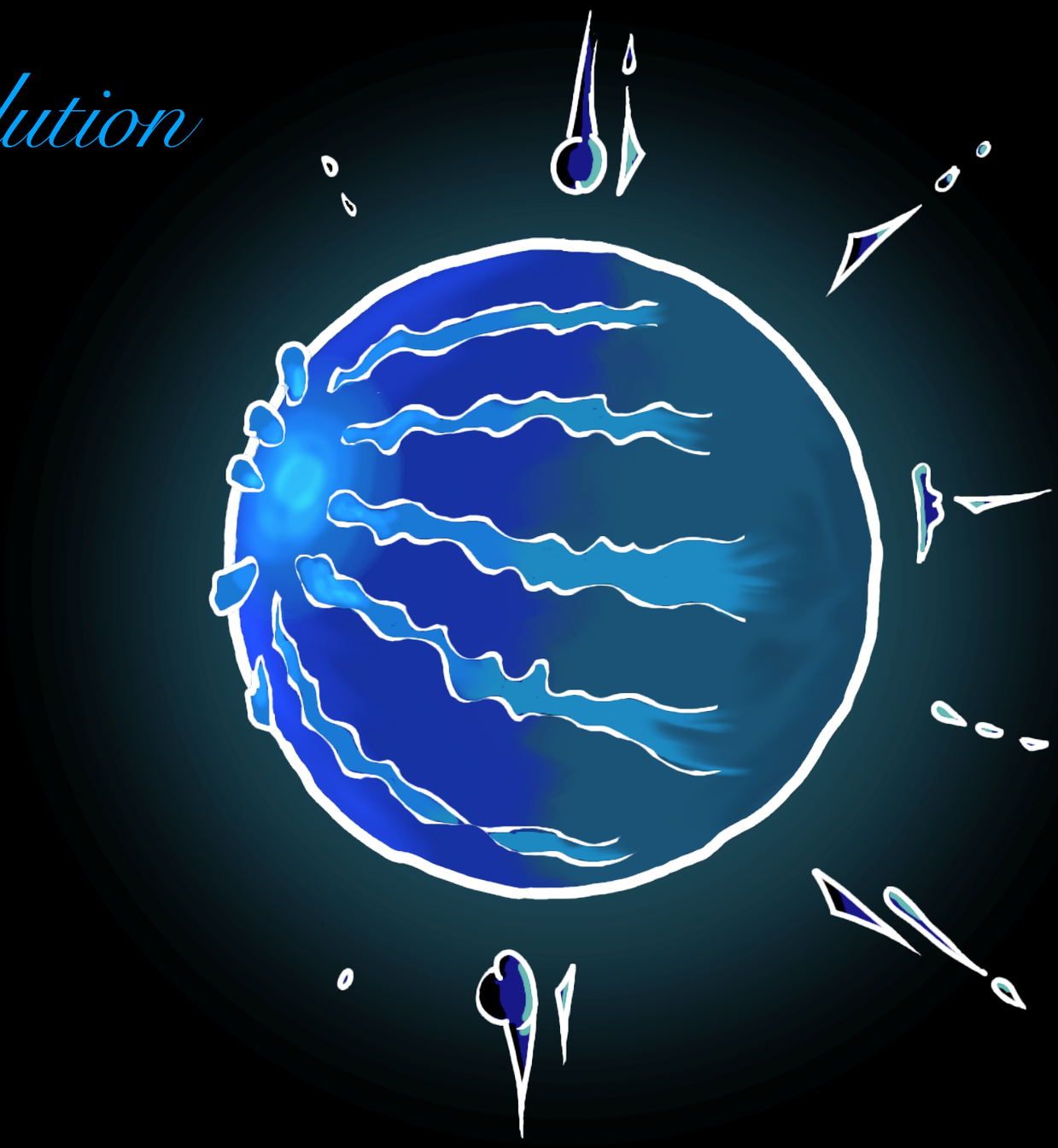
Observing exoplanet winds

Or: an ode to high-resolution

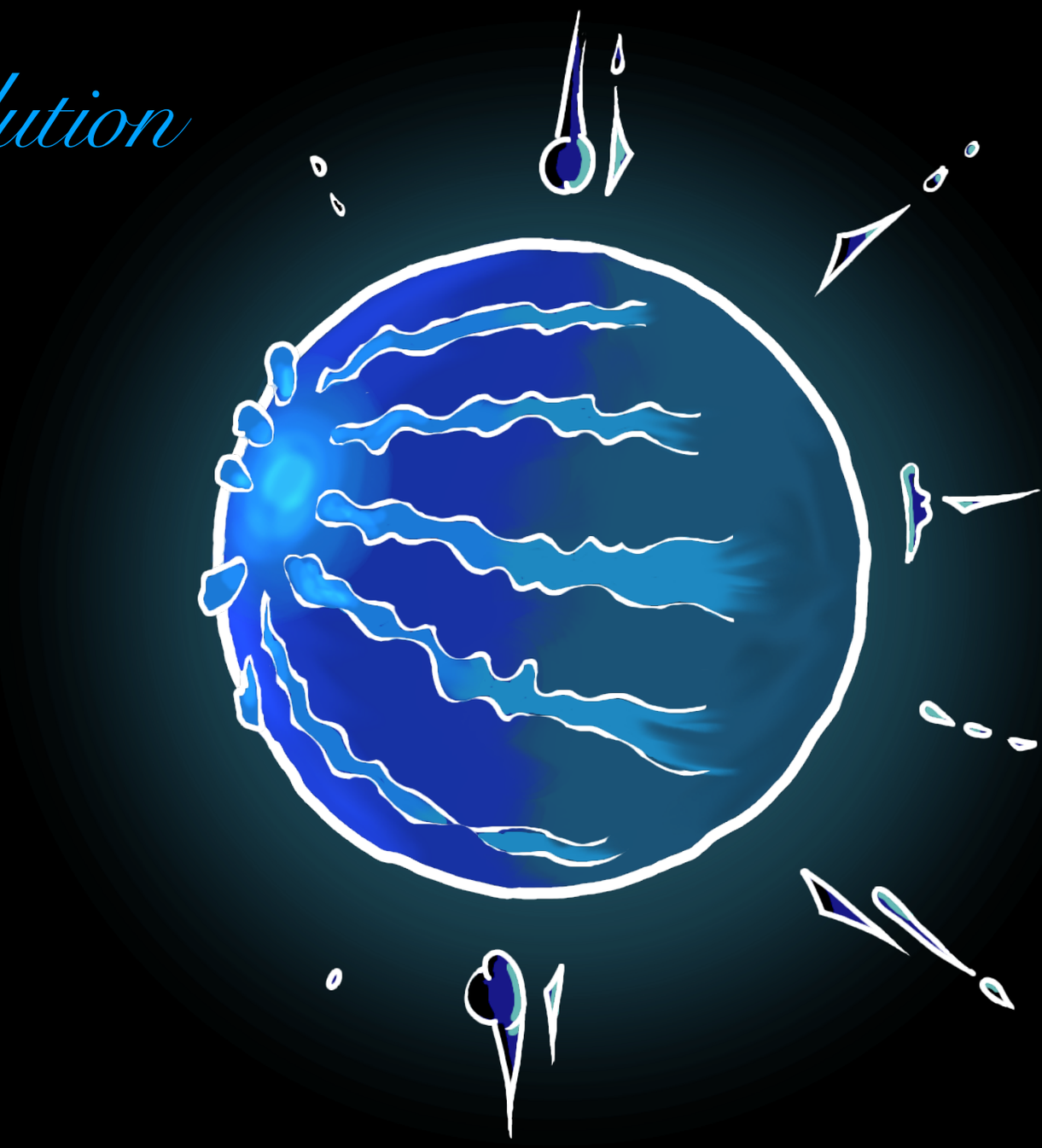
Julia Victoria Seidel

JuliaVSeidel



Observing exoplanet winds

Or: an ode to high-resolution



Julia Victoria Seidel

JuliaVSeidel

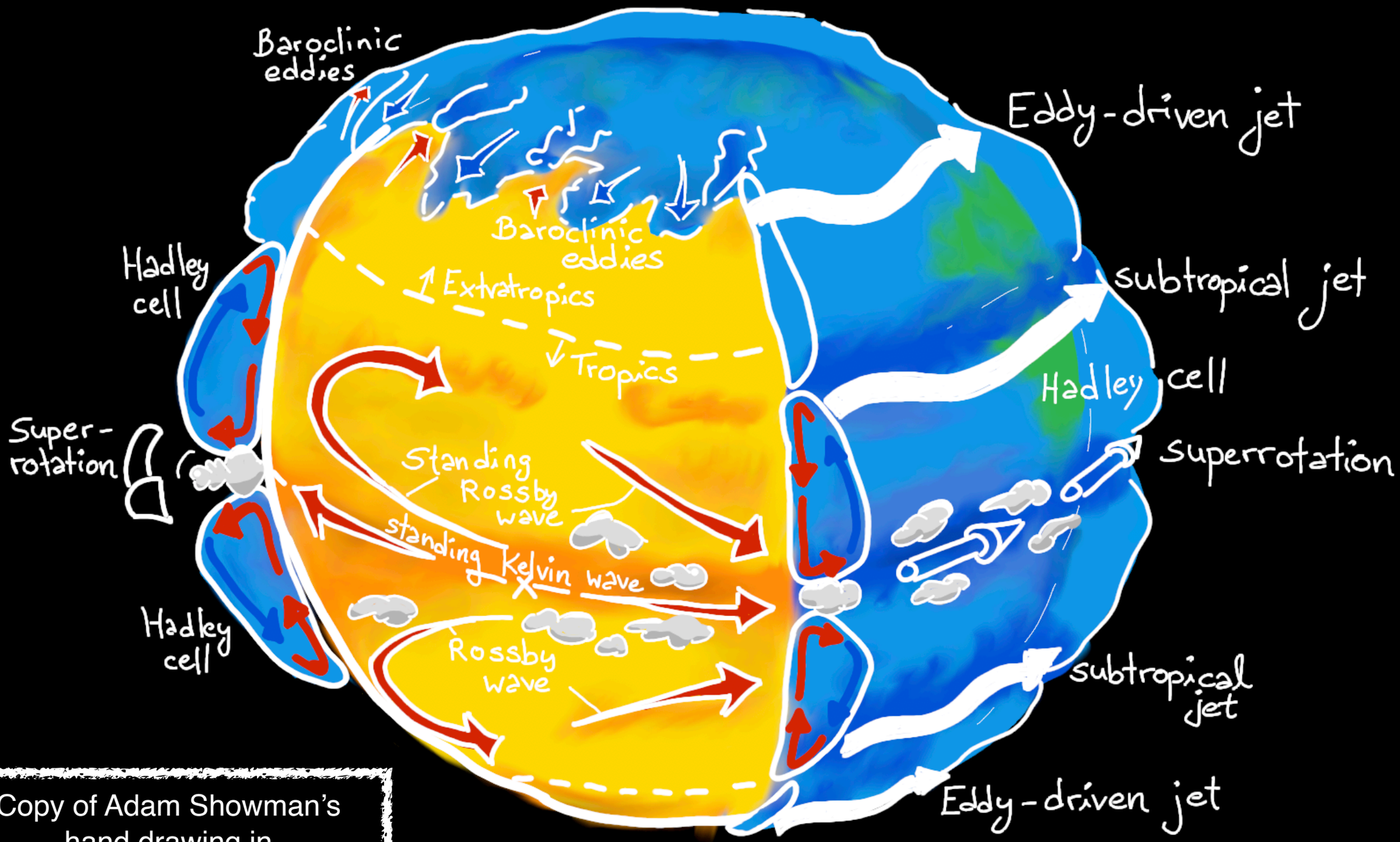
UNIVERSITÉ DE GENÈVE

FACULTÉ DES SCIENCES

Département d'astronomie

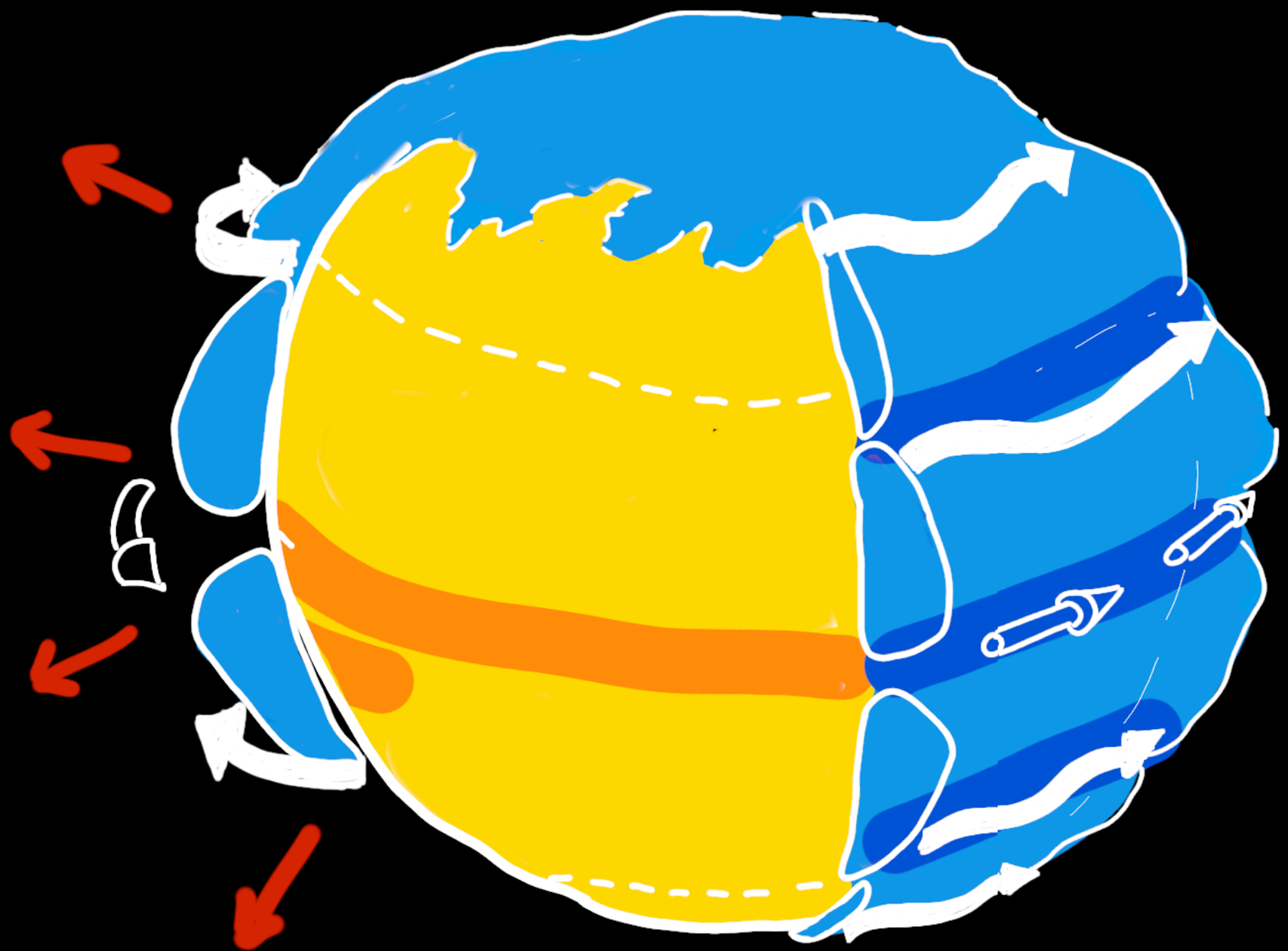
Earth atmospheric dynamics

(After the late Adam Showman)



Copy of Adam Showman's hand drawing in Kaspi (2021)

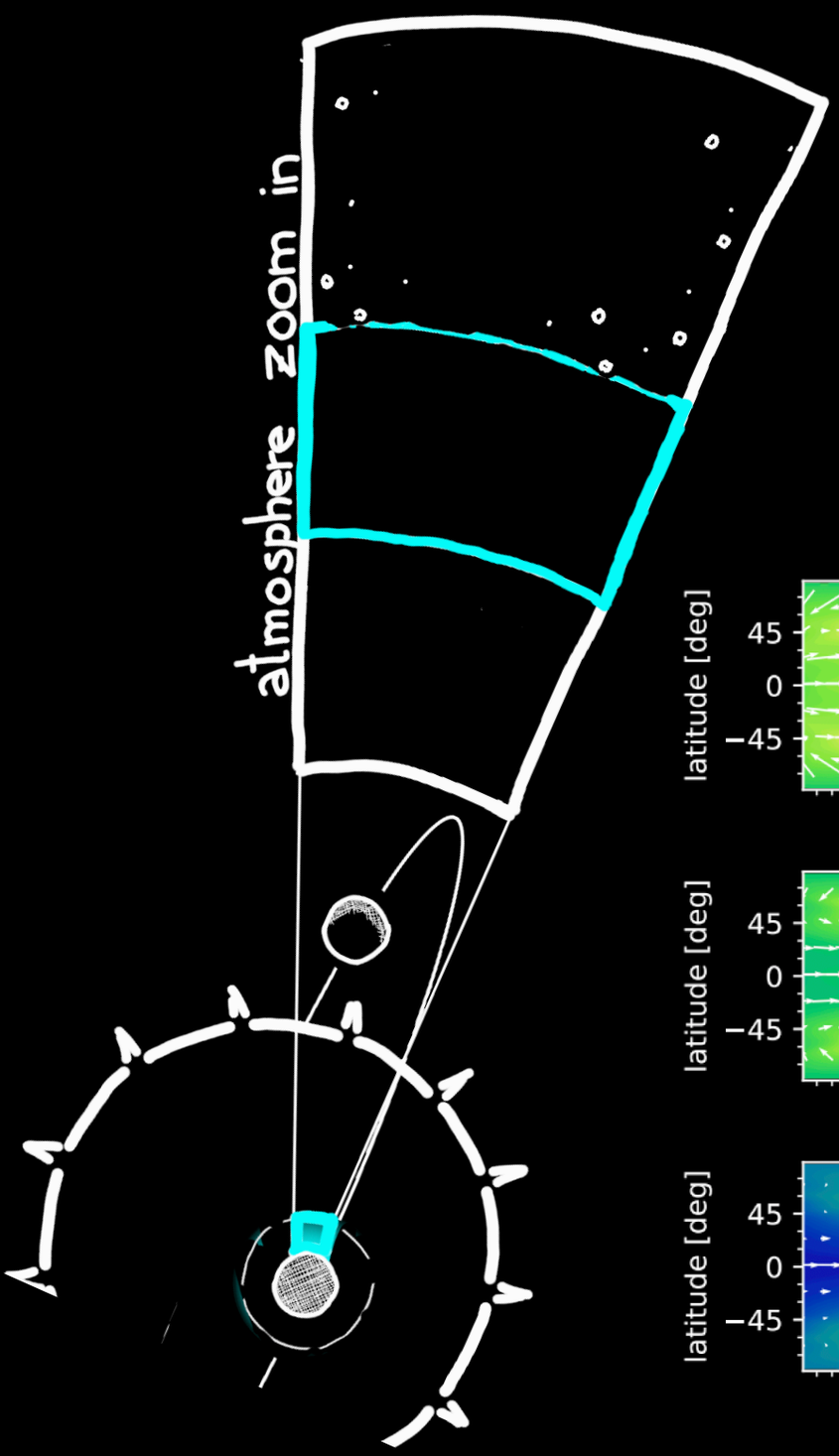
Julia V. Seidel @JuliaVSeidel

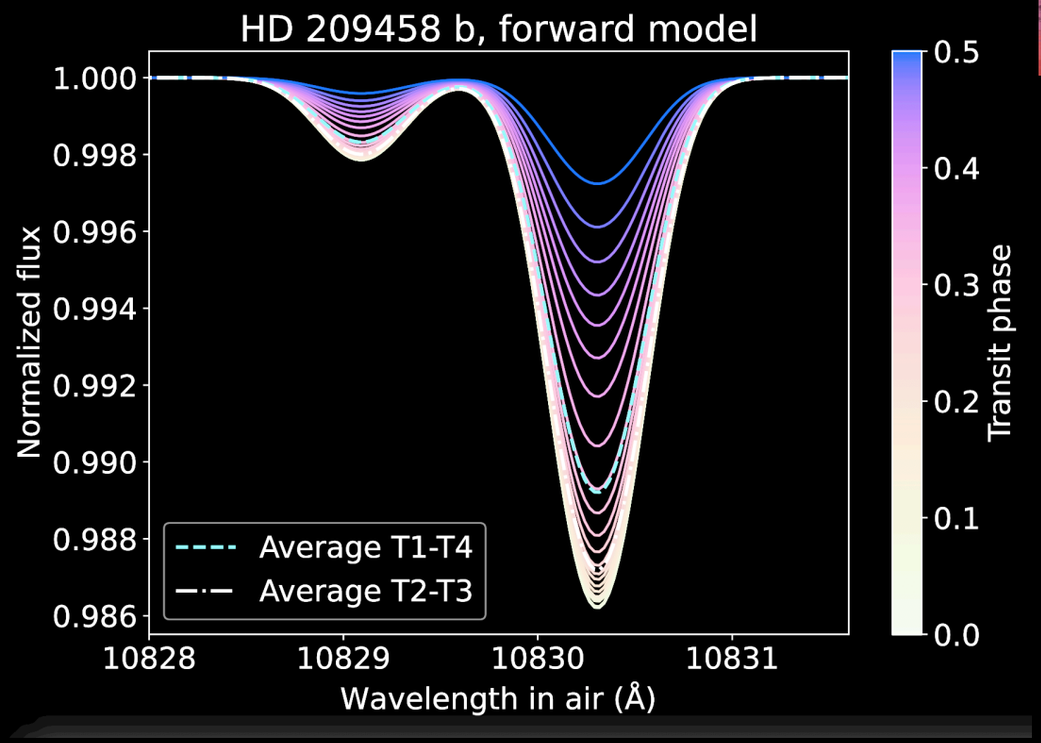


Definitely not Adam Showman's hand drawing

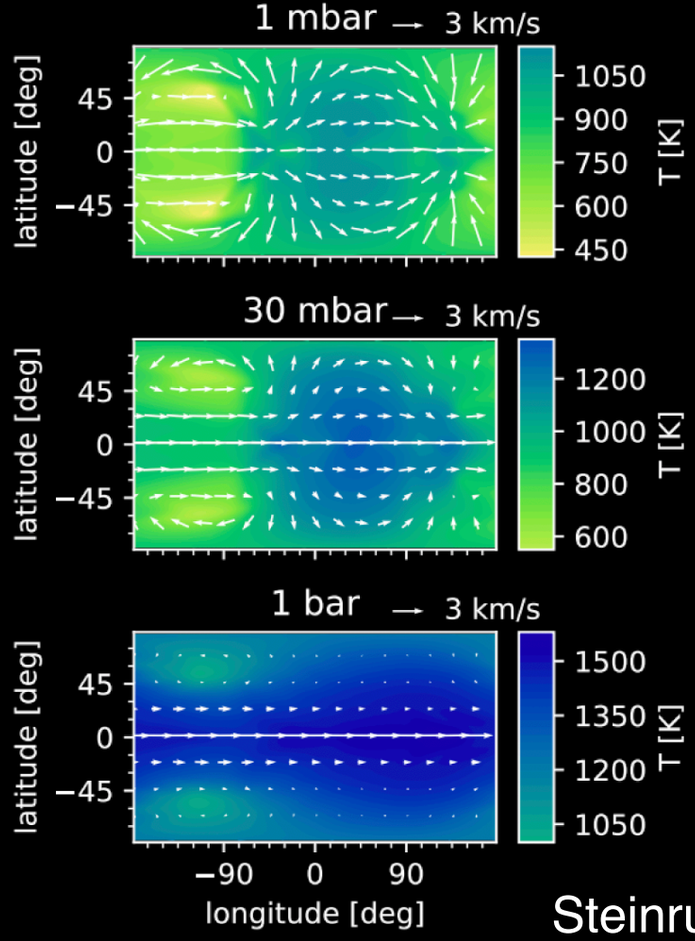
Julia V. Seidel @JuliaVSeidel

Atmospheric layers





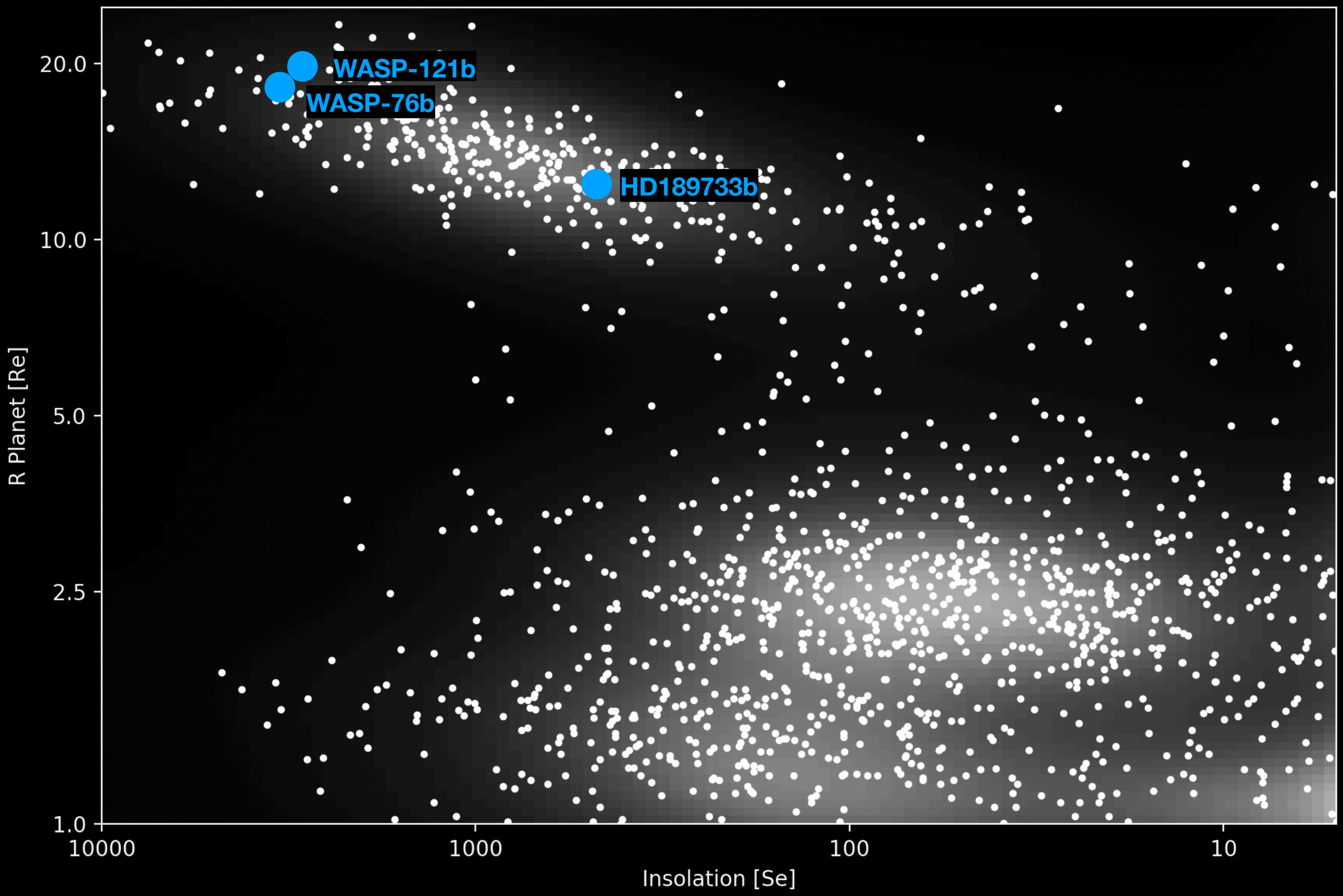
Dos Santos et al. 2022



Steinrueck et al. 2019

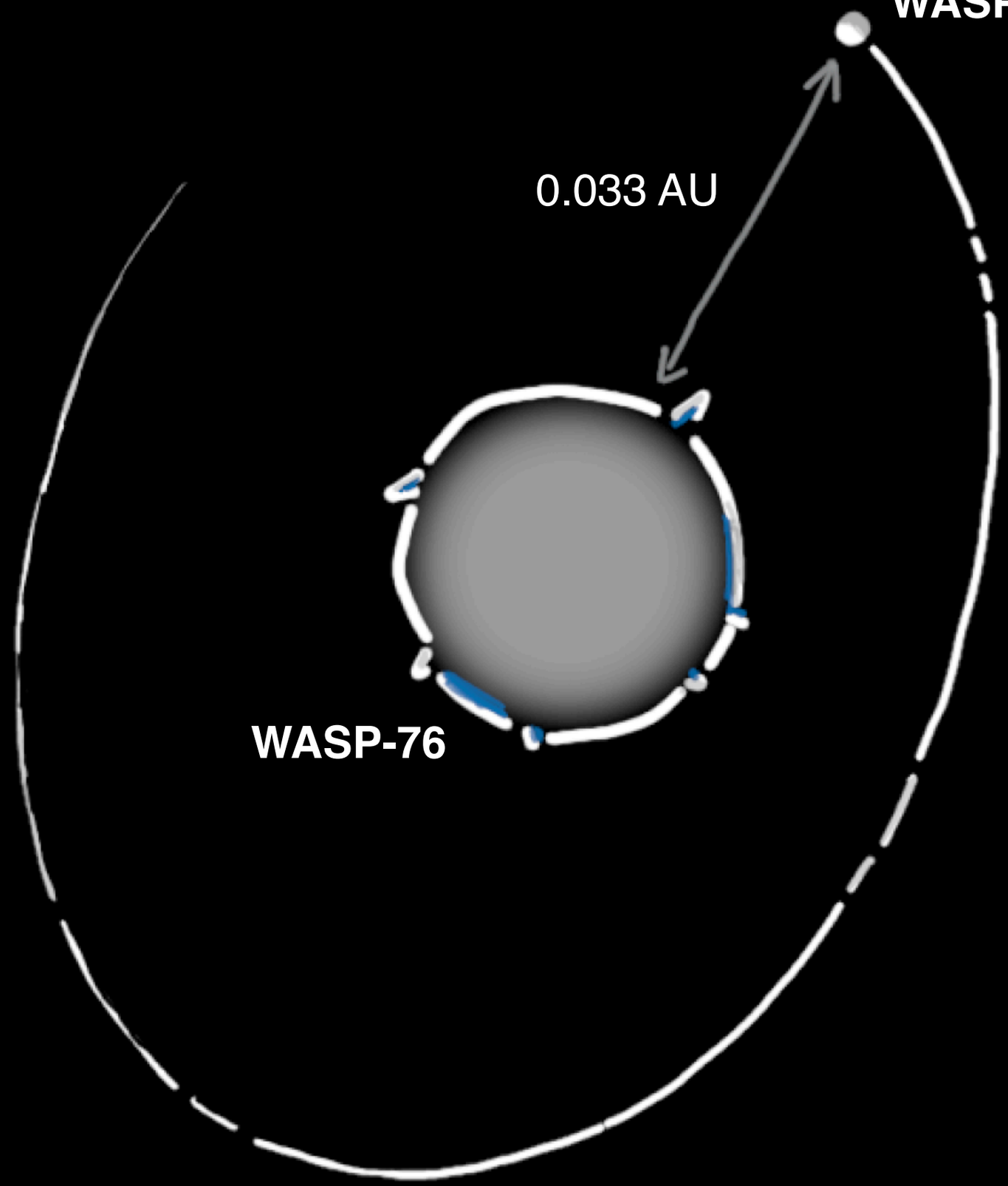
Julia V. Seidel @JuliaVSeidel

Hot Jupiters



Julia V. Seidel @JuliaVSeidel

The WASP-76 b system



Julia V. Seidel @JuliaVSeidel

HD 189733 b

Height [R_p]

1.1

1.0

5890

5896

λ [Å]

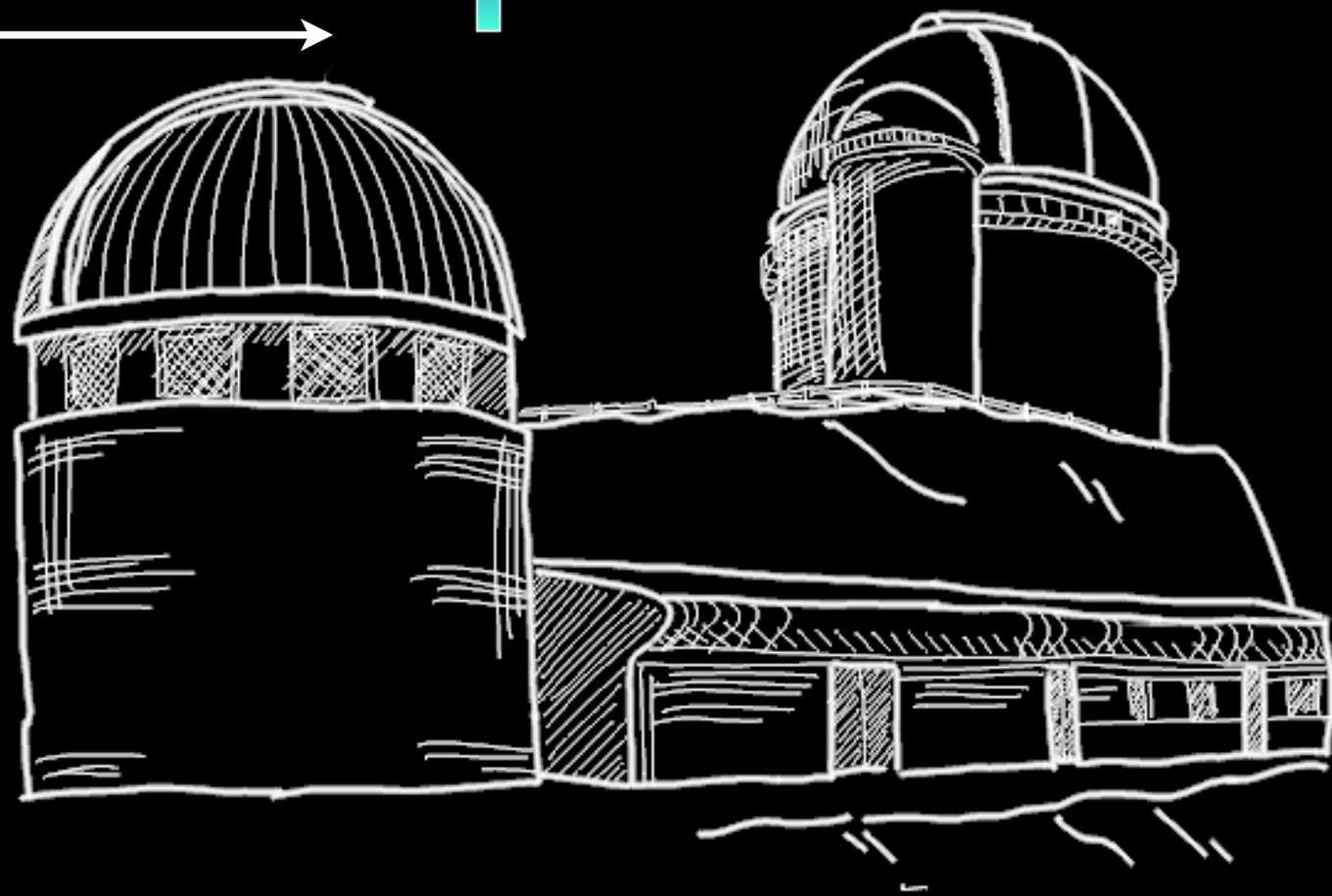
T [K]

3500

2500

1500

HARPS@3.6m



Wyttenbach et al. 2015

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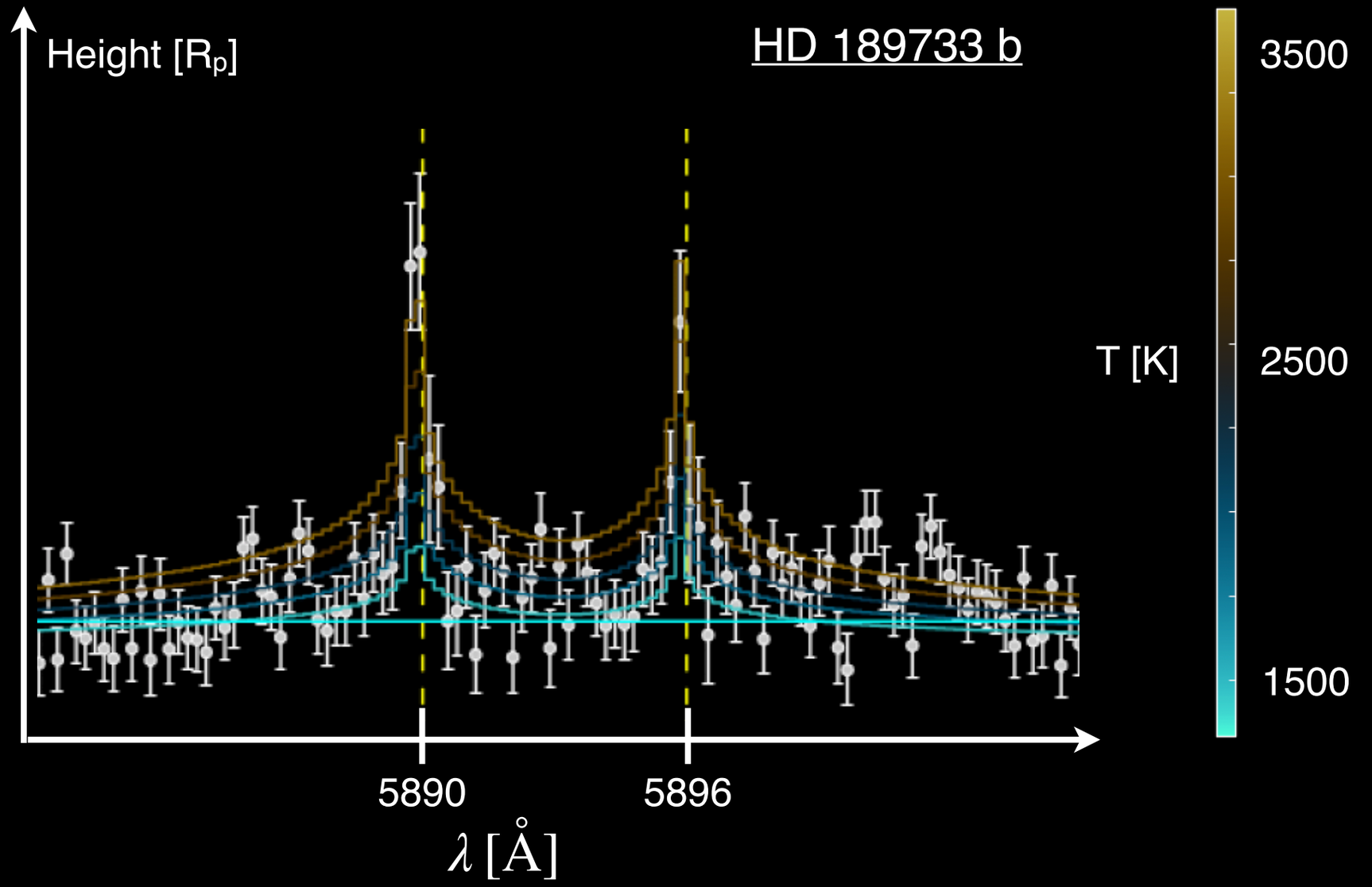


Wyttenbach et al. 2015

Height [R_p]

HD 189733 b

1.1

1.0

T [K]

3500

2500

1500

Wyttenbach et al. 2015

5890

5896

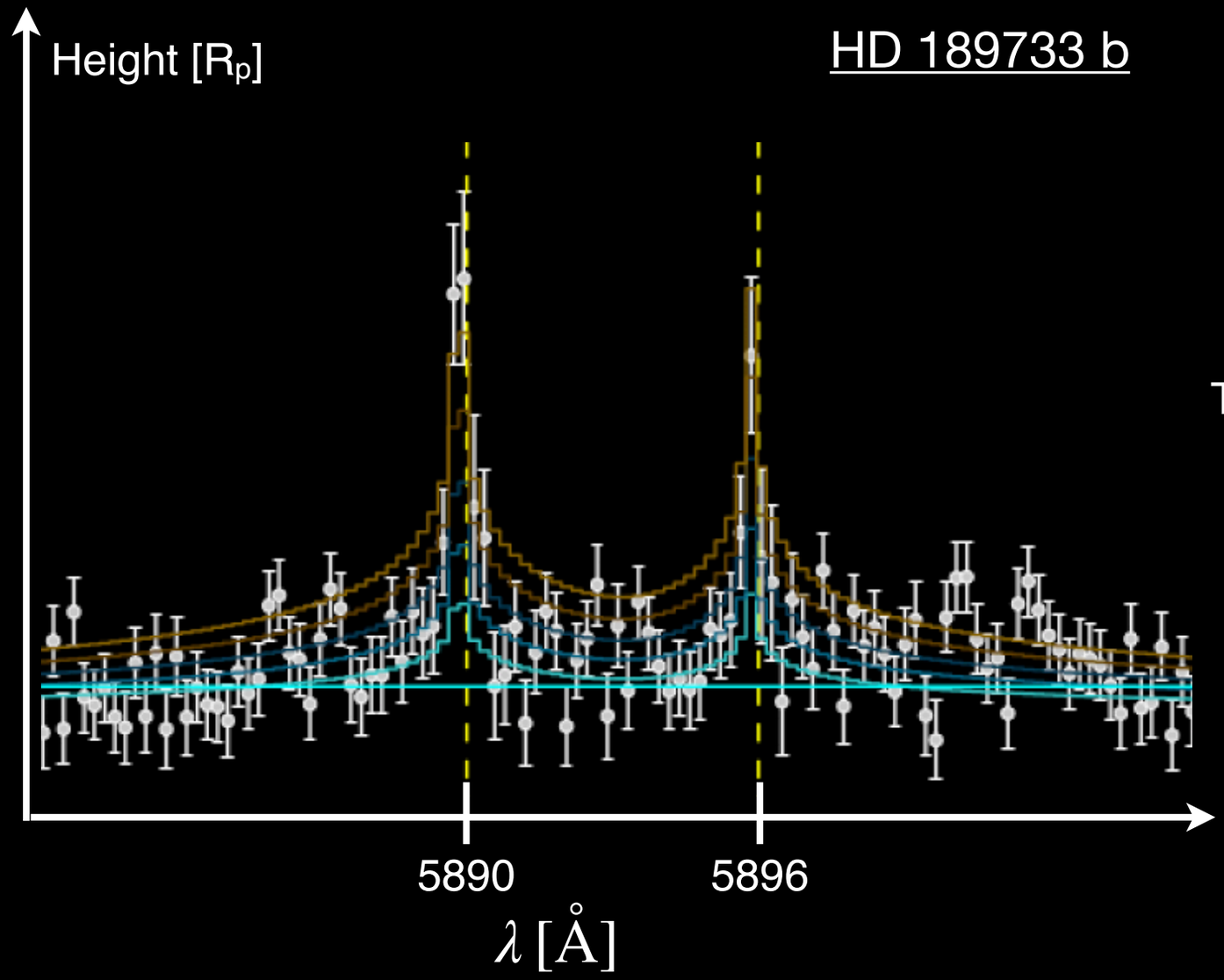
λ [Å]

Sodium abundance

T

Wind

Julia V. Seidel @JuliaVSeidel



HD 189733 b

T [K]

3500

2500

1500

Wyttenbach et al. 2015

Forward model + Winds + Multi-nested Sampling Retrieval = MERC

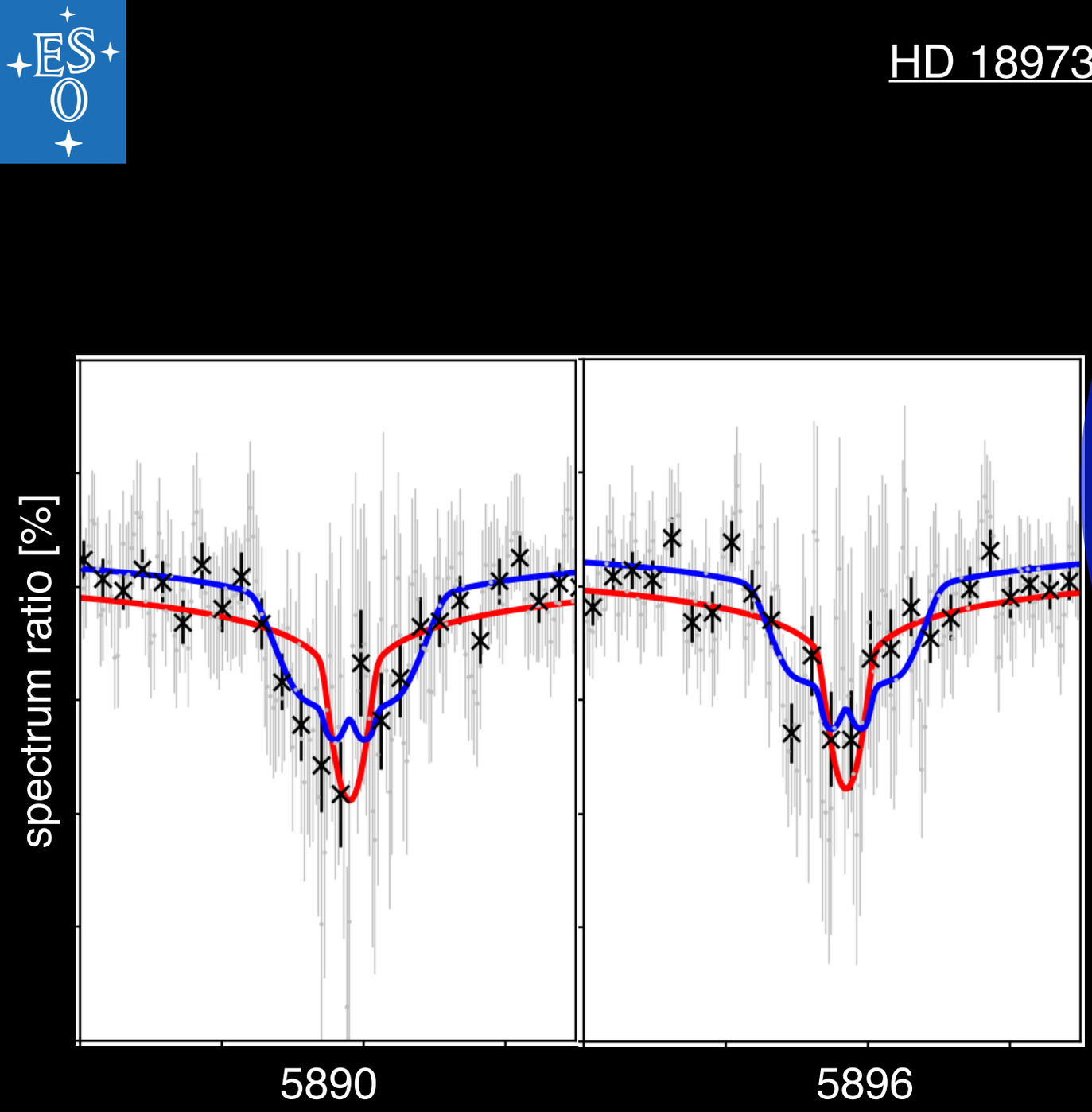
Ehrenreich et al. 2006
Pino et al. 2018

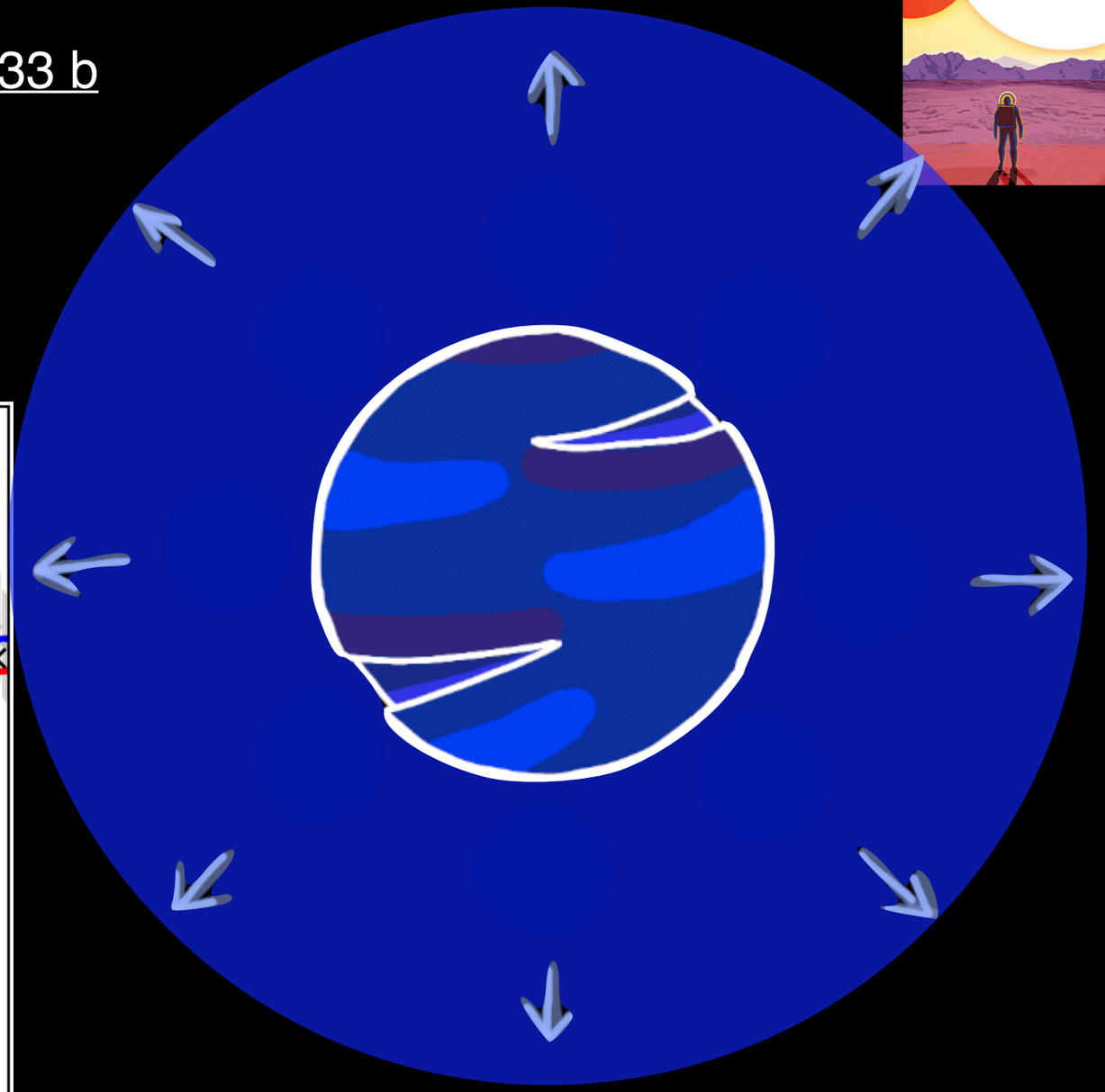
Buchner et al. 2014

Seidel et al. 2020a

Julia V. Seidel @JuliaVSeidel

HD 189733 b

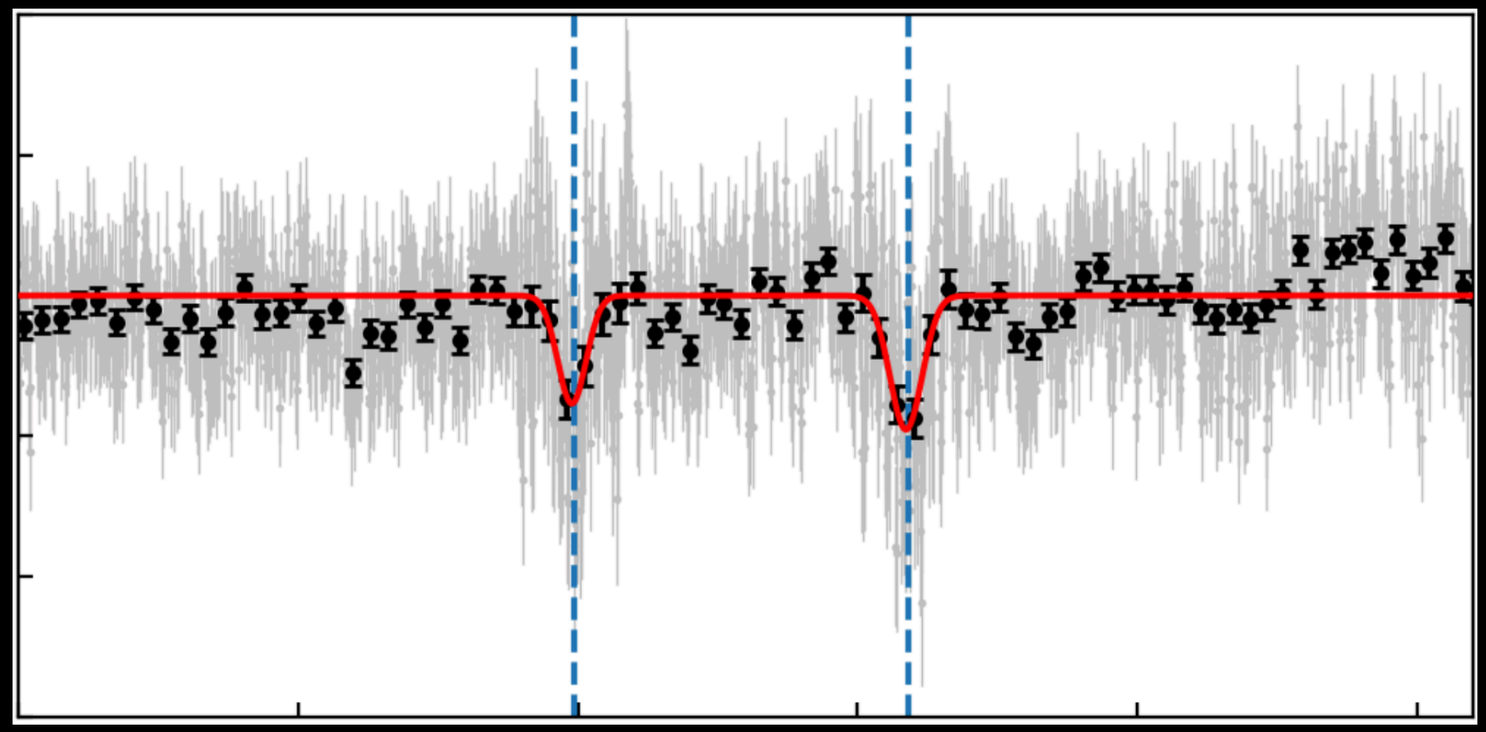




Seidel et al. 2020a

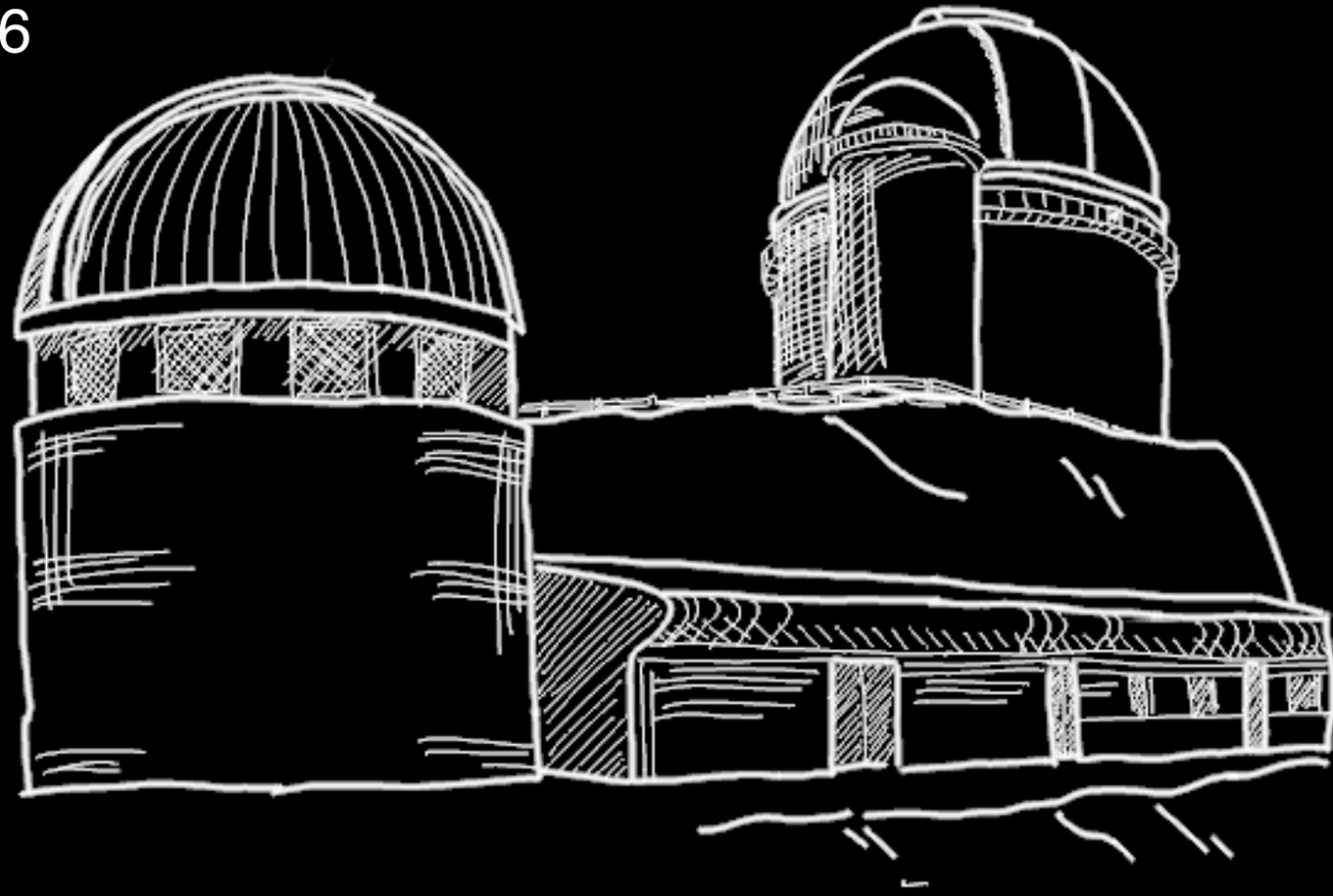
Julia V. Seidel @JuliaVSeidel

Ultra Hot Jupiter WASP-76b
Sodium doublet



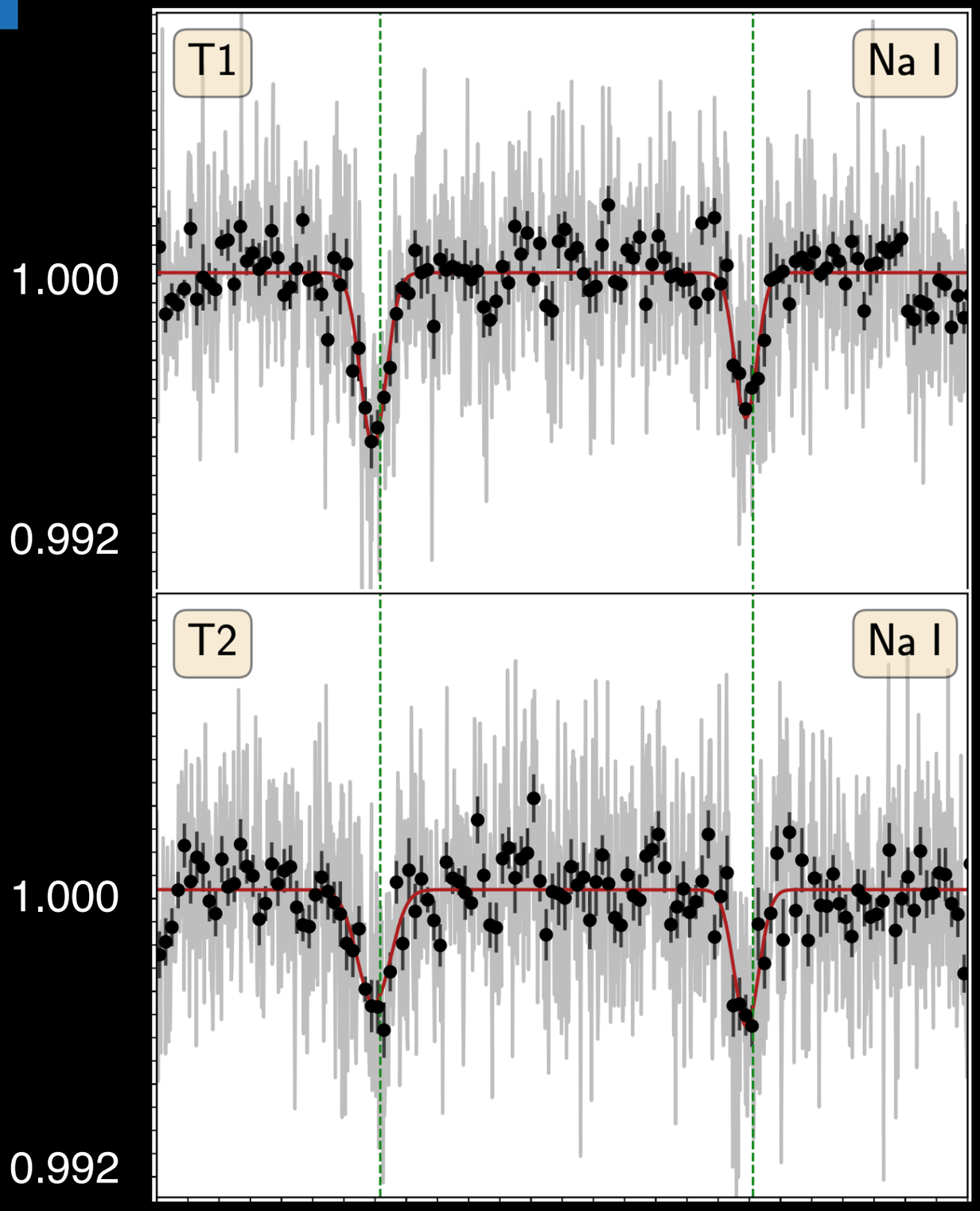
Seidel et al. 2019

HARPS@3.6m



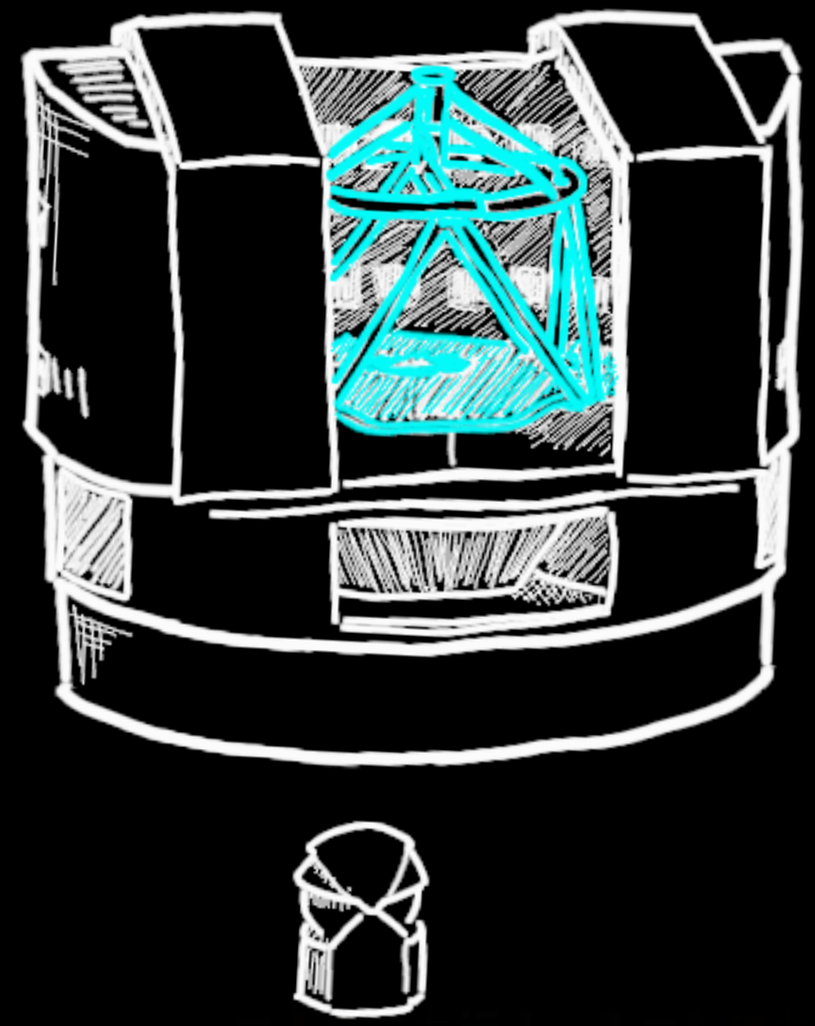
Julia V. Seidel @JuliaVSeidel

Ultra Hot Jupiter WASP-76b
Sodium doublet



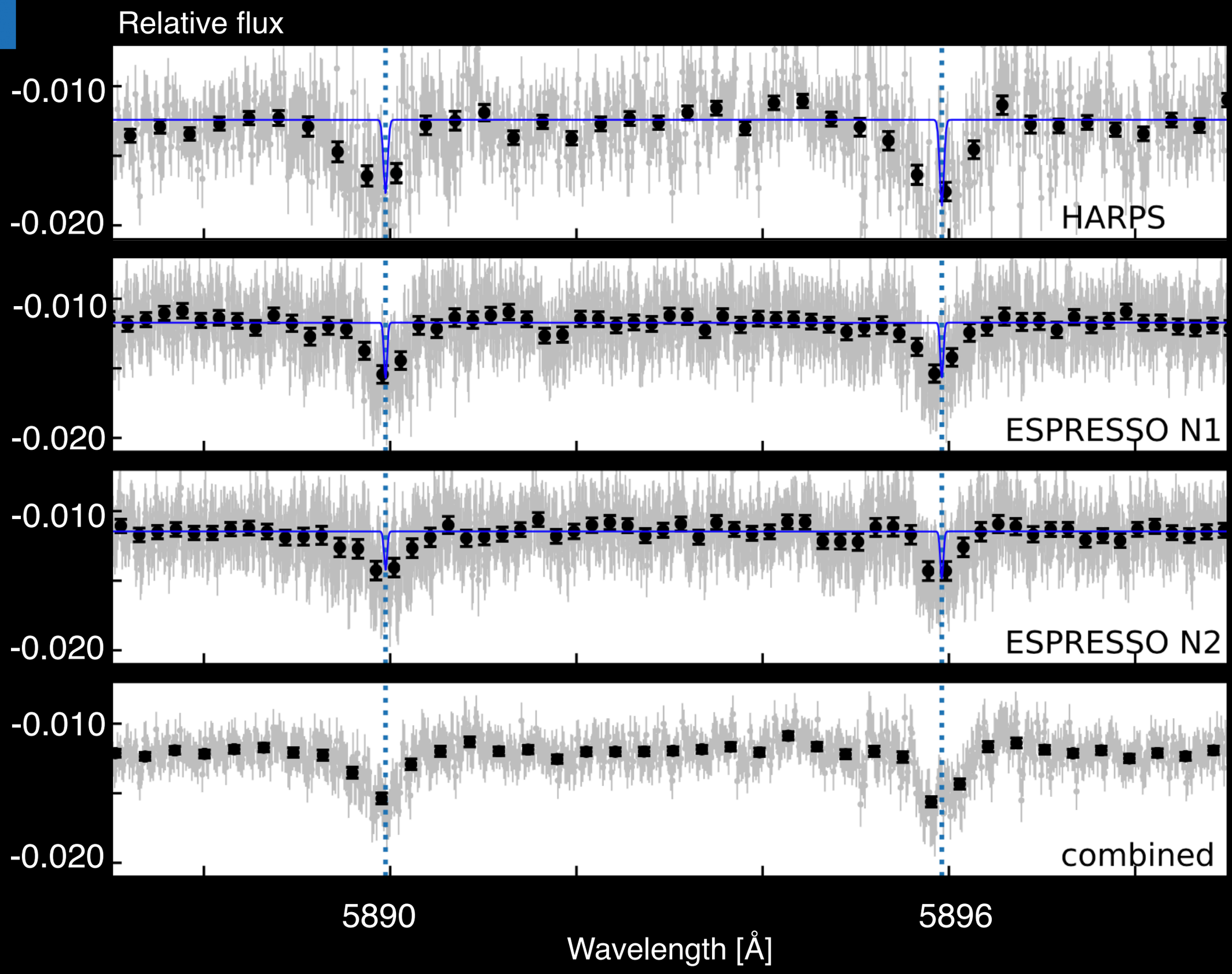
Tabernero et al. 2020

ESPRESSO@VLT



Julia V. Seidel @JuliaVSeidel

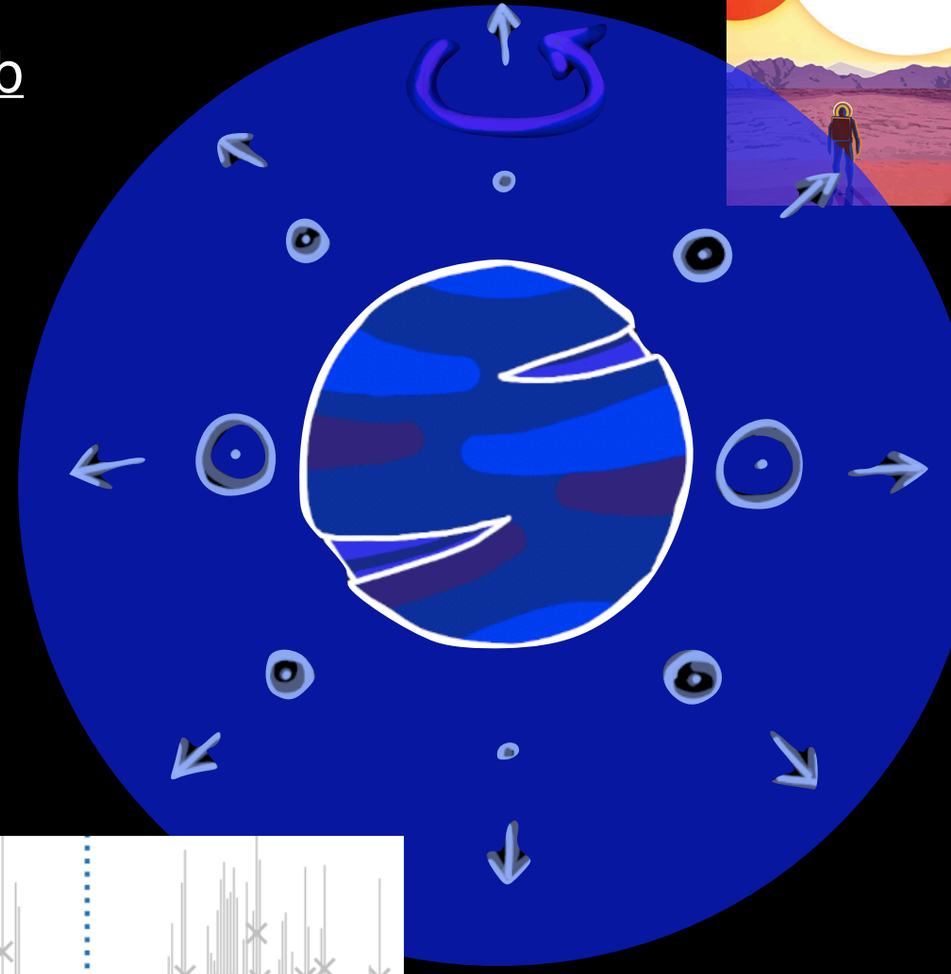
Ultra-Hot Jupiter WASP-76b

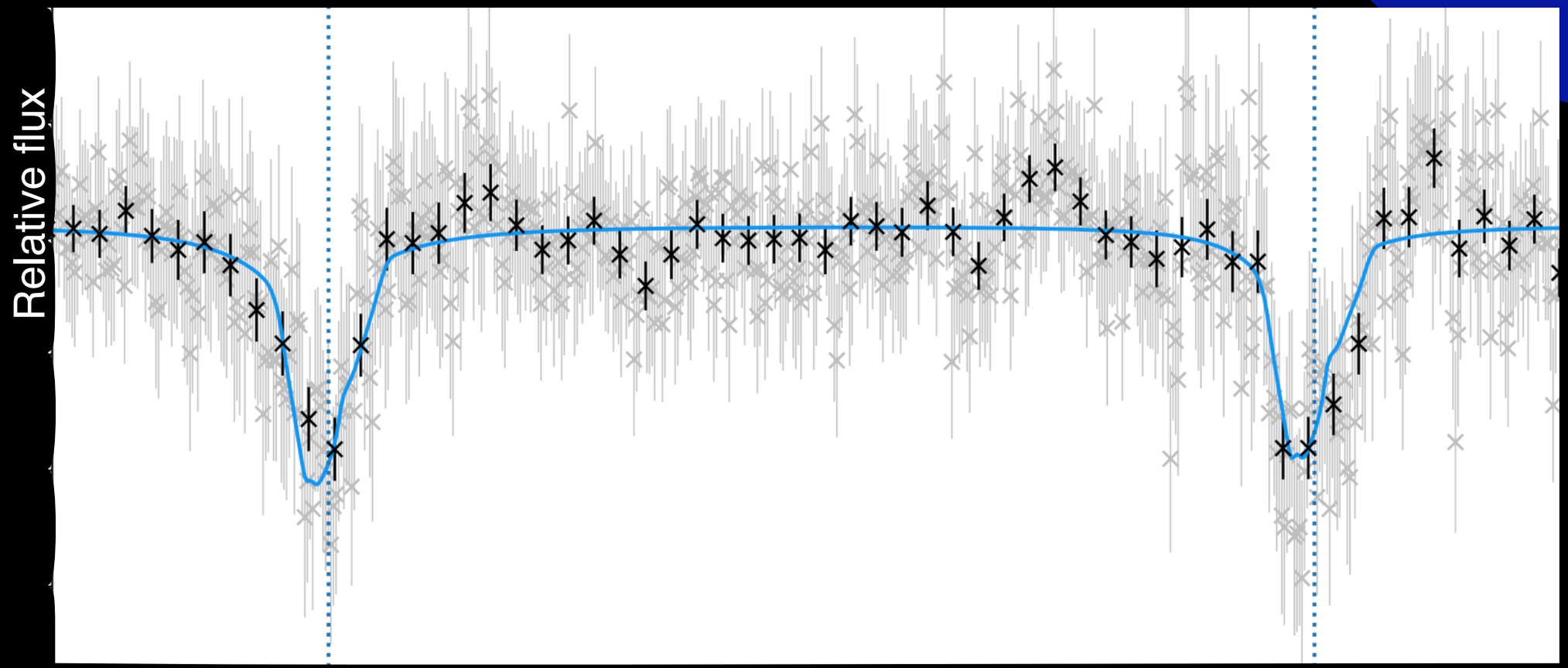


Seidel et al. 2021

Julia V. Seidel @JuliaVSeidel

Ultra-Hot Jupiter WASP-76b

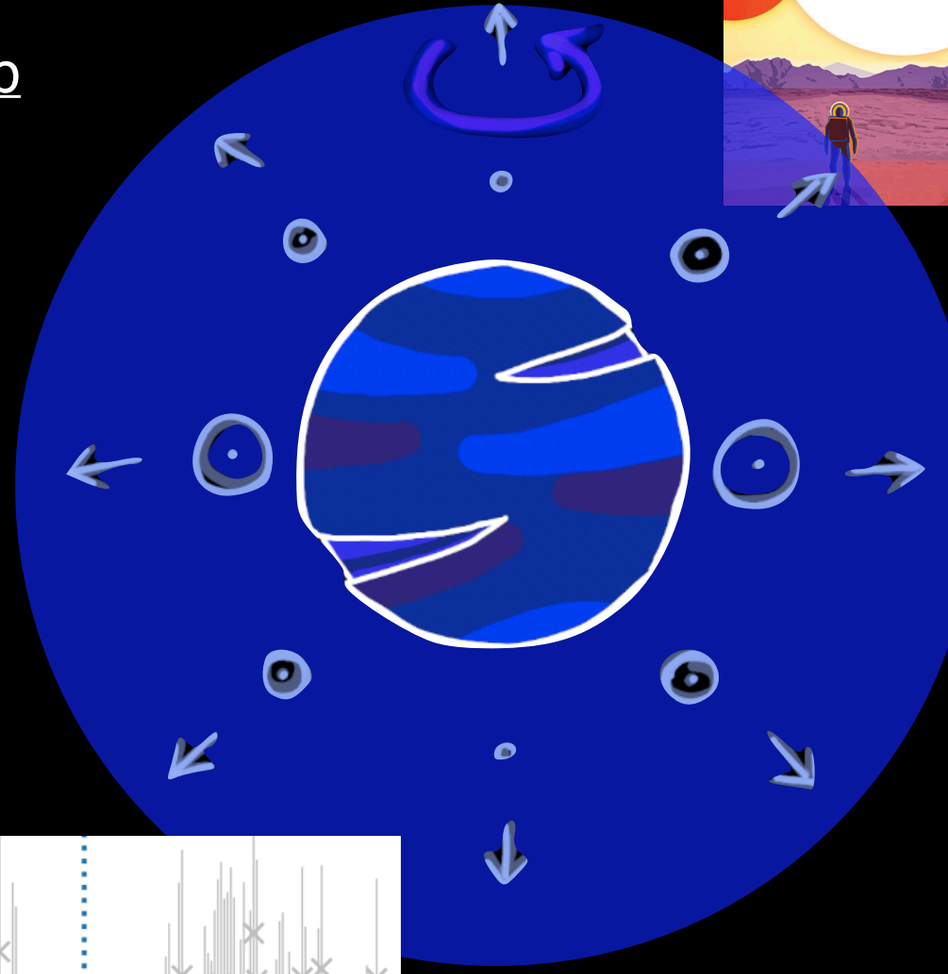




Seidel et al. 2021

Julia V. Seidel @JuliaVSeidel

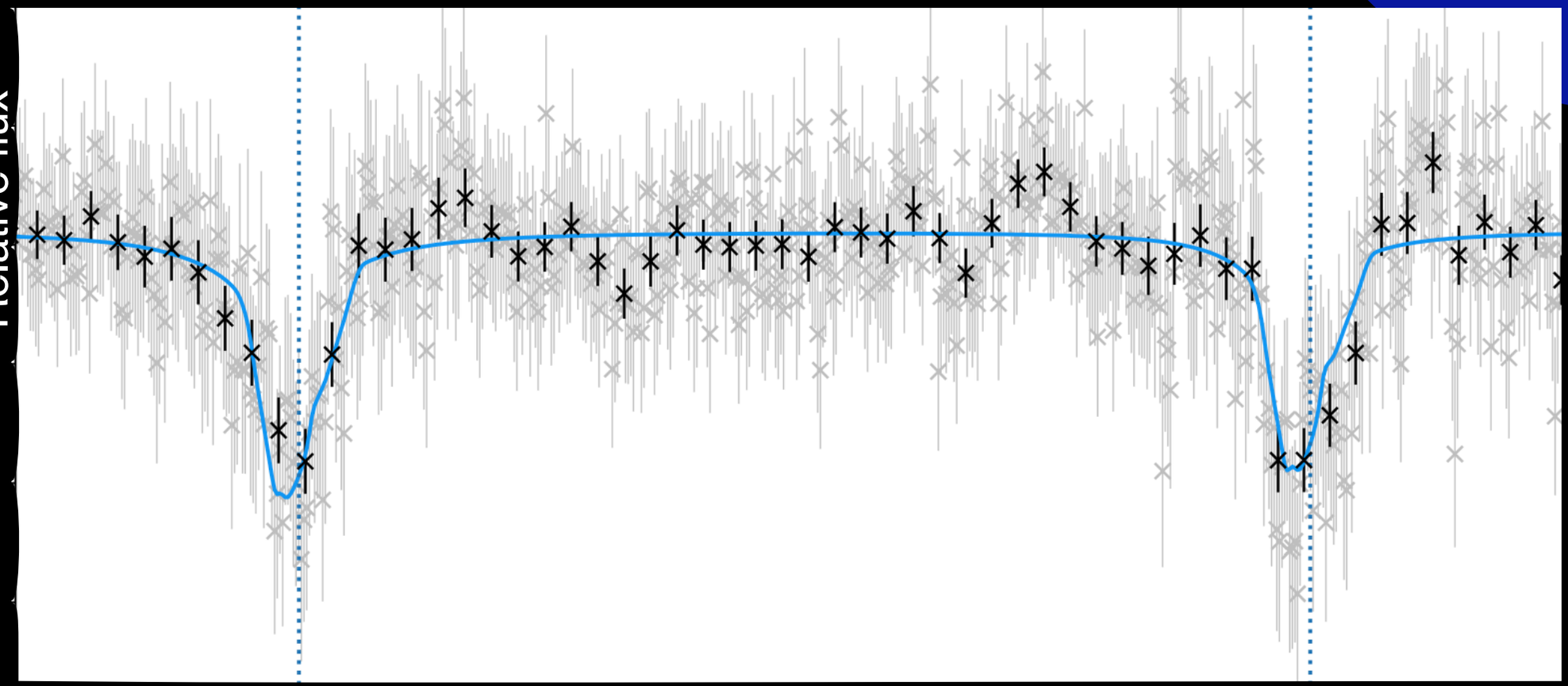
Ultra-Hot Jupiter WASP-76b



Wind patterns

- Lower day-to-night side wind: 5.5 km/s
- Upper vertical wind: 22 km/s

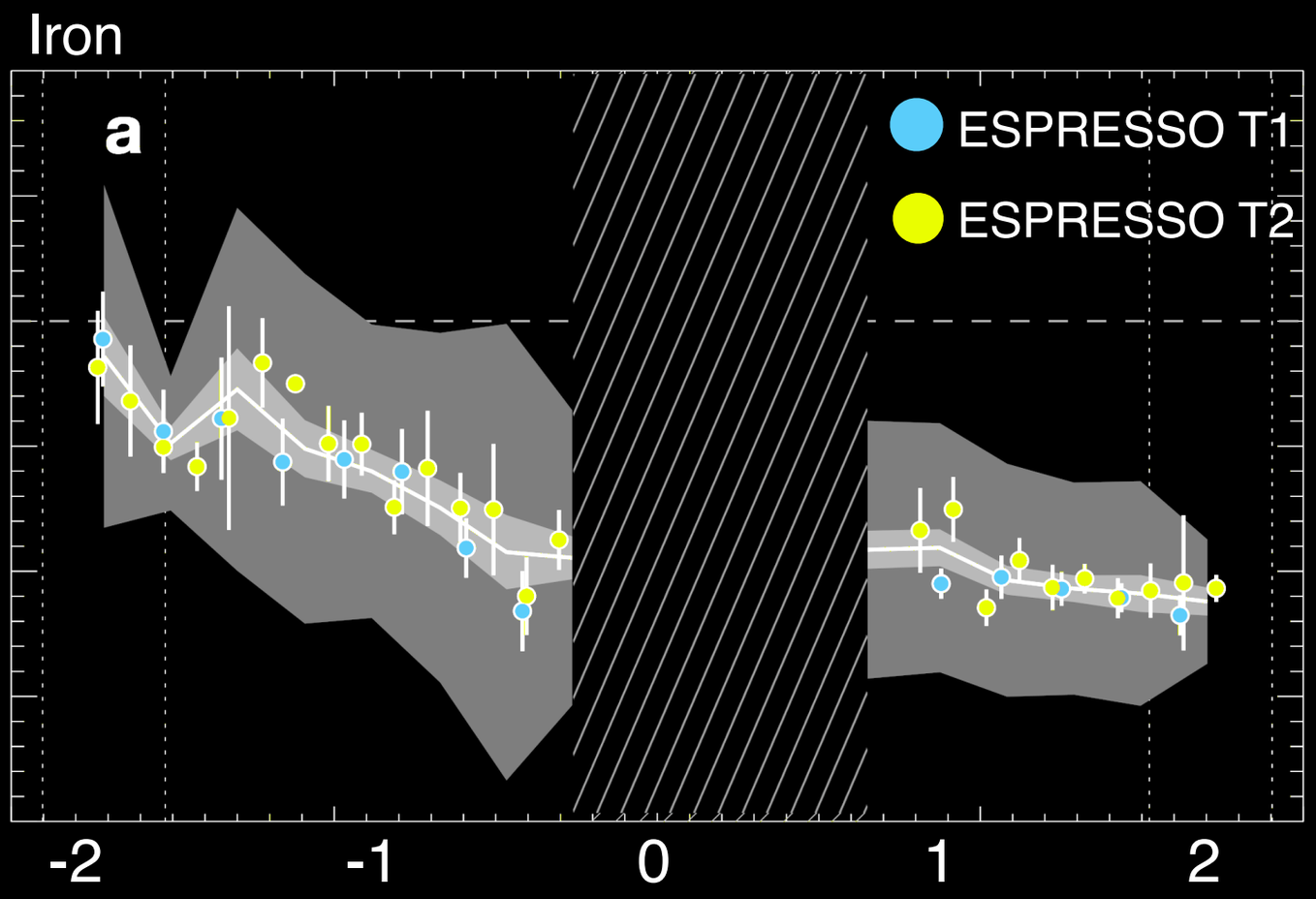
Similar to HD189733b (Seidel et al. 2020a)

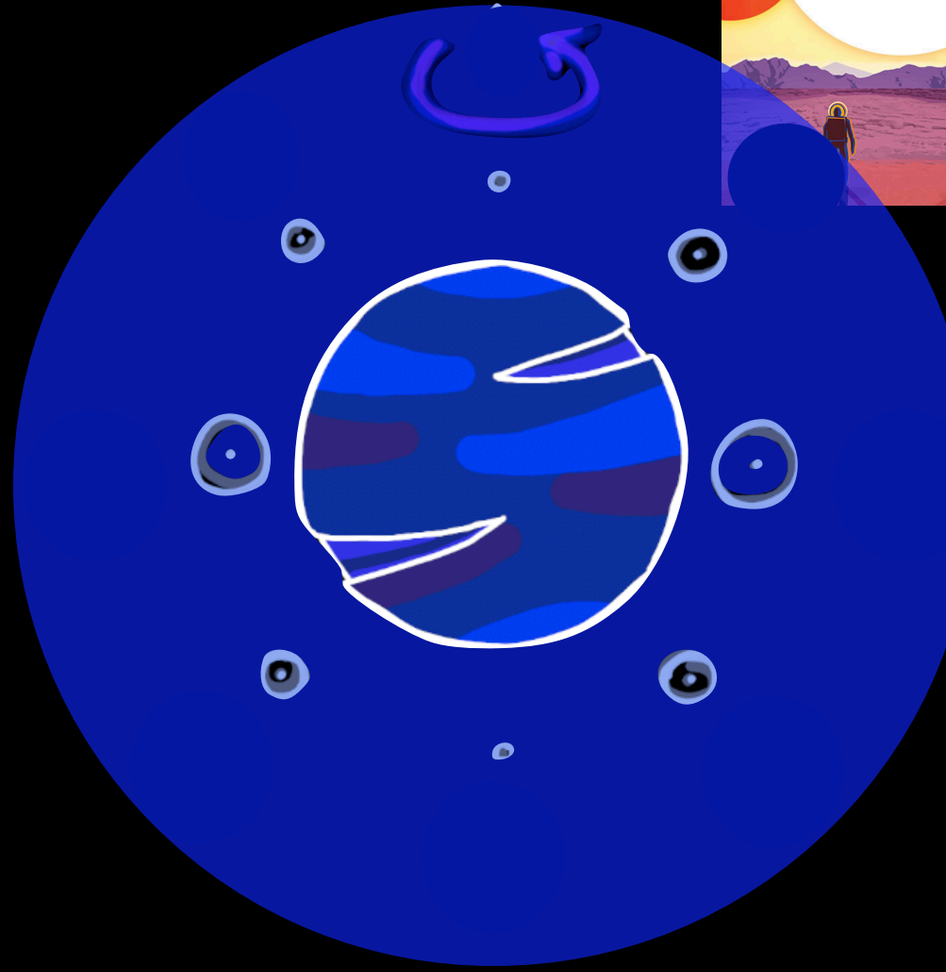


Seidel et al. 2021

Julia V. Seidel @JuliaVSeidel

WASP-76 b





Ehrenreich et al. 2020

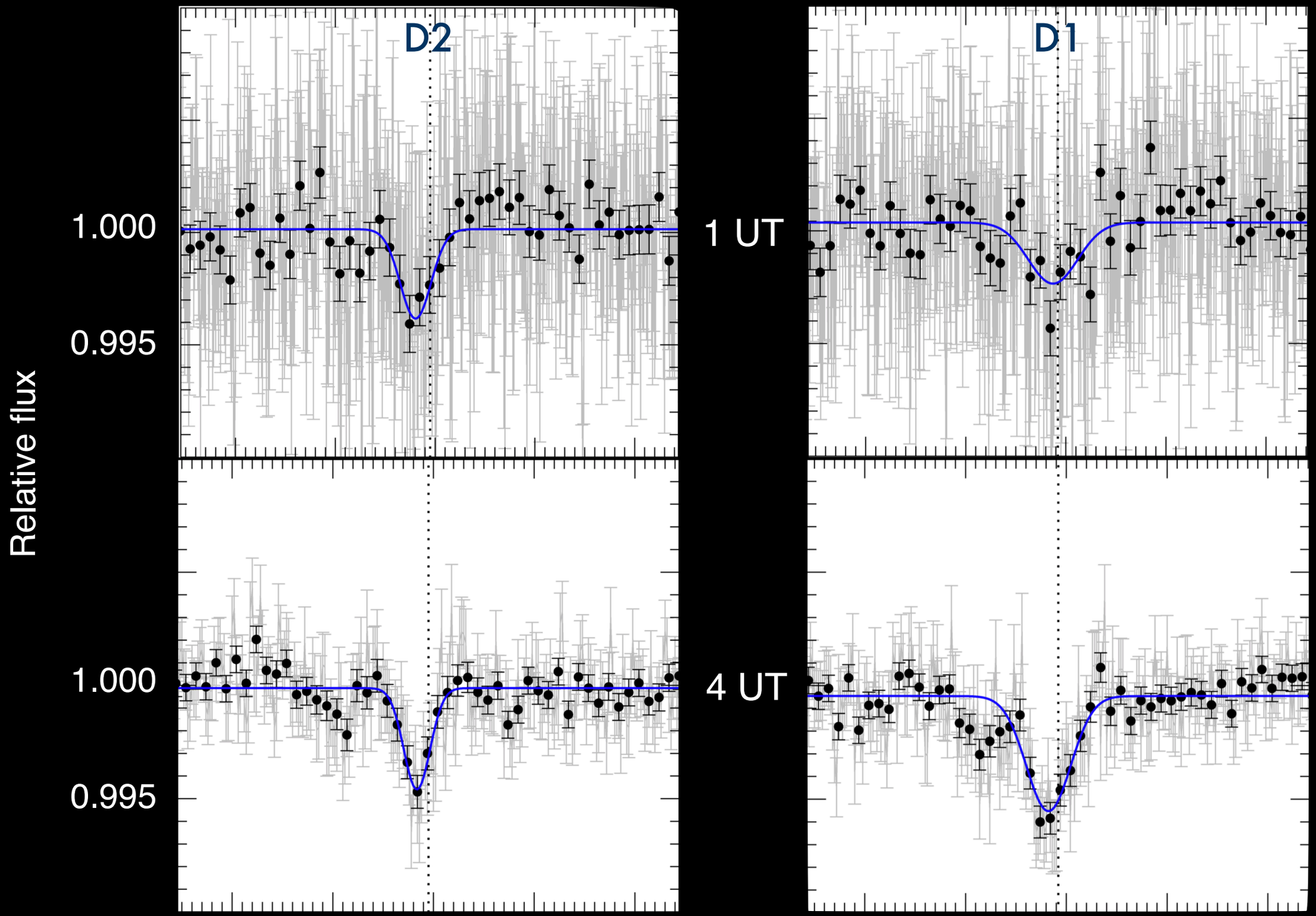
5 km/s planetary rotation
+ 5 km/s day to night wind
= 10 km/s offset

Caveats apply:
Wardenier et al. 2021

Julia V. Seidel @JuliaVSeidel

WASP-121 b

ESPRESSO, 1 night each

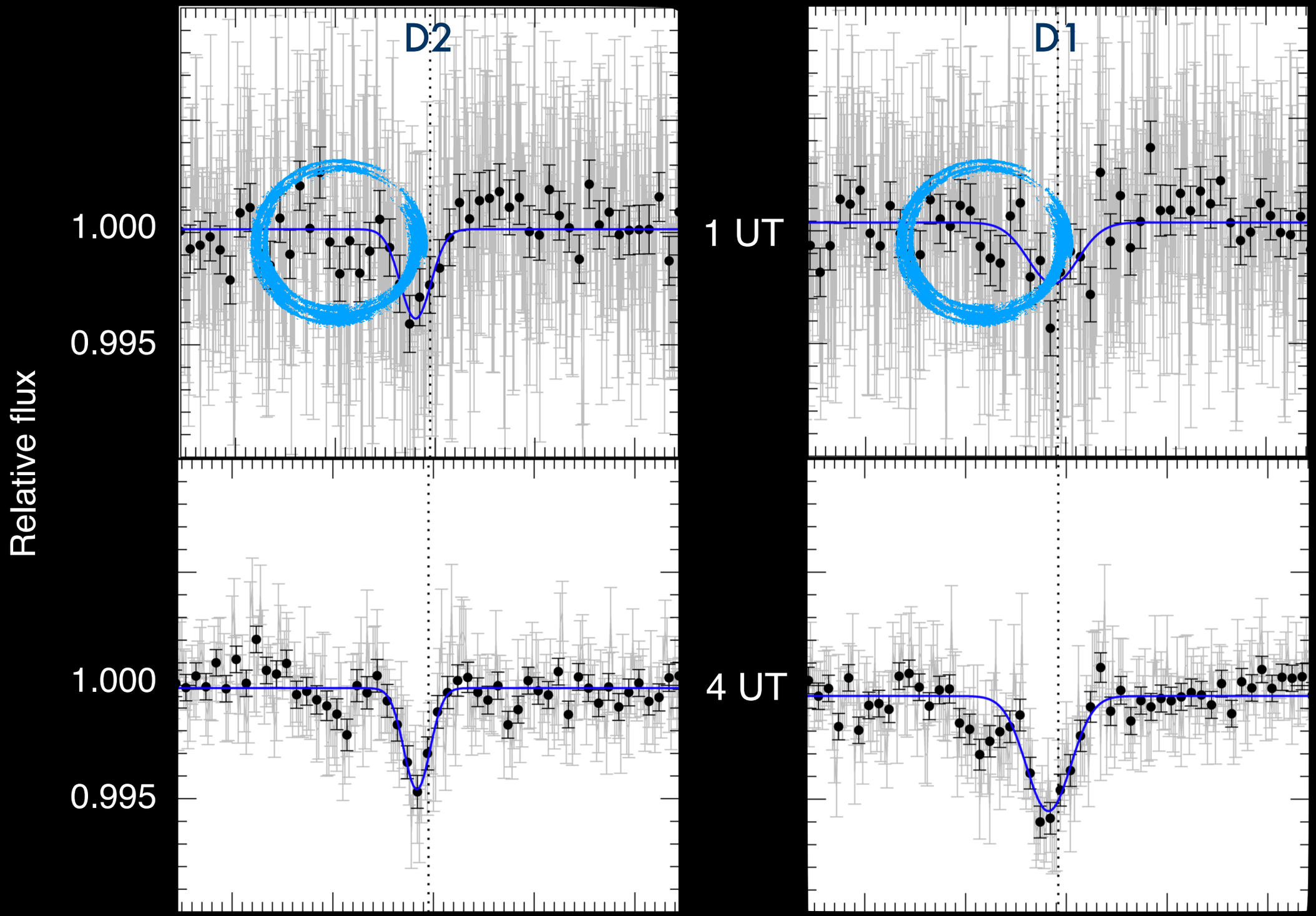


Borsa et al. 2020

Julia V. Seidel @JuliaVSeidel

WASP-121 b

ESPRESSO, 1 night each

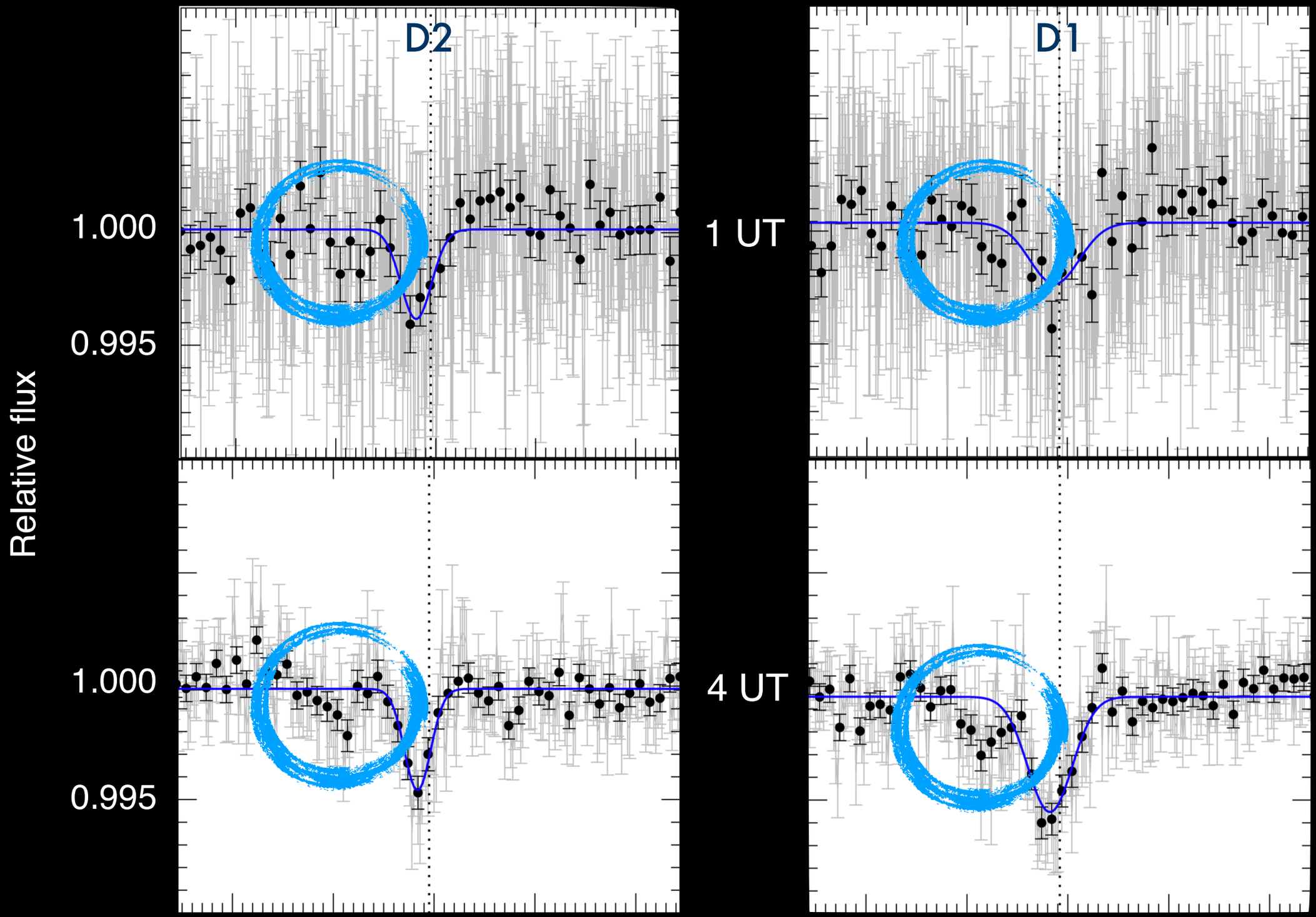


Julia V. Seidel @JuliaVSeidel

Borsa et al. 2020

WASP-121 b

ESPRESSO, 1 night each



Borsa et al. 2020

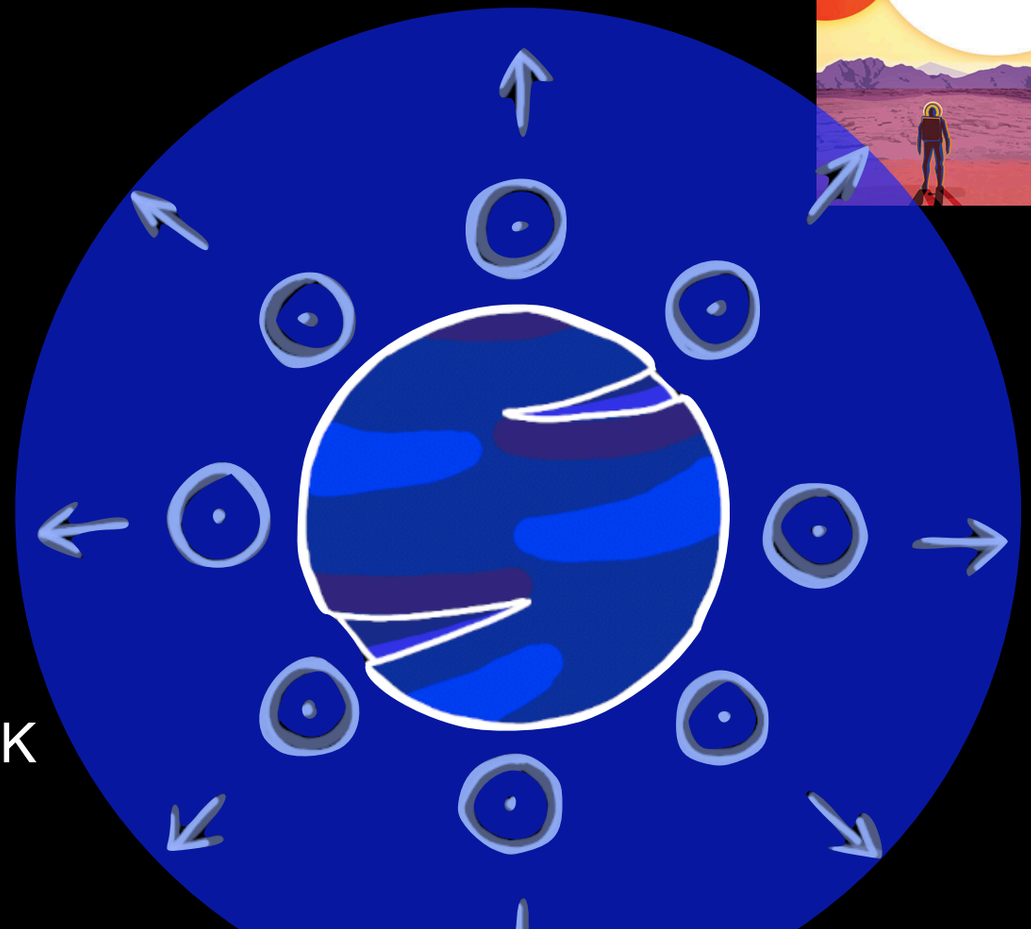
Julia V. Seidel @JuliaVSeidel

WASP-121 b
1 UT

$v_{day\text{-}to\text{-}night} = 10.3 \pm {}^{3.1}/_{2.6}$ km/s

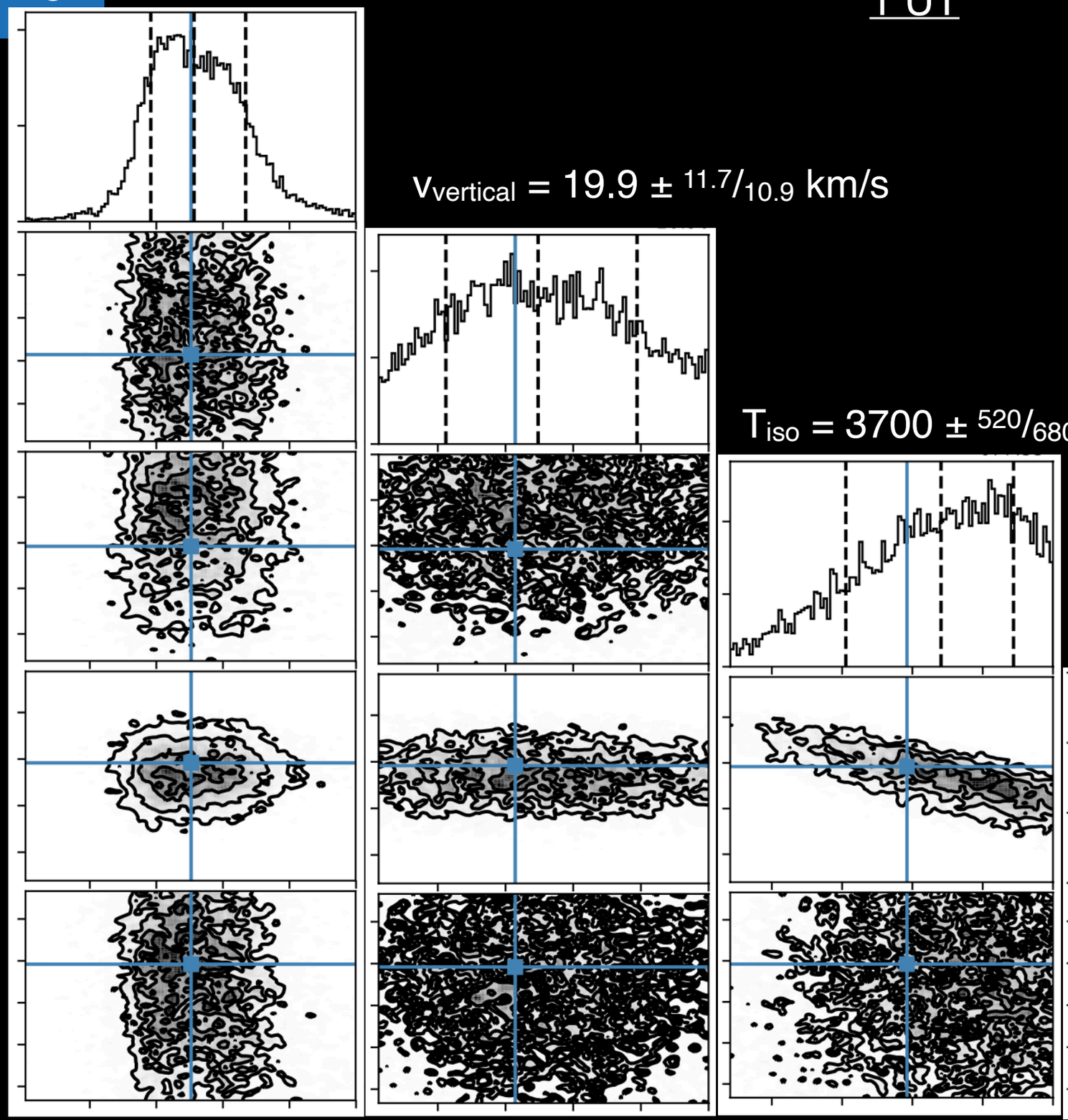
$v_{vertical} = 19.9 \pm {}^{11.7}/_{10.9}$ km/s

$T_{iso} = 3700 \pm {}^{520}/_{680}$ K



NaX = -3.3 ± 0.2

Switch = -2.6 ± 0.9



Julia V. Seidel @JuliaVSeidel

Seidel et al. 2022 in prep.

WASP-121 b
4 UT

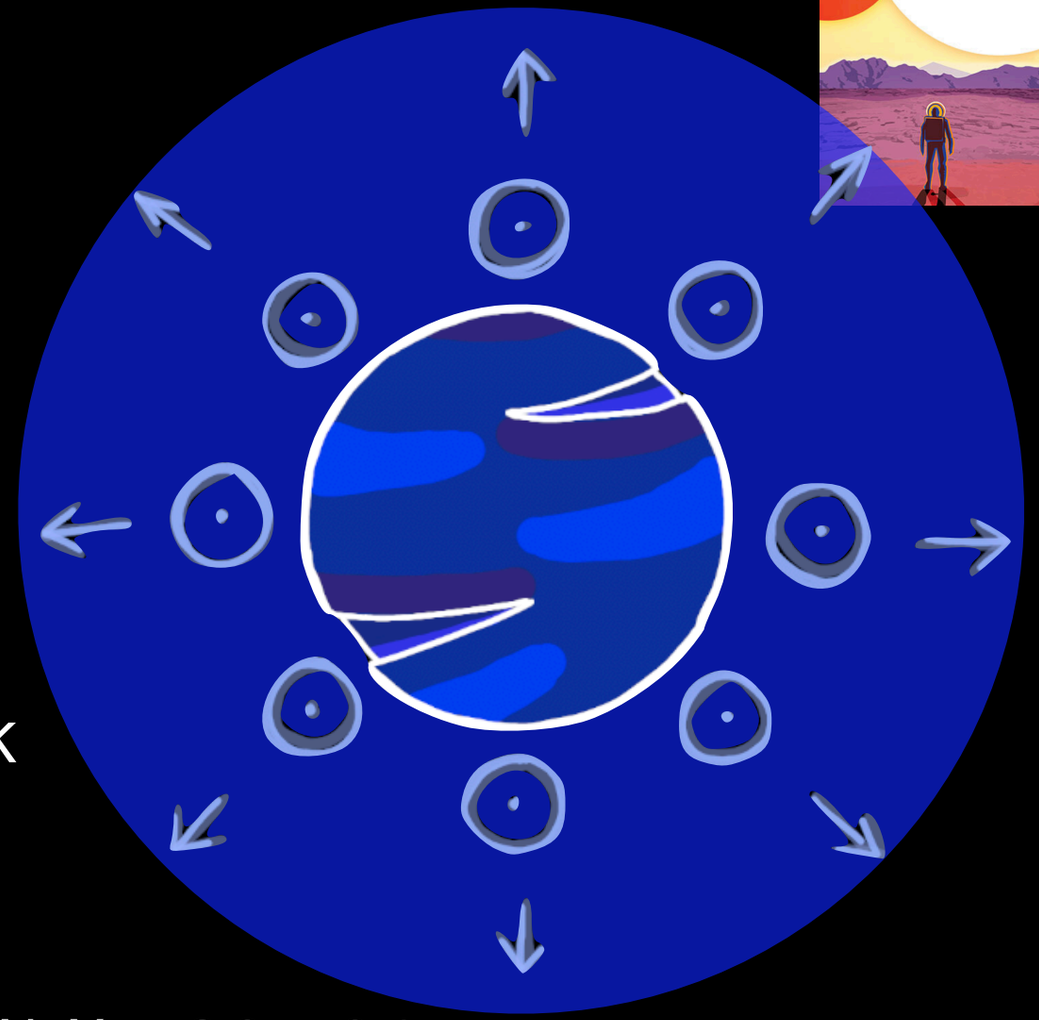
$v_{day\text{-}to\text{-}night} = 16.4 \pm {}^{2.2}/_{2.6}$ km/s

$v_{vertical} = 10.2 \pm {}^{4.5}/_{3.9}$ km/s

$T_{iso} = 3900 \pm 245$ K

NaX = -2.9 ± 0.1

Switch = -1.9 ± 0.5



Julia V. Seidel @JuliaVSeidel

Seidel et al. 2022 in prep.

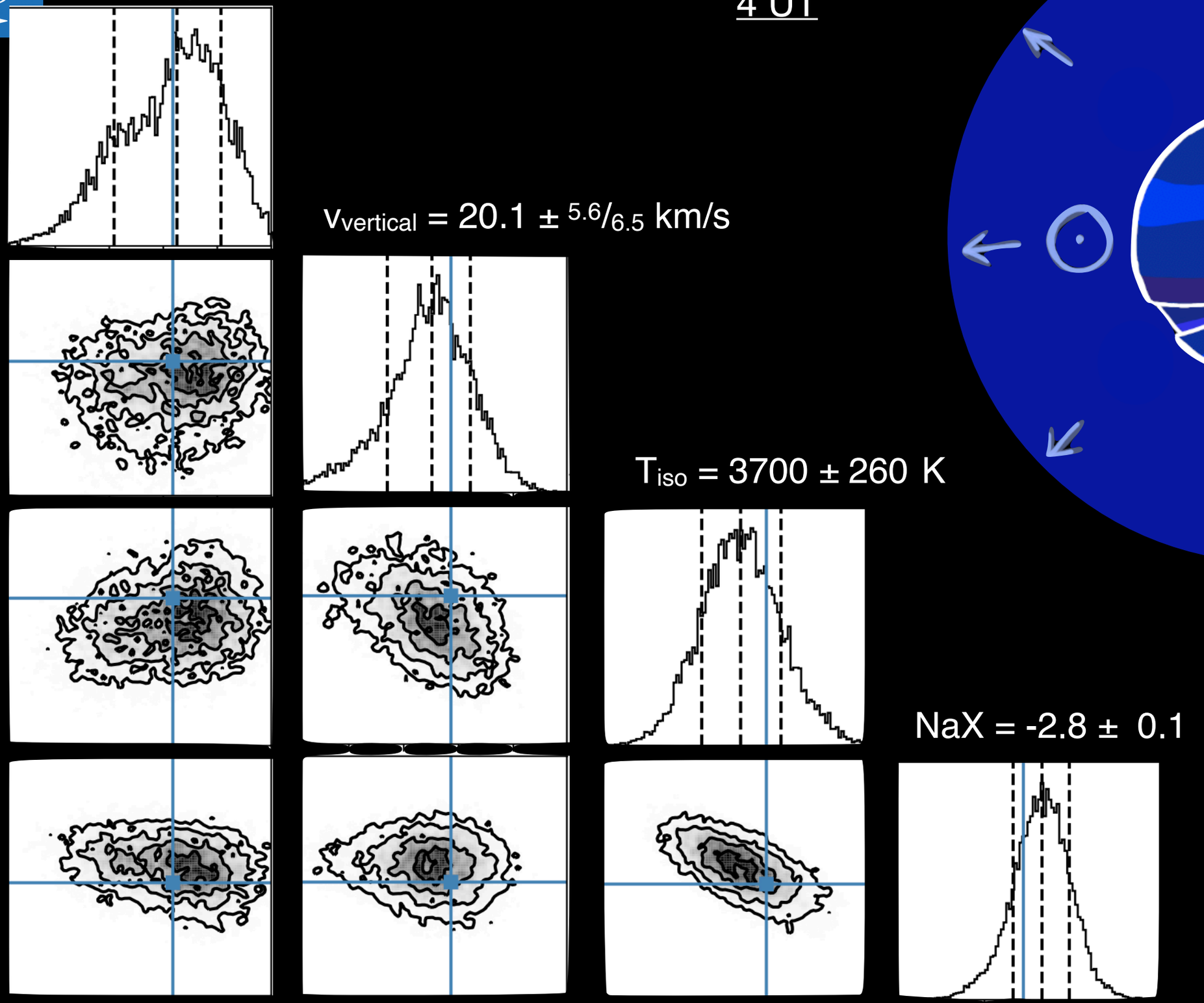
WASP-121 b
4 UT

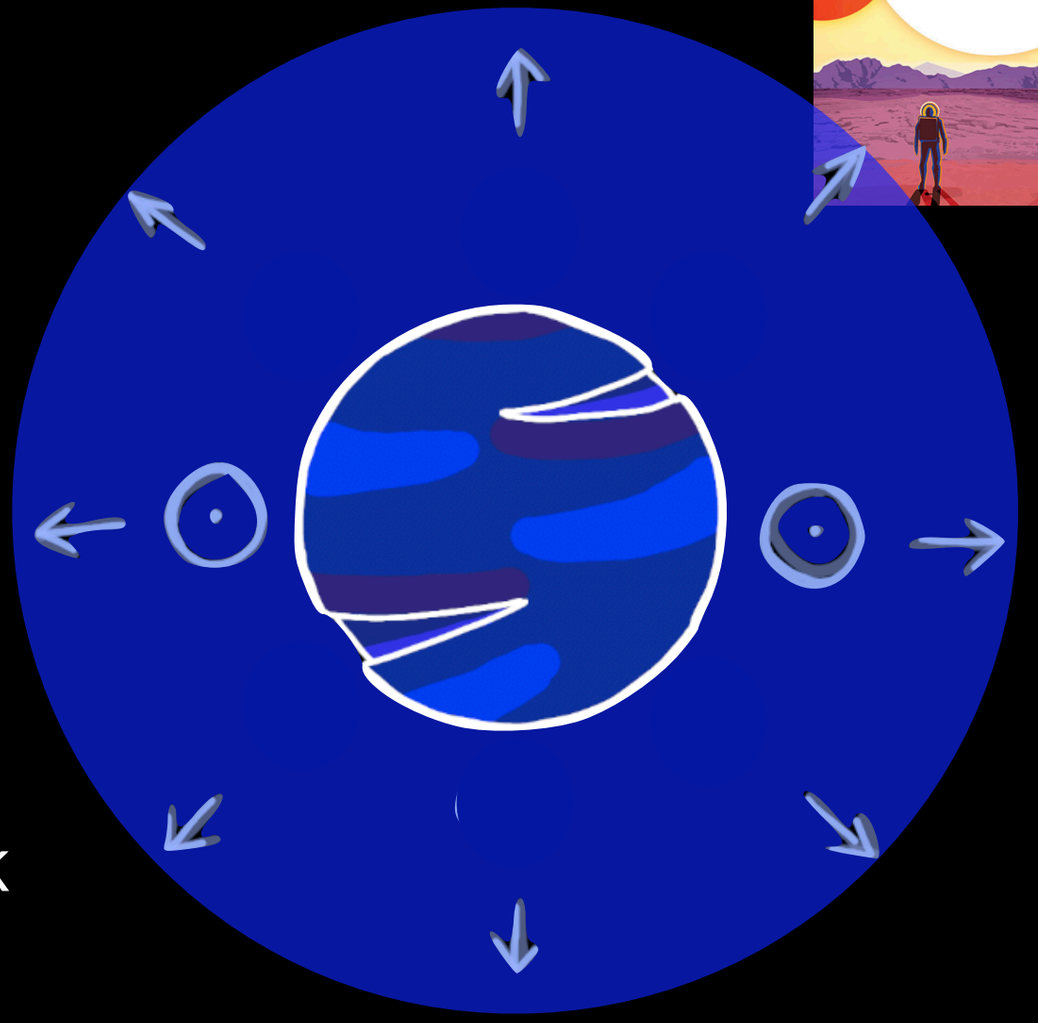
$v_{day\text{-}to\text{-}night-} = 32.5 \pm {}^{8.2}/_{11.6}$ km/s

$v_{vertical} = 20.1 \pm {}^{5.6}/_{6.5}$ km/s

$T_{iso} = 3700 \pm 260$ K

NaX = -2.8 ± 0.1



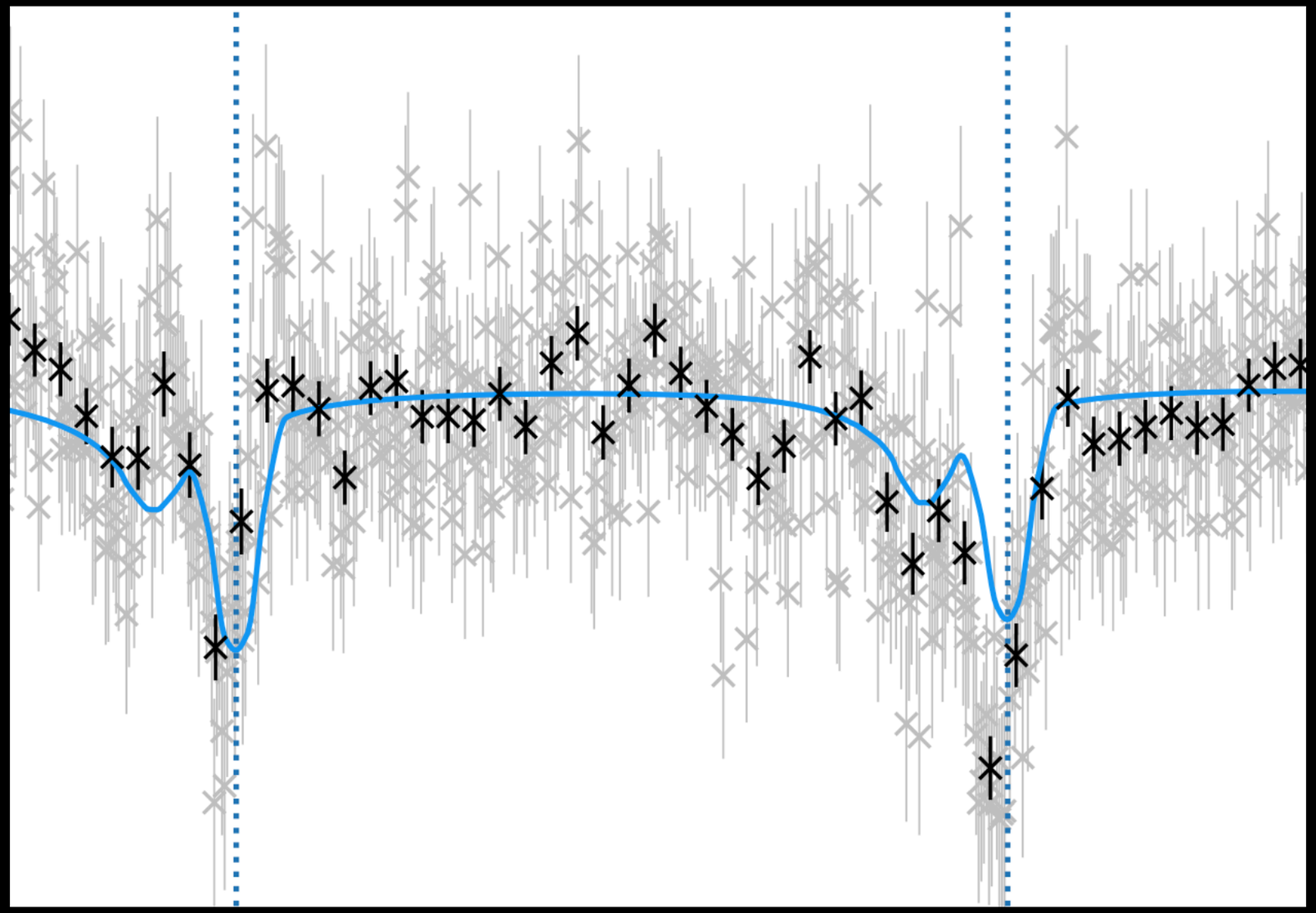


Julia V. Seidel @JuliaVSeidel

Seidel et al. 2022 in prep.

WASP-121 b

ESPRESSO 4 UT



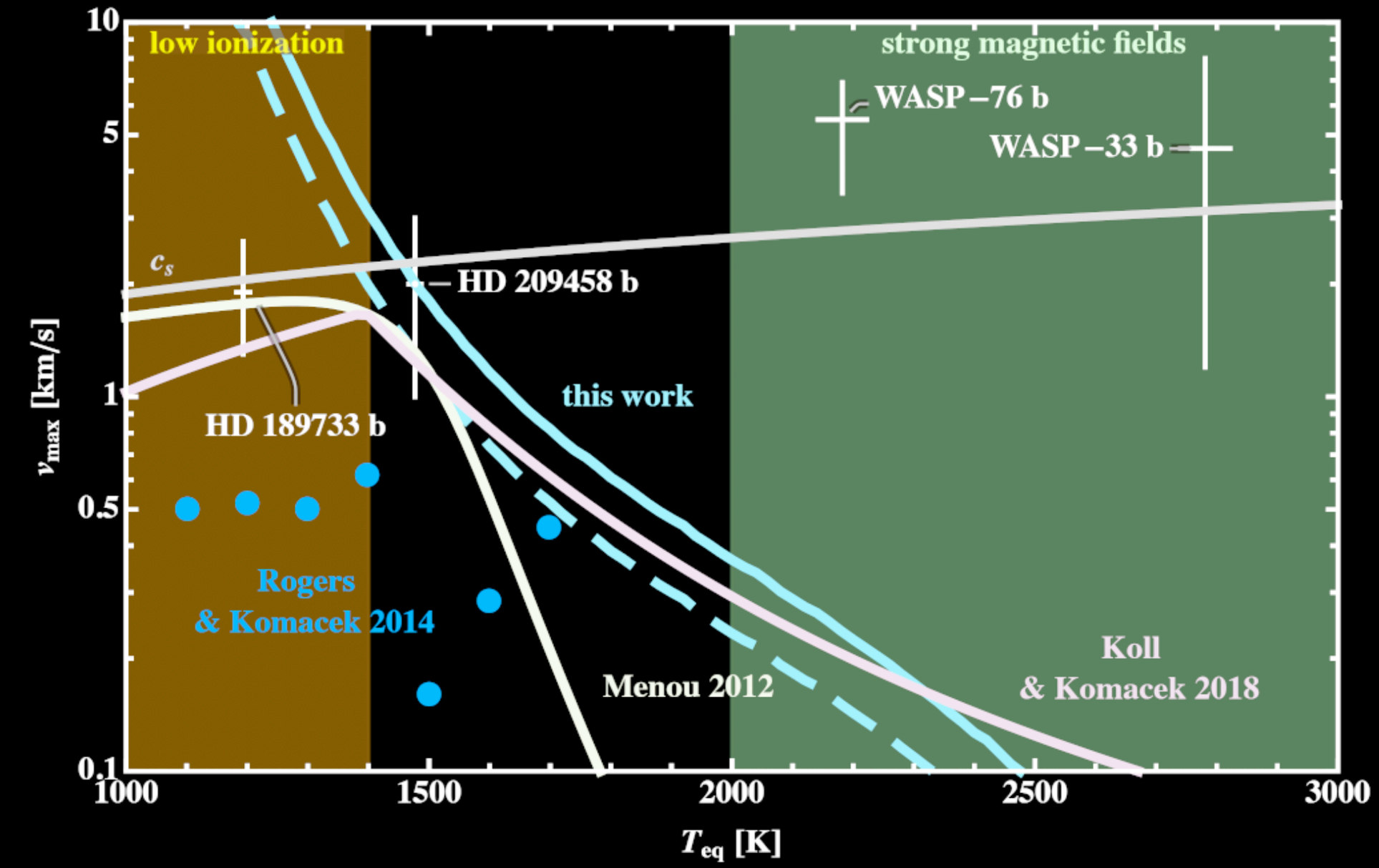
Seidel et al. 2022 in prep.

So, winds are great!

But what else is this good for?

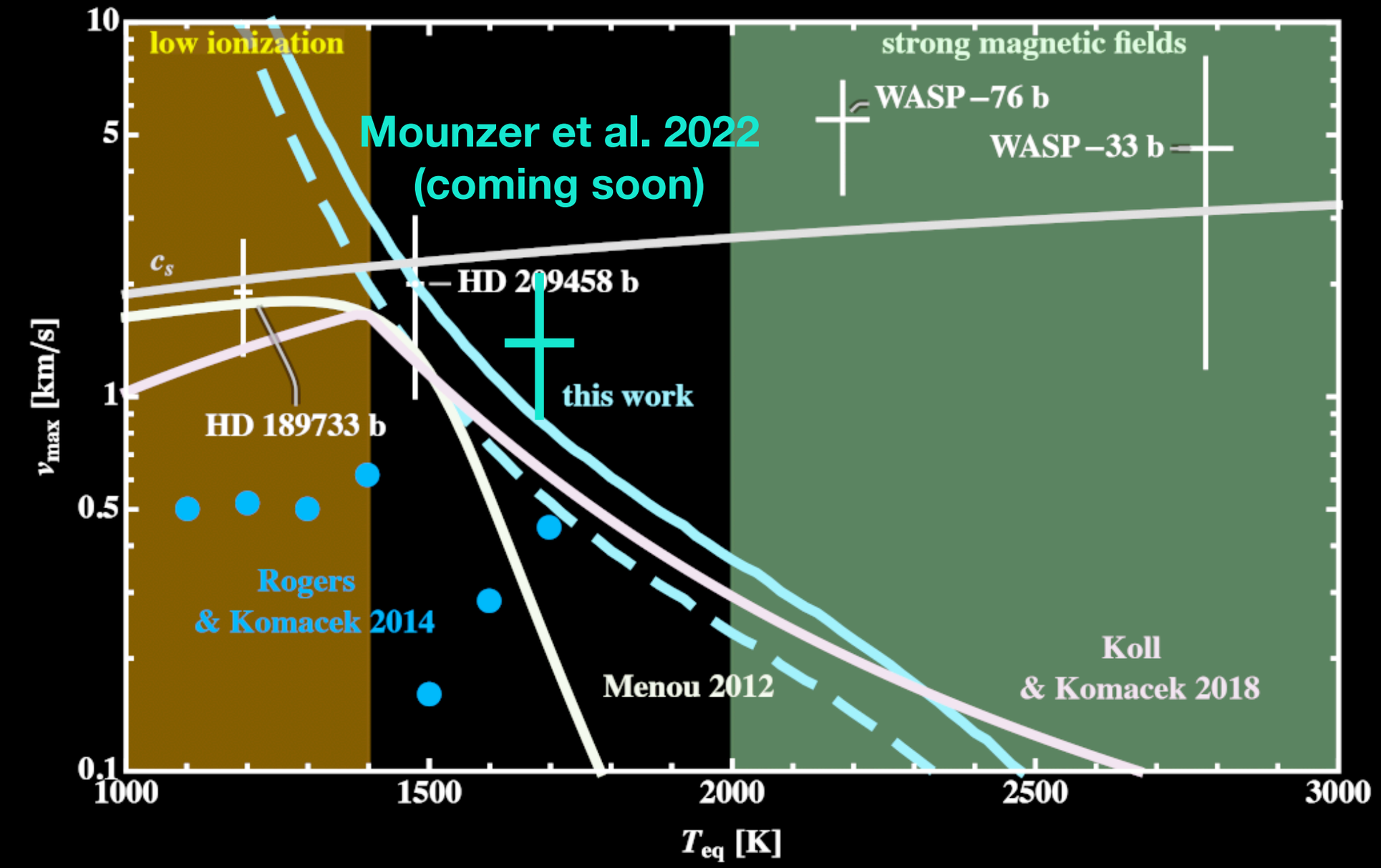
Julia V. Seidel @JuliaVSeidel

Magnetic fields



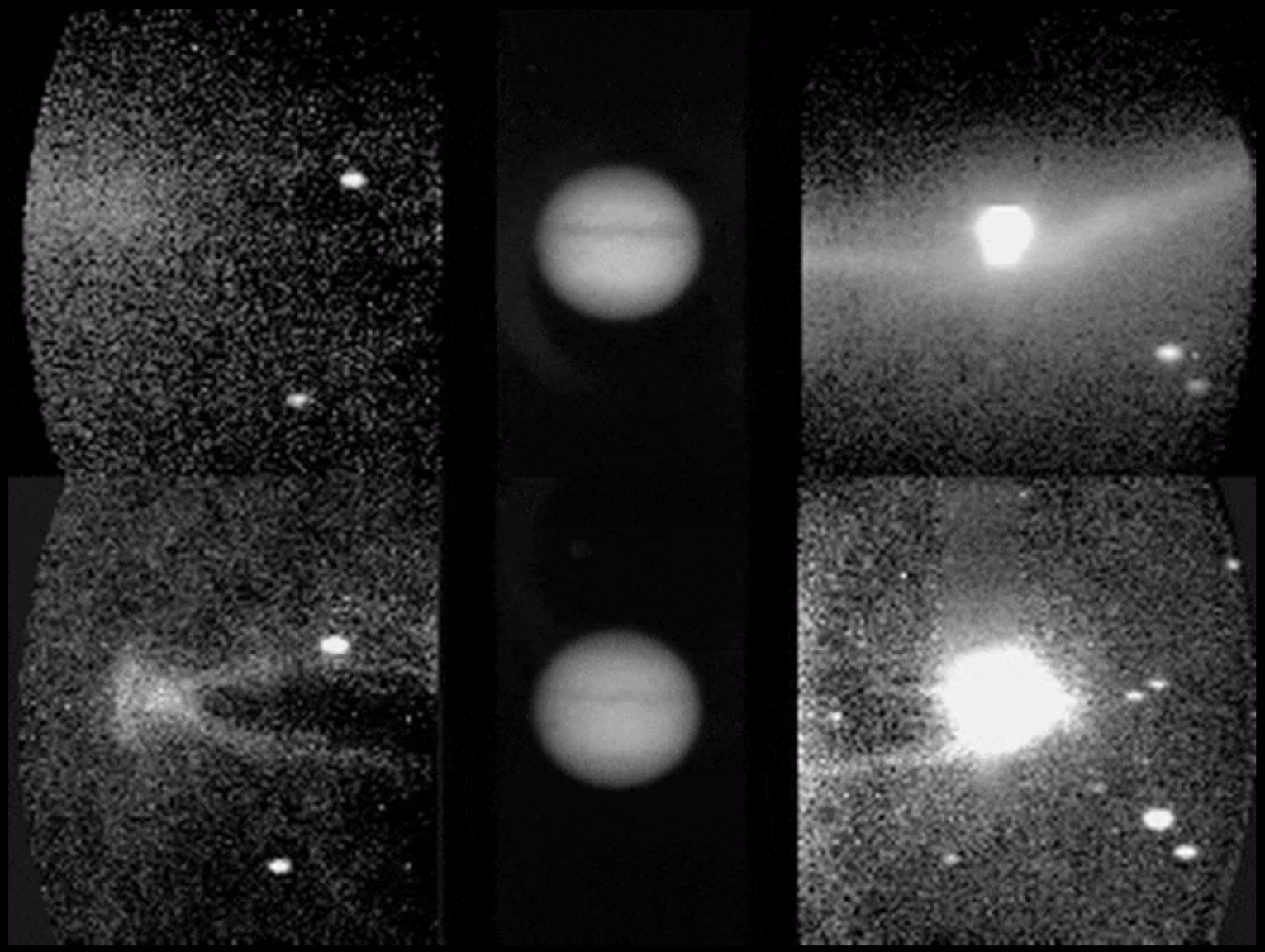
Knierim et al. 2022

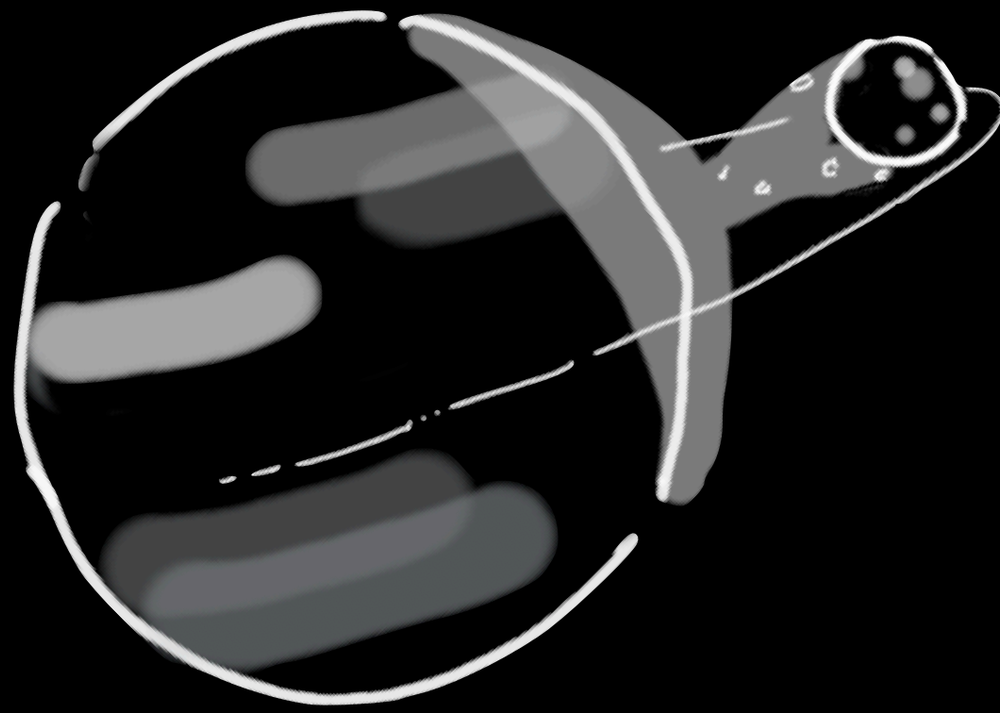
Magnetic fields



Knierim et al. 2022

MOONS

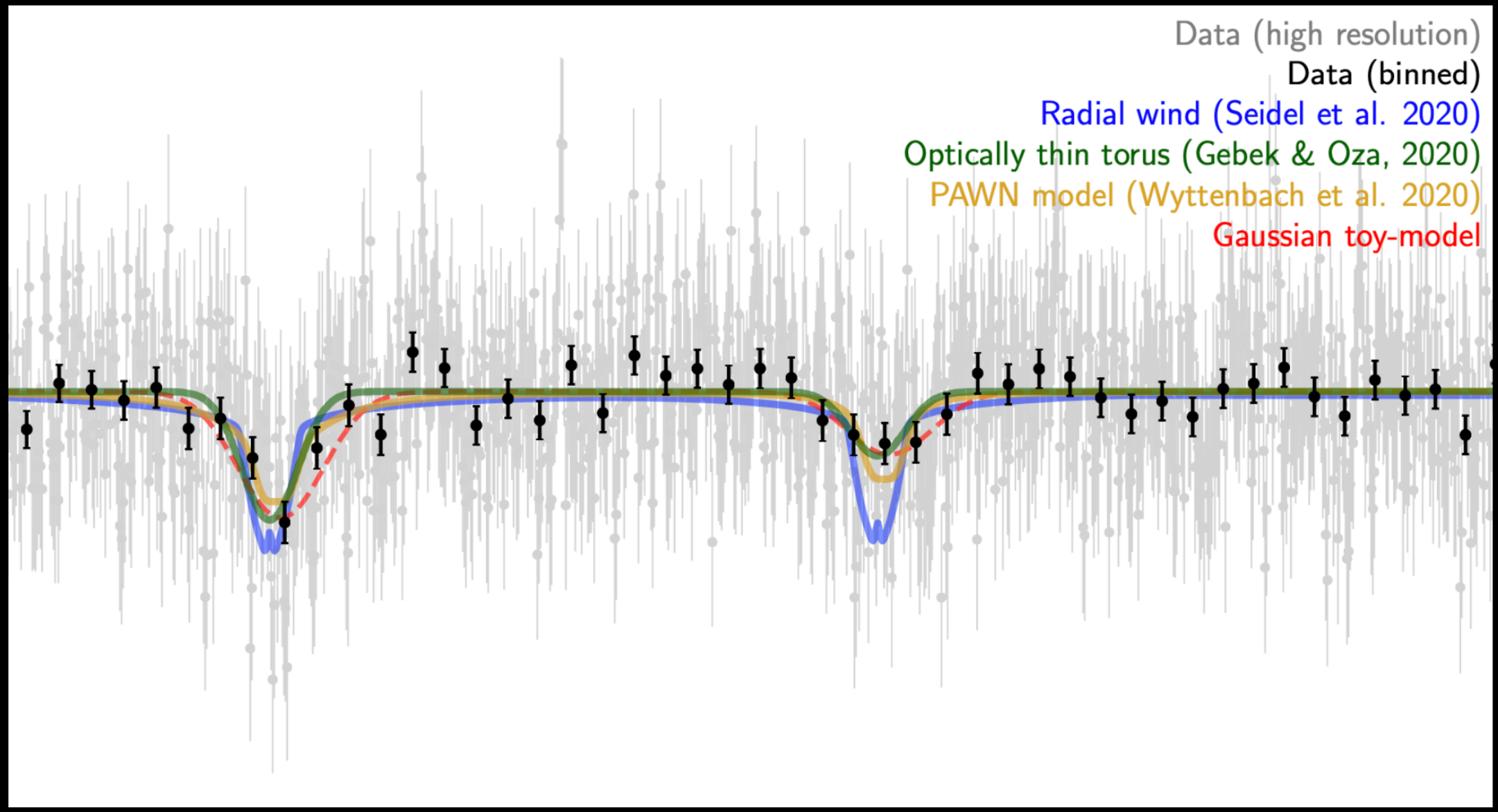




Schneider et al. 1991

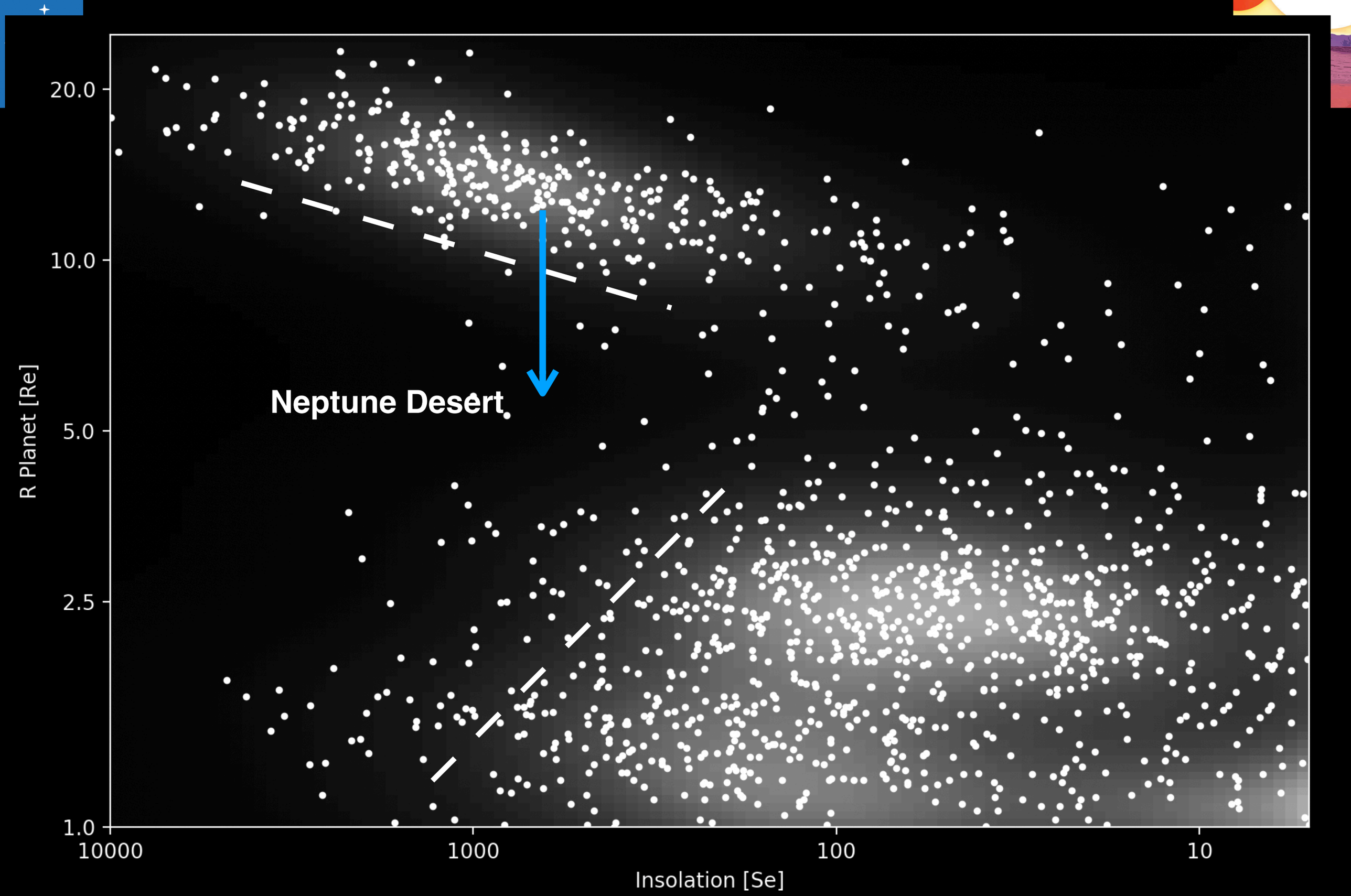
WASP-121 b

HARPS, 3 nights combined

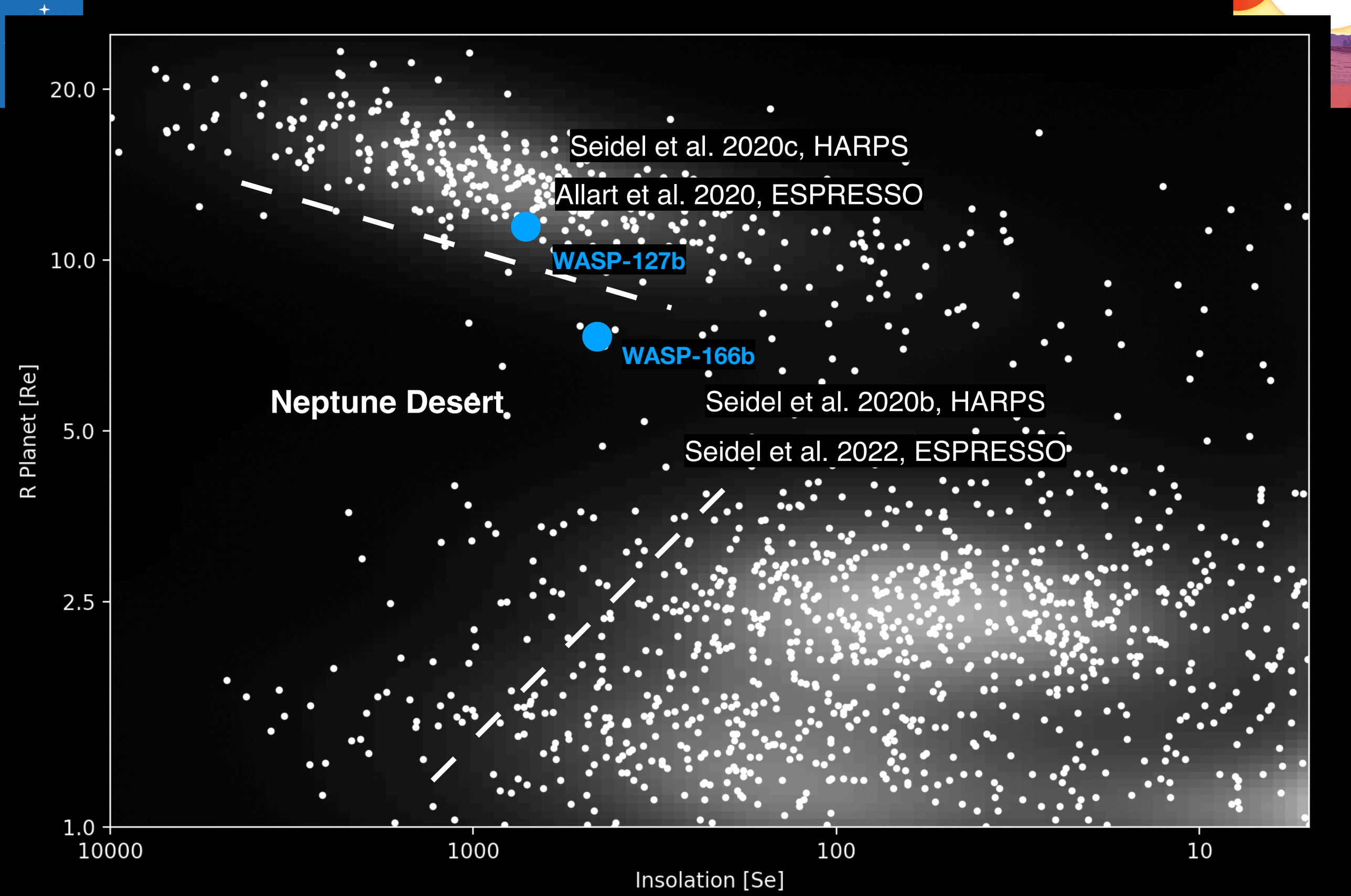


Hoeijmakers et al. 2020

Julia V. Seidel @JuliaVSeidel

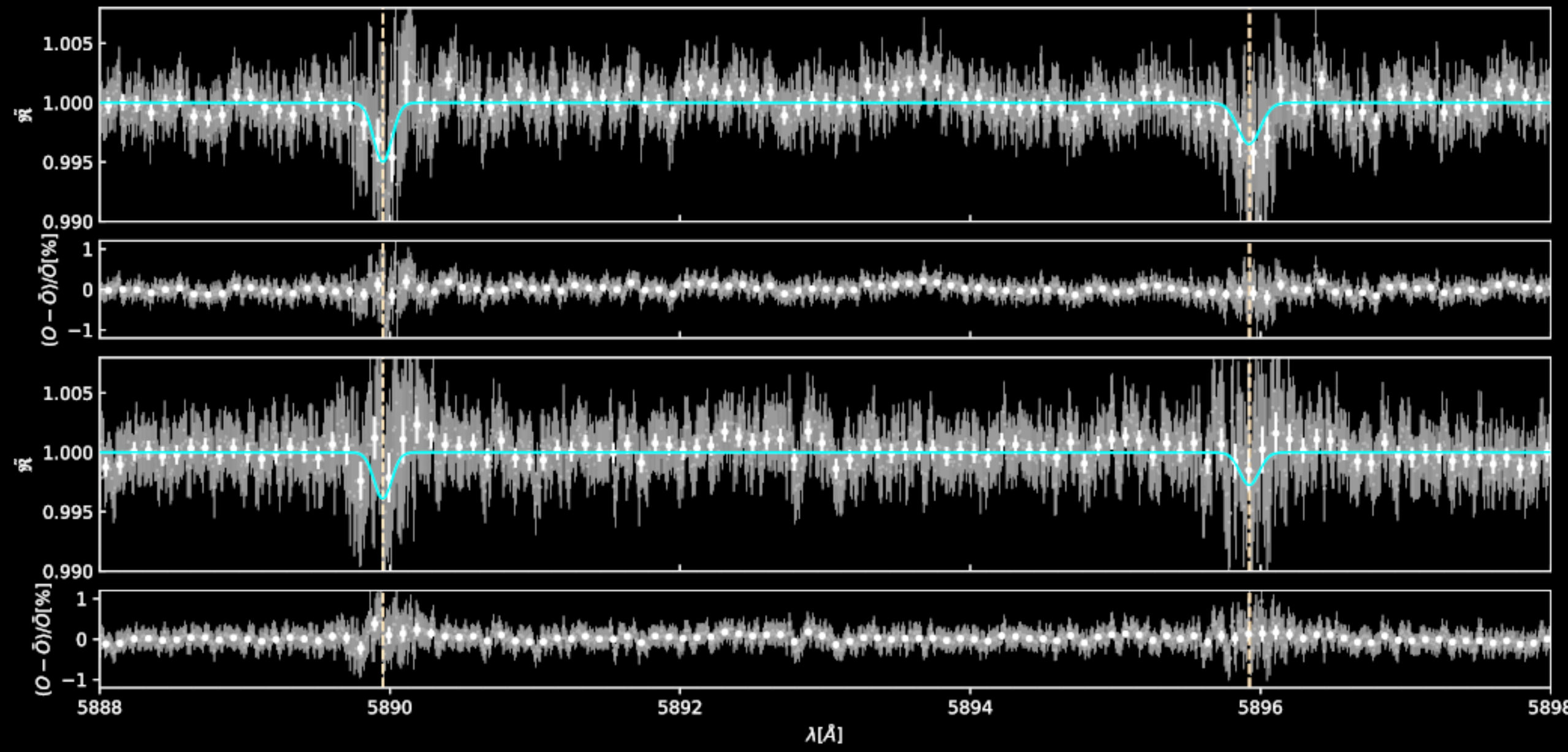


Julia V. Seidel @JuliaVSeidel



Julia V. Seidel @JuliaVSeidel

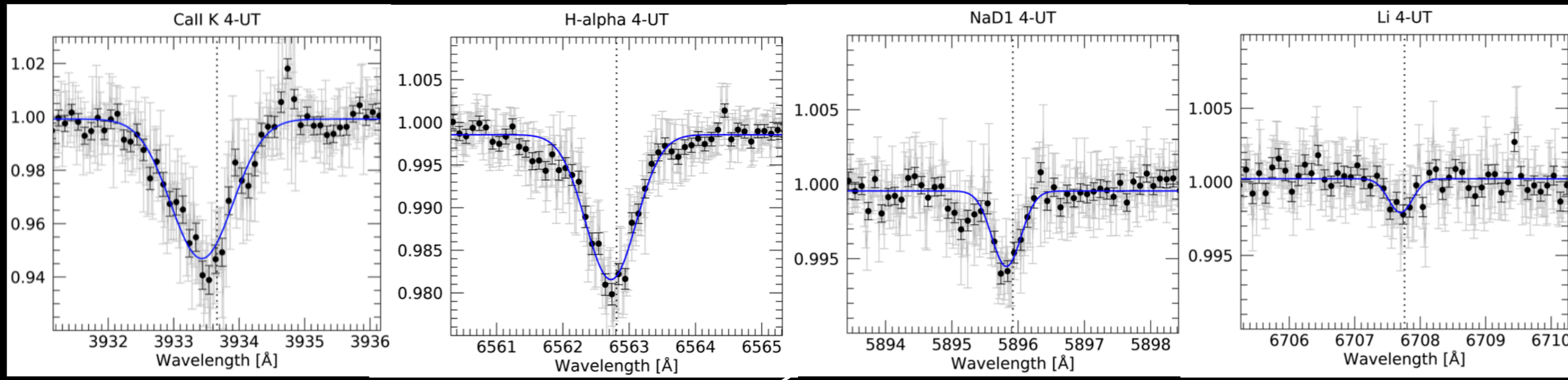
WASP-166 b



Julia V. Seidel @JuliaVSeidel

ESPRESSO 4UT data

Summary

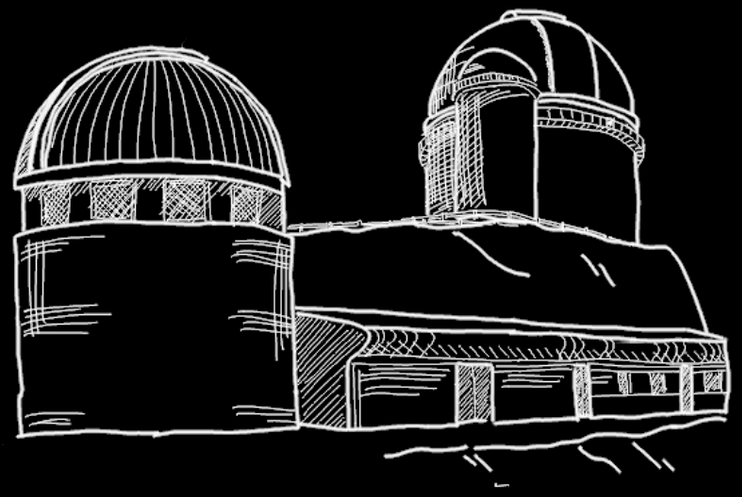


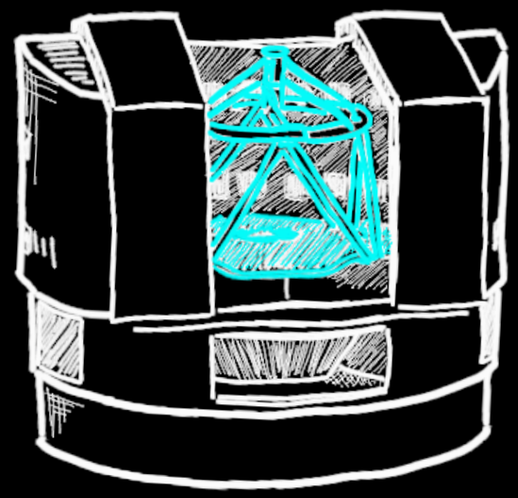
Borsa et al. 2020

Additional spectral lines

CRIRES+@VLT

NIRPS@3.6m

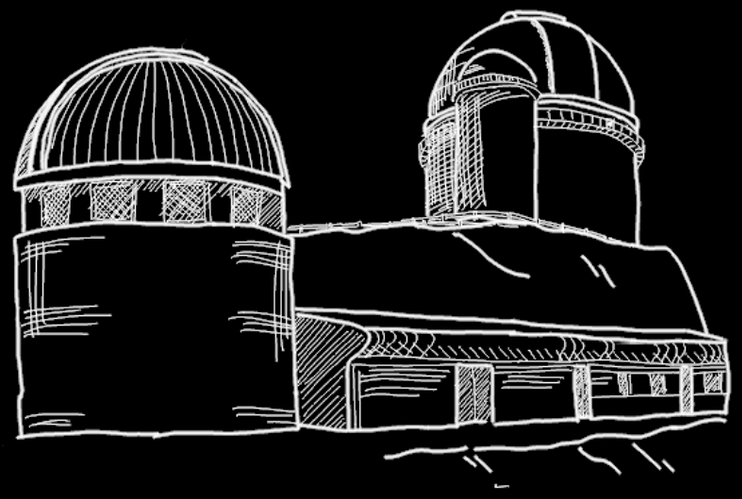


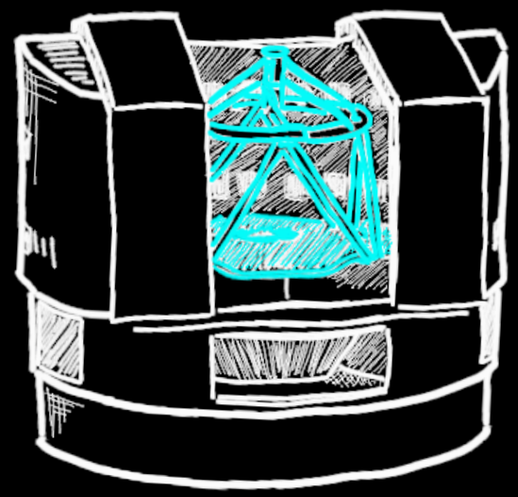


Julia V. Seidel @JuliaVSeidel

Additional spectral lines

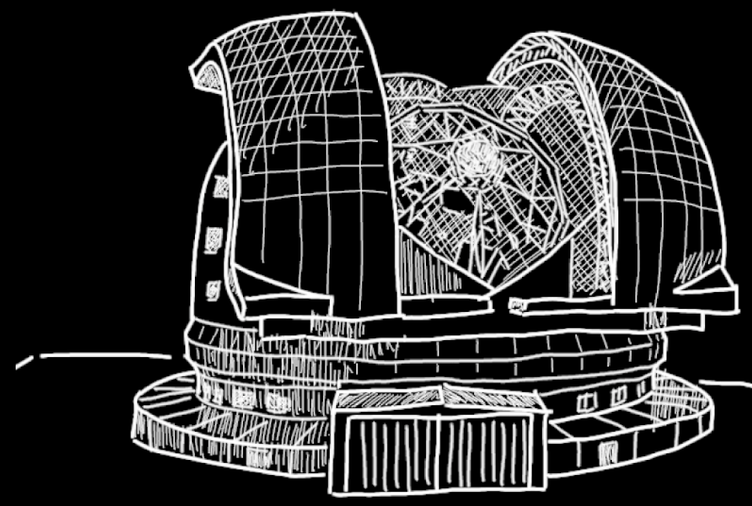
CRIRES+@VLT
NIRPS@3.6m





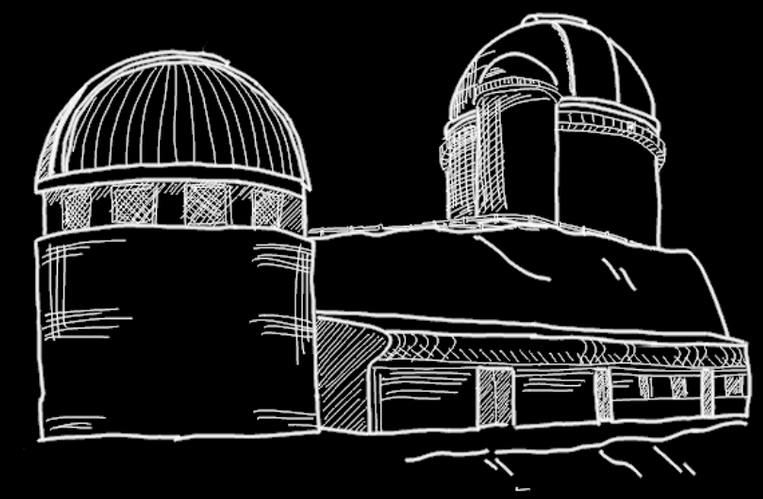
Higher precision

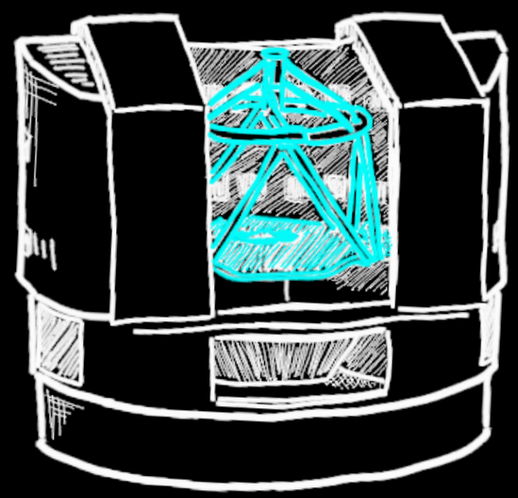
ESPRESSO@VLT
ANDES@ELT

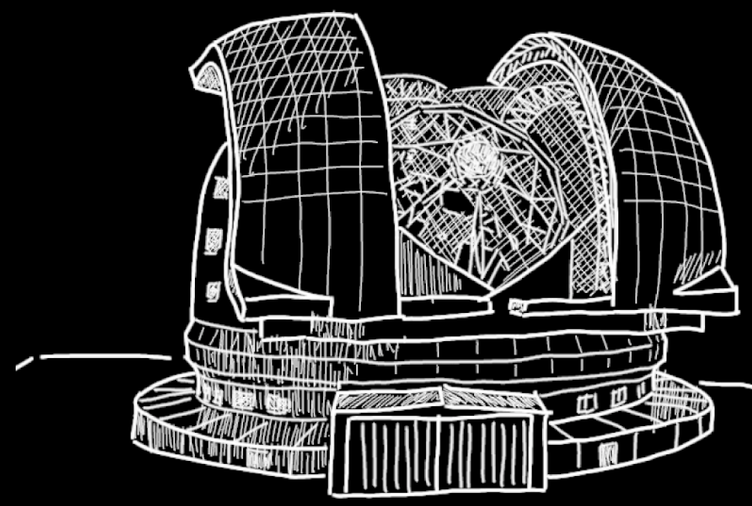


Julia V. Seidel @JuliaVSeidel

A Non-Member State Proposal is a proposal where 2/3 or more of the proposers are not affiliated to ESO member state institutes







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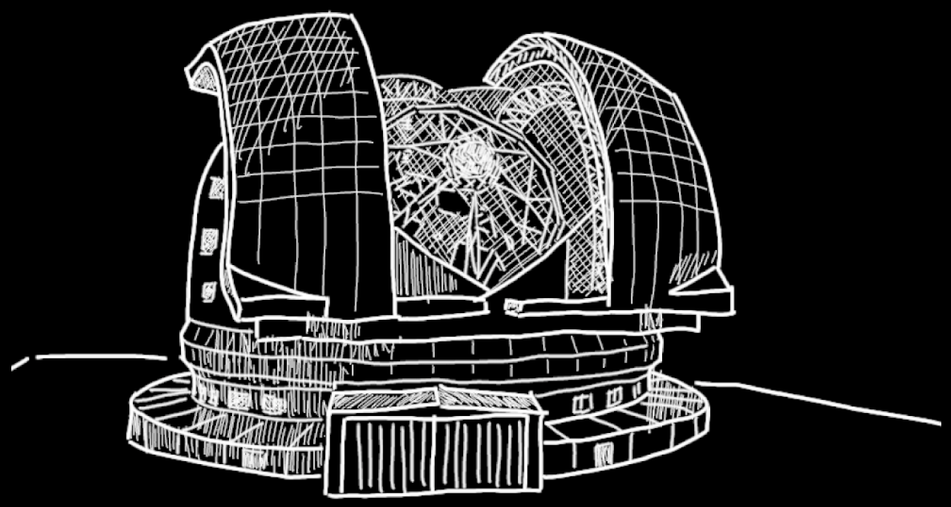

- Ultra-high resolution is magical!
- Gives access to resolved lines which can be used to track winds/magnetic fields
- We can even help the hunt for moons!