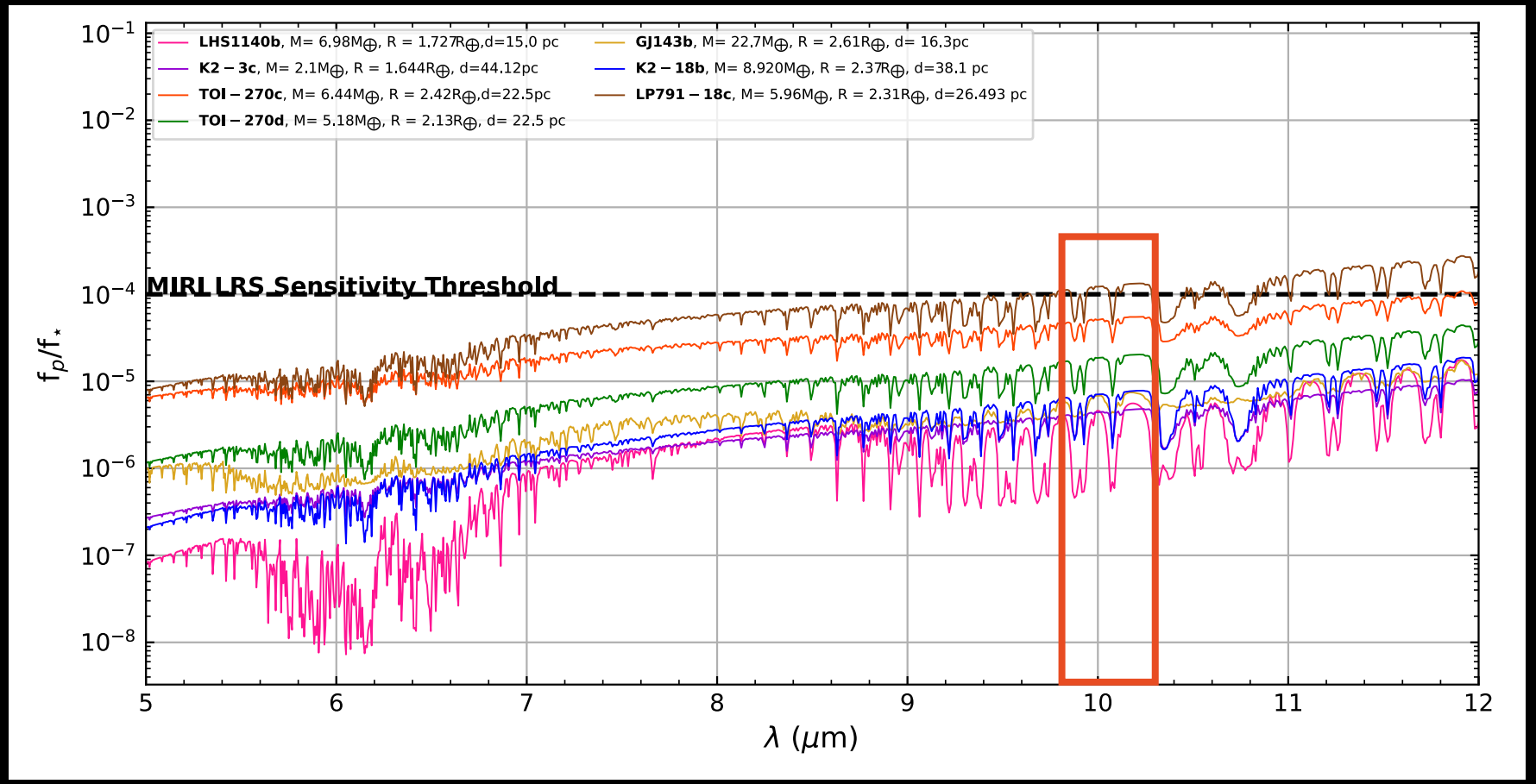
Caprice Phillips (ExoPAG 23)



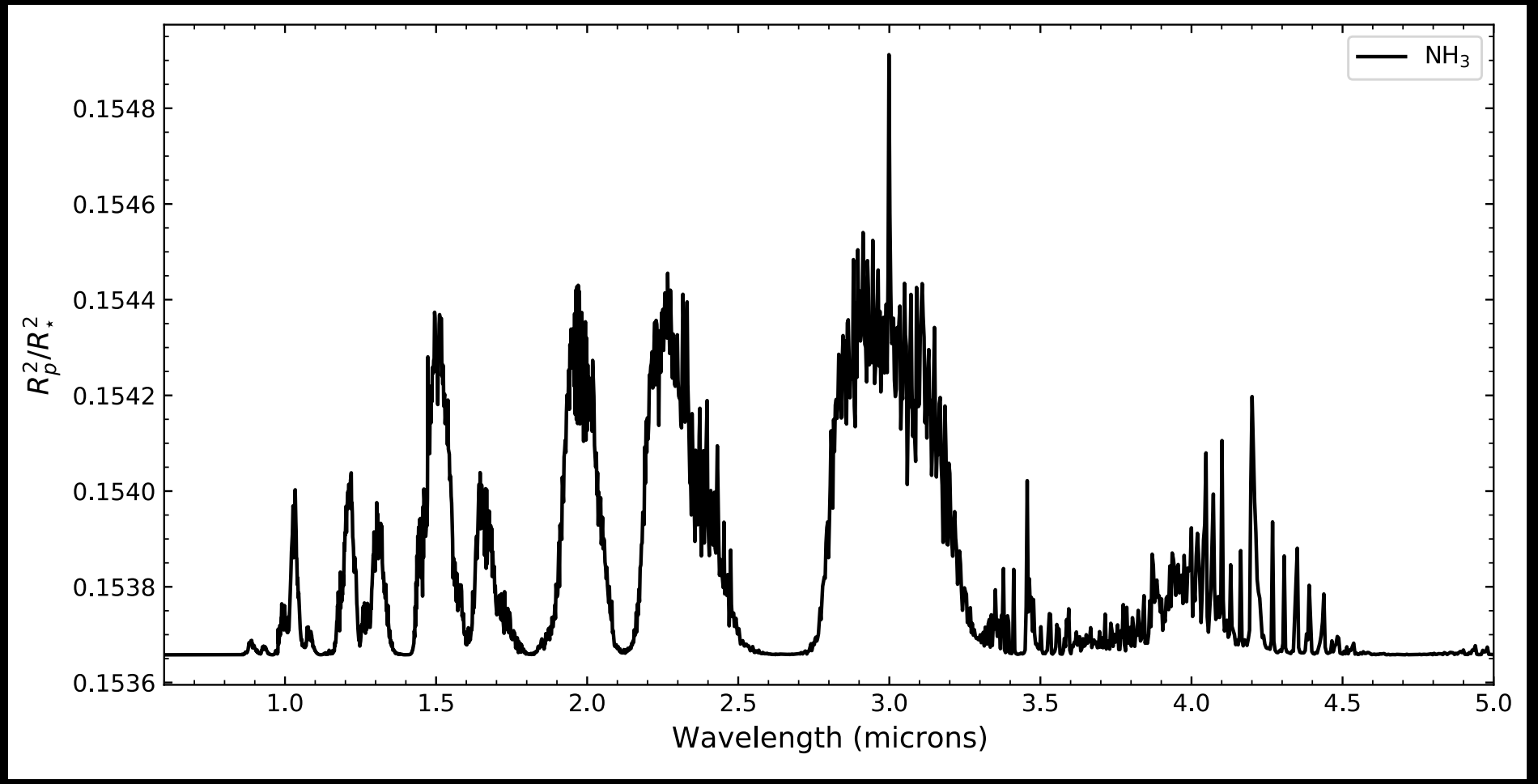


10μm Ammonia Feature Is Difficult to Detect with MIRI LRS

Phillips et al. 2021 (In Prep)

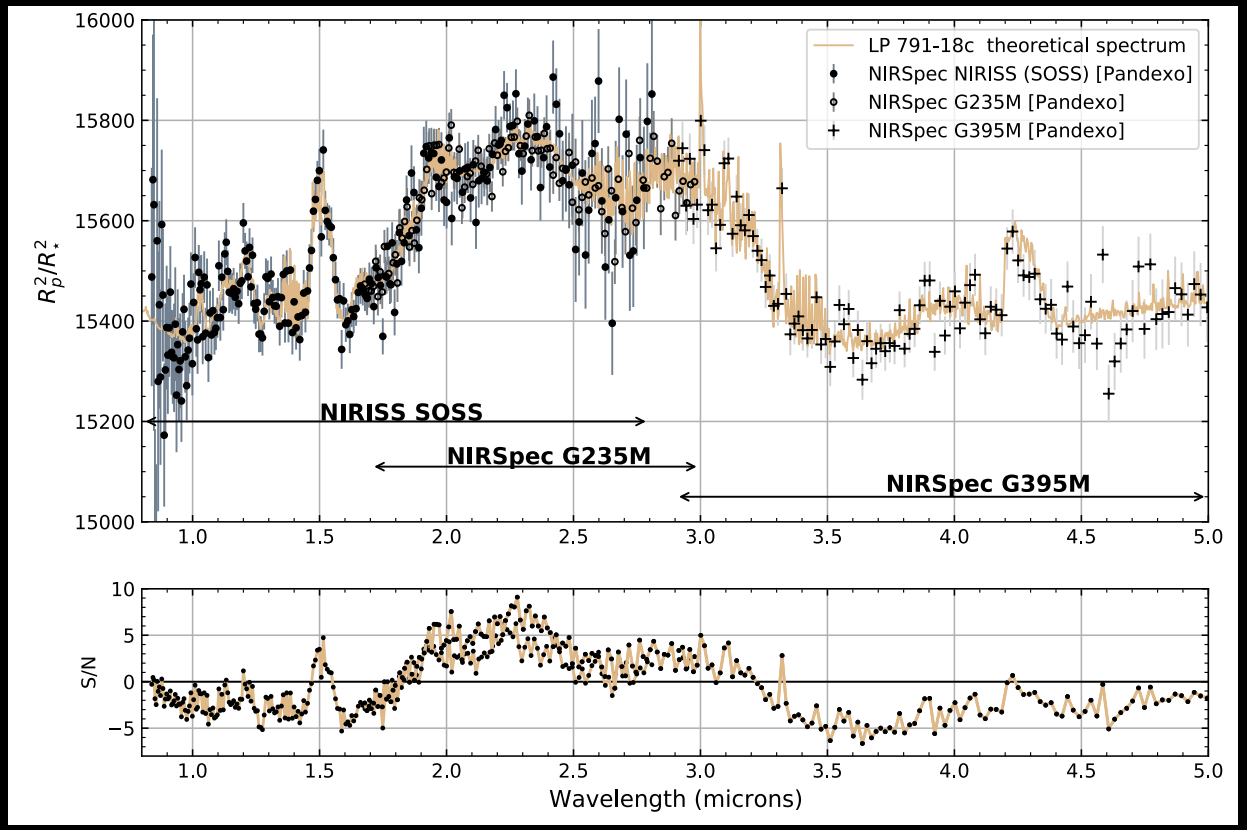


Ammonia has many features in the NIR

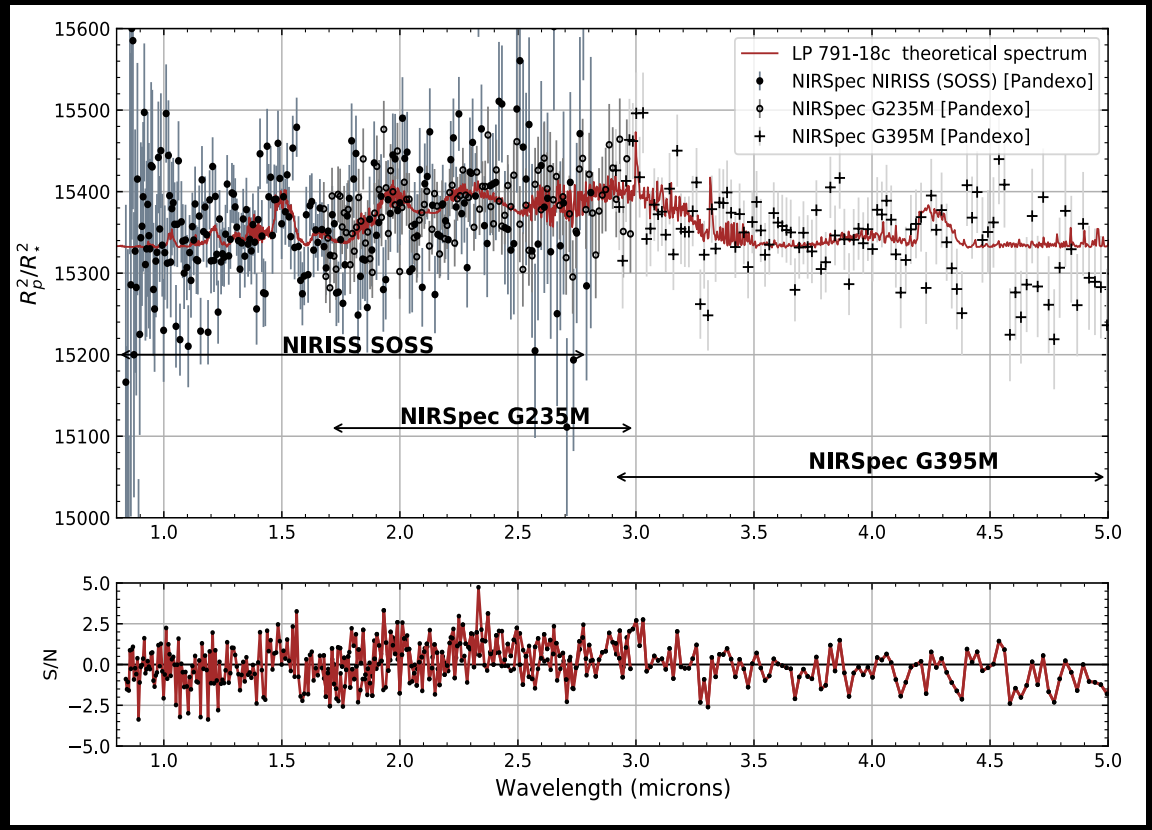


Signal-To-Noise Scales with $\frac{1}{\mu}$ → Mean Molecular Weight

μ~4.55
(90%H_2:10% N_2)

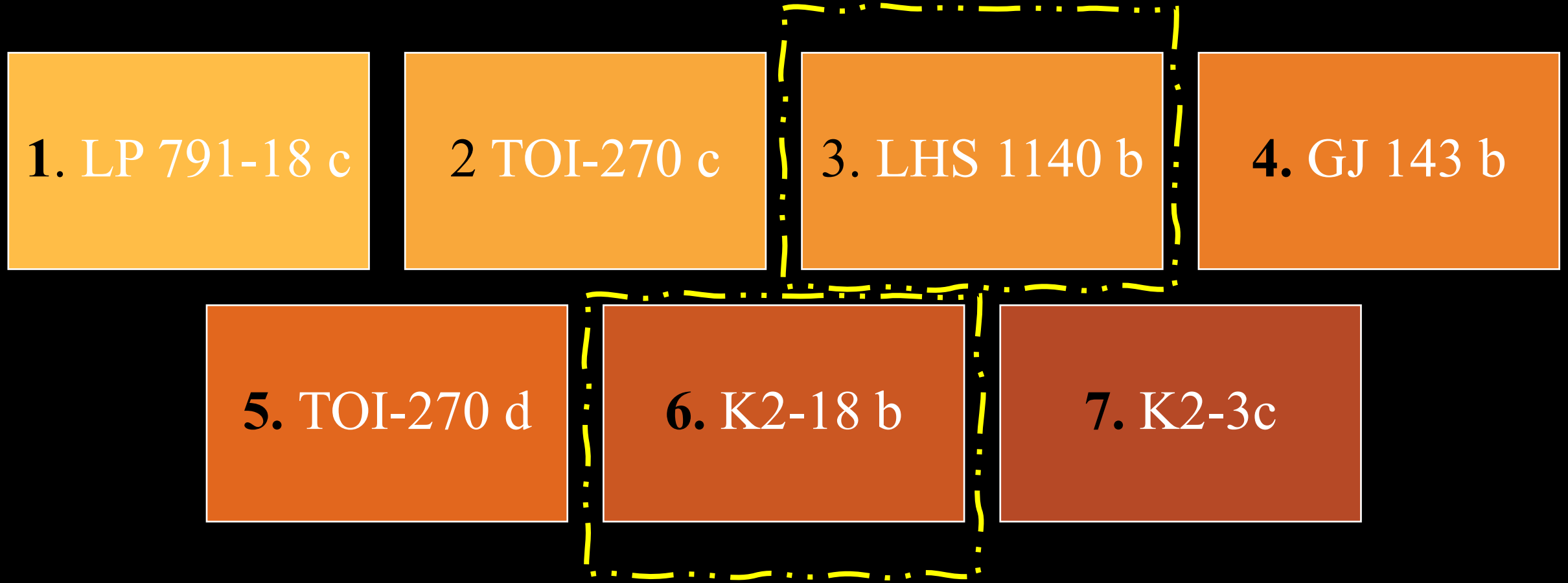


μ~21.5
(25% H_2:75% N_2)



Phillips et al. 2021 (In Prep)

Rank List of Targets



Takeaways

- super-Earths are more massive/common than Earth and are promising sites to look for signs of life
- Ammonia is a biosignature unique to a hydrogen dominated atmosphere
- The 10μm ammonia feature is difficult to detect with the MIRI LRS instrument
- A lower mean molecular weight atmosphere produces stronger features with transmission spectroscopy
- NIRSpec may be a better tool than MIRI LRS to detect ammonia in the atmosphere of super-Earths