UV OBSERVATIONS OF EXOPLANET ATMOSPHERES: THE CURRENT LANDSCAPE

Jessie Christiansen, Caltech/IPAC
(with input from Jessica Spake, Hannah Wakeford)

THE ERA OF EXOPLANET ATMOSPHERES IS HERE

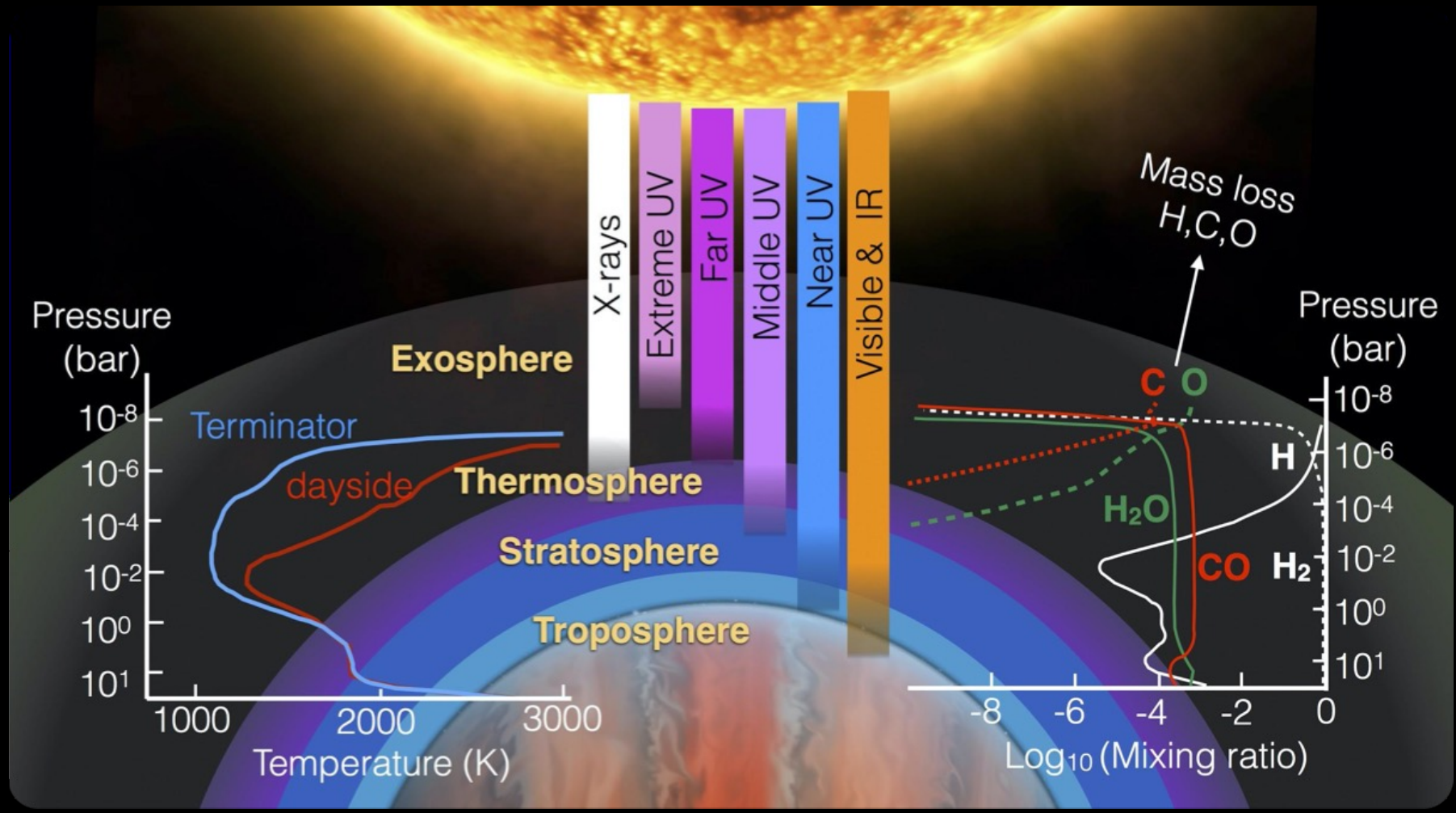
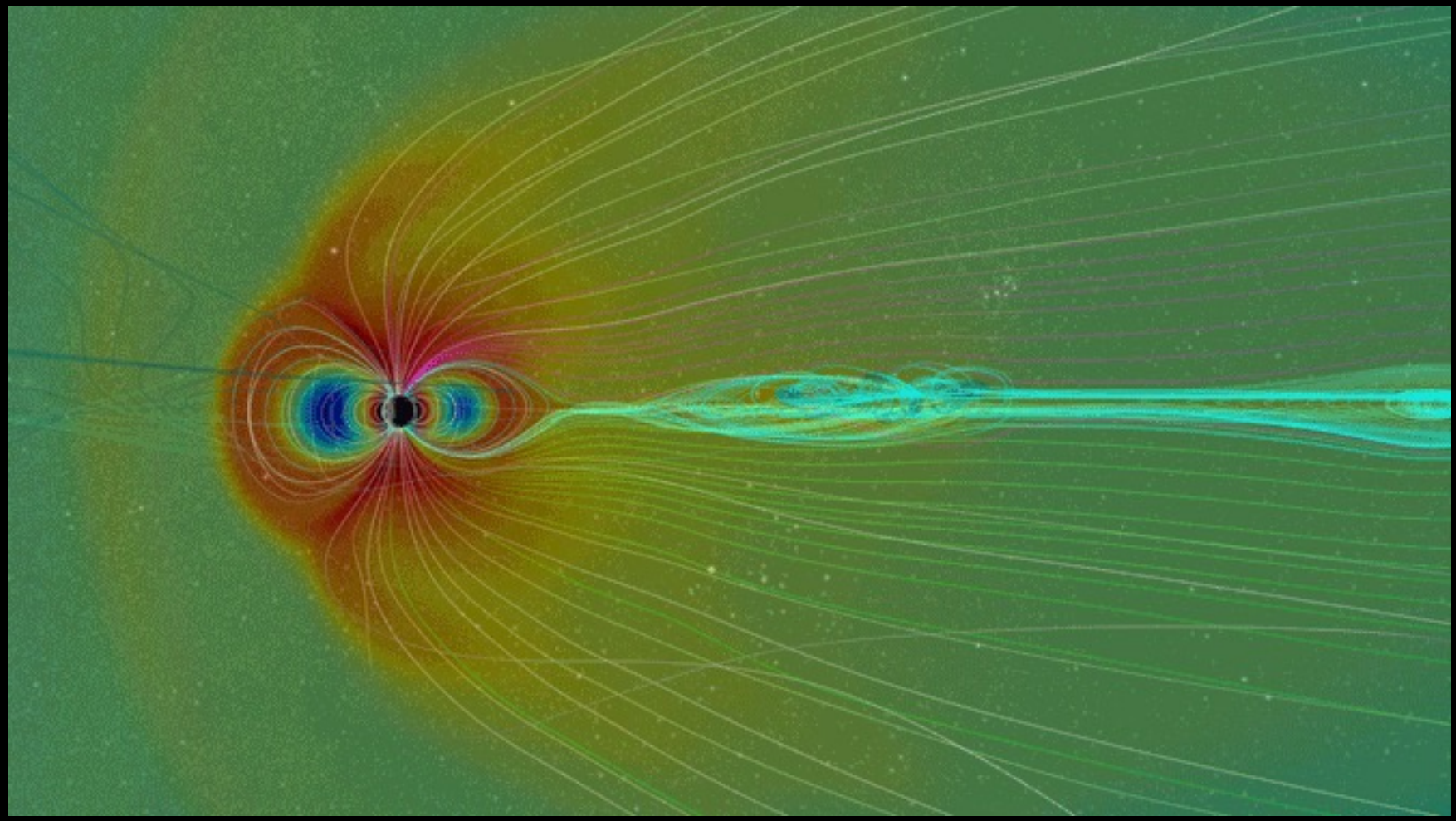


Image credit: M. Lopez-Morales & D. Sing

MAJOR EXOPLANET ATMOSPHERES PROCESSES PROBED BY UV

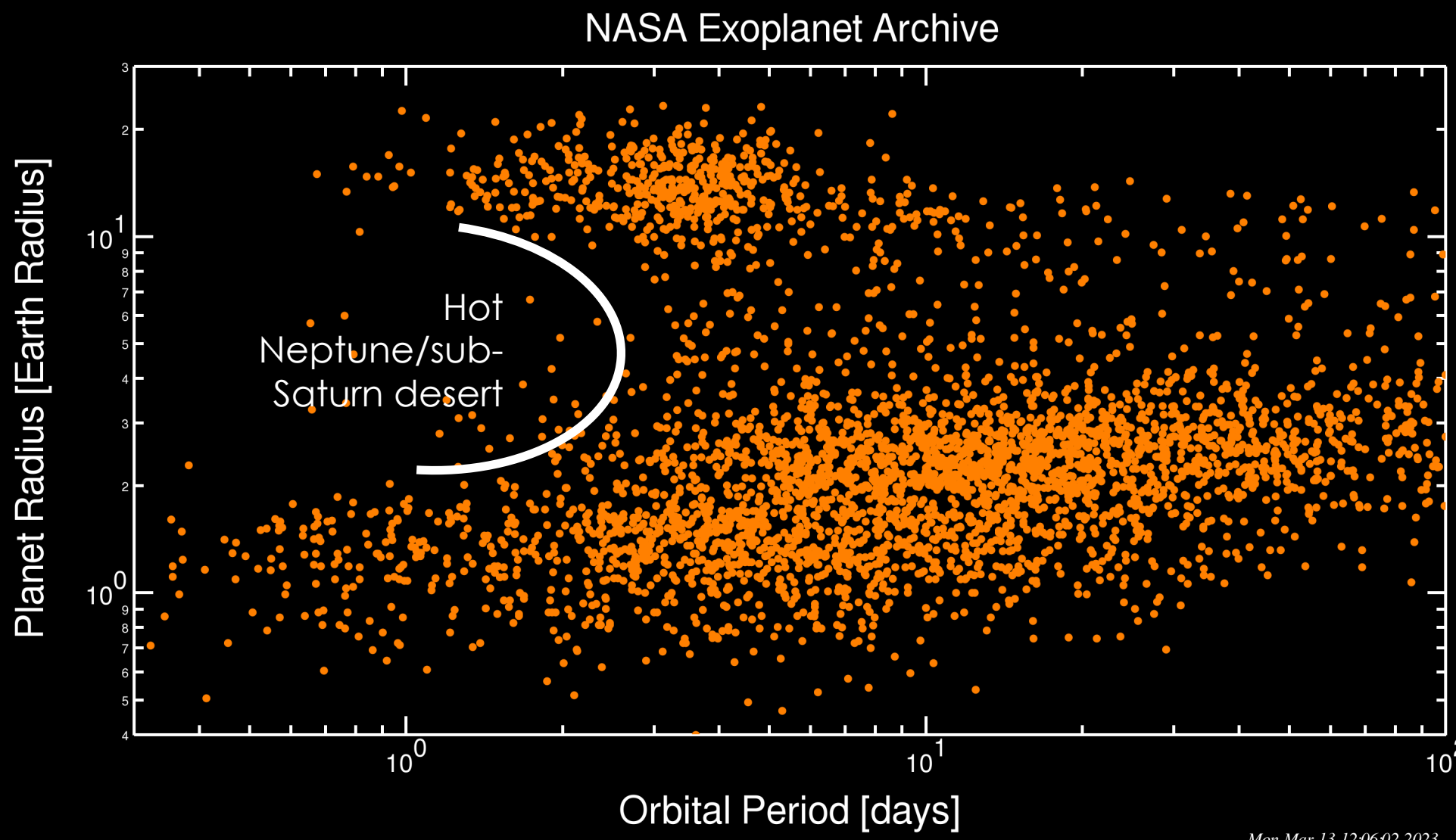
1. Atmospheric escape
2. Metal rain-out in ultra-hot atmospheres
3. Aerosol production in cooler atmospheres

ATMOSPHERIC ESCAPE

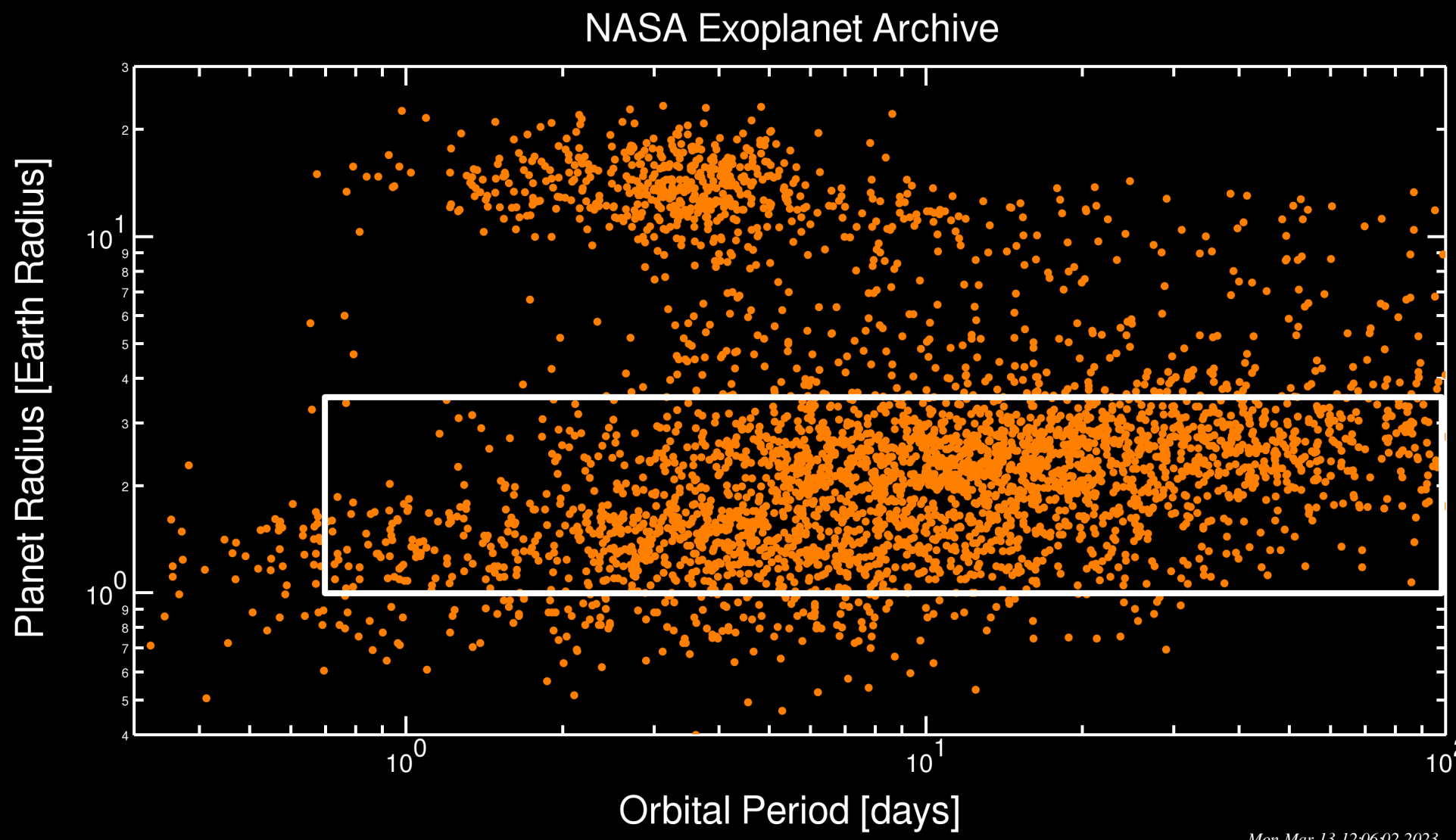


GSFC CCMC

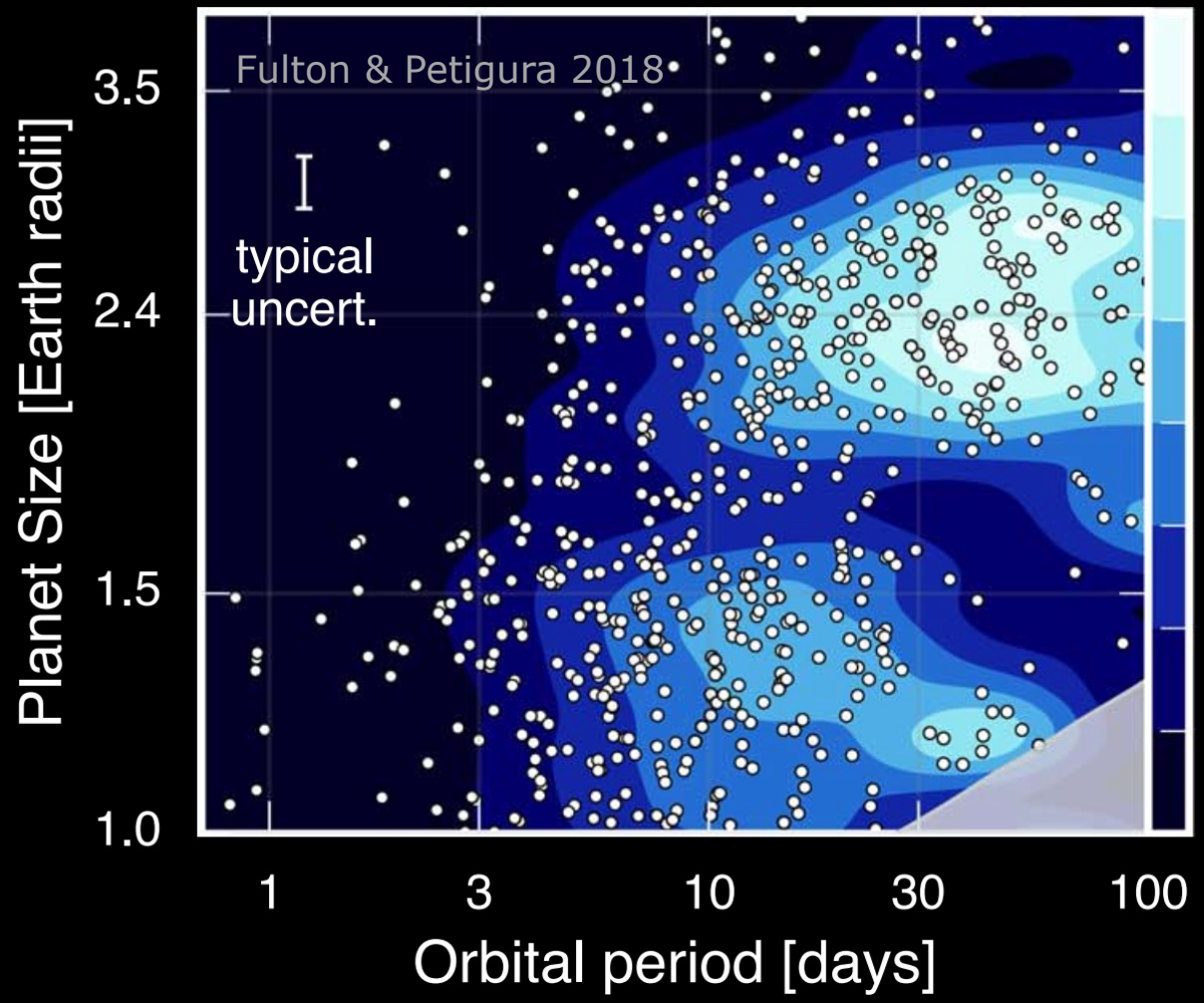
ATMOSPHERIC ESCAPE

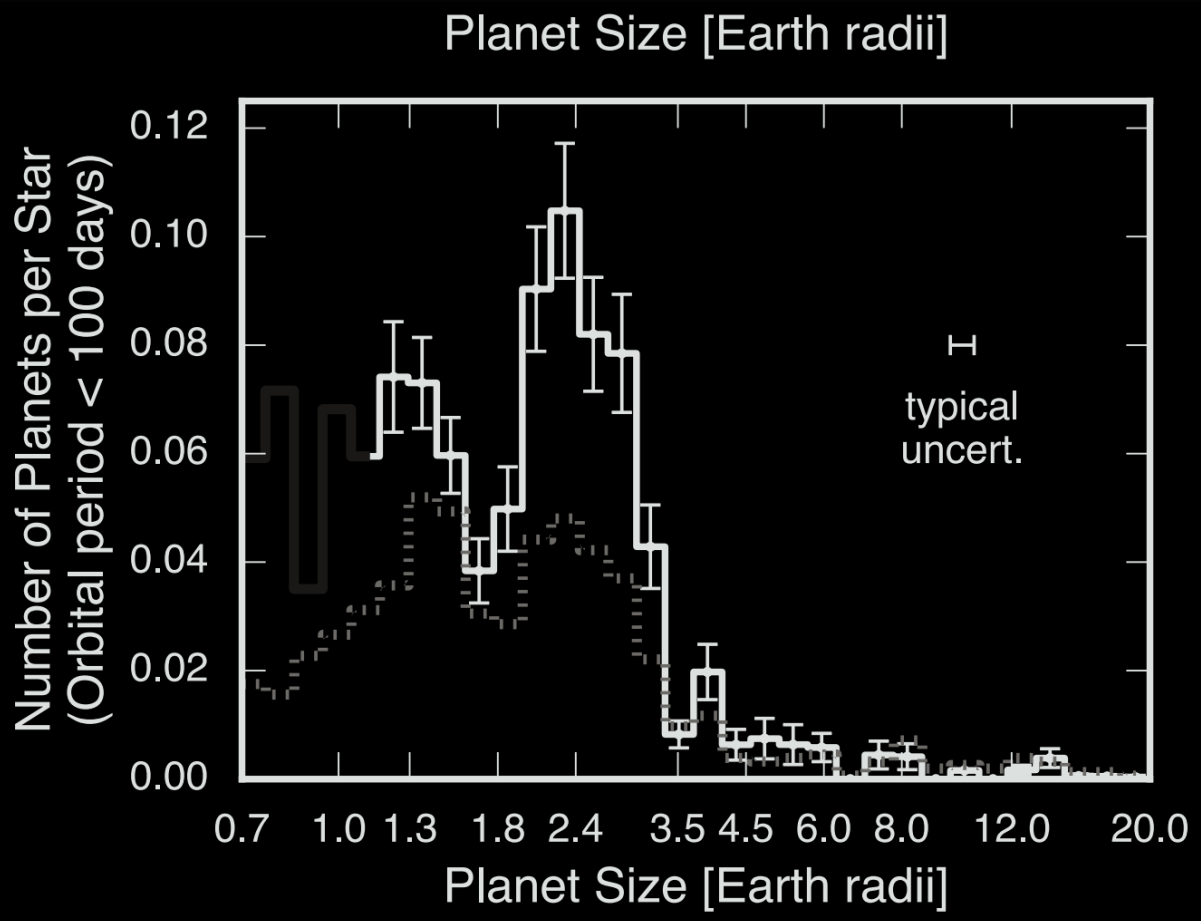


ATMOSPHERIC ESCAPE



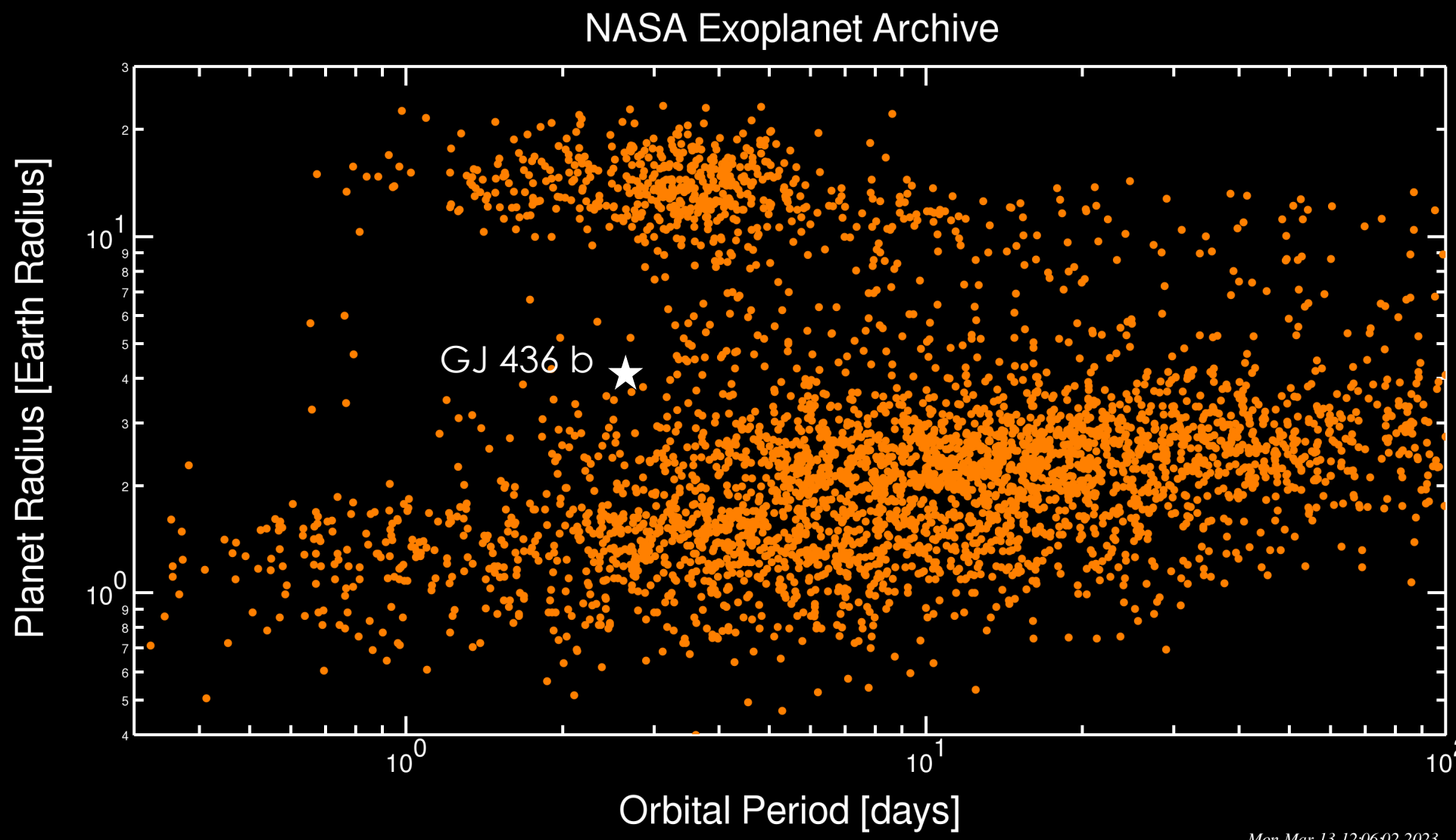
ATMOSPHERIC ESCAPE



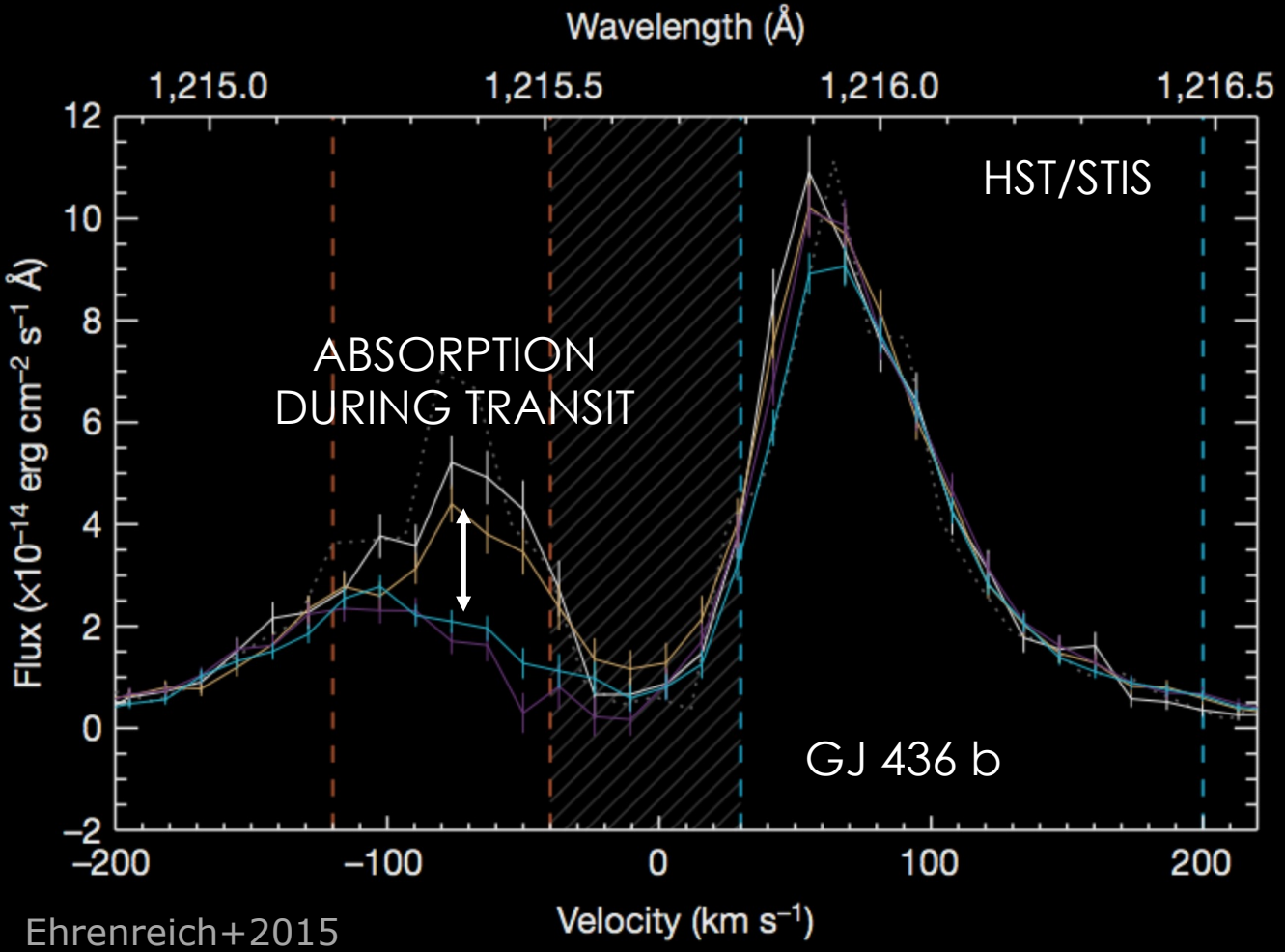


Potentially very significant for $\eta_{\oplus}$!!

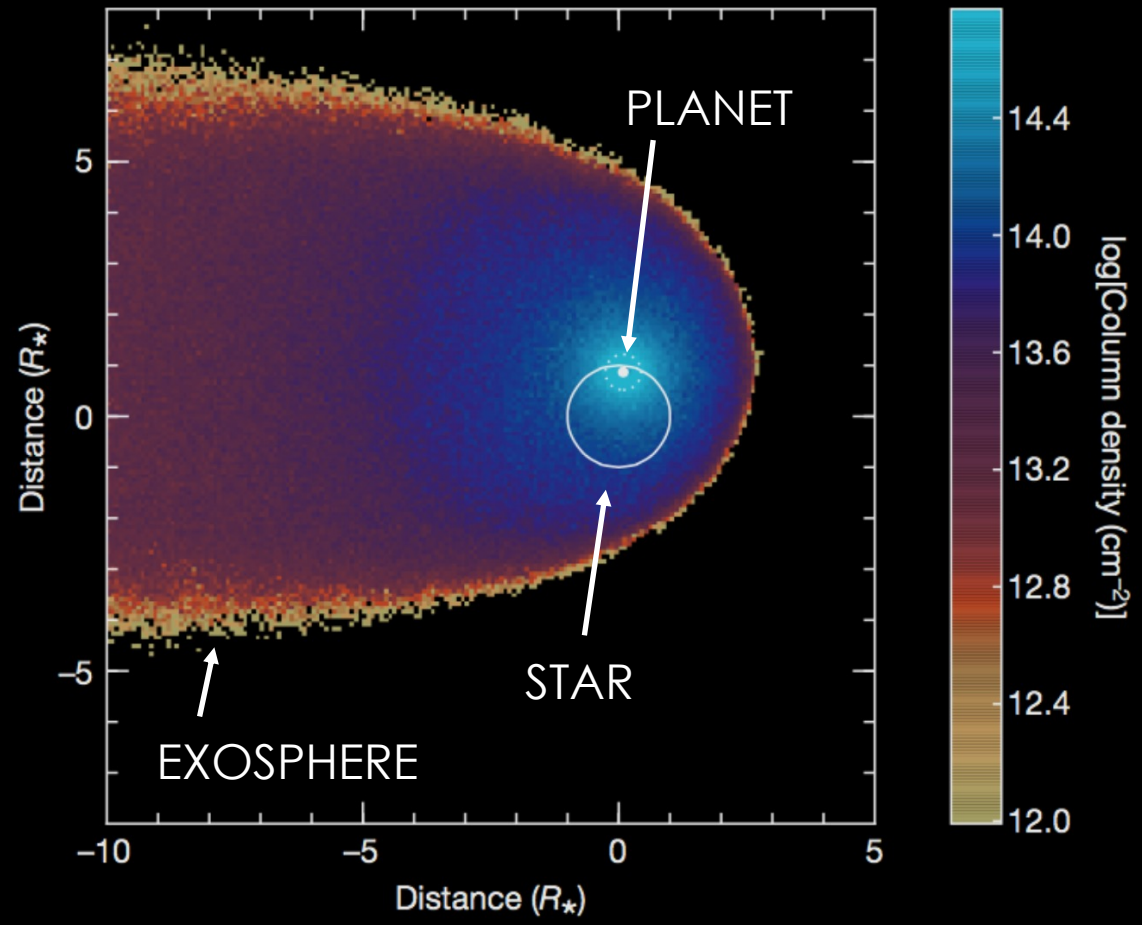
ATMOSPHERIC ESCAPE



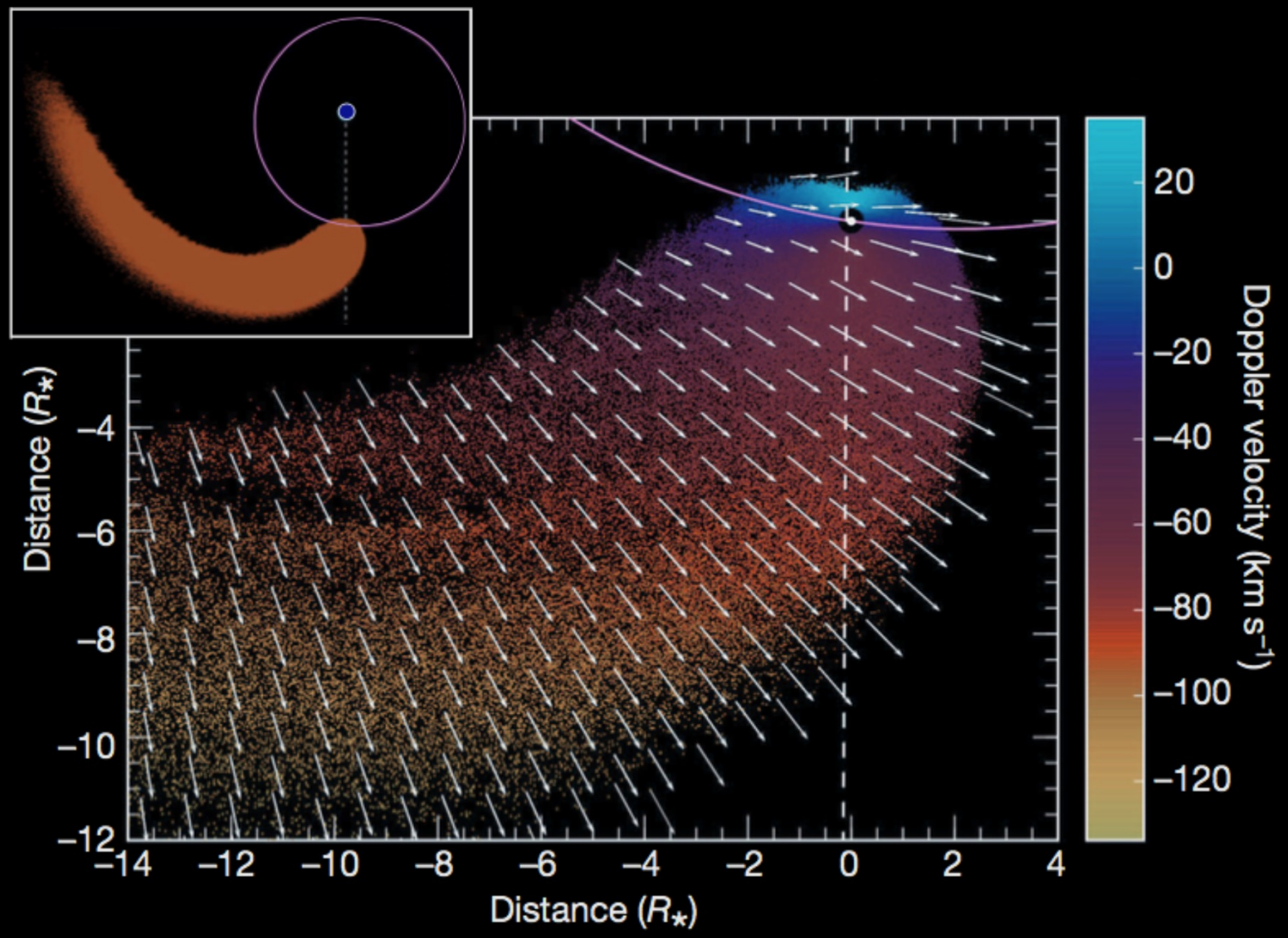
ATMOSPHERIC ESCAPE



Ehrenreich+2015



ATMOSPHERIC ESCAPE



$\dot{M}$=~10^8-10^9 g/s

(Ψ ~ 10^{32} g)

(Nice review by L. dos Santos (2022) of the detections (and non-detections!) of atmospheric escape to date)

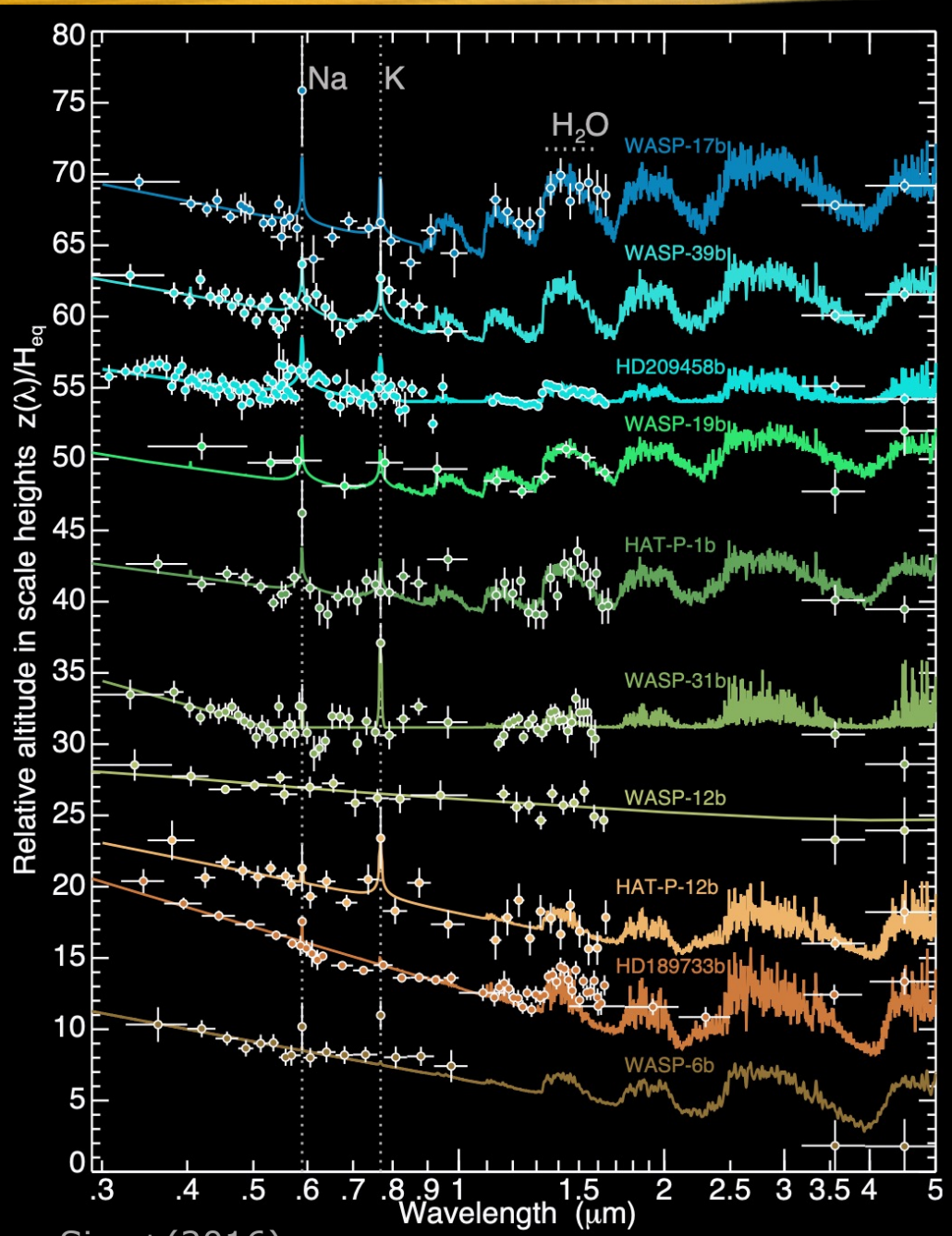
(Coming soon: AU Mic b detection AND non-detection with STIS)

ATMOSPHERIC ESCAPE

Takeaway: we need to study atmospheric escape for a larger sample of planets, around younger stars…

…UVEX?

AEROSOLS

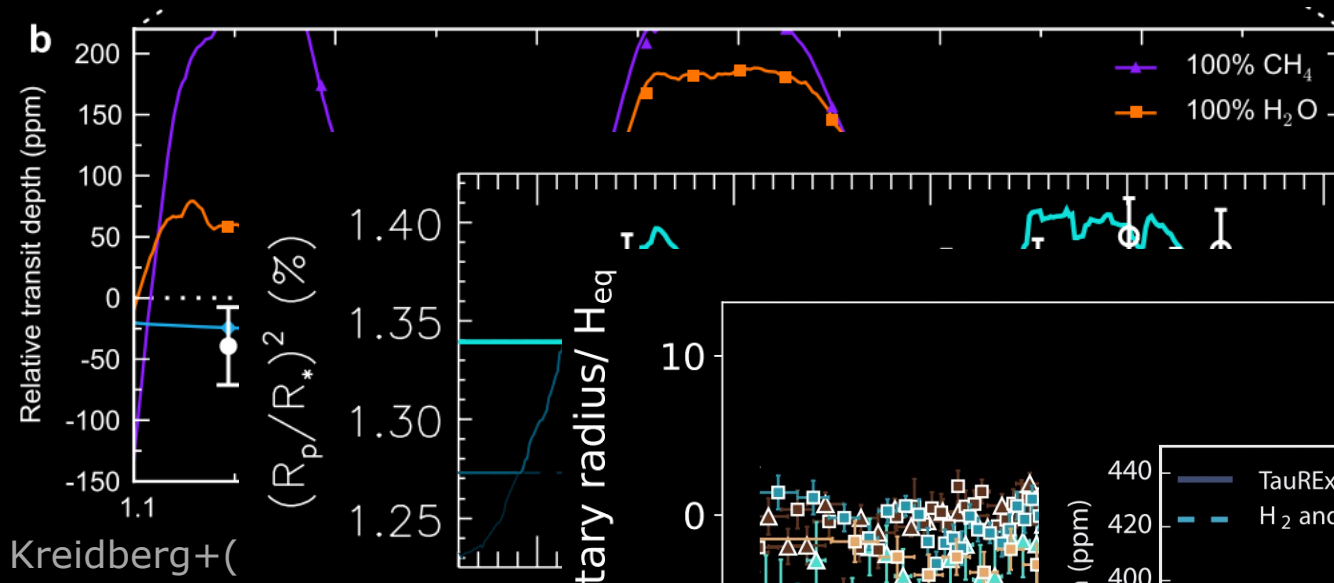


Sing+(2016)

CLEAR

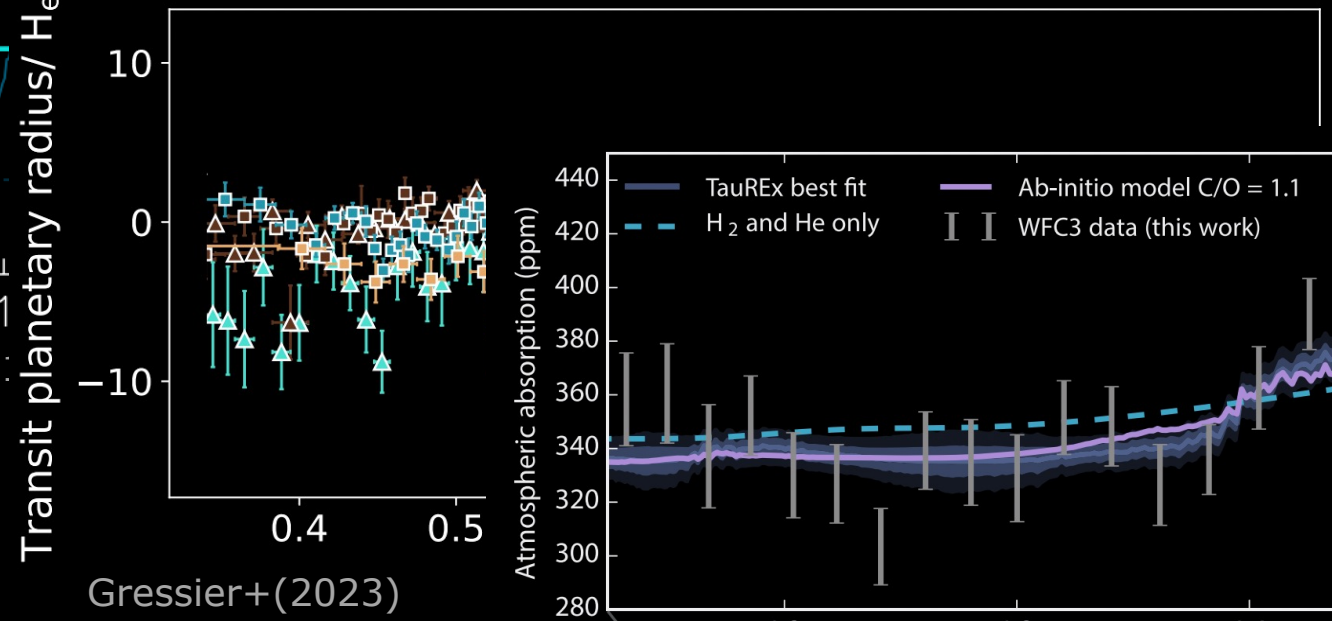
CLOUDY

AEROSOLS



Kreidberg+(

Berta+(20

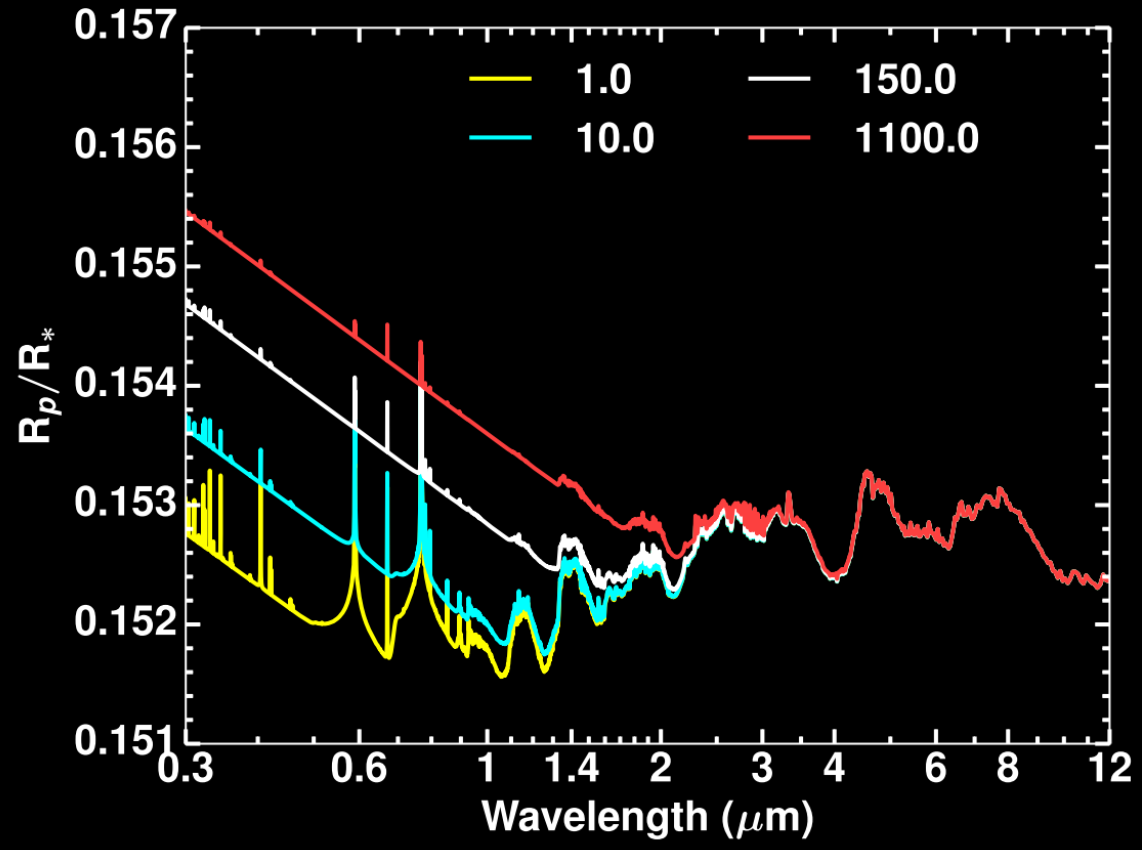


Gressier+(2023)

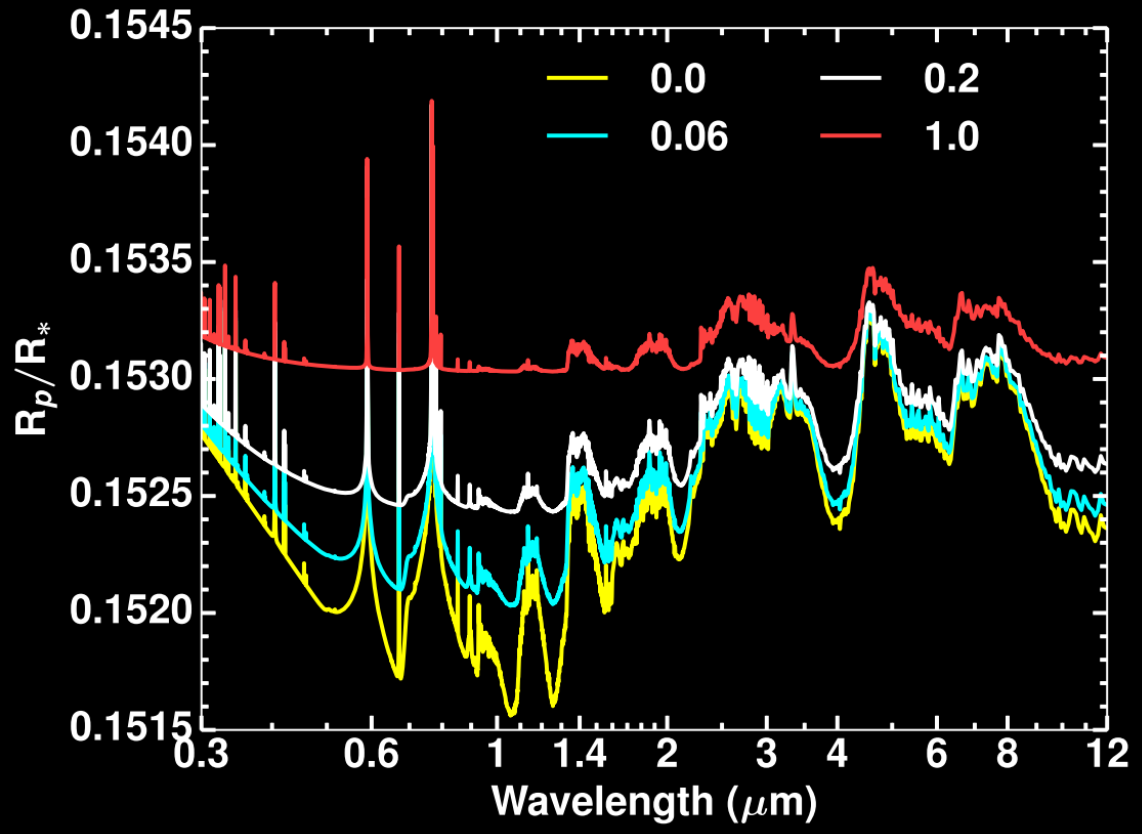
Tsiaras+(2016)

AEROSOLS

PHOTOCHEMICAL HAZES

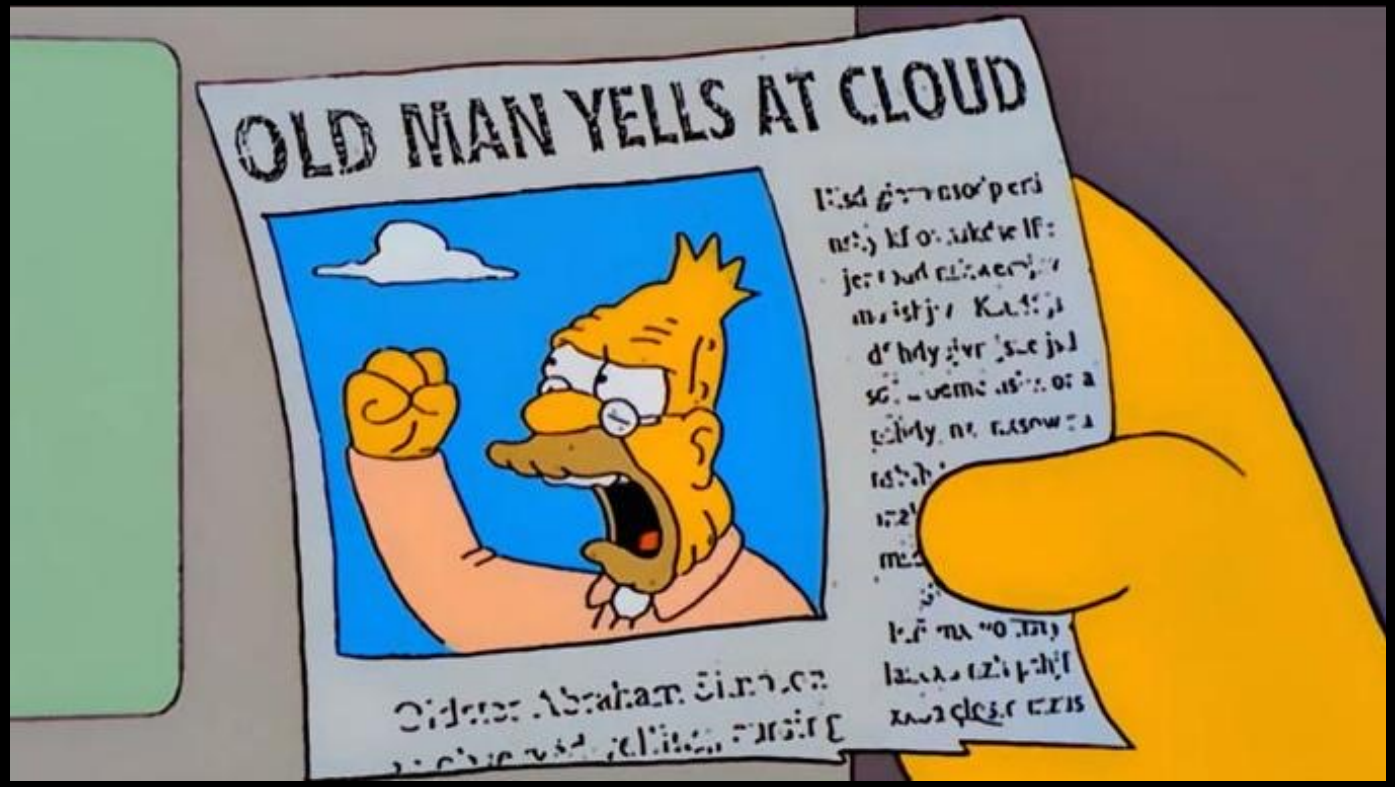


CONDENSATION CLOUDS



Goyal+2017, see also review by Ohno & Kawashima 2020

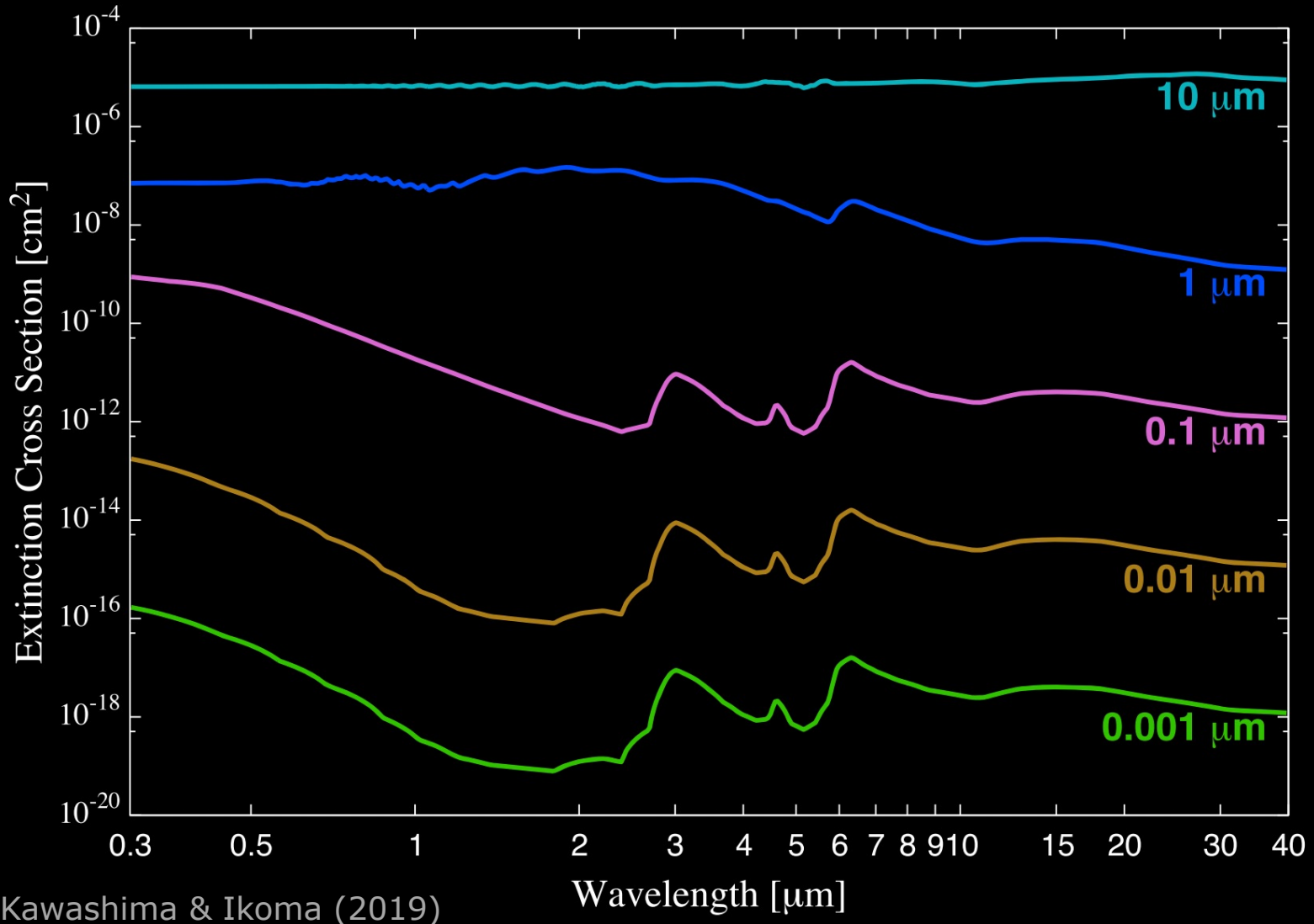
AEROSOLS



There is a *degeneracy* in the cause for muted spectral features

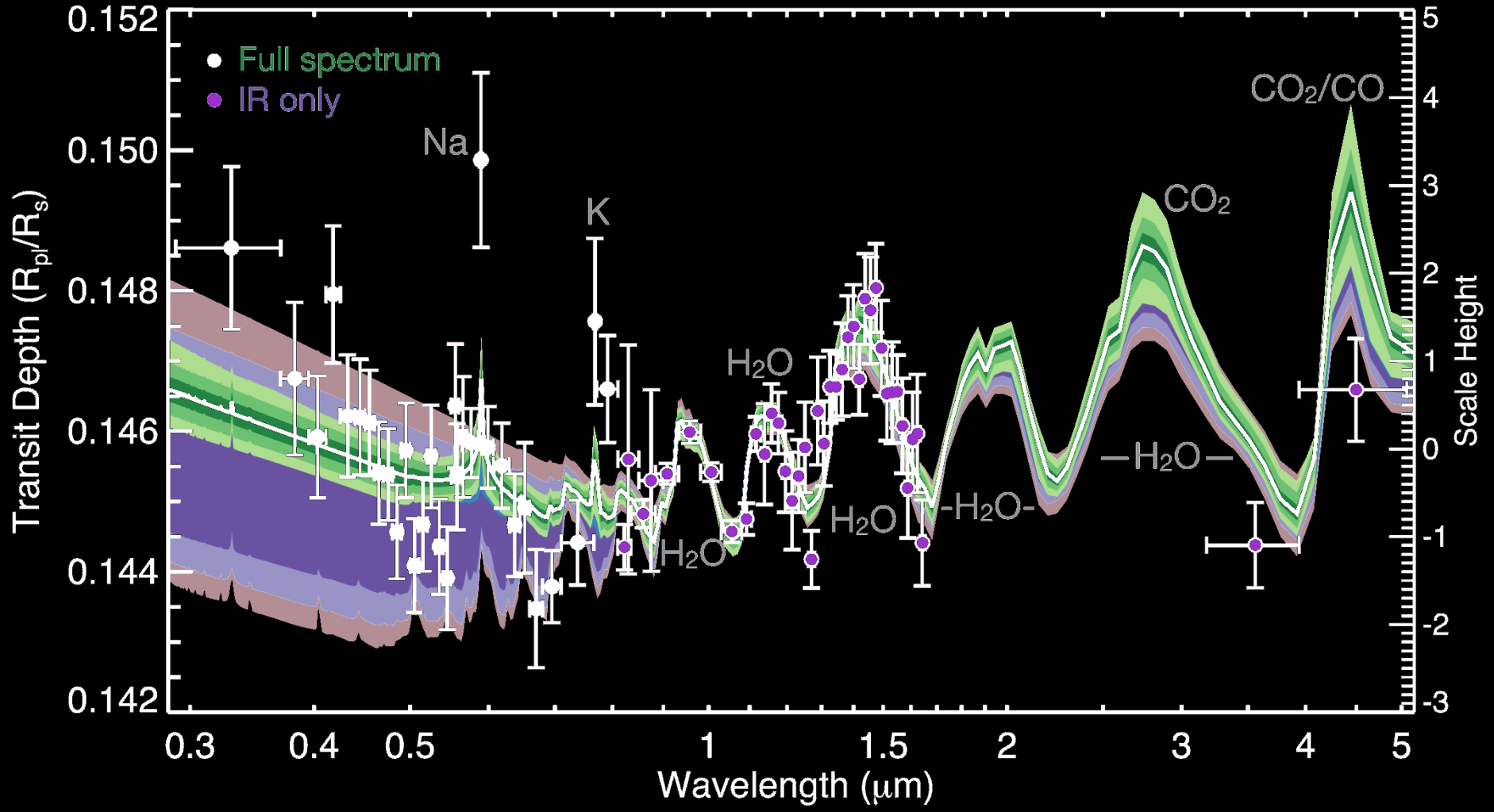
Either the atmosphere has a high mean molecular weight, or aerosols (clouds/hazes) are scattering/blocking the starlight

AEROSOLS



Kawashima & Ikoma (2019)

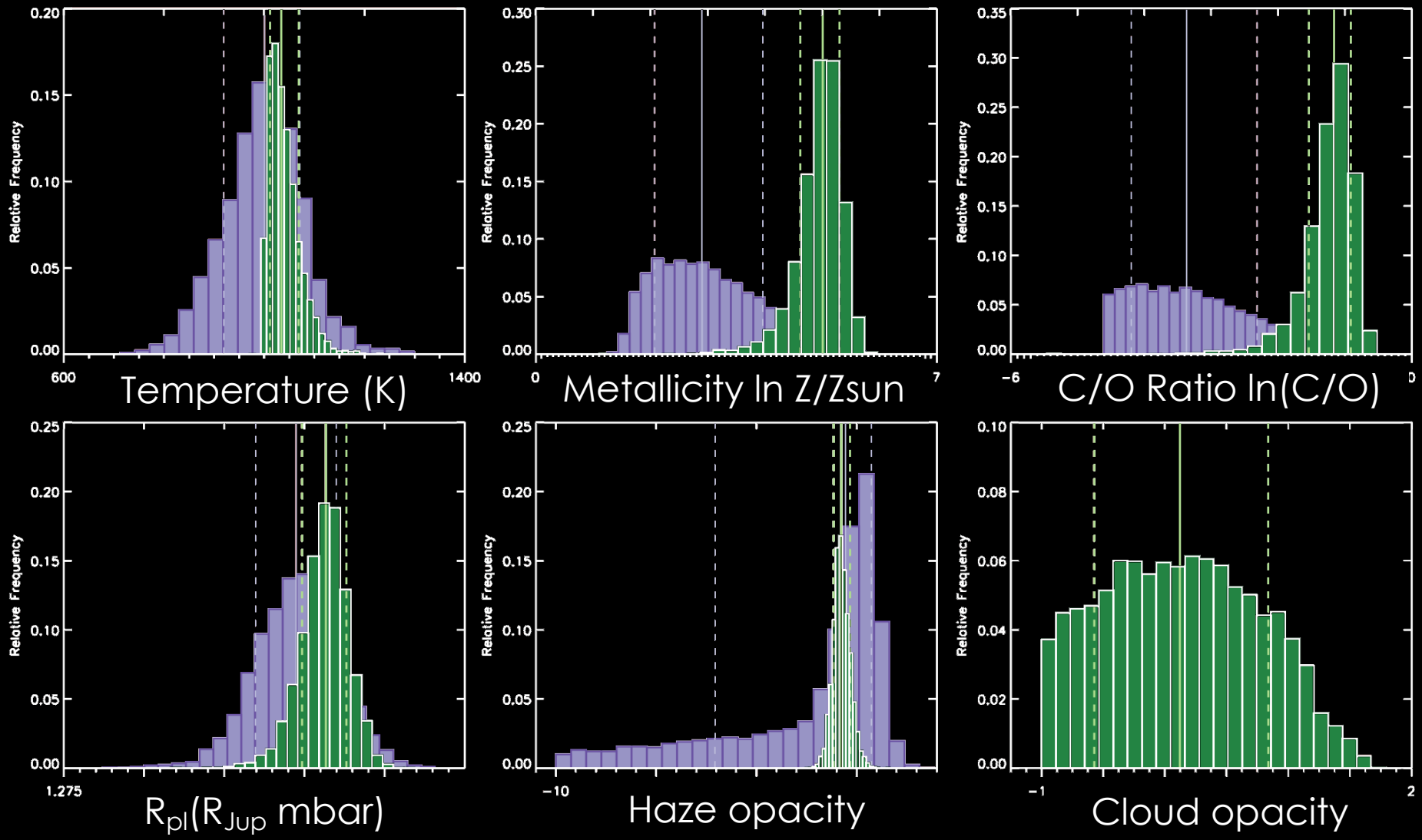
AEROSOLS



Wakeford+(2018)

AEROSOLS

Wakeford+(2018)



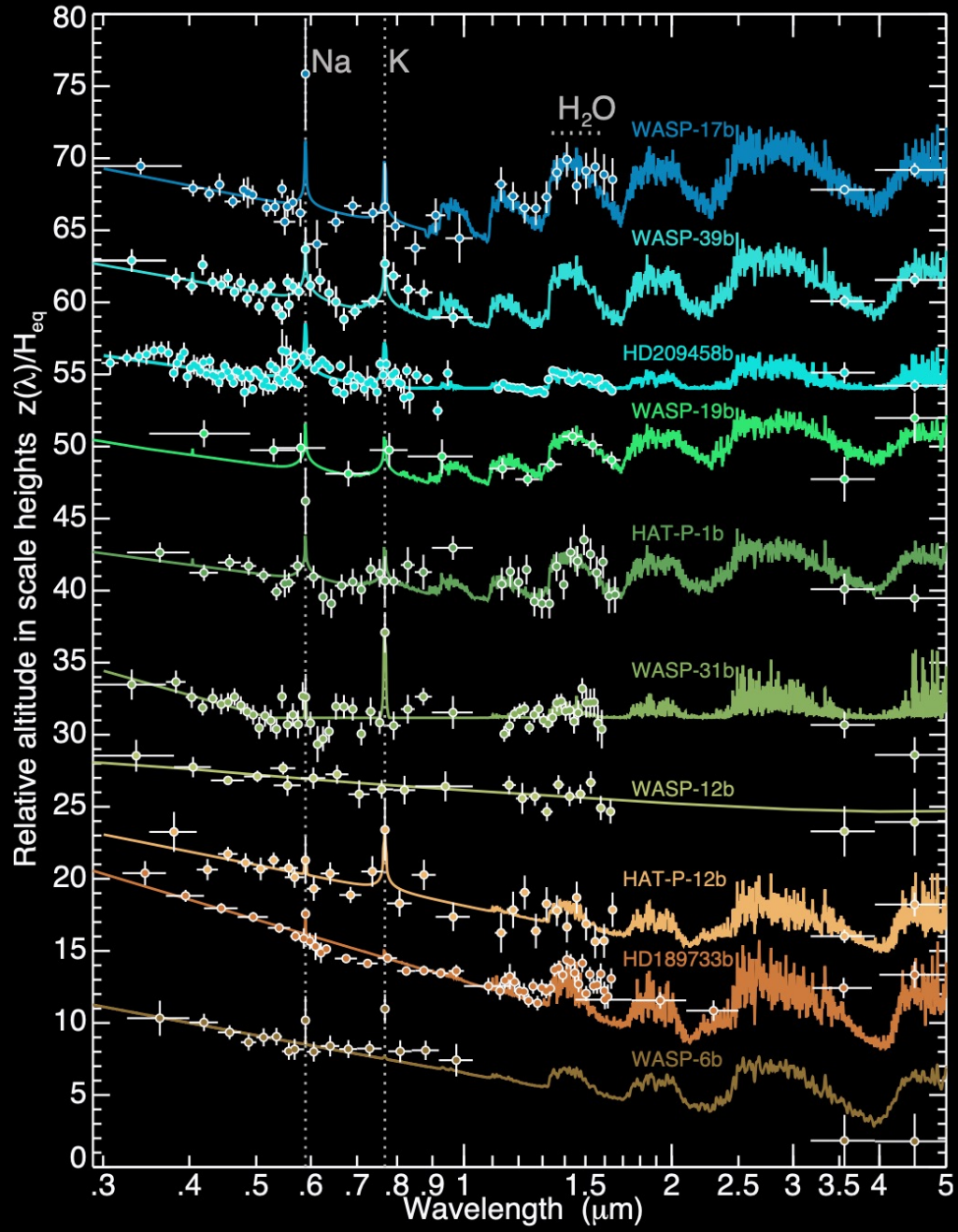
AEROSOLS

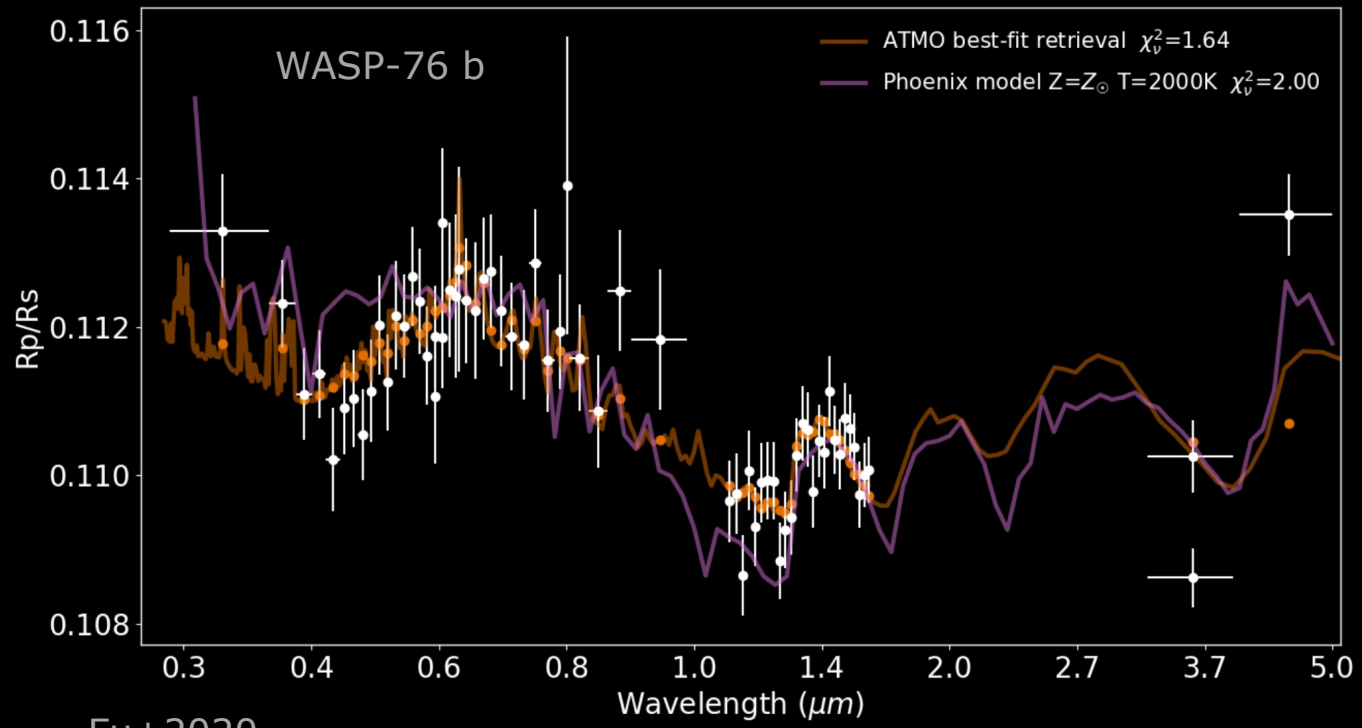
"…without the signature of molecular Rayleigh scattering—even with robustly detected infrared absorption features (>10σ)—there is no reliable way to tell from the transmission spectrum whether the absorber is a main constituent of the atmosphere or just a minor species" (Benneke & Seager 2012)

Takeaway: JWST infrared spectra will likely need additional transmission spectra at NUV/blue optical wavelengths to constrain aerosols and enable the most robust characterization of the atmospheric properties - especially for small, cool planets…

…UVEX?

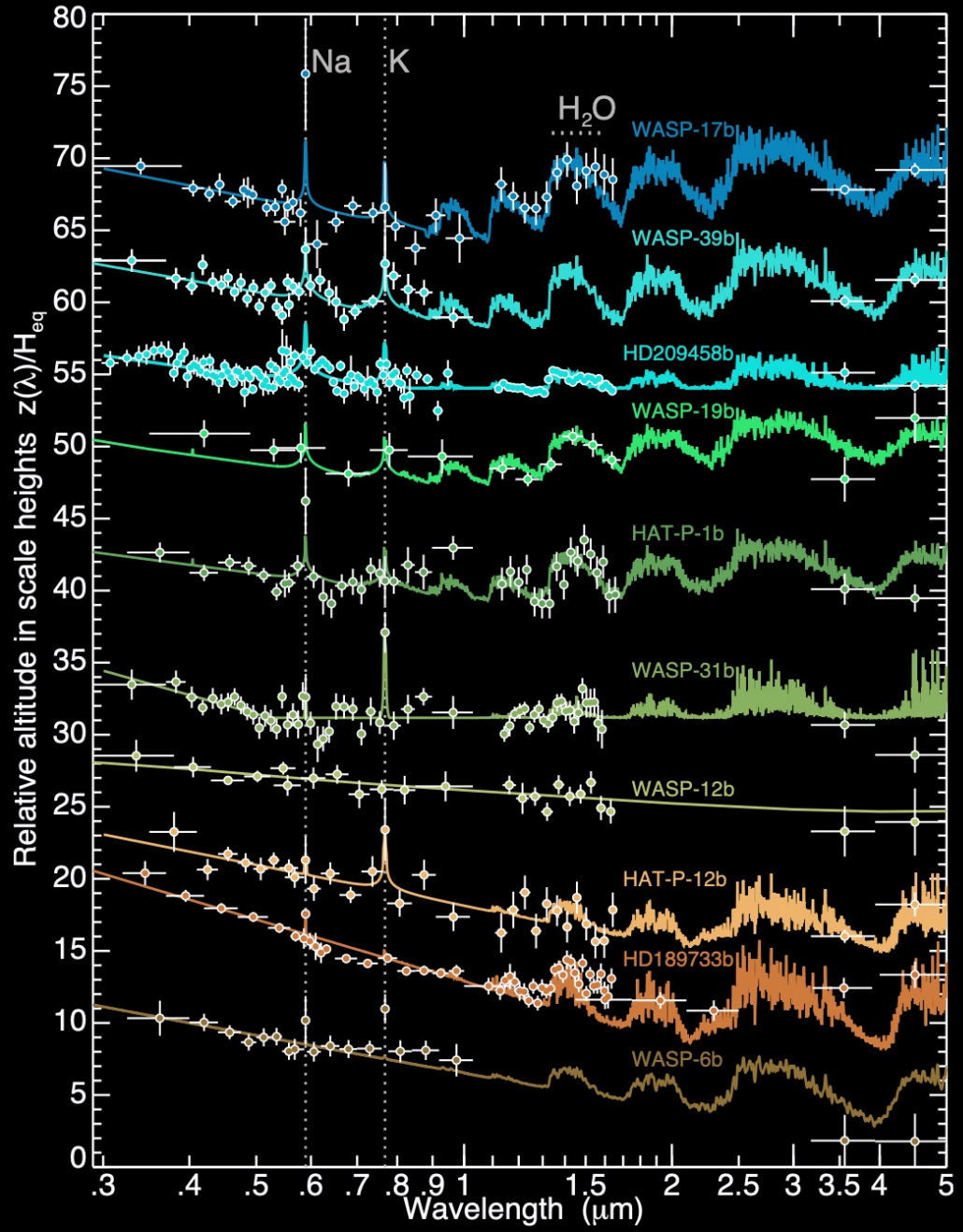
METAL RAIN-OUT





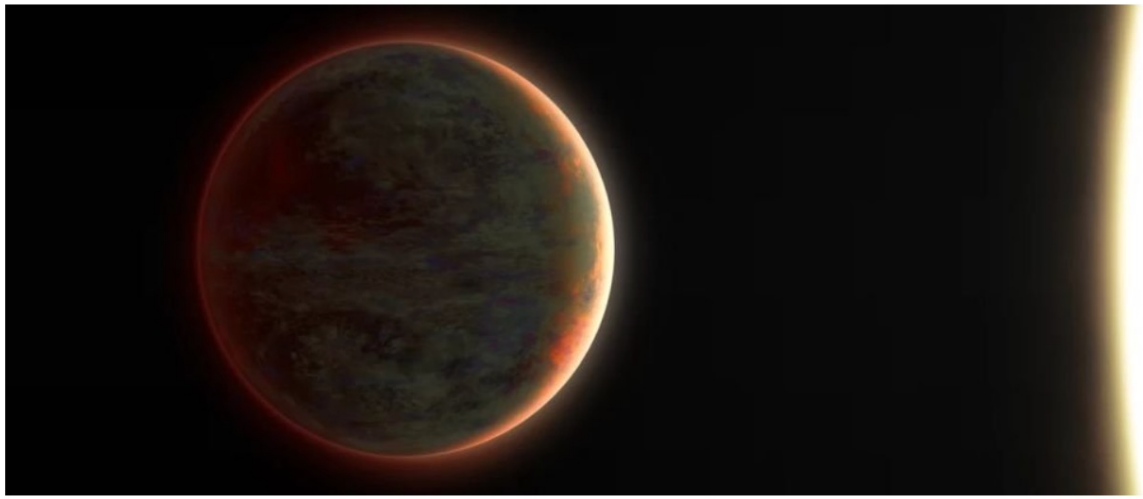
Fu+2020

METAL RAIN-OUT



This Extremely Extreme Exoplanet Has Metal Vapor Clouds And Rains Liquid Jewels

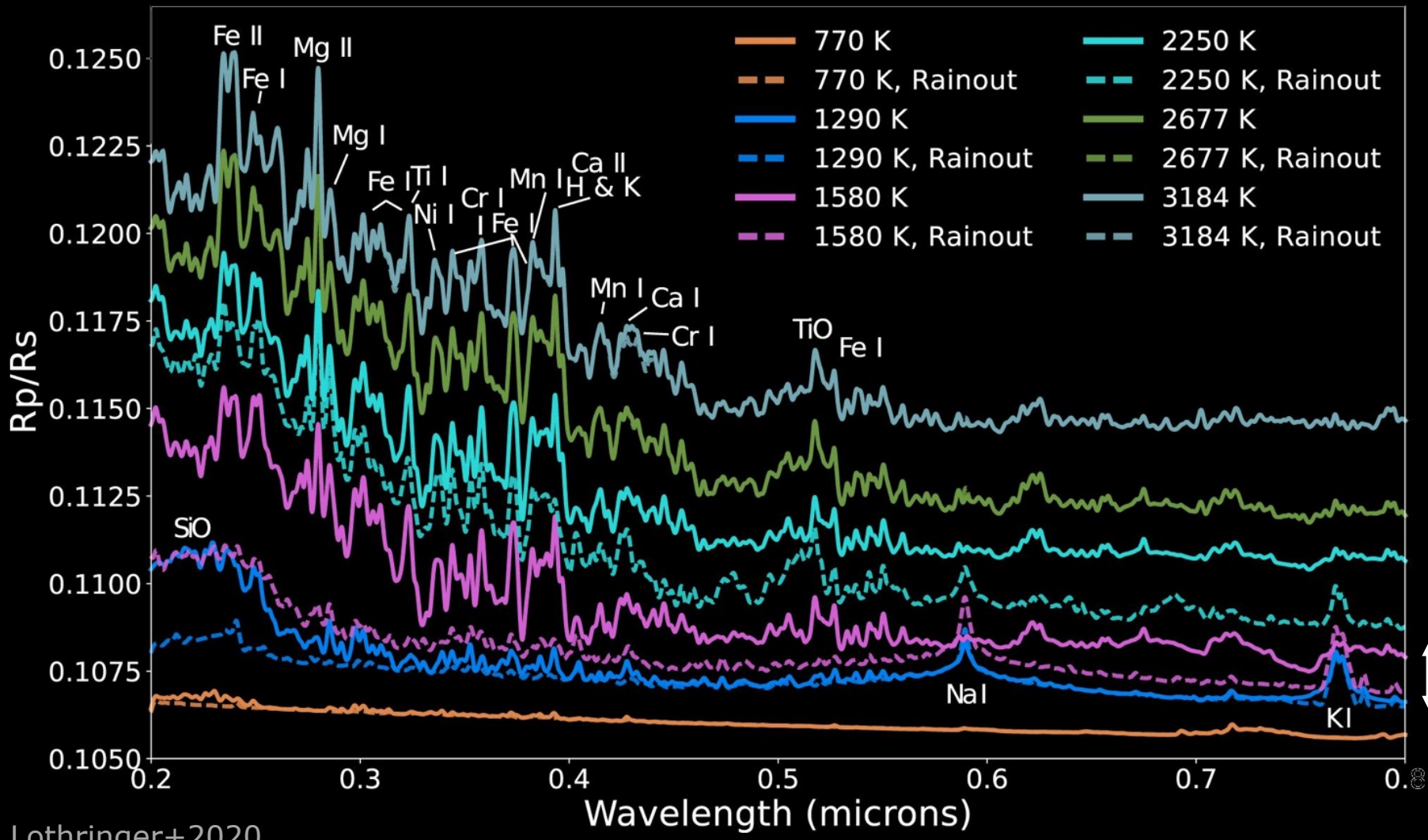
SPACE 21 February 2022 By MICHELLE STARR



Artist's impression of WASP-121 b. (Patricia Klein and MPIA)

METAL RAIN-OUT

At T > 1000 K, absorption dominated by gaseous metals

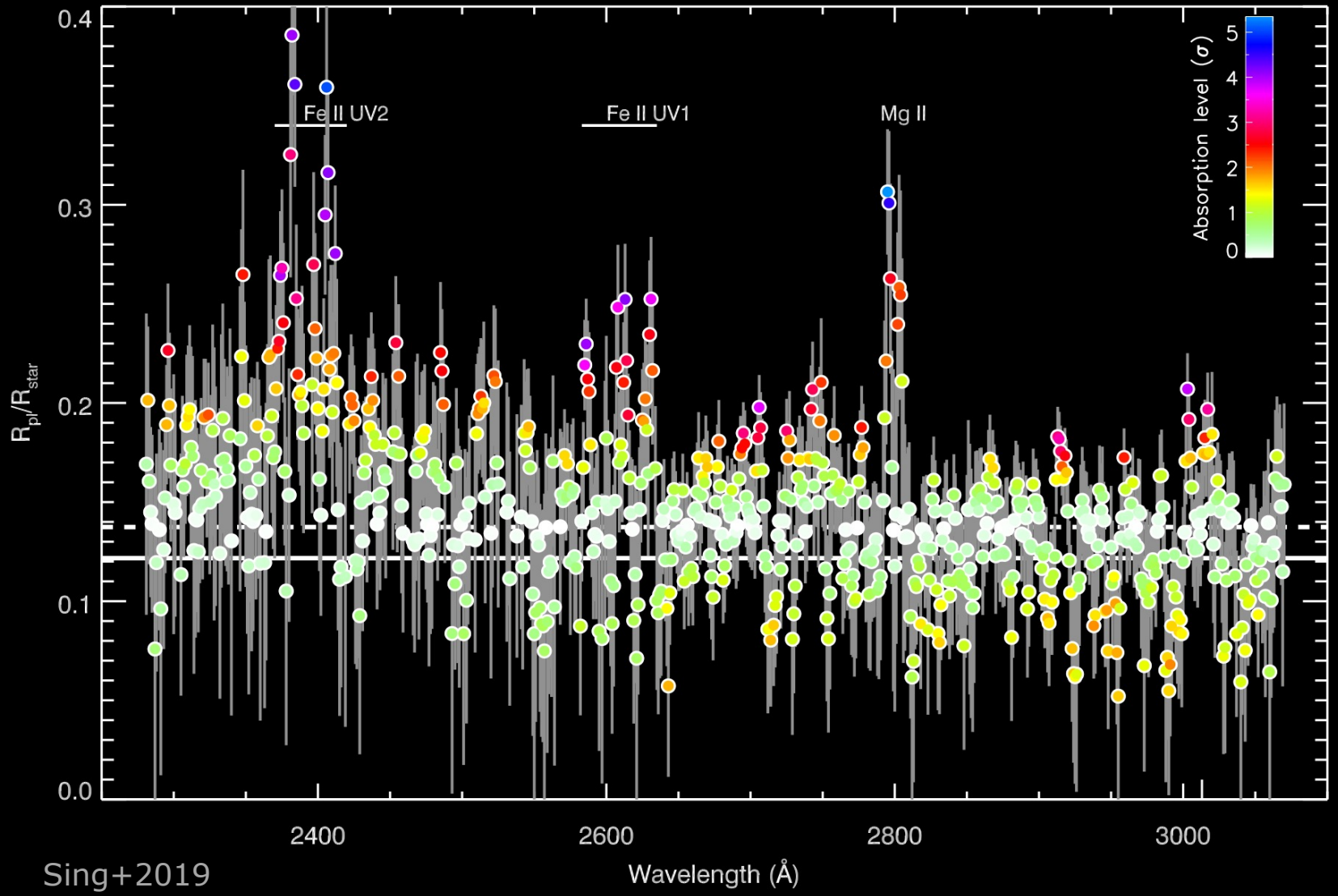


Large change in UV

Small change in optical

Lothringer+2020

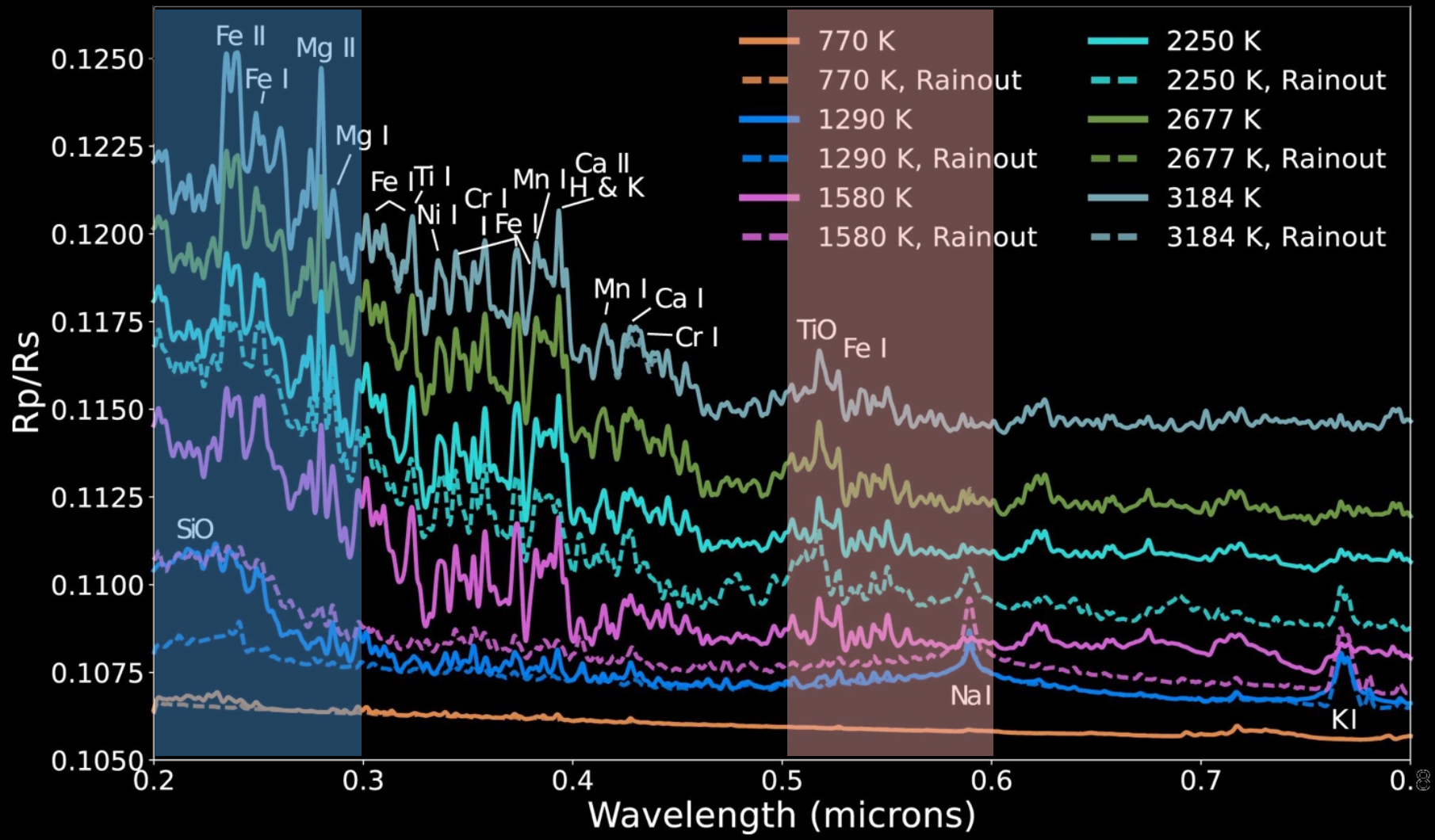
METAL RAIN-OUT



Sing+2019

METAL RAIN-OUT

NUV - Red spectral index



METAL RAIN-OUT

Takeaway: TESS will give us Red transit depths for all bright transiting planets – a complementary NUV transit depth could point to planets out of disequilibrium chemistry…

… UVEX?

UV FACILITIES

Stars are not actually very bright in UV, and exoplanet observations typically hours of observations per event (or days of observations to characterize the stellar UV flux)

There are limited facilities (HST/STIS+WFC/UVIS, XMM-Newton, Swift, CUTE, SPARCS for stars) to address these questions

SUMMARY

There is a real need for UV observations of exoplanets, even with/especially with missions like JWST flying, Ariel upcoming

A modest survey with UVEX (described in the next talk by Jessica Spake) could address multiple outstanding questions in exoplanet formation and evolution

- Can we break the flat spectrum degeneracy in the infrared with a suite of complementary NUV transmission spectra?
- Can we diagnose planets in disequilibrium by producing a set of NUV-Red spectral indices?

In addition, longer targeted observations with UVEX could address how atmospheric mass loss sculpts the planet population features we see today