Exoplanets : progress in instrumentation and results

(Doppler and transmission spectroscopy)

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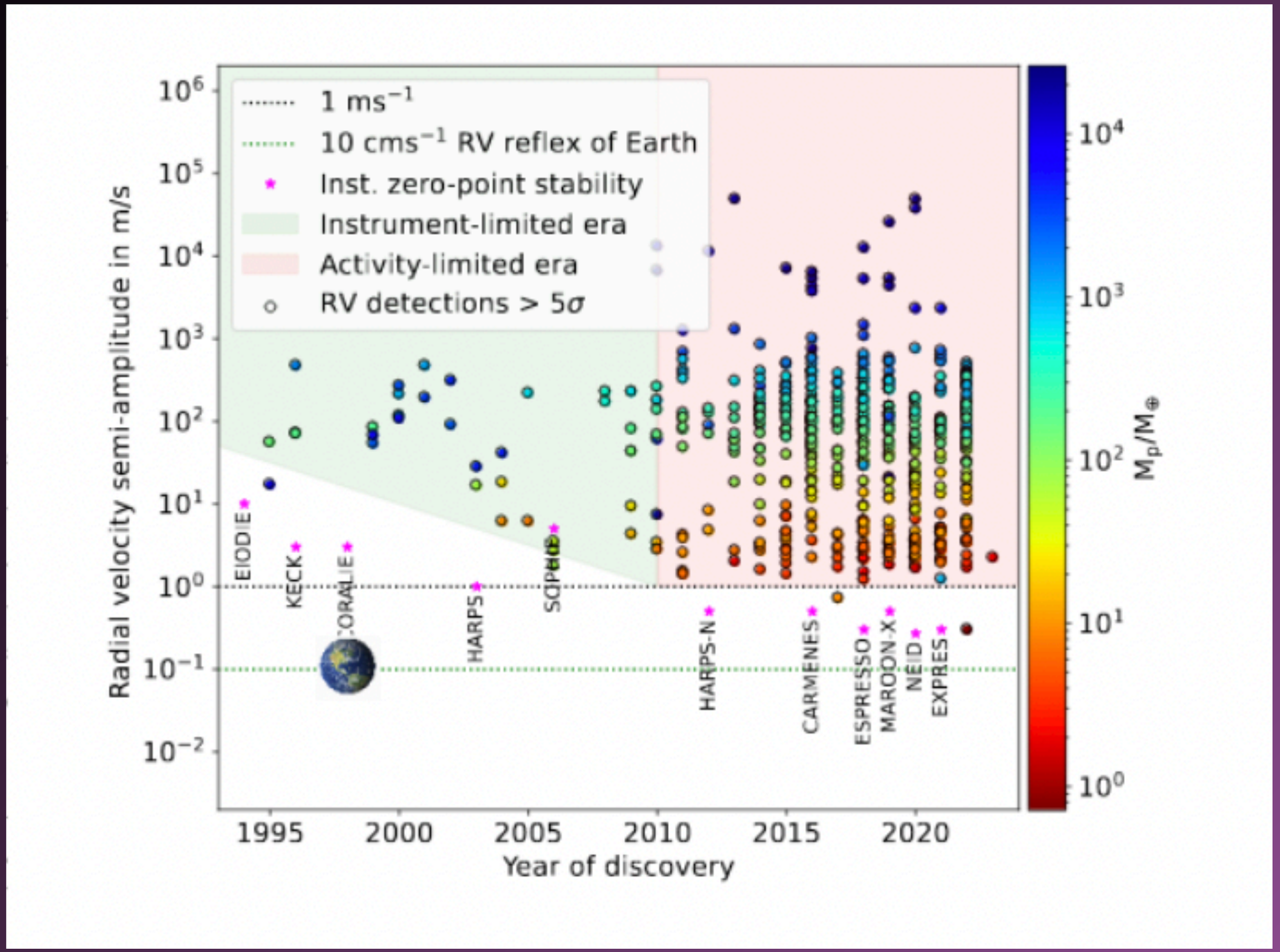
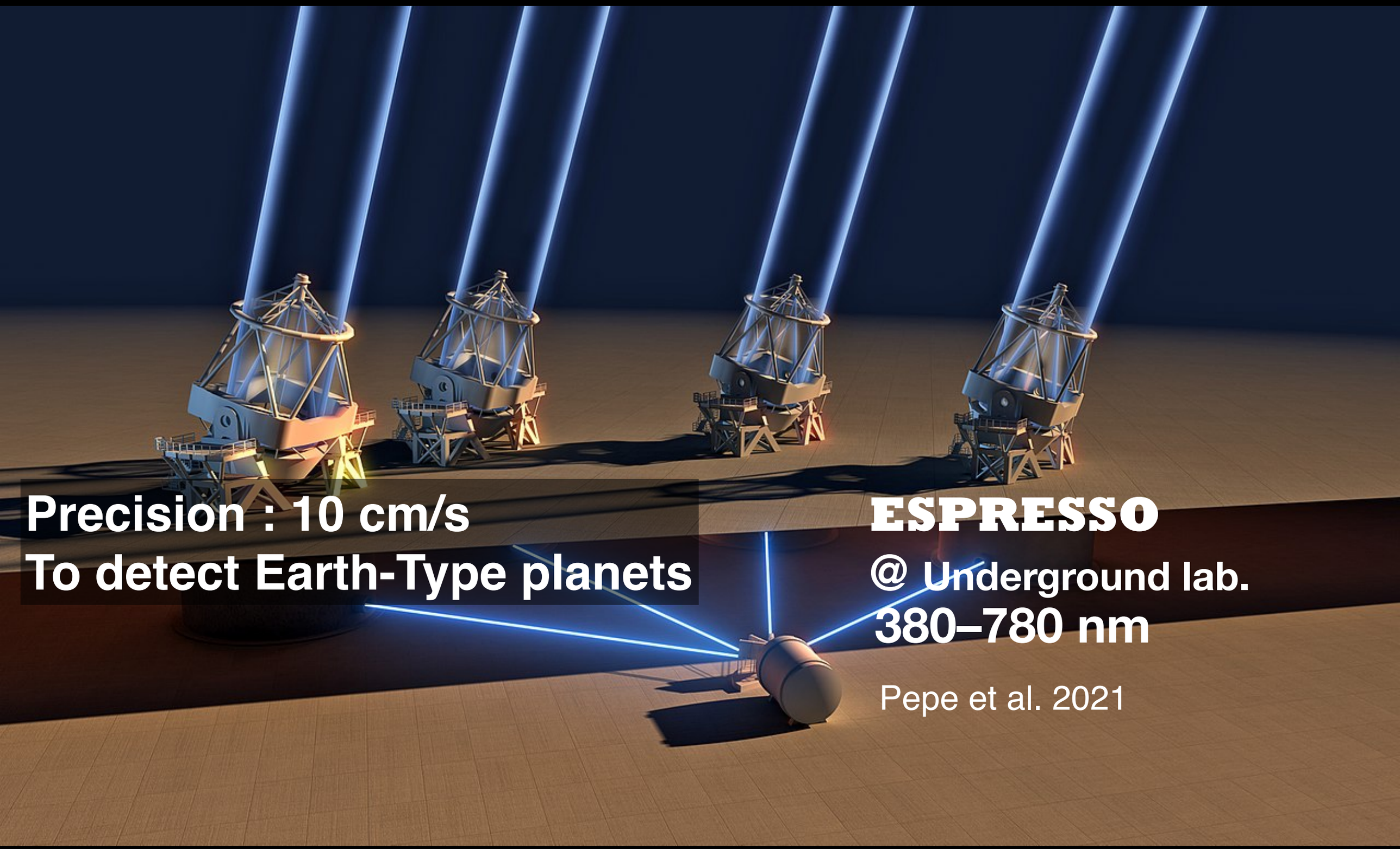
Université de Genève

Doppler spectroscopy

towards 10 cm/s … but


1 ms^{-1}
10 cms^{-1} RV reflex of Earth
Inst. zero-point stability
Instrument-limited era
Activity-limited era
RV detections > 5σ
Radial velocity semi-amplitude in m/s
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
ELODIE
KECK
CORALIE
HARPS
SOPHIE
HARPS-N
CARMENES
ESPRESSO
MAROON-X
NEID
EXPRES
1995
2000
2005
2010
2015
2020
Year of discovery
10^4
10^3
10^2
10^1
10^0
$M_p/M_\oplus$

ESPRESSO @ 1 to 4 VLT (8m telescopes), Paranal Observatory (ESO)



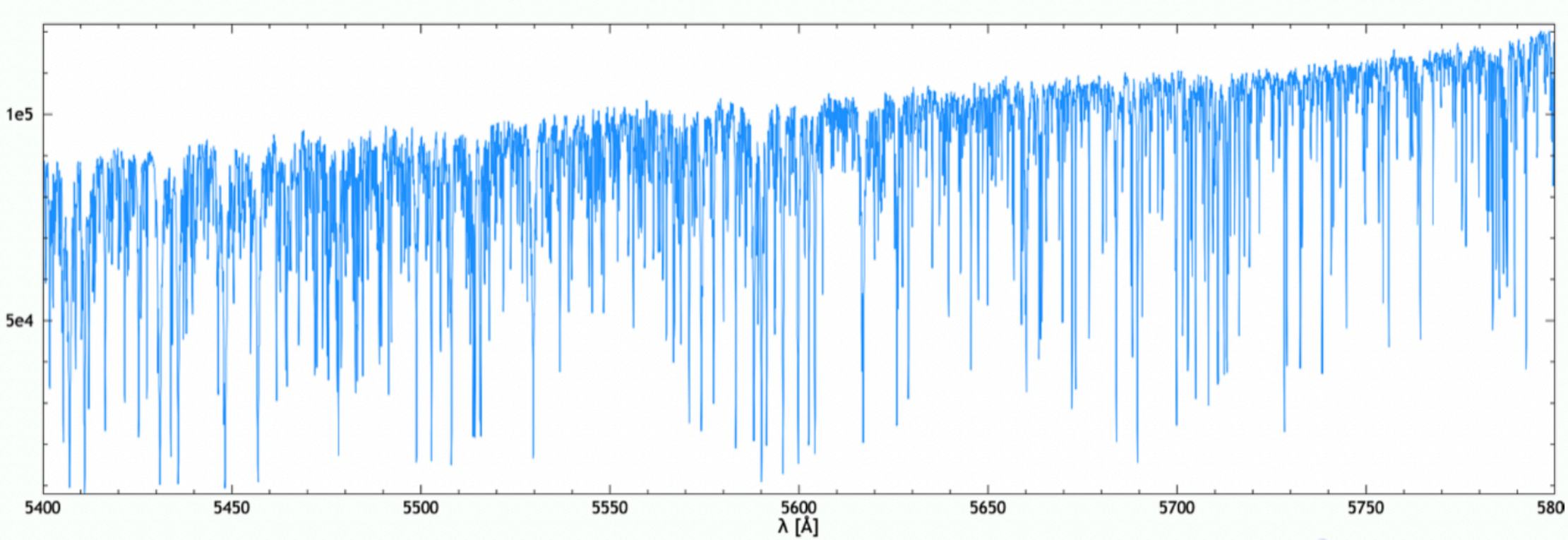
Precision : 10 cm/s
To detect Earth-Type planets

ESPRESSO
@ Underground lab.
380–780 nm

Pepe et al. 2021

The variation in stellar radial velocity induced by the influence of a planet analogous to our Earth.

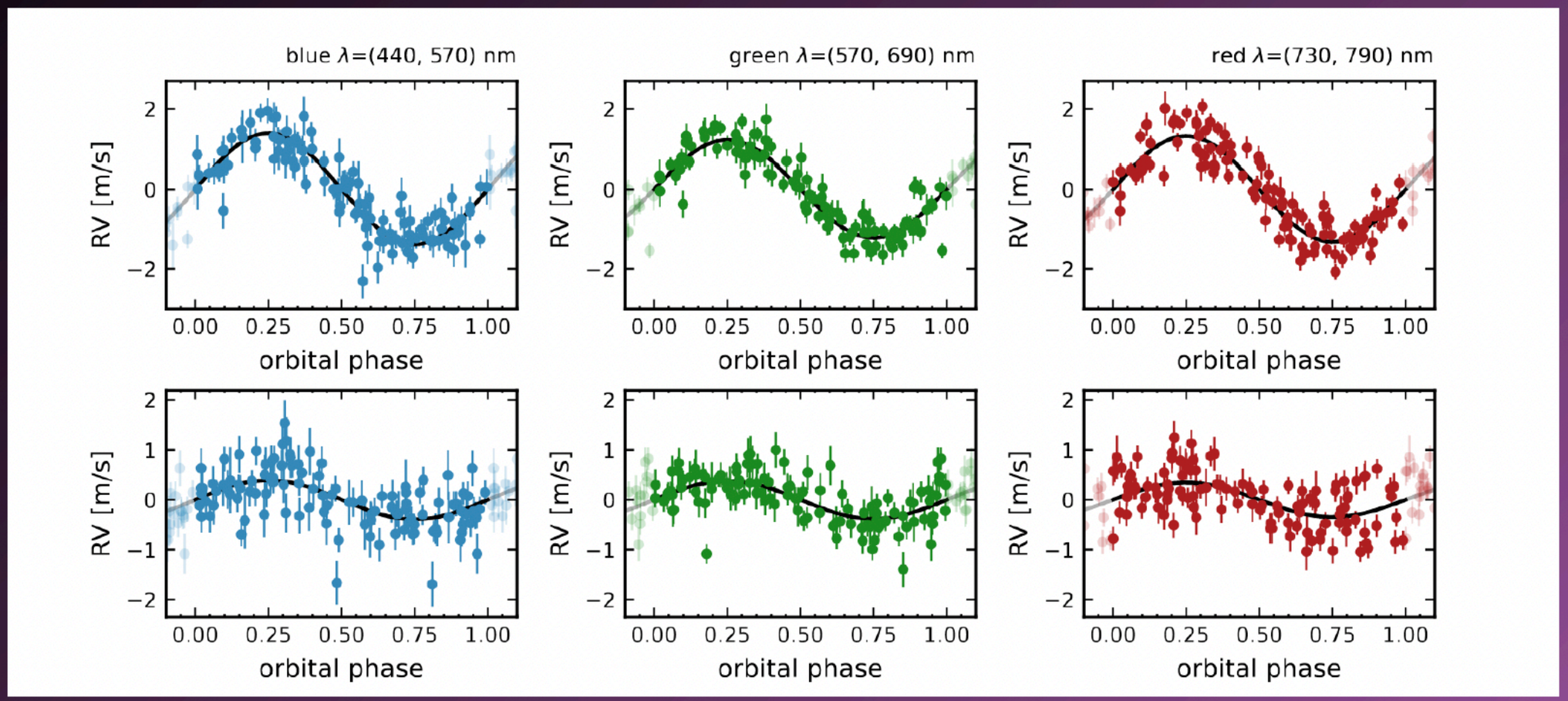
Below: 1/10 of the spectral range used for the determination of the radial speed using the Doppler effect. (ESPRESSO Spectrograph , ESO Paranal Obs.)
The variation in the speed of a solar star due to an Earth-like planet (P = 1 year) is 8 cm / s therefore relative variation of 0.3 x 10 ** (- 4) of the width of the spectral lines. (about 1 nanometer)
>>>>>>> the cross-correlation technique makes it possible to concentrate the Doppler information of several thousand spectral lines to achieve this precision.

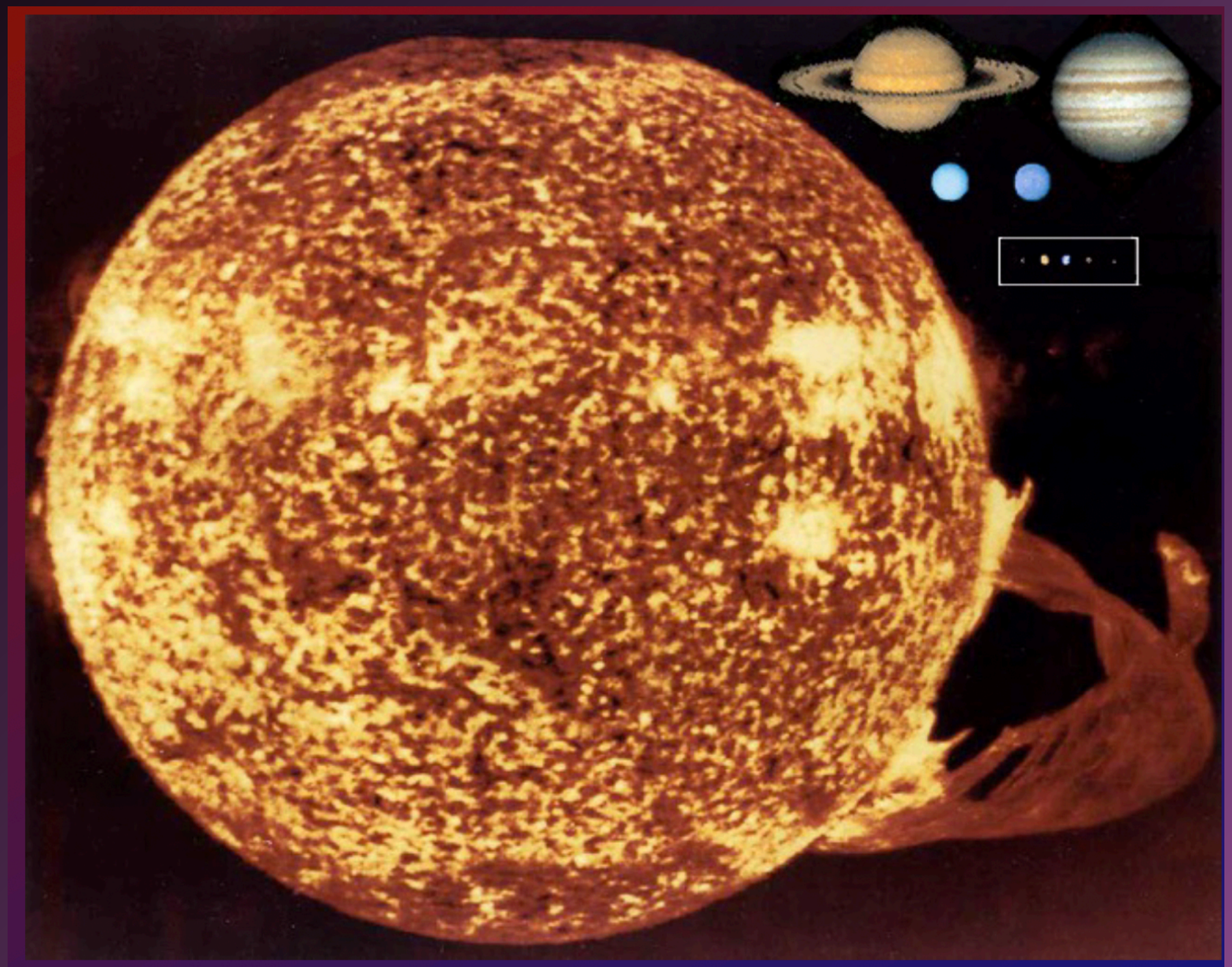


8

Proxima Centauri , ESPRESSO measurements of the 2 inner planets,

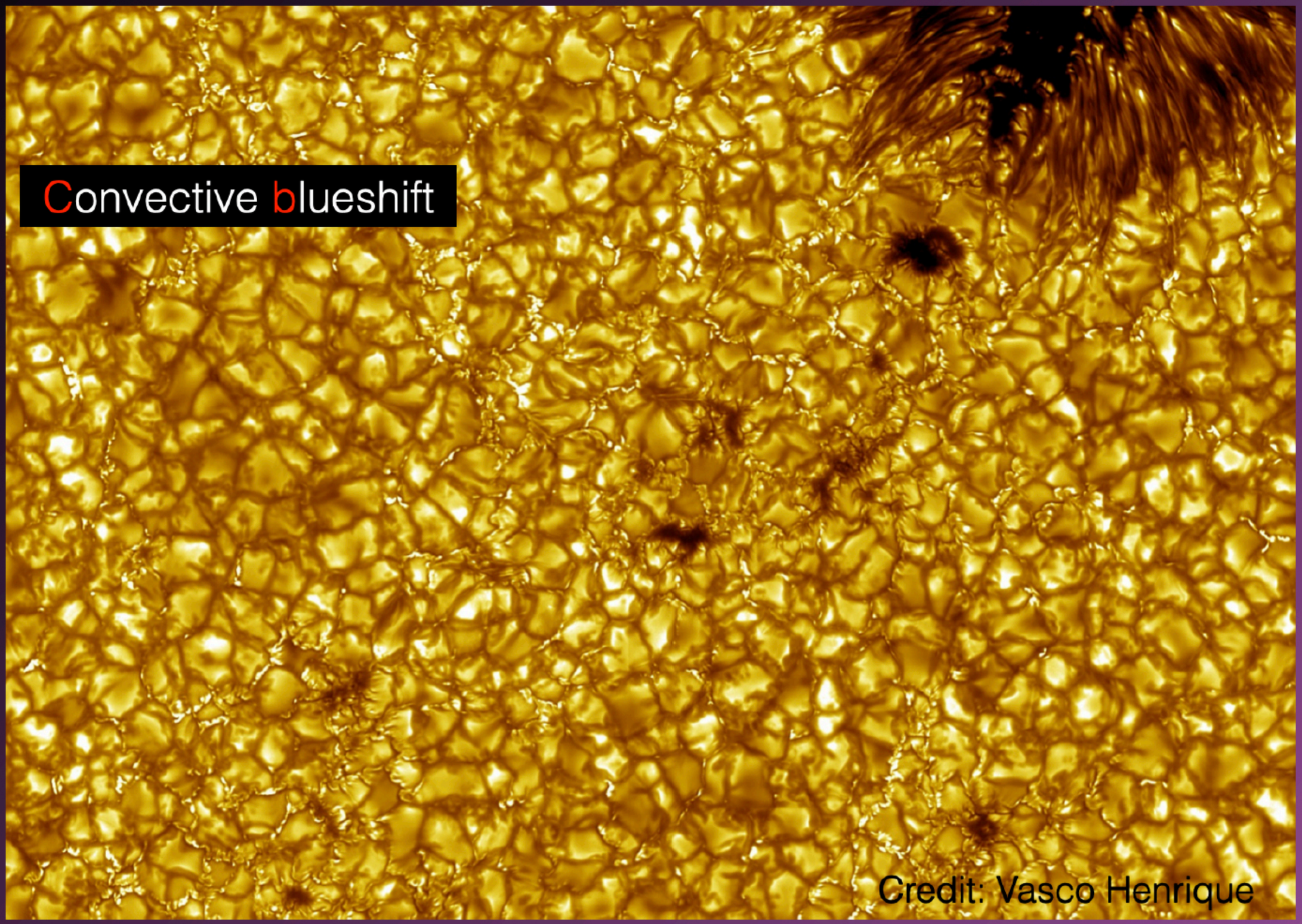
Proxima b P = 11 d Anglada-Escudé et al. 2016
Proxima d P= 5.12 d Faria et al. 2022 Mass = 0.26 Earth.mass

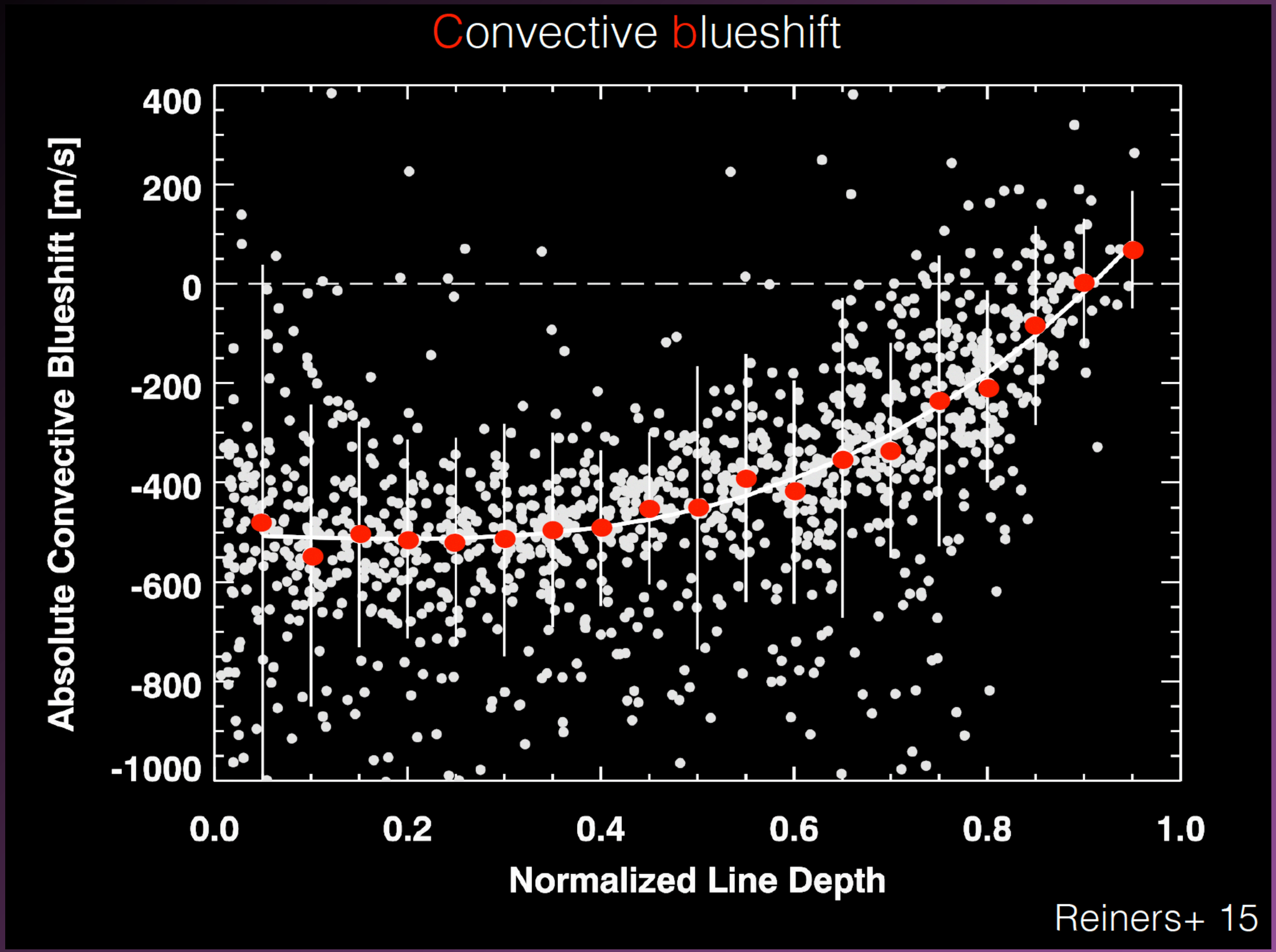




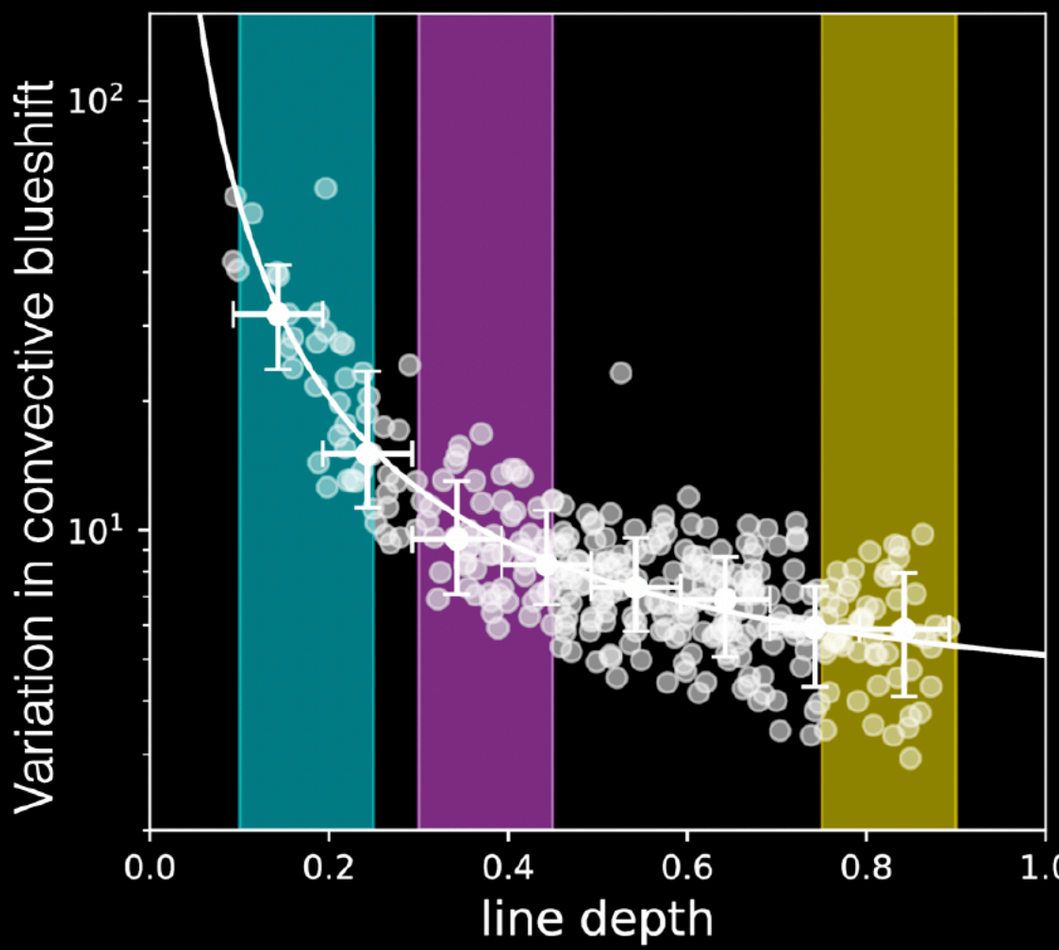
HARPS-N Observes the Sun as a Star

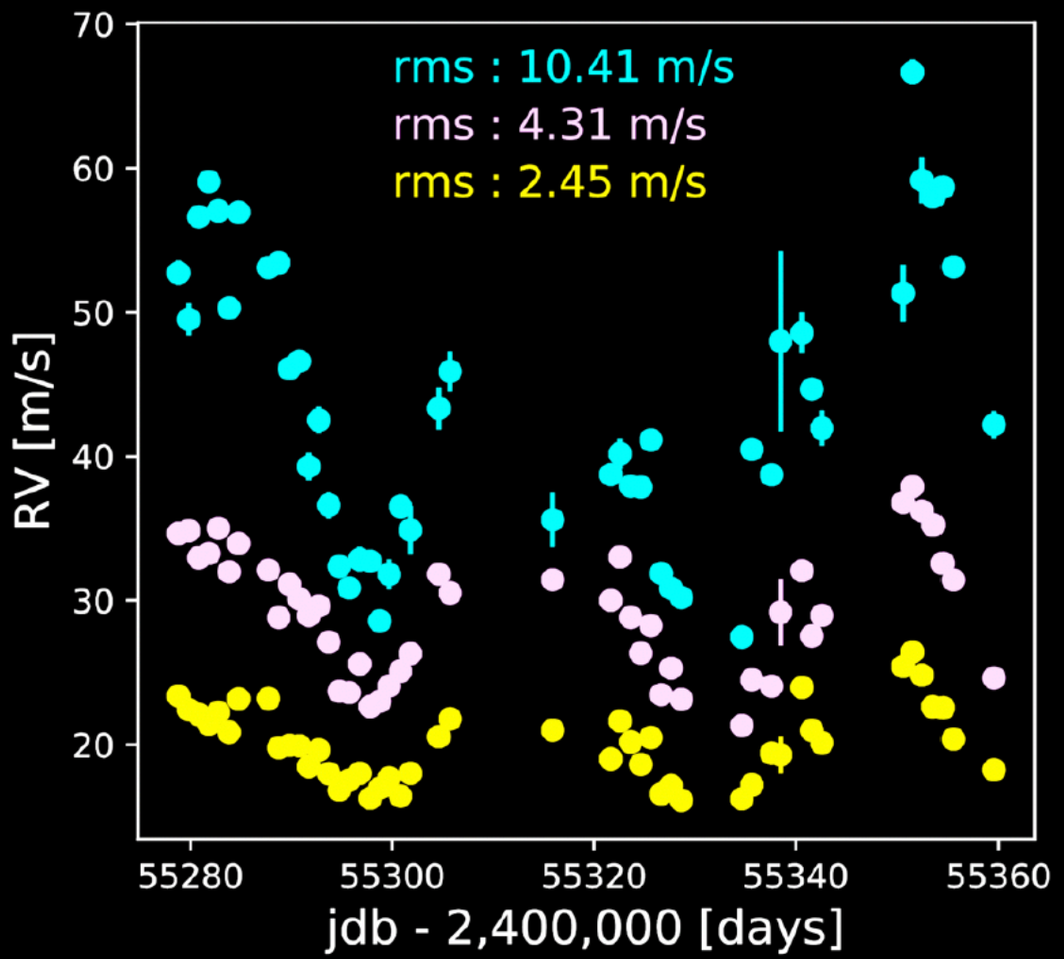
X. Dumusque et al. 2017


Convective blueshift
Credit: Vasco Henrique

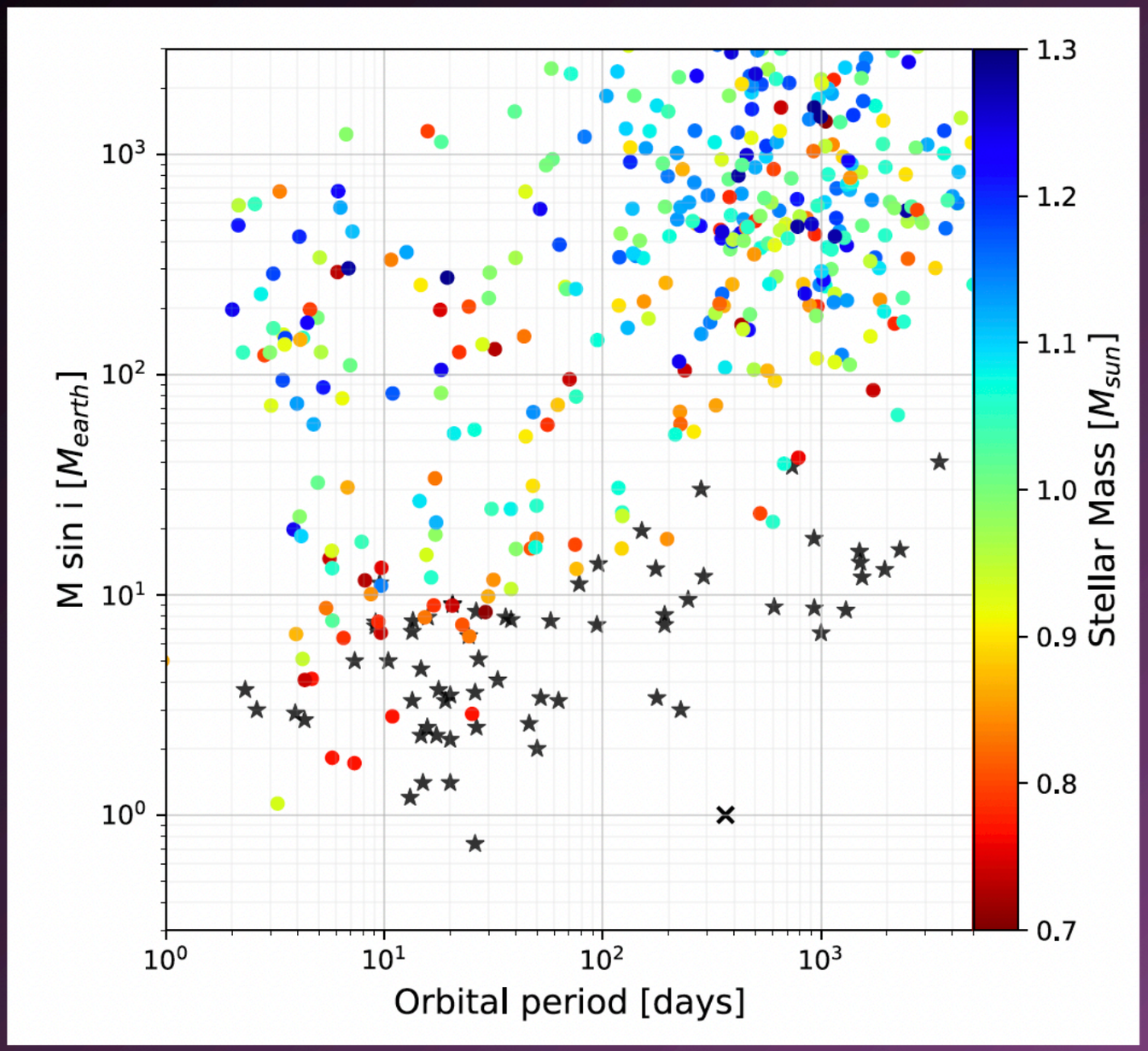

Convective blueshift
Absolute Convective Blueshift [m/s]
400
200
0
-200
-400
-600
-800
-1000
0.0
0.2
0.4
0.6
0.8
1.0
Normalized Line Depth
Reiners+ 15

Stellar signal amplitude as a function of line depth





Cretignier+ 20



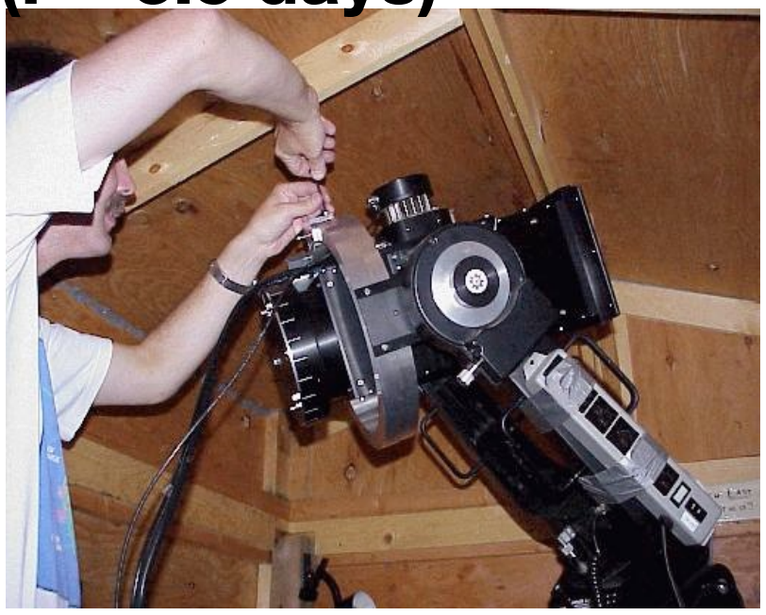
Cretignier 2022 , PhD (HARPS measurements , '*' New low mass candidates detected with the Yarara software)

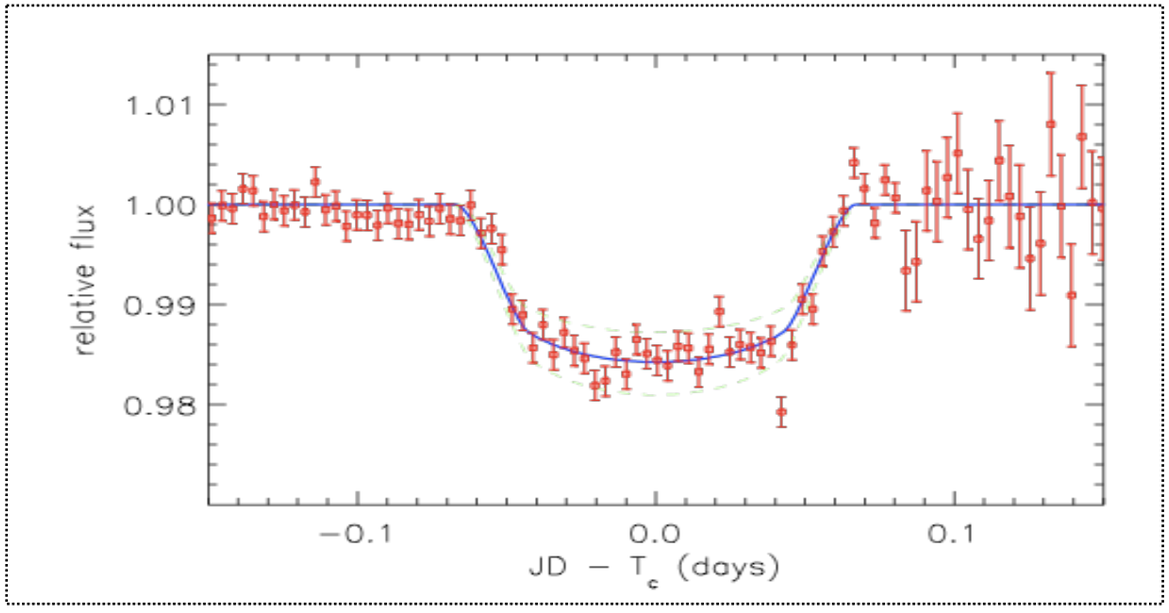
Transit spectroscopy

G. Bryden

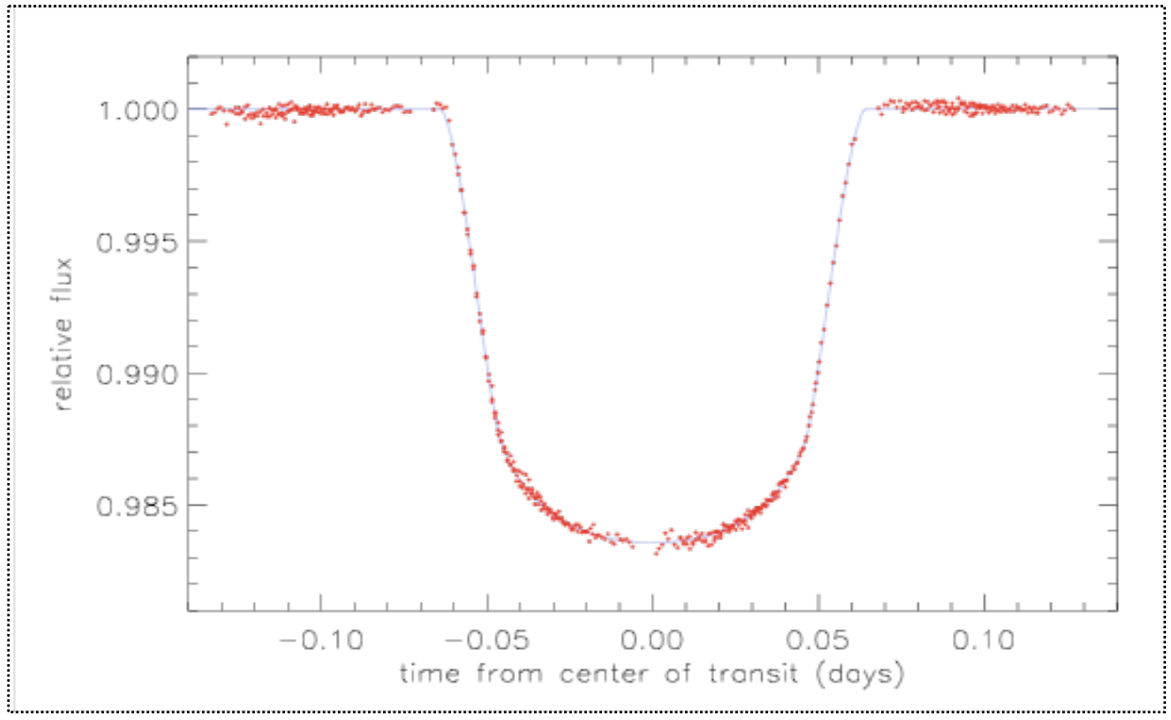
9 et 16 Sept 1999: A first planetary transit.

(P= 3.5 days)





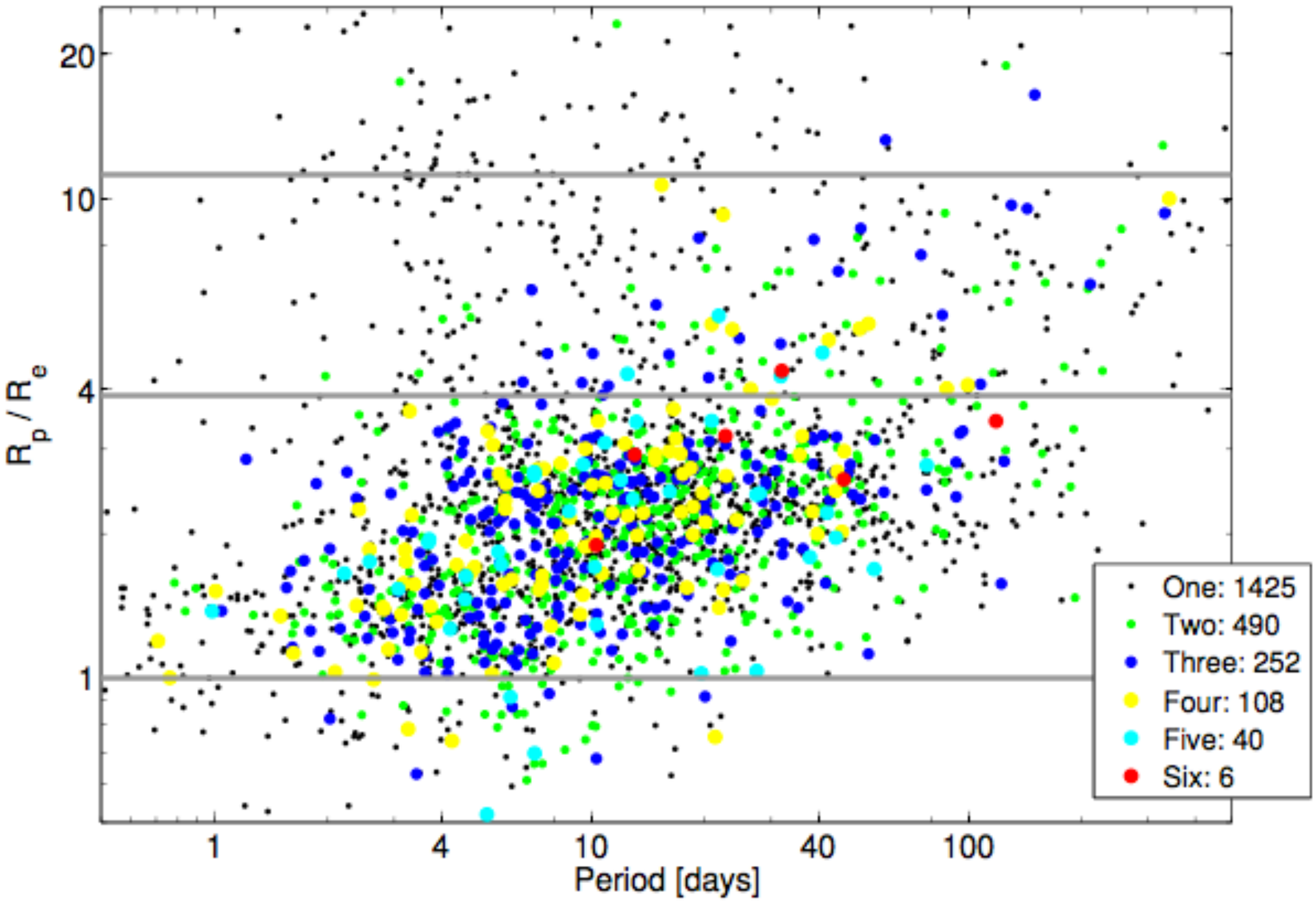
Charbonneau, Brown,Latham, Mayor 2000, ApJ,529



Brown, Charbonneau, Gilliland, Noyes, Burrows 2001,ApJ,552,699

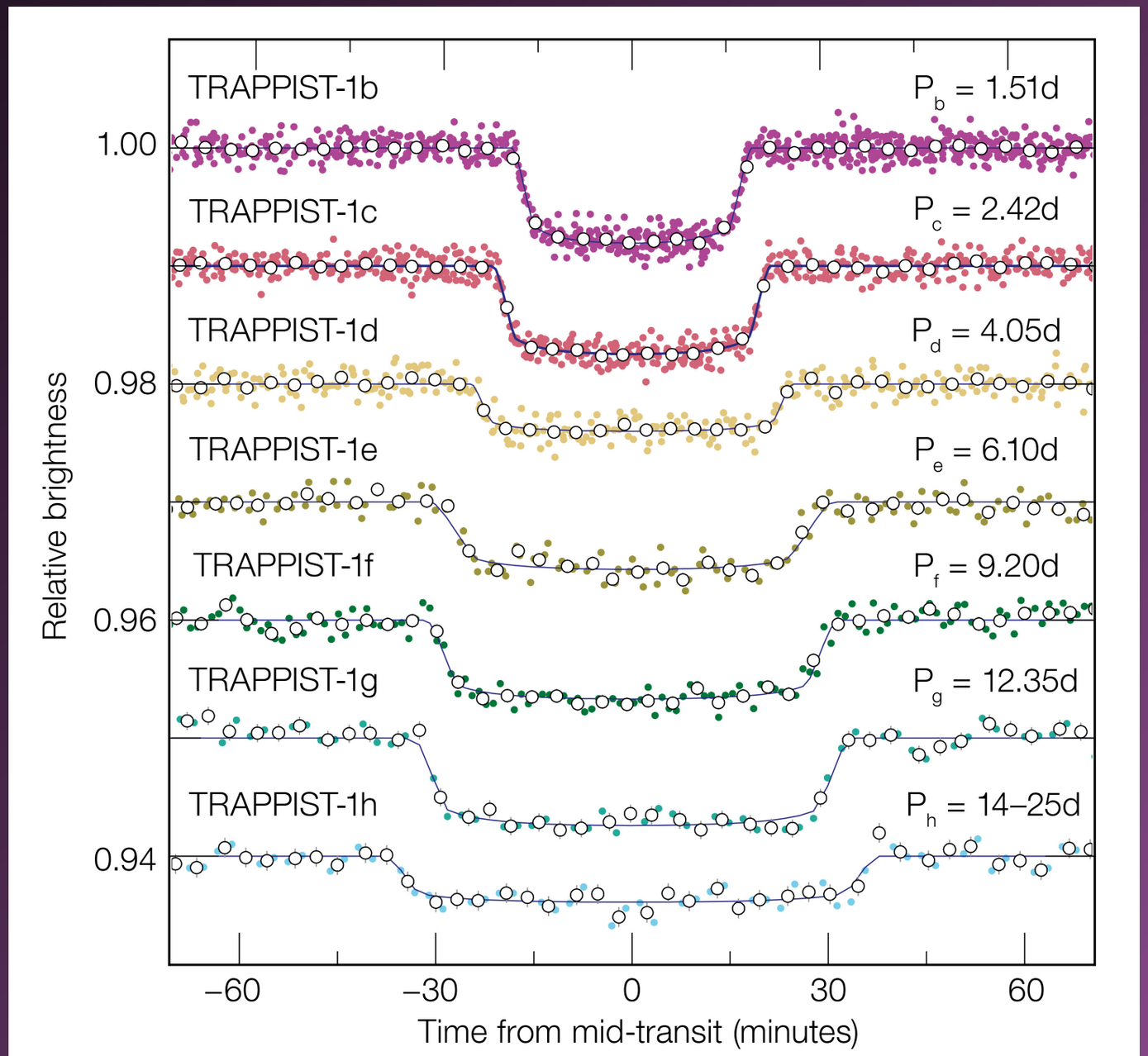
Hot Jupiters are gaseous giant planets : density = 0.3 gr/cm3

La richesse des détections de la mission spatiale KEPLER



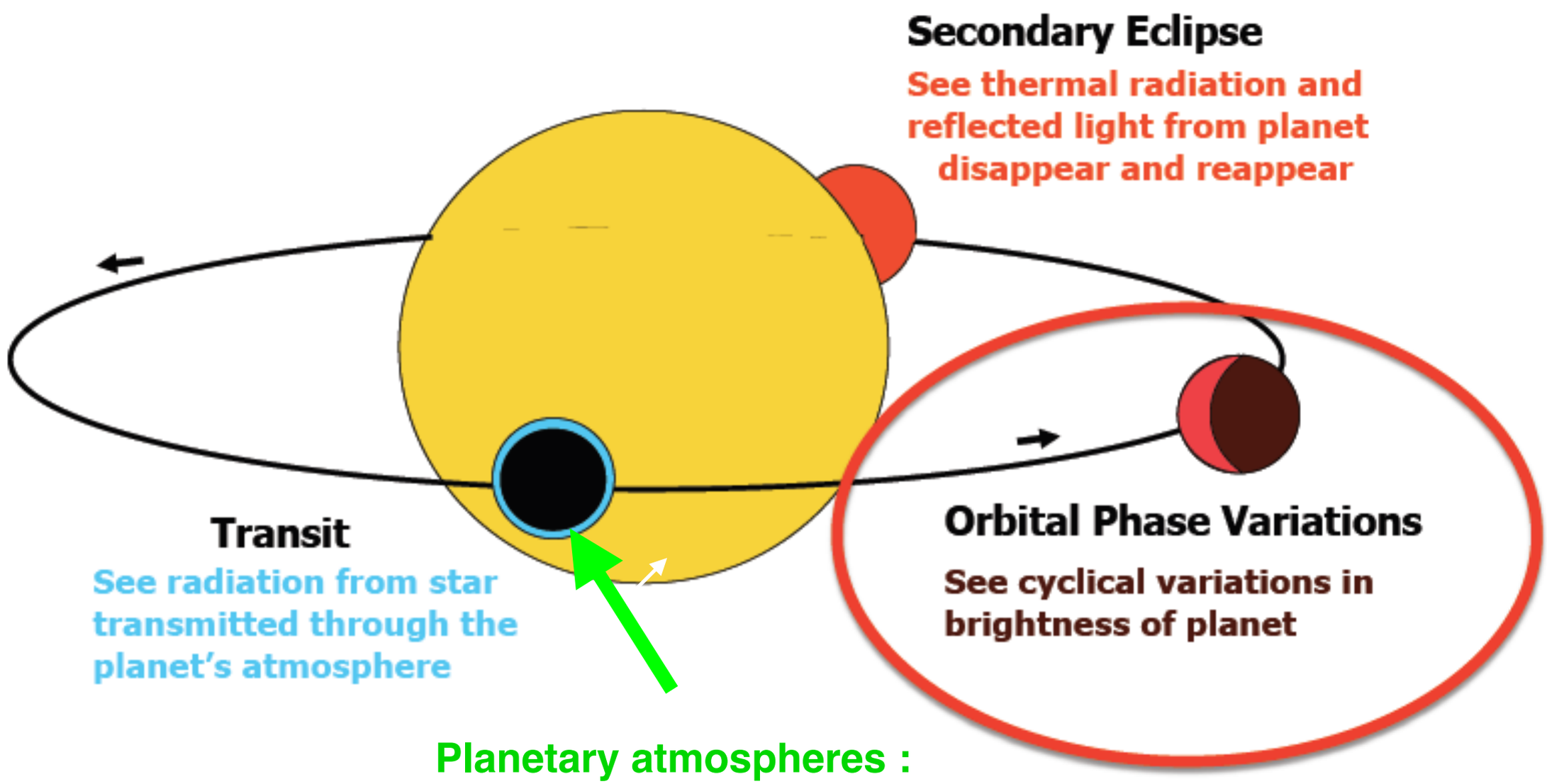
Batalha et al. 2013

Trappist 1 : A planetary system wth 7 rocky planets (2 in the habitable zone) la zone habitable (liquid water on the surface)



Gillion et al.

Transiting Planets as a Tool for Studying Exoplanetary Atmospheres

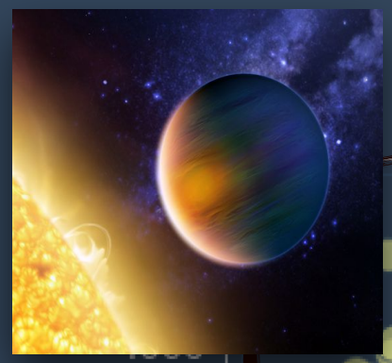


Planetary atmospheres :
A priority topic for the next decade (or more)
>>>> biomarkers

A first glimpse into the JWST-powered exoplanet era

The JWST Transiting Exoplanet Community ERS Program

Courtesy
Monika Lendl
Université de Genève

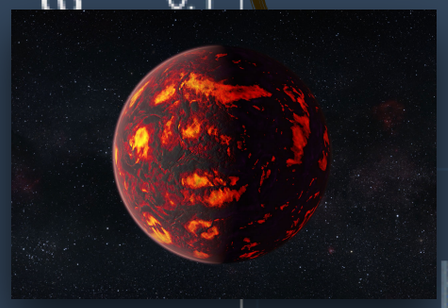


HOT JUPITERS

COLD JUPITERS

MINI-NEPTUNES

ROCKIES



Hugh Osborn

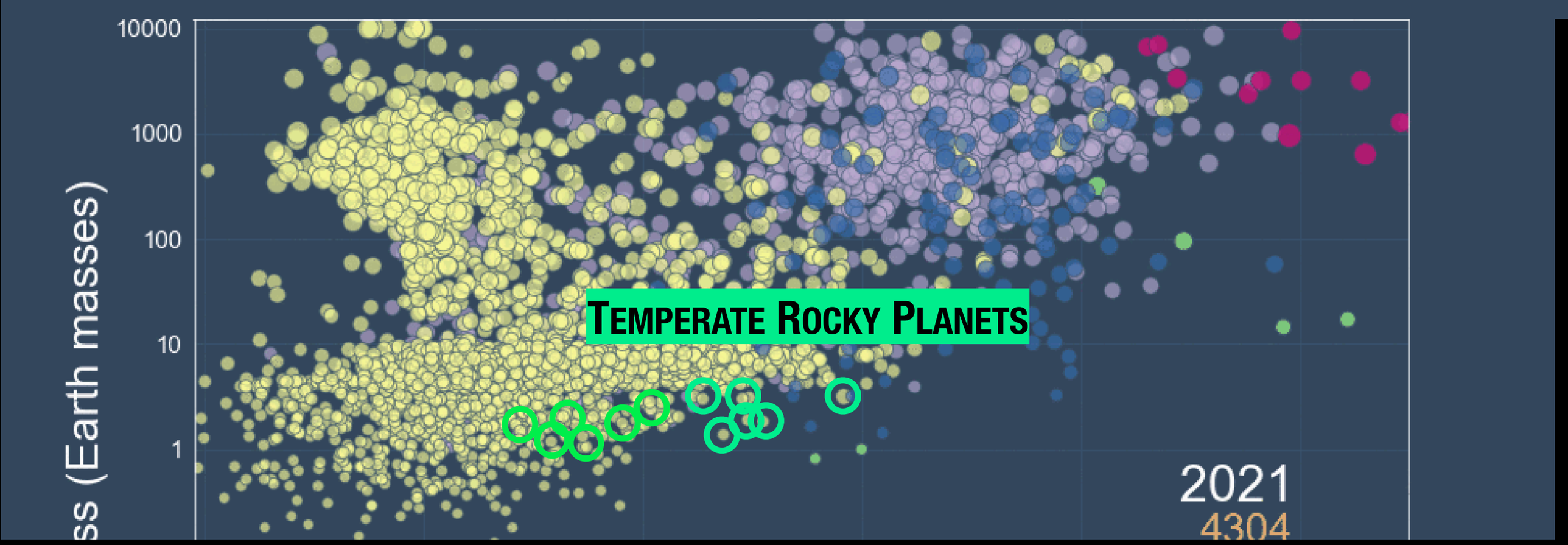
Solar System
RVs
Transits
Microlensing
Imaging

Mass (Earth masses)

1000
100
10
1
0.1
0.001

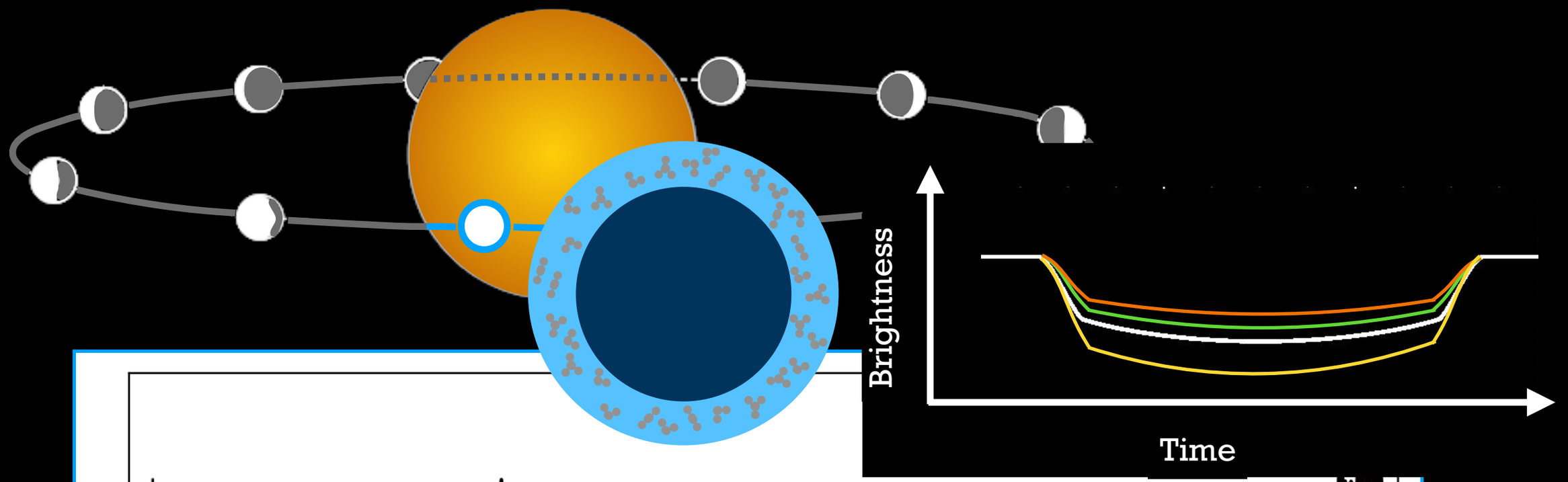
0.001
0.01
0.1
1
10
100

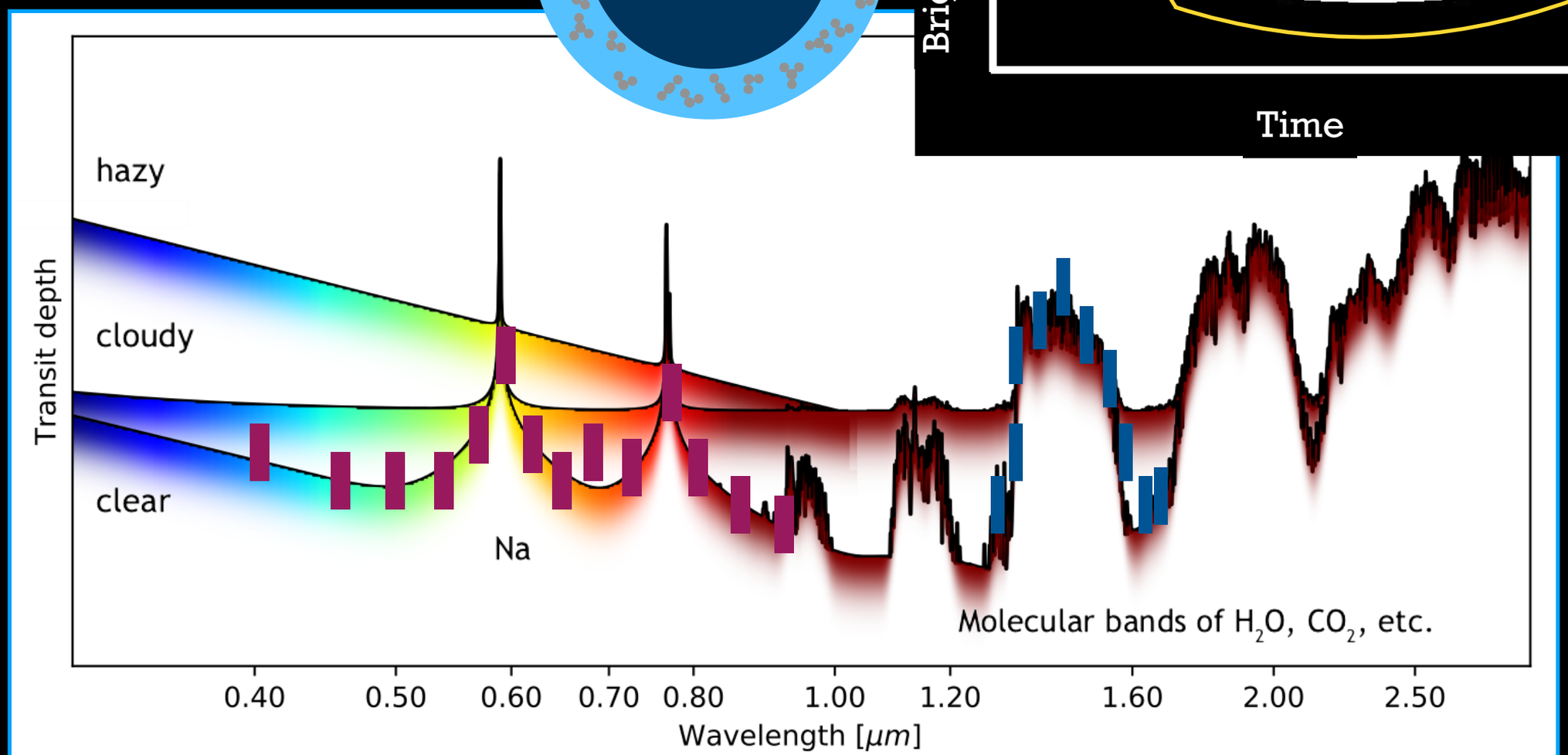
Period (years)



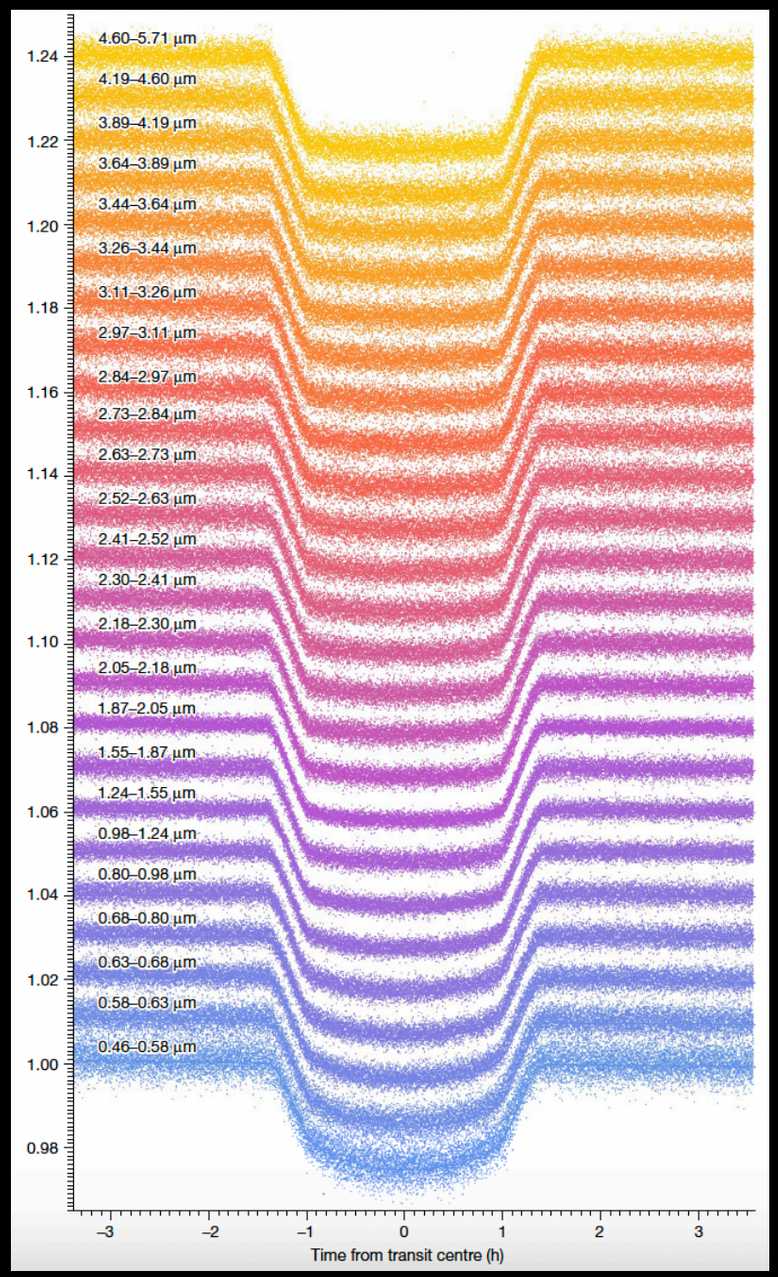
- Do all warm rocky planets have atmospheres?
- Do they have Venus-like or Earth-like atmospheres?
- Do planets orbiting M dwarfs differ?

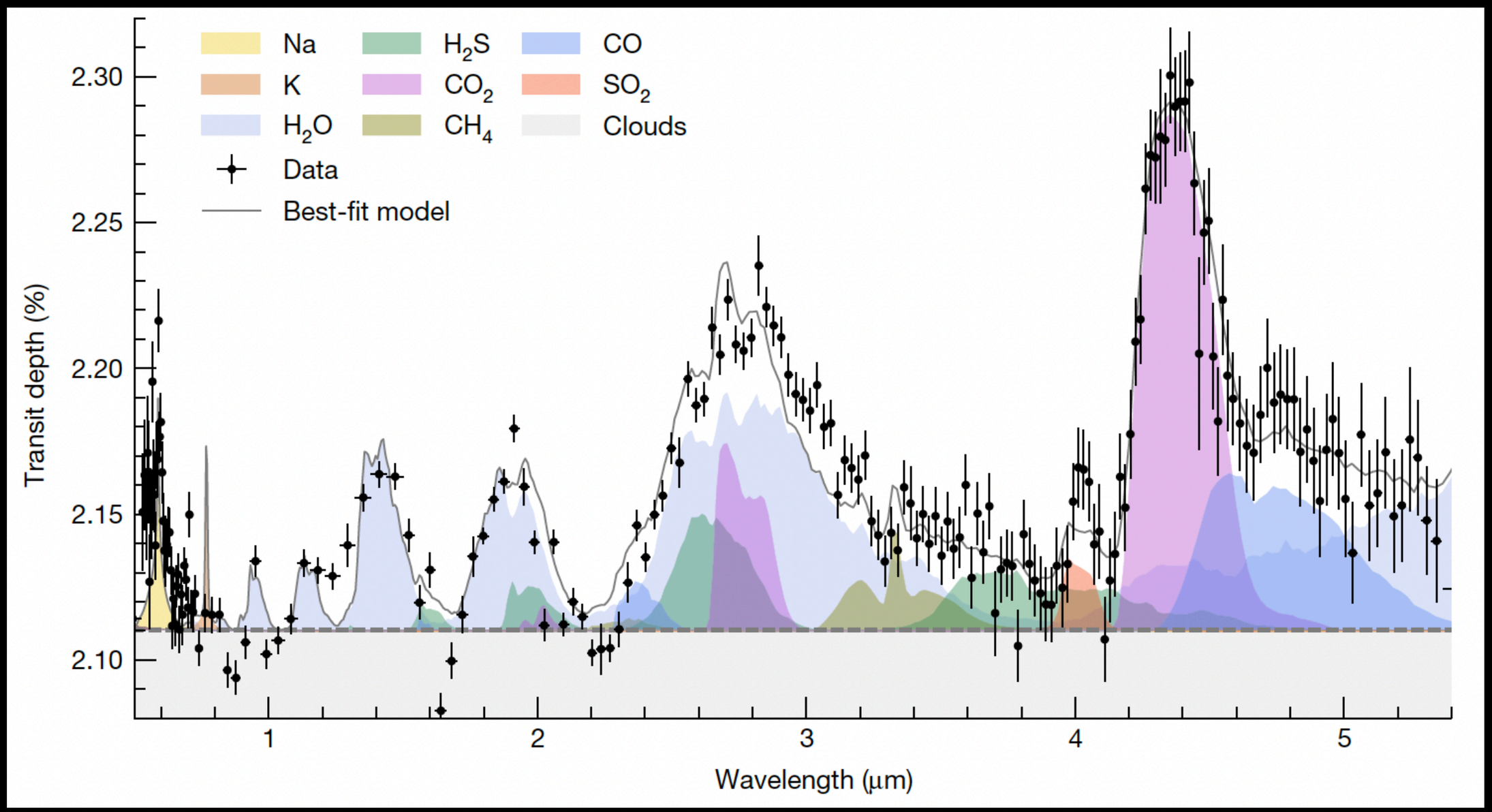
Transmission Spectroscopy





Multi-Wavelengths of a planetary transit measured with the JWST



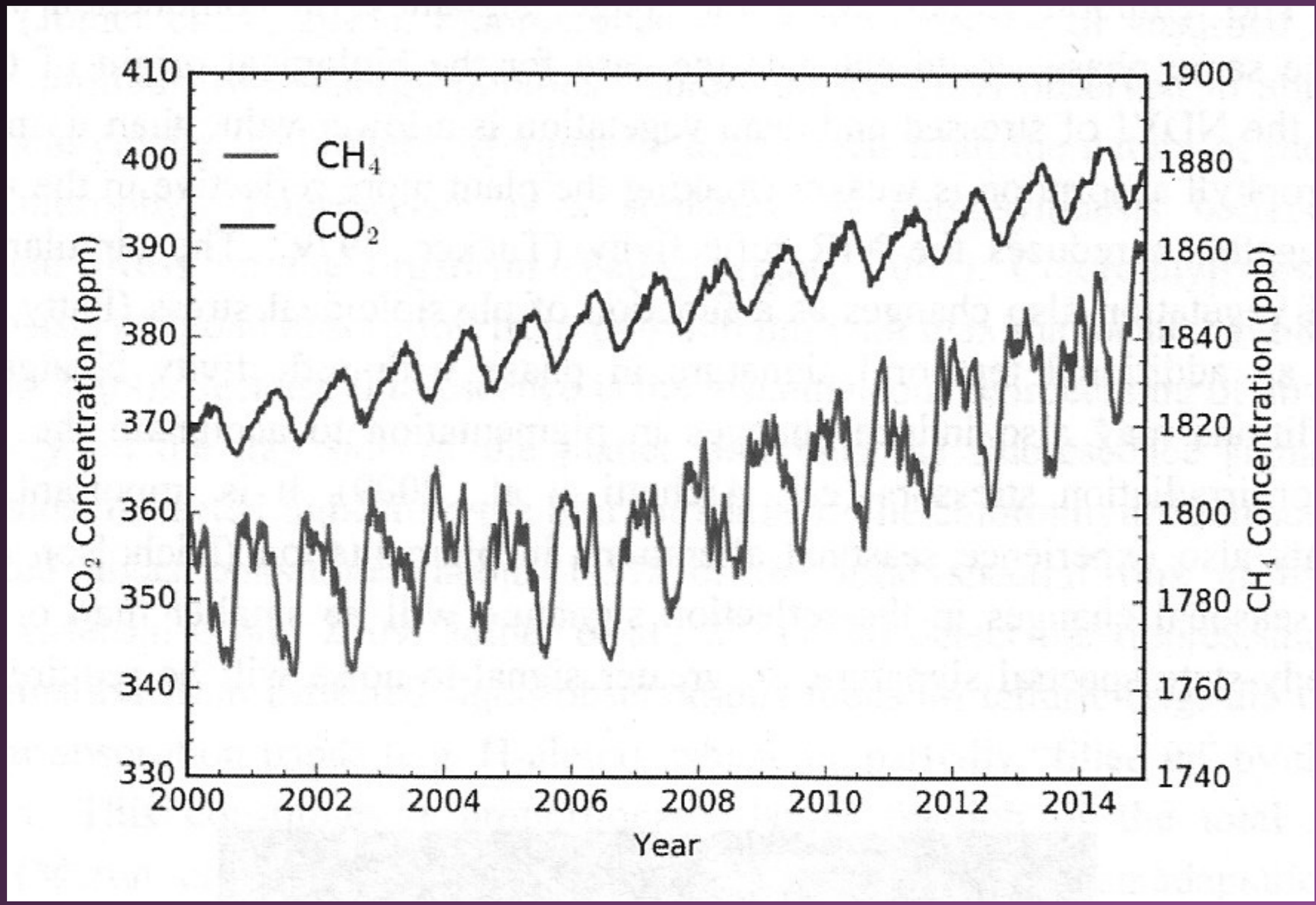


✦ ~10x Solar metallicity

Rustamkulov et al. 2022

✦ No CH_4

Atmospheric Seasonality as an Exoplanet Biosignature
(see for example S.L.Olson et al. 2018, ApJ Lett May 18)



Merci